Ref. Ares(2022)8903836 - 21/12/2022

trinity ENGAGE WITH AGILE MANUFACTURING

D4.3. Catalogue of use case demonstrations

Grant Agreement no.	825196
Project Title	Digital Technologies, Advanced Robotics and increased Cyber-security for Agile Production in Future European Manufacturing Ecosystems
Project Abbreviation	TRINITY
Project Funding Scheme	H2020 Innovation Action (IA)
Call Identifier	DT-ICT-02-2018: Robotics - Digital Innovation Hubs (DIH)
Project Website	http://www.trinityrobotics.eu/
Project Start Date	1.1.2019
Project Duration	54 months
Deliverable Information	D4.3 Catalogue of use case demonstrations – updated
WP Leader	CIVITTA (WP4)
Authors	Natasa Siljkovic, Sander van der Molen
Contributors	All partners
Reviewers	All partners
Contractual Deadline	M48 - 31.12.2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 825196.

CHANGES LOG

VERSION	DATE	DESCRIPTION AND COMMENTS	AUTHOR
RV0.1	03.10.2022	First draft	N. Siljkovic
RV0.2	06.12.2022	Content updates	S. van der Molen
RV0.3	09.12.2022	Final edits, language check	S.van der Molen
RV0.4	12.12.2022	Version 1 of the deliverable	S. van der Molen
RV0.5	20.12.2022	Version 2 of the deliverable	S. van der Molen
RV0.6	21.12.2022	Final edits and checks	M. Lanz

DISSEMINATION LEVEL

PU	Public	X
PP	Restricted to other programme participants (incl. Commission Services)	
RE	Restricted to a group specified by the consortium (incl. Commission Services)	
CO	Confidential, only for the members of the consortium (incl. Commission Services)	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

List of Figures

List of Tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

1. Introduction

The main objective of this document is to **showcase modules, use cases** and **demonstrator landing pages**, which together create a **unique robotics solutions catalogue.** This deliverable includes all options regarding advanced filtering and comprehensive information about every item (module or demonstrator) in the Catalogue, with links and screenshots. The robotics solutions catalogue is developed from a user-centric perspective to create a smooth and convenient experience while navigating through the **TRINITY Robotics** web page.

The following links below can be used to access modules, use cases and demonstrator pages:

1. TRINITY homepage
2. Modules
3. Use cases
4. SME Demonstrators DEMO 1 (2020 - 2021)
5. SME Demonstrators DEMO 2 (2021 - 2022)
6. SME Demonstrators FAQ

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

1 SME Demonstrators page

Demonstrators page combines all necessary information about the **TRINITY** demonstration programs. The page is created to be easy, simple access to an online library of demonstrators as well as their descriptions and contact information. After closing the open calls, the demonstration page was redesigned to provide a better user experience and information access.

After both calls ended, the idea behind creating an SME Demonstrators page was to showcase winners of demonstration programs and to provide a simple, however, informative presentation of winning solutions and their partners.

To access the Demonstrators page, follow the **Trinity Robotics** link and choose the 3rd menu option as presented in **Figure 1**, which is located at the top of the web page named "SME Demonstrators".

Figure 1 Accessing the Demonstrators page

Users can choose between **DEMO 1** and **DEMO 2** based on the year in which the demonstrator was funded to access the sub-page with a list of respective demonstrators.

Figure 2 Extended SME Demonstrators options

Figure 3**,** presented below, shows the SME Demonstrators page, where the users can see all demonstration programs and choose according to their criteria by clicking the blue "Learn More" button. The criteria are based on the following:

- Partners participating
- Short name of demonstration
- One sentence explanation of the demonstration, mainly focusing on the objective of the demonstration
- Location information about countries participating in the demonstration, shown as national flags

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

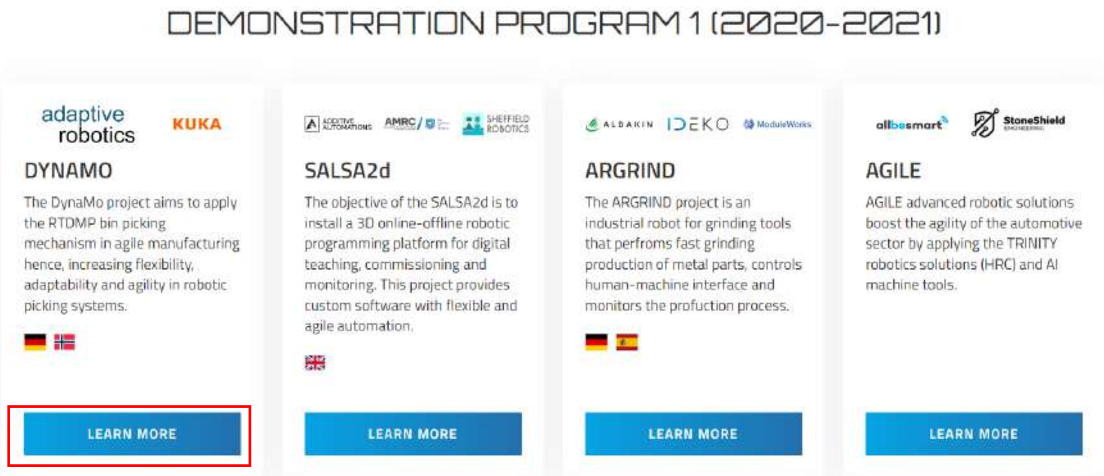


Figure 3 SME Demonstrators

This design approach provides not only information about winning solutions but also gives visibility to the partners who participated in developing the solution. In this way, the TRINITY project promotes the community of partners behind the solutions.

More information about each demonstrator opens up as a pop-up window after clicking the blue "Learn More" button. This is presented in Figure 4 in which users are able to see the demo name, location, technology area, and technology description. In order to return to the main demonstration program page, the blue "Learn More" button should be clicked again.

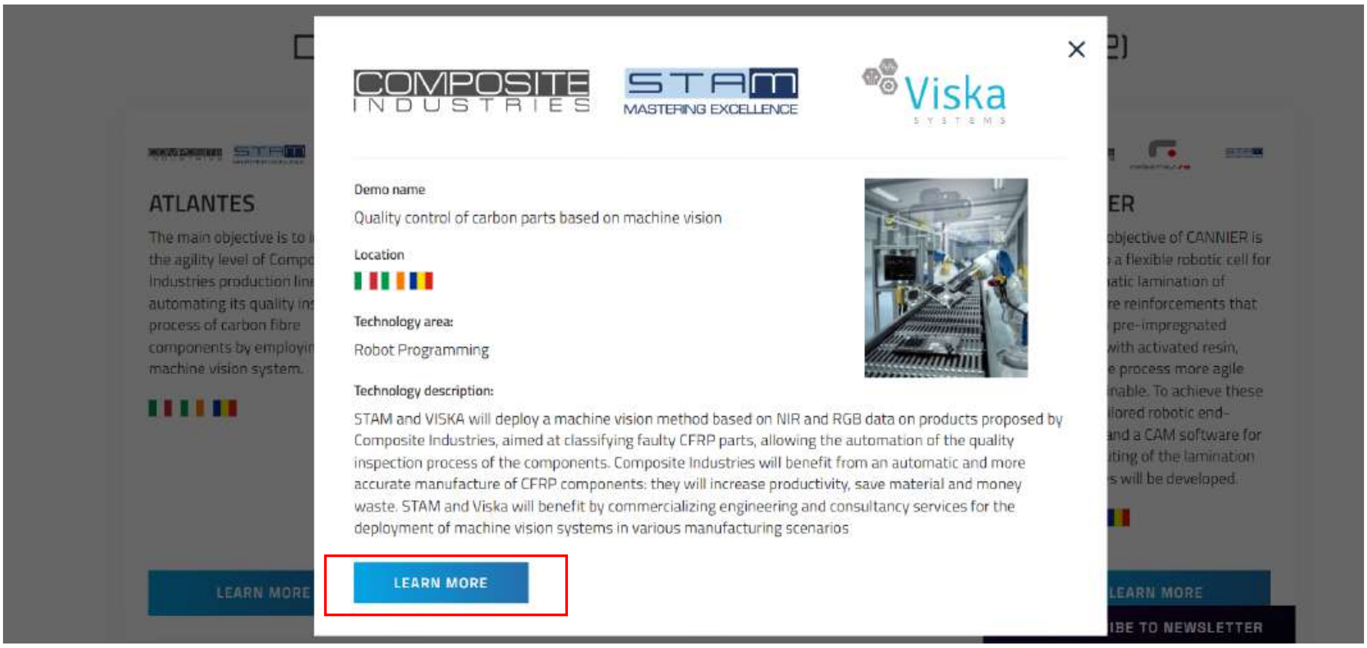


Figure 4 Pop–up window of a Demonstrator

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

2 TRINITY Catalogue

The purpose of the Catalogue page is to combine all necessary information about the TRINITY Use Cases and Modules which are further detailed in the below sections of the deliverable. The page is created to be easy, simple access to an online library so that users can navigate without disruptions. The information in the Catalogue's landing page is similar to what is currently represented in the modules/demonstrators feed, i.e. a list of available items.

The TRINITY design was updated and confirmed in mid-April 2021, followed by additional functions. The functions include Use cases and Modules submission interface. The latter was refined by the end of May 2021, and the prototype was sent for member feedback and final iterations. The interface was then refined according to the response, preparing for rollout by the end of June 2021. After careful testing and validation, the Modules and Use cases pages have been modified to fit the user needs.

To access the Catalogue page, follow the Trinity Robotics (link) and choose the 4th option as presented in Figure 5, which is located at the top menu of the web page named "Catalogue".

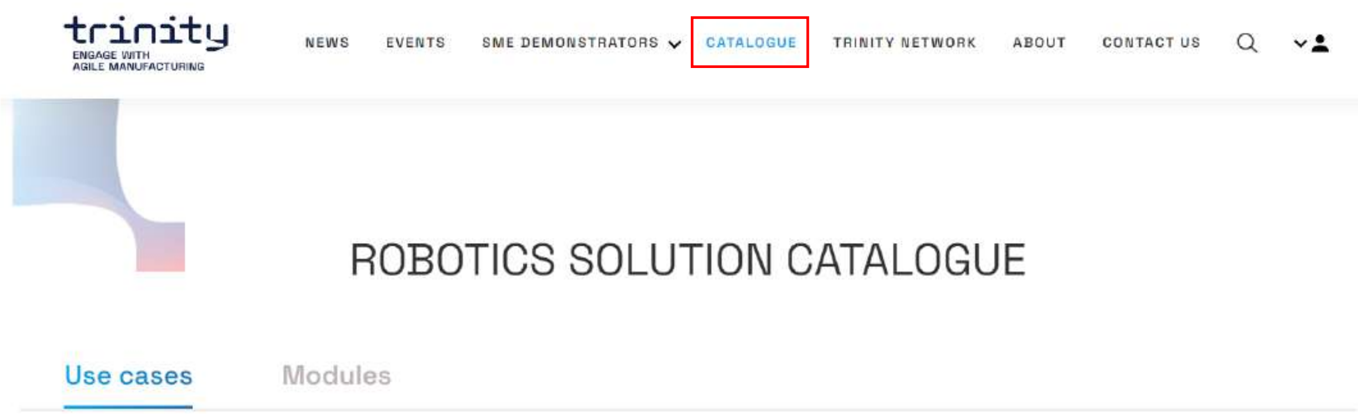


Figure 5 Renamed catalogue view

In order to improve the user's experience and maintain a distinction between different items, additional functionality, i.e. filtering, was necessary. Figure 6 shows the main catalogue's page. Users can see all available filters on the left side of the page, while the cases are presented on the right side.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

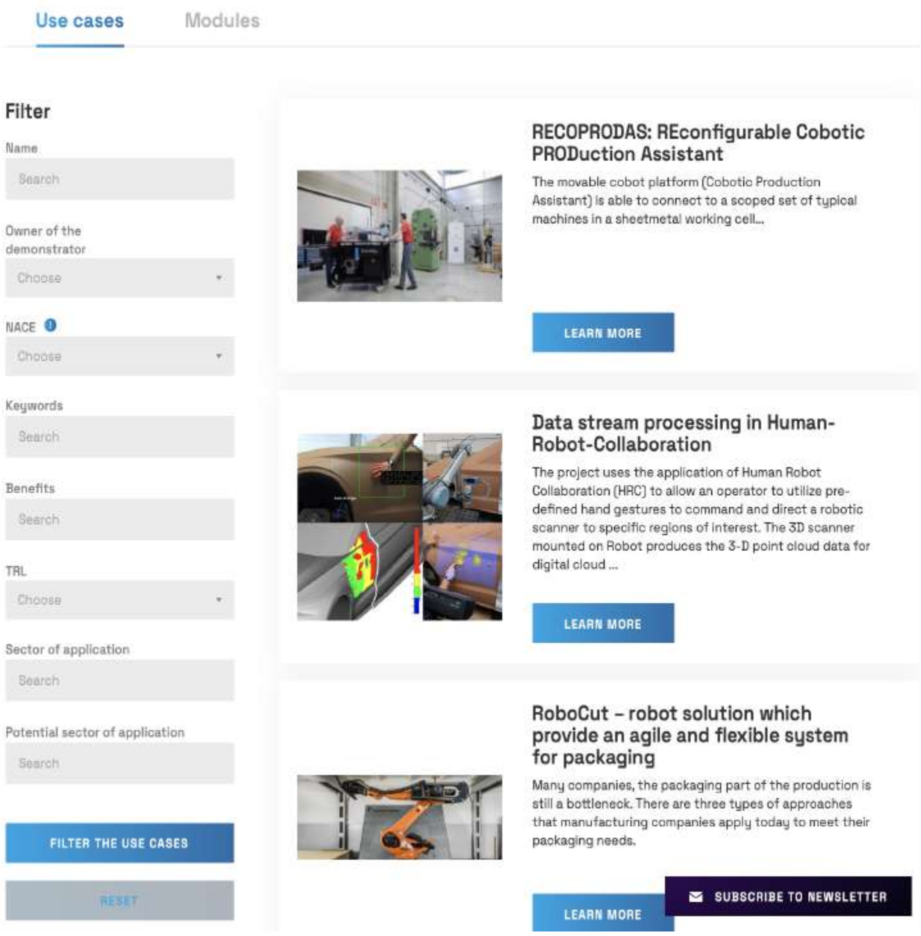


Figure 6 Detailed overview of Use Cases

According to Figure 7, every use case has a dedicated module or modules, and information about the different modules is available within the use cases' tabs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

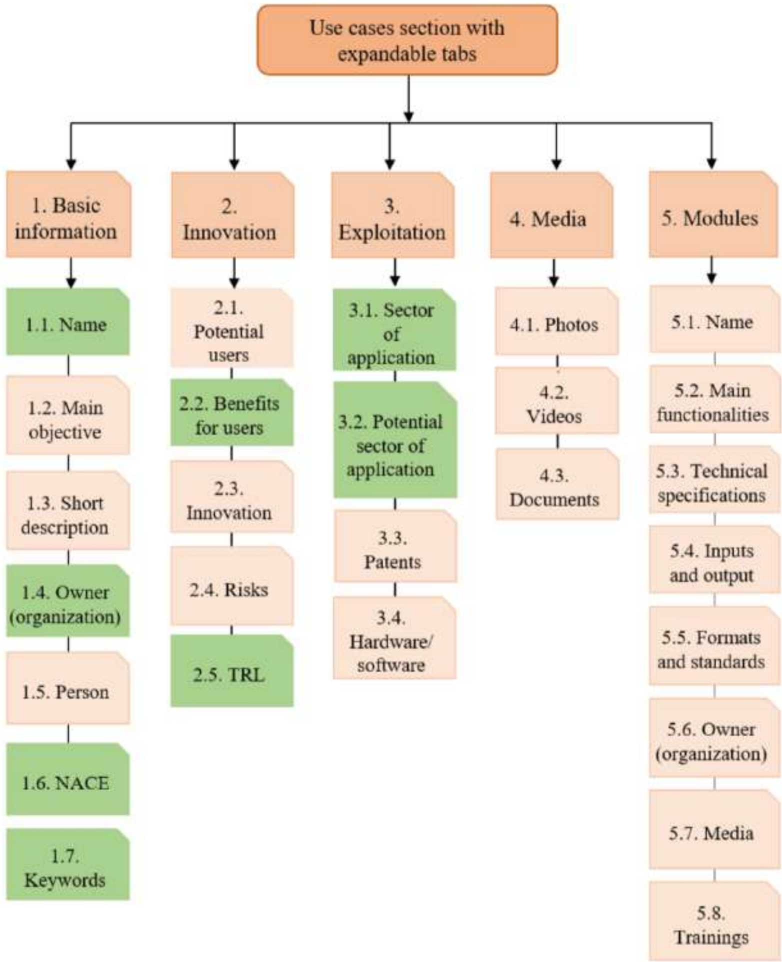


Figure 7 Structure of use cases' tabs

As it is presented in Figure 8, the users have two options - either browsing without filters, i.e. seeing a full list, or applying filters and browsing through the list of items that match the criteria.

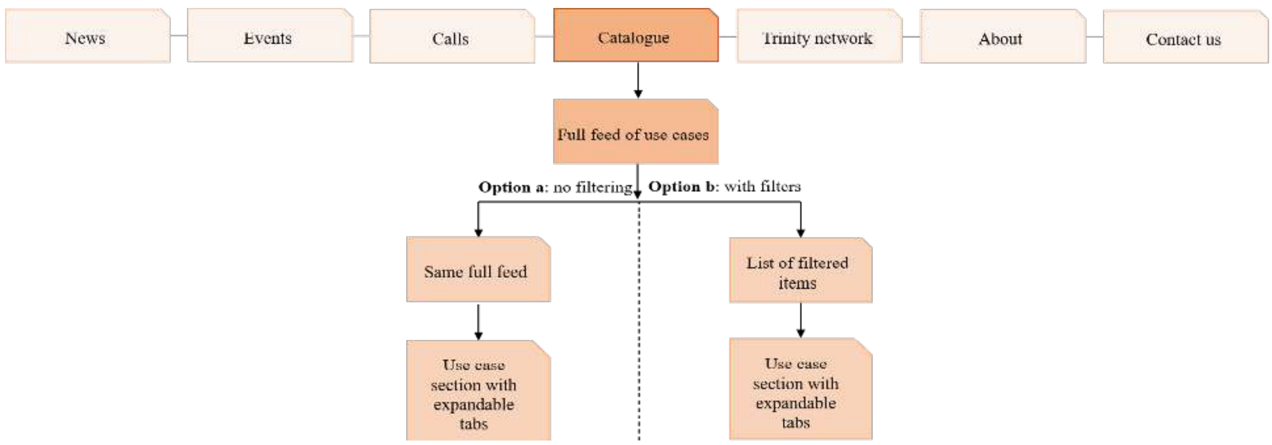


Figure 8 General structure of the catalogue's landing page

All filters are listed on the left side of the page and users are able to choose the relevant ones accordingly. When users select a preferred filter and click on the blue "Filter the Use Cases" button (either type the text or choose something from a dropdown menu, see "Type of entry" in Table 1, it appears as a removable tag.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Table 1 List of filters including the descriptions and types of entry

Filter name	Description	Type of entry
1. Name	Users can search items by entering specific names.	Open text
2. Owner	Users are able to filter according to the owner, i.e. organization, which created the demonstrator.	Dropdown
3. NACE	Level 1 and level 2	Dropdown
4. Keywords	Every item includes relevant information such as keywords, e.g. industry, main objectives, etc., and users can filter according to their needs.	Open text
5. Benefits	Like keywords, users can filter according to the state-of-the-art benefits.	Open text
6. TRL	Users are able to select TRL.	Dropdown
7. The sector of application	Every item has a specific application sector, which is relevant for the technology users; therefore, DAP visitors can filter accordingly.	Open text
8. The potential sector of application	Same as with the sector of application, users are able to filter according to the potential sector of application.	Open text

Figure 9 presents the website view after applying a new filter. When filters are selected, only the items that match the criteria are displayed. If users do not want to use a specific filter, they can click on the “X” mark to remove the filter. Also, the reset function, which is found below the filter options, can erase all chosen filters if needed.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

trinity

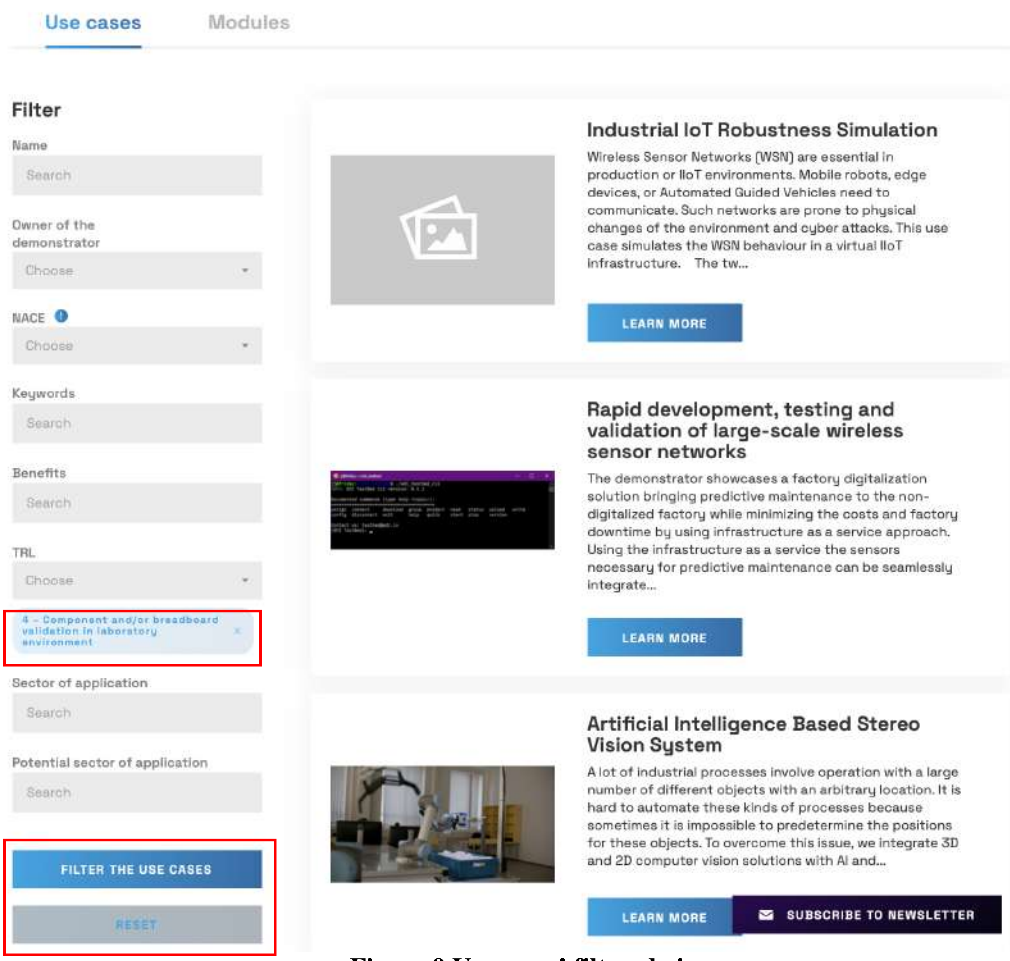


Figure 9 Use cases' filtered view

Figure 10 below presents the view after clicking on the "Learn More" button, and the following window opens. On the left side, sub-categories are presented. The sub-categories include:

- Basic information;
- Innovation;
- Exploitation;
- Media;
- Modules.

On the right side, the users can find expanded information based on their chosen category.

On the bottom of the page, there is a "Back to List" button that brings users back to the filtering and use-cases window. Worth noting that after pressing the "back to modules list", the chosen filters are removed automatically.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

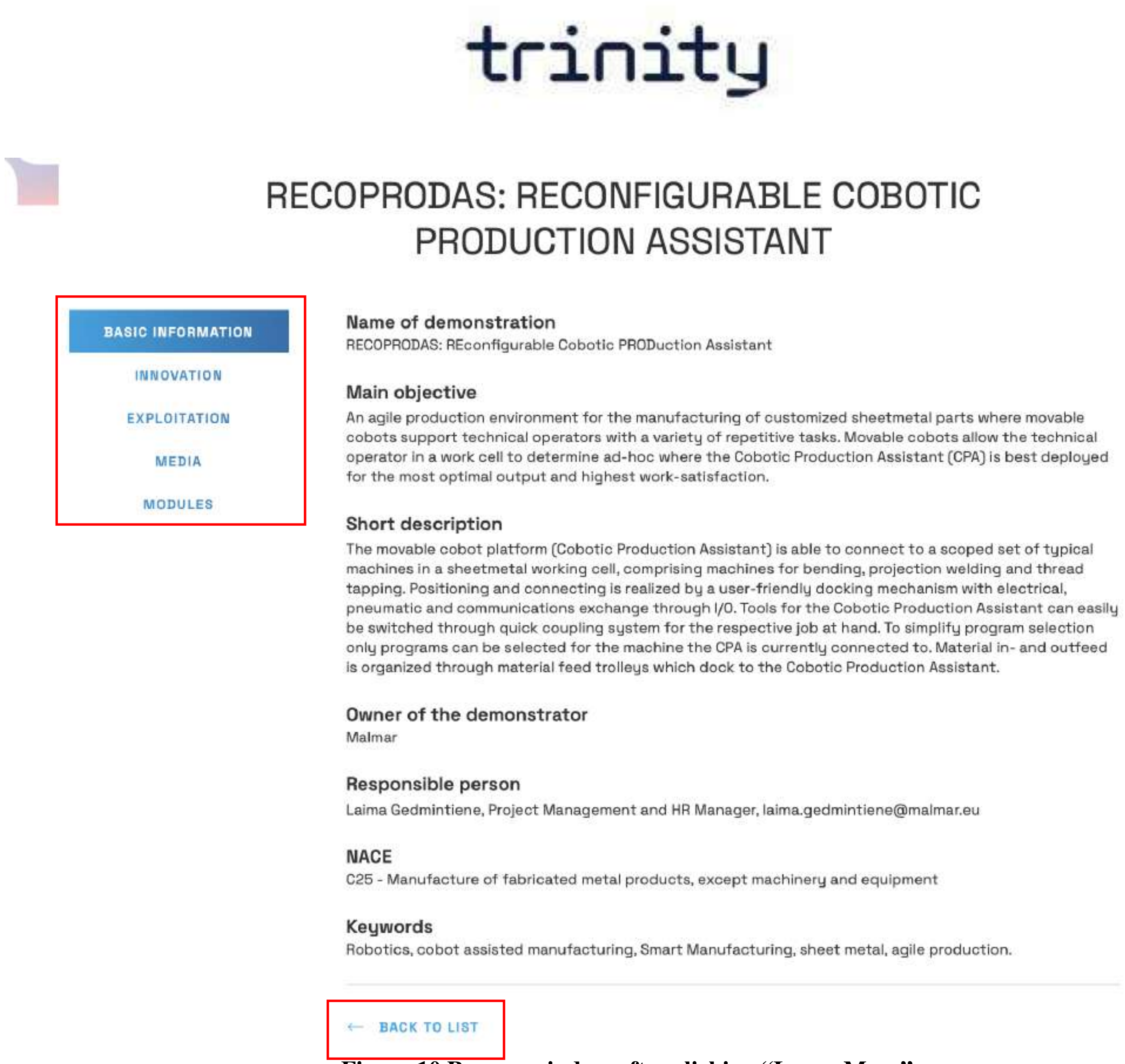


Figure 10 Pop-up window after clicking "Learn More"

In order to improve the user's experience and maintain a distinction between different items, additional functionality, i.e. filtering, is necessary. Figure 11 indicates all available filters on the left side of the Catalogue's page, while the cases are on the right side.

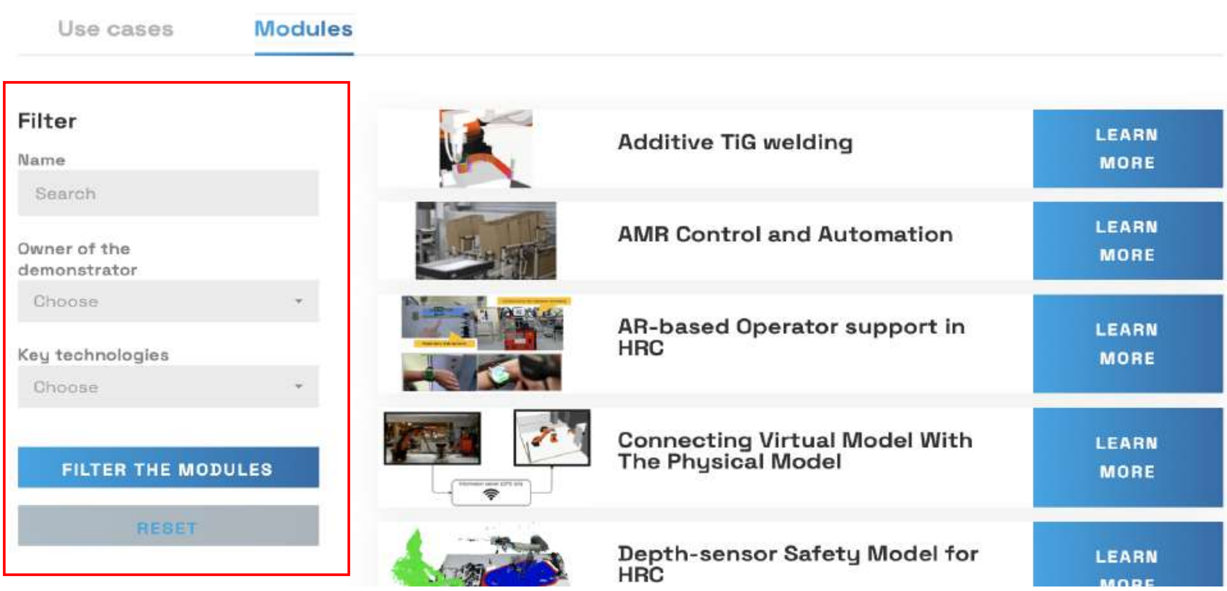


Figure 11 Detailed overview of Modules

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Table 2 shows users' two options - either browsing without filtering, i.e. seeing a full list or applying filters and browsing through the list of items that match the criteria.

Table 2 List of filters including the descriptions and types of entry

Filter name	Description	Type of entry
1. Name	Users are able to search items by entering specific names.	Open text
2. Owner of the demonstrator	Users are able to filter according to the owner, i.e. organization, which created the demonstrator.	Dropdown
3. Key technologies	Users are able to filter according to the technologies such as simulation, robot safety, etc.	Dropdown

Figure 12 presents a pop-up window if a user clicks on the blue "Learn More" button. Users find expanded information grouped in sub-headings based on their chosen case.

On the bottom of the page, there is a "Back to Modules List" button that brings users back to the filtering and modules window. Worth noting that after pressing the "back to modules list" and upon the return to the list, the chosen filters are removed automatically.

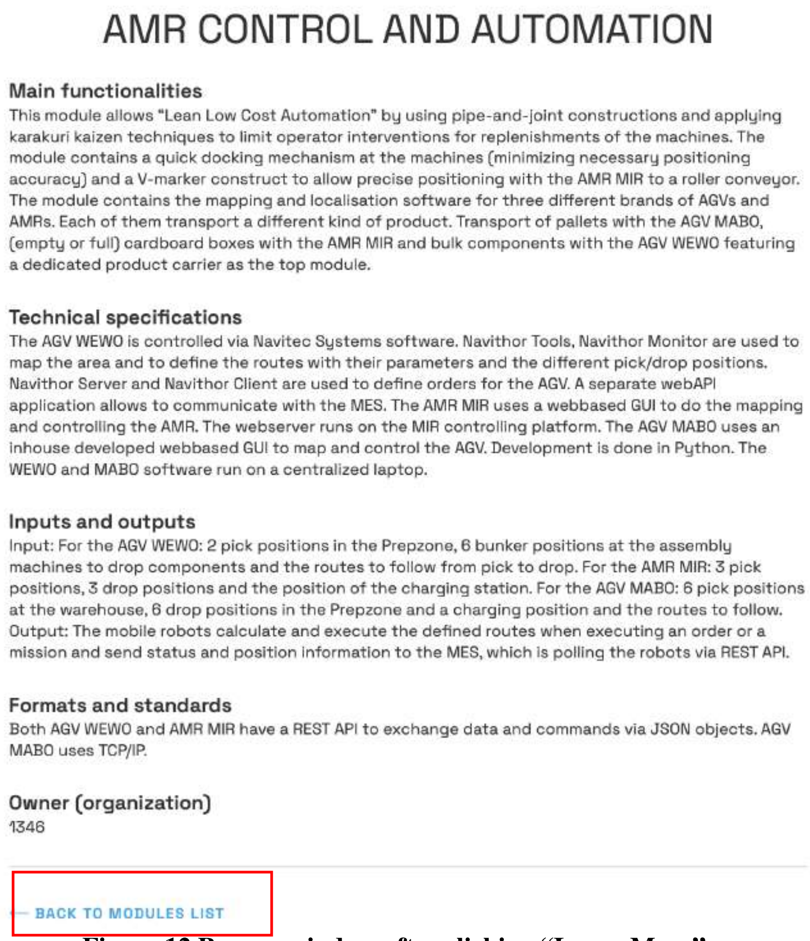


Figure 12 Pop-up window after clicking "Learn More"

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Table 3 indicates the categories of the TRINITY Robotics page, short descriptions, and the links to the website to access chosen categories conveniently.

Table 3 Trinity Robotics page categories

Category	Short description	Website
1. TRINITY homepage	TRINITY homepage allows users to see the necessary news, find useful information regarding the innovation actions, etc.	https://trinityrobotics.eu
2. Modules	The users have two options - either browsing without filters or applying filters and browsing through the list of cases that match the criteria.	https://trinityrobotics.eu/catalogue/
3. Use Cases	The users have two options - either browsing without filters or applying filters and browsing through the list of cases that match the criteria.	https://trinityrobotics.eu/catalogue/
4. SME Demonstrators DEMO 1 (2020 - 2021)	The page is created to allow easy, simple access to an online library of demonstrators (2020 - 2021) as well as their descriptions and contact information.	https://trinityrobotics.eu/demonstrators/
5. SME Demonstrators DEMO 2 (2021 - 2022)	The page is created to allow easy, simple access to an online library of demonstrators (2021 - 2022) as well as their descriptions and contact information.	https://trinityrobotics.eu/sme-demonstrators-2/
6. SME Demonstrators FAQ	Frequently asked questions allow users to keep up with up-to-date information regarding various topics.	https://trinityrobotics.eu/faq/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

3 Conclusion

This deliverable presented detailed TRINITY Robotics web-page guidance. The document's main goal was to provide a comprehensive overview of the modules, use cases and demonstrator landing pages by emphasizing key focus areas from a user perspective. Figures and tables added in this document allow users to get visual insights and prepare to navigate through the TRINITY Robotics page conveniently.

The other relevant information regarding various topics is provided in the Annex that users will find highly beneficial while navigating through the website. The appendix includes the current input of the internal and external use cases (originating from the TRINITY open calls). Please note, that the catalogue is under continuous update process for new modules and use cases. The most recent information of the use cases can be found from the website.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 1: RECOPRODAS: reconfigurable cobotic production assistant

1. Basic Information

Name of demonstration
RECOPRODAS: REconfigurable Cobotic PRODuction Assistant

Main objective
An agile production environment for the manufacturing of customized sheetmetal parts where movable cobots support technical operators with a variety of repetitive tasks. Movable cobots allow the technical operator in a work cell to determine ad-hoc where the Cobotic Production Assistant (CPA) is best deployed for the most optimal output and highest work-satisfaction.

Short description
The movable cobot platform (Cobotic Production Assistant) is able to connect to a scoped set of typical machines in a sheetmetal working cell, comprising machines for bending, projection welding and thread tapping. Positioning and connecting is realized by a user-friendly docking mechanism with electrical, pneumatic and communications exchange through I/O. Tools for the Cobotic Production Assistant can easily be switched through quick coupling system for the respective job at hand. To simplify program selection only programs can be selected for the machine the CPA is currently connected to. Material in- and outfeed is organized through material feed trolleys which dock to the Cobotic Production Assistant.

Owner of the demonstrator
Malmar

Responsible person
Laima Gedmintiene, Project Management and HR Manager, laima.gedmintiene@malmar.eu

NACE
C25 - Manufacture of fabricated metal products, except machinery and equipment

Keywords
Robotics, cobot assisted manufacturing, Smart Manufacturing, sheet metal, agile production.

2. Innovation

Benefits for the users
After successful integration of the Cobotic Production Assistants in the highly flexible sheetmetal production environment the operators will be relieved from repetitive tasks on products where the cobot can be used.
The reduction of non-adding value, monotonous tasks for the operator will lead to higher job satisfaction.
Cell operators controlling where to put the CPA to use in order to increase productivity and reduce repetitive tasks willincrease operator ownership.
The freed-up time of the operator can be used for cell improvement and quality control

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The operator responsibility will shift to ownerschip of the cell focusing amongst others on quality control and time-based planning of the cell to assure ultra-short leadtimes (Quick response manufacturing).

Innovation

The innovation in this demonstrator is situated in different areas:

– Technological area
  - The physical platform specifically suitable for typical metal working job shop environments with material supply trolleys docking to the cobot platform.
  - A flexible docking mechanism for dimensional, electrical and pneumatic connection suitable for the relatively harsh environment in metalworking industry
  - I/O connector for handshake between multiple different machine types and the cobot platform including recognition of the docking station thus reducing the risk of wrong program execution
  - Flexible gripper / tool system to accommodate different part handling and machine operations
  - Low-level programming through typical cobot teach-by-demonstration

– Organizational level
  - Operator awareness training to allow for smooth transition from purely manual working to cell responsibility including responsibility for Cobotic Production Assistant
  - Changed routings in production distinguishing between products which pass through the RECOPRODAS cell and products which don’t

Risks and limitations

Scoping of the initial machines and products. The number of different machines in a typical job shop environment can be high, a mobile platform able to dock and interface with all these different processes will require additional development. Hence, the number of different machines has been scoped to three. To scope the number of products for the demonstrator a pareto analysis has been made in combination with the consideration that the selected products would require one or more of the scoped machine processes. This resulted in 80 different products. Solution does not meet the operators' expectations The Cobotic Production Assistant must be easy to use, meaning that it must be flexible to switch between products and it must be flexible to switch between machines. If either of these two requirements are not met the Cobotic Production Assistant will never reach its targeted use. Moreover, the Cobotic Production Assistant should be able to work autonomously during a long enough period to unburden the operator. Tending to the Cobotic Production Assistant for material supply or material removal should not cause additional stress nor take up too much of the operators time.

Technology readiness level

7 - System model in operational environment

3. Exploitation

Sectors of application

Metal working industry: Metal working companies are often a supplier to OEM or Tier1 manufacturers and as such are confronted with a high-mix, low-volume product portfolio and the need to meet very short delivery times. As such these companies are struggling to automate processes mainly due to large variety in products and processes and the lack of time to setup or repurpose automation for another product or another process. A flexible and reconfigurable mobile cobot platform can allow these companies to semi-automate certain tasks such that the repetitive tasks are automated and the less frequent tasks or more demanding tasks (quality control, cell and process optimization, planning) can be done by the human operator.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Potential sectors of application

Other potential sectors of application are sectors where a comparable situation with regard to high-mix, low-volume product portfolio and a multitude of machining processes are encountered such as: laboratory test labs, wood working industry,...

Hardware / Software

Hardware:

Cobot UR10e the core element of the Reconfigurable Cobotic PRODuction Assistant platform for handling the parts between the material supply trolley and the respective machine the Cobotic Production Assistant is tending.

Tool quick change system for flexibly changing tools at the cobot flange.

Bending machine for the bending operation in the demonstrator.

Tapping machine for tapping of thread in certain holes.

Projection welding machine for the projection welding of hexagonal and square nuts.

Nut-separator unit for the nut supply to the projection welding machine.

Docking stations for the docking of Cobotic Production Assistant at the different machine stations.

Material trolley for docking to the Cobotic Production Assistant.

Software:

Universal Robot Polyscope for the programming of the UR10e cobot.

Robotiq Copilot for ease of programming, teach by demonstration.

4. Media

Photos

Video

HTTPS://VIMEO.COM/748584525/7E6C78677A

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 2: data stream processing in human-robot-collaboration

1. Basic information

Name of demonstration
Data stream processing in Human-Robot-Collaboration

Main objective
The main objective of the AURORA use case is to demonstrate the feasibility and potential of data stream processing in HRC-supported finishing processes for car body models.

Short description
The project uses the application of Human Robot Collaboration (HRC) to allow an operator to utilize pre-defined hand gestures to command and direct a robotic scanner to specific regions of interest. The 3D scanner mounted on Robot produces the 3-D point cloud data for digital cloud comparison and projection of heat map onto the car clay surface. For gesture recognition, a smart IMU wearable device is used to capture the movements of human arm based on machine learning gesture recognition algorithm.

Owner of the demonstrator
Dr. Pierre T. Kirisci

Responsible person
Dr. Pierre Taner Kirisci (Project Coordinator), pierre.kirisci@pumacy.de

NACE
C – Manufacturing

Keywords
Robotics, Vision System, Machine Learning, Motion Planning, IoT - Cybersecurity - Artificial Intelligence - Predictive Maintenance – Revamping, human-robot collaboration, wearables, artificial intelligence, Collaborative Robotics, Finishing, automation, Smart Manufacturing.

2. Innovation

Benefits for the users
The solution provides substantial benefits for the users in respect to increasing the process efficiency (e.g., reducing cycle times and post-work), the quality of products, and ergonomics of human workers.

Innovation
The innovation is evident when considering that collaborative robots in combination with AI based data analytics are yet rarely applied for supporting and optimizing finishing processes. It should also be noted that the solution provides a good basis for a whole spectrum of other applications (training & qualification, product/work quality assessment, process mining, teaching-in).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Risks and limitations
Applying human gesture tracking might be an issue for some users. Limitations are related to the fact that collaborative robots might be too slow for some processes, or too limited regarding the possible payloads. Also, the parameters of the industrial environment (such as lighting conditions) could play a role regarding the quality of the camera images and projections on the car body model.

Technology readiness level
5

3. Exploitation

Sectors of application
The project mainly focused on the finishing processes within the automotive sector. This particularly included the clay laying process on car body models. However, the solution can also support other finishing activities such as polishing and carving.

Potential sectors of application
Industrial Assembly Processes in general from various sectors such as Automotive, Consumer Goods, Construction, as Maritime.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
UR10 Robot

3D machine vision TriSpectorP1000

Zed2i Camera

METAMOTIONS IMU sensor

Projector

Software:
UR10 control software

Data Analytics Tool

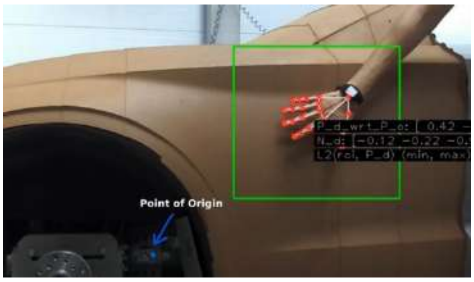
Python: For Machine Learning and Object detection

CloudCompare: For 3D point cloud comparison

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video
This video represents the implementation of Trinity project: AURORA. AURORA is a data stream processing experiment that supports process control and optimization of Human-Robot-Collaboration (HRC) workplaces through data stream processing and machine learning. The experiment is conducted on behalf of a finishing process for car exterior clay models.

[HTTPS://YOUTU.BE/DTQRNB7GK68](https://youtu.be/DTQRNB7GK68)

[HTTPS://YOUTU.BE/DRSTX4WITQG](https://youtu.be/DRSTX4WITQG)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 3: ROBOCUT – robot solution which provide an agile and flexible system for packaging

1. Basic information

Name of demonstration
RoboCut - robot solution which provide an agile and flexible system for packaging

Main objective
RoboCut – the in-site packaging robot increased effectiveness and efficiency of the whole production process, as well as boosting the productivity of the whole company and reducing waste. In the long term will play a key role in helping custom small batch manufacturing by providing an agile and flexible system for packaging-on-demand needs.

Short description
Many companies, the packaging part of the production is still a bottleneck. There are three types of approaches that manufacturing companies apply today to meet their packaging needs.

- SME's usually have a packaging supplier which accepts custom measurements for packaging.
- Another approach used mostly by SMEs is to order raw materials and make packaging in-house using the manpower.
- Lastly, some large companies use packaging machines. Currently, these machines are very expensive, not flexible

None of the approaches has all of the following – fast, agile and (relatively) cheap.

<u>We solved all of these challenges</u>.
The project **RoboCut** let us remove the technological challenges of finding the right packaging for custom production by enabling companies to tackle their packing issues in an agile approach and allow us to be more competitive globally and against the other manufacturers.

Owner of the demonstrator
BaltLed

Responsible person
Ieva Semberiene

NACE
C28.9.5 - Manufacture of machinery for paper and paperboard production

Keywords
Robotics.

2. Innovation

Benefits for the users

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

To optimize the last stage of the production process (packaging), the packaging process is easily controlled and able to deliver custom packages for a variety of products. We use robot solutions which automatically optimize and map the layout of packaging liners on standard cardboard sheets, cuts the layouts ensuring a flexible and rapid product life cycle.

Innovation

This system is in line of custom products and the solution – the human-machine interface is integrated with the Odoo ERP system.

Risks and limitations

Helping custom small batch manufacturing by providing an agile and flexible system for packaging-on-demand needs.

Technology readiness level

7 - System model in operational environment

3. Exploitation

Sectors of application

Manufacrure.

Potential sectors of application

SME's with flexible production to remain competitive in the market especially for those developing custom solutions for its customers.

Patents / Licenses / Copyrights

Hardware / Software

Hardware:
Robocut Kuka

Software:
Odoo ERP

4. Media

Video
RoboCut
HTTPS://YOUTU.BE/5M6FZOHPUCO

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 4: BRILLIANT - a collaborative work cell and solutions for flexible artisanal manufacturing

1. Basic information

Name of demonstration
A collaborative work cell and soLutions for flexIble artisanal manufacturing (BRILLIANT)

Main objective
BRILLIANT pursues two main objectives towards the autonomous uptake of collaborative robotics solutions by SMEs:

- Developing smart, orchestrated and reconfigurable collaborative workcells to reduce adoption barriers of collaborative solutions for SMEs. For this reason, it introduces solutions for the seamless connection of company equipment and digitisation of signals and parameters coming from legacy systems into a cloud platform based on ILVM. At the same time, it provides a stepwise procedure, with guidelines and quantifiable KPIs, for evaluating the potential of current industrial applications towards the adoption of collaborative approaches.
- Combine flexibility and dexterity of humans with the repeatability of cobots towards artisanal manufacturing 4.0. Such an ambitious goal, key to a company like Ideal-tek and many other SMEs, is made possible by providing the BRILLIANT solution with an orchestrating entity like the IM that allows defining strategies to propose task assignment to cobot(s) and automated machines (based on speed and repeatability) vs human (based on experience, flexibility and dexterity).

Short description
The BRILLIANT work cell design foresees a cobot mounted on a mobile station to easily move it through different applications. The BRILLIANT application let the operator managing production orders and controlling the current work cell status.

The BRILLIANT application exploits SUPSI's Intervention Manager and HOLONIX' iLiveMachine to autonomously orchestrate the collaborative work cell.

The BRILLIANT application allows managing sequences of part programs to instruct the cobot and applies interventions to deal with critical situations. It handles several parameters dealing with part numbers and station specificities.

The BRILLIANT application simplifies the workstation setup and relocation. A structured procedure and a set of dynamic parameters have been defined to deal with possible positioning errors. A laser system helps the operator in visually detect positioning errors, supporting the reset of the station position to its initial setup.

Owner of the demonstrator
University of Applied Science and Arts of Southern Switzeralnd, Sustainable Production System Lab

Responsible person
Phd, Donatella Corti, donatella.corti@supsi.ch

Project manager, Serena Albertario, serena.albertario@holonix.it

VC of Operations, Salvatore Alivesi, salvatore.alivesi@ideal-tek.ch

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

NACE
C25.7.3 - Manufacture of tools

Keywords
industrial robotics, Collaborative Robotics, Industry 4.0, SME, Smart Manufacturing.

2. Innovation

Benefits for the users
The end-user applying the solutions proposed by BRILLIANT can develop a collaborative work cell that allowed the Ideal-tek production system to:

- produce 100% of in-quality soldered blades;
- produce 97% of in-quality cleaned and finished tweezers;
- +40% of the variability of workers' jobs thanks to both extrinsic and intrinsic job variations to improve well-being;
- Obtain a relevant reduction of the cobot relocation time in other work stations.

Innovation
Ideal-tek obtained a smart-work cell that take advantage of both machines and human capabilities and ensure a considerable improvement to the agility of the manufacturing system. The cobot can be applied to different part numbers and it can be relocated in different work stations. The BRILLIANT app allows to autonomously orchestrating the collaborative work cell and managing sequences of part programs to instruct the cobot. It also applies interventions to deal with critical situations. It handles several parameters dealing with part numbers and station specificities.

Risks and limitations
The solution has to be configured and integrated depending on the production system characteristics and requirements.

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Labour intensive manufacturing, The target end-users of the BRILLIANT solutions are all the companies that have labour intensive, repetitive and intensive tasks and aim to increase process performances and at the same time improve wellbeing of their workers. In particular, SMEs often struggle to keep the pace with the digital and technology evolution. The traditional approach to automation isn't much of a help for SME's case. As a matter of fact, traditional automation relies on rigid programming made by experts, most of the time external to the manufacturing company, that perfectly optimize lines dedicated to a fixed production – a car, a fridge – for a consistent time span. Transposing this approach to SMEs, even employing cobots, is simply going to fail, for their industrial needs are substantially different.

Hardware / Software

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Hardware:
Universal Robot UR10

FAE Box

Software:
BRILLIANT Intervention Manager

iLiveMachine

4. Modules

SAFE HUMAN DETECTION IN A COLLABORATIVE WORK CELL

Main functionalities
Creating safety areas: flexible and adaptive creation of dynamic safety areas is based on information from safety approved safety equipment such as laser scanners, microwave radars, and additional safety equipment such as RF indoor positioning and 360 cameras. The aim is to create a safe collaborative working cell for robots and employees performing tasks such as collaborative assembly. The hardware of the solution is based on off-the-shelf commercial components.

Technical specifications
The system consists of safety-approved systems and additional systems for increased safety. Any suitable combination for the application can be used. The system is able to observe/detect people around the robot cell and the robot can be controlled correspondingly. The robot can be slowed down or stopped depending of the distance from a human to the robot. The dynamic safety system can use laser scanners, light curtains, microwave radars, indoor positioning, and 360 cameras.

Inputs and outputs
Data from each sensor is transferred to the robot controller as a digital signal, which in configuration with the inputs on the industrial robot may be used to slow or stop the robot's motion, depending on the type of safety zone violation. The safety zones may be reconfigured as preset settings, which makes it possible to dynamically reconfigure safety solution combinations for different scenarios. The sensors also feature configurable inputs and outputs for basic functionality and interoperability.
SICK S300 Standard Series safety scanner, Pilz PSENscan, and SICK saferRS connect straight to appropriate inputs on robot controller or to a separate PLC. Safety scanners use different outputs for different signalling purposes, such as warning zone violations or lens contamination. These signals can be used in great variety, depending on the production cell's requirements. SICK saferRS safety radar sensors operate on two states: motion detected or motion not detected where the state information is transmitted

Formats and standards
ISO 10218-1:2011, Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
ISO 10218-2:2011, Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration

Owner (organization)
Centria University of Applied Sciences

Trainings
Online training material is available through the TRINITY training platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 5: RAISE - Robots as an intelligent services ecosystem

1. Basic information

Name of demonstration
RAISE (Robots as an Intelligent Services Ecosystem)

Main objective
The objective of the RAISE™ project was to turn the manufacturing servitization trend to the benefit of robotic manufacturers developing a **Robots-as-a-Service (RaaS)** platform demonstrating the possibility for 3rd party providers to offer value-adding services (e.g. prognostic maintenance, production intelligence, insurance, and payment services ..) to Industrial Robots manufacturers by means of new open interoperability standards (e.g. the Robotics open standard by OPC UA).

Short description
The demonstrator was based on the Equipment as a Service (EaaS) platform of prime proposer MYWAI SRL custom enhanced for a world-leading Robots Manufacturer, Mitsubishi Electric™, with the engagement of Italian and Lithuanian Insurtech and Neurocomputing start-ups YOLO SRL and Neurotechnologijos UAB.

Owner of the demonstrator
MYWAI SRL

Responsible person
CEO MYWAI Fabrizio Cardinali, f.cardinali@myw.ai

NACE
C28.4.9 - Manufacture of other machine tools

Keywords
Robotics, Machine Learning, IoT - Cybersecurity - Artificial Intelligence - Predictive Maintenance – Revamping, iot, artificial neural networks.

2. Innovation

Benefits for the users
The RAISE™ Project enables robotic machine tool vendors to manage their Robotic fleet as an Intelligent Services EcoSystem using AI, IIoT and DLTs at the very edge of Industrial Robots working in Real World today and in the Productive Metaverse tomorrow.To date the RAISE™ project has piloted delivering advanced Servicetech (e.g. prescriptive and prognostic maintenance), Insurtech (e.g. parametric insurances and warranty extension) and Fintech (e.g. pay per use, pay per outcome) services to Robotic Workforces using the standard OPC UA™ Robotics Information Model to interface Robots and their digital twins to the MYWAI™ EaaS (Equipment as a Service) Platform.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Innovation
The RAISE platform supports the delivery of Artificial Intelligence based Prognostic Maintainance and Production Quality Control at the very edge of Industry 4.0 machiner via Time Series Smart Data Labelling, MLOPS AI Pipeline Build UP followed by Edge, Fog or Cloud Delivery of developed algorythms also supporting chip based delivery of neural networks

Risks and limitations
The RAISE demonstrator helps robotic machine tool vendors to move towards a product as a service model in order to cope with the slow down and rocky performance during pandemic and war period

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Robotics.

Potential sectors of application
Maintenance, Quality Control

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
The Demonstrator was based on a proprietary edge computer and IMU sensors by MYWAI

Software:
d on the mYWAI Equipment as a Service platform provided by MYWAI

4. Media

Photos

Video
Project Intro Video
HTTPS://YOUTU.BE/SDZHJNKGM9W

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Commented Video
HTTPS://YOUTU.BE/CS-BOCTRW5Q

5. Modules

MYWAY 4 Robotics AI algorithms catalogue

Main functionalities
This module consists of a catalogue of AI algorithms for the analysis of sensory data coming from industrial equipment. In particular, the presented algorithms allow to highlight deviations from standard behaviours and identify recurrent patterns. All the presented algorithms have been tested on triaxial data coming from a series of Inertial Measurement Units (IMUs) attached to a robotic manipulator, but their interfaces are modular, and they can be adapted to other applications or sensors.
In particular the first set of AI algorithms developed and shared enable the intelligent, unsupervised detection of:

- Robotic Joints fault detection
- Robotic Movement pattern searching
- Robotic Multivariate cross related fault detection

Technical specifications
The module groups three different algorithms for the analysis of industrial machinery activities:

- Radial Basis Function Neural Network for fault detection
- Dynamic Time Warping for pattern searching
- Principal Component Analysis for fault detection

Radial Basis Function Neural Network for fault detection

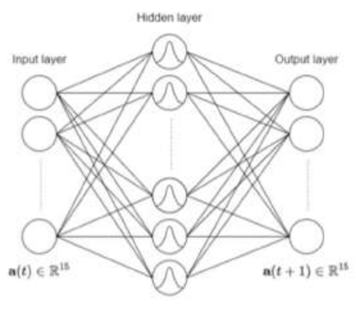


Figure SEQ Figure * ARABIC 1: Graphical representation of the RBF network. The input layer consists of 15 acceleration values captured at time instant t by 5 triaxial accelerometers, whereas the output layer is composed of the predicted acceleration values at the subsequent time instant t+1.

This algorithm is distributed as two functions one to train the Radial Basis Function Neural Network (RBF-NN) and the second one to monitor the machinery behavior. In this algorithm the RBF-NN is used as a regressor to predict the sensor information at the next time instant given the information at the previous time stamp, as depicted in Figure 1. For this reason, it is necessary to train the RBF-NN to correctly predict the sensor information by providing an example of the expected behavior. Therefore, the training function gets as input a multidimensional array containing the sensor data stream and the network parameters (i.e., number of neurons and a value, aka gamma, controlling the level of non-linearity of the radial basis activation function). The sensor array has a dimension of NxL, where L is the number of features (e.g., for

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

a triaxial accelerometer is going to be equal to tree) and N is the number of time stamps collected. Notice that, since the RBF-NN parameters are computed in closed form and only a single repetition of the expected behavior is necessary to train the network, this step is carried out in a very limited amount of time. A vector containing the network parameter resulting from the training process is then saved on file. Similarly, the second function gets as input a multidimensional array, containing the data that should be monitored, a threshold, and loads from file the RBF-NN parameters. The RBF-NN processes each time stamp up to N-1 generating a prediction and matches the prediction with the real value using and Euclidean distances. If for a time stamp the prediction error is higher than the threshold received, that timestamp is reported as an anomaly. Therefore, the module output is binary array of length N-1 specifying if each time stamp presents an anomaly. An example of fault detection applied to the IMU data acquired from the robotic arm is shown in Figure 2.

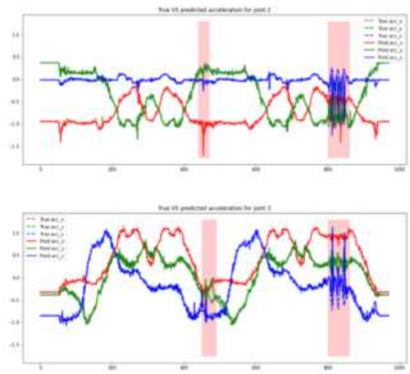


Figure SEQ Figure * ARABIC 2: These graphs show the comparison between measured and predicted acceleration patterns for two separate joints of the robot's arm. During abrupt and unexpected anomalies in the robot's behavior (here highlighted in red), the predicted patterns greatly differ from the ones measured, therefore a malfunction is issued.

Dynamic Time Warping for pattern searching

This algorithm is composed of a single function. This function gets as input two multidimensional arrays, one containing data associated to the reference pattern and a second one containing the whole window of data where the search should be performed. Furthermore, the function gets as input two parameters, specified as percentage values: the level of desired correspondence between the reference pattern and possible matches, and a value controlling the overlap between two consecutive windows. Notice that, the higher the overlap value, the more computationally intensive the function becomes, as more iterations of the search are performed, but with a higher accuracy in successfully identifying correspondences.

The reference pattern has a size of NxL, where N is the sample length and L is the number of features. Instead, the second array has a size of MxL, where M is the dimension of the full window on which the search is run. The module inspections the data using a sliding window of length N and uses Dynamic Time Warping (DTW) to measure the distance of the data contained in the windows with the reference pattern. If the distance is under the given threshold (which, in turn, is based on the desired level of correspondence), the window is recognized as a match with the reference pattern. The module returns a binary array of length M where each sample is specified if they belong to the reference pattern or not. Examples of the execution of the presented algorithm are shown in Figure 3 and Figure 4.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

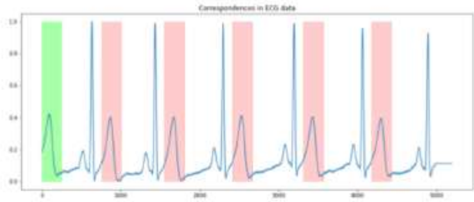


Figure SEQ Figure * ARABIC 3: Example of pattern matching in ECG data. The reference pattern (here highlighted in green) is sought over the entire window of data and several matches (in red) are found, with a correspondence of 95% between the waveforms.

Principal Component Analysis for fault detection

This algorithm is composed of a single function. This function gets as input a single multidimensional array containing the data to process, the maximum number of components that the algorithm should consider and a threshold value. The multidimensional array of dimension NxL, where L is the number of features (e.g., for a triaxial accelerometer is going to be equal to tree) and N is the number of time stamps collected, is transformed using the Principal Component Analysis (PCA). PCA is a transformation process for multivariate data usually used for feature reduction. The components computed by the PCA are ranked according to the data variation that they represent. This mechanism implies that, especially when a repetitive behavior is present, the first few principal components represent the behavior while the other contains only noise. We use this mechanism monitoring the last components extracted from the PCA to identify the occurrence of faults. This is performed thresholding the less representative components. Therefore, the module output is binary array of length N specifying if each time stamp presents an anomaly or not. The working mechanism of this algorithm is illustrated in Figure 5 and 6.

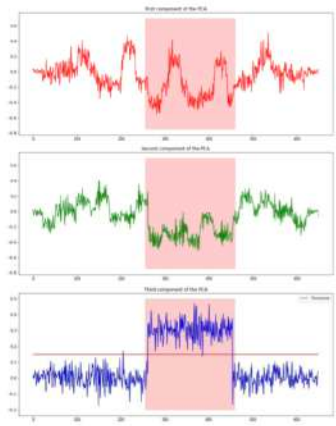


Figure SEQ Figure * ARABIC 6: The PCA decomposition of the data presented in Figure 5. The first two component represent the normal behavior of the robot and therefore no difference can be observed in the red area. The third component instead represents the signal noise, and a threshold can be applied to identify the disturbance.

Inputs and outputs

Radial Basis Function Neural Network for fault detection

The training function gets as input an NxM array and the network parameters (number of neurons and a value, aka gamma, controlling the level of non-linearity of the radial basis activation function). The training function writes on file the learned network parameters whose size depends on the number of neurons specified. The monitoring function gets as input and NxM array, a threshold and the trained parameters previously saved on file. The monitoring function returns a binary array of length N-1 specifying if each time stamp represents an anomaly or not. Therefore, the function output is binary array of length N specifying if each time stamp presents an anomaly or not.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Dynamic Time Warping for pattern searching

The algorithm gets as input an NxL array representing the pattern thought, an MxL array consisting of the full window of data and two percentage values: correspondence and overlap. Then it returns a binary array of length M specifying if each time stamp belongs to the reference pattern or not.

Principal Component Analysis for fault detection

The algorithm gets as input an NxL array containing the data to monitor, the number of principal components to compute and a threshold. Then it returns a binary array of length N specifying if each time stamp presents an anomaly or not.

Formats and standards

All the algorithms Python implementation uses standard libraries and are available at the following link: **HTTPS://GITHUB.COM/THEENGINEROOM-UNIGE/MYWAY4ROBOTICS-REPO**

Owner (organization)

KNOWHEDGE SRL
UNIVERSITY OF GENOA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 6: EAF - Robotized inspection system for high – temperature electric arc furnaces

1. Basic information

Name of demonstration
Robotized inspection system for high-temperature electric arc furnaces (EAF)

Main objective
The proposed solution is expected to address **human safety-related** challenges in the steel industry, by proposing the automation of a demanding process that is currently performed by humans:

- High temperature **robotized inspection** system
- **Remote control** robotic operations assisted by human decision and supervision system
- **AR human operator support** for maintenance tasks

Short description
The **Robs4Steel** proposes the robotization of visual inspection in the refractory of the furnace after every tapping of liquid steel, allowing to human operators to remotely guide the robot around the furnace refractories so to ensure their safety.

Owner of the demonstrator
CASP

Responsible person
George Papanikolopoulos, CASP

Konstantinos Smyrniotakis, STOMANA

NACE
C24.1 - Manufacture of basic iron and steel and of ferro-alloys

Keywords
Robotics, Motion Planning, human-robot collaboration, wearables, Augmented Reality.

2. Innovation

Benefits for the users
The Robs4steel solution is an easy-to-use system for controlling remotely industrial robots that are operating in hazardous environments. In the system could be integrated advanced vision sensors, various robotic platforms and different user interfaces (table, AR, VR).

Innovation
Robs4steel addresses human safety-related challenges in the steel industry, by proposing the automation of a demanding process that is currently performed by humans. The physical existence of human workers

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

around the furnace currently is counted up to 10 times and with the Robs4steel system, this could be reduced down to 1. Moreover, the easy teleoperation of the robots increases their overall utilization of more tasks.

Risks and limitations
The application area, which is hazardous workplaces, is primarily responsible for Robs4steel's limitations and risks. To function in challenging environments, high-quality, long-lasting hardware is needed.

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application
Steel Industry: Inspection of the furnaces with the easy teleoperation of high payload industrial robot, Steel Industry: Robotized sampling of the tapped metal.

Potential sectors of application
Robs4steel solution could be applied in every sector that requires the teleoperation of a robotic system for ensuring the safety of human workers. Industries with hazardous environments such apart from Steel Industry are the Mining Industry, Construction industry etc.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
Industrial Robot (no specific vendor)

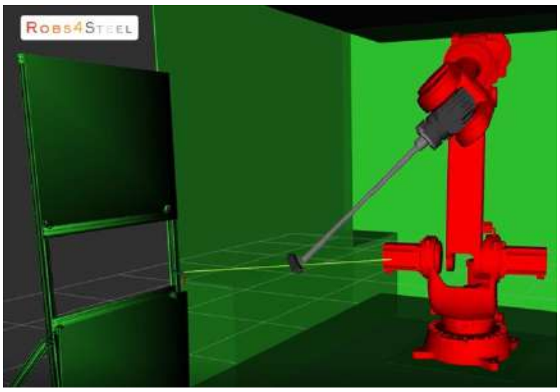
Android Tablet or AR/VR Headset

Industrial PC

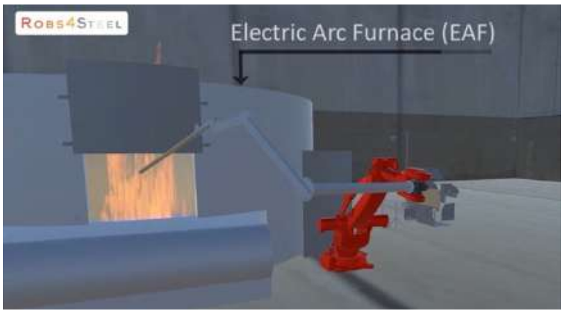
Software:
Robs4Steel Human Interface (Android, AR/VR)

Robs4Steel Robot Controller

4. Media



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



5. Modules

Main functionalities

The AR based Operator support module aims to increase human operator safety awareness, during human robot collaborative assembly tasks. The developed AR Application supports the human operator during the assembly process, through visual signals and notifications, in order to be aware of the execution status of every operation and the status of every resource, see figure below. Furthermore, this module provides to the operator the ability to navigate the mobile robot if considered necessary.

AR Application functionalities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Technical specifications

The application is developed using the Unity3D game engine to cover the communication and the visualization needs, and the Vuforia library, to realize the AR functionality. The main advantage offered by the Unity3D software, apart from the ease of use, is the possibility of exporting the same application to different platforms (Android, iOS, Windows). Taking into consideration that the hardware is running either Android (Epson Moverio BT200 AR glasses, etc.) or Windows (HoloLens AR glasses), this is a really helpful feature to run, test and evaluate the same application to multiple devices.

Inputs and outputs

The Augmented Reality Operator Support Application uses a set of input data from the system to provide the aforementioned functionalities to the operators. The required input data are listed below:
List of assembly tasks that need to be executed
Assigned resource for each task
Assembly instructions
System recovery instructions
Dimensions of robot safe working volumes
The Augmented Reality Operator Support Application provides a set of outputs:
Assembly instructions
Robot behaviour information for increasing safety awareness
Safe working volumes
Production status information

Formats and standards

Standards: ISO / TS 15066:2016 Robots and robotic devices – Collaborative robot,
Formats: Web standards, XML / JSON format

Owner (organization)

LMS – University of Patras

Trainings

Trainings will be added in the TRINITY Training Platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 7: DYNCOMM: Dynamic collaborative control of mobile manipulators for complex picking

1. Basic information

Name of demonstration

DynCoMM: Dynamic Collaborative control of Mobile Manipulators for complex picking

Main objective

The general objective of the project is to develop a novel computer vision guided collaborative control solution for mobile manipulators. The proposed technological modules are shown. The integration and synchronization of control and computer vision modules will be done in an external real-time controller that will manage and control the multiple agents and systems involved in the operation (i.e. mobile platforms, collaborative manipulators, perception devices and/or robotic tools).

The general objective of the project is to develop a novel computer vision guided collaborative control solution for mobile manipulators. This concept is represented in Figure 1, where the proposed technological modules are shown.

The integration and synchronization of control and computer vision modules will be done in an external real-time controller that will manage and control the multiple agents and systems involved in the operation (i.e. mobile platforms, collaborative manipulators, perception devices and/or robotic tools).

Short description

DynCoMM is an advanced robotic solution for external control of mobile platforms to perform dynamic operations in collaborative scenarios. The objective is to control and synchronize both application operation and platform dynamics simultaneously, increasing the productivity and flexibility of potential applications. Thus, three prominent aspects must be considered: the environment and process analysis, the collaborative integral control of the mobile manipulator, and the application integration. DynCoMM solution includes the integration of computer vision algorithms for both the application and the environment reconstruction.

The developed RealTime (RT) external control system will use the obtained information to perform complex picking applications in industrial collaborative scenarios. More specifically, the demonstrator will be focused on complex manufacturing processes where manual operations are still needed, facing technology challenges in the field of robotics and vision-based Human-Robot Collaboration (HRC). The project presents a novel solution for mobile manipulators, embedding the robot manipulator into a mobile platform to combine their benefits. The combination of both actuators increases productivity, as the mechanism will be synchronized to operate in RT with the manufacturing line workers, creating a human-machine collaborative environment. This high level of coordination between the mobile manipulator and the human employer is obtained by integrating a novel artificial vision framework designed to recognize in RT the environment and make decisions about the mobile platform position to maintain human safety without halting the production.

Owner of the demonstrator

Electrotécnica Alavesa

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Responsible person
ELECTROTÉCNICA ALAVESA
Oihane Mayo Ijurra,
Engineer at R&D department E-mail: o.mayo@aldathink.es

NACE
M71 - Architectural and engineering activities; technical testing and analysis

Keywords
Robotics, Vision System, Machine Learning, human-robot collaboration, Collaborative Robotics.

2. Innovation

Benefits for the users

Transfer repetitive operations from humans to robots.

Automate complex production processes through HRC environments.

Implement higher automation and efficiency levels for increased competitiveness employing Computer Vision and AI-based control technologies for mobile manipulators.

Solve picking limitations in dynamic and mobile manipulators.

Progress in the use of technologies that allow self-adaptability and flexibility in industrial processes

Innovation

Novel mobile platform designed to coordinate the robotic manipulator and the mobile platform through a novel artificial vision algorithm in RT.

New platform capable of performing dynamic manipulation of complex pieces in collaborative and hazardous environments.

Flexible and easy integration of RT controllers and computer vision solutions.

Risks and limitations

Failure in the integration of software modules and developments. Inaccurate specifications of use case scenario or demonstrator platform. Inaccuracies in the reconstruction of systems through Computer Vision. Synchronization inaccuracies between robot and platform systems. Loss of consortium partnership. Failure to achieve industrial relevance. Real-Time limitations in commercial Hardware. Failure to complete the demonstration. Failure to manage the project effectively.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Automotive, Aerospace, Medical, Electrical.

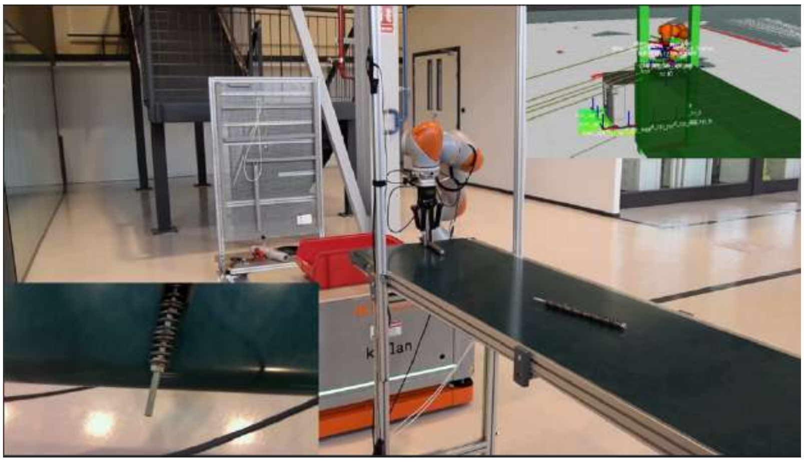
Potential sectors of application
Cross-sectoral approach through mechanical operation enhancement.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
KMR
External CPU
Computer Vision Cameras
iiwa 14 R820
Battery Charging Station
External control unit (ROS)
Operation Interface – HMI

Software:
ROS
TRINITY Modules
Sunrise

4. Media

Photos



Video
[HTTPS://YOUTU.BE/QFFPTPZDOLS](https://youtu.be/QFFPTPZDOLS)

5. Modules

DEPTH – SENSOR SAFETY MODEL FOR HRC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

Depth-based safety model for human-robot collaboration: Generates three different spatial zones in the shared workspace which are then online modelled, updated and monitored.

Technical specifications

The overall description of the hardware requirements and the different software nodes in the module are shown in Fig 2 The workspace is monitored by the Kinectv2 sensor at the frame rate of 30 Hz and the robot is UR5 from the Universal Robot family. Other depth sensors can be used with model as long as they support the same data structure of the depth cloud information. All the nodes exchange messages using the TCPROS transport layer where the nodes that are interested in data subscribe to the relevant topic and the nodes that generate data publish to the relevant topic. Arrows show the direction of the transmission.
A modified version of ur_modern_driver and univeral_robot ROS packages is used to establish communication channel between the robot low-level controller and the safety system node. Iai-kinect2 ROS package is used to receive data from the Kinect-2 sensor and further transmit it to the safety node which monitors safety violations and changes on the workspace.
The robot and depth sensor are connected to a single laptop computer that runs the ROS Melodic distribution on Ubuntu 18.04 and performs all computing. To successfully compile the module, OpenCV and PCL libraries must be installed in addition to standard C++ libraries. Currently Kinect v2 and Universal Robot 5 are supported.

Inputs and outputs

All the data is transferred via a standard ROS transport system with publish / subscribe semantics. Input and output data formats as well as the topic names are shown in Fig 5. and Fig 6. The vision-based safety system subscribes to topics where it can receive the color and depth image and the CameraInfo message which contains the sensor intrinsic parameters. In addition, the information from the JointState message is used to generate the safety hull.

Figure 5 Data streams connected to Vision Safety system node

The only output of the node is the stop command for the robot which is published over the /ur_driver/dash board_command topic.

Figure 6 Data streams that are created from Vision Safety system node

Formats and standards

ROS communication layer with external image_transport package. Details about the message formats can be found from [HTTP://WIKI.ROS.ORG/SENSOR_MSGS IN](http://wiki.ros.org/sensor_msgs) addition ROS-industrial, OpenCV, PCL and C++ and Python standard libraries.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Owner (organization)

Tampere University, Finland
HTTPS://RESEARCH.TUNI.FI/PRODUCTIONSYSTEMS/

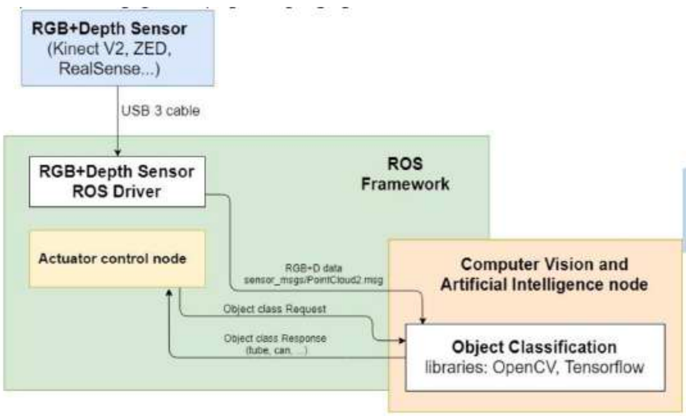
OBJECT CLASSIFICATION

Main functionalities

A deep convolutional neural network (CNN) is used to classify and sort objects. This is a robust and fast implementation of 112×112 image classification software for several classes based on specially optimized deep neural network architecture. When industrial robot picks the object, it is then classified using a convolutional neural network. In order to train the classifier to recognize new classes of objects, new training datasets must be provided.

Technical specifications

Training can be done on standard desktop PC, to ensure precision up to 99% training model requires at least 1000 images of the object. The maximum amount of the different object classes is not specified, the system has been tested with 7 different types of classes.
The depth sensor is connected to PC that runs the ROS Melodic on Ubuntu 18.04. Currently, Intel RealSense d415, d435, Kinect v2 and Zivid depth cameras are supported, but any camera with ROS driver can be used, if the data can be published as PointCloud2. All the software for this module is implemented using Python 2.7 programming language.



Inputs and outputs

All the data is transferred via a standard ROS transport system with publish/subscribe and request/response semantics. This module subscribes to RGB+Depth sensor data and produces requested object class.

Formats and standards

ROS service communication to request object class.
The sensor data is received from the sensor driver in sensor_msgs.PointCloud2.msg format.
ROS, OpenCV, Tensorflow, PCL, Python standard libraries.

Owner (organization)

Institute of Electronics and Computer Science (EDI)

Trainings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Under development

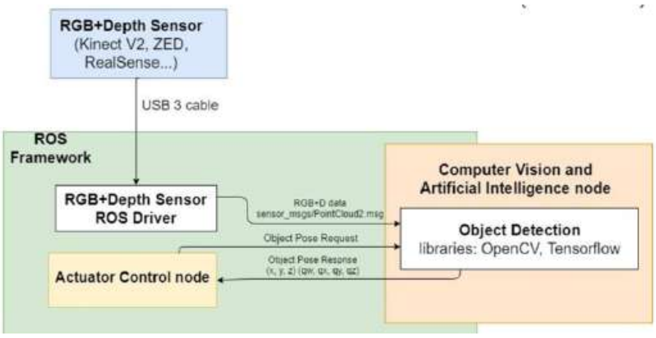
OBJECT DETECTION

Main functionalities

The object detection module is used to perceive the changing environment and modify systems actions accordingly. The module receives color frames and depth information from a camera sensor and returns information about objects to the robot control. The camera sensor could be placed above the pile of objects as well as at the end-effector of the robot manipulator. The object detection module is mainly responsible for the detection of objects that can be picked by an industrial robot and estimation of object pose.

Technical specifications

Object detection module uses an RGBD camera to detect and estimate the pose of an object. The object detection is done using the RGB frame and the depth frame is used to determine the object pick-up position. This module allows one to choose between two detection approaches – a handcrafted detector and a learned convolutional neural network-based detector (YOLO architecture).



The handcrafted approach uses segmentation algorithms (Canny Edge Detector, Selective Search, Watershed Segmentation) to divide input images into candidate regions. The parameters of candidates are compared with preselected or automatically determined values corresponding to the objects of interest (e.g. height, width, area, the ratio between the main axis of the object). Also, such parameters as the mean and variance of the depth inside the candidate region are taken into account to determine the regions most likely corresponding to the pickable objects of interest. Using these parameters, candidates are scored. If the highest-scoring candidate also surpasses a threshold score, its centre position is sent to the robot for the picking. This method is relatively hard to adjust for usage with new objects and does not classify the localized object, therefore, additionally object classification must be used for example object classification module.

The second approach is based on a convolutional neural network. When trained on specific objects, the machine learning-based approach (YOLO) detects all these objects in each frame if they are present. The object for picking is chosen by the confidence score which is returned by the YOLO model along with the bounding box coordinates and the class of the detected object. No additional classification has to be performed since object localization and classification are done simultaneously.

The YOLO-based approach allows more flexibility in the environment, as well as in shape, size, mutual similarity and complexity of objects. With good training, these aspects do not significantly impact object detection. But before the training, some preparation steps must be taken:

– acquire images of object piles,
– label objects in the images,
– set up a training environment or use a pre-built environment,
– use trained model weights to detect objects.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The labelling of real images can be done manually, however that is a long and laborious task. One must draw the bounding boxes over all pickable objects in all training samples. Therefore, EDI provides an approach of generating synthetic data that is labelled automatically. The automatic annotations include the position (bounding box) and the class of all unobstructed objects. The YOLO has been tested with simple shape objects (bottle, can), but it can be trained and adjusted for more complex shape objects.

Synthetic data generation

The depth sensor is connected to the PC that runs the ROS Melodic on Ubuntu 18.04. Currently, Intel RealSense d415, d435, Kinect v2 and Zivid depth cameras are supported, but any camera with ROS driver can be used, if the data can be published as PointCloud2. All the software for this module is implemented using Python 2.7 programming language. Robot and 3D camera must be extrinsically calibrated.

Inputs and outputs

All the data is transferred via a standard ROS transport system with publish/subscribe and request/response semantics. This module subscribes to RGB+Depth sensor data and produces pose of the object: position (x, y, z) and orientation in quaternion format (qw, qx, qy, qz) as a response to ROS service request.

Formats and standards

– ROS service communication to request the pose of the object.
– The sensor data is received from the sensor driver in sensor_msgs.PointCloud2.msg format.
– ROS, OpenCV, Tensorflow, PCL, Python standard libraries.

Owner (organization)

Institute of Electronics and Computer Science (EDI)

Trainings

Under development

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 8: CANNIER - Robotic lamination of composite parts

1. Basic information

Name of demonstration
Robotic lamination of composite parts (CANNIER)

Main objective
The main objective is to develop a flexible robotised moulding cell, capable of automatically laminating carbon fibre reinforcements that have been pre-impregnated (prepreg) with activated resin for variable product specifications.

The aim is to make the manufacturing process more agile, overcoming the bottlenecks of manual moulding (hand lay-up), to increase production performances and repeatability, with a reduced final cost of the composite parts. Develop a flexible robotic system, capable to adapt to different specific geometries, without the need for complex and time-consuming reprogramming of the robot.

Short description
CANNIER brings together two key technologies:

1- Lamination CAD designer – a software tool to generate the lamination trajectories, extracting all required parameters from the CAD of the parts to be manufactured and of the robotic tools.

2- Mechanical design of the end-effectors for the ply lamination and the tool changer. These tools dynamically adapt the pressure applied on the prepreg.

Owner of the demonstrator
Roboticssa

Responsible person
Title: Roboticsaa CEO

Name: Mr. Ignacio Secades

Contact: ignacio.secades@roboticssa.es

NACE
C28.9.9 - Manufacture of other special-purpose machinery n.e.c.

Keywords
Collaborative Robotics, carbon fiber, prepreg, composites, CFRP, lamination of CFRP components.

2. Innovation

Benefits for the users
Thanks to CANNIER, the lamination process of CFRP components will be more agile, leading to an automated environment that ensures improved quality and repeatability of the parts manufactured.

Moreover, CANNIER contributes to the achievement of significant economic and environmental benefits:

- Increase productivity: maximising the exploitation of moulds, which are very expensive assets;
- Time reduction for the moulding time of carbon fibre prepregs by 40%, compared to manual lamination;

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- Reduction of manufacturing cost by 25%, considering robot cost-effectiveness and reduced defected parts;
- Reduction of waste material due to non-compliant products between 2-3%, caused by operator mistakes;
- CO2 emissions are saved thanks to the reduction of waste and faulty components in the production process. A reduction of about 0.9 tons of CO2 is estimated, referred to as a batch of 1000 parts;

Innovation
Small manufacturers of CFRP components widely use manual labour in their production process. Options for

automation are available only to manufacture large batches or very specific parts. CANNIER introduces technologies that are more suitable than the “hand lay-up” process.

The mechanical design of a custom robot end-effectors presents a set of blunt tools for lamination of different geometries and geometrical features, and a dedicated tool changer to enable reconfiguration based on the specific process needs. The end-effector designs have achieved a balance between the variability of tools, to overcome the constraints induced by multiple shapes, geometries, and sizes of the parts.

The lamination CAM software makes the process more agile, generating the trajectories performed by the robot on the base of the parts 3D CAD models and the selected tools; the CAM tool will allow expert operators to adjust the generated trajectories based on their experience and to select the best-suited tool for each step of the lamination with an intuitive user interface (HMI).

The HMI also allows a simple reprogramming of the robot for new parts, making the process more agile and significantly reducing the time needed to reconfigure the system.

Risks and limitations
CANNIER could present limitations in two aspects that nonetheless can be addressed for a particular customer: 1- Work with molds of big dimensions. The robotic cell could be scaled up and the collaborative robot changed for a larger one. 2- Work with special geometries. For this case, new tools will be designed.

Technology readiness level
9- System/model proven and ready for full commercial deployment

3. Exploitation

Sectors of application
The sector of application is small manufacturers of prepreg carbon-fibre-reinforced polymers (CFRP) parts. These companies have the strong need to improve the agility of their manufacturing process, increasing productivity, quality and repeatability of products, and to reduce manufacturing costs. Small manufacturer of CFRP components widely use manual labour in their production process. Options for automation are available only to manufacture large batches or very specific parts. Furthermore, with the increase of components produced, other manufacturing technologies are more suitable than the “hand lay-up” process. The main industrial challenges related to the automation of the lamination process concern the achievement of the high degree of flexibility of the robotic cell (with reduced reprogramming time) and the quality improvement for the broad range of products that can be manufactured.

Potential sectors of application

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Large manufacturer of CFRP components can also potentially benefit from CANNIER. They add to the benefits that CANNIER brings to small manufacturers of prepreg carbon-fibre-reinforced polymers the potential for bigger margins due to economies of scale. The production of bigger batches could enhance the productivity of CANNIER and incentivize the development of more lamination tools for our solution.

Hardware / Software

Hardware:

Collaborative 6 DOF arm

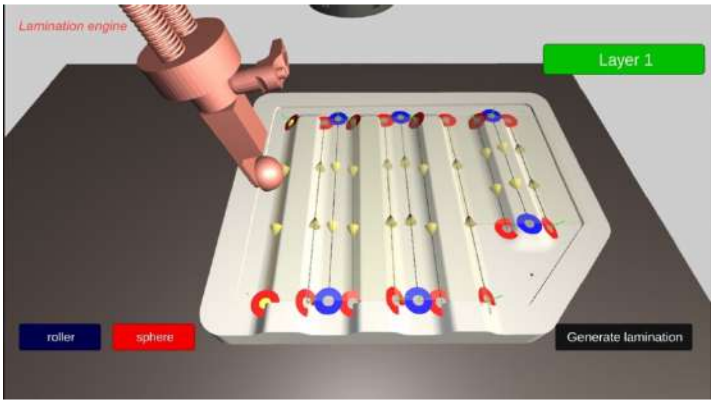
Lamination tools

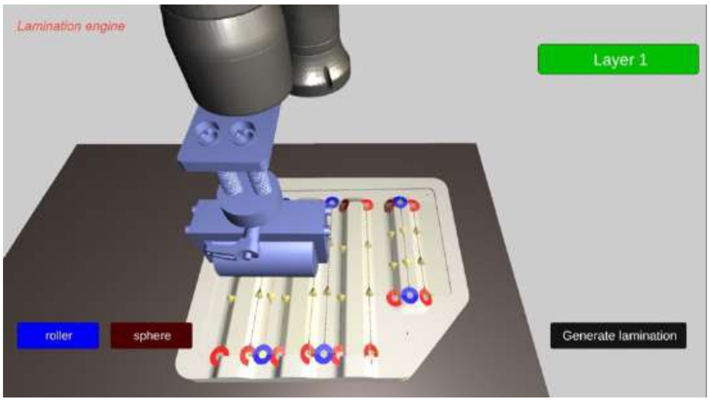
Software:

Lamination CAD designer: software for generating the lamination trajectories. A program executing these trajectories with the selected laminaiton tools is sent to the robot arm.

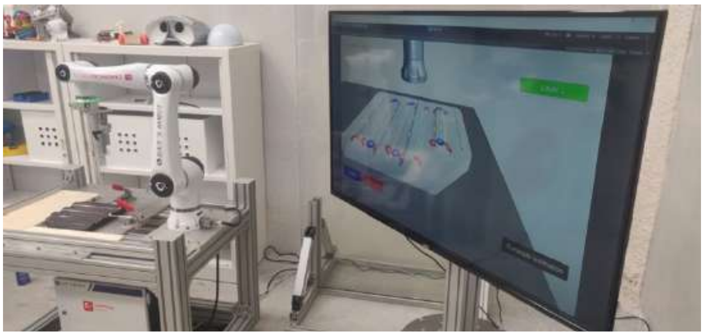
4. Media

Photos





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video

Prepreg lamination of a mold using two different lamination tools.

HTTPS://DRIVE.GOOGLE.COM/FILE/D/1CJCTG7LHRS01P_7IPIMPUUSJVQD0OIKF/VIEW?USP=SHARING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 9: DYNCOMM: Dynamic collaborative control of mobile manipulators for complex picking

Basic information

Name of demonstration
DynCoMM: Dynamic Collaborative control of Mobile Manipulators for complex picking

Main objective
DynCoMM is an advanced robotic solution for external control of mobile platforms to perform dynamic operations in collaborative scenarios. The objective is to control and synchronize both application operation and platform dynamics simultaneously, increasing the productivity and flexibility of potential applications. Thus, three prominent aspects must be considered: the environment and process analysis, the collaborative integral control of the mobile manipulator, and the application integration. DynCoMM solution includes the integration of computer vision algorithms for both the application and the environment reconstruction. The developed RealTime (RT) external control system will use the obtained information to perform complex picking applications in industrial collaborative scenarios. More specifically, the demonstrator will be focused on complex manufacturing processes where manual operations are still needed, facing technology challenges in the field of robotics and vision-based Human-Robot Collaboration (HRC).

Short description
The project presents a novel solution for mobile manipulators, embedding the robot manipulator into a mobile platform to combine their benefits. The combination of both actuators increases productivity, as the mechanism will be synchronized to operate in RT with the manufacturing line workers, creating a human-machine collaborative environment. This high level of coordination between the mobile manipulator and the human employer is obtained by integrating a novel artificial vision framework designed to recognize in RT the environment and make decisions about the mobile platform position to maintain human safety without halting the production.

Owner of the demonstrator
Aldakin

Responsible person
Oihane Mayo Ijurra,

Engineer at R&D department

E-mail: o.mayo@aldathink.es

NACE
M71.2 - Technical testing and analysis

Keywords
Robotics, Vision System, Machine Learning, Motion Planning.

2. Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Benefits for the users

Cost efficiency: Factories would obtain high degrees of automation, increasing their efficiency and profitability in the long term.

Ergonomy: In the collaborative environment presented, operators are aided through the mobile platform in their daily tasks. This situation will reduce the absenteeism of workers, as the mobile platform will deal with the most physically intensive operations, increasing the manufactory competitiveness.

Flexibility and agility: Manufactured products complexity has been increased during the previous years, while their live cycles have been decreased. This situation requires developing novel technological solutions and processes in constant adaptation to maintain production stability without reducing product quality or increasing costs

Innovation

Novel mobile platform designed to coordinate the robotic manipulator and the mobile platform through a novel artificial vision algorithm in RT.

New platform capable of performing dynamic manipulation of complex pieces in collaborative and hazardous environments.

Flexible and easy integration of RT controllers and computer vision solutions.

Risks and limitations

Failure in the integration of software modules and developments. Inaccurate specifications of use case scenario or demonstrator platform. Inaccuracies in the reconstruction of systems through Computer Vision. Synchronization inaccuracies between robot and platform systems. Loss of consortium partnership. Failure to achieve industrial relevance. Real-Time limitations in commercial Hardware. Failure to complete the demonstration. Failure to manage the project effectively.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Cross-sectoral approach through mechanical operation enhancement.

Patents / Licenses / Copyrights

Hardware / Software

Hardware:

KMR

Laptop

Computer Vision Cameras

External CPU

KUKA iiwa 14 R820

Intel RealSense D455

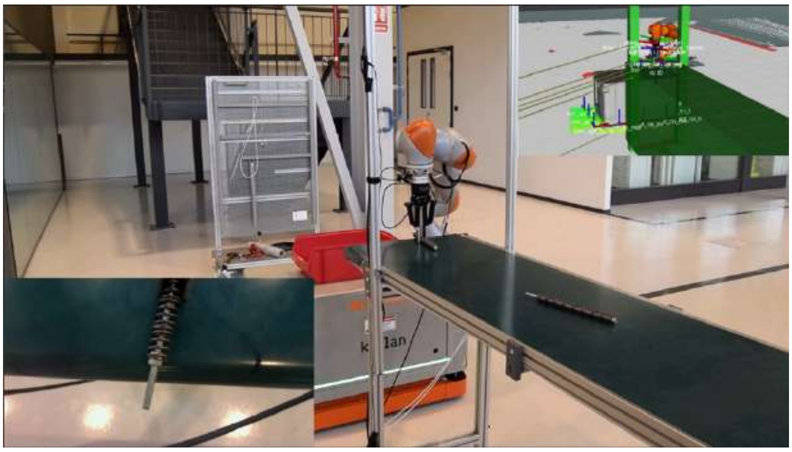
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Intel RealSense LiDAR L515

Software:
ROS
TRINITY Modules
Sunrise

4. Media

Photos



Video
Demonstration and promotional video
HTTPS://YOUTU.BE/QFFPTPZDOLS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 10: SHARKY: worker-centric programing tools for free designing of lightweight aluminium-based products

1. Basic information

Name of demonstration

SHARKY: Worker-centric programing tools for free designing of lightweight aluminium-based products

Main objective

The main objective is to demonstrate the Automation of the production in a difficult environment, integrating technologies for smart agile manufacturing, in an easy to use and flexible worker-centric programming approach to leverage the free desing of lightweight aluminium-based products.

Short description

Metal structures will be welded using the innovative "Dummy Tools" method (6DoF Measuring), preventing welding workers from exposing themselves to unnecessary risks. Collaborative robots will perform the heaviest welding activities, following the data provided by the dummy tools.

Owner of the demonstrator

AITIIP Technology Centre

Responsible person

Alberto Laguia – R&D Advanced Manufacturing

alberto.laguia@aitiip.com

NACE

C30.1 - Building of ships and boats

Keywords

Robotics, Vision System, Motion Planning, human-robot collaboration, safety, Industry 4.0, Machine Vision, automation, Additive manufacturing, Smart Manufacturing, WAAM.

2. Innovation

Benefits for the users

The project will permit to increase the market segment by empowering and automating the product production chain in the company, as in the case of their current welded brands production capaticy will be increased in 40%, delivery time reduced in 25%, as the traceability and the automation will permit to reduce the scraps and quality defects in 30%. Set up time will be reduced in 20%, as the increase of 60% of the digitization will allow the human-robot collaboration to improbe the operators work quality in 50% and reduce the injuries and labour illnesses in 50%. Full mass customization of the production will be achieved.

Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

SHARKY ROBOTIC ASSISTED WELDING SYSTEM:System will enable easier programming capabilities. The system will be composed of 6Dof cameras to track the position of the Dummy Tool at all times (position and orientation recording), at the same time, the Dummy Tool will have 6DoF sensors that will be recognised by the cameras to track the position and orientation of the tool. All this allows the operator to reduce programming time, as well as avoiding exposure to intense light and dangerous fumes caused by welding processes. Innovative hardware and software system allow the company to increase its potential capacity for automatise the welding chains actuating directly on the baud rate and the time exposure for the workers to the main welding risks (high intensity lights and dangerous fumes).

Risks and limitations

Since it is a machine vision trajectory sensing system, a high level of cleanliness in the ambient air is required. Dusty environments, large amounts of smoke... could prevent the correct capture of points, leading to errors in the trajectories. The high intensity of the light generated by the welding process could cause severe damage to the cameras of the spot detection system, it is advisable to avoid exposing all these systems. High knowledge of MIG/MAG welding processes is required, as well as previous training in the use of these tools.

Technology readiness level

5

3. Exploitation

Sectors of application

MEDIUM SIZE ALUMINIUM BOATS: Applications for the production of automatic and customisable welding seams (accessible areas for the robot).

Potential sectors of application

All types of industries where customised welding processes are required (taking into account the geometrical constraints of the robot).

Patents / Licenses / Copyrights

Hardware / Software

Hardware:

Industria robots with 6 DOF, Cameras for point capture, Dummy tool to trak

Cameras for point capture

Dummy tool to record the needed trajectory

Welding machine

Software:

MatLab

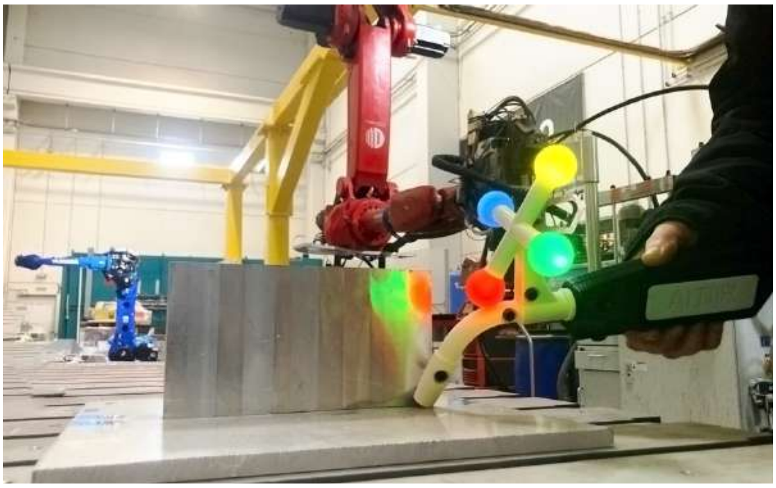
ROS

Destinated software for the comunication between all systems

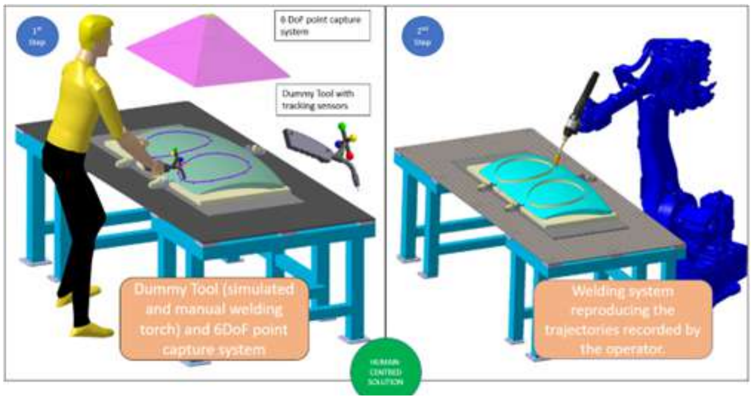
4. Media

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Photos



SHARKY



Video

Promotional video: Showing the objectives and possibilities of the SHARKY project.

HTTPS://YOUTU.BE/JF5WNMCTGUU

Dummy Tool OPEN DAY presentation.

HTTPS://WWW.LINKEDIN.COM/POSTS/AITIIP-CENTRO-TECNOL-GICO_JORNADA-DUMMYTOOL-INGENIEROS-ACTIVITY-6952533079970209792-KGTQ?UTM_SOURCE=SHARE&UTM_MEDIUM=MEMBER_DESKTOP

Executive video: Showing the main conceps and results of SHARKY project.

HTTPS://YOUTU.BE/J6UJEVXDKRY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 11: SHIPWELD

1. Basic information

Name of demonstration
ShipWeld

Main objective
Development of a robotic welding system to automate ship newbuilding and repair operations, providing technicians with the tools to work on pieces of unknown geometry, while increasing their safety and productivity.

Short description
ShipWeld is a pre-programmed free and CAD-independent welding solution, based on a UR10e collaborative 6-DoF robotic arm equipped with a welding kit. Integrated sensors handle the 3D workspace reconstruction, ensuring obstacle-free motion planning, and seam tracking. A deep learning algorithm paired with explainable AI or a handheld 3D tracking system can be used to identify seams. In total, ShipWeld reduces manufacturing costs for shipbuilders, while preventing technician exposure to harmful welding radiation and toxic fumes.

Owner of the demonstrator
iKnowHow

Responsible person
Efthymios Pachos, Technical Manager,MPACHOS@IKNOWHOW.COM

NACE
C28.9 - Manufacture of other special-purpose machinery

Keywords
Robotics, Welding, AI.

2. Innovation

Benefits for the users
The adoption of ShipWeld solution is anticipated to upsurge the user's welding capacity, leading to increase in revenues (3-fold increase in the profit margin assuming that ShipWeld efficiency will be approx. triple that of manual welding). Moreover, the impact of an automated welding solution will improve the quality of the resulting welding seam through more precise welding procedure of the steel plates. Consistency in the welding result can be achieved with the adoption of an automated solution as the robot lacks the "fatigue" factor of the manual labour. The project management will be a much easier task using a single platform for real-time result visualization and data storage for later use and analysis through specific dashboards. The robotic welding system lowers the hazard level by preventing exposure of technicians to harmful welding radiation and toxic fumes. To this end, this opportunity will lead to the modernization of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

jobs in the company like welding technicians – the welding industry is facing a workforce crisis expected to lead to higher costs, reduced competitiveness, increased turnaround times, lost revenue and declining margins-, while generating new and advanced professions embracing Industry 4.0 technologies.

Innovation

ASSET 1: One of the most important features of ShipWeld is the 3D workspace reconstruction. The 3D scanner takes multiple scans and the produced point clouds are stitched to create an accurate model of the welding piece and its surroundings, in a process that takes a fraction of the time of the previous photogrammetry method. This model is used to achieve collision free trajectory planning. The system is completely CAD-independent – no other such system is available – therefore reducing usage complexity and dependence on third-party software platforms.

ASSET 2: Trying to keep the solution as generic and versatile as possible while retaining the human expertise in the loop, we decided to provide the end-user of the system with a means of control, a way to pinpoint seams that must be welded. For that purpose, we integrated an HTC Vive tracking device, which broadcasts pose data. This pose data is used to define a desired trajectory for a particular welding target. Our solution includes communication with the UI so that the user can signal recording of the intended trajectory. However, the greatest advantage lies in the integrated laser seam tracker; users do not have to be too accurate while defining the trajectory. The seam tracker will scan along the defined path and produce the correct welding trajectory.

ASSET 3: The shipbuilding industry tends to include welding of large parts. In such cases, defining seams by hand could be tiring and counterproductive. Here comes a deep learning, in-house developed algorithm, that identifies seams along welding parts. In addition, Umnai provided technology capable of converting the black-box algorithm model into a fully-explainable and actionable white-box model. In this white-box model, or eXplainable Neural Net (XNN), the function and purpose of every node and connection within the model is known and understandable allowing for improved model interpretation, design and optimisation. Furthermore, XNNs provide explanations for predictions in real time which means that we are able to act on predictions meaningfully and with purpose, leading us to achieve the desired accuracy in results.

Risks and limitations

The welding interface is not yet integrated in the ShipWeld pipeline. The user needs to preselect the welding parameters before the system scans and welds the workpiece. Multiple paths and weaving are under development.

Technology readiness level

7 - System model in operational environment

3. Exploitation

Sectors of application

Shipbuilding, Welding.

Patents / Licenses / Copyrights

Hardware / Software

Hardware:

UR10e manipulator coupled with welding machine

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

HTC Vive

Photoneo PhoXi Scanner M

EVT Saturn laser Scanner

Software:

ROS

Bespoke ShipWeld software

4. Media

Photos

Video

ShipWeld video showcasing workpiece scanning, user interaction with workpiece using WeldWand, user interface, seam tracking, welding

HTTPS://YOUTU.BE/BDHBIFCFCYU

Documents

ShipWeld promotional material

SHIPWELD-80X200-01-1-1-SCALED.JPG

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 12: SPINEYE: AI & cloud enabled vision system for agile teach-in of assembly processes

1. Basic information

Name of demonstration
SpinEye: AI & Cloud enabled vision system for agile teach-in of Assembly processes

Main objective
Every day, millions of screws and bolts are mounted in the European manufacturing industry by employees with handheld screwdrivers in everything from windows to cars & electronic products. The Trinity demonstrator shows how to automate high/Mix – low/volume productions involving screw assembly task, by introducing an easy-to use camera system – SpinEye which is fast to setup and program.

Short description
The data is being gathered through an integrated camera sensor – light source and being processed by a cloud-based scheme that enables remote monitoring, data annotation and data management. A robust specialized Artificial Intelligence (AI) scheme that has been extensively trained on the collected data and validated on various samples has been adopted. This module is responsible for detecting and accurately localizing screw holes on PCBs. Additionally, a teach-in user friendly interface, the so-called URcap, has been implemented for simplifying the hand-eye calibration process. Last but not least, a SpinEye low-cost box that controls the communication interfaces between all the components has been included.

Owner of the demonstrator
Spin Robotics

Responsible person
Dr. Thomas Sølund, CTO Spin Robotics – email: **TS@SPIN-ROBOTICS.COM**
Lazaros Lazaridis, Machine Learning Engineer – email: **LAZAROS.LAZARIDIS@D-CUBE.EU**

NACE
C26 - Manufacture of computer, electronic and optical products

Keywords
Robotics, Vision System, Machine Learning, human-robot collaboration, artificial intelligence, cobot assisted manufacturing, Collaborative Robotics, Industry 4.0, Machine Vision, robotic cell, automation, robotics and automation, AI.

2. Innovation

Benefits for the users
Customers that will deploy SpinEye will benefit from faster changeover between tasks, while there is also no need for highly skilled workers to set up an assembly task. The quality rate will be increased, as the vision system will be able to detect slight mispositions of the fixture and adjust the cobot's instructions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Innovation
Manual screwdrivers are the norm is most assembly lines, as they are cheap and can handle the task of screwing. When using manual screwdrivers, employees are presented with strain to the body and the operation can be process to human errors due to fatigue. With robots, these factors are eliminated, and every screw will be inserted unison with precise torque. The SD35 innovates the market by making it possible for all enterprises to get access to a robotic assembly workforce, since it has a low implementation time/cost, and the fact that there is no need to change the setup of the production line.
Accidents can happen in a production line, but due to the safety features, such as the safety shield, of the SD35, those accidents will be eliminated.

The screw holes on PCBs have a diameter between 4-8 mm. The screws that will be mounted on those holes seem to have almost the same diameter as the holes. The cross on the middle of each screw is no more than 4mm. Therefore, from the AI/detection perspective, due to the screws and screw holes tiny nature, an extremely accurate machine learning object detection module has been developed.

Deep learning vision systems rely extensively on the quantity, quality and availability of input data for training. Thus, a specialized recording framework has been designed to capture and prepare the data. This framework has been implemented with respect to the assembly task, indenting to fit as closely as possible to scenarios that will be encountered during the assembly. The collected data from the recording framework is uploaded and stored in Trinity's immersive framework cloud infrastructure enabling continuous analysis, data management and annotation procedures.

Risks and limitations
Risk/limitation: Before deploying and start using collaborative robots with the SD 35 screwdriving tool a risk assessment is always required. The risk assessment must be done in accordance with the ISO12100 standard that describes how to do a proper risk assessment. At Spin Robotics web page, you can find more information about how to do a risk assessment. Here you can download a risk assessment template in excel. Furthermore, you can download test reports from force impact tests the compute be applied during the risk assessment to prove that the tool is safe in according to the ISO/TS 15066. Always remember to update your risk assessment if you change the robot installation or the robot program. Remember also to take into consideration the physical installation or the environments that the robot I inserted into. For instance, are the robot installed close to a wall such that people can get trapped between the wall and the robot. Remember to always read the user manual before starting to implement a new screwdriving application with the SD 35 screwdriving tool.

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application
Small parts assembly.

Potential sectors of application
Automotive Industry, Electronic Industry, Wood Industry

Patents / Licenses / Copyrights
Hardware / Software

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Hardware:
SD35 screwdriving tool
SPINBridge
Camera sensor and light source

Software:
Robot Apps for Universal Robots
Collaborative Robot
Screw presenter unit
Cloud infrastructure
AI – Deep learning screw detection module

4. Media

Photos

Video
Spin Eye promotional video
HTTPS://WWW.YOUTUBE.COM/WATCH?V=9GJ5FGBX2BG

Executive video
HTTPS://DCUBEEU-MY.SHAREPOINT.COM/:V:/G/PERSONAL/DIMITRIOS_KATSIKAS_D-CUBE_EU/ECTRJ0HXCHNNMD8-QSODD_0BCLBXYDAU-RZFYG1TMYYRQW?E=VLMING

D3.2 - Demonstration of Hole detection model for the Screwdriver tool
HTTPS://DCUBEEU-MY.SHAREPOINT.COM/PERSONAL/DIMITRIOS_KATSIKAS_D-CUBE_EU/_LAYOUTS/15/STREAM.ASPX?ID=%2FPERSONAL%2FDIMITRIOS%5FKATSIKAS%5FD%2DCUBE%5FEU%2FDOCUMENTS%2FDCUBE%2FCLIENTS%2FTRINITY%2DSPINEYE%2F9%2EOTHER%2FTRINITY%5FAI%5FVISION%5FSYSTEM%5FVIDEO%2FTRINITY%5FAI%5FVISION%5FSYSTEM%5F%5F%2EMP4&WDLOR=CD0A58994

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

trinity

%2D6F2D%2D499D%2DBA8F%2D5725FCE27CA9&CT=1664482358273&OR=OUTLOOK-BODY&CID=1138EADC-C51D-43B0-9523-2B9C31153639&GA=1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 13: Vision-guided deburring

1. Basic information

Name of demonstration
Vision-guided deburring

Main objective
Vision-guided deburring radically improves the quality of cleaning

Short description
In the VisDeburr project, robotized vision based system for cleaning the weld seams was developed. System is targeted for products which need very high quality result from the outlook.

Owner of the demonstrator
Convergent Information Technologies GmbH

Responsible person
Mikko Sallinen, VP Innovation and Sales
Mikko.Sallinen@convergent-it.at

NACE
C – Manufacturing

Keywords
Robotics, Vision System, Grinding.

2. Innovation

Benefits for the users
Excellent surface quality for parts, automatic removal of welding seams and cast burrs.

Innovation
Provide excellent surface quality automatically.

Risks and limitations
System needs to be trained for new type of parts.

Technology readiness level
9 - System/model proven and ready for full commercial deployment

3. Exploitation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Sectors of application
heavy industry, plastic industry, wood industry.

Potential sectors of application
Applications where parts needs to be cleaned

Hardware / Software
Hardware:
Industrial robot, sensor, grinding tool.

Software:
AUTOMAPPPS software

4. Media

Photos

Video
[HTTPS://WWW.LINKEDIN.COM/POSTS/CONVERGENT-INFORMATION-TECHNOLOGIES-GMBH_VISDEBURR-AUTOMAPPPS-FANUC-ACTIVITY-6962265908413128704-DWR_?UTM_SOURCE=SHARE&UTM_MEDIUM=MEMBER_DESKTOP]

5. Modules

Dynamic robot trajectory generation based on information from 3d camera

Main functionalities
This module provides a flexible and adaptive way to create robot trajectories dynamically based on point cloud data created automatically with 3D-camera. Module can be utilized in processing of work objects with varying physical characteristics to create robot trajectories dynamically for processes such as painting, sandblasting and pressure washing. Camera may be mounted onto the robot arm or installed in a stationary

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

manner. Secondary functionality is to provide point cloud data of scanned object to be saved as 3D-model file.

Technical specifications
Hardware:
3D camera system (Microsoft Kinect V2, Intel Realsense D435)
A laptop/desktop computer with Windows or Ubuntu 18.04
Software:
AutoMAPPPS
CloudCompare or similar point cloud data processing software
AutoMAPPPS is a family of robot programming software tools developed by Convergent Information Technologies GmbH. The software allows for fast computing of collision-free robot trajectories and program upload to robot controller for execution.
CloudCompare is a 3D point cloud and triangular mesh processing software. The software is originally designed to perform comparison between two dense 3D point clouds or between a point cloud and a triangular mesh. The software has since been developed suitable for more advanced point cloud processing, including algorithms for resampling, scalar fields handling and more.

Inputs and outputs
The input format is depth-map data provided by 3D-camera to CloudCompare and AutoMAPPPS in PLY format. This input data is used to generate a mesh model file of work object in STL or STEP format using CloudCompare, and dynamic robot trajectories are created using AutoMAPPPS.

Formats and standards
Point cloud and 3D model data formats: PLY, STEP, STL

Owner (organization)
Centria University of Applied Sciences https://tki.centria.fi/en

Trainings
Online training material is available through the TRINITY training platform.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 14: INTELLI5.0: toward industry 5.0: collaborative intelligence for supporting enhanced human-cobot interaction in agile production, demonstrated through the creation of innovative in-process quality inspection services

1. Basic information

Name of demonstration
Intelli5.0: Toward Industry 5.0: Collaborative Intelligence for supporting enhanced human-cobot interaction in agile production, demonstrated through the creation of innovative in-process quality inspection services

Main objective
The main goal is to design and develop a new technology for **realizing Collaborative Intelligence** between the cobot and human operator, based on a **novel combination of Human Cognition and Artificial Intelligence**, inspired by the way how human react on the unusual variation in external world (cognitive perception). The technology leverages the **existing work of partners: existing cobot-based product testing by TIME and cognition-driven manufacturing by Nissatech**.

Short description
Briefly, our approach detects the moment of changes in the physical parameters (force, angle, vibration) which are inducing a change in the human judgement (comfortable / not comfortable, high quality / lowe quality – i.e. human psychological perception). Since the cobot use case is related to the functional testing of household appliances we should even argue that we have developed a new approach for testing a subjective perception of the quality (based on the psychology of customers) – this seems to be very novel and interesting for our own advertisement (analytics for special cases). It is important that, based on literature, it is required to perform this “subjective / touch feeling based” test in which 50% of tested customers are confirming to “notice” difference in feeling after N usage cycles
Moreover, this method can be used for calculating the “subjective” (human touch feeling) quality of a device, like quality1 or quality2, classifying each particular device in one of these quality categories (influencing the price)

Owner of the demonstrator
Nissatech

Responsible person
dr. Nenad Stojanovic
Nenad.Stojanovic@nissatech.com

NACE
J63 - Information service activities

Keywords
cobot assisted manufacturing, data analytics, usability testing.

2. Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Benefits for the users
Main **exploitable results** are:
1) Collaborative Intelligence 5.0 as a concept for cobot-based in-process qualiy control,
2) Cognitive perception as a software module for collecting and analysing data collected from the cobot,
3) Human-cobot interaction as a service for detecting the minimal variation in the cobot operation which will impact/change the user touch-feeling
Main **exploitation** is related to offering a new service for cobot-based and cognition-driven usability testing based on all three exploitable results. It will be realized as a joint exploitation. Main market: home appilances.
Additionally, exploitable results 1) and 2) will be used for offering a data analytics service, based on cognition, for analysing process behaviour in the cobot-driven automation (not only functional and usability testing). Main market: cobot-based quality (in process) control

Innovation
There are two main issues here, which are not covered properly by the traditional cobot-based device testing and are focus of our solution:
– What is the (minimal) degradation level which indicates that the device cannot be used from the technical point of view (e.g. that the door cannot be closed completely)
– What is the (minimal) degradation level which indicates that a PERSON doesn't feel comfortable in using the device (e.g. that the door cannot be closed smoothly, from a user point of view)
Especially important is the second issue, since it reflects the aspects of the user/human "touch feeling" when using a device. The assumption is that the user will not prefer a device which, after a period of usage, will be more difficult for the operation (e.g. more force to be used for opening the door).

Risks and limitations
R1: Data obtained from the sensor is not of the desired quality for the ML process

Technology readiness level
5

3. Exploitation

Sectors of application
cobot-based functional and usability testing.

Potential sectors of application
tool wear detection

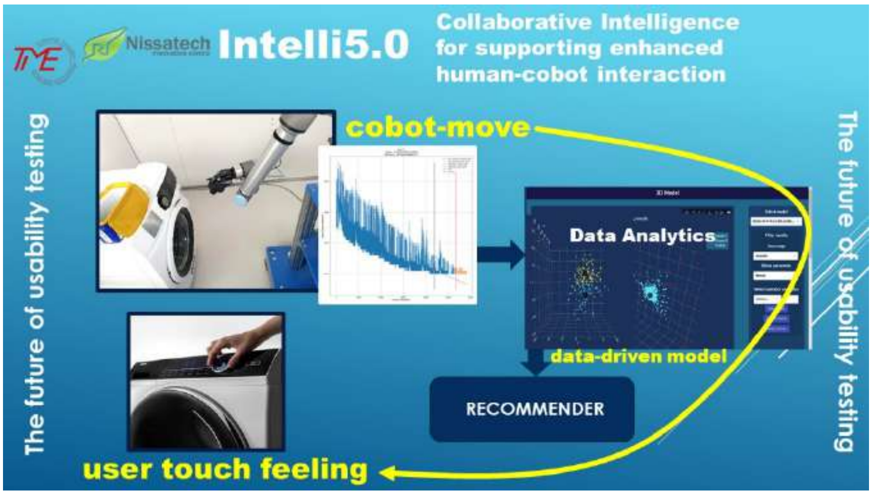
Hardware / Software
Hardware:
Cobot UR 10 E, External Load Cell,
National Instruments cDAQ acquisition system

Software:
Labview software developed for specific purpose
D2Lab (data analytics)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

4. Media

Photos



Video

Video explains the contributions of the partners

HTTPS://YOUTU.BE/UAW6YDKFCIQ

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 15: CORS - collaborative robotic solution for laser micromachining

1. Basic information

Name of demonstration
COLLABORATIVE ROBOTIC SOLUTION FOR LASER MICROMACHINING (CORS)

Main objective
To achieve micron accuracy automation solution for wafer sample placement

Short description
We have built a proof of concept, proving that even femtosecond fabrication processes requiring micron accuracy can be automated given the right tools. A collaborative manipulator arm working in tandem with machine vision technologies can achieve sub-micron accuracy required for precise sample allignment

Responsible person
PhD Gintare Grybauskaite-Kaminskiene – R&I Project Manager
gintare.kaminskiene@wophotonics.com

NACE
C28 - Manufacture of machinery and equipment n.e.c.

Keywords
Industry 4.0, automation, robotics and automation.

2. Innovation

Benefits for the users
Automation of sample placement for femtosecond fabrication / remote monitoring

Innovation
Automation of sample placement for femtosecond fabrication / remote monitoring

Risks and limitations
a. Risk – not a stable system
b. Limitations – each different fabrication must be coded separately

Technology readiness level
7 - System model in operational environment

3. Exploitation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Sectors of application
Femtosecond fabrication (job shop production).

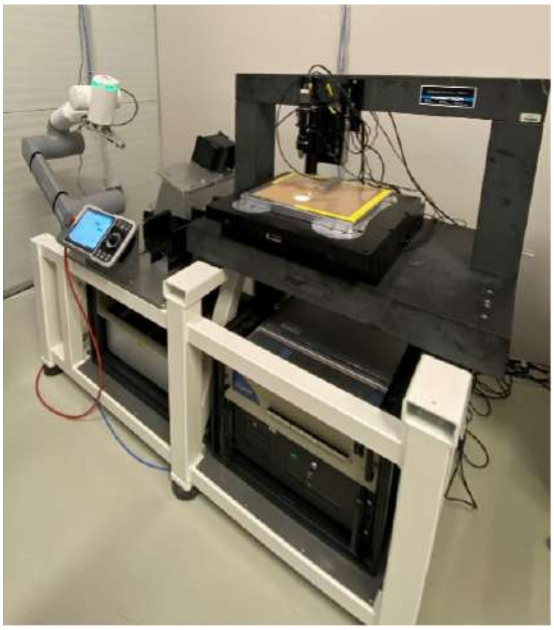
Potential sectors of application
Femtosecond fabrication mass production process

Hardware / Software
Hardware:
Aerotech controller; Aerotech XY Stage; Frame; Z Axis with camera assembly; IDS camera with 10x objective; ABB GoFa™ CRB 15000 colaborative robot; ABB controller; GoFa™ CRB 15000 compatible wafer gripper;Wafer casette; Laser sensor for wafer position and count; Industrial grade windows PC

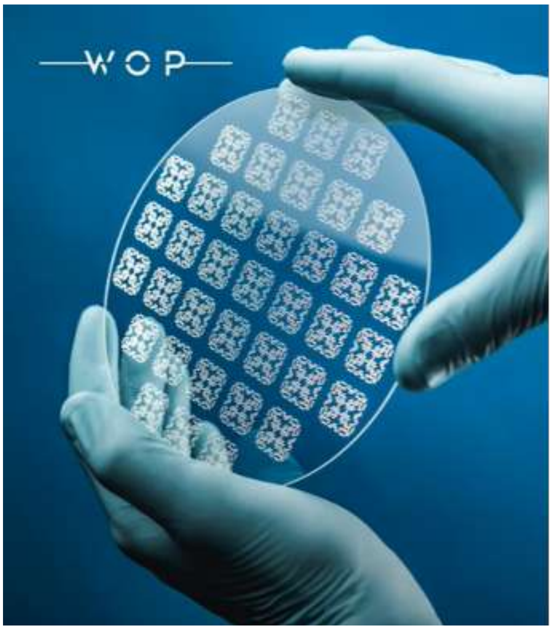
Software:
SCA laser fabrication system control software;Single software solution responsible for the whole process (machine vision, stage movement, robot control, recording of results); SCAApp,Mobile software designed for remote monitoring and control; ABB Robot Studio, Software to create robot programs and behaviours to be initiated by SCA; Aerotech/IDS drivers, Drivers required to enable communication with corresponding hardware

4. Media

Photos



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video
Workshop of Photonics, in collaboration with ABB AS, under the TRINITY Robotics DIHs project, has developed a complete robotized laser micro-micromachining workstation based on the collaborative robotic solution with the integration of machine vision and custom software.

HTTPS://WWW.LINKEDIN.COM/FEED/UPDATE/URN:LI:ACTIVITY:6976150993780535297

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 16: MCPPS – demonstrator for a milling CPPS

1. Basic information

Name of demonstration
MCPPS - Demonstrator for a milling CPPS

Main objective
This use case shows the advantages of using a CPPS in the area of machining production. It enables the user to analyse and improve machining processes on the basis of real process data. The mobile demonstrator contains all the necessary hardware and software and can be used on various machine tools without any problems.

Short description
The demonstrator combines the subsystems data acquisition and data processing into a mobile, universally applicable cyber-physical production system using the example of milling. Process data can be recorded and processed at high frequency (e.g. actual position data, utilisation data of the drives, speeds) and at low frequency (e.g. tool number, programme name). Further processing makes it possible to save the entire process as a digital twin and thus meet the highest requirements for process documentation in the course of the introduction of Industry 4.0.

Owner of the demonstrator
Technische universität Dresden, Chair of Machine Tools Development and Adaptive Controls

Responsible person
Ms. Anna Debora Renner
anna-debora.renner@symate.de

NACE
C25.6.2 – Machining

Keywords
Industry 4.0, metal processing industry automation, Process Control, CAM Simulation, modular, automation, Smart Manufacturing.

2. Innovation

Benefits for the users
The user can analyse his process holistically on the basis of the real process data from the milling process. By combining this with mathematical approaches, additional information is generated from the process data, e.g. information on dimensional accuracy and surface quality. It is possible to record and analyse the entire machining process including high-frequency and highly dynamic parameters.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Innovation
The innovation shows a mobile demonstrator for a CPPS in the field of manufacturing, especially milling. It shows the smooth interaction of data acquisition from machine and process, data management and simulation models. The analysis of the process and the resulting quality of the machined part will be based on real process data, not just simulated data. Process optimisation can already begin after the first part. The data obtained will be stored in a digital twin and can meet future requirements for gapless process documentation as part of the spread of Industry 4.0.

Risks and limitations
actual version of the demonstrator is for use with a CNC Sinumerik 840D only, use of real process data depends on the Siemens licensing

Technology readiness level

a. - System model in operational environment

3. Exploitation

Sectors of application
The demonstrator is used in the field of machining, especially for the milling process. It shows the advantages of using a CPPS over just collecting data with an Egde device, processing the data and analysing the data according to different objectives. The acquisition of high and low-frequency process data directly from the channels of the machine control system without the need for additional sensors makes it possible to acquire data very close to the process. Further processing and use in combination with mathematical models (e.g. cutting force, surface) and artificial intelligence approaches enables a new quality of process evaluation.

Potential sectors of application
The demonstrator can also be used for other processes and machines that are equipped with a Sinumerik 840D. These can include lathes, forming machines and highly automated systems.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
Machine tool with control Sinumerik 840D

SIMATIC EDGE as interface to the Sinumerik 840D

PC for using the DETACT system and the digital twin

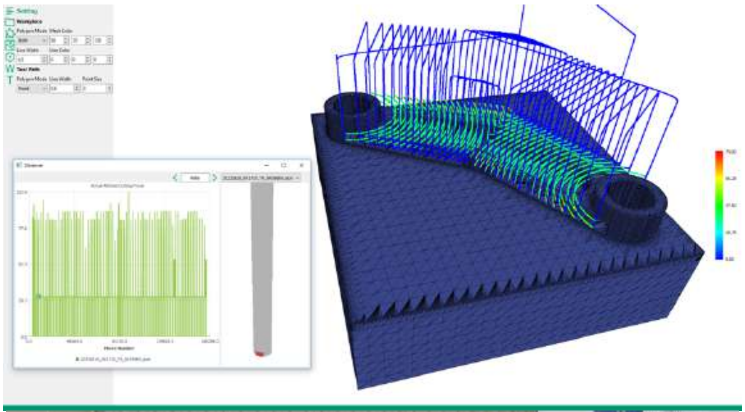
Software:
WINDOWS OS

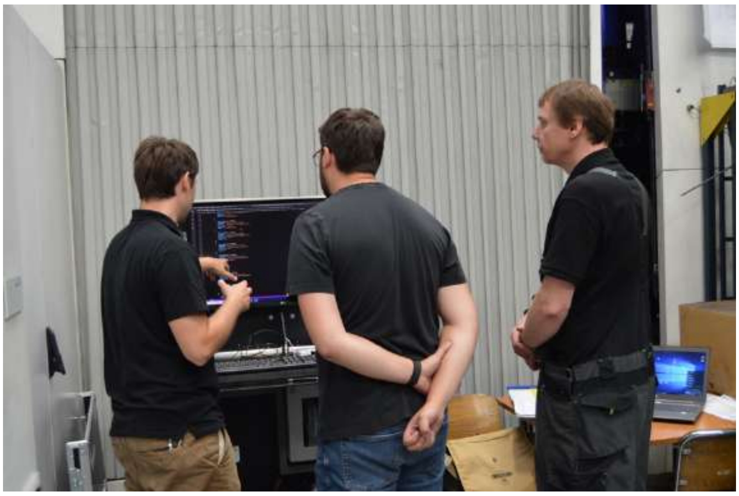
DETACT

Siemens software licenses (depending from the software at the CNC used at the machine tool)

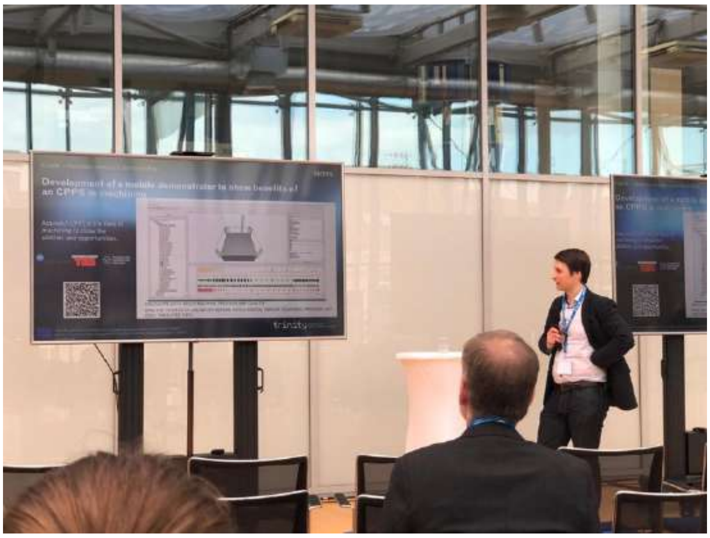
4. Media

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

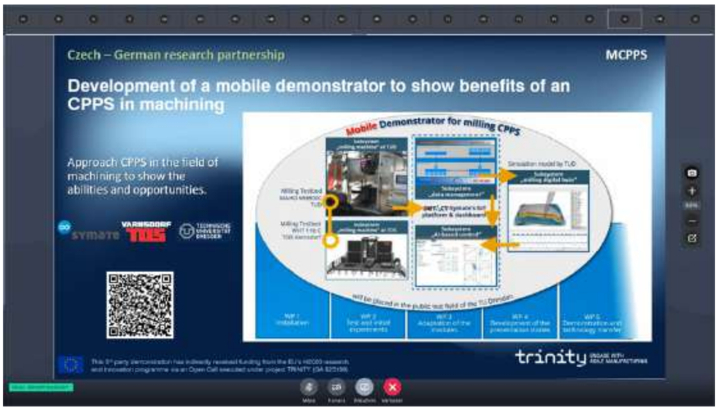




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video
The video is the summary of the project with information about the scope and teh partners.
HTTPS://CLOUDSTORE.ZIH.TU-DRESDEN.DE/INDEX.PHP/S/XSD3OHFYAPBC3JO

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 17: Predictable bin picking of shafts and axles

1. Basic information

Name of demonstration
Predictable bin picking of shafts and axles.

Main objective
The main objective is to demonstrate reliable bin picking of shafts and axles in real industrial scenarios and to quantify performances in order to confirm the technical readiness of the solution for the industry.

Short description
The seamless integration of a versatile gripper integrated with the Pickit 3D vision platform and specific software for shaft handling, allows a robot manipulator to pick shafts randomly positioned in a bin to feed CNC machines.

Owner of the demonstrator
Pickit 3D

Responsible person
Tim Habra, VP Engineering

tim@pickit3d.com

NACE
C25 - Manufacture of fabricated metal products, except machinery and equipment

Keywords
Robotics, Vision System, industrial robotics, artificial intelligence, Bin-Picking, Machine Vision.

2. Innovation

Benefits for the users
Compare to a mechanical feeder, this solution significantly reduces maintenance costs and saves floor space. Also, thanks to its flexibility, it can cover a wide range of parts.

Compared to manual feeding, this solution relieves workers from ergonomic injuries and greatly improves safety.

Finally, the proven gripper design combined with validated performances provides a risk-free solution for system integrators.

Innovation
The patent-pending gripper builds on the concept of having an adaptable tooltip with a magnet or suction module mounted on a passive rotational axis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- It maximizes the likelihood of finding a pickable part compared to a classical straight or slanted tool. This is because the tooltip (in this case, the magnet fingers) can adopt any position within a continuous range between -45 to +45 degrees, instead of only one (straight tool) or two (slanted/eccentric tool) discrete positions.
- It minimizes the required cell footprint by reducing the robot tilting workspace
- It simplifies the picking motion and helps to extract part blocked

Risks and limitations
Depending on the number of different parts that need to be picked, different gripper picking modules may be required (suction cup, small or large magnets). For such applications, the picking module has to be manually changed.

Technology readiness level
9 - System/model proven and ready for full commercial deployment

3. Exploitation

Sectors of application
FORGING: Picking of raw billets to feed the furnace or pick the shafts to load machines., AUTOMOTOVIE FACTORY: feed shafts and axles into CNC machines.

Potential sectors of application
The pipe industry could also benefot from the solution

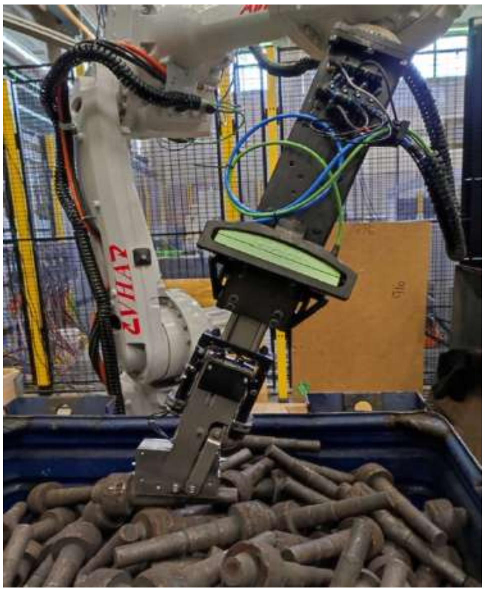
Patents / Licenses / Copyrights
Hardware / Software
Hardware:
Pickit bin Picker Gripper
Robot arm

Software:
Pickit 3D vision platform

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Video
HTTPS://WWW.YOUTUBE.COM/WATCH?V=ITXA5RB0VYWHTTPS://DRIVE.GOOGLE.COM/FILE/D/1EBNUBBBW0LPCPJKR-ZQLTBKNMGGYP7AZ/VIEWHTTPS://WWW.YOUTUBE.COM/WATCH?V=CC6SPF6QW28HTTPS://WWW.YOUTUBE.COM/WATCH?V=C4ARX2HLE7G

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 18: WAAM CLAMP: hybrid wire arc additive manufacturing to reduce production lead time for the oil and gas industry

1. Basic information

Name of demonstration
WAAM Clamp: Hybrid Wire Arc Additive Manufacturing to reduce production lead time for the oil and gas industry

Main objective
The demonstrator shows a new alternative approach for the manufacturing of pipeline clamps or parts, by combining traditional manufacturing technologies with 3D metal printing.

Short description
During the scope of the WAAM Clamp project, a typical repair part for pipelines has been researched and manufactured with Hybrid Wire Arc Additive Manufacturing (WAAM). This technique provides a smart production solution, by combining the advantages of traditional manufacturing (such as precision machining) with the advantages of wire arc additive manufacturing (such as form freedom, high deposition rates and minimal material waste)

Owner of the demonstrator
MX3D

Responsible person
Thomas Van Glabeke – R&D Manager
thomas@mx3d.com

NACE
C28 - Manufacture of machinery and equipment n.e.c.

Keywords
industrial robotics, Industry 4.0, robotic cell, Process Control, Welding, Additive manufacturing, robotics and automation, Smart Manufacturing, WAAM, Hybrid Manufacturing.

2. Innovation

Benefits for the users
Potential benefits:

- reduction of lead time due to faster production
- reduction of material waste by additive manufacturing
- reduction of human errors or highly speciality (welding) skills
- manufacturing automation (vs. human labour)
- on-demand production

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- on-site fabrication

Final demonstrator: 60 x 60 x 30 cm
Alloy: E70C 6M H4 (Metal Cored)
Weight: 30 kg printed, 87kg total weight

Savings: at least 80% material savings compared to CNC-manufacturing

Innovation
Current repair processes by clamps typically rely on CNC milling, specialized manual labour, or a combination of both. Each of these processes has its downsides, as CNC milling has high material waste (on average >80% of the original material) and specialized labourers are becoming more scarce.

Hybrid manufacturing provides a smart production solution, by combining the advantages of traditional manufacturing (such as precision machining) with the advantages of wire arc additive manufacturing (such as form freedom, high deposition rates and minimal material waste). This level of hybrid WAAM has not been shown yet at this size, flexibility and inspection requirements before.

The project team managed to reach a high level of assurance for the WAAM clamp demonstrator. BWI (Belgian Welding Institute) tested the materials and confirmed the printed material complied with key TEAM Industries requirements for this material. The MX3D M1 Metal AM System, facility and procedures were qualified by Lloyds Register. TiaT Europe performed non-destructive testing, such as Ultrasonic Testing (UT), Penetrant Testing (PT), Radiographic Testing (RT), showing no relevant defects. TEAM Industries has performed a pressure test, which ran until the maximum pressure of the test installation (i.e. > 60 Bar) without any failure.

Risks and limitations
Further testing and extensive inspection is required to achieve the full certification of this hybrid WAAM pipeline clamp application. As the material (wire), process (with the M1 Metal AM System) and DPS (deposition procedure specification) has been certified already, it is likely that the certification of the full application can be achieved. Furthermore, although the hybrid WAAM has been shown on various size and diverse shapes (including straight pipe and curved pipe), it is to be determined whether is achievable for more size, shapes and materials.

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Oil & Gas Industry, Chemicals Industry.

Potential sectors of application

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Hybrid WAAM can be extended to other industries where a combination of traditional manufacturing and 3D metal printing can be put to good use. Any industry that is using casting, CNC-milling, sheet metal fabrication, or robotic welding could be interested in this application.

Hardware / Software
Hardware:
MX3D M1 Metal AM System: Turn-key solution for the hybrid WAAM process

MX3D MetalXL Control System: to monitor and control the hybrid WAAM process

CNC-machine: to pre-manufacture the sidebars and flange

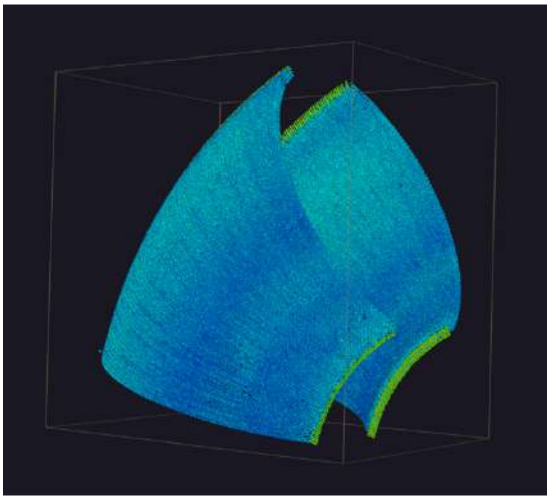
Software:
CAD program: To design a new clamp shape or edit an existing design

MX3D MetalXL software: To prepare, control and log the hybrid WAAM process

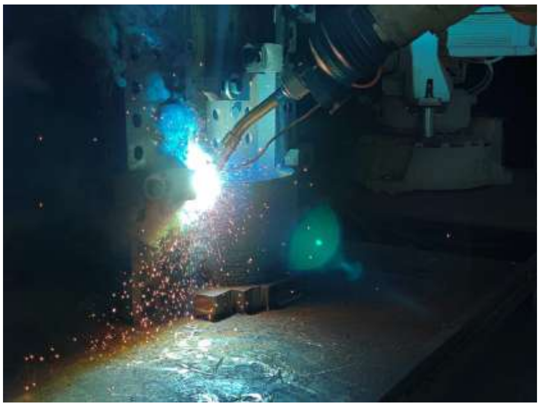
4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video

WAAM Clamp, a Hybrid Wire Arc Additive Manufacturing to reduce production lead time for the oil and gas industry

HTTPS://YOUTU.BE/J5ZEZMVOQBE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 19: Robotic lamination of composite parts

1. Basic information

Name of demonstration
Robotic lamination of composite parts

Main objective
The **main objective of CANNIER** is to develop a robotized moulding cell, capable of automatically laminating of carbon fibre reinforcements that have been pre-impregnated (prepreg) with activated resin. The aim is to make the **manufacturing process more agile, overcoming the bottlenecks of manual moulding**.

Short description
Robotized moulding cell for automatically lamination of prepeg.

To achieve the objectives of CANNIER, the expertise of the partner involved in the project is fundamental.**Roboticssa** will develop the **CAM software for the robot trajectories generation**, starting from the CAD of the parts to be manufactured and considering tools geometry as well as operator's experience (through an HMI) to maximize effectiveness.
STAM, with its consolidated **background in the development of robotic systems**, will be responsible for the **mechanical design of the tool exchanger and the end-effectors for the ply lamination**.
Composite Industries represents the end-user responsible to **test and validate the robotic solution** in its industrial facility.

Owner of the demonstrator
Roboticssa

Responsible person
Main contact:

Name: Mr. Ignacio Secades

Title: Roboticssa CEO

email: ignacio.secades@roboticssa.es

phone: +34 607 555 188

NACE
C – Manufacturing

Keywords
Robotics, Motion Planning.

2. Innovation

Benefits for the users

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- Increase of **productivity**: 70-75%, maximising the exploitation of moulds, which are costly assets;
- **Time reduction** for the moulding time of carbon fibre prepregs by 40%, compared to manual lamination;
- **Reduction of manufacturing cost** by 25%, considering robot cost-effectiveness and reduced defected parts;
- **Reduction of waste material** due to non-compliant products between 2-3%, caused by operator mistakes;
- **CO2 emission saved** thanks to the reduction of waste and faulty component in the production process. A reduction of about 0.9 ton of CO2 is estimated, referred to a batch of 1000 parts;

Innovation
Thanks to CANNIER, the lamination process of CFRP components at Composite Industries facilities will be more agile, leading to an automated environment that ensures an improved quality and repeatability of the parts manufactured. Moreover, CANNIER contributes to the achievement of significant economic and environmental benefits. In the next few years, the growing interest in carbon fibre materials will determine a rise of the product sold, emphasizing the important advantages achieved.

Risks and limitations
The lamination process may be not possible laminating pieces of big size or with geometries with high curvatures.

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Manufacturing carbon fibre reinforcements that have been pre-impregnated (prepreg) with activated resin.

Hardware / Software
Hardware:
Universal Robot 10: collaborative robot with 10 Kg payload

Lamination tools: set of tools necessary for lamination

Tool exchanger: tool exchanger to enable robot cell to interchange tools

Software:
Lamination trajectory generator: outputs the trajectories that the robot will follow during the lamination process. Requires a computer with Windows 10

Robot program generator: generates a UR10 program given the lamination specification for a given piece. Requires computer with windows 10

4. Modules

Dynamic robot trajectory generation based on information from 3d camera

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities
This module provides a flexible and adaptive way to create robot trajectories dynamically based on point cloud data created automatically with 3D-camera. Module can be utilized in processing of work objects with varying physical characteristics to create robot trajectories dynamically for processes such as painting, sandblasting and pressure washing. Camera may be mounted onto the robot arm or installed in a stationary manner. Secondary functionality is to provide point cloud data of scanned object to be saved as 3D-model file.

Technical specifications
Hardware:
3D camera system (Microsoft Kinect V2, Intel Realsense D435)
A laptop/desktop computer with Windows or Ubuntu 18.04
Software:
AutoMAPPPS
CloudCompare or similar point cloud data processing software
AutoMAPPPS is a family of robot programming software tools developed by Convergent Information Technologies GmbH. The software allows for fast computing of collision-free robot trajectories and program upload to robot controller for execution.
CloudCompare is a 3D point cloud and triangular mesh processing software. The software is originally designed to perform comparison between two dense 3D point clouds or between a point cloud and a triangular mesh. The software has since been developed suitable for more advanced point cloud processing, including algorithms for resampling, scalar fields handling and more.

Inputs and outputs
The input format is depth-map data provided by 3D-camera to CloudCompare and AutoMAPPPS in PLY format. This input data is used to generate a mesh model file of work object in STL or STEP format using CloudCompare, and dynamic robot trajectories are created using AutoMAPPPS.

Formats and standards
Point cloud and 3D model data formats: PLY, STEP, STL

Owner (organization)
Centria University of Applied Sciences https://tki.centria.fi/en

Trainings
Online training material is available through the TRINITY training platform.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 20: ROBOLIBRI – efficient rfid 3d-inventory robot and autonomous guide to objects as an intralogistics cornerstone for agile production.

1. Basic information

Name of demonstration
RoboLibri – efficient RFID 3D-inventory robot and autonomous guide to objects as an intralogistics cornerstone for agile production.

Main objective
With RoboLibri, we have developed a mobile robot platform equipped with a novel RFID reader architecture for autonomous inventory and very precise product localisation in all three spatial directions, as required in agile intralogistics. In addition, multimodal interaction interfaces are integrated on the platform for people guidance in the context of intelligent production environments or as a service application such as for libraries and for general information provision, allowing as well seamless access to the metainformation of the inventoried products.

Short description
With the equipped functional safe motor control system and LIDAR sensors as well as 3D-camera, wheel odometry and gyroscope sensors, the robot is able to autonomously navigate with up to 1 m/s in large warehouses of tens of thousands square metres, as well through narrow corridors such as between rows of bookshelves alongside people, meeting safety regulations. On its way, the platform creates a 3-dimensional map of the environment, where tens to hundreds of thousands of RFID-tagged items can be located with up to centimeter precision, thanks to the advanced RFID reader system on board, incorporating multiple, coherently receiving antennas. For the direct interaction with people, a large touchscreen and voice recognition are implemented, allowing visitors, warehousemen and librarians to find products, physical files, books or sections of interest. An intelligent score-based search without speech patterns ensures a high success rate in finding the desired objects or content, providing an intuitive and satisfying service to the users. In the future, a smartphone app could complement the interaction and provide a call function to the service desk.

Owner of the demonstrator
MetraLabs GmbH

Responsible person
Dr.-Ing. Johannes Trabert, JOHANNES.TRABERT@METRALABS.COM

NACE
R91.0.1 - Library and archives activities

Keywords
Robotics, automation, robotics and automation, inventory, UHF RFID, libraries.

2. Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Benefits for the users
The robot is able to autonomously navigate in large warehouses with tens of thousands square metres and can locate thousands of RFID-tagged items with up to centimeter precision and without any help. With its knowledge it is also able to navigate visitors to their favorite books or other things of their interest.

Innovation
- precise 3D-locations of rfid tags
- interactive search in a library
- voice controlled robot

Risks and limitations
The roboter requires (careful) planning and setup in the library to enable proper/efficient navigation. Libraries with multiple floors require multiple robots or temporary sharing of the robot. One-time setup to generate search terms for library items (for voice control) can only be done semi-automated, ie. requires at least checking and declaring special cases (e.g. alternative search terms or coordinates for areas).

Technology readiness level
5

3. Exploitation

Sectors of application
libraries, warehouses, hardware stores, large shopping malls, furniture stores, exhibitions.

Potential sectors of application
Robot can be reconfigured to serve as a user guide in any field with rfid-tagged items in an indoor environment. Ideal for commercial venues where people may ask for the location of specific items from a huge inventory, or venues which are sufficiently large so that employees might not always be nearby to help, e.g. warehouses, hardware stores, large shopping malls, furniture stores, exhibitions.

Hardware / Software
Hardware:
The robot is equipped with the functional safe motor control system and LIDAR sensors as well as 3D-camera, wheel odometry and gyroscope sensors. - LCD touch screen - microphone - rfid-reader and antennas - safety features (bumper, stop button (in UI for goals and physically for emergency stop))

Software:
MIRA: middleware for robotic applications (https://www.mira-project.org)

software for control of rfid reader/antennas

front-end application (+UI) for user interaction and information retrieval/display

algorithms/application/implementation stuff for speech recognition, custom specialized algorithm for extraction of commands and search terms ft. adjustable scoring system

4. Media

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Photos

Video

Every bookworm's friend: RoboLibri, an RFID 3D-inventory robot and interactive guide to books

HTTPS://FB.WATCH/9NJX4YL2-5/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 21: Global dynamic robot motion planning for agile production

1. Basic information

Name of demonstration
Global Dynamic Robot Motion Planning for Agile Production

Main objective
The objective of the project is to demonstrate the value of global dynamic motion planning in agile production by lowering the time it takes to make changes to the setup and making complex robot motions possible.

Short description
The developed system consists of a motion planner for efficient bin picking. This system can solve a complex application with multiple bins, where each bin and the environment in general is flexible and can change during the operation. This has the following advantages:

- No need to program any waypoints for the robot
- Motion planning handles changes in the cell on the fly
- More direct and efficient paths leading to reduced cycle time
- Seamless use of robot mounted 3D camera

Owner of the demonstrator
Adaptive Robotics

Responsible person
CEO, Joachim Paasche, joachim@adaptiverobotics.com

NACE
C – Manufacturing

Keywords
Robotics.

2. Innovation

Benefits for the users
The user will be able to:

- Program a new robot cell without specifying any waypoints for the robot
- Develop more robust cells which can handle changes in the cell on the fly. Less support due to
- fewer production stops.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- Lower development time per new robot cell
- Easier to reprogram a robot cell
- Lower the cycle time per cell

Innovation
In traditional robot programming, the robot movement must be programmed with predefined waypoint which the robot has to move through. This is tedious, requires a lot thinking, creates movement which are not always optimal and makes the robot cell very inflexible and intolerant to changes. These problems increase even more when objects have variable positioning which is very often the case with vision enabled robot cells such as bin picking. Real time dynamic motion planning removes the above-mentioned challenges. The motion planner uses CAD and/or 3D point cloud as input to understand the environment. Based on this it will calculate the optimal movement for the robot on the fly. In the case of bin picking for instance, this means that the robot finds the optimal path per cycle. In the future with human-robot applications, the robot will continuously adapt the movement of the human and plan its path accordingly.

Risks and limitations
The motion planning software is dependent on accurate information of the environment. If CAD data or 3D point cloud is inaccurate or incorrectly positioned relative to the robot, it can result in a collision. The motion planner is dependent on a robot with an accurate absolute position. Often robots have very high repeatability, while the absolute position might be off. If the absolute position of the robot is inaccurate, it might result in unsuccessful picks, and in the worst-case scenario, collision with the environment. The motion planning software does not have any object detection capabilities. In case of bin picking applications for instance, it is necessary to have a 3rd party object recognition software which can detect objects based on 3D point cloud data.

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application
Manufacturing: Bin picking, Machine tending Warehouse logistics: Piece picking, Palletizing, Depalletizing.

Potential sectors of application
Manufacturing: Human robot applications Warehouse logistics: Human robot applications

Hardware / Software
Hardware:
Industrial robot: 5-7 DOF robot for performing the operation. 3D sensor: Sensor for providing point cloud to the system. This is used both for grasp detection and for updating the environment for safe motions. Robotic gripper: Gripper for manipulating the pieces.

Software:
Detection system: Software or dedicated hardware for detecting the grasps, which are sent to the motion planner.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

4. Media

Photos

Video

The demonstration setup: - One 6-axis robotic arm - One on-arm 3D camera - A vacuum gripper with one suction cup - 6 separate bins with flexible positioning - Detection software with classification - Motion planner controlling the robot

HTTPS://WWW.ADAPTIVEROBOTICS.COM/TRINITY/ADAPTIVE_BIN_PICKING.MP4

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 22: SALSA2D: Separation of additive layer support by automation via 2-way digital twin

1. Basic information

Name of demonstration
SALSA2d: Separation of Additive Layer Support by Automation via 2-way Digital Twin

Main objective
This project aims to automate the support material removal post-processing step of additive manufactured components (specifically metal AM) by leveraging computer vision, robotic proprioception and simulation software. We seek to demonstrate the use of custom teaching software to effortlessly **plan complex trajectories.**

Short description
The following demonstration shows robotic support removal on an additive manufactured part using force controlled percussive tools. Three-dimensional computer vision is used to compensate for part variability and the process is simulated and visualised on Rviz. This demonstration will be valuable to industries looking to advance towards fully digital post-processing of near-net-shape manufactured components.

Owner of the demonstrator
Additive Automations

Responsible person
Chief Technology Officer, Dr David Alatorre, alatorre@additiveautomations.com

NACE
C28 - Manufacture of machinery and equipment n.e.c.

Keywords
Robotics, Machine Vision, automation, Additive manufacturing, near-net-shape manufacturing, machine perception.

2. Innovation

Benefits for the users

Design flexibility: The ability to quickly and intuitively modify machine code from a user interface allows operators to iterate designs quickly or work efficiently with always-custom components such as medical devices. **Ease of operation:** The elimination of skilled work and the simplification of robot programming by use of a simulated environment greatly decreases the time required to train production line technicians to use the robotic post-processing system. **Volume production:** Manual post processing is currently a bottleneck during production. Eliminating this barrier would allow production of additive manufactured components to scale with demand. This value proposition applies to customers in the industrial, energy,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

aerospace and automotive sectors, and any business currently unable to leverage AM at scale.**Repeatability:** The guaranteed consistency that comes with digital manufacturing leads to a 90% reduction of defects. Such a reduction in defects and scrap rates is a clear benefit for all of the potential users listed above. **Cost saving:** The combination of improved efficiency, decreased training time, reduced defect rate and 24-hour uptime is estimated to result in a 77% cost reduction. This includes depreciation of the CapEx cost of a robotic post-processing cell.

Innovation

As with any new venture in automation, our target is to outperform a manual process and repeatability is the key dimension to differentiate our technology. Our approach relies on proprioception, computer vision and intelligent software to give an industrial robotic arm the necessary dexterity to perform delicate tasks.

A computer vision algorithm developed in partnership with NRC Canada is used to compensate for part variability – a common aspect of additive manufactured parts – by aligning depth measurement data to the expected component 3D geometry.

A proprietary force control algorithm designed specifically for machining with low-stiffness robots serves to protect the system from surface-level imperfections often found in additive manufactured components, and helps achieve high accuracy results with a low-cost and light-weight robot arm.

Cutting edge software tools powered by ROS (Robot Operating System) incorporate machine perception with an intuitive user interface to guide the robot arm along complex and dynamic trajectories.

Risks and limitations

Compatibility: Our demonstrator must be used with ROS-compatible robot controllers capable of receiving pose streaming commands for instantaneous trajectory corrections by the force controller. One such controller is the Yaskawa YRC100micro. Our demonstrator must be used with ROS-compatible peripheral and tool controllers. Capability: The force control algorithm requires a 6-axis force transducer capable of streaming wrench data at at least 1000Hz. The machine vision algorithm requires a measurement system (stereo and/or structured light) capable of producing point cloud captures with better than 50 micron accuracy, such as a LMI 3D Gocator 3210. Application: The proposed system is intended to be used on near-net-shape parts and is not intended to perform bulk material removal or broader subtractive manufacture.

Technology readiness level

7 - System model in operational environment

3. Exploitation

Sectors of application

AEROSPACE: Manufacturers of aeroengines, aircraft components or satellite/spacecraft components requiring complex and light weight parts may use this demonstrator to eliminate the bottleneck to volume production of AM components and to simplify the certification process for new AM parts., ENERGY: Manufacturers of energy generation turbomachinery may use this demonstrator to increase production of advanced fuel injectors, heat exchangers and other complex parts. Remote plants may use AM with post-production robot cells to eliminate the need for spare parts and reduce repair downtime., AUTOMOTIVE: Manufacturers of sport and luxury vehicles requiring lightweighting of components and volume production of customised interior components may use automated post-processing to cut costs., MEDICAL: Companies producing bio-compatible metal implants, high-temperature custom moulds for dentures and complex dental aligners may use these cells to guarantee part compliance and achieve fully digital

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

manufacture., DEFENCE: Organisations or companies overseeing supply logistics and asset maintenance for military equipment may use in-situ additive manufacturing and robot post-processing to make components and tools, eliminating the need to stock spare parts or send equipment away for overhaul.

Potential sectors of application

Consumer electronics: As luxury products become more customised, the use of additive manufacturing with automated post-processing will play a part in achieving economies of scale in this and other similar sectors. Marine: Similar to the energy sector, marine manufacturers may use this demonstrator to increase production of complex power generation components using corrosion resistant materials. Construction: As additive manufactured building gains traction, a scaled up version of this demonstrator may be used to automate the finishing steps of printed structures.

Patents / Licenses / Copyrights

Patent pending: Finishing system for near net shape parts (GB2114701.2)

Hardware / Software

Hardware:

ROBOT ARM (hardware): A series manipulator with at least six axes of motion is required to orient and apply tools on additive manufactured parts.

ROBOT CONTROLLER (hardware): A ROS-compatible robot controller is required to receive instructions from and return feedback to the perception, planning and control nodes running on a control PC.

POSITIONER (hardware): A rotary stage capable of turning the additive manufactured parts through 360 degrees may be required to augment the workspace of the robot arm.

3D VISION SYSTEM (hardware): A 3D measurement system (stereoscopic or structured light) may be required to provide feedback for the motion control and quality control nodes running on a control PC.

WRIST FORCE SENSOR (hardware): A six-axis force/torque sensor is required to provide tactile feedback to the force control nodes running on a control PC.

LINUX/WINDOWS PC (hardware and software): A computer running a Linux operating system such as Ubuntu or a Microsoft operating system such as Windows 10 is required to run the software nodes for perception, planning, control, user input, simulation, etc.

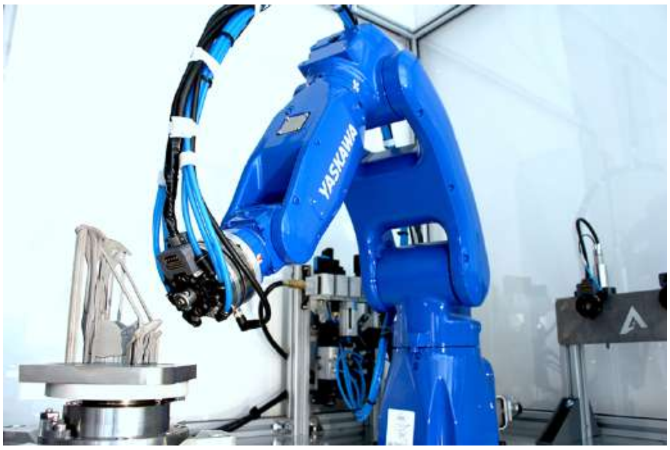
Software:

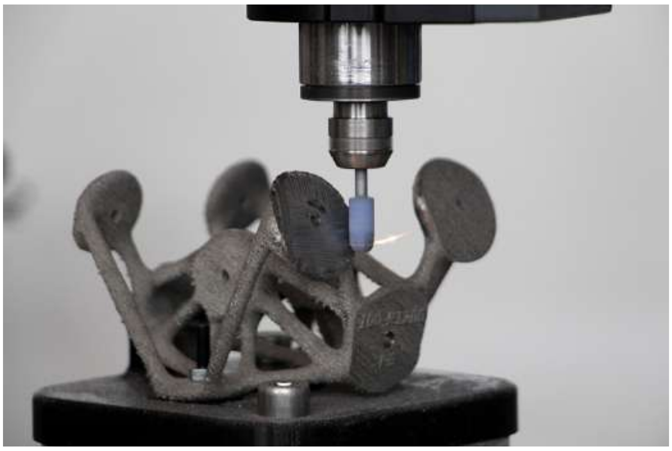
ADDITIVE AUTOMATIONS APPLICATION (software): A copy of Additive Automations' support removal control application is required to establish communication, send commands and receive feedback from the hardware elements.

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196





5. Modules

Digital twin ⇌ plan visualise control

Main functionalities
Our team has created intuitive software tools that seamlessly merge teaching, simulation and control of industrial robots. The result is an intuitive and versatile automation platform. The platform is agnostic to robot vendor and modular by design. Users can now manage, monitor and configure their robot cell from one software platform. No more jumping between expensive proprietary software applications, no more

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

custom post-processors and no more commissioning online with a pendant. All this can be performed remotely from one software platform.

Technical specifications

- Industrial PC
    - Ubuntu 20.04
    - ROS Noetic running in a docker container
    - Local ethernet network connected to:
        - Industrial Robot Controller
        - Industrial Raspberry Pi
        - Force Sensor (optional)
        - 3D Camera (optional)
        - HQ Raspberry Pi Camera

Inputs and outputs

Communication runs over the ROS (Robotic Operating System) bus using the TCP/IP protocol. An external axis servo operates over CANopen via a PLC also on the ROS bus. The two schematics attached show the technology stack overview and inputs/outputs. The key is as follows:

Red : ROS software
Green : Configuration files
Yellow : Human machine interface
Orange : Robot hardware
Blue : Hardware peripherals (e.g. IOT devices)

Formats and standards

Formats: ROS, ROS-I, TCP/IP, CANopen

Standards: IEC 61508 (Functional Safety of Electrical / Electronic / Programmable Electronic Safety-related Systems)

Training material

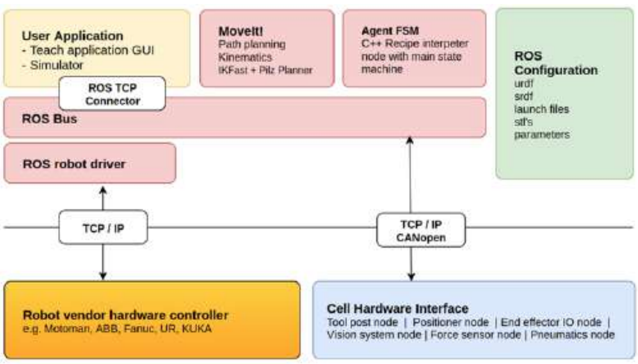
undefined

Owner (organization)

Rivelin Robotics

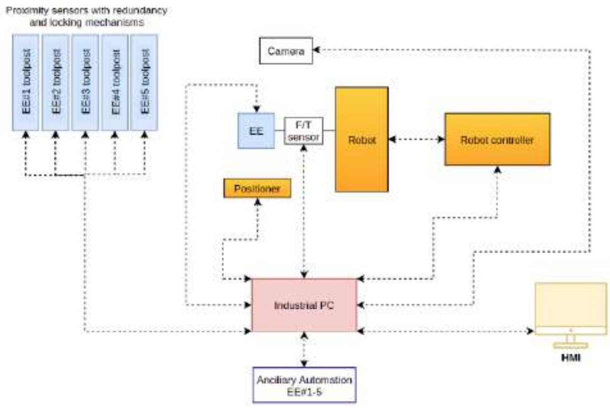
Documents

Tech stack schematic

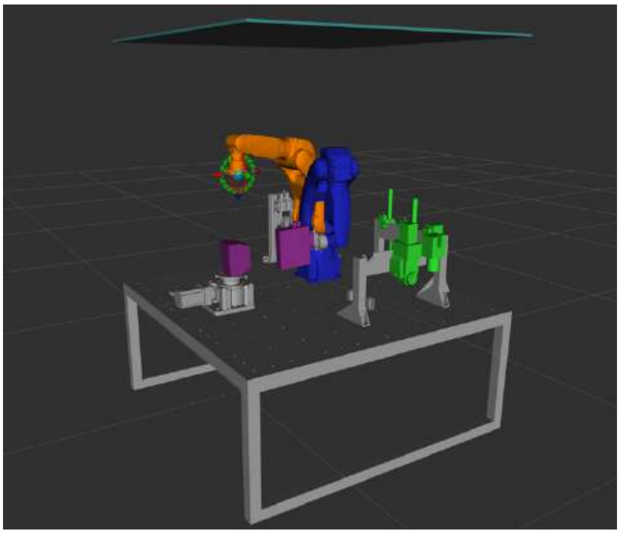


Architecture schematic

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Digital Twin



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 23: AMR logistics orchestration for agile production

1. Basic information

Name of demonstration
AMR Logistics Orchestration For Agile Production

Main objective
A flexible production system complemented by digitisation and automation of internal logistical processes, achieves agility in production. Autonomous Mobile Robots (AMR) ensure this automation through an ERP driven Manufacturing Execution System (MES), that allows an orchestration of multiple brands of AMR, where the loading and unloading is quick and flexible.

Short description
The MES solution acts a controller for both the digitization of the paper flow on the shopfloor, and the AMR orchestration. This is done by helping the human operators in a user-friendly way to execute their tasks, while orchestrating the different AMR's to bring parts and boxes to the different manufacturing machines. The parts preparation zone allows for a flexible and continuous stream of parts and frees up already limited floorspace. The loading and unloading of the parts themselves following the karakuri kaizen principle using kinetic energy speeds up the logistical performance.

Owner of the demonstrator
Flagstone BV

Responsible person
Jurgen Dekeyser, Managing Partner Flagstone, JURGEN@FLAGSTONE.TECH

NACE
J62.0 - Computer programming, consultancy and related activities

Keywords
AMR, MES, Agile Logistics, Smart Manufacturing, Orchestration.

2. Innovation

Benefits for the users
When we look at the post-situation, the machine operators needed to walk a lot from one machine to another to conduct specific tasks such as supplying the machines with components, supplying empty boxes, palletizing and intervening when machine errors occurred.

A spaghetti diagram was set up and as a result, we found out that operators spent 20% of their time by walking around, from one task at one location, to another task at another location.
Another finding of this spaghetti diagram was that operators walk 17.000 steps on average per shift.

Finally, in the past, there were component pallets and finished goods pallets everywhere near the machines.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

By using multiple AGV's and AMR's, orchestrated via a single platform;
1) We were able to remove all pallets from near the machines and centralise them in a preparation zone and a finalization zone, which created a more open view over the machines.
2) The amount of steps that operators needed to do was greatly reduced.
3) The workload was reduced while the production capacity remained the same.
4) The machine operator was able to focus more on the machines than ever before.

NOTE: There is a slight difference between an AGV (Automated Guided Vehicle) and an AMR (Autonomous Mobile Robot). Both terms can however be used in conjunction.

Innovation
The innovation of this demonstrator is showcased on three levels :
· For Altachem: the demonstrator showed that it is feasable to optimise the internal production logistics to become more agile. We moved away from a situation where goods were supplied manually and decentralised, to a situation where one AGV supplies all machines from a central location, orchestrated via Flagstone's MES system.
· Sirris developed the necessary automation add-ons to allow easy docking, loading and unloading of the AMRs for different types of load (boxes and bulk components). Sirris also programmed the missions/orders for the AMRs and defines the most optimal routes for the AGVs.
· For Flagstone: the new way to integrate all systems in an existing ecosystem can deliver the company a new leverage on the market as the time to implement and test will shorten drastically.

Risks and limitations
Two AMR's that arrive in each others detection area at the same time might result in a deadlock situation. There is no standard in the height of the bunkers of the machines which might result in too many different AMR topmodules. For each different brand of AMR a map has to be made upfront. If the environment changes then the maps have to be remade for each. When implementing AMR's in a brown field environment, it is important pay the necessary attention to the dimensions of the pick-up and drop-off zones. In our specific case, adjustments had to be made on the machine to be able to pick up the finished boxes since these were too low for the AMR. The orchestration solution is dependent on the AMR manufacturer's interfacing capabilities, which can potentially prevent flexible communications.

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Discrete manufacturing industries in need of optimizing internal logistics. The application concerns the supply or removal of raw materials, packaging, semi-finished products, or finished products, 10: Manufacture of food products, 11: Manufacture of beverages, 13: Manufacture of textiles, 14: Manufacture of wearing apparel, 16: Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials, 17: Manufacture of paper and paper products, 20: Manufacture of chemicals and chemical products, 21: Manufacture of basic pharmaceutical products and pharmaceutical preparations, 22: Manufacture of rubber and plastic products, 23: Manufacture of other non-metallic mineral products, 24: Manufacture of basic metals, 25: Manufacture of fabricated metal products, except machinery and equipment, 28: Manufacture of machinery and equipment n.e.c., 29: Manufacture of motor vehicles, trailers and semi-trailers, 30: Manufacture of other transport equipment, 31: Manufacture of furniture.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Hardware / Software
Hardware:
AGV WEWO to move parts from the preparation zone to the production machines + automatic charging station

AMR MIR to move empty boxes to the production machines and to move full boxes with finished products from the production machines ton the taping zone + automatic charging station

AGV MABO to move boxes with parts from the warehouse to the preparation zone.

Following tube constructions were prepared: o a topmodule on AGV WEWO o an unloading station for the boxes from AMR MIR o 2 (un)loading quays for the preparation zone

AMR MIR was adapted with a conveyor

Box erector: A machine that folds boxes

Conveyor for empty boxes: Buffer lane next to box erector that serves as pick-up point for AMR MIR

Conveyor for finished boxes: Drop off zone and buffer for finished boxes

Box taper: A machine that closes and tapes the finished boxes so that they are ready to palletize.

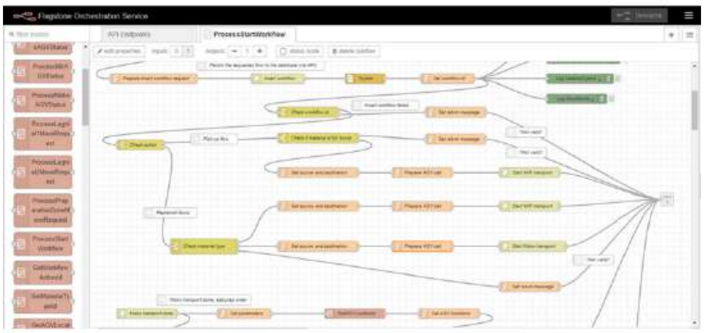
Preparation station: A place that enables the operator to fill the AMR WEWO with components

Software:
Flagstone MES : a Manufacturing Execution System to digitise work orders and to orchestrate different AMR brands and operators.

The AGV WEWO programming and configuration

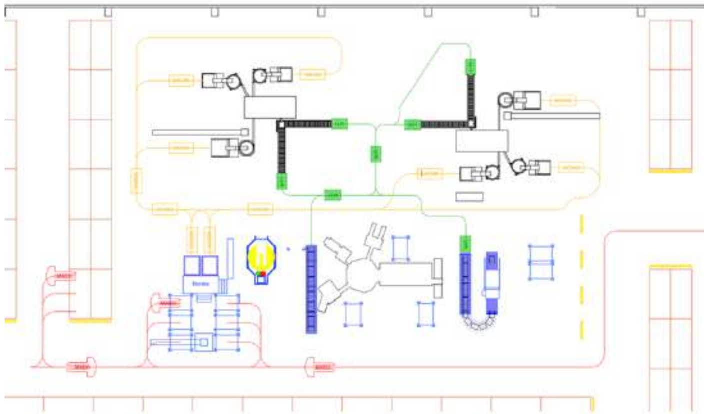
4. Media

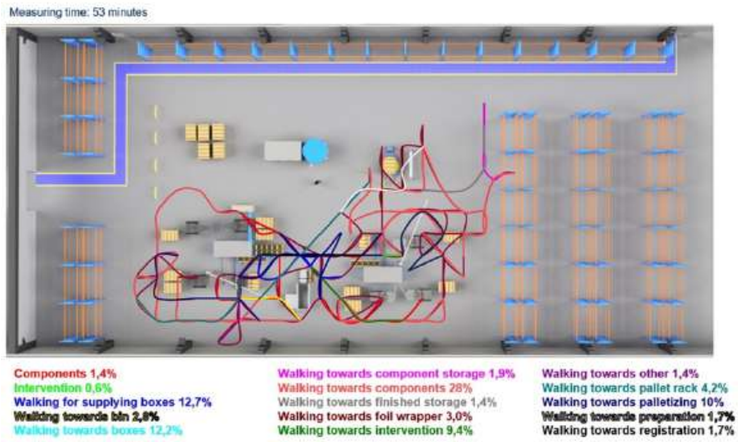
Photos

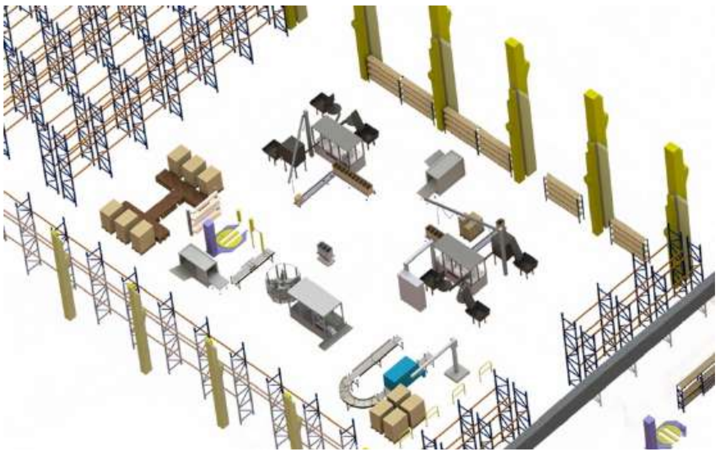


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196







This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Video

Dissemination video of the project

HTTPS://YOUTU.BE/4APX_5661DE

Annex 24: PROBOT OY

1. Basic information

Name of demonstration
Probot Oy

Main objective
To integrate a system capable of conveying, identifying, labelling and sorting out used portable batteries. In addition, the two following sub-objectives were set as well:

1. To have cognitive system which is agilent to future variation in the fraction, as well as
2. Validate the usability of AI based machine vision system with real-world industrial process

Short description
The project Robotic Sorter for Used Portable Batteries, or RoSo_UPB, focused on examining the recyckle process for used portable batteries from the point-of-view of automatic sorting. In the project, various methods for identifying the type of battery were investigated and listed. Based on these methods, the most efficient ones were selected for testing them in practice as well as forming suggestions for making the sorting of the used portable batteries automatically. One of the main goals of the project was to form a realistic overview on how the sorting should be done in practice when automated – and trough this overview, to bring the end-user closer for the real-world application.

Owner of the demonstrator
Probot Oy

Responsible person
Mr. Matti Tikanmäki
MATTI.TIKANMAKI@PROBOT.FI

NACE
E38.3.2 - Recovery of sorted materials

Keywords
Robotics, Machine Vision, modular, automation, concepting.

2. Innovation

Benefits for the users
Agile recycling and sorting automation made cost-efficiently

Innovation
Enabling affordable automation and robotics for application which has typically expensive solutions only

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Risks and limitations
N/A

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application
Recycling industry.

Potential sectors of application
Various potential sectors, especially those processes that depends on sorting and identification skills

Hardware / Software
Hardware:
Several

Software:
Several

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 25: X-WELD

1. Basic information

Name of demonstration
X-WELD

Main objective
Significant reduction in both the required programming and cycle times of standardized robotic cells with large economic impacts in companies with small batch sizes.

Short description
The objective of X-WELD is the development of a complete automated system for robotized welding through the combination of advanced (collision free) offline programming, with advanced sensing for part localization and robot calibration.

Owner of the demonstrator
SARKKIS Robotics

Responsible person
Dr. Pedro Tavares, SARKKIS Head of R&D, pedro.tavares@sarkkis.com

NACE
C28.9 - Manufacture of other special-purpose machinery

Keywords
Robotics, Machine Vision, Welding, SME.

2. Innovation

Innovation
X-WELD project has developed some important outputs for the industrial robotic community. The complete bundle aims to be used in multiple workstations allowing for a deeper reduction in programming time of the robotic system and also in an increase of efficiency due to reduction of wasted material and dynamic welding path correction due to sensing. There was no complete solution like this in the market.

Asset 1: The first relevant contribution is the Collision-free Off-line Programming with Interfaces for Advanced 3D sensing. This software is able to read 3D geometrical file such as STEP, IGS, STL and automatically generated welding candidates and consequent vectors that are key to validate the part completion and to generate robotic postures. From there, a clean integration with sensors is consider to retrieve data regard part localization. This serves as a software optimizer as this information allows to complete a digital model of the workstation and generate the complete operation accordingly in a safe manner.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Asset 2: Then, the usage of active perception and sensor fusion allows the system to cope with part geometry imperfections such as bends or warps. The development of the correct pipeline allows to gather information, filter it and obtain correct measurements on the local welding joint. Despite the change of camera 3D sensor to laser-line sensor at the end of the project, this pipeline proves useful due to its robustness for future works where the 3D sensor can ensure better precision and accuracy. Regarding the local sensing obtained from laser-line sensor, the work put on this methodology allowed the consortium to proposed a dynamic approach that detects misreading and automatically re-parametrize the sensor to overcome the most common issues find in industrial shop-floor related to part preparation, material deformation or even lighting.

Asset 3: At last, the global perception of the workstation is a fundamentally important output of the project. The development of new sensing pipelines for parts detection and then robot accuracy correction, the consortium is able to overcome two of the more limitative conditions in robotic systems

Risks and limitations
Risk 1 - Sensing: As a complete product, X-WELD proposes a bundle of software and hardware that is flexible to be applied to most industrial scenarios due to its flexibility. The risk is only related to the perception conditions. The 3D sensor requires lighting conditions that ensure part measurement. To cope with this added difficulty it may be require additional lighting. Risk 2 – COVID-19: The current pandemic situation has imposed some restraints. In particular, dissemination activities have been put on hold and the overall landscape has changed. However, new paradigms have surge considering, as an example, online tools. The risk has also significative reduce due to current vaccination status.

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Industrial robots are a mature technology, but the full potential applications are still unexplored. This is clear by observing the current collaborative robots phenomena, and also by comparing the numbers of industrial robots against, for example, machining equipment. The market potential is very significant. Robotic integrators state that up to 70% of their robot sales fill in the scope of the standard robotic cells. Considering that the annual shipment of industrial robots for welding peaked in 2018 to 818003 units, a conservative estimate of 35% of the market results in more than 28000 robotics systems with the potential to integrate the X-Weld solution., STEEL INDUSTRY: This demonstrator is focus on the steel industry, namely welding of structural components. It has been validated in a steel manufacturing SME, where the focus is to weld separate parts ensuring stability and robustness to structural parts.

Potential sectors of application
This demonstrator can be applied to multiple area of applications. The flexibility associated to the X-WELD solution enables the automatic welding parametrization and robot control. The sensors parameters may need to be change considering different materials and exposures. However, the development has considered facility adaptation that enables the overall solution to be resistant to these pitfalls. From the number of application areas that may benefit from this solution we can list the following: AGRICULTURE: machinery for agriculture. ENERGY: welding of energy components such as containers. AEROSPACE: welding of aerospace parts such as propellers or wings. OTHERS: any area of application that requires non-structured welding.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Hardware / Software
Hardware:
Photoneo L

Wenglor Laser-Line

Robotic system integrated with welding machine

Software:
X-WELD software

4. Media

Photos

Video
Promotional Video

HTTPS://SARKKIS-MY.SHAREPOINT.COM/:V:/P/PEDRO_TAVARES/EBE3V2N2N0LKUVUTUYOVQAWBMKIBO_O39J6Y_L8EIBX9LA?E=MC33C3

Executive video

HTTPS://SARKKIS-MY.SHAREPOINT.COM/:V:/P/PEDRO_TAVARES/EXD93M4SZBFAGDWB7SOUU_CB4WUUXSW3PJYACNCPZJJEZW?E=6GY0CK

5. Modules

Easy programming module

Main functionalities
The main goal of this module is to allow the easy and fast implementation of a new robotic application. In classical robot programming, the introduction of a new product variant can lead to a severe re-programming of the entire task. This module allows to create or adapt a robot program in an intuitive way: The operator can program an entire application simply by interacting with a screen or with the cobot directly. Therefore, the operator does not need to have an expert level in robot programming to create a new program. He can easily visualize which actions the cobot is able to perform and assemble those robot actions in the order of interest augmented with the required parameters to fulfilled the desired application. The taught tasks can be adapted in the future by changing steps in the process or parameters to correct the behaviour.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Technical specifications
The module comes with an HMI that can be used to easily create/visualize new applications or to modify/execute the previously taught applications. This HMI allows keeping track of the mains functionality in the application: available tasks, available robots actions, the current status of different device manager. The application is built-in using several Finite State Machines (FSM) which are responsible for the application logic. The change of states in the FSM can be triggered by either using the HMI or internal process.

Inputs and outputs
The programming of the new application follows a logic of robot skills and device primitives. A skill is a more complex robot actions that are composed of several robot device primitives. A device primitive is an elementary robot's action. As an example, a skill can be a 'Pick' skill which is therefore composed of four device primitives (Arm motion to approach location, Arm motion to location, Grasp, Arm motion to release location). This idea behind the structured programming using skills is intended to keep the programming of a new application very intuitive for an inexperienced operator. This structure allows having a series of robot actions that follow a logical order. The new application can be a combination of several robot skills such as: teach-by-demonstration trajectories, forced-based insertion, pick, place, etc. An inexperienced operator can interact with the module using either the screen where the main functionalities are displayed (skills, current device primitives,etc.)

Formats and standards
ISO/TS 15066:2016
ISO 10218-1/2
ISA-95

Training material
undefined

Owner (organization)
Flanders Make

Trainings
EASY PROGRAMMING

Online trajectory generation with 3d camera for industrial robot

Main functionalities
this module provides depth-based real-time information of workspace for generating dynamic trajectories for the robot. The module offers a flexible and adaptive way of generating robot trajectories for human-robot collaboration based on information from 3D-camera(s). The module can be utilized in example with bin picking applications including workpieces with varying physical characteristics and random orientation. Another way of utilizing module is processing task including processing targets of varying locations in example assembly.

Technical specifications
Hardware:
3D camera (e.g. Microsoft Kinect V2, Intel Realsense D435)
A laptop/desktop computer with Ubuntu 16.04 – 20.04
Software:
ROS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

ROS-Industrial
Packages for camera data processing and robot programming
3D cameras (or other peripherals that can produce a point cloud) are used to image/scan the object/scene. After scanning the data can be converted to point cloud and saved for later purposes or utilized online by AutoMAPPPS or ROS to create trajectories for robot.

ROS (Robot Operating System) is a set of open-source software libraries and tools that simplifies complex robot tasks by using hardware abstraction, drivers, libraries and simplified process communication. ROS was originally developed to create a universal platform and user support base for manufacturer-independent robot programming.

ROS-Industrial extends the advanced capabilities of ROS software to industrial relevant hardware and applications, such as industrial robots and sensor data processing. ROS and ROS-Industrial together provide a high level of adaptability to a wide variety of robot manufacturers, which significantly eases project implementation on different device structures.

Inputs and outputs
Input of this module is RGB-Depth data provided by 3D camera to a suitable ROS module for camera data processing, such as depth_based_collaboration. This node recalculates robot trajectories if necessary, based on information provided by 3D-camera. Recalculation is needed, for example, if obstacles are placed in robot path or work piece is misaligned.

As output, the module provides calculated trajectories and translated program code for robot controller. The programming language depends on the manufacturer of the used robot. For example, KUKA robots run programs written in KRL and ABB robots run RAPID code. The resulting program code is directly transferred to the robot controller without user interaction using a ROS hardware interface module, such as kuka_eki_hw_interface

Formats and standards
File formats: KRL, PLY

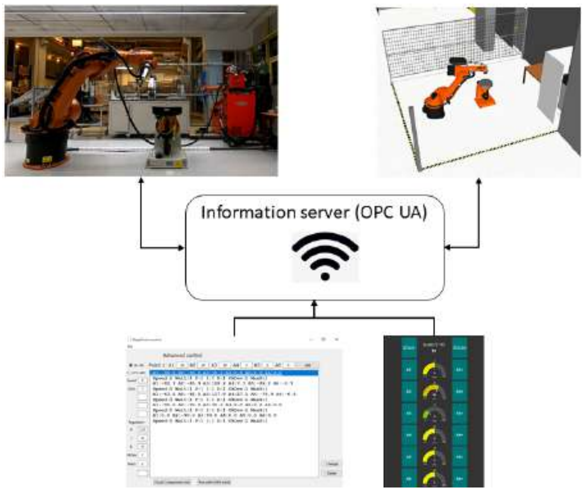
Owner (organization)
Centria University of Applied Sciences https://tki.centria.fi/en

Trainings
Online training material is available through the TRINITY training platform.

Remote control of industrial robots

Main functionalities
The module offers a method to control a general industrial robot remotely. This module offers a robot controlling method through IoT by using an information server. The interface takes input from the robot operator and the operator is able to program or move robots remotely.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Proposed setup

Technical specifications
The module is used to showcase how an interface can be connected to robots and enable remote control. Two interfaces are created, the first one is running in python which has advance control function, the second one is running in Node-red which allows robot operator to control it on mobile device.
The interface connects to the server and is able to read and write data in the server.

Inputs and outputs
Inputs: The module gets input from the robot operator on where the robot will move and with what speed.
Outputs: The robot will execute the movements remotely as operator inputted.

Formats and standards
Formats: OPC UA standard, KUKA RSI, KUKAVARPROXY-OpenShowVar

Owner (organization)
The Owner of the demonstrator is: The Artic University of Norway (UiT) https://en.uit.no/startsida
The Arctic University of Norway is a medium-sized research university that contributes to knowledge-based development at the regional, national and international level. UiT is the third largest university in Norway and northernmost university in the world. UiTs study portfolio covers all classical subject areas from Health Sciences, Social Sciences, Education and Humanities, Science and Technology to Economics, Law, Social Work, Tourism, Sports and Fine Arts. While the key research areas covers the polar environment, climate research, indigenous people, peace and conflict transformation, telemedicine, medical biology, space physics, fishery science, marine bioprospecting, linguistics and computational chemistry.

Trainings
Training material is under production. The tutorial shows two examples/methods on how robot can be controlled wirelessly. http://heinlein.mech.upatras.gr/trinity/remote-control-for-industrial-robot/

Robot trajectory generation based on digital design content

Main functionalities
Speeding up robot simulation and programming: by using data from digital design data, such as Building Information Model (BIM). Utilizing digital design information for robot simulation and offline programming. Existing digital design data from a CAD model can be utilized to generate trajectories for robotized tasks such as milling at an early phase of development, which shortens design-to-production time and, in turn, significantly eases integration of new workpiece production.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Rapid AR/VR models: utilizing design data to create AR/VR models. The goal is to speed up the creation of AR/VR models or virtual twin models by using data from the digital design data. This module can be utilized in training, safety and production planning purposes.

Technical specifications
Hardware:
HTC Vive or similar virtual reality headset
Desktop PC with Windows 10

Sufficient hardware for VR applications
Software:
RoboDK
SolidWorks or similar CAD software
Unity
SteamVR

SolidWorks or similar CAD software is used to integrate robot trajectory data into the product's design data, which is preserved in the form of curves or points. This data can then be utilized in robot simulation or offline programming in a robot simulation or programming framework such as RoboDK. Data can also be utilized with Unity and SteamVR for creating AVR-experiences of production for training and marketing purposes.

Inputs and outputs
Inputs of this module are simulation data files and digital design data files provided in STL, STEP and BIM formats. These inputs can be utilized with 3D development platforms, such as Unity, Blender or Vuforia to create an AVR-experience for training purposes, or with RoboDK simulation software in order to create robot trajectories. Keypoints for robot trajectory generation can be integrated into the design data using CAD software such as Solidworks. Outputs of this module are robot trajectory files or AVR-executables.

Formats and standards
Digital design file formats: STL, STEP

Owner (organization)
Centria University of Applied Sciences https://tki.centria.fi/en

Trainings
Online training material is available through the TRINITY training platform

Simulation welding

Main functionalities
The main functionality of the module is to use a simulation software to program a welding path by creating a connection between the simulation software (Visual Components), the industrial robot and rotary table (KUKA).

The system works by having a translator between the simulation software and the industrial robot. The translator takes the data from the simulation and uses the data to control the robot with the parameters from the simulation software.

Benefits of the module:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Creates a simple method for re-programming and configuration of the welding system
Offline testing of welding program

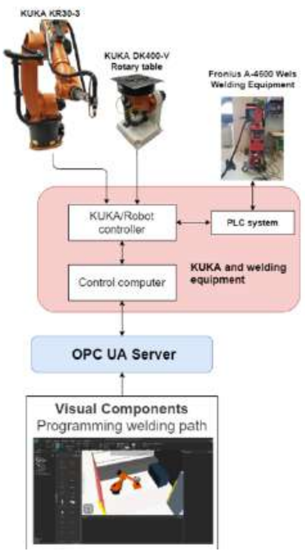
Verification of welding program before running it on the physical robot.

Being able to program the robot while not being in the production environment. Remote programming.

Monitoring of the system

Release humans from labor-intensive, heavy work, or hazardous work environments.

Technical specifications
The system consists of an industrial KUKA Robot and a rotary table coupled to the same KUKA controller (KR C2). A Fronius MagicWave 5000, a completely digitized TIG welder, is connected to a PLC and then to the KUKA controller as shown in Fig 1. With the KUKA controller It is possible to set welding parameters and control the welding machines. For this reason, the system is setup with an external computer connected to the KUKA controller, which can control the KUKA robot, rotary table and welding equipment in real time.



How the 3D structure is generated in Visual Components

Inputs and outputs
Inputs: The robot and rotary table are programmed in Visual Components to generate robot motion data.
Output: Data to the KUKA robot, rotary table and welding equipment.

Formats and standards
Visual Components Premium 4.2 (simulation/programming tool), OPC UA standards (Connecting robot and simulation software), translator from Visual Components to the robot and rotary table (made in Python) and KUKA controller with the Robot Sensor Interface (RSI) add-on for real time control of the robot and rotary table.

Owner (organization)
The Owner of the demonstrator is: The Artic University of Norway (UiT) https://en.uit.no/startsida
The Arctic University of Norway is a medium-sized research university that contributes to knowledge-based development at the regional, national and international level. UiT is the third largest university in

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Norway and northernmost university in the world. UiTs study portfolio covers all classical subject areas from Health Sciences, Social Sciences, Education and Humanities, Science and Technology to Economics, Law, Social Work, Tourism, Sports and Fine Arts. While the key research areas covers the polar environment, climate research, indigenous people, peace and conflict transformation, telemedicine, medical biology, space physics, fishery science, marine bioprospecting, linguistics and computational chemistry.

Trainings

The training material is under development.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 26: LMD-AUTO

1. Basic information

Name of demonstration
LMD-Auto

Main objective
Transforming an operator driven Laser Metal Deposition cell into a fully automated cell to improve laseron time, reduce setup time, validation time and operator dependency. This to increase efficiency and reduce yield loss.

Short description
The implemented LMD-Auto system enables to transform an operator driven clad cell into a fully automated turnkey system. This automation is successful realised by implementing 3 key technologies: By using vision technology together with a robot parts of varying series can be detected and picked up from a pallet. Once the part is picked up the clad robot will work together with the pick robot to perform robot-robot welding to coat the part on the correct spots. During the cladding a coaxial camera monitors the melt pool to log the quality and if necessary, control the laser power.

Owner of the demonstrator
LASER CLADDING VENTURE NV

Responsible person
CTO, dr. ir. Stijn Clijsters, stijn.clijsters@lcv.be

NACE

Keywords
Industry 4.0, Laser Metal Deposition, Valves, Ground engagement tools, Laser Cladding.

2. Innovation

Benefits for the users
The developed module results in reduce of cost of the products this is the result of 4 main benefits: less setup time, less validation time, increased laser-on time and reduced yield loss. Each of these benefits are the result of the implementation of the three key technologies.

Vision based picking: Reduces the complete setup time of valves. The completely automatic detecting and allignment reduces also the possibility for human errors and therefore reduces the yieldloss.

Robot-robot welding: with the implemented robot-robot welding setup time and laser-on time is increased by a parametric robotprogram. This results additionally in reduced yield-loss

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Meltpool control: opens the possibility to perform online quality controll and reduces the yield-loss and process validation. Based on the melt pool signal the process can be judged on their performance, without time consuming macro analyses.

Innovation
At the start of the project the laser metal deposition or laser cladding process is purely operator driven. The process is characterized by regular operator checks to validate that hardware, process and toolpaths are running as they should; multiple operator manipulation to setup a machine and a lot of expertise to judge and estimate the process.

By implementing the LMD-Auto module LCV made a step towards a turn-key installation which enables machines to perform checks automatically and avoiding labor intensive manipulation of parts. This results in an increased up-time and reduced yield-loss which results in a more cost-effective solution for end users.

Risks and limitations
Complexity of robot-robot welding: for most applications basic robot-robot welding can be applied. One robot positions it self's while the other performs the welding. However for complex synchronous multi robot actuation no clear solution could yet be found. This step is quite an R&D topic on its own. Melt pool process variation: it is clear from the experiments that cladding the same parts results in similar melt pool behaviors and therefore the melt pool can be controlled towards a validated specimen. However to bring melt pool control to a level that unique parts can be cladded without expertise still a big step is to be taken.

Technology readiness level
7 - System model in operational environment

3. Exploitation

Sectors of application
Process industry Parts such valves, pistons come in various sizes and all need a corrosion weld overlay or hardfacing. The developed module is perfect for such applications, Ground engagement Components of the ground engagement such as drill bits all need a cost efficient coating. Often manipulation of these components is the cost driver, therefore these components are perfect for the module.

Potential sectors of application
All industries with weld overlay or hardfacings could benefit of this development.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
Vision Camera: necessary to detect parts and to pick them up

Robots: robots to perform the robot robot welding

Thermal coaxial melt pool camera: this camera is necessary to monitor the melt pool to have data to perfrom melt pool control

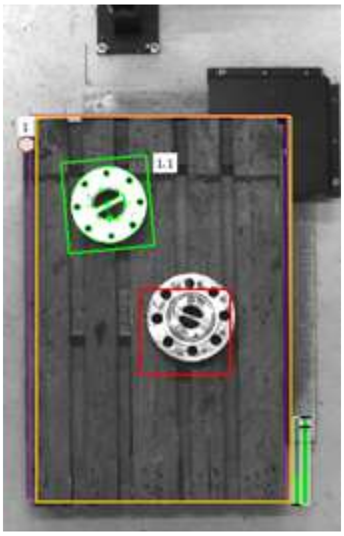
LMD-Auto controller: A controller who can coordinate the separate modules and run feedback loops for melt pool control

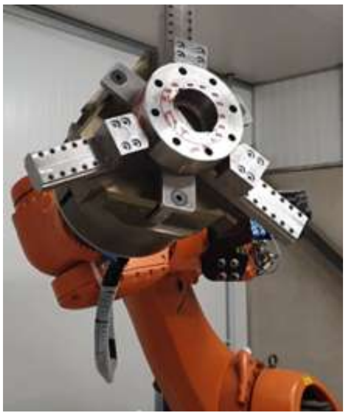
Software:
Software to program the controller loops and to manage all seperate modules

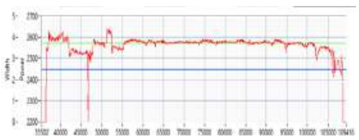
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

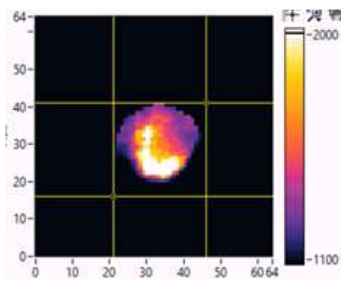
4. Media

Photos









Video

Promotional video: LMD-Auto

HTTPS://YOUTU.BE/KGOE12GGC_E

Executive Summary video of LMD-AUTO

HTTPS://YOUTU.BE/VGJR8SLKGKM

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

5. Modules

LMD-AUTO

Main functionalities
Transforming an operator driven Laser Metal Deposition cell into a fully automated cell to improve laser-on time, reduce setup time, validation time and operator dependency. This to increase efficiency and reduce yield loss.

Technical specifications
Reduced operator interferance

Inputs and outputs
Processing parameters together with parts are fed into the system, the output are toolpaths for pick and clad robot and configuration settings for the melt pool control.

Formats and standards
OPC-UA, Profinet

Owner (organization)
1330

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 27: Robotic solution for accurate grinding of complex metal parts

1. Basic information

Name of demonstration
Robotic solution for accurate grinding of complex metal parts.

Main objective
The main objective is to provide a robotic solution for grinding complex metal parts, integrating all the technological features in a single turn-key solution and a companion software with embedded compliant grinding tool physics to simulate the ground surface to minimize robot programming time for each new part.

Short description
The robotic solution includes a controller to guarantee homogeneous material removal along the part compensating tool wear for accurate grinding, increased productivity with automatic collision-free tool changing and continuous robot and process monitoring for production traceability. It is included a companion software with embedded compliant grinding tool physics to simulate the ground surface to minimize robot programming time for each new part and prevent the current situation of part scrapping during trial and error validation of the grinding trajectories.

Owner of the demonstrator
Aldakin

Responsible person
R&D Manager

Ibai Inziarte

i.inziarte@aldathink.com

NACE
Keywords
Robotics, Process Control, Grinding, Finishing, CAM Simulation.

2. Innovation

Benefits for the users
Automation of a grinding process: the grinding process of complex metal parts is usually done by skilled operators. This is a tedious and dangerous tasks, but complex to robotize. This complete solution demonstrates the viability of the combination of robotics and ICT in order to create a robot that will be able to perform the grinding of complex metal parts. Process control: grinding processes does not control the tool wear and the variable material removal rate. This solution incorporates a robot feed controller based on the corresponding tool wear model in order to guarantee a continuous material removal rate during the whole grinding process. Scrap part reduction: The grinding simulation software combines the real grinding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

belt geometry, physics of the pneumatic compliant tools, and inputs from the robot's material removal model to predict removed material based on the contact surface at each point. This simulation software provides an accurate simulation that reflects the real grinding operation, allowing a the trajectory optimization capability without trial and error tests.

Innovation

– Continuous material removal control: current grinding robots do not incorporate any tool wear control. This solution includes a robot feed controller based on the corresponding tool wear model in order to guarantee a continuous material removal rate during the whole grinding process. – Centralised full grinding process manager to allow the operator to configure process parameters such as the final material quantity to be removed and types of abrasives to be used.

– Cloud based process monitoring system: market solutions only offer cloud monitoring of robot parameters, but this demonstration also allows the monitoring of process parameters for productivity traceability.

– An innovative ground surface simulation software that considers the real tool geometry and physics.

Risks and limitations

Part complexity: A complex metal part refers to those with significant curvatures, require long grinding processes and have to fulfil strict geometry tolerances. Due to the current abrasive type used by the robotic solution, surfaces with very complex geometries, with multiple curvatures in different directions, are difficult or even unable to process. Additionally, if the geometry has significant tolerances (>1mm), the compliant effect of the tool might not able to absorb the deviation, producing unwanted marks.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Metal part manufacturing companies: companies that have manual grinding processes and want to robotize the process or improve part accuracy.

Patents / Licenses / Copyrights

Hardware / Software

Hardware:

Industrial robot

Laptop

Software:

CAM Software

4. Media

Video

ARGRIND is an advanced robotic solution for accurate grinding of complex metal parts. ARGRIND robot includes a controller to guarantee homogeneous material removal along the part compensating tool wear

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

for accurate grinding, increased productivity with automatic collision-free tool changing and continuous robot and process monitoring for production traceability. ARGRIND solution includes a companion software with embedded compliant grinding tool physics to simulate the ground surface to minimize robot programming time for each new part and prevent the current situation of part scrapping during trial and error validation of the grinding trajectories.

HTTPS://WWW.YOUTUBE.COM/WATCH?V=RWOOJBU4OJW

Executive video

HTTPS://YOUTU.BE/CJSTDVUK-SG

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 28: TRAINMAN-MAGOS - training of an industrial manipulator using the magos platform (classification: robotics, haptic-technology, robotic development time saving)

1. Basic information

Name of demonstration
TRAining of an INdustrial MANipulator Using the MAGOS Platform – TRAINMAN-MAGOS (Classification: Robotics, haptic-technology, robotic development time saving)

Main objective
TRAINMAN-MAGOS is a haptic-based solution which transforms the gathered hand movements into a tangible set of instructions to a set of robot and gripper, which can decrease the development time of robotic implementations in high dexterity process operations. Moreover, this tool can register and exploit this skilled knowledge.

Short description
TRAINMAN-MAGOS is a system composed by a haptic-glove, a robot and a gripper. It is function is to translate hand movements performed with the haptic glove into a set of instructions. These instructions are then processed by the robot and the gripper, which could reproduce these movements, having thus the possibility to automate high dexterity process operations in which nowadays human intervention is still needed.

Owner of the demonstrator
MAGOS

Responsible person
Mr. Greg Agriopoulos GAGRIOPOULOS@THEMAGOS.COM
Mr. Vasilapostolos VASILAPOSTOLOS@THEMAGOS.COM
Ms. Gema Antequera GEMA.ANTEQUERA@CTAG.COM

NACE
Keywords
Robotics, human-robot collaboration, safety, wearables, Collaborative Robotics, Industry 4.0, Augmented Reality.

2. Innovation

Benefits for the users
Programming time is reduced: Taking into account that movements are translated into instructions, programmers don't have to spend hours programming point per point complicated paths to reproduce high dexterity movements, being able to save up to 70% of the time used in the usual programming procedure.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Commissioning time of the robotic application is decreased: Time spent by the robotic technician making fine adjustments is reduced up to 20% due to the high quality of the draft path provided by the glove.

Commissioning expenses are decreased: It is common to damage involved products during adjustments of robotic paths. However, expenses done by these damages are decreased because using TRAINMAN-MAGOS there are less possibilities of making damages than programming the path from scratch. The probability of damaging parts is reduced up to 20% using TRAINMAN-MAGOS.

Skilled knowledge is kept in the company: Expert knowledge normally confined in the hands of a skill operator is in this way kept in company's know-how, being an important asset of the organization that should be managed and controlled.

Operators' wellbeing is improved: Automating high-dexterity operations usually means improving operators' wellbeing by reducing repetitive high-demanding tasks, so they can use their time in more added value activities.

Innovation

In contrast to the usual programming procedures, in which a robotic technician has to specify point per point the path to be followed by a robot, TRAINMAN-MAGOS solution decreases dramatically robotic development time, since movements captured by the glove are translated into a set of instructions which are processed by a set of a robot and a gripper, which are able to reproduce them without the necessity of spending hours defining points position.

In addition, skilled knowledge in hands of skill operators is therefore kept in company's know-how, which is an important asset to manage in order to train apprenticeship operators or to improve a specific process.

Moreover, with this system is possible to save commissioning time and expenses due to the high quality of the draft path provided by the glove, (which would not be possible if programming would be done from scratch as in the usual programming procedure).

Risks and limitations

Using data only from the first phalange and not from all phalanges (gripper limitation): All data provided by the MAGOS glove was from the first phalange, (the base of the finger), since this is the only degree of freedom that can be controlled by the 3-finger Robotiq gripper. Using data from the third phalange would be very complicated to adapt to gripper's movements. Using data from only three fingers and not all fingers (gripper limitation): As the gripper used in this project was the 3-finger Robotiq gripper, data came only from 3 fingers (the thumb, the index and the middle finger). Gripper weight limitation: As the gripper has a fingertip payload limitation of 2,5 Kg, a support had to be created in the window glass model in order to get stability. In addition, gripper's pressure had to be at maximum to pick the window model, not having thus the possibility of using glove's pressure sensors to study in a more accurate way which pressure would be suitable to perform assembly movements. Units and axes adapted in an external software: Units and axes had to be adapted in an external simulator, not being able to integrate it in robot's software.

Technology readiness level

7 - System model in operational environment

3. Exploitation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Sectors of application
AUTOMOTIVE INDUSTRY: Car manufacturers can have much profit using TRAINMAN-MAGOS solution because this system saves robotic development time, which is very important nowadays since both automation and time are being more and more crucial in the automotive sector. Therefore, time saved using TRAINMAN-MAGOS could be used to automate other operations. In addition, car manufacturers can preserve skilled knowledge to train inexperienced operators or to improve their processes. , Welding industry: cases that robotic programming is inevitable or too difficult, Oil & Gas: cases that robotic programming is inevitable or too difficult, Industry 4.0: cases that robotic programming is inevitable or too difficult.

Potential sectors of application
TEXTILE INDUSTRY: Nowadays, some textile brands prefer to manufacture their garments by hand because the quality of stitching is much better than automated stitches done by a robot. However, with TRAINMAN-MAGOS solution, stitching could be automated having the same quality as the by-hand stitches since robots could perform the same paths performed by tailors' hands. They would have much more precision when stitching. HEALTH SECTOR: TRAINMAN-MAGOS would be very useful to automate very accurate movements in complicated operations which highly qualified professionals with high dexterity are required. In addition, the TRAINMAN-MAGOS solution would be also very helpful to train new surgeons who have just been graduated.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
MAGOS glove: Sensorized haptic glove providing finger tracking, hand orientation tracking and indoor localization, to be used to monitor the hands of a skilled operator performing, in this case, the assembly of a side car window glass in a car door.

3-Finger Robotiq gripper: This was the gripper chosen to automate the assembly of the side car window glass. Therefore, the gripper is the physical interface between the robot arm and the window model reproducing worker’s fingers movements during the assembly.

KUKA LBR IIWA 14 R820: This was the collaborative robot used to perform the assembly, reproducing worker’s arm during the conduction of the task.

Software:
Magos core software: for the collection and recording of the users motion data

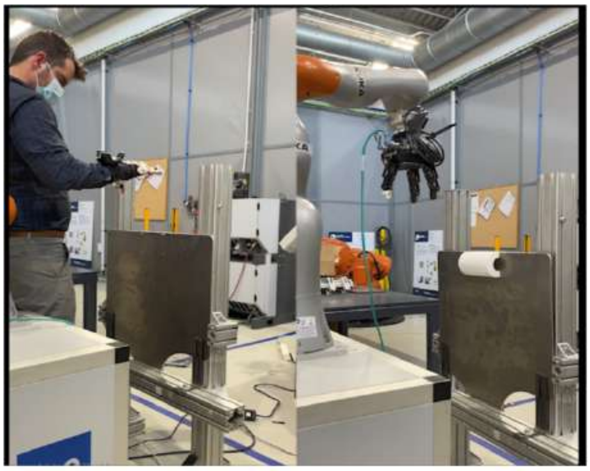
Robot controller: The collaborative KUKA LBR IIWA 14 R820 is managed by its controller, which provides the programming environment to import and develop robotic solutions, including the development of trajectories, the usage of the gripper, and communication procedures.

Tecnomatix Process Simulate v. 15. This offline simulation software adapts orientation and scales the read values into valid gripper instructions. The path and gripper steps are manually refined in this virtual model by the robotic technician, so that it can be finally implemented in real world afterwards.

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



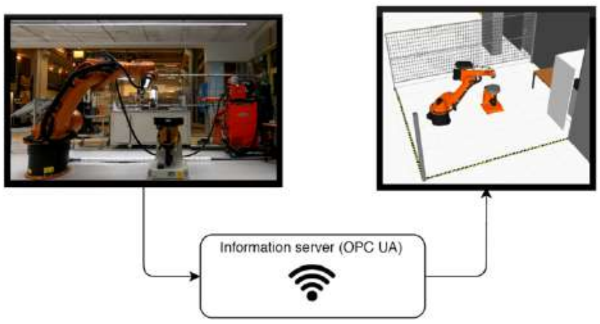
Video
The user (worker) performs high dexterity tasks (grab car door glass replica); Magos records the data. The data are utilized to make the robotic hand perform the same action.
HTTPS://WWW.YOUTUBE.COM/WATCH?V=AQ-YC1_LRQU&AB_CHANNEL=INFOTHEMAGOS

Demonstration executive summary
HTTPS://VIMEO.COM/615797210/0B304D2E97

5. Modules

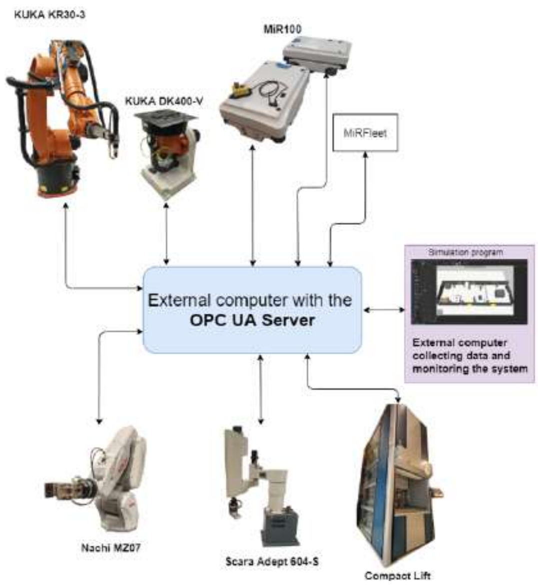
Connecting virtual model with the physical model

Main functionalities
The module describes how robots and other machines can be connected together, through an information server. A connection is created between the physical system and the virtual model, that can be used for remote monitoring.

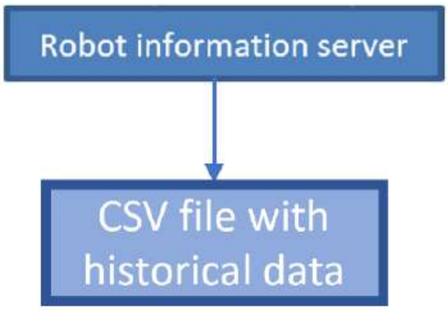


Technical specifications
The module contains a simulation of a production line that constantly imitates the physical production line in real-time. To connect the physical and digital world we use the industrial automation data server as a middleware. All the data from the physical production line is stored in an industrial automation data server. The simulation software is acquiring data from the server, to be able to replicate the physical world in the digital world.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



All the relevant data of the robots and other machines is stored in the information server.
To do analyses on the robot and other machines afterward, there will be saved historical data in a CSV file or a SQL database. The data collected can be used for optimization of the program and used to look for errors in the program.



Inputs and outputs
A server that collects the relevant data from the production line and is able to send the data to the simulation software to recreate the physical world in the digital world.

Formats and standards
Formats: ISO 10303, OPC UA
Standard: KUKA RSI

Owner (organization)
The Owner of the demonstrator is: The Artic University of Norway (UiT) https://en.uit.no/startsida
The Arctic University of Norway is a medium-sized research university that contributes to knowledge-based development at the regional, national and international level. UiT is the third largest university in Norway and northernmost university in the world. UiTs study portfolio covers all classical subject areas from Health Sciences, Social Sciences, Education and Humanities, Science and Technology to Economics, Law, Social Work, Tourism, Sports and Fine Arts. While the key research areas cover the polar environment, climate research, indigenous people, peace and conflict transformation, telemedicine, medical biology, space physics, fishery science, marine bioprospecting, linguistics and computational chemistry.

Trainings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Training material is under production. The tutorial demonstrates how robots can be connected through a central industrial information server. http://heinlein.mech.upatras.gr/trinity/real-time-simulation-for-industrial-robot/

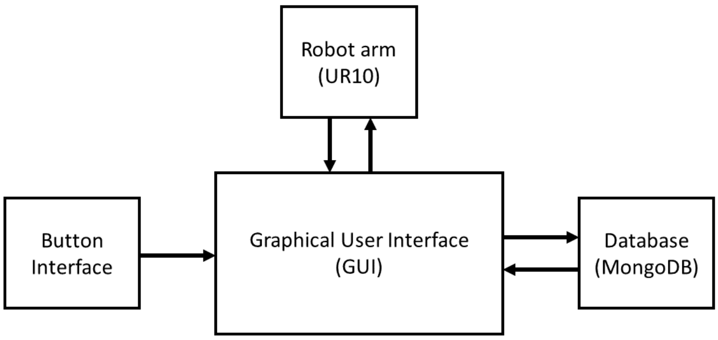
Hardware & software interface for robot programming by manual guidance

Main functionalities

The module for robot programming by manual guidance enables fast and intuitive programming of new robot motions without using traditional programming tools such as teach pendants. Programming with teach pendants is namely slow and cumbersome. Our module enables the operator to simply grab the robot arm with her/his own hands and guide it through the desired task. This way both single robot postures and complex robot movements (free-form trajectories) can be programmed easily. To enable programming by manual guidance (also called kinesthetic teaching), the robot must provide the gravity compensation mode. Robots with gravity compensation mode include Kuka LBR iiwa, Universal robots UR series, and Franka Emika Panda. This module provides a button interface and a GUI to support easy programming and storing of the acquired information.

Technical specifications

The module is implemented in ROS (Robot Operating System, HTTPS://WWW.ROS.ORG) Kinetic environment and provides a Graphical User Interface (GUI) that facilitates robot motion acquisition by manual guidance. The newly programmed motions can be saved in the MongoDB database provided by ROS. Point to point movements and free-form trajectories represented by dynamic movement primitives (DMPs) are supported.



The GUI, called The Helping Hand, is at the front-end of the module. It has two tabs: the main tab called Capture controls and the secondary one called Settings/Configuration. The database component is at the back-end of the module. The mongodb_store ROS package is used to provide the database, as it allows all ROS nodes on the network to access the database. A physical button interface must be mounted on the robot arm. It eases the acquisition of data as it lowers the effort and shortens the time needed for teaching. The GUI communicates with the robot and ROS through the buttons. We developed hardware buttons for Universal UR-10 and Franka Emika Panda robots. These robots are also supported by The Helping Hand software.

While the GUI software is free of charge and available for download, suitable hardware buttons and a robot with gravity compensation must be purchased by a user. JSI offers support for software installation as well as button construction free of charge in TRINITY open calls and on contract basis

Inputs and outputs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

All the data is transferred via the ROS backbone of the system.
Inputs:
The desired commands are specified by pressing the buttons on the button interface. The communication occurs via ROS standard bool message type std_msgs/Bool.
The button presses specify 1. the beginning and the end of manual guidance, 2. control the (de)activation of the gravity compensation mode (the robot can be guided only in gravity compensation mode), and 3. determine the type of motion information to be stored.

The following outputs are possible once the motion has been demonstrated by manual guidance:
sensor_msgs/JointState; this message type is used to store joint angles
geometry_msgs/Pose; this message type is used to store Cartesian space poses
robot_module_msgs/JointSpaceDMP; this message type is used to store a trajectory encoded with joint space DMPs
robot_module_msgs/CartesianSpaceDMP; this message type is used to store a trajectory encoded with Cartesian space DMPs

In the above list, DMP stands for dynamic movement primitives, which are used to encode complex trajectories in a compact way. Same message types are used to communicate with the robot driver to execute the programmed trajectories.

Formats and standards
The software module is open source and released under a three-clause BSD license **HTTPS://OPENSOURCE.ORG/LICENSES/BSD-3-CLAUSE**

Standards:
ROS Kinetic is used as the backbone of the module.
Safety standard for human-robot collaboration must be considered.

Owner (organization)
Jožef Stefan Institute, Department of Automatics, Biocybernetics and Robotics

Documents
A more detailed description of this module
RPD.PDF
https://github.com/tgaspar/helping_hand

Trainings
A training manual describing the module, installation procedure, and how to use the module can be found at HTTPS://WWW.IJS.SI/USR/AUDE/TRINITY/RPD_MANUAL.PDF

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 29: Standardised industrial robotic solution for metal bending automation

1. Basic information

Name of demonstration
Standardised industrial robotic solution for metal bending automation

Main objective
Provide the world's first standard bending robot with an easy to manage hardware and unique control solution, enabling it to be used at any of the existing press brakes.

The solution is an integrated intelligent system that operate bending machine fully replacing the operator.

Short description
RoboBend introduces a standard robot that operates bending machine. An operator specifies the piece that needs to be bent through an easy-to-use user interface. This process is repeated only for new pieces since all information is stored and can be accessed from the cloud server. The robot picks up prefabricated pieces from the feeder system with the robot arm and relevant gripper (vacuum, mechanical, electromagnetic), places them in the bending machine, takes them out once bent, and neatly stacks them on a pallet. It operates until all prefabricated pieces are bent and the feeder cartridge needs to be replaced.

Owner of the demonstrator
RoboBend ApS

Responsible person
Thomas Ronlev, CEO & Co-Founder

+370 685 35 145, tsr@robobend.dk

NACE
C28.4.1 - Manufacture of metal forming machinery

Keywords
Robotics, Machine Learning, industrial robotics, metal processing industry automation, flexible metal bending, standard industrial robotic solution, robotic cell, standard design and universal tending technology.

2. Innovation

Benefits for the users
Speed and ease of programming: conversion of drawings into robot programs takes only ~15 minutes per 1 bend (if a part has 3 bends, then it will take around 45 minutes). That is a major improvement and benefit as anyone in the factory would be able to program new parts into the robot.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Costs savings: RoboBend will improve the manufacturing processes and whole industrial productivity: repeatable accuracy and improved quality of production by more than 25%; increased machine and system utilization from 70% to 95%, furthermore, the price of RoboBend solution and its integration is lower 2 times (70K EUR vs 140K EUR on average) – case study with a Danish company shows that the potential gains from this for a company are up to 140K EUR annually. It also leads to the decreased Return on Investment (ROI) period for a company to 8 months if RoboBend is used regularly and to 6.5 months if used additional 400 hours per year.

Increased safety: RoboBend works autonomously and replaces the operators reducing the number ofaccidents at work in the metal industry (now, 363K accidents and 135 fatalities at work in the EU annually).

Quality: RoboBend solution control the most affecting production quality issues (the machine inaccuracies, programming challenges and metal piece picking/alignment)

Standardization: standard solution compatible with any press brake makes the clients become more convinced to invest into robots.

Enabled robotization: RoboBend has the potential to robotize the metal industry which will have a significant impact on reducing metal worker shortages – it is estimated that up to 2M vacancies in the industry could potentially be filled by 2025.

Innovation

This use case possesses the following innovation features:

- Automation of the entire process performance – advancement in agile planning and manufacturing. Automation allows rapid change of manufacturing from one order to another and performance measurement from order to order. It also provides ability to move the system to another press brake or storage area in the need of manual work.
- Old processes use custom made solutions for every potential customer. It means expensive solutions are either specifically designed for one problem or even more costly solution is a full system that includes a press brake, robot, and all of the peripherals. RoboBend system delivers a standard solution for sheet bending tasks. It is built specifically to be integrated with any of the existing press brakes. With it the customer receives easy to use User interface with easy checkpoints to ensure easy and correct robot pre-set for production with ability of monitoring.

Risks and limitations

Integration: RoboBend is a sophisticated standard solution which can be used with all press brakes and all robot arms. But there may be new products in the future that will introduce some limitations for integration of RoboBend. However, in near future nothing might affect the integration.

Technology readiness level

9 - System/model proven and ready for full commercial deployment

3. Exploitation

Sectors of application

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Metal processing industry – metal bending: RoboBend is the World's first standard bending robot operating bending machines. It solves the problem of finding qualified machine operators, provides higher capacity on company's present machines, lowers production costs, and delivers consistent high quality for your clients. An important component in RoboBend is the press brake control interface (RBMI) – the brain, which has embedded the software giving an "intelligent solution" and allows RoboBend to work with any existing press brake on the market. This is a key feature and makes RoboBend easy to implement and to use – providing the robot control over the machine, easy programming interface, quality control and at the same time is based on Industry 4.0 philosophy, making it possible to integrate data from the cloud and from other sources to optimize both the set-up and daily machine performance.

Potential sectors of application

Metal processing industry – other metal processing operations (e.g., machine tending, stamping, grinding, etc.): RoboBend solution can later be applied to other metal processing operations. This will depend on specific client's needs, and the solution will require adaptation for every other process.

Hardware / Software

Hardware:

Magnetic separator system – pneumatically controlled system to magnetize prefabricated parts to separate placed pieces with magnetization

Mechanical aligner – mechanical aligner unit with specific angle for prefabricated part to be placed and aligned at the same coordinates always

Pneumatic overturner – vacuum system with suction grippers to hold a piece if robot arm needs to take a part differently but with some axis rotation before

Gripper rack – Small, Medium & Large vacuum grippers

Robot arm – 6 axis robot arm

Linear axis – 7th axis for the robot to cover bigger area around

RBMI – robot machine interface to control press brake

Electrical box – electrical control components of the system

Pneumatic system – pressurized air system components to feed specific pressure to robot arm for gripper change, gripping parts; overturned - to hold parts for regripping

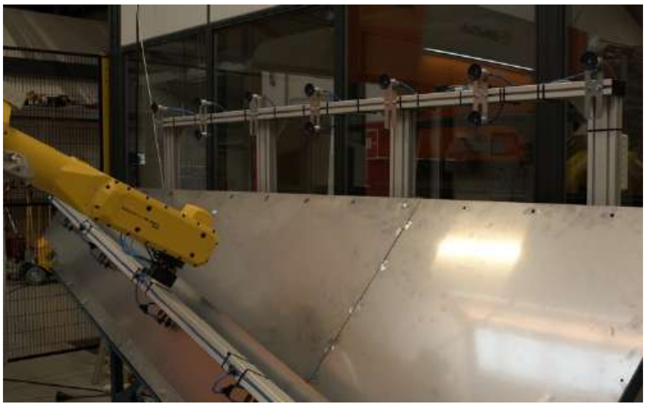
Software:

Digital twin – Obelisk – digital twin of the full cell with offline programming, programs and simulations generation

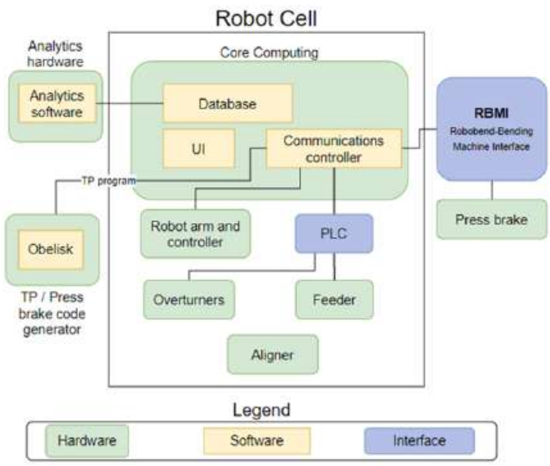
4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video

Video describing the solution, problem behind the idea, summarizing key features, KPIs and benefits.

[HTTPS://YOUTU.BE/B2LHAENONDG](https://youtu.be/B2LHAENONDG)

Final RoboBend3000 Demonstration Online at BCM Transtech premises in Broby, Denmark that took place on the 29th of June, 2021. Video consists of the presentation of a RoboBend use case and a demonstration of the RoboBend in action.

[HTTPS://WWW.YOUTUBE.COM/WATCH?V=MLQFYDQF81E](https://www.youtube.com/watch?v=MLQFYDQF81E)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 30: Safe and collaborative screwdriving for high-mix/low-volume productions with iot data logging and analytics

1. Basic information

Name of demonstration
Safe and Collaborative screwdriving for High-mix/Low-volume productions with IoT data logging and analytics

Main objective
The main objective of the demonstrator is to showcase how to increase the flexibility and lower programming time for assembly task with collaborative robots running screwdriving task. The focus has been fast and easy teach-in while ensuring high screw insertion process quality. A monitoring system logs all screw insertion data.

Short description
Every day, millions of screws and bolts are mounted in the European manufacturing industry by employees with handheld screwdrivers in everything from windows to cars & electronic products. The Trinity demonstrator shows how to automate high/Mix – low/volume productions involving screw assembly task, by introducing an easy-to use system which is fast to setup and program. The Easy teaching is ensured by using a small teach pen to pinpoint each screw insertion hole. The system comes with different robot apps e.g. for UR and Omron TM robots to ensure ease of use and a cloud logging system to store torque data.

Owner of the demonstrator
Spin Robotics

Responsible person
The demonstrator is developed by the three partners – Spin Robotics (DK), Trendlog.io (DK) and Elvez d.o.o. (SI)
Spin Robotics is a Danish end-of-arm tool manufacture specialized in assembly applications involving Collaborative Robots. The mission of Spin Robotics is to remove manual and repetitive task during industrial assembly operations by introducing collaborative Plug & Play end-of-arm screwdriver tools for collaborative robots which is fully safety certified.
Spin robotics Aps ***HTTPS://SPIN-ROBOTICS.COM/EN/***
TRENDLOG.IO is a Danish IT tech-company (SME) established in 2003, specialized in data logging and industry 4.0 technology. Trendlog.io helps production companies -big and small – gain full insight into their daily production. Using a secure data collection method and a user-friendly cloud-based platform we collect and visualize all important production data.
Trendlog.io Aps ***HTTPS://TRENDLOG.DK/***
ELVEZ D.O.O. (SME), is the manufacturer of specialized products for automotive industry, electrical and mechanical engineering, and white goods manufacturers. Their employees are constantly engaged in development and implementation of innovative and flexible solutions to meet an outstanding quality and highest customer satisfaction which are the foundation for long term relationship. ELVEZ`s core activity is manufacturing.
Elvez d.o.o ***HTTPS://ELVEZ.SI/***
Contact: Dr. Thomas Sølund, CTO Spin Robotics – email: **TS@SPIN-ROBOTICS.COM**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

NACE
C26 - Manufacture of computer, electronic and optical products

Keywords
Robotics, IoT - Cybersecurity - Artificial Intelligence - Predictive Maintenance – Revamping, human-robot collaboration, safety, artificial intelligence, cobot assisted manufacturing, Collaborative Robotics, Industry 4.0.

2. Innovation

Benefits for the users
With the SD35 screwdriver, the technology user will get reduced production cycles of 40-60%, due to implementing automation in the production line and the removal of human errors. Along with this, the technology user also gets a pick-and-place solution, which comes right off the shelve, that due to its price and low integrator cost comes with a low ROI of 12-14 months, compared to other traditional products on the market. The solution also makes it possible to get a detailed online quality assessment of each screw, and data such as torque will be stored in the device or cloud and can be used to incorporate the tool in industry 4.0 setups. Due to the safety operations programmed in the SD35 the tool is safe alongside humans and allows for true collaborative use, which only needs a short risk assessment time. The tool will also remove the strain on the shoulders and neck manual screwdriving processes take.

Innovation
Manual screwdrivers are the norm is most assembly lines, as they are cheap and can handle the task of screwing. When using manual screwdrivers, employees are presented with strain to the body and the operation can be process to human errors due to fatigue. With robots, these factors are eliminated, and every screw will be inserted unison with precise torque. The SD35 innovates the market by making it possible for all enterprises to get access to a robotic assembly workforce, since it has a low implementation time/cost, and the fact that there is no need to change the setup of the production line.

Accidents can happen in a production line, but due to the safety features, such as the safety shield, of the SD35, those accidents will be eliminated.

Risks and limitations
Risk/limitation: Before deploying and start using collaborative robots with the SD 35 screwdriving tool a risk assessment is always required. The risk assessment must be done in accordance with the ISO12100 standard that describes how to do a proper risk assessment. At Spin Robotics web page, you can find more information about how to do a risk assessment. Here you can download a risk assessment template in excel. Furthermore, you can download test reports from force impact tests the compute be applied during the risk assessment to prove that the tool is safe in according to the ISO/TS 15066. Always remember to update your risk assessment if you change the robot installation or the robot program. Remember also to take into consideration the physical installation or the environments that the robot I inserted into. For instance, are the robot installed close to a wall such that people can get trapped between the wall and the robot. Remember to always read the user manual before starting to implement a new screwdriving application with the SD 35 screwdriving tool.

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Sectors of application
Automotive Industry, Electronic Industry, Wood Industry.

Potential sectors of application
The SD35 screwdriver system for collaborative robots and other products of Spin Robotics are protected by several patents in global publication process.

Hardware / Software
Hardware:
SD35 screwdriving tool (hardware): The end of arm tool together with a mechanical SpinMount coupling that makes it easy to mount the tool at various collaborative robots. The SpinMount makes it easy to shift between different tools due to its click and connect functionality.

SPINBridge (hardware): The heart of the control. The spin bridge box is where all computation and control software are running.

Collaborative Robot (hardware): Universal Robot UR3e, UR5e or UR10e + Omron Techman Robot TM5-900, TM5-700, TM12 or TM14

Screw presenter unit (hardware): Screw presenters can be ordered together with the SD35 screwdriving tool. Different models exist that handles from M2 to M6 screws.

Software:
SpinInterface (software): At the SpinInterface the user can inspect how the current screwdriving process are running and see statistical/historical data about the screw insertion process.

Robot Apps for Universal Robots or Omron TM robots (software): Apps for both Universal Robot (UR), Techman and Omron Techman can be downloaded at our website.

4. Media

Photos

Video
The Trinity promotional video is a case video showing how easy it is to setup and operate a screwdriving process with collaborative robots and the technology developed during the Trinity project. The Trinity executive video explains the developed technology and how it has been utilized in the Trinity demonstrator.
HTTPS://VIMEO.COM/579802633

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 31: AGILE: Increasing the agility of the automotive cable assembly industry using trinity robotics solutions

1. Basic information

Name of demonstration
AGILE: Increasing the agility of the automotive cable assembly industry using TRINITY robotics solutions

Main objective
Showcase advanced robotics solutions that increase the agility of the automotive cable production industry.

Short description
Three use-cases are exploited: (i) collaborative robotics, demonstrate a collaborative assembly of different car fuse boxes between a human and a robot. Safety areas and a safety line are projected on the assembly station to keep the worker aware of his working space; (ii) Human-Robot Interface (HRI) using an Augmented Reality (AR) application for training-on-the-job and assisting workers in maintenance operations; (iii) bin-picking with machine vision where a robot detects different types of connectors in unpredictable positions, determines the best grabbing position and sort them in different output trays, depending on the connector type.

Owner of the demonstrator
Allbesmart, Lda

Responsible person
PhD Paulo Marques, PMARQUES@ALLBESMART.PT

NACE
J62.0 - Computer programming, consultancy and related activities

Keywords
Collaborative Robotics, Industry 4.0, Augmented Reality, Bin-Picking, Machine Vision.

2. Innovation

Benefits for the users
Collaborative assembly reduction of 30%: Collaborative assembly has the potential to considerably reduce assembly times, whilst ensuring, reduction in human errors by inspecting the final product quality. They may also increase workplace ergonomics. Using a mid-range collaborative robot, assembly times can be reduced by, at least, 30%. Collaborative robots may also be used for other non-collaborative tasks, so that, when not used in a collaborative activity, they can solo perform automated tasks to improve ROI.

Training-time reduction by 50%: Augmented Reality (AR) based solutions improve knowledge transfer, and reduced training time by 50%. They also improve field service quality and productivity, reducing overtime spend with maintenance operations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Cost savings up to 70%: AR with remote video assistance considerably reduces, the need for travels related to maintenance.

Automated bin-picking with cycle times below 10s: AI machine vision is currently an accessible technology that can be coupled with affordable robotic machines to perform automated tasks of bin-picking with ordered sort, which are applicable in many industry use cases. Mid-range robots can achieve cycle times below 10s, depending on the type of target objects and the robot gripper (clamp or suction).

Innovation
Collaborative assembly with cobots brings better working conditions and higher profitability through improved adaptability, flexibility, performance and seamless workflow integration. Worker safety can be achieved by projecting dynamic safety zones and a safety line on the working area, to ensure the operators keep conscious of the restrictions and regions of operation.

Augmented Reality (AR) is an upgradable technology that enhances the user experience by putting holographic images in the user physical environment. These holograms can be interactive and can be easily and intuitively manipulated by the user. The AR holograms can be applicable in many industry use cases.

Bin-picking allows for randomly placed parts (in any position and orientation) on a container to be removed with minimum disruption of the environment and put (ordered or not) on multiple containers, where the robot adjust its position and trajectory to extract and place the part in its new position (optionally, with the correct orientation). This solution is very flexible (AI based machine vision, allows reaction to the environment), adaptive (the robot can be rescheduled for other tasks), with minimal supervision, whilst operating in a safe condition (powered by computer vision and sensors).

Risks and limitations
Worker injuries: Any interaction with machines brings hazards, therefore, injuries by cobots is always a possibility, despite all safety measures in-place. Workers must be properly trained for the dangers in human-robot collaborative operations. AR Hologram precision: The precision of the holograms projected by current AR technology is almost excellent and is expected to improve for the next years. Still, different devices and operating systems produce different results on low light and under different materials conditions (e.g., reflective materials). LiDAR technology substantially improves the AR experience but has just been introduced on some commercial-of-the-shelf devices. AR glasses are still intrusive (no seamless integration in human daily activities) and have a limited field-of-view. Tablets and smartphones produce the best AR holograms, but require that, at least, one hand will be used to operate the device. Increased bin-picking cycle time: for more complex scenarios, involving objects that cannot be picked by suction and require a clamp gripper, an expensive depth camera may be required. In such scenarios, object recognition (in different depths), and object pick-up may require additional time.

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application
Industries: • Machine vision algorithms to assist automated tasks and perform quality control (visual inspection) of assembled products., Industries: • Augmented reality applications for training-on-the-job and assistance in machine maintenance operations., Industries: • Collaborative robots (cobots) assisted by

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

machine vision and safety systems, for a quicker, more efficient assembly process, also ensuring quality in assembled products by reducing worker fatigue.

Potential sectors of application
• Services: Augmented reality solutions to support technicians in the maintenance operations for many different types of machines (e.g., heating, ventilation and air conditioning (HVAC)); • Construction: Augmented reality solutions to visualize and interact, on-site, with building construction projects (CAD models) or existing building metadata (e.g., details on the construction license), with no need for the user to search databases; • Utilities: Augmented reality solutions to support technicians visualize and interact with buried infrastructure (e.g., water, electricity and gas), with high-precision geo-referenced holograms.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:
OMRON TM5-900 (hardware): collaborative robot for collaborative assembly and bin-picking activities.

Intel Real-Sense camera (hardware): stereoscopic camera to capture image depth information for bin-picking

Android/iOS smartphone or tablet (hardware): for running AR applications

Software:
OpenCV (software): an open source computer vision and machine learning software library.

TMFlow (software): a robot programming environment for the OMRON TM5-900.

Robot Operating System (ROS) and ROS packages (software): a flexible framework for writing robot software and a set of image processing libraries for ROS.

TensorFlow/PyTorch (software): open source platforms for machine learning.

Unity (software): a framework purpose-built for AR development.

Microsoft’s Mixed Reality Toolkit (software): a cross-platform providing foundational components and common building blocks for spatial interactions.

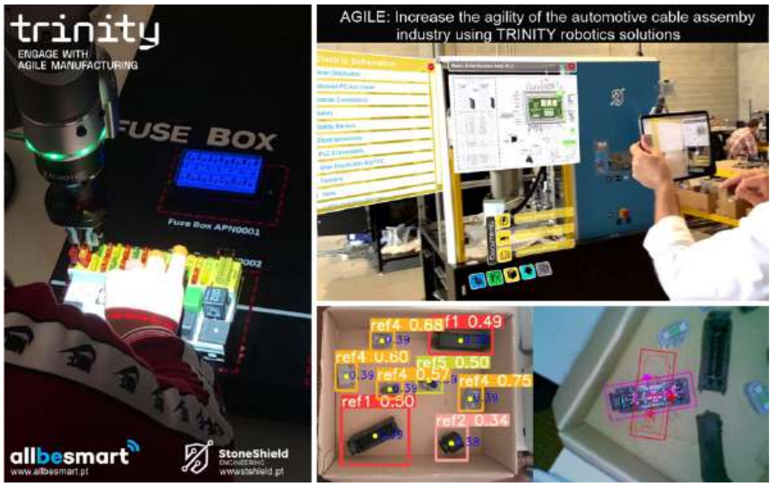
ARKit and/or ARCore (software): AR platforms for iOS and Android devices, respectively. Enable applications to use advanced AR tools and device's capabilities (e.g., cameras and sensors).

MixedReality-WebRTC (software): a collection of libraries that enable the integration of peer-to-peer real-time audio and video communication into AR applications

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video
AGILE-TRINITY promotional video
HTTPS://WWW.YOUTUBE.COM/WATCH?V=HHVXPFW64BI

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 32: Affective manufacturing system

1. Basic information

Name of demonstration
Affective Manufacturing System

Main objective
The objective of the project is to demonstrate a smart factory concept, for robotics-based manufacturing of complex photonic products, with in-line operator stress detection for safety and optimized production (in terms of yield and product quality). The demonstration is based on a modular machine platform with robotics functionalities for efficient and customized production of complex photonic systems. The platform has in-line monitoring and quality control functionalities for in-line adaption of production steps. The demonstration includes an appealing showcase in which human factors are successfully included in the execution of a manufacturing process for optimized production, eventually to open the gateway for affective cobots.

Short description
A robot can take over complex tasks, making the assembly process safer, faster and qualitatively better. The downside of working with a cobot is that the potential loss of control can cause stress for the operator. And stress has a negative impact on well-being, safety and productivity.

The affective manufacturing system has an integrated robotics system for manufacturing of complex photonic systems and contains a sensor system for in-line process monitoring. The platform integrates a novel operator stress detection module, based on measured physiological features of the operator, and artificial intelligence algorithm for stress detection. Production performance and related operator stress is displayed on an interactive dashboard, used for both stress management and process control.
The measured stress levels are used in a smart decision algorithm that takes into account all relevant decision factors, such as the stress indications (emotional state) of the individual operators as determined by the measured and analyzed features; information about circumstances (private, work) of the employee; information about the production process, such as the measured performance indicators (product quality, productivity, failure, etc.); and production instructions (such as the complexity of the instruction or work).

Owner of the demonstrator
Mentech

Responsible person
Erwin Meinders **ERWIN.MEINDERS@MENTECHINNOVATION.EU**

NACE
C28 - Manufacture of **machinery and equipment n.e.c.**

Keywords
Stress management, wearables, artificial intelligence, cobot assisted manufacturing, affective manufacturing.

2. Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Benefits for the users

Affective manufacturing leads to improved efficiency and productivity, by incorporating human stress factors in the optimization of the production processes. The performance of a process depends on the complexity of tasks and the arousal level the operator experiences. For simple tasks, low arousal (inattention of the operator) leads to poor performance, high arousal leads to high performance. Difficult tasks however require moderate arousal for optimum performance. A too low arousal (inattention or drowsy) as well as a too high arousal (stress) lead to poor performance and should be avoided.

Affective manufacturing leads to improved product quality. One of the requests is error-free production through a self-learning production method in which the system responds autonomously to any errors. The addition of affective strategies will further be strengthening this self-learning and will cause a paradigm shift in smart manufacturing. It will create higher standards of production, and more operator and happiness.

Affective manufacturing leads to improved safety, by preventing under-alertness or drowsiness.

Affective manufacturing leads to improved self-control and operator satisfaction/happiness

Innovation

Mentech and Tegema demonstrate an affective production platform for high-quality production of low-volume high-mix products. The demonstration is based on a modular machine platform with robotics functionalities for efficient and customized production of complex photonic devices. The platform integrates operator stress monitoring to harmonize productivity and operator happiness.

The platform comprises a pick-to-light module and a cobot module for cobot-assisted assembly. The pick-to-light module consists of several manufacturing bins with LED indicators to guide the operator through the assembly tasks. The sequence of assembly is indicated by the subsequent switching on and off the LED indicators. The bins also contain proximity sensors to measure the completion of the different assembly tasks. A cobot platform is integrated in the assembly line to assist the operator with complex assembly tasks. Multiple assembly sequences can be uploaded to the system, making the system a flexible manufacturing platform.

The operator stress is determined from real-time measured stress features, like heartrate, skin conductance and face expressions. A trained neural network model makes a prediction of the stress levels of an operator during assembly based on the measured physiology and recognized patterns.

A dashboard visualizes the system metrics, like the required time for assembly tasks, assembly errors and cobot performance, and the measured operator stress. Based on the dashboard outcome, system and operator interventions can be initiated.

The AMS showcases that a hybrid manufacturing platform with a decision algorithm based on operator stress levels will harmonize production and increase yield and production quality.

Risks and limitations

Stress measurement – the measurement of distinct stress levels is difficult in a dynamic high-tech environment. Mentech has a lot of experience with the development and training of personalized stress models. The stress model used in the Affective manufacturing system were trained with personal data obtained in a well-conditioned reference setting. After training, the model was applied to the operator setting. Operator Acceptance - Measuring operator physiology can also backfire. He or she may experience this as a check by the manager. The merits of operator stress measurement are both operator/machine safety and productivity. Particularly, safety is a key selling feature for acceptance of stress detection. Reliability / Accuracy - The stress detection models must be accurate enough to be integrated as a feature for increased

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

safety and productivity. Inaccurate predictions of stress levels might lead to reduced productivity of reduced safety. The development and training of models in reference setting, with the addition of face expression, contributes to accurate stress detection capability. Acceptance by operator – The affective manufacturing system will not be accepted by the operator/customer. The benefits of stress detection, also for operator safety and happiness, need to be made explicit. The privacy of operators need to be secured via a privacy statement.

Technology readiness level
6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application
Tooling industry: equipment manufacturers (OEM), addition of human-machine interface to improved product quality and system productivity |, Transportation industry: manufacturers of cars/trucks/busses/trains/planes/etc., including affective strategies for road safety and driving performance (economics like action radius and energy consumption, passenger comfort), Making and processing / food industry: optimization of production, increase of operator engagement (happiness and arousal), Labour-intensive industries, with operators with a mild intellectual disability, labour-assisted manufacturing.

Potential sectors of application
All segments in which human-machine interfaces are relevant, like manufacturing, system control, production control, operation of machines and systems.

Hardware / Software
Hardware:
Cobot-assisted Pick to light assembly unit with manufacturing bins, consisting of control electronics and software, LED indicators, proximity sensors and assembly tools for complex products; with an integrated Cobot assembly unit.

Software:
HUME stress detection platform, consisting of wearables and trained models (operating in the cloud), optionally a camera system for face recognition and stress detection can be integrated.

Dashboard which visualizes the production metrics (like productivity, production times, production errors) and operator stress levels.

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Video

Smart factory concept, for robotics-based manufacturing of complex photonic products, with in-line operator stress detection for safety and optimized production in terms of yield and product quality.

HTTPS://WWW.YOUTUBE.COM/WATCH?V=2EOMWKSG5SC&T=3S

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 33: End-to-end automatic handling of small packages

1. Basic information

Name of demonstration
End-to-end Automatic Handling of Small Packages

Main objective
The demonstrator provides a complete robotized sorting solution for logistics. The system localizes and picks each parcel post from a large bin, weighs it, measures its volume, and sorts it into different outgoing containers according to their destination. The implemented solution is designed for easy integration into existing production lines.

Short description
The developed system is a complete robotized pick and place solution for logistics. It is composed of several modules. A vision system based that exploits neural networks is used to identify and localize packages from the inbound container. A grasping synthesis module identifies the best parcel to be picked up and computes the optimal grasping point. A motion planner module generates collision-free trajectories to perform a pick and place routine to sorting the package in the correct outbound container according to the parcels tracking system.

The implemented solution is designed for easy integration into existing production lines and is safe to use without safety cages.

Owner of the demonstrator
IT+Robotics srl

Responsible person
Dr. Nicola Castaman
NICOLA.CASTAMAN@IT-ROBOTICS.IT

NACE
H53 - Postal and courier activities

Keywords
Robotics, Vision System, Machine Learning, Motion Planning, Logistics.

2. Innovation

Benefits for the users
Parameter-less configuration: the recognition algorithm moves to a data-driven approach, allowing even untrained personnel to provide meaningful information to the application. Whenever the application does not recognize well the object of interest, it just needs to be fed with some images of the desired object to achieve better results, there is no need to fix/change dozens of parameters.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Reduction of human errors: the automatized system developed in the demonstrator reduces the number of sorting errors reducing costs and increasing customers satisfaction.

Easy deployment: using a collaborative robot and a vision system, the system can be easily integrated into current production lines without safety cages and requiring less free space.

Healthier workplace: operators are no more subjected to perform repetitive operations and stressful cycle time.

Innovation

The main innovation of the workcell is the machine-learning-based vision system to recognizing and localize parcels for a bin-picking application. Typically, industrial bin-picking applications exploit a CAD of the objects to perform the localization and compute a suitable grasping point. Unfortunately, this approach is not feasible with packages and parcels because they have different sizes, colors, shapes, and could be deformed.

The demonstrator exploits a model-less approach to bin-picking that enables an application to detect boxes and parcels in the inbound container. The approach first exploits state-of-the-art machine learning frameworks to recognize and segment packages in a color image of the inbound container. Then an internally developed algorithm merges the segmented instances and the relative point cloud to find a 3D cluster for each package. Finally, the best points for the robot to grasp the desired package are computed.

This approach lets a potential user to setup a pick and places application with a very small effort, at least from the recognition point of view: no model of the object to pick needs to be defined. The recognition algorithm moves from a parameter-based approach to a data-driven approach, allowing even untrained personnel to provide meaningful information to the application.

Risks and limitations

Wrong object identification: as the localization module is based on a machine-learning model, there are chances that recognition is not correctly performed on the object of interest. Localization accuracy: lights can disturb the depth sensor and cause point cloud to be not dense enough for accurate localization. In this case it is necessary to structure the workcell to reduce the noise source or use different vision systems technologies. Motion planner failure: the motion planner may fail when the objects are placed inside complex containers. Software Malfunction: As the entire system operates by a computer, there are chances that software and connections through devices get malfunctioned. It requires a back-up safety system is running all the time and malfunctioning this system results in protective stop of robot system.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Express couriers: sorting of boxes or parcels. This automatic sorting system allows to reduce the number of sorting errors., Logistics and Intralogistics: automatic handling, palettizing, and depalletizing of boxes.

Potential sectors of application

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The demonstrator uses a machine learning approach that can be generalised localize different objects whose CAD is not available. For this reason, the system is adaptable for sectors like retail, food, manufacturing and others. Food industry: manipulate fresh food, e.g., fruits, vegetables, etc. Such a solution could increase hygiene level. Manufacturing: bin picking application of model-less or deformable objects which shape, or colours are irregular. E-commerce: localize and manipulate heterogeneous type of objects placed in containers or on a conveyor.

Patents / Licenses / Copyrights
Hardware / Software
Hardware:

Collaborative Robot (Universal Robots UR10)

RGB-D Vision System (ENSENSO N35 + IDS RGB camera)

Control PC

Software:

ROS

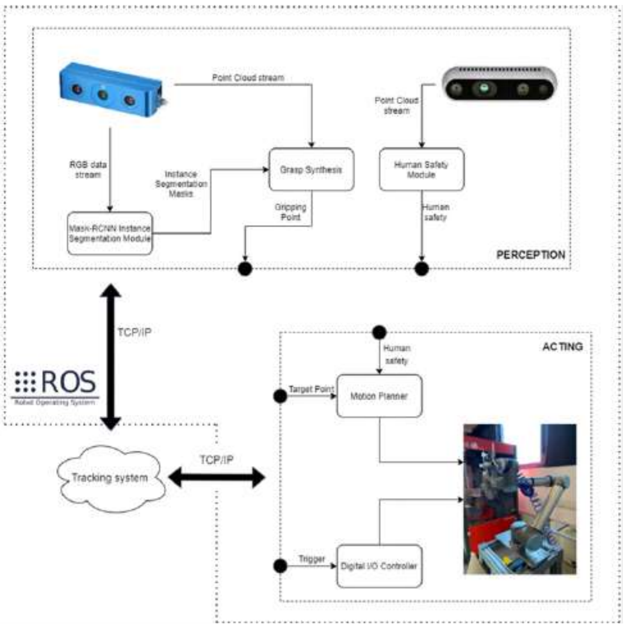
PCL

OpenCV

PyTorch

4. Media

Photos



Video

The EACHPack project provides a complete robotic sorting solution for logistics. The system localizes and picks up both randomly placed and palletized parcels. The parcels are then weighed and sorted into different outbound containers based on their destination. The implemented solution is designed for easy integration into existing production lines.

HTTPS://YOUTU.BE/9F-GKIM1PKO

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 34: SNIPE: Sensor network for intelligent predictive enterprise. Iot / cybersecurity and ai-based demonstrator for predictive maintenance in the foundry industry.

1. Basic information

Name of demonstration

SNIPE: Sensor Network for Intelligent Predictive Enterprise. IoT / Cybersecurity and AI-based demonstrator for predictive maintenance in the foundry industry.

Main objective

The main objective of the demonstrator is to create a Smart Monitoring infrastructure for revamping 4.0 of non-digitalized Foundry process, predicting machine down-time collecting and analysing process data.

Short description

SNIPE project proposes an AI-based, modular decision support system for predictive maintenance and real-time monitoring of operation performance, to improve efficiency in the foundry and casting industry.
SNIPE demonstrator creates an end-to-end solution that goes from a sensor network, through a multi-protocol IoT Gateway, up to a Cloud Dashboard for data storage and analysis, with a dedicated cybersecurity infrastructure.

Owner of the demonstrator

FAE TECHNOLOGY SPA

Responsible person

Manuel Lobati – Innovation Manager.
E-mail: **M.LOBATI@FAE.TECHNOLOGY**

NACE

C26.1.2 - Manufacture of loaded electronic boards

Keywords

IoT - Cybersecurity - Artificial Intelligence - Predictive Maintenance – Revamping.

2. Innovation

Benefits for the users

- Increase of productivity level (OEE performance index) and reduction of process instability that typically brings complex procedures to restore correct working conditions.
- Energy savings, in all conditions where energy consumption cannot be adjusted during process interruption and machine down-time (e.g. melting furnaces).
- Reduction of machine down-time through the application of AI algorithms and predictive maintenance technologies.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- Reduction of Cybercrime and hacking protection when the plant is digitally connected, through the application of best-in-class cybersecurity techniques.
- Easy transfer of information from the Smart Monitoring Cloud platform to the workers, with the use of a wearable device.

Innovation

New and modern 4.0 machines generally have sophisticated and integrated monitoring solutions, so as to prevent failure. However, most of the equipment that is currently in use in the heavy industry is not digital yet, and the business using it usually has to realize the maximum possible value, before replacing it. Consequently, maintenance is an issue, because the cost of machine down-time in heavy industry is high. Over the years, businesses have overhauled maintenance processes to alleviate down-time and improve effectiveness, and the scheduled maintenance has been mostly implemented with pros and cons.
Within this scenario, SNIPE demonstrator proposes the use of prognostic and health management AI algorithms, to control the production process and plan maintenance only when really necessary. Moreover, the introduction of an IoT modular infrastructure – like the one proposed in SNIPE demonstrator – lets companies monitor critical processes with low investment w.r.t. buy new equipment, and open the way to prevent failure through AI based elaboration of data.

Risks and limitations

Technical limitations are mainly related to the implementation of electronic and IOT sensors in the industrial environment: a detailed system architecture planning phase must be considered so to anticipate possible interferences / problems in the wireless data transmission. Risks can emerge when the production plant is web-connected, but the application of Cybersecurity Hardware and Software technologies can protect data and IT infrastructures from possible external attacks and data leaks.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Foundry and casting industry (heavy industry): predicting maintenance and real-time anomaly detection to reduce energy waste and improve efficiency., | Manufacturing companies: revamping production processes with the application of IoT Sensors to collect critical data from the field (e.g. engine vibration, current consumption...)., | Manufacturing companies: machine-human interface through the use of dedicated wearable IoT devices to transfer information on process and cycle performances.

Potential sectors of application

Plastic Moulding companies: smart tracking of production goods along the production process with application of tracking sensors. | Logistic companies: predictive maintenance application on belt conveyor transfer process. | Airport: predictive maintenance of the belt conveyors to transfer baggage in the airport.

Hardware / Software

Hardware:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

IoT sensor node: based on STWIN.BOX device Wireless Industrial Node, collecting data (vibration, temperature, humidity and energy consumption) from belt conveyor engine and transmitting via Wi-Fi to Gateway.

IoT Gateway FAE Technology KITRA GTI, Linux Ubuntu machine with Wi-Fi, 4G LTE / GPS, Ethernet connection based on Samsung CPU (https://fae.technology/en/prodotti/kitra-gti/).

Secure Element for IoT sensor node based on NXP SE050 security crypto component.

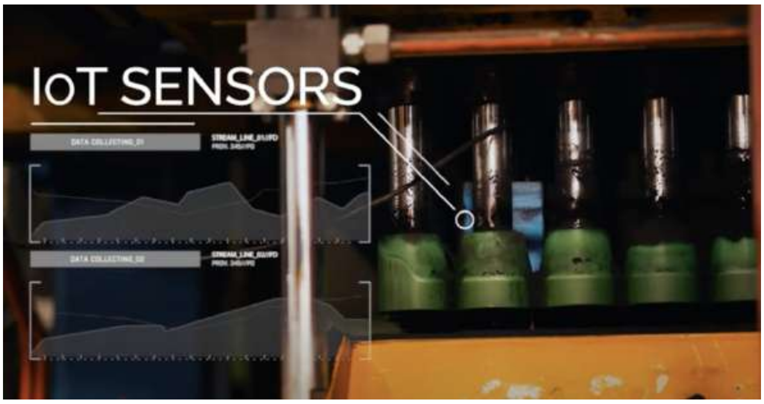
Wearable device based on STM32 MCU, Espressif ESP-WROOM-32 Wi-Fi module, vibromotor and LED

Secure Element USB plug for IoT Gateway based on NXP SE050 security crypto component.

Software:
Cloud Dashboard, data storage and data analytics based on MangroviaIoT platform (https://www.mangroviaiot.com/).

4. Media

Photos



Video

Promotional Video

HTTPS://WWW.YOUTUBE.COM/WATCH?V=NITWWTHUEIY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 35: ICON – agile electric motor manufacturing

1. Basic information

Name of demonstration

ICON - agIle eleCtric mOtor maNufacturing

Main objective

The main objective of the demonstrator is to make the manufacturing process of electric motors more agile, by deploying three TRINITY-originated modules in a production line. This leads to: increased HRC level and productivity in the coils winding step, waste material saving, economic and social benefits.

Short description

This demonstrator introduces three TRINITY-originated modules into an existing robotic cell for coils winding. Thanks to them, the cell is enhanced with new collaborative skills. The “Safe Human Detection in a Collaborative Work Cell” module allows the operator to work safely alongside the robot, creating dynamic and adaptive safety areas. Thanks to the “Projection-based Interaction Interface for HRC” module it is possible to control the robot using an innovative interface projected on the working-table. The “Object Classification” module allows to automatically recognize different stator designs and load the related parameter set to generate the robot trajectory to wind the coils.

Owner of the demonstrator

Stam S.r.l.

Responsible person

STAM Business Area Manager – Robotics and Mechatronics, Stefano Ellero

S.ELLERO@STAMTECH.COM

ICPE Servomotors Department Manager, Paul Minciunescu
PAUL.MINCIUNESCU@ICPE.RO

NACE

Keywords

Robotics, human-robot collaboration, industrial robotics, safety, object classification

2. Innovation

Benefits for the users

Thanks to this demonstrator, the manufacturing process of electric motors is:

– More agile: reduced time for cell reconfiguration.
– More productive: less time wasted in cell reprogramming and task parallelization.
– More automated and with an increased level of HRC.

In particular, it is possible to achieve:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

– Time reduction: for the HRC-based process, which allows the operator performing preparatory and finishing tasks on a stator while the robot is winding another stator.
– Increased operators' satisfaction and trust: following the deployment of HRC tasks.
– Material cost saving: thanks to the HRC-based winding process instead of semi-automatic process.
– CO2 emissions saving: thanks to material saving.

Innovation

The low flexibility of automated winding machines and conventional robotic systems, i.e. the time and costs required to switch from one design to another, coupled to their high cost, force small manufacturers to employ human operators in this task, who are obviously much more flexible, but more expensive (because of labour cost and equipment). Moreover, if the robotic cell responsible for coils winding is not able to guarantee the safety of the operator, no collaboration can be achieved between the human and the robot and therefore, while the robot is active, the operator has to stay behind a safety fence. Thanks to the three TRINITY-originated modules deployed in this use-case demonstrator, the implementation of collaborative tasks is possible, achieving multiple benefits. It is possible for the operator to work safely alongside the robot, significantly reducing idle times and speeding up the process.

Risks and limitations

ROS compatibility: this use-case demonstrator is based on ROS. The system has been tested with ROS supported hardware, such as Intel RealSense and Microsoft Kinect RGB-D cameras, the compatibility with different hardware depends on the ROS driver availability of the intended hardware. Knowledge of ROS: developers need to be familiar with ROS and its communication protocols. Cybersecurity aspects: since for the object classification task a dataset of stator pictures has to be acquired, further consideration on cybersecurity should be done to protect data from intellectual property theft, such as theft of proprietary design or pictures.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Manufacturing.

Potential sectors of application

Manufacturing: various sizes companies dealing with manufacturing systems that aim to increase automation in their processes or companies that already have robotic cells in their production line and want to introduce collaboration between the operator and the robot. Thanks to this technology, companies would be able to improve the safety level of the robotic environment and make the robot perform the most repetitive and heavy tasks.

Patents / Licenses / Copyrights

Hardware / Software

Hardware:

KUKA KR6 sixx collaborative robotic arm.

KRC4 compact robot controller.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Rotary table combined with a self-centering chuck.

Industrial PLC: for handling the communication between the various components.

Control panel: to manage the basic signals for activation, start-up and emergency stop of the robotic cell.

End-effector: for winding the wire.

Linux industrial PC running ROS: for the software computations.

Lidar sensor: for detecting the proximity of the operator to the robot (such as KEYENCE SZ-01S).

Projector: for projecting the user interface components and the safety contour on the workspace (such as SHARP XR-32s).

RGB-D camera: for monitoring the depth values of the workspace and thus detecting the interaction of the operator with the interface (such as Microsoft Kinect v2).

RGB-D camera: for stator classification (such as INTEL RealSense D415).

Software:

TRINITY module: Safe Human Detection in a Collaborative Work Cell

TRINITY module: Projection-based Interaction Interface for HRC

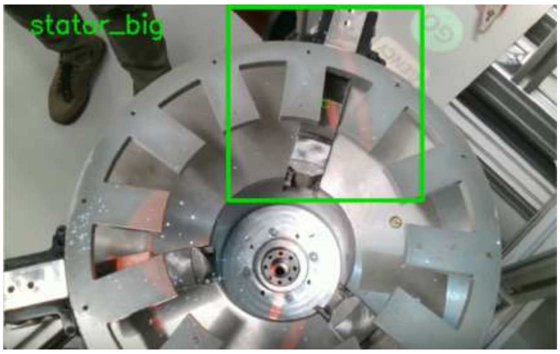
TRINITY module: Object Classification

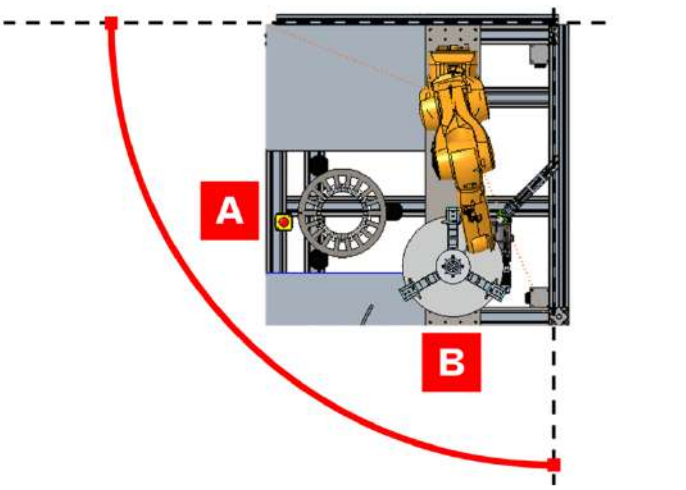
ROS

OpenCV

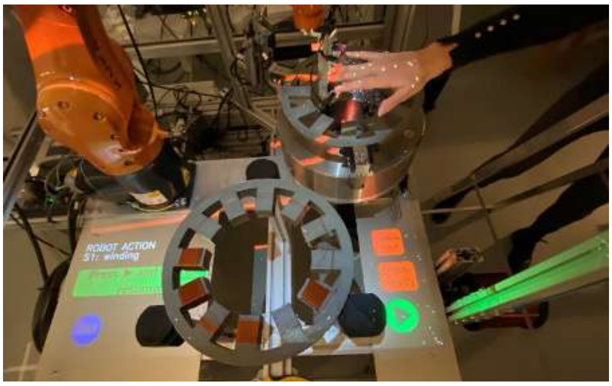
4. Media

Photos





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video
Promotional video of the ICON project
HTTPS://WWW.YOUTUBE.COM/WATCH?V=D1UOB6EVGKS

5. Modules

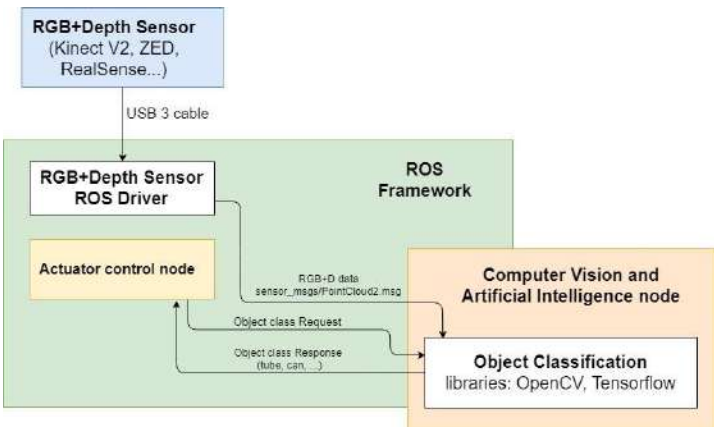
Object classification

Main functionalities

A deep convolutional neural network (CNN) is used to classify and sort objects. This is a robust and fast implementation of 112×112 image classification software for several classes based on specially optimized deep neural network architecture. When industrial robot picks the object, it is then classified using a convolutional neural network. In order to train the classifier to recognize new classes of objects, new training datasets must be provided.

Technical specifications

Training can be done on standard desktop PC, to ensure precision up to 99% training model requires at least 1000 images of the object. The maximum amount of the different object classes is not specified, the system has been tested with 7 different types of classes.
The depth sensor is connected to PC that runs the ROS Melodic on Ubuntu 18.04. Currently, Intel RealSense d415, d435, Kinect v2 and Zivid depth cameras are supported, but any camera with ROS driver can be used, if the data can be published as PointCloud2. All the software for this module is implemented using Python 2.7 programming language.



Inputs and outputs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

All the data is transferred via a standard ROS transport system with publish/subscribe and request/response semantics. This module subscribes to RGB+Depth sensor data and produces requested object class.

Formats and standards

ROS service communication to request object class.
The sensor data is received from the sensor driver in sensor_msgs.PointCloud2.msg format.
ROS, OpenCV, Tensorflow, PCL, Python standard libraries.

Owner (organization)

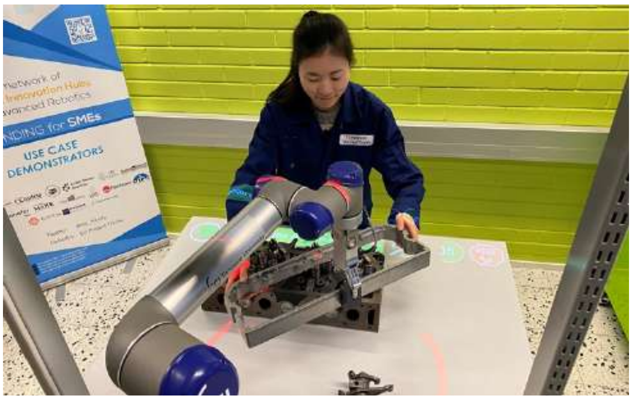
Institute of Electronics and Computer Science (EDI)

Trainings

Under development

Projection-based interaction interface for hrc

Main functionalities



Interface Generation: The module projects interface that the user can interact with by placing a hand over it. The interface includes GO and STOP buttons to control the robot, CONFIRM button and CONFIRM OBJECT button to update workspace model manually. To prevent accidental start of the robot, the START button should be pressed simultaneously with the CONFIRM button.

Technical specifications

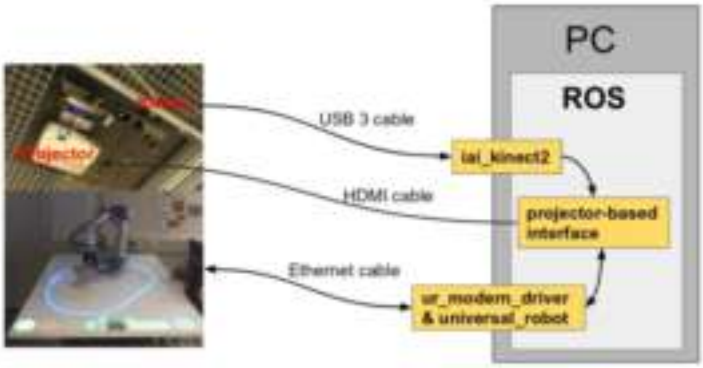
The system consists of:

- standard FullHD 3LCD projector.
- Microsoft Kinect v2
- Universal Robot UR5
- Workstation with Ubuntu operating system

The workspace is monitored by the Kinect v2 sensor which can be installed at the ceiling overseeing the whole working area. The frame rate of the sensor is 30 Hz. A standard 3LCD projector is used to project the safety hull and the user interface components on the workspace. The projector outputs a 1920×1080 color projection image with 50 Hz frame rate. Due to the short distance from the ceiling to the workspace the physical projection size can be increased by installing a mirror in 45˚ angle to re-project the image to the workspace. The robot is UR5 from the Universal Robot family.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

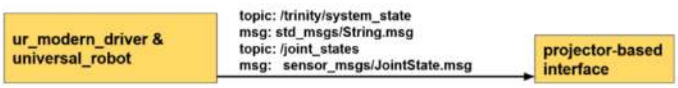
A modified version of ur_modern_driver and univeral_robot ROS packages are used to establish a communication channel between the robot low-level controller and the projector node. Iai-kinect2 ROS package is used to receive data from the Kinect-2 sensor and further transmit it to the projector node. The sensor monitors the usage of the interface components. The projector node is responsible for creating RGB images of the current status of the workspace for the projector and sending start and stop commands for the robot controller.
Projector, robot and depth sensor are all connected to a single laptop computer that runs the ROS Melodic distribution on Ubuntu 18.04 and performs all computing. Right now, only Kinect v2 and Universal Robot 5 are supported.



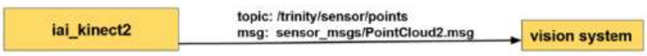
Module software nodes and the hardware components
Before the module can be used,
1) projector, robot and sensor must be extrinsically calibrated,
2) placement of the user interface components and size of the virtual safety hull has to be defined,
3) the locations of the interface buttons on the workspace must be defined and
4) wired communication link between PC and robot must be established.

Inputs and outputs

All the data is transferred via a standard ROS transport system with publish-subscribe semantics.The projector node subscribes to topics /joint_states and /trinity/system_data where the robot joint values and the task related data are published respectively. The joint values are used to calculate the shape and position of the safety hull. The text in the information bars and the appearance of other interface components are based on the system data.

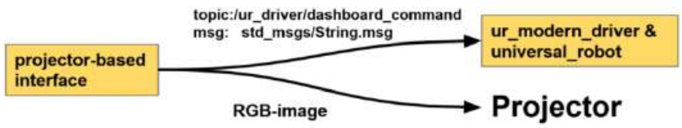


In addition, the projector node subscribes to /trinity/sensor/points topic where the depth measurements from the sensor are published. The measurements are used to calculate the usage of the interface components (e.g. is a human hand on the stop button)



Data transport layer
An 1920×1080 RBG image is sent to the project and start/stop command can be published to the robot controller over /ur_driver/dashbord_command topic.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Data transport layer

Formats and standards

ROS communication layer, ROS-industrial, OpenCV, PCL and C++ and Python standard libraries.
– Availability: Module library **HTTPS://GITHUB.COM/HERRANDY/HRC-TUNI.GIT**
– Application scenarios: Industrial assembly.
– Available for internal/external use.

Owner (organization)

Tampere University, Finland

HTTPS://RESEARCH.TUNI.FI/PRODUCTIONSYSTEMS/

Safe human detection in a collaborative work cell

Main functionalities

Creating safety areas: flexible and adaptive creation of dynamic safety areas is based on information from safety approved safety equipment such as laser scanners, microwave radars, and additional safety equipment such as RF indoor positioning and 360 cameras. The aim is to create a safe collaborative working cell for robots and employees performing tasks such as collaborative assembly. The hardware of the solution is based on off-the-shelf commercial components.

Technical specifications

The system consists of safety-approved systems and additional systems for increased safety. Any suitable combination for the application can be used. The system is able to observe/detect people around the robot cell and the robot can be controlled correspondingly. The robot can be slowed down or stopped depending of the distance from a human to the robot. The dynamic safety system can use laser scanners, light curtains, microwave radars, indoor positioning, and 360 cameras.

Inputs and outputs

Data from each sensor is transferred to the robot controller as a digital signal, which in configuration with the inputs on the industrial robot may be used to slow or stop the robot's motion, depending on the type of safety zone violation. The safety zones may be reconfigured as preset settings, which makes it possible to dynamically reconfigure safety solution combinations for different scenarios. The sensors also feature configurable inputs and outputs for basic functionality and interoperability. SICK S300 Standard Series safety scanner, Pilz PSENscan, and SICK saferRS connect straight to appropriate inputs on robot controller or to a separate PLC. Safety scanners use different outputs for different signalling purposes, such as warning zone violations or lens contamination. These signals can be used in great variety, depending on the production cell's requirements. SICK saferRS safety radar sensors operate on two states: motion detected or motion not detected where the state information is transmitted

Formats and standards

ISO 10218-1:2011, Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
ISO 10218-2:2011, Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Owner (organization)
Centria University of Applied Sciences

Trainings
Online training material is available through the TRINITY training platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 36: Collaborative (dis)assembly with augmented reality interaction

1. Basic information

Name of demonstration

Collaborative (dis)assembly with augmented reality interaction

Main objective

The main goal is to provide a safe and intuitive robotic interface for multimachine work environments, where the human worker operates together with traditional industrial robots (payload up to 50kg) and mobile robots. The safety is realized using an external vision system and AR-based technology.

Short description

We introduce a robotic application consisting of multiple robot agents that share a common task with a human co-worker. The introduced system has an external vision system that can scan products and recognize their type and pose (position and orientation) in the shared workspace. The cell control system will make task allocation between robots and the operator. The operator can see the instructions regarding the disassembly and safety-related information using a wearable AR (Microsoft HoloLens). He/she communicates with the system using hand gestures and speech. Multi-camera/RGBD system monitors the workspace for safety violations and halts the robot or reduces its speed. The system is demonstrated in the disassembly of an industrial product.

The presented use case has been demonstrated on technology readiness level TRL 6. The concept has been proven functional. However as the technology was build based on commercial hardware no longer supported, the further development of this use case has been suspended. Related technology modules and technical solutions can be found as technical modules in use case "Collaborative Assembly with Vision-Based Safety System" (Please link demonstration name to **HTTPS://TRINITYROBOTICS.EU/USE-CASES/COLLABORATIVE-ASSEMBLY-WITH-VISION-BASED-SAFETY-SYSTEM/)**

Owner of the demonstrator

Tampere University

Responsible person

Morteza Dianatfar **MORTEZA.DIANATFAR@TUNI.FI**

NACE

C26 - Manufacture of computer, electronic and optical products

Keywords

Robotics, Human-Robot Collaboration, Safety, Augmented Reality, Manufacturing.

2. Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Potential users

SME's: The technology can be adopted for improving safety during manufacturing processes, as well as making safety zones more distinguishable to the workers Research Institute and Academy: the system can be used as a framework for teaching the safety regulations in human-robot collaboration. It can be also used for creating interactive practical exercises by using AR to create instructions for each task, as well as keeping safety regulations in check.

Benefits for the users

Increasing safety awareness: Using vision-based safety system can decrease violation of safety which is related to decreasing the human error. As a result, this can lead to reducing production cycle time where a human doesn't stop the production line by these mistakes. Here, proper GUI notifies human with violating robot working zone and assist human to avoid this error. UI consists of instruction of assembly in front of the operator which will assist the operator to focus on the task replace of getting distracted to read manual in the traditional method. This type of interaction helps the operator to perceive the task sequence faster and avoid mistakes in the assembly of components. Based on user test and survey, the application of this use case compared to the baseline where the robot was not moving in the same workspace with an operator. The result of this experience can be explained by measuring robot idle time and total execution time.

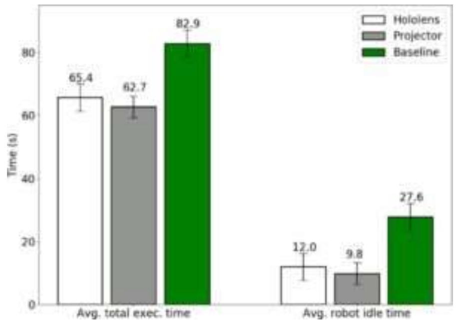


Figure 1 AR-based interaction for human-robot collaborative manufacturing (Antti Hietanen, Roel Pieters, Minna Lanz, Jyrki Latokartano, Joni-Kristian Kämäräinen)

Improving user experience: the AR interface can be used to provide instructions on how to execute the current task. Research have shown that tasks performed with the help of the safety system can be completed 21-24% faster. Robot idle time is reduced by 57-64%.

Innovation

This use-case utilizes augmented reality head-mounted display technologies to overcome human error in the assembly sequence. It's worth to mention, depth sensors such as Kinect track human body part whenever violation could happen. This is a new approach for collaborative work cell and provides a concept of safety vision-based for the operator. This approach studied in the academy research laboratory and 20 participants have participated in the survey, where questionary contains 6 categories as following: Safety, Information Processing, Ergonomics, Autonomy, Competence, and Relatedness.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

		HoloLens	Baseline
Safety	Q1	3.7	**4.6**
	Q2	3.9	3.6
Information Processing	Q3¬	2.6	**1.3**
	Q4¬	2.3	**1.4**
	Q5	3.2	2.9
Ergonomics	Q6¬	**1.7**	2.5
	Q7¬	1.7	2.4
Autonomy	Q8	3.5	3.3
	Q9	3.1	2.7
Competence	Q10¬	1.8	1.9
	Q11	3.4	3.4
	Q12	**3.6**	**3.5**
Relatedness			
	Q13	**4.0**	3.4

Table 1. Average scores for the question (Q1-Q13). Higher is better except for those marked with "¬". The best result emphasized (multiple if no statistical significance).

Risks and limitations

Battery Shortage: As the whole application runs on HMD, it needs to consider that this technology has limited battery capacity. Therefore, it requires recharge the headset during working shift, which it can increase idle time of production line.

Software Malfunction: As the monitoring of system operates by a computer, there are chances that software and connections through devices get malfunctioned. These can endanger the operator's safety while the system stopped. As a result, it requires a back-up safety system is running all the time and malfunctioning this system results in protective stop of robot system.

Field of View: Field of View and monitoring the working area depends on the specification of HMD. Based on these limitations, it can distract the operator to access the UI of working space and lose focus on the task itself. In this case, Microsoft Hololens v1 has limited FOV and operator require to turn around his/her head to observe the GUI.

Limitations of depth sensor: Scaling system to bigger environments with one depth sensor can cause point cloud to be not dense enough for accurate estimation. Synchronization between multiple depth sensors is needed.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Collaborative manufacturing. This technology improves the safety of robot cell environment and provides tools for setting UI and instructions for the manufacturing task. , Manufacturing assembly on mid-heavy components. User can benefit by collaborating with robot where robot picks heavier components. Human intelligence is utilized in complex part. The system will be safe where robot is inherently safe designed and vision-based safety system assists human to avoid error and possible injuries. , Quality Assurance of assembled components, Robot system can detect and sort obvious, easier defects, while human inspects less certain cases. The vision-based safety system assists human in their task and allows smooth cooperation between human and robot.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Patents / Licenses / Copyrights

The module will be licensed under BSD-3-Clause licence.

Hardware / Software

Hardware:

UR5 from Universal Robot family (tested on CB3 and UR software 3.5.4)

Microsoft Hololens v1

Laptop/workstation

Software:

ROS Melodic

OpenCV (2.4.x, using the one from the official Ubuntu repositories is recommended)

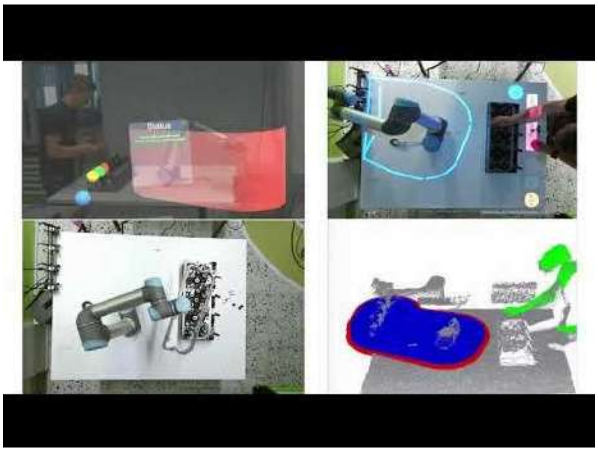
PCL (1.8.x, using the one from the official Ubuntu repositories is recommended)

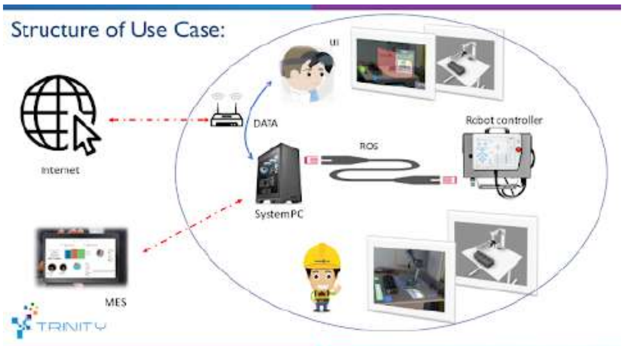
ROS Interface to the Kinect One (Kinect v2)

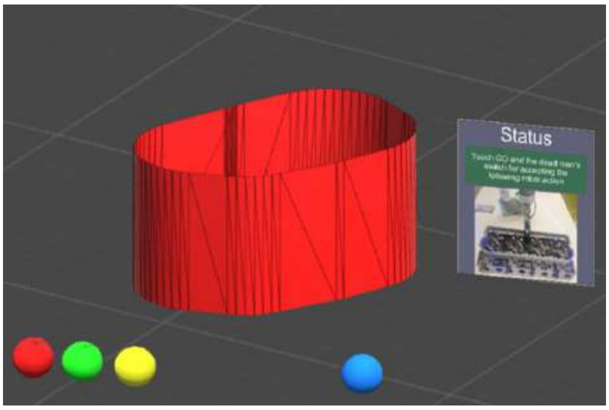
4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196







Video

Demonstration

HTTPS://WWW.YOUTUBE.COM/WATCH?V=-WW0A-LEGLM&FEATURE=YOUTU.BE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 37: Virtualization of a robot cell with a real controller

1. Basic information

Name of demonstration

Virtualization of a Robot Cell with a Real Controller

Main objective

The main objective for the demonstrator is that a virtual model can substitute physical hardware in the context of training, testing and simulating the various functions of a flexible robotic cell.

Short description

This module enables the control of simulated manufacturing hardware using a real controller. The simulated hardware is represented in a real-time 3D-environment which can be used for demonstrating actual system functionality, training employees, virtual commissioning and testing production operations for new parts. These activities can be done before the system even exists or after commissioning when they can be done without disturbing the ongoing production. This way changes can be made and tested without losing valuable production time. It also means that the layout design can be iterated multiple times before committing to the final one.

Owner of the demonstrator

Fastems Oy Ab

Responsible person

Teemu-Pekka Ahonen, Product Manager, Fastems Oy Ab

NACE

M71.1.2 - Engineering activities and related technical consultancy

Keywords

Manufacturing, Simulation, Training, Virtual commissioning, Robotics.

2. Innovation

Potential users

SMEs in the metal cutting industry, Educational establishments wanting to teach about agile manufacturing in metal cutting industry

Benefits for the users

For SMEs: faster and safer ramp-up, reduced risk when making changes to production, safer and more efficient training for employees, reduced uncertainty when planning for the future

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

For education: cheap, compact and safe alternative to a physical robot cell, allows teachers to create interactive learning exercises to teach the fundamental concepts of agile manufacturing and robotics.

Innovation

The innovation in this module comes from the interface and communication method between the virtual model and the production control software. Previously this type of communication between the Fastems MMS and Visual Components was not possible.

Risks and limitations

This use case requires Windows 10, Visual Components 4.2 and Fastems specific hardware and software. Without these, the use of the described use case is not possible.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Manufacturing sector: training and simulating the production off-line, Educational sector: teaching agile manufacturing without real robot system hardware.

Hardware / Software

Hardware:

Fastems cell controller

Workstation PC

Software:

Fastems MMS

Visual Components

Windows 10

4. Media

Photos

Video

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

[HTTPS://WWW.YOUTUBE.COM/WATCH?V=DTJNKYHQUXK](https://www.youtube.com/watch?v=DTJNKYHQUXK)

5. Modules

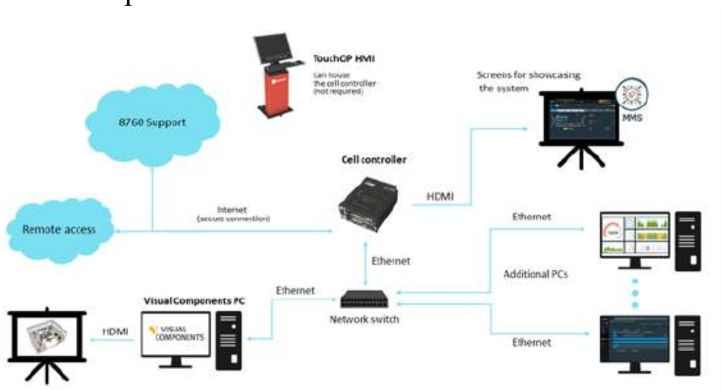
VIRTUALIZATION OF A ROBOT CELL WITH A REAL CONTROLLER

Main functionalities

Enables the control of simulated manufacturing hardware using a real controller. The simulated hardware is represented in a real-time 3D-environment which can be used for demonstrating actual system functionality, training employees, virtual commissioning and testing production operations for new parts. These activities can be done before the system even exists or after commissioning when they can be done without disturbing the ongoing production. Since the control software used is identical to the real-world control software all master data created with the virtual system can be transferred to the real one.

Technical specifications

The main hardware consists of two PCs that are connected with an Ethernet-cable and communicate with each other through the WebSocket-protocol.



Hardware:

The Fastems cell controller is an industrial PC that is used to host the MMS (Manufacturing Management Software). It is identical to the one used to control real manufacturing hardware. The cell controller can also be housed inside a TouchOP -device which provides the user with a screen, keyboard and mouse that can be used to interact with the MMS user interface. Otherwise, a separate set of these peripherals is required. The cell controller includes a Fastems specific connectivity solution which allows the Fastems 8760 Support and user to connect to the system remotely.

The sole purpose of the Visual Components PC is to run the virtual model and after the model is configured and running it doesn't require any additional user inputs. Therefore, only a screen is required for this PC. A virtual reality headset can be attached to allow the user to walk around the virtual system . There are no specific system requirements for the PC, but it must meet the minimum requirements for running Visual Components 4.2.

Additionally, multiple PCs and screens can be connected to the system to view and interact with the MMS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

user interface. These PCs can be used to add and edit master data, view and create production orders, import NC-programs, view the key performance indicators (KPIs) etc. locally or remotely. The screens allow the user to display the virtual model or e.g. system KPIs to a larger audience.

Software:
Both PCs are run on the Windows 10 operating system. The version of the control software is MMS 7.2 and the Visual Components version is 4.2.

Inputs and outputs

All data between the control software and the virtual cell is transferred using the WebSocket-protocol. The data consist of six different types of messages which are sent in the JSON format. Five of these messages are sent from the MMS to the model and one is sent from the model to the MMS. These messages contain the necessary information (coordinates, IDs, grippers etc.) to fulfill the requested task. The model will listen for incoming messages until it is stopped or paused.

Formats and standards

WebSocket, JSON, Python 2.7

Owner (organization)

Fastems Oy Ab, www.fastems.com

Trainings

Available later from TRINITY DAP

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 38: Efficient programming of robot tasks by human demonstration

1. Basic information

Name of demonstration

Efficient Programming of Robot Tasks by Human Demonstration

Main objective

Traditional systems for robot programming are rather complex and rely on user knowledge about robotics. In this demonstrator, we address challenges of robot programming by providing software and hardware frameworks to integrate programming by demonstration paradigm into an effective system for programming of industrial production tasks, e.g. automated robot assembly, finishing operations, bimanual tasks, robot motion for visual quality control, etc.

Short description

Robot programming by demonstration (RPD) paradigm offers a much more intuitive approach to specify robot tasks than traditional robot programming systems, including simulation-based systems. It allows the user to show the desired operations using his own physical skills and does not require any expert knowledge about robotics. Our laboratory demonstrator comprises various approaches to robot programming by demonstration and their possible industrial applications: manual (kinesthetic) guidance to record robot motion and the arising forces and torques, manual guidance to specify bimanual assembly tasks, optical marker-based system to record human motion, sensorized tools equipped with markers and 6-D force-torque sensor to record tool motion, and mechanical digitizers. Software to convert the recorded data into executable robot motion is provided.

Owner of the demonstrator

Jožef Stefan Institute

Responsible person

Prof. Dr. Aleš Ude ALES.UDE@IJS.SI

NACE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

C – Manufacturing

Keywords
Robot programming by demonstration, Human-robot cooperation, Human motion capture, Kinesthetic guidance, Bimanual systems.

2. Innovation

Potential users

Manufacturing companies, **System integrators**

Benefits for the users

Ease of robot programming: With robot programming by demonstration, the programming of new robot operations becomes easier, more intuitive, and also much faster. In this demonstrator we provide both hardware and software interfaces for a variety of programming by demonstration approaches. By robot programming by demonstration, the user can program new robot operations or adapt the existing with ease. The developed Graphical User Interfaces further ease the programming process.
Quick adaptation to product variations: If a new variation of the product is introduced, an existing robot operation can be quickly adapted based on the provided technologies.
Automation of force-based operations: Robot operations that require force control are rarely used in industrial production. With the technologies included in this demonstrator, complex finishing operations (polishing, brushing, grinding) can be programmed quickly and efficiently.

Innovation

Robot programming by demonstration (RPD) has shown great promise in many research projects but its utilization by industrial users is still limited. This is mainly due to the lack of effective user interfaces for programming by demonstration in industrial environments. In this demonstrator, we provide such interfaces for a variety of RPD systems that can be used for the specification of robot operations in industrial production tasks. The demonstrator shows that RPD is a viable paradigm to improve the programming of classic industrial production tasks such as autonomous robot assembly, as well as tasks that are rarely automated in industrial production, e.g. finishing operations and bimanual tasks that include force control. By making use of RPD, end-users can reduce their reliance on system integrators as it becomes possible to program many complex tasks without expert knowledge. On the other hand, system integrators can reduce the cost of their products by employing RPD.

Risks and limitations

Programming by human demonstrations is only possible if suitable robots and sensors are available. Sensorized tools require additional sensors that increase the price the robot programming. In order to manually guide a robot arm, it needs to support gravity compensation mode, where the weight of the robot is compensated by its motors and the robot arm can be guided with a minimal effort so that a user can focus on the demonstration. Gravity compensation requires the availability of torque values at each joint, which is best measured with torque sensors in each joint. This can significantly increase the price of the robot. Nevertheless. the recently introduced Framka Emika PANDA robot shows that low-cost robots with torque sensors in all jopints are possible.

As the user is demonstrating the skill as he sees fit, the quality of the recorded data and consequently the quality of robot programs rely on the quality of the performed demonstrations. Although programming by

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

demonstration reduces the need for in-depth knowledge in robotics, know-how about the actual production process is still necessary.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Manufacture of furniture, Treatment and coating of metals; machining,

.

Potential sectors of application

Automotive industry, White goods industry, Aviation industry, Electronics industry, Shoe industry, Manufacturing of machinery

Patents / Licenses / Copyrights

The software package for programming by manual guidance including the GUI is freely accessible under a three-clause BSD license. It is available as one our modules and JSI can provide support. HTTPS://GITHUB.COM/TGASPAR/HELPING_HAND/ Our programming by demonstration system is integrated into ROSto accelerate the deployment of the programmed operations.HTTPS://WWW.ROS.ORG

Hardware / Software

Hardware:

Robots with gravity compensation (Universal robot UR-10, Franka Emika Panda, and Kuka LWR-4 are available at JSI)

6-D force-torque sensors (JRC, ATI)

MicroScribe 3D digitizer

OptiTrack V120

CyberGlove with Polhemus electromagnetic tracker

Software:

HelpingHand

Matlab

Python

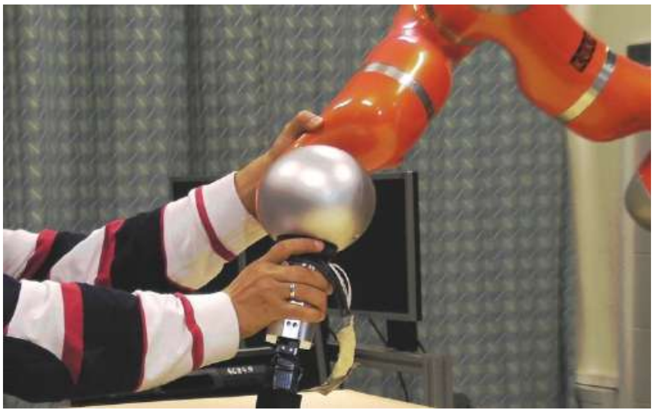
Trainings

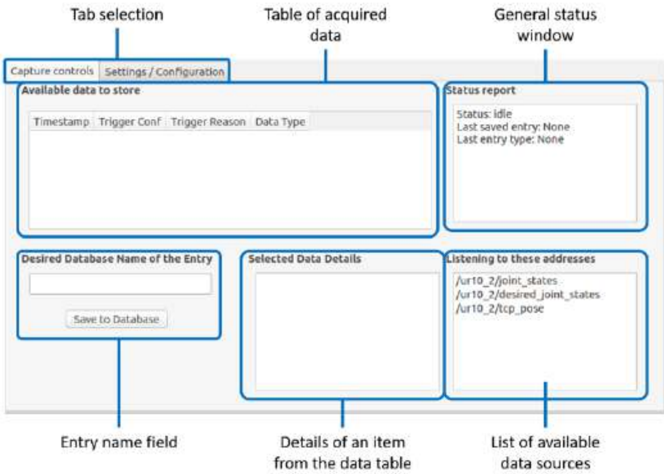
The training material currently being prepared and will be announced when it is ready.

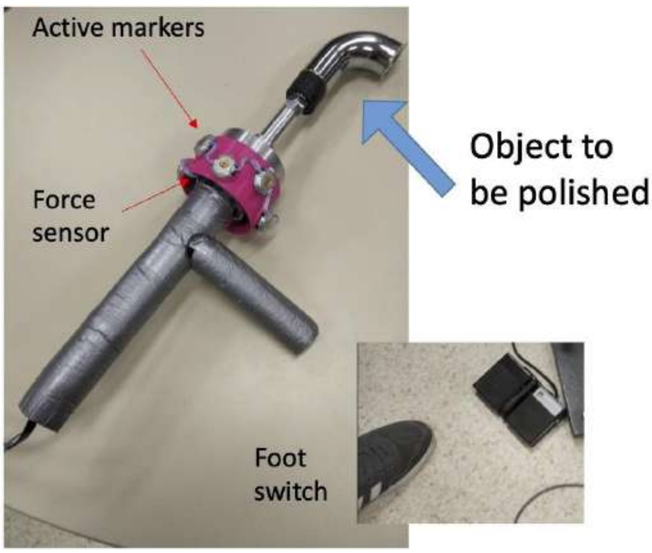
4. Media

Photos

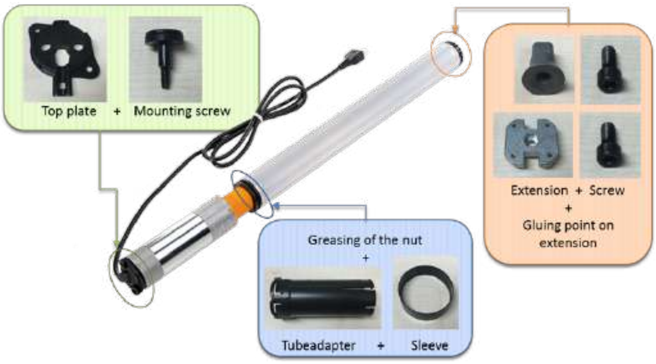
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

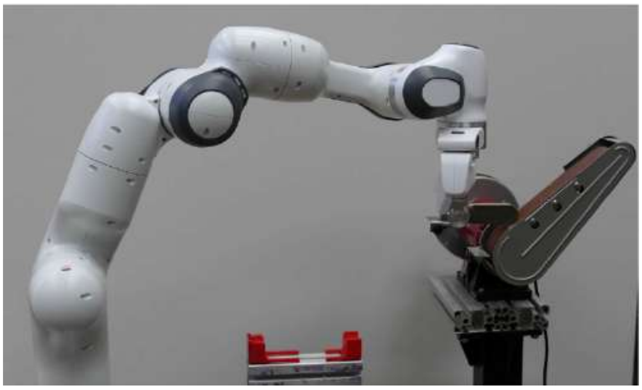






This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196





Video

Manual guidance for the specification of key configurations in robotic assembly.
HTTPS://IJS.SI/USR/AUDE/TRINITY/GUIDANCE_POINT_TEACHING.WEBM

Specification of a complex trajectory by manual guidance
HTTPS://IJS.SI/USR/AUDE/TRINITY/GUIDANCE_PARALLEL.WEBM

Programming by demonstration of a polishing operation
HTTPS://IJS.SI/USR/AUDE/TRINITY/CAPTURE_POLISHING.WEBM

Programming by manual guidance of a polishing operation
HTTPS://IJS.SI/USR/AUDE/TRINITY/GUIDANCE_POLISHING.WEBM

Performance of the programmed polishing operation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

HTTPS://IJS.SI/USR/AUDE/TRINITY/POLISHING.WEBM

5. Modules

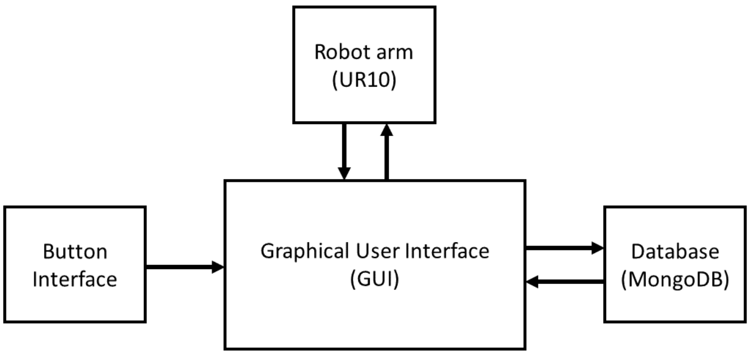
Hardware & software interface for robot programming by manual guidance

Main functionalities

The module for robot programming by manual guidance enables fast and intuitive programming of new robot motions without using traditional programming tools such as teach pendants. Programming with teach pendants is namely slow and cumbersome. Our module enables the operator to simply grab the robot arm with her/his own hands and guide it through the desired task. This way both single robot postures and complex robot movements (free-form trajectories) can be programmed easily. To enable programming by manual guidance (also called kinesthetic teaching), the robot must provide the gravity compensation mode. Robots with gravity compensation mode include Kuka LBR iiwa, Universal robots UR series, and Franka Emika Panda. This module provides a button interface and a GUI to support easy programming and storing of the acquired information.

Technical specifications

The module is implemented in ROS (Robot Operating System, HTTPS://WWW.ROS.ORG) Kinetic environment and provides a Graphical User Interface (GUI) that facilitates robot motion acquisition by manual guidance. The newly programmed motions can be saved in the MongoDB database provided by ROS. Point to point movements and free-form trajectories represented by dynamic movement primitives (DMPs) are supported.



The GUI, called The Helping Hand, is at the front-end of the module. It has two tabs: the main tab called Capture controls and the secondary one called Settings/Configuration. The database component is at the back-end of the module. The mongodb_store ROS package is used to provide the database, as it allows all ROS nodes on the network to access the database. A physical button interface must be mounted on the robot arm. It eases the acquisition of data as it lowers the effort and shortens the time needed for teaching. The GUI communicates with the robot and ROS through the buttons. We developed hardware buttons for Universal UR-10 and Franka Emika Panda robots. These robots are also supported by The Helping Hand software.

While the GUI software is free of charge and available for download, suitable hardware buttons and a robot with gravity compensation must be purchased by a user. JSI offers support for software installation as well as button construction free of charge in TRINITY open calls and on contract basis

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Inputs and outputs

All the data is transferred via the ROS backbone of the system.
Inputs:
The desired commands are specified by pressing the buttons on the button interface. The communication occurs via ROS standard bool message type std_msgs/Bool.

The button presses specify 1. the beginning and the end of manual guidance, 2. control the (de)activation of the gravity compensation mode (the robot can be guided only in gravity compensation mode), and 3. determine the type of motion information to be stored.

The following outputs are possible once the motion has been demonstrated by manual guidance:
sensor_msgs/JointState; this message type is used to store joint angles
geometry_msgs/Pose; this message type is used to store Cartesian space poses
robot_module_msgs/JointSpaceDMP; this message type is used to store a trajectory encoded with joint space DMPs
robot_module_msgs/CartesianSpaceDMP; this message type is used to store a trajectory encoded with Cartesian space DMPs

In the above list, DMP stands for dynamic movement primitives, which are used to encode complex trajectories in a compact way. Same message types are used to communicate with the robot driver to execute the programmed trajectories.

Formats and standards

The software module is open source and released under a three-clause BSD license HTTPS://OPENSOURCE.ORG/LICENSES/BSD-3-CLAUSE
Standards:
ROS Kinetic is used as the backbone of the module.
Safety standard for human-robot collaboration must be considered.

Owner (organization)

Jožef Stefan Institute, Department of Automatics, Biocybernetics and Robotics

Documents

A more detailed description of this module
RPD.PDF
https://github.com/tgaspar/helping_hand

Trainings

A training manual describing the module, installation procedure, and how to use the module can be found at HTTPS://WWW.IJS.SI/USR/AUDE/TRINITY/RPD_MANUAL.PDF

ROS PERIPHERAL INTERFACE

Main functionalities

The ROS periphery interface provided in this module is implemented on a micro-computer, e.g. Raspberry Pi. It provides a bridge between hardware that is not ROS-compliant and the ROS backbone of the system, e.g. robot workcell. It acts as a proxy between the ROS-based system and exchangeable elements of the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

cell without ROS capabilities. It allows users to quickly integrate existing hardware into the ROS-based software system. It can be customized to meet the needs of different peripheral equipment in terms of shape, size and connectivity. The included software initializes all interfaces at boot time and thus provides plug-and-produce connectivity to the newly integrated hardware element.

Peripheral elements without ROS interface might include active components that need to be controlled, e.g. actuators, breaks, sensors, etc. It is beneficial if they are controlled using the same software infrastructure as the rest of the ROS-based system. In addition, sometimes it is necessary that peripheral elements provide or store data. Stored data can include coordinates of points of interest, maintenance data, information about products, etc. With all this in mind, the ROS periphery interface has been designed as a self-contained unit.

Technical specifications

At the core of the ROS periphery interface is a micro-computer that runs ROS. It implements ROS-compliant interfaces for the GPIOs (general purpose inputs-outputs), which are used to communicate with the new peripheral element to be integrated into the ROS system. A 3rd generation Raspberry Pi micro-computer can be used for this purpose, with version B+ recommended. It is usually encased for protection. The power comes through Power-over-Ethernet with an additional PoE HAT board. The real-world integration of the module depends on the shape and possibly other characteristics of the new hardware element.

To make the micro-computer ROS-compatible, a Pi image with Raspbian OS and pre-installation of ROS is mounted. As the peripheral elements should enable swapping, the ROS instance on the micro-computer runs automatically when the periphery interface receives power. Standard ROS communication protocols are used to send and receive commands to the micro-computer. The commands are then further relayed to the non-compliant peripheral.

Inputs and outputs

Power and Ethernet are mandatory, though power can also be provided via the Power over Ethernet (PoE) standard. Ethernet is used to communicate with the rest of the ROS-based system. GPIOs (general purpose inputs-outputs) to communicate with the newly integrated hardware element. Both communication channels are bidirectional.

Formats and standards

Licenses:
The software to be installed on the micro-computer is released under 3-clause BSD license (https://opensource.org/licenses/BSD-3-Clause).
Support for software installation and the development of hardware interface is available free of charge within TRINITY open calls and on contract basis otherwise.
Standards:
ROS Kinetic is currently supported. It can run either directly under Raspbian OS or inside a Docker container.

Owner (organization)

Jožef Stefan Institute, Department of Automatics, Biocybernetics and Robotics
ABR conducts basic and applied research in the area of robotics (including intelligent control, robot learning, exoskeletons, humanoid robotics, and industrial robotics), factories of the future, industrial automation, and environmental physiology. The aim of the group is to create robots that are capable of acquiring new knowledge through learning and can collaborate with people, which is essential for bringing robots to new application domains. Besides research projects, ABR researchers also provide support for transferring robotics technologies to practical applications.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Web address: http://abr.ijs.si
Contact for this module: Rok Pahič, e-mail: rok.pahic@ijs.si

Trainings

Manual for the implementation of ROS periphery interface is available at https://www.ijs.si/usr/aude/trinity/ros_periphery_interface.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

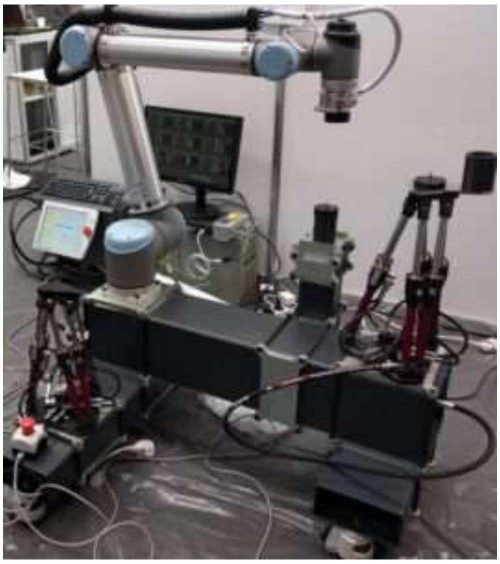
Annex 39: Robot workcell reconfiguration

1. Basic information

Name of demonstration

Robot Workcell Reconfiguration

Main objective



Robot workcell reconfiguration

The ability to reconfigure production cells is crucial for agile production processes where production frequently changes from one product to another. In this demonstrator, we developed a robotic workcell that includes hardware components with passive degrees of freedom to enable quick robot-supported reconfiguration from one product to another without any manual intervention.

Short description

The developed robot workcell is a reconfigurable manufacturing system suitable not only for large production lines but also for low-volume high-diversity production. The workcell consists of the following crucial components to achieve this goal:

– Modular and largely passive hardware components aimed towards cost-effective, autonomous workcell reconfiguration.

– New hardware design methods based on 3-D printing.

– A software backbone based on ROS, which provides modularity of all software components.

– Fast programming of production tasks through kinesthetic guidance and script-based state machine description methods.

– Support for quick workcell reconfiguration by manipulating and exchanging the available hardware components, facilitated by a digital twin.

Owner of the demonstrator

Jožef Stefan Institute

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Responsible person

Dr. Igor Kovač IGOR.KOVAC@IJS.SI

NACE

C - Manufacturing

C26.1 - Manufacture of electronic components and boards

C29.3 - Manufacture of parts and accessories for motor vehicles

C28.2 - Manufacture of other general-purpose machinery

C28.1.5 - Manufacture of bearings, gears, gearing and driving elements

Keywords

Reconfigurable robot systems, Fixtures with passive degrees of freedom, ROS-based workcell control, 3-D printing, Plug and produce.

2. Innovation

Potential users

Manufacturing companies with low-volume, high-diversity production

Benefits for the users

The main benefits of the reconfigurable robot workcell for the user include quicker setup times for new production tasks and automated or partly automated reconfiguration from one production task to another. New production tasks can typically be set up in 2-4 days if no new hardware is required or 2-4 weeks if hardware development is necessary. On the other hand, many reconfiguration processes can be performed fully automatically in matters of minutes. If reconfiguration requires manual intervention to, for example, exchange hardware elements, the reconfiguration can be usually accomplished in tens of minutes due to the plug-and-produce connectivity included in the workcell and supported both in hardware and software.

If new hardware is necessary, the setup times usually increase. The system, however, also support such cases through the modular design of components that often need to be adapted. This includes exchangeable gripper fingers, exchangeable fixture clamps, and exchangeable screw bits, which can be quickly manufactured using 3-D printing technologies without the need to replace the rest of the required hardware.

Innovation

The main innovation of the workcell lies in the application of passive reconfigurable components. The main reasoning behind this idea is that a robot workcell already contains an active component, namely a robot(s), which can be used to (re)configure the rest of the robot's workspace. Thus hardware components with passive degrees of freedom can be manipulated by a robot and moved to a configuration suitable for the desired task. They are a more affordable option compared to high-cost active solutions, which are often prohibitively expensive for manufacturing SMEs that want to keep the costs of automation low. Besides fully automated reconfiguration, the cell also supports manual reconfiguration when full automation is not feasible.

Passive reconfiguration is supplemented by modular hardware and software integrated via ROS HTTPS://WWW.ROS.ORGThe various tools and features that are available within ROS enabled us to achieve the pursued software reconfigurability of the cell. In our case, software reconfigurability means that it is possible to expand the cell's functionalities without disrupting the existing software architecture.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

New software components can be developed without the need to reprogram any of the existing ROS nodes. Hardware modularity is supported by plug-and-produce connectors that enable the fast exchange of hardware components.

Risks and limitations

While the system offers many automated capabilities for workcell reconfiguration, some reconfiguration tasks still require manual intervention. Nevertheless, manual reconfiguration is supported by a simulation system and other software tools that can be used to accelerate the reconfiguration process. Another issue can be the integration with ROS for hardware components that do not have ROS interfaces. For this purpose, we developed a special module called "ROS periphery interface" that enables the integration of hardware without ROS capabilities.

The developed system provides many facilities to support the users when setting up and (re)configuring robotic workcells. While many setup tasks can be performed by users without in-depth knowledge, some of them can only be performed by users with in-depth engineering knowledge. To mitigate this issue, we prepared a classification of setup processes according to the level of required user expertise.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Automotive industry: assembly of parts, e.g. assembly of automotive light housings., Electronic industry: Mounting of printed circuit boards (PCBs) on a backplate.

Potential sectors of application

Automotive industry, White goods industry, Aviation industry, Electronics industry, Furniture industry, Manufacturing of machinery

Patents / Licenses / Copyrights

The workcell includes many widely available parts like collaborative robots (Universal robot UR-10 are currently used), tool exchange systems, 3-D cameras, workstations for sensor data processing, simulation, and workcell control and ROS-based control software. It includes open-source software (three-clause BSD licence) as well as closed-source software that is available with the purchase of the corresponding hardware modules. The technology behind passive reconfigurable fixtures has been patented (European patent application Cardan joint, PCT/EP2018/060387). The developed system is not a stand-alone product that can be purchased but needs to be adapted for the respective applications. This is typically done on a project contract basis. The licenses for the workcell control software need to be negotiated within the contract.

Hardware / Software

Hardware:

2 Universal robots UR-10

2 ATI 6-D force-torque sensors

2 Basler cameras with PoE interface

Destaco QC-30 quick tool changer system

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

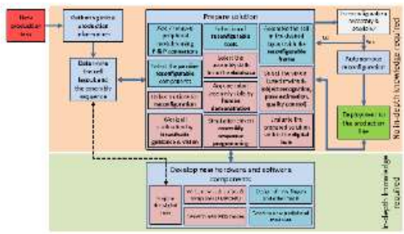
Several two-finger grippers
Up to 6 passive reconfigurable fixtures based on Stewart platforms
Passively reconfigurable rotary table
Passive linear guide for relocation of robot bases
Passive rotary table
Tool hanger module
Plug-and-produce connectors
Trolleys with integrated plug-and-produce connectors
Reconfigurable frame based on BoxJoint system
Two Linux workstations with GPUs for workcell control, simulation, and vision processing

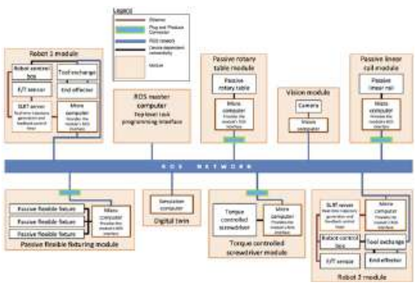
Software:
ROS
Trainings
The training material in current being prepared and will be announced when it is ready.

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196





Video

The videos of example applications implemented in the reconfigurable robot workcell.

HTTP://WWW.RECONCELL.EU/CONTENT/SPACE/EXPERIMENTS.HTML

5. Modules

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Optimal locations and postures of reconfigurable fixtures

Main functionalities

The module can be used to mount multiple workpieces onto a fixturing system constructed from two or more Stewart platforms (hexapods) with passive degrees of freedom. The fixturing system does not contain any actuators, but each hexapod can be reconfigured into any desired posture by a robot arm. This module provides software to automatically compute – given the geometry of workpieces to be mounted onto the fixturing system – the suitable postures of hexapods for each workpiece.
The module is used as follows: First the geometry of all workpieces is provided and the software computes the locations and postures of hexapods so that all workpieces can be mounted. The bases of hexapods are then manually installed in the production cell. Next the robot moves the top plates of the hexapods so that the selected workpiece can be mounted and then places this workpiece onto the resulting fixturing system. The desired production process can start now. Once there is a request to change the production from one workpiece to another, the robot(s) can automatically move the hexapods to the pre-computed postures for this new workpiece, the new workpiece can be placed onto the fixturing system and its production can start.

Automotive light housing mounted onto the fixturing system composed of three hexapods

The robot can reconfigure the hexapods by latching onto the top plates of the hexapods

Technical specifications

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The module requires the following hardware and software:
– One or more robot arms, e.g. Universal robot UR-10.
– Two or more hexapods with passive degrees of freedom and pneumatic brakes. The price of each hexapod is ca. 8000 EUR, but for a limited number of hexapods, a loan agreement can be made for participants of TRINITY open calls without any costs besides transportation.
-Tool exchange system, e.g. Destaco QC-30, to be mounted onto the hexapods and the tip of the robot.
-Pneumatic air.
-Software program provided together with the hexapods to compute the locations and postures of hexapods comprising the fixturing system for a given set of workpieces.

The following robot movements and operations need to be programmed:
-Robot motion to latch onto the hexapod and disengage the hexapod's brakes.

-Robot motion to move the hexapod from one posture to another.

-Robot motion to move away **from the hexapods after engaging its brakes.**

Inputs and outputs

Phase 1 – computing the hexapod postures by taking into account the geometry of workpieces to be mounted onto the fixturing system:

Inputs:
-CAD models of all workpieces in STEP format. For each workpiece, the locations where the workpiece should be attached to the hexapods comprising the fixturing system must be specified in workpiece coordinate system.
-Kinematic models of hexapods in URDF format. The location on each hexapod where the workpieces should be mounted must be specified in hexapod coordinate system.
-Kinematic model of a robot arm involved in the production process in URDF format.
-Kinematic constraints regarding the robot and hexapod workspace that need to be considered by the optimization algorithm.

Outputs:
-The locations of hexapod bases in the robot coordinate system.
-The locations of hexapod top plates for each of the given workpieces specified in the hexapod coordinate system.

Phase 2: industrial production
Input:
Identity of the workpiece to be mounted.
Outputs:
-Hexapods top plates are moved to the new configuration of the fixturing system by a robot.
-The production process involving the new workpiece is started.

Formats and standards

Licenses:
The software for the computation of hexapod postures is not open source but is provided in a package together with hexapods.

Formats:
STEP FORMAT to provide CAD models of workpieces.
URDF FORMAT to provide kinematic models.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Owner (organization)

Jožef Stefan Institute, Department of Automatics, Biocybernetics and Robotics

Trainings

We provide information about the example implementation of the industrial production task "Assembly of automotive light housings" that was implemented in collaboration with a manufacturing SME. It involves mounting of different automotive light housings onto the fixturing system composed of hexapods and the reconfiguration of hexapods:

Description of the task **HTTP://WWW.RECONCELL.EU/CONTENT/SPACE/EXPERIMENTS.HTML#ELVEZ**

Assembly of light housing 1 **HTTP://WWW.RECONCELL.EU/CONTENT/SPACE/VIDEOS/ELVEZ_ASSEMBLY_X07.MP4**

Assembly of light housing 2 **HTTP://WWW.RECONCELL.EU/CONTENT/SPACE/VIDEOS/ELVEZ_ASSEMBLY_X82.MP4**

Reconfiguration of hexapods **HTTP://WWW.RECONCELL.EU/CONTENT/SPACE/VIDEOS/X07_TO_X82_FAST.MP4**

ROS PERIPHERAL INTERFACE

Main functionalities

The ROS periphery interface provided in this module is implemented on a micro-computer, e.g. Raspberry Pi. It provides a bridge between hardware that is not ROS-compliant and the ROS backbone of the system, e.g. robot workcell. It acts as a proxy between the ROS-based system and exchangeable elements of the cell without ROS capabilities. It allows users to quickly integrate existing hardware into the ROS-based software system. It can be customized to meet the needs of different peripheral equipment in terms of shape, size and connectivity. The included software initializes all interfaces at boot time and thus provides plug-and-produce connectivity to the newly integrated hardware element.

Peripheral elements without ROS interface might include active components that need to be controlled, e.g. actuators, breaks, sensors, etc. It is beneficial if they are controlled using the same software infrastructure as the rest of the ROS-based system. In addition, sometimes it is necessary that peripheral elements provide or store data. Stored data can include coordinates of points of interest, maintenance data, information about products, etc. With all this in mind, the ROS periphery interface has been designed as a self-contained unit.

Technical specifications

At the core of the ROS periphery interface is a micro-computer that runs ROS. It implements ROS-compliant interfaces for the GPIOs (general purpose inputs-outputs), which are used to communicate with the new peripheral element to be integrated into the ROS system. A 3rd generation Raspberry Pi micro-computer can be used for this purpose, with version B+ recommended. It is usually encased for protection. The power comes through Power-over-Ethernet with an additional PoE HAT board. The real-world integration of the module depends on the shape and possibly other characteristics of the new hardware element.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

To make the micro-computer ROS-compatible, a Pi image with Raspbian OS and pre-installation of ROS is mounted. As the peripheral elements should enable swapping, the ROS instance on the micro-computer runs automatically when the periphery interface receives power. Standard ROS communication protocols are used to send and receive commands to the micro-computer. The commands are then further relayed to the non-compliant peripheral.

Inputs and outputs

Power and Ethernet are mandatory, though power can also be provided via the Power over Ethernet (PoE) standard. Ethernet is used to communicate with the rest of the ROS-based system. GPIOs (general purpose inputs-outputs) to communicate with the newly integrated hardware element. Both communication channels are bidirectional.

Formats and standards

Licenses:
The software to be installed on the micro-computer is released under 3-clause BSD license (https://opensource.org/licenses/BSD-3-Clause).
Support for software installation and the development of hardware interface is available free of charge within TRINITY open calls and on contract basis otherwise.
Standards:
ROS Kinetic is currently supported. It can run either directly under Raspbian OS or inside a Docker container.

Owner (organization)

Jožef Stefan Institute, Department of Automatics, Biocybernetics and Robotics
ABR conducts basic and applied research in the area of robotics (including intelligent control, robot learning, exoskeletons, humanoid robotics, and industrial robotics), factories of the future, industrial automation, and environmental physiology. The aim of the group is to create robots that are capable of acquiring new knowledge through learning and can collaborate with people, which is essential for bringing robots to new application domains. Besides research projects, ABR researchers also provide support for transferring robotics technologies to practical applications.

Web address: http://abr.ijs.si
Contact for this module: Rok Pahič, e-mail: rok.pahic@ijs.si

Trainings

Manual for the implementation of ROS periphery interface is available at https://www.ijs.si/usr/aude/trinity/ros_periphery_interface.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 40: HRI support application for operator

1. Basic information

Name of demonstration
HRI support application for operator

Main objective
Industries need to increase quality level of process in terms of precision and repeatability, to reduce throughput time in assembly stations, to enable traceability of the performed operations and to reduce operators' ergonomic stress (e.g. by reducing the applied physical strength). This can be done with the introduction of automation and robot systems to the assembly lines that will take over the strenuous tasks. Driven by industry needs for the flexibility of human operator as also robots automation,this use-case demonstration aims at increasing operator's "safety feeling" and acceptance when working close to large industrial robots by visualizing data coming from a robot's controller and by displaying visual alerts to increase their awareness for a potentially hazardous situation.

Short description
To this direction, is demonstrated an HRI framework for operator support in human robot collaborative operations. This Use Case consists of high payload industrial robot, a monitoring system and an AR application. The combination of the Hardware and software of this Demonstrator provide to the human operators:
1. Assembly instructions
2. Robot behaviour information for increasing safety awareness
3. Safe working volumes
4. Production status information

Also, interfaces on smart wearable devices enable the easy and direct human robot interaction while the HRC execution is orchestrated and monitored through a service – based controller.

Owner of the demonstrator
University of Patras

Responsible person
Dr. Sotiris Makris MAKRIS@LMS.MECH.UPATRAS.GR

NACE
C29.3 - Manufacture of parts and accessories for motor vehicles

Keywords
Human Operator Support, High payload robot, Augmented Reality , Robotic cell, Safety awareness.

2. Innovation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Potential users

SMEs or bigger companies that are interested in exploiting the synergy effect of humans and high payload robots in their production line ensuring the operators safety and making him/her feel safe close to robots

Benefits for the users

The proposed operator support application improves the agility of the assembly system by providing assembly guidance for the operator and increasing safety awareness.

- The synergy effect of the robot's precision, repeatability and strength with the human's intelligence and flexibility is great, especially in the case of small-scale production.
- Additionally, the introduction of robots to support assembly operators reduces the need for physical strength. Therefore, it is possible for older people to continue working inside the production facility, having to undertake. In this direction the AR tools need to be enriched with further functionalities to support this collaboration in a user-friendly way.
- The assembly guidance provided through the application helps unexperienced operators to familiarise themselves with new tasks faster and easier.
- Pop-up messages provide recovery instructions to the operators in case of a malfunction.
- Unexperienced operators can be allocated to work in HRC cells and new processes limiting the training requirements thus providing agility in the system on re-allocating human resources according to the production needs

Innovation

– Co-existence of humans and high payload robots in a collaborative environment, sharing both workplaces and tasks.
– Reinforces operators' critical position in manufacturing in the transition to agile manufacturing.
– Contributes to agile manufacturing by supporting dynamic knowledge transfer to the human operators in a way that is perceivable and does not limit operators' capabilities
– Increases operator's "safety feeling" and acceptance when working close to large industrial robots by displaying visual alerts for a potentially hazardous situation.
– Allows real-time communication between the operators and the execution system.
– Supports remotely assembly workstations.

Risks and limitations

- The safety monitoring system is not operating optimally to non-ideal environmental conditions (e.g. insufficient lighting).
- The use of the AR Glasses can be challenging for unfamiliar operators.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Various company sizes dealing with product assembly and can to manufacturing systems that aim to increase automation in their processes., Companies that have already robotic cells in their production line and want to introduce the operator to work with them.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Potential sectors of application

Each company that deals with products assembly and has introduced robots to support operator can enrich the collaboration with this AR application.

Patents / Licenses / Copyrights

License pricing should be customized as per each individual end user's requirements. The agreement will be made upon contact with the module owner.

Hardware / Software

Hardware:

Industrial robots

Augmented reality glasses

Smart watch

Software:

Open source software (ROS)

RosBridge

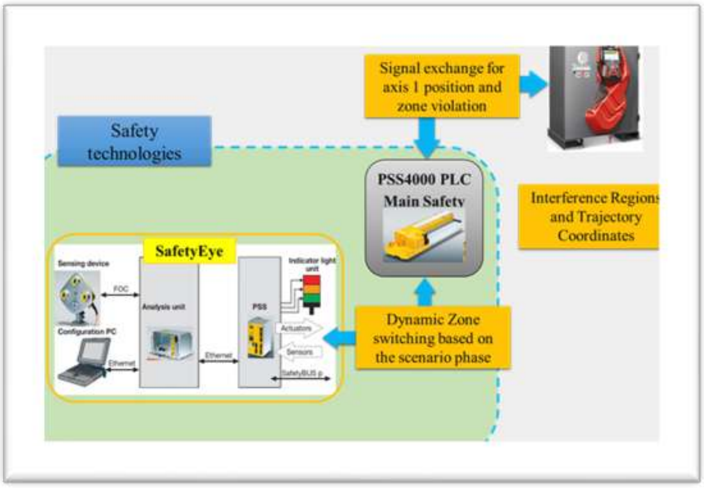
ROS Java

Unity

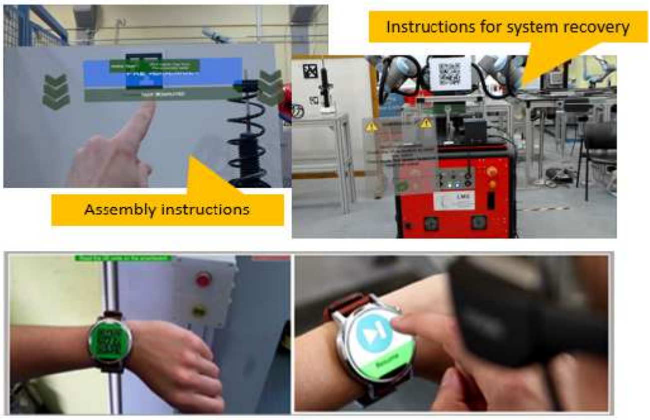
Vuforia

4. Media

Photos



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

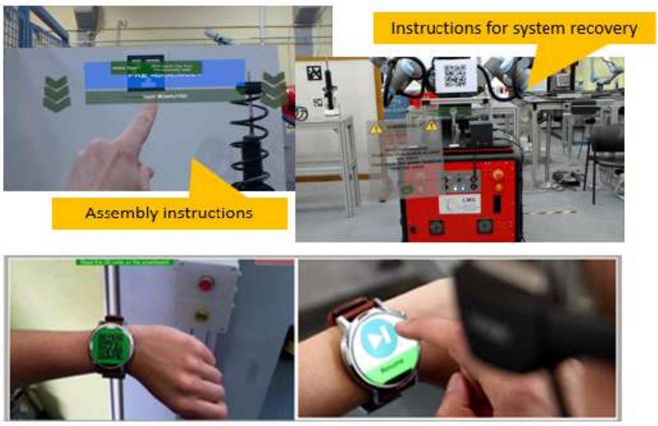


5. **Modules**

AR-based operator support in hrc

Main functionalities

The AR based Operator support module aims to increase human operator safety awareness, during human robot collaborative assembly tasks. The developed AR Application supports the human operator during the assembly process, through visual signals and notifications, in order to be aware of the execution status of every operation and the status of every resource, see figure below. Furthermore, this module provides to the operator the ability to navigate the mobile robot if considered necessary.



AR Application functionalities

Technical specifications

The application is developed using the Unity3D game engine to cover the communication and the visualization needs, and the Vuforia library, to realize the AR functionality. The main advantage offered by the Unity3D software, apart from the ease of use, is the possibility of exporting the same application to different platforms (Android, iOS, Windows). Taking into consideration that the hardware is running either Android (Epson Moverio BT200 AR glasses, etc.) or Windows (HoloLens AR glasses), this is a really helpful feature to run, test and evaluate the same application to multiple devices.

Inputs and outputs

The Augmented Reality Operator Support Application uses a set of input data from the system to provide the aforementioned functionalities to the operators. The required input data are listed below:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

- List of assembly tasks that need to be executed
- Assigned resource for each task
- Assembly instructions
- System recovery instructions
- Dimensions of robot safe working volumes

The Augmented Reality Operator Support Application provides a set of outputs:
Assembly instructions
Robot behaviour information for increasing safety awareness
Safe working volumes
Production status information

Formats and standards

Standards: ISO / TS 15066:2016 Robots and robotic devices – Collaborative robot,
Formats: Web standards, XML / JSON format

Owner (organization)

LMS – University of Patras

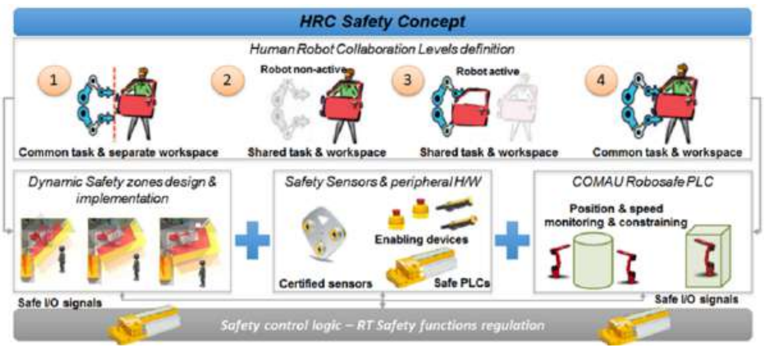
Trainings

Trainings will be added in the TRINITY Training Platform

Safety logic for seamless hrc

Main functionalities

This module refers to the safety architecture that has been implemented and includes all the safety certified technologies used to ensure human safety inside the collaborative cell. The layout of the cell has been regulated in accordance with the implemented safety systems. Given the available space for the cell the involved components have been in a way ensuring that the human may not need to walk close to walls minimizing the risk for entrapment. Then, the hardware devices that will be used for implementing the safety system such as cameras, enabling devices, safety PLCs, emergency buttons etc. are selected. The overall safety control logic (Figure Below) that integrates the different components is responsible for regulating the activation of each safety method at each point of the execution depending on the current phase of the scenario.



Technical specifications

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The hardware and software requirements for this demonstrator are described below. The main hardware consists of a Comau industrial robot, a monitoring system and a safety PLC provided by PILZ and an AR headset. On the software side, a specified software tool for safety zones design provided by PILZ is used. Three different but complementary systems have been deployed for physically implementing the discussed safety concept:
C5G Robosafe:

The COMAU C5G Robosafe system, is based on B&R safety certified PLCs that monitor and regulate in real time robot's position and speed.

PILZ SafetyEye – Safe camera system:
A certified safe camera system is used for real time monitoring of the collaborative workspace.
Safety Controller – PILZ PSS4000
Safety Controller is an external PLC.

Inputs and outputs

The Safety logic for seamless HRC module uses a set of input data from the system to provide the safety awareness to the operator. The required input data are listed below:
Human location in the working area
Dimensions of robot safe working volumes

Set of Outputs:
Robot behavior information for increasing safety awareness
During the robot's operations, information related to the actions of the robot is visualized in the form of informative messages, e.g., a text message describing the current operation that the robot is performing.
Safe working volumes
Messages in the form of safe working volumes help the operator to watch out about potential dangers that exist in the shopfloor while working, such as the movement of the robot, the working status of a machine etc.

Formats and standards

ISO 10218-1 Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
ISO 10218-2 Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration
ISO / TS 15066:2016: Robots and robotic devices – Collaborative robots
ISO 13855:2010 Safety of machinery- Positioning of safeguards with respect to the approach speeds of parts of the human body

Owner (organization)

LMS – University of Patras

Trainings

Trainings will be added in the TRINITY Training Platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 41: Dynamic task planning & work re-organization

1. Basic information

Name of demonstration

Dynamic task planning & work re-organization

Main objective

This demonstrator core objective is to support production designers during the manufacturing system design process and reduce the time and size of the design team needed for applying a change in the existing line.

Short description

Task planner generates and evaluates alternatives for task allocation and rough motion planning of human and robot operations, using information and data extracted from simulations. The evaluation of the generated alternatives is based on multi-criteria decision-making modules, integrating 3D graphical representation, simulation, and embedded motion planning. Dynamic Task planning & work re-organization Use case can be applied in production lines that use either mobile or station robots.

Owner of the demonstrator

University of Patras

Responsible person

Dr. Sotiris Makris MAKRIS@LMS.MECH.UPATRAS.GR

NACE

C29.3 - Manufacture of parts and accessories for motor vehicles

Keywords

Human Robot Collaboration , Layout design, Mobile robot, Task planning, Manufacturing.

2. Innovation

Potential users

Manufacturing SMEs or bigger companies from multiple sectors that they aim to explore Human Robot collaborative work cells or need novel solutions for optimizing their production, while automating the design process

Benefits for the users

– Allocate tasks to resources with respect to ergonomic rules and in order to increase the quality of operator's job.
– Maintain the cycle time as is defined by the End User.
– Achieve better utilization of resources.
– Increase systems reconfiguration as it reassigns tasks and resources in case of unexpected events

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

– Generalize unified model for active (humans and robots) and passive (working tables, fixtures etc. resources
– Generate HRC workplace layout can upon the criteria defined by the user and depending on the requirements and specifications.
– The criteria can be changed if new requirements and specification introduced because of a new product or a Graphical User
– Graphical User Interface (GUI), that provides a detailed view on workcell information, scheduling settings, search parameters and evaluation criteria.

Innovation

The existing modelling of human and robot tasks, as well as the taxonomy of the existing resources, in a consolidated model, is innovative. The evaluation of an HRC workplace layout, given multiple criteria, such as ergonomics, investment cost, robot reachability, minimum floor space etc. is quite similar to that of the designers' experience. The incorporation of the resources' suitability check, given the skills of humans and robots, for a specific task, is also a part of the decision to be made. Last, the integration of the decision-making software with 3D simulation models, in order for the use of spatial representation techniques to be overcome, enables the layout overview and a valid solution to be had in a short time.

Risks and limitations

Familiarized production designers and integrators with Ubuntu OS and ROS are recommended for the integration of task planning module.

There are several robotic manipulators and mobile platforms without ROS controller. Robots without ROS controller are not supported by the task planner module. ROS controllers are required to execute robot manipulators' motion actions and mobile platforms' navigation actions.

The simulated execution of a task plan in GAZEBO simulator might be a time-consuming process raising the total time duration of the task planning process for the end users.

The selected simulation tool (GAZEBO) requires enough computing power for the simulated execution of a use case including big number of resources (robots, mobile platforms etc.). In this case, another simulation tool might be used.

Creation/modifications of GAZEBO simulation environment might be easier for production designers familiarized with ROS and GAZEBO simulation environment.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Automotive industry , Consumer goods industry , White goods, Elevators Industry, Industrial Modules Production.

Potential sectors of application

Production lines of materials, pharmaceuticals, machines, equipment and mining and many others where humans and robots work together in the production line

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Patents / Licenses / Copyrights

License pricing should be customized as per each individual end user's requirements. The agreement will be made upon contact with the module owner.

Hardware / Software

Hardware:

High performance computer

Software:

ROS

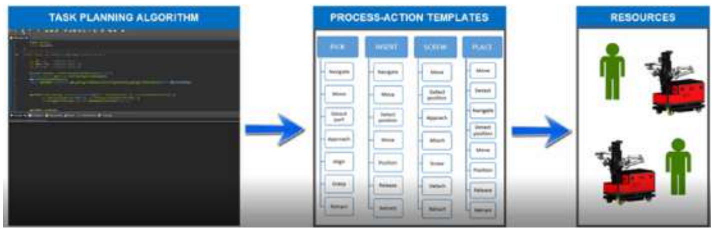
Siemens - Process Simulate

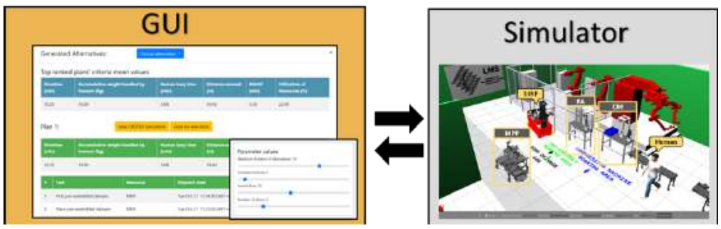
Trainings

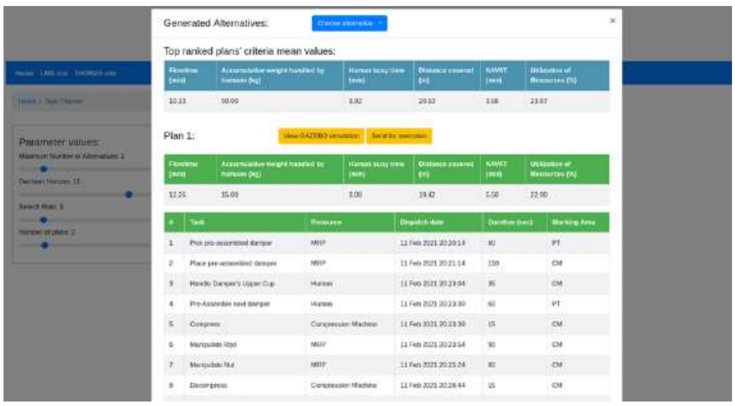
Trainings will be available soon on the training platform.

4. Media

Photos







5. Modules

Dynamic task planning & work re-organization module

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

Current the designing process is a manual operation which requires some time to be applied when needed by the designers. Applying a change into an existing production line including human operators and robot resources is a time-consuming process performed by a big sized design team. This module suggests a multi-level decision making framework targeting on the dynamic work balancing among the human operators and robot resources. An intelligent decision-making framework for task allocation to the available resources in the production line, motion planning of robot tasks and criteria estimation is implemented. This will minimize the time needed for the evaluation of different task plan alternatives. The task planning algorithm takes under account the suitability and the availability of the different resources during task plans generation phase. Each task plan generated by the intelligent scheduler can be visualized in the ROS Gazebo simulator. This simulation mechanism supports both human and robotic tasks execution.

Technical specifications

The hardware infrastructure of this module is a high performance PC with an OS compatible with ROS, Java, SQL and Gazebo simulator. The core decision making that facilitates the cognitive aspects of the line level work re-organization is the Dynamic Task Planner. In parallel with the implementation of the search-based algorithm for multiple alternative generation, multi-criteria decision-making mechanisms have been integrated for evaluating the multiple generated alternatives based on user defined criteria. The dynamic task planner module is triggered to plan and allocate the required tasks to the existing resources. The activation of the Task Planner may be outcome either of human input / request through the developed UI or any other unexpected event such as resource breakdown. The proposed task planner module is based on the information of each task saved in the database. The intelligent scheduler generate several task plans which can either sent or not to the simulation mechanism for validation. This simulation mechanism is also used for the calculation of the different evaluation data. Information about the time duration of each task executed and the distance covered from each resource during the execution of each task is exported through the simulation mechanism and is stored in the database for future usage. The proposed module consists of custom C++ and Java codes using ROSJava libraries for the communication of the task planning database and the intelligent scheduler with the ROS nodes of the simulation mechanism.

Inputs and outputs

Input:
The input for the decision-making framework includes:
Resources,
Tasks,
Task-resource suitability,
Task precedence constraints,
Duration of tasks
Time of starting and completing a task.

Output:
List of operations assigned to resources.
Templates of robot actions for the operations assigned to robots.
Visualization of the most suitable task planning alternative through the simulation mechanism.

Formats and standards

C++, XML, JSON, Web standards, CAD models

Owner (organization)

LMS – University of Patras

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Trainings

Trainings will be prepared and uploaded in the TRINITY Training Platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 42: Deployment of mobile robots in collaborative work cell for assembly of product variants

1. Basic information

Name of demonstration

Deployment of mobile robots in collaborative work cell for assembly of product variants

Short description

The following use case introduces mobile robots equipped with manipulators in a shared workplace to assist assembly operations in a collaborative work cell for assembly of product variants. The potential application sector for such use case is foreseen to be in SMEs and large-scale companies that need flexible mobile robotic solutions.

Owner of the demonstrator

Flanders Make

Responsible person

dr. ir. Raheel Afzal, trinity@flandersmake.be

NACE

C28 - Manufacture of machinery and equipment n.e.c.

Keywords

Collaborative robots, Mobile Manipulation, ROS, Mobile Robots, Robot control.

2. Innovation

Potential users

The potential users can be any company small or large that has the need to deploy mobile robots. It is especially useful for companies that are engaged in assembly operations and requires material transfer from warehouse to assembly stations.

Benefits for the users

Mobile manipulators collaborating in such use cases will allow the deployment of robotics in manufacturing operations with unlimited reach. The onboard and external sensing systems with the ability of mobile manipulation enable the realization of autonomous and agile manufacturing that can cope with variability in the manufacturing processes and provide extensive flexibility in assembly operations.

Innovation

This demonstration will showcase the capabilities of mobile manipulators in work places shared by humans. The mobile manipulator will be able to assist in logistics of different tasks being performed in the work cell by navigating to the pick points of different parts, picking and kitting, and dropping the parts to the designated drop points. Accurate localization of the robot in an indoor working environment is fundamental for precise navigation and manipulation. The platform which will be used for the demonstration is KUKA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

KMR mobile robot equipped with KUKA LBR iiwa collaborative manipulator. KMR robot localizes itself by fusing sensory information from the wheel encoders and laser scanners alongside sensor fusion of UWB tags and beacons. Mobile manipulator movements are planned with obstacle avoidance by solving a numeric optimization problem which takes into account of a continuously updated digital representation of the environment.

Risks and limitations

A thorough functional safety analysis is required before deployment. The demonstrator is made on KUKA KMR iiwa.

Technology readiness level

5

3. Exploitation

Sectors of application

Manufacturing.

Potential sectors of application

medical sector, service sector and food sector can also deploy this technology with necessary constraints

Hardware / Software

Hardware:

KUKA iiwa KMP200 omnimove

Robotiq 3 Finger Gripper

External PC

Software:

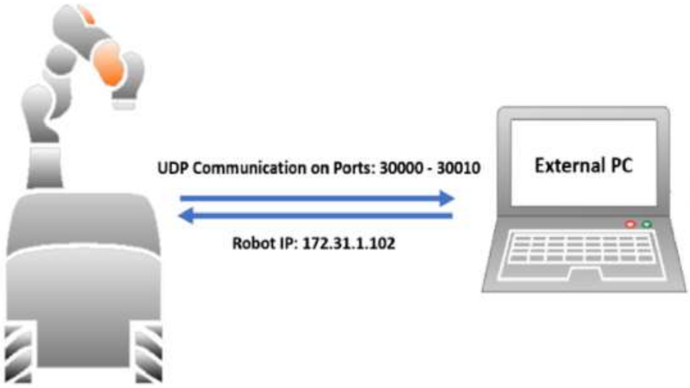
KUKA sunrise

ROS/ROS2

4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



5. Modules

KMR external control module

Main functionalities

This module allows to control a KUKA KMR from an external PC. With this module, programming a specific application with KMR iiwa becomes intuitive using skill-based programming approach. The PC which runs the application connects to the mobile robot over WLAN and provides an API in order to send parametrized skills to the mobile robot remotely. The mobile robot controller runs a UDP Server listening to the messages sent by the external controller on the specific port.

Technical specifications

The robot is programmed using the native programming environment (Sunrise Workbench). The different skills and functionalities of the mobile robot and arm are defined in this programming environment. From the controlling computer, API requests are sent and received in the mobile robot controller that corresponds to a defined skill. The localization skills are programmed in a modular method allowing them to be easily reused. The available skills are: current location check, move to waypoints, move to location, fine localization.

Inputs and outputs

For the external control module to be used, a map of the environment should be built and the locations, waypoints and zones can be defined on the built map in the KUKA map perspective. The robot arm also possesses predefined skills such as pick and place. Due to the low precision of the mobile platform in general, a calibration skill is available and uses the arm in order to obtain a precise X,Y offset data that will then result in a precise grasp of the robot arm.

Formats and standards

ISO/TS 15066:2016
ISO 10218-1/2
ISA-95

Training material

undefined

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Owner (organization)

Flanders Make

Documents

Trainings

KMR EXTERNAL MODULE

UWB based indoor localization module

Main functionalities

To introduce mobile manipulators in industrial settings localization capabilities need to be added. We use localization based on the Ultra Wide Band (UWB) to facilitate deployment of mobile robots in collaborative work cell for assembly of product variants.

Technical specifications

The Ultra Wide Band module uses firstly the ranging hardware which is the Decawave TREK1000 evaluation kit containing four evaluation boards and antennas. For two-dimensional ranging the minimum advised number of anchors is four. To obtain heading information the ranges of two tags will be fused in the Localization Processing Unit, which can be e.g. a PC or single-board computer like Raspberry PI3. Each of the evaluation boards has online visualization and (re)programming capabilities. The interface to the evaluation boards is always over USB.

Inputs and outputs

The requirements for the ultra wide band module will be split into the next main sections:
1. Firmware for the TREK1000 evaluation boards.
2. ROS Kinetic based localization for Ubuntu LTS16.04.

Supporting tools for visualization and configuration of the firmware on the evaluation boards. The TREK1000 evaluation boards will be flashed with optimized firmware compared to Decawave COTS firmware. The dipswitch on these boards will be read as initial configuration e.g. tag or anchor. These configurations can be altered using supporting tools described later. Within the Localization Processing Unit, the actual ranging data is read over USB from each tag's firmware API and published as a self-defined message on a ROS topic by USB2topic submodule. The USB2topic submodule publishes its ranges from each of the anchor configured evaluation boards. The Localization submodule subscribes to these ROS topics and publishes the two-dimensional position (X, Y) and orientation.

Supporting tools will be provided to:

- Flash firmware to the TREK1000 evaluation boards.
- Calibration of different antenna configurations.
- (Re)program UWB firmware
- Anchor placement tool using Dilution-of-precision (DOP) analysis.

Formats and standards

LTS16.04,
IEEE802.15

Training material

undefined

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Owner (organization)
Flanders Make

Documents

Trainings
UWB BASED INDOOR LOCALIZATION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 43: User-friendly human-robot collaborative tasks programming

1. Basic information

Name of demonstration

HRI support application for operator

Main objective

Industries need to increase quality level of process in terms of precision and repeatability, to reduce throughput time in assembly stations, to enable traceability of the performed operations and to reduce operators' ergonomic stress (e.g. by reducing the applied physical strength). This can be done with the introduction of automation and robot systems to the assembly lines that will take over the strenuous tasks. Driven by industry needs for the flexibility of human operator as also robots automation,this use-case demonstration aims at increasing operator's "safety feeling" and acceptance when working close to large industrial robots by visualizing data coming from a robot's controller and by displaying visual alerts to increase their awareness for a potentially hazardous situation.

Short description

To this direction, is demonstrated an HRI framework for operator support in human robot collaborative operations. This Use Case consists of high payload industrial robot, a monitoring system and an AR application. The combination of the Hardware and software of this Demonstrator provide to the human operators:

1. Assembly instructions
2. Robot behaviour information for increasing safety awareness
3. Safe working volumes
4. Production status information

Also, interfaces on smart wearable devices enable the easy and direct human robot interaction while the HRC execution is orchestrated and monitored through a service – based controller.

Owner of the demonstrator

University of Patras

Responsible person

Dr. Sotiris Makris MAKRIS@LMS.MECH.UPATRAS.GR

NACE

C29.3 - Manufacture of parts and accessories for motor vehicles

Keywords

Human Operator Support, High payload robot, Augmented Reality , Robotic cell, Safety awareness.

2. Innovation

Potential users

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

SMEs or bigger companies that are interested in exploiting the synergy effect of humans and high payload robots in their production line ensuring the operators safety and making him/her feel safe close to robots

Benefits for the users

The proposed operator support application improves the agility of the assembly system by providing assembly guidance for the operator and increasing safety awareness.

- The synergy effect of the robot's precision, repeatability and strength with the human's intelligence and flexibility is great, especially in the case of small-scale production.
- Additionally, the introduction of robots to support assembly operators reduces the need for physical strength. Therefore, it is possible for older people to continue working inside the production facility, having to undertake. In this direction the AR tools need to be enriched with further functionalities to support this collaboration in a user-friendly way.
- The assembly guidance provided through the application helps unexperienced operators to familiarise themselves with new tasks faster and easier.
- Pop-up messages provide recovery instructions to the operators in case of a malfunction.
- Unexperienced operators can be allocated to work in HRC cells and new processes limiting the training requirements thus providing agility in the system on re-allocating human resources according to the production needs

Innovation

– Co-existence of humans and high payload robots in a collaborative environment, sharing both workplaces and tasks.
– Reinforces operators' critical position in manufacturing in the transition to agile manufacturing.
– Contributes to agile manufacturing by supporting dynamic knowledge transfer to the human operators in a way that is perceivable and does not limit operators' capabilities
– Increases operator's "safety feeling" and acceptance when working close to large industrial robots by displaying visual alerts for a potentially hazardous situation.
– Allows real-time communication between the operators and the execution system.
– Supports remotely assembly workstations.

Risks and limitations

- The safety monitoring system is not operating optimally to non-ideal environmental conditions (e.g. insufficient lighting).
- The use of the AR Glasses can be challenging for unfamiliar operators.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Various company sizes dealing with product assembly and can to manufacturing systems that aim to increase automation in their processes., Companies that have already robotic cells in their production line and want to introduce the operator to work with them.

Potential sectors of application

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Each company that deals with products assembly and has introduced robots to support operator can enrich the collaboration with this AR application.

Patents / Licenses / Copyrights

License pricing should be customized as per each individual end user's requirements. The agreement will be made upon contact with the module owner.

Hardware / Software

Hardware:

Industrial robots

Augmented reality glasses

Smart watch

Software:

Open source software (ROS)

RosBridge

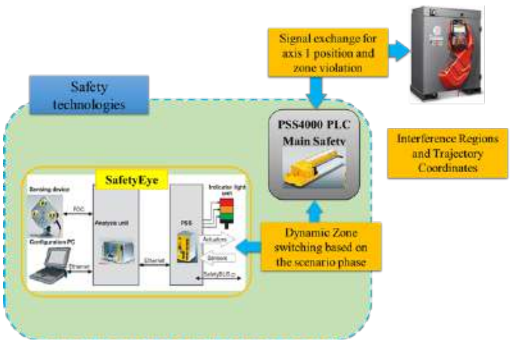
ROS Java

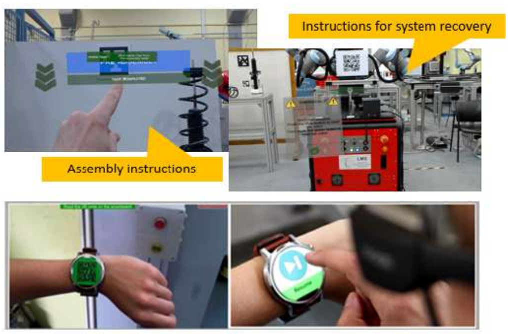
Unity

Vuforia

4. Media

Photos





5. Modules

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

EASY PROGRAMMING MODULE

Main functionalities

The main goal of this module is to allow the easy and fast implementation of a new robotic application. In classical robot programming, the introduction of a new product variant can lead to a severe re-programming of the entire task. This module allows to create or adapt a robot program in an intuitive way: The operator can program an entire application simply by interacting with a screen or with the cobot directly. Therefore, the operator does not need to have an expert level in robot programming to create a new program. He can easily visualize which actions the cobot is able to perform and assemble those robot actions in the order of interest augmented with the required parameters to fulfilled the desired application. The taught tasks can be adapted in the future by changing steps in the process or parameters to correct the behaviour.

Technical specifications

The module comes with an HMI that can be used to easily create/visualize new applications or to modify/execute the previously taught applications. This HMI allows keeping track of the mains functionality in the application: available tasks, available robots actions, the current status of different device manager. The application is built-in using several Finite State Machines (FSM) which are responsible for the application logic. The change of states in the FSM can be triggered by either using the HMI or internal process.

Inputs and outputs

The programming of the new application follows a logic of robot skills and device primitives. A skill is a more complex robot actions that are composed of several robot device primitives. A device primitive is an elementary robot's action. As an example, a skill can be a 'Pick' skill which is therefore composed of four device primitives (Arm motion to approach location, Arm motion to location, Grasp, Arm motion to release location). This idea behind the structured programming using skills is intended to keep the programming of a new application very intuitive for an inexperienced operator. This structure allows having a series of robot actions that follow a logical order. The new application can be a combination of several robot skills such as: teach-by-demonstration trajectories, forced-based insertion, pick, place, etc. An inexperienced operator can interact with the module using either the screen where the main functionalities are displayed (skills, current device primitives,etc.)

Formats and standards

ISO/TS 15066:2016
ISO 10218-1/2
ISA-95

Training material

undefined

Owner (organization)

Flanders Make

Trainings

EASY PROGRAMMING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

trinity

Annex 44: Collaborative Assembly with Vision-Based Safety System

1. Basic information

Name of demonstration

Collaborative Assembly with Vision-Based Safety System

Main objective

Demonstrating capabilities of vision-based safety system with projector and AR interface. Safety violations are captured through changes in 3D point map of working environment.

Short description

Demonstration of a vision-based safety system for human-robot collaboration in the assembly of diesel engine components. A dynamic 3D map of the working environment (robot, components + human) is continuously updated by depth sensor and utilized for safety and interaction between resources with virtual GUI. Robot's working zone is augmented for the user to provide awareness of safety violation. Virtual GUI aims to provide instructions of the assembly sequence and map proper UI as the controller of the system.

Owner of the demonstrator

Tampere University

Responsible person

Project Researcher Dmitri Monakhov DMITRII.MONAKHOV@TUNI.FI

NACE

C29.3 - Manufacture of parts and accessories for motor vehicles

Keywords

Robotics , Safety, Augmented Reality , Manufacturing, Human-Robot Collaboration.

2. Innovation

Potential users

SME's, Research Institute and Academy

Benefits for the users

Increasing safety awareness: Using vision-based safety system can decrease operator violation of robot safety zones by decreasing the possibility of human error As a result, this can lead to reducing production cycle time where a human doesn't stop production line by these mistakes. Here, proper GUI notifies human with violating robot working zone and assist human to avoid this error. Based on user test and survey, both scenarios vision-based safety system compared to the baseline where the robot was not moving in the same workspace with an operator. The result of this experience can be explained by measuring of robot idle time and total execution time.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Improving user experience: the projector/AR interface can be used to provide instructions on how to execute the current task. Research have shown that tasks performed with the help of the safety system can be completed 21-24% faster. Robot idle time is reduced by 57-64%.

Innovation

This use-case utilizes projection-based and augmented reality head-mounted display technologies to overcome human error in the assembly sequence. It's worth to mention, depth sensors such as Kinect track human body part whenever violation could happen. This is a new approach for collaborative work cell and provides a concept of safety vision-based for the operator. This approach studied in the academy research laboratory and 20 participants participated in the survey, where questionary contains 6 categories as following: Safety, Information Processing, Ergonomics, Autonomy, Competence, and Relatedness.

Risks and limitations

Software Malfunction: As the whole system operates by a computer, there are chances that software and connections through devices get malfunctioned. These can endanger the operator's safety while the system stopped. As a result, it requires a back-up safety system is running all the time and malfunctioning this system results in protective stop of robot system.

Environmental disturbances: lighting conditions, dust electrical interferences can affect the depth sensor information, which can cause mistakes when estimating changes in the environment. In case of AR HMD's field of view limitation should be encountered

Limitations of depth sensor: Scaling system to bigger environments with one depth sensor can cause point cloud to be not dense enough for accurate estimation. Synchronization between multiple depth sensors is needed.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Manufacturing assembly, Quality Assurance of assembled components.

Potential sectors of application

Generation of safety zones in public environment

Hardware / Software

Hardware:

UR5 from Universal Robot family (tested on CB3 and UR software 3.5.4)

Standard 3LCD projector

Laptop/workstation

Software:

ROS Melodic

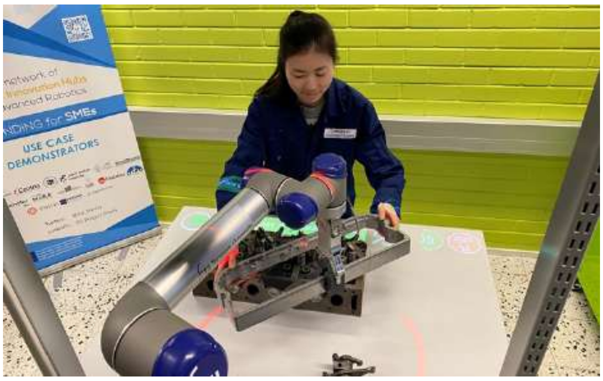
OpenCV (2.4.x, using the one from the official Ubuntu repositories is recommended)

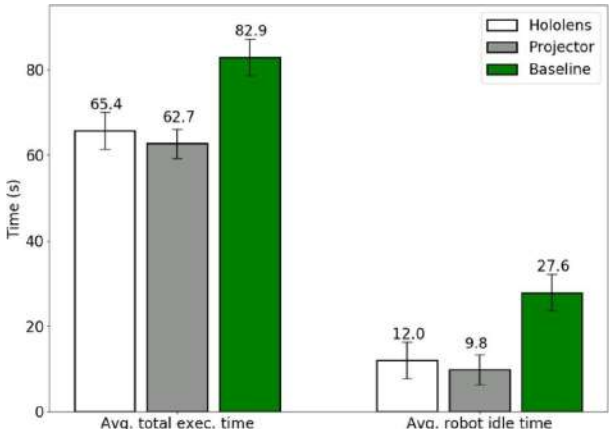
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

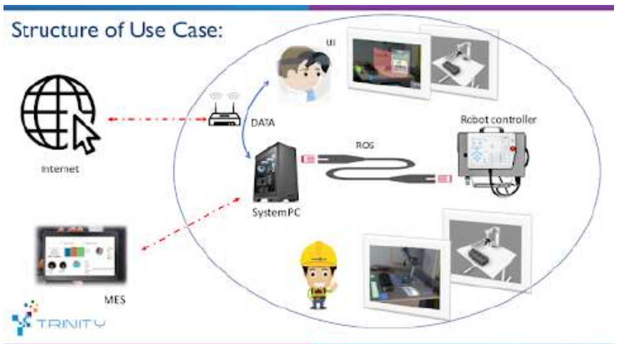
PCL (1.8.x, using the one from the official Ubuntu repositories is recommended)
ROS Interface to the Kinect One (Kinect v2)

4. Media

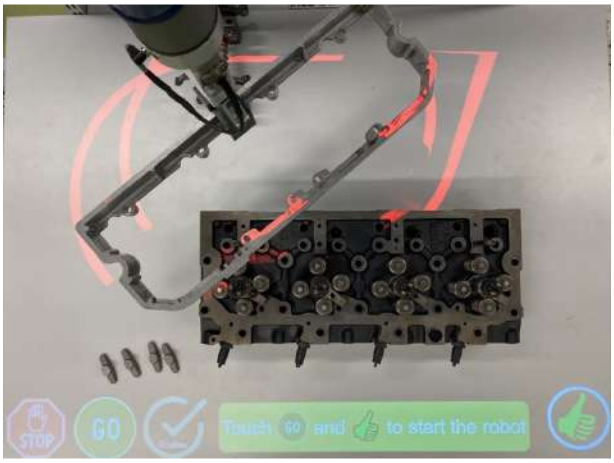
Photos



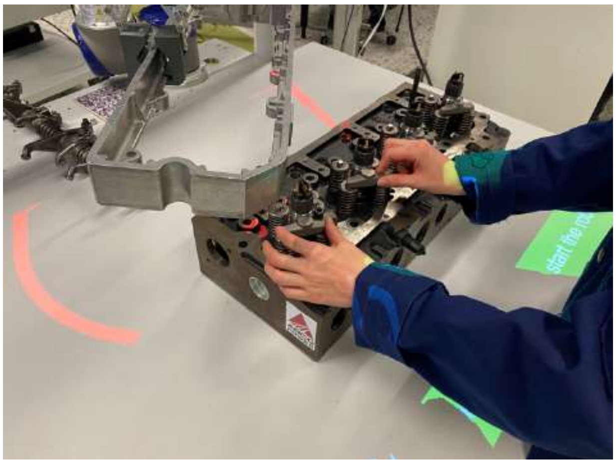




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Video

Collaborative assembly with vision based safety system, a TRINITY use case

HTTPS://WWW.YOUTUBE.COM/WATCH?V=BLNJK7SY_2Y&T=160S

5. Modules

Depth-sensor safety model for hrc

Main functionalities

Depth-based safety model for human-robot collaboration: Generates three different spatial zones in the shared workspace which are then online modelled, updated and monitored.

Technical specifications

The overall description of the hardware requirements and the different software nodes in the module are shown in Fig 2 The workspace is monitored by the Kinectv2 sensor at the frame rate of 30 Hz and the robot is UR5 from the Universal Robot family. Other depth sensors can be used with model as long as they support the same data structure of the depth cloud information. All the nodes exchange messages using the TCPROS transport layer where the nodes that are interested in data subscribe to the relevant topic and the nodes that generate data publish to the relevant topic. Arrows show the direction of the transmission.

A modified version of ur_modern_driver and univeral_robot ROS packages is used to establish communication channel between the robot low-level controller and the safety system node. Iai-kinect2 ROS package is used to receive data from the Kinect-2 sensor and further transmit it to the safety node which monitors safety violations and changes on the workspace.

The robot and depth sensor are connected to a single laptop computer that runs the ROS Melodic distribution on Ubuntu 18.04 and performs all computing. To successfully compile the module, OpenCV and PCL libraries must be installed in addition to standard C++ libraries. Currently Kinect v2 and Universal Robot 5 are supported.

Inputs and outputs

All the data is transferred via a standard ROS transport system with publish / subscribe semantics. Input and output data formats as well as the topic names are shown in Fig 5. and Fig 6. The vision-based safety system subscribes to topics where it can receive the color and depth image and the CameraInfo message

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

which contains the sensor intrinsic parameters. In addition, the information from the JointState message is used to generate the safety hull.

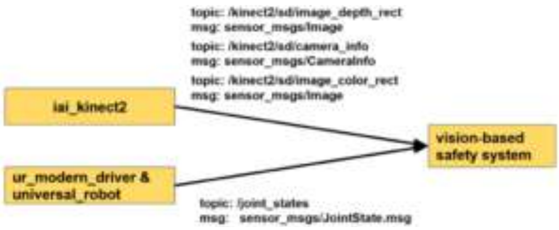


Figure 5 Data streams connected to Vision Safety system node

The only output of the node is the stop command for the robot which is published over the /ur_driver/dash board_command topic.

Figure 6 Data streams that are created from Vision Safety system node

Formats and standards

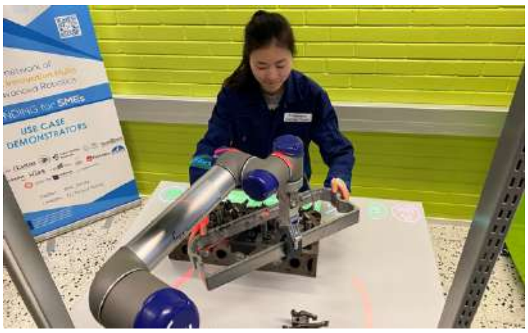
ROS communication layer with external image_transport package. Details about the message formats can be found from **HTTP://WIKI.ROS.ORG/SENSOR_MSGS** In addition ROS-industrial, OpenCV, PCL and C++ and Python standard libraries.

Owner (organization)

Tampere University, Finland **HTTPS://RESEARCH.TUNI.FI/PRODUCTIONSYSTEMS/**

Projection-based interaction interface for hrc

Main functionalities



Interface Generation: The module projects interface that the user can interact with by placing a hand over it. The interface includes GO and STOP buttons to control the robot, CONFIRM button and CONFIRM OBJECT button to update workspace model manually. To prevent accidental start of the robot, the START button should be pressed simultaneously with the CONFIRM button.

Technical specifications

The system consists of:

– standard FullHD 3LCD projector.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

– Microsoft Kinect v2

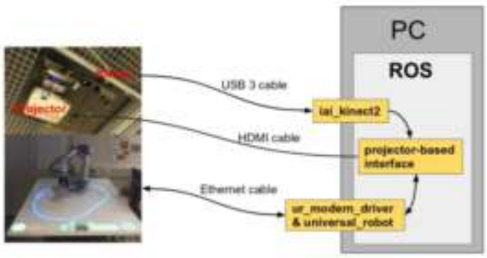
– Universal Robot UR5

– Workstation with Ubuntu operating system

The workspace is monitored by the Kinect v2 sensor which can be installed at the ceiling overseeing the whole working area. The frame rate of the sensor is 30 Hz. A standard 3LCD projector is used to project the safety hull and the user interface components on the workspace. The projector outputs a 1920×1080 color projection image with 50 Hz frame rate. Due to the short distance from the ceiling to the workspace the physical projection size can be increased by installing a mirror in 45° angle to re-project the image to the workspace. The robot is UR5 from the Universal Robot family.

A modified version of ur_modern_driver and univeral_robot ROS packages are used to establish a communication channel between the robot low-level controller and the projector node. Iai-kinect2 ROS package is used to receive data from the Kinect-2 sensor and further transmit it to the projector node. The sensor monitors the usage of the interface components. The projector node is responsible for creating RGB images of the current status of the workspace for the projector and sending start and stop commands for the robot controller.

Projector, robot and depth sensor are all connected to a single laptop computer that runs the ROS Melodic distribution on Ubuntu 18.04 and performs all computing. Right now, only Kinect v2 and Universal Robot 5 are supported.



Module software nodes and the hardware components

Before the module can be used,

1) projector, robot and sensor must be extrinsically calibrated,

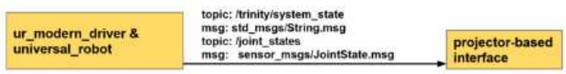
2) placement of the user interface components and size of the virtual safety hull has to be defined,

3) the locations of the interface buttons on the workspace must be defined and

4) wired communication link between PC and robot must be established.

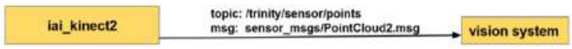
Inputs and outputs

All the data is transferred via a standard ROS transport system with publish-subscribe semantics.The projector node subscribes to topics /joint_states and /trinity/system_data where the robot joint values and the task related data are published respectively. The joint values are used to calculate the shape and position of the safety hull. The text in the information bars and the appearance of other interface components are based on the system data.



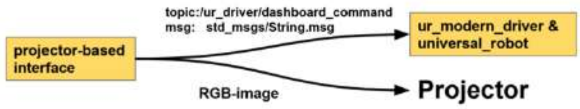
In addition, the projector node subscribes to /trinity/sensor/points topic where the depth measurements from the sensor are published. The measurements are used to calculate the usage of the interface components (e.g. is a human hand on the stop button)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



Data transport layer

An 1920×1080 RBG image is sent to the project and start/stop command can be published to the robot controller over /ur_driver/dashbord_command topic.



Data transport layer

Formats and standards

ROS communication layer, ROS-industrial, OpenCV, PCL and C++ and Python standard libraries.
– Availability: Module library [HTTPS://GITHUB.COM/HERRANDY/HRC-TUNI.GIT](https://github.com/herrandy/hrc-tuni.git)
– Application scenarios: Industrial assembly.
– Available for internal/external use.

Owner (organization)

Tampere University, Finland
[HTTPS://RESEARCH.TUNI.FI/PRODUCTIONSYSTEMS/](https://research.tuni.fi/productionsystems/)

Wearable AR-based interaction interface for HRC

Main functionalities

Generation of AR-based interface for human-robot collaboration: Increase the human operator awareness, safety and capabilities during a human-collaboration task in a shared workspace. Software module creates and visualize a dynamic safety hull around the robot as 3D holograms which are visualized using a wearable display, in this case, Microsoft HoloLens. Similarly, as in module 1, additional user-defined interface components can be created and projected to the workspace as 3D holograms.

Technical specifications

The overall description of the hardware requirements and the different software nodes in the module are shown in Fig. 9. The state-of-the-art head-mounted AR display is used to visualize the user interface components. The headset can operate without any external cables and the 3D reconstruction of the environment, as well as accurate 6-DoF localization of the head pose, is provided by the system utilizing an internal IMU sensor, four spatial-mapping cameras, and a depth camera. HoloLens is communicating with the Linux-based server using wireless TCP/IP. The Linux server synchronizes data from the robot to HoloLens and back. The usage of the interface components is monitored by the Kinect v2 sensor installed

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

at the ceiling. A modified version of ur_modern_driver and univeral_robot ROS packages are used to establish a communication channel between the robot low-level controller and the projector node. Software running on HoloLens is responsible for creating and updating the 3D holograms projected on the workspace.

HoloLens, robot and depth sensor are all connected to a single laptop computer that runs the ROS Melodic distribution on Ubuntu 18.04 and performs all computing. Right now, only Kinect v2 and Universal Robot 5 are supported.

Inputs and outputs

The data is transferred via a standard ROS transport system with publish/subscribe semantics between robot, sensor and the server PC.

The TCP/IP Server node subscribes to topics /joint_states and /trinity/system_data where the robot joint values and the task-related data are published respectively. The joint values are used to calculate the shape and position of the safety hull. The text in the virtual information bars and the appearance of other interface components are based on the system data.

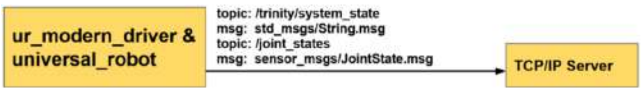


Figure 8 Description of the data transport layer

In addition, the TCP/IP Server node subscribes to /trinity/sensor/points topic where the depth measurements from the sensor are published. The measurements are used to calculate the usage of the interface components (e.g. is a human hand on the virtual stop button)

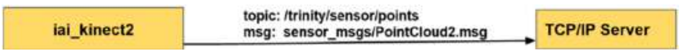


Figure 9 Description of the data transport layer

Finally, the two-way communication between PC and HoloLens is done using the TCP/IP Server node. The node communicates with HoloLens using custom TCP packages with a fixed length.

Interface specification:

The main interface components are the same as in module 1 but everything is rendered in 3D. Interactive buttons (GO, STOP, CONFIRM OBJECT, CONFIRM) are modelled as spheres and information bar as a 3D plane. The safety fence is rendered as a polygonal mesh having semi-transparent red texture.

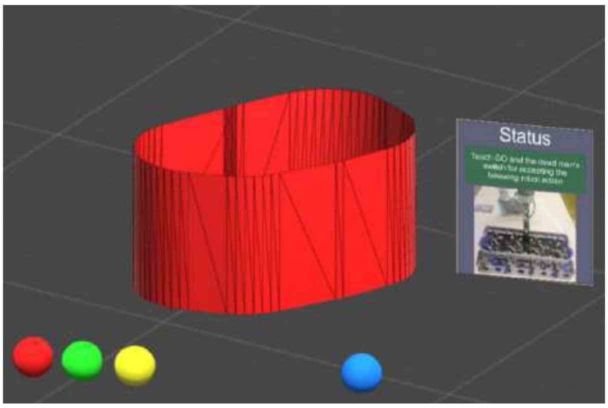


Figure 10 Wearable AR user interface

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Formats and standards

ROS communication layer, ROS-industrial, OpenCV, Microsoft Visual Studio, Unity, Vuforia

Owner (organization)

Tampere University, Finland
https://research.tuni.fi/productionsystems/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 45: Industrial IoT Robustness Simulation

1. Basic information

Name of demonstration

Industrial IoT Robustness Simulation

Main objective

The Industrial IoT (IIoT) Robustness Simulation provides an extensible and configurable discrete event simulator. The implementation of different simulation models realizes a simulation for wireless sensor networks in a 3D environment.

Short description

Wireless Sensor Networks (WSN) are essential in production or IIoT environments. Mobile robots, edge devices, or Automated Guided Vehicles need to communicate. Such networks are prone to physical changes of the environment and cyber attacks. This use case simulates the WSN behaviour in a virtual IIoT infrastructure.

The two modules that are emphasized by the TRINITY project are “Network Device Positioning” and “Cyber-security Fallback Simulation”. The two software artefacts are extending the core functionality of a software project called d3vs1m – discrete events & development for network device simulation. The d3vs1m project is an open source library and simulation tool to simulate WSNs in order to support the integration process of such IIoT networks in the factory domain.

Owner of the demonstrator

Fraunhofer Institute for Machine Tools and Forming Technology (IWU)

Responsible person

M.Sc. Adrian Singer ADRIAN.SINGER@IWU.FRAUNHOFER.DE

NACE

J58.2 - Software publishing

Keywords

IIoT, WSN, Simulation, Cyber Security.

2. Innovation

Potential users

Software Developers, Software Operations, Simulation Scientists

Benefits for the users

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Low-cost test: Software-based simulations of the network behavior is a low-cost approach compared to a testbed installation or a test in a productive environment.

Innovation

There is a number of technologies to investigate the behaviour of IIoT networks, mostly real-world test bed installations or various types of hard- and software simulations. There is also a number of technologies, in terms of Breach and Cyber-Attack simulations (BAS). Popular systems can be summarized as Vulnerability Scans, Traffic-based Monitoring or Mulit-Vector Testing. This use case proposes another technology called Network and Intrusion Detection System (IDS) Simulation. On the one hand, d3vs1m provides an application-programming interface (API) to compose individual simulators in one application. On the other hand, it can be used also directly as an executable that users can install and configure.

Risks and limitations

Knowledge of software: Developers needs to be familiar with the provided software artefacts and their implementation process into the IT environment of their organization.

Knowledge of simulation environment: Users needs to be familiar with the functionalities and the user interfaces provided by d3vs1m.

Technology readiness level

4 – Component and/or breadboard validation in laboratory environment

3. Exploitation

Sectors of application

Network-Integration, Research.

Potential sectors of application

Breach Attack Simulation (BAS)

Patents / Licenses / Copyrights

All software artefacts are licensed under GNU General Public License v3.0.

Hardware / Software

Hardware:

100% hardware- or platform-independent modules

Software:

.NET Core Runtime or .NET Core Software Development Kit (SDK), version 3.1 with long-term support (LTS)

.NET Framework 4.8 Runtime or Development Pack

.NET 5 Runtime or SDK

4. Modules

IIOT network device positioning

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

This module provides the simulation environment d3vs1m in order to compute the optimal distribution of the network devices, e.g. located inside a physical building. It takes a 3D model of the building and other additional properties of the mobile radio devices as input and simulates the propagation of electromagnetic waves. Depending on the simulation result, an optimal distribution of the network devices is calculated.

Technical specifications

Processor – 1 GHz
RAM – 512 MB
Disk space (Minimum)
32-bit – 4.5 GB
64-bit – 4.5 GB

Inputs and outputs

Inputs:
JSON configuration files
OBJ files (Wavefront) as 3D environment

Outputs:
JSON files with meta information
CSV files as simulation data report
HTTP+JSON on web service

Formats and standards

The simulation modules are developed completely in C# and based on the .NET Standard 2.0. This can be seen as the contract to multiple target environments that can execute the application logic. The provided runtime may be installed on Windows, Linux, Mac or even mobile or industrial computers. The modules can be used on every system where one of the following runtime versions is installed:

.NET Core Runtime or .NET Core Software Development Kit (SDK), version 3.1 with long term support (LTS) is recommended.
.NET Framework 4.8 Runtime or Development Pack
.NET 5 Runtime or SDK

The application uses different file formats and APIs summarized in the following list:
REST-full API: the interface of the web service provides HTTP+JSON endpoints
JSON files as input and output configuration
CSV files as simulation data report

Owner (organization)

Fraunhofer Institute for Machine Tools and Forming Technology (IWU), https://www.iwu.fraunhofer.de/

Documents

Online repository of the source code, licenses, API and user documentation:
https://github.com/adriansinger87/d3vs1m

IIOT Network fallback simulation

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

This module provides the simulation environment d3vs1m in order to simulate the network behaviour, specified with the IIoT Network Device Positioning, and a selected cyber-attack scenario. It takes properties of the mobile radio devices as input and simulates the network behaviour and the energy consumption of battery-powered devices. Depending on the simulation setup, the user gets the adapted network behaviour with an applied fallback strategy to block or mitigate the simulated cyber-attack.

Technical specifications

Processor – 1 GHz
RAM -512 MB
Disk space (Minimum)
32-bit – 4.5 GB
64-bit – 4.5 GB

Inputs and outputs

Inputs:
JSON configuration files
OBJ files (Wavefront) as 3D environment

Outputs:
JSON files with meta information
CSV files as simulation data report
HTTP+JSON on web service

Formats and standards

The simulation modules are developed completely in C# and based on the .NET Standard 2.0. This can be seen as the contract to multiple target environments that can execute the application logic. The provided runtime may be installed on Windows, Linux, Mac or even mobile or industrial computers. The modules can be used on every system where one of the following runtime versions is installed:
.NET Core Runtime or .NET Core Software Development Kit (SDK), version 3.1 with long term support (LTS) is recommended.
.NET Framework 4.8 Runtime or Development Pack
.NET 5 Runtime or SDK

The application uses different file formats and APIs summarized in the following list:
REST-full API: the interface of the web service provides HTTP+JSON endpoints
JSON files as input and output configuration
CSV files as simulation data report

Owner (organization)

Fraunhofer Institute for Machine Tools and Forming Technology (IWU), https://www.iwu.fraunhofer.de/

Documents

Online repository of the source code, licenses, API and user documentation: https://github.com/adriansinger87/d3vs1m

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 46: Rapid development, testing and validation of large-scale wireless sensor networks

1. Basic information

Name of demonstration

Rapid development, testing and validation of large-scale wireless sensor networks

Main objective

Showcase infrastructure as a service to help in factory digitalization process introducing predictive maintenance to non-digitalized factory.

Short description

The demonstrator showcases a factory digitalization solution bringing predictive maintenance to the non-digitalized factory while minimizing the costs and factory downtime by using infrastructure as a service approach. Using the infrastructure as a service the sensors necessary for predictive maintenance can be seamlessly integrated and validated in the factory. We are using the EDI WSN/IoT TestBed as infrastructure as service which provides the ability of large-scale sensor network deployment and additional debug features such as energy consumption monitoring etc.

Owner of the demonstrator

Institute of Electronics and Computer Science

Responsible person

Researcher Janis Judvaitis, HTTPS://WWW.EDI.LV/EN/TEAM/JANIS-JUDVAITIS_ENG/

NACE

J61.2 - Wireless telecommunications activities

Keywords

IoT, Factory digitalization, Predictive maintenance, Infrastructure as service.

2. Innovation

Potential users

Tech integrators, WSN/IoT R&D companies

Benefits for the users

Reduced cost: no need to buy expensive equipment etc.
Faster implementation: infrastructure as a service provides barebone technical implementation and software management tools leaving mostly business logic to be implemented.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The flexibility of experimentation for validation and finetuning: since no equipment is purchased this provides the factory management with complete information before making an investment and purchasing the digitalized solution as a standalone.

Minimal factory downtime: the installation of infrastructure does not require the installation of new wires, etc.

Innovation

In the factory not yet digitized, the complexity and cost of undergoing the digitization process is quite cumbersome. In the traditional way, this requires the acquisition of new equipment supporting the digitalized features leading to high costs in equipment purchase, human resource re-training with the new equipment and lost revenue due to downtime of factory while the upgrade process is undergoing.
The proposed solution tries to provide an alternative route of introducing digitalization in the factory still running the original equipment, thus completely avoiding all the previously mentioned downsides of factory digitalization.

Risks and limitations

Precise data: one of the main risks is the possibility to acquire precise enough data from external sensors about the state of the machinery used, thus limiting, or completely negating the possibility of predictive maintenance from the sensor data gathered. On the other hand, this solution allows validating this without making huge investments in infrastructure.

Technology readiness level

4 – Component and/or breadboard validation in laboratory environment

3. Exploitation

Sectors of application

Manufacturing.

Potential sectors of application

Manufacturing

Hardware / Software

Hardware:
WSN/IoT TestBed

WiFi

Software:
EDI WSN/IoT TestBed

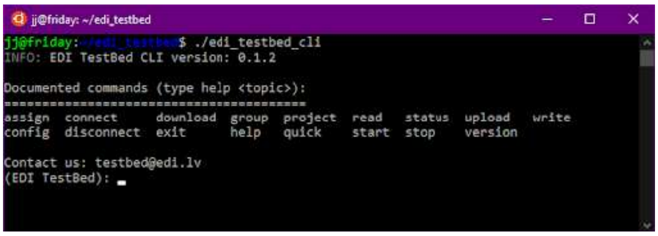
Trainings

Under development

4. Media

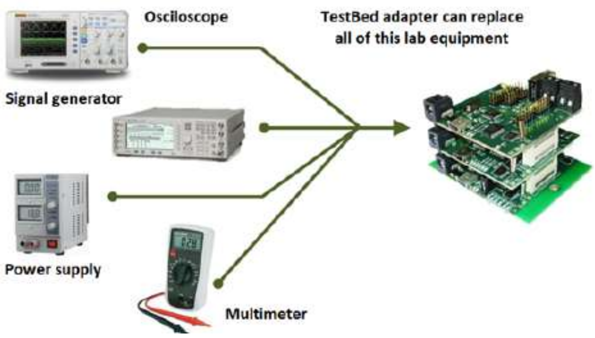
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Photos



Processor		
Processor Model	TI MSP430F2618	Texas Instruments MSP430 family
Memory	116KB 8KB 1MB	Program flash Data RAM External Flash (ST® M25P80)
ADC	12bit resolution	8 channels
Interfaces	UART, SPI, I2C USB	Serial Interfaces External System Interface (FTDI® FT2232H)
Radio		
RF Chip	TI CC2420	IEEE 802.15.4 2.4GHz Wireless Module
Frequency Band	2.4GHz ~ 2.485GHz	IEEE 802.15.4 compliant
Sensitivity	-95dBm typ	Receive Sensitivity
Transfer Rate	250Kbps	IEEE 802.15.4 compliant
RF Power	-25dBm ~ 0dBm	Software Configurable
Range	~120m(outdoor), 20-30m(indoor)	Longer ranges possible with optional SMA antenna attached
Current Draw	RX: 18.8mA TX: 17.4mA Sleep mode: 1uA	Lower RF Power Modes reduce consumption
RF Power Supply	2.1V ~ 3.6V	CC2420 Input Power
Antenna	Dipole Antenna / PCB Antenna	Additional SMA connector available for extra antenna

Sensors		
Light 1	Hamamatsu® S1087	Visible Range (560 nm peak sensitivity wavelength)
Light 2	Hamamatsu® S1087-01	Visible & Infrared Range (960 nm peak sensitivity wavelength)
Temperature & Humidity	Sensirion® SHT11	Temperature Range: -40 ~ 123.8ºC Temperature Resolution: ± 0.01(typical) Temperature Accuracy: ± 0.4 ºC (typical) Humidity Range: 0 ~ 100% RH Humidity Resolution: 0.05 (typical) Humidity Accuracy: ± 3 %RH (typical)



5. Modules

EDI WSN/IOT testbed

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

Management: remotely reprogram multiple sensor nodes simultaneously;
Communications: control serial communication with sensor nodes;
Experiments: start, stop and repeat experiments;
Monitoring: retrieve real-time and historical experiment data;
Asses: measure and record IoT device power consumption;
Test: simulate battery discharge for IoT device;

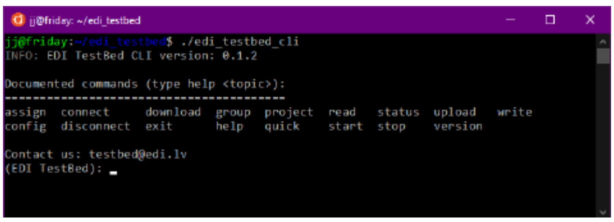
Technical specifications

For the default sensor node, we are using the Advanticsys XM1000 node based on widely adapted TelosB architecture. Of course, if the users need to attach their own sensor nodes to the TestBed it is possible using the USB connection. Different connection types are also possible, but they must be discussed individually.

Processor		
Processor Model	TI MSP430F2618	Texas Instruments MSP430 family
Memory	116KB 8KB 1MB	Program Flash Data RAM External Flash (ST M25P80)
ADC	12bit resolution	8 channels
Interfaces	UART, SPI, I2C USB	Serial Interfaces External System Interface (FTDI FT232BM)
Radio		
RF Chip	TI CC2420	IEEE 802.15.4 2.4GHz Wireless Module
Frequency Band	2.4GHz ~ 2.485GHz	IEEE 802.15.4 compliant
Sensitivity	-95dBm typ	Receive Sensitivity
Transfer Rate	250Kbps	IEEE 802.15.4 compliant
RF Power	-25dBm ~ 0dBm	Software Configurable
Range	~120m (outdoor), 20~30m (indoor)	Longer ranges possible with optional SMA antenna attached
Current Draw	RX: 18.8mA TX: 17.4mA Sleep mode: 1uA	Lower RF Power Modes reduce consumption
RF Power Supply	2.1V ~ 3.6V	CC2420 Input Power
Antenna	Dipole Antenna / PCB Antenna	Additional SMA connector available for extra antenna

Sensors		
Light 1	Hamamatsu S1087	Visible Range (560 nm peak sensitivity wavelength)
Light 2	Hamamatsu S1087-01	Visible & Infrared Range (960 nm peak sensitivity wavelength)
Temperature & Humidity	Sensirion SHT11	Temperature Range: -40 ~ 123.8 ºC Temperature Resolution: ± 0.01 (typical) Temperature Accuracy: ± 0.4 ºC (typical) Humidity Range: 0 ~ 100% RH Humidity Resolution: 0.05 (typical) Humidity Accuracy: ± 3 %RH (typical)

The interface for using TestBed is based on Python3 and implemented as a command-line interface, so it can easily be included in the existing workflow or IDE by scripting. The command-line interface enables users to access the full functionality of EDI TestBed. It is operating with high-level concepts of project and experiment, you can think of them as definition and instance accordingly. The system accepts precompiled binary files for sensor node reprogramming. Serial communication is bi-directional and can support string or binary information as necessary.



For IoT device control we are using proprietary TestBed adapter:
Modular design
Integrated USB hub

Currently three layers:
Control layer
Battery discharge and power measurement layer
Analog signal layer

Technical specification:
Power consumption: 4uA – 100mA
Noise ~35uA
Supply voltage: 0.8-4.8V
8 channel ADC/DAC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Inputs and outputs

The system accepts precompiled binary files for sensor node reprogramming. Serial communication is bi-directional and can support string or binary information as necessary. The system accepts commands related to experiment control as well as provides historical experiment data.

A PC capable of running a Python3 application with an internet connection is required.

Formats and standards

Google Protocol Buffers and gRPC for low level communication with EDI TestBed infrastructure.

Owner (organization)

Institute of Electronics and Computer Science (EDI)

Trainings

None

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 47: Artificial Intelligence Based Stereo Vision System

1. Basic information

Name of demonstration

Artificial Intelligence Based Stereo Vision System

Main objective

Detect, recognize and classify randomly distributed objects that are overlapping each other in a pile and pick them up by a robotic arm.

Short description

A lot of industrial processes involve operation with a large number of different objects with an arbitrary location. It is hard to automate these kinds of processes because sometimes it is impossible to predetermine the positions for these objects. To overcome this issue, we integrate 3D and 2D computer vision solutions with AI and robotic systems for object detection, localization and classification.

Owner of the demonstrator

Institute of Electronics and Computer Science

Responsible person

Researcher **Janis Arents** JANIS.ARENTS@EDI.LV

NACE

C – Manufacturing

Keywords

Robotics, Manufacturing, Computer Vision, Artificial Intelligence, Bin-Picking.

2. Innovation

Potential users

Tech integrators, SMEs

Benefits for the users

Implementing AI-based solutions can be effective in the manufacturing industry by improving process and product quality, reducing cycle time, decreasing costs and much more.
The use of AI-based stereo vision systems can reduce adjustment time, the complexity of the system and is more flexible to changes in manufacturing lines.

The AI-based stereo vision system of UC17 can be trained to detect and estimate the pose of different objects that are randomly distributed in a pile, therefore, enabling automation of industrial processes involving a different kind of objects with unpredictable positions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Innovation

Traditionally working with randomly distributed objects requires human resources or dedicated sorting hardware that usually is spacious, expensive and hardly adjustable if product assortment changes. The problem becomes more complex if different kinds of objects are mixed in one pile and need to be sorted and structured into determined position and orientation. The proposed system deals with this kind of uncertainty of the environment by use of AI-based computer vision system that can detect and estimate the pose of such objects. In combination with an industrial robot detected objects can be picked up and placed in a determined position.

Risks and limitations

This use-case demonstration has been built upon the Robot Operating System (ROS). The compatibility with different hardware depends on the ROS driver availability of the intended hardware, such as Industrial Robots and 3D cameras. The system has been tested with ROS supported hardware: Universal Robots UR5 industrial robot and multiple RGBD cameras, such as Intel RealSense, Kinect and Zivid.

Technology readiness level

4 – Component and/or breadboard validation in laboratory environment

3. Exploitation

Sectors of application

Manufacturing.

Potential sectors of application

Any environment that can use AI based computer vision for their benefit

Hardware / Software

Hardware:

Industrial robot

RGBD camera

ROS PC

Software:

ROS

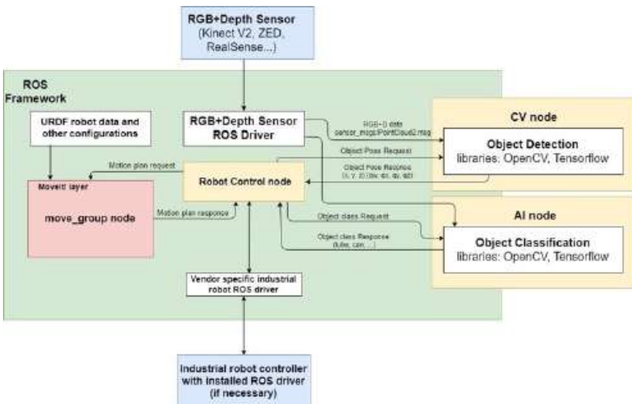
Trainings

Under development

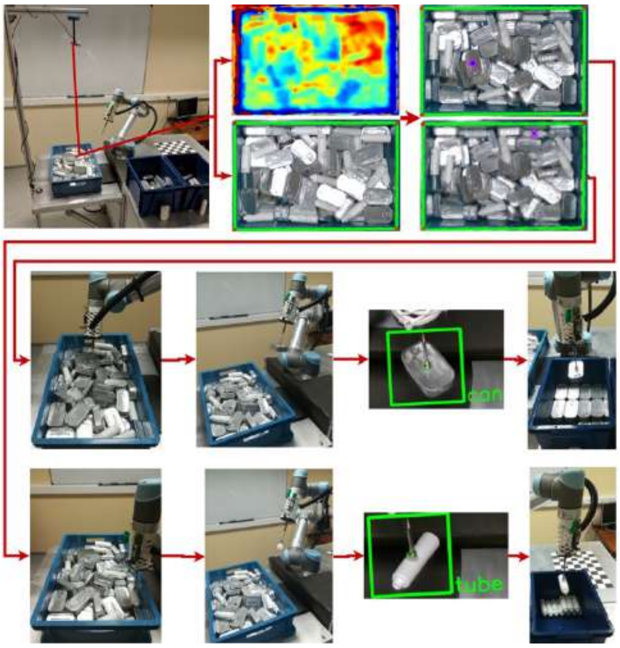
4. Media

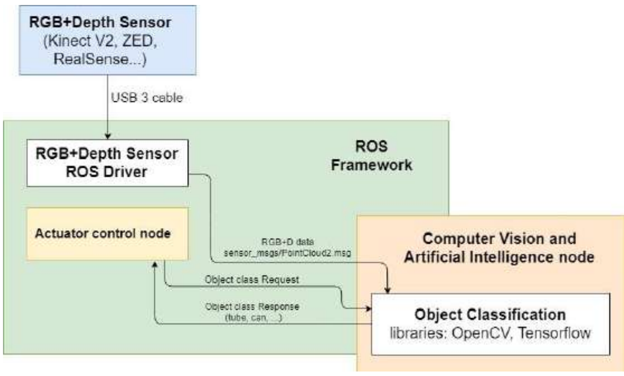
Photos

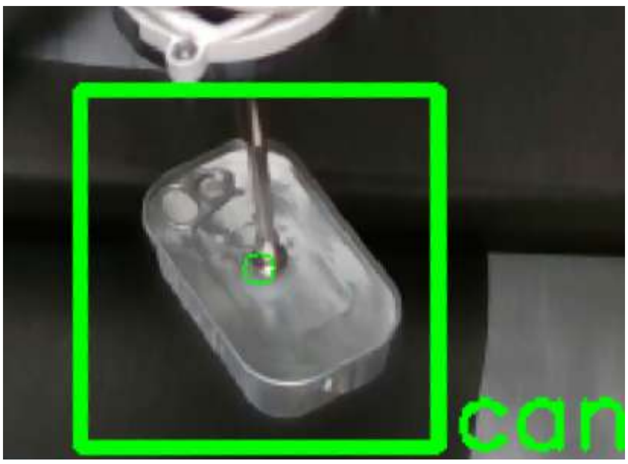
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



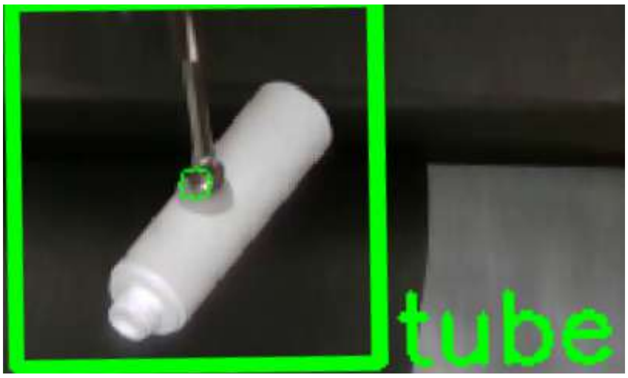
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

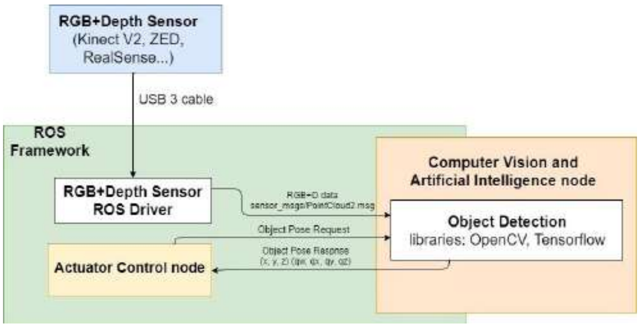






This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196





Video

[HTTPS://WWW.YOUTUBE.COM/WATCH?V=WSDU8GIZ6IK&T](https://www.youtube.com/watch?v=WSDU8GIZ6IK&t)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 48: Flexible Automation for Agile Production

1. Basic information

Name of demonstration

Flexible Automation for Agile Production

Short description

Highly flexible solutions for handling and clamping parts during the assembly process are needed to realize small lot sizes with a high variety. Flexible grippers and jigs are a possible solution. Requirements of different product types must be considered while planning, designing and constructing such systems. The main idea is to develop methods for planning workstations for assembly and handling processes. The use case demonstrator's task is the automated handling of electronic parts used for LED-lamp production and the assembly of printed circuit boards (PCB).

Owner of the demonstrator

LP-Montagetechnik

Fraunhofer Institute of Machine Tools and Forming Technology

Responsible person

Dr. Ing. Marcel Todtermuschke MARCEL.TODTERMUSCHKE@IWU.FRAUNHOFER.DE
Tel.: +49 371 5397-1301

NACE

C26.1 - Manufacture of electronic components and boards

Keywords

Robotics, Mechanical Engineering, Automation, Assembly, Process Planning.

2. Innovation

Potential users

Electronics industry, SMES/larger companies interested in automation

Benefits for the users

The higher degree of automation of the assembly process will result in various positive benefits. The rate of misplaced components will be reduced which results in a reduction of quality errors thus decreasing the amount of time spent on rework. Shifting manual process steps towards being handled by a robot allows the workers to focus on other assembly processes that are still too complex to automate for small batch sizes. This means that the increased automation can dispense with the monotonous work and, if necessary, night shifts at this workstation. Automating the assembly process supports to reduce the impact of a shortage of skilled production workers. The automated assembly process enables a better integration into

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

the factory's production control software, which improves the possibility to monitor and control the production processes and to react quickly to changes in orders, product variants and lot sizes.

Innovation

Whereas the assembly of surface-mounted devices (SMD) printed circuit boards is highly automated, through-hole-technology (THT) printed circuit boards are still being assembled manually for smaller and medium quantities due to its components having long and thin leads that have to be put through the PCB. The developed demonstrator, however, performs the automated assembly with THT components. The robot is able to remove components from different removal situations, e.g. precisely positioned parts from a blister pack, as well as completely unaligned parts in a box.

Risks and limitations

With the current design of the manipulation tool using a suction cup, it is not possible to automate the handling of all existing components due to their surface form. For other types of the gripper, such as parallel grippers, the available place on the PCB between components is not sufficient. Therefore, the components necessary for assembly have to be divided between the workers and the robot.

A possible risk is that the demonstrator's performance will not keep up with the worker's in the real production environment, thus increasing production times or the implementation effort of the demonstrator.

Technology readiness level

4 – Component and/or breadboard validation in laboratory environment

3. Exploitation

Sectors of application

Electronic Industry.

Potential sectors of application

Mechanical Engineering Industry

Hardware / Software

Hardware:

Kawasaki RS007LFF60

Camera

Ring light

Controller

Software:

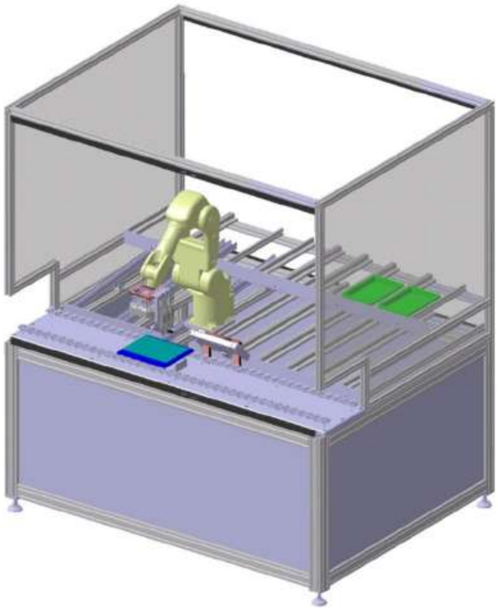
Keyence

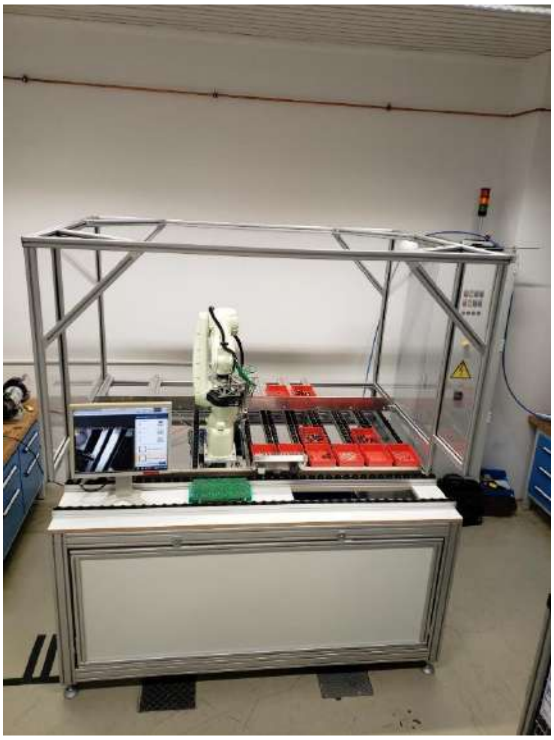
KR-Term

4. Media

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Photos





5. Modules

Handling and assembly

Main functionalities

This module provides a guideline on how to plan a workstation that has to perform handling and assembly actions. The example that is used for the guideline focuses on the gripping of small electronic components

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

with a universal usable robot gripper. The methodology, however, is applicable for the handling of other components, too. In order to plan such a workstation, a vast amount of aspects has to be considered beforehand, which makes the planning process complex and expensive. Due to the fact that changes during the planning phase are way less expensive than changes during the manufacturing phase or even afterwards during series production, the additional time spent during planning is worth it in the long run. To achieve the goal of a well-planned workstation, a vast amount of interdependencies between factors have to be identified and considered, such as component geometry, number of pieces, cycle times and so on. The results of the analysis are the selection of a suited stand-alone robot, the design of the gripping tool and the plant layout including required safety equipment for the desired application.

Technical specifications

To perform the handling and assembly tasks, a Kawasaki industrial robot of the Type RS007LFF60 is used. It is a high-performance variant with excellent repeatability, which is needed for the precise assembly task that it is going to perform. The Software KR-Term is used to access programmes that run in continous loops (i.e. image recognition) via the robot control. Adaptation of the robot‘s programmes are performed via the robot‘s operating panel or a separate computer.

Inputs and outputs

Inputs:
Budget framework / payback period
Variety of variants / range of components / batch sizes
Max. Workspace
Available sources
Fire and occupational safety regulations
Component’s delivery position
Can the component’s design be adapted according to the assembly strategy?
Weight, surface geometry, surface structure, material of components
Desired degree of automation, is human-robot-collaboration desired?
What is the aim of (re)planning? Reduce costs, increase output, save floor space, new environmental regulations, more / (significantly) fewer parts to be used, increased quality requirements, increase ergonomics, reduce shift work, etc.

Specific requirements: Clean room, explosion-proof, special requirements in food industry, use for medical products, and use of ESD parts, etc.
Which quality factors are to be tested?
Software interfaces, e.g. order database, quality assurance, control integration
Logistics requirements
Is it necessary to consider later adaptation of the system due to component changes?
Are upstream or downstream discontinuous processes present?
Is comparable plant technology already available?
Climate condition

Formats and standards

The factory pre-installed robot software from Kawasaki is used. To program the Kawasaki, the Kawasaki AS Language is used.

Owner (organization)

Fraunhofer Institute for Machine Tools and Forming Technology (IWU)

Trainings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

The training material and the complete float chart for the handling and assembly module are found at the TRINITY training platform: http://heinlein.mech.upatras.gr/trinity/handling-and-assembly-module/

VISION SYSTEM AND QUALITY ASSURANCE

Main functionalities

A vision system serves as an aid for detecting optically detectable features and converting them into data that can be easily processed further, e.g. as switching signals for controls or text for quality documentation. Therefore, an overview of the main aspects to consider when implementing a vision system in a production system are given in the following. This module is supposed to support the participant's process of selecting and implementing an appropriate vision system. Following the aspects in this guide, the planning of workstations and production systems can be improved and streamlined. In the following, an explanation is given for inputs that have to be considered in order to implement a vision system.

Technical specifications

The vision system consist out of the following components from „Keyence“: Camera CA-H500CX-MX, objective CA-LHR8, controller CV-X400 and ring light CA-DQP12X. The pre installed software of the manufacturer of the vision system Keyence is required for image recognition, image processing and for calculating the position correction. The Software KR-Term is used to access programmes that run in continous loops (i.e. image recognition) via the robot control.

Inputs and outputs

Inputs:

Presence of components
Presence of persons
Gestures of persons
Position/orientation of components
Colourfulness
Geometry
Object detection
Labels on components (text, QR codes)
Error detection (e.g. cracks)
Surface condition
Static or moving objects

Outputs:

Once all these preliminary considerations and boundary conditions have been made, the concrete system must be selected for its specific application. Due to the high dynamics in this field of development and the constantly improving evaluation algorithms, it is necessary to approach the relevant manufacturers of such products in order to get the most suited vision system. If the quality requirements are not too high, inexpensive cameras can usually be used, but most attention should be paid to the evaluation software. This software determines the performance of the entire system. Moreover, with many systems, separate lighting is important for an economical overall result. A distinction needs to be made between the incident light and transmitted light systems.

Formats and standards

Keyence image processing software is used for image recognition and processing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Owner (organization)

Fraunhofer Institute for Machine Tools and Forming Technology (IWU)

Trainings

Training material for the Vision System and Quality Assurance module are found at the TRINITY training platform: http://heinlein.mech.upatras.gr/trinity/vision-system-quality-assurance/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 49: Robotized Serving of Automated Warehouse

1. Basic information

Name of demonstration

Robotized Serving of Automated Warehouse

Main objective

The demonstration was created as a fully functional, scaled-down, table-top model of an automated warehouse served by an omnidirectional mobile robot to be used as an attraction in exhibitions. The goal is to demonstrate the feasibility of using omnidirectional mobile robots in intralogistics.

Short description

Agile manufacturing is one of the main trends in research and development nowadays. The TRINITY project aims to increase the agility of various manufacturing processes. This section describes the hardware and software infrastructure and requirements, furthermore, the available modules offered of the Use Case demonstration titled Robotized serving of automated warehouse of the TRINITY project. The demonstration incorporates existing automated ground vehicle (AGV) solutions and other emerging technologies widely used in intralogistics: for example, optical line following and visual serving of an omnidirectional mobile robot. The potential users are SMEs who are dealing with smart assembly involving mobile robots.

Owner of the demonstrator

Budapest University of Technology and Economics

Responsible person

PhD, András Czmerk CZMERK@MOGI.BME.HU
Levente Raj RAJ@MOGI.BME.HU

NACE

H52.1 - Warehousing and storage

Keywords

Robotics, Vision System, Logistics, Collaborative Robotics, Machine Vision.

2. Innovation

Potential users

Intralogistics, AGVs and AMRs

Benefits for the users

Possible benefits of the demonstration are applications with mobile robots, optical character recognition, target detection, and controlled maneuvering, as well as path tracking without compromising safety.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Furthermore, increased digitalization, new functionalities of systems, and increased efficiency. Applications based on this demonstration can optimize the traceability, speed, and accuracy of routine operations in warehousing and manufacturing.

Innovation

Autonomous guided vehicles, also known as AGVs, are often used in applications where material must be moved between facilities, covering distances greater than 300 meters. Mobile robots can also bring value in long distance applications if multiple inputs and output locations are required, especially if it's important to make changes during transportation. Autonomous mobile robots (AMRs) are a good solution for last-meter deliveries where flexibility is required.

Risks and limitations

The demonstration is a closed system with no need for access to the internet. Nevertheless, cybersecurity issues need to be taken into account to ensure the fluent and safe operation of the system in all conditions.

The setup consists of a laptop, a mobile robot (FESTO Robotino®), and an onboard Wi-Fi access point mounted on the robot. The mobile robot runs back and forth from the User to the Wending machine, serving the desired product. The elements of the setup are on top of a 2x2 m table. The User stands by the table and starts a delivery process by showing the desired product's card to the robot's camera.

Error! Filename not specified.
Technology readiness level

5

3. Exploitation

Sectors of application

Automated storage and retrieval systems , Automotive industry, Manufacturing.

Potential sectors of application

Training material is under development.

Patents / Licenses / Copyrights

Hardware / Software

Hardware:
Omnidirectional Mobile Robot

Pen Wending Machine

Microcontroller

FESTO Robotino®

Software:
LabVIEW™

Optical Character Recognition

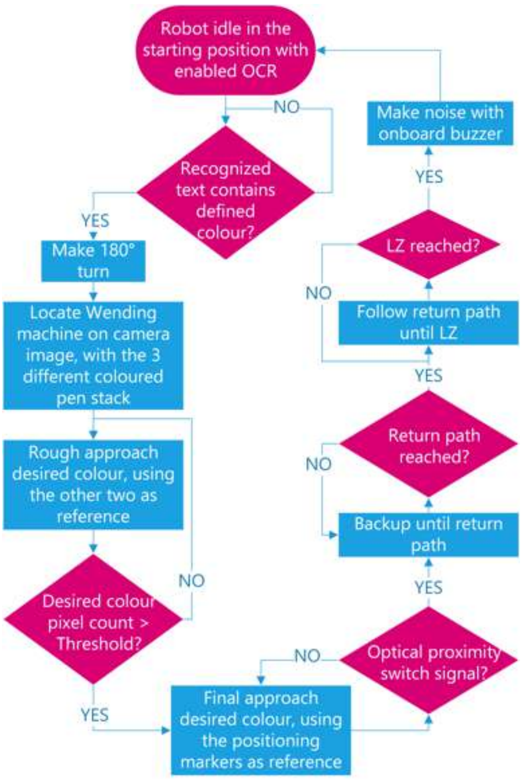
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Trainings

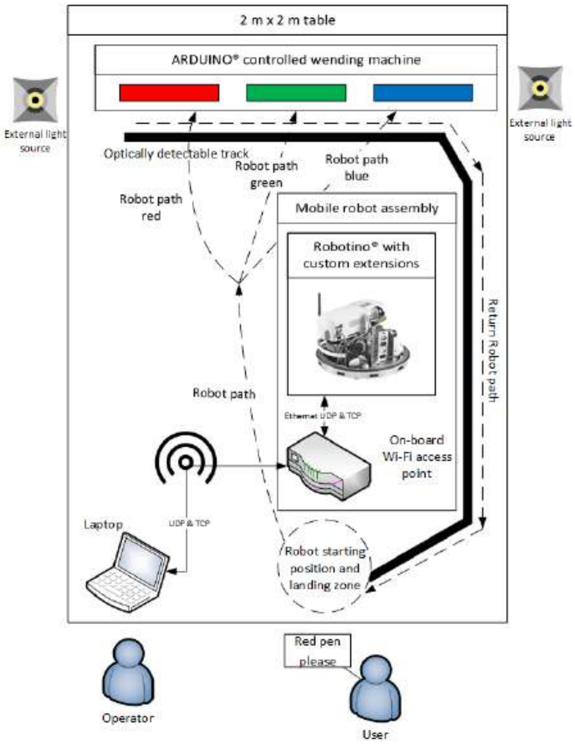
Training material is under development.

4. Media

Photos



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196



5. Modules

ENVIRONMENT DETECTION

Main functionalities

This module consists of three sub-modules, each performing different sensory tasks.
Optical character recognition (OCR): the main functionality of this sub-module is to recognize human-readable characters from images.
Object detection by chromatic discrimination: the main functionality of this sub-module is to detect objects on an image based on their color.
Optical line following: the main functionality of this sub-module is to implement movement algorithms along optically detectable tracks on the ground.
In case these sub-modules are in operation, i.e., the robot control software for the use case demonstration is operated by the end-user, then the end-user cannot perform any modification on these sub-modules because these sub-modules are parts of the robot control software. In case these sub-modules are included in another robot control software (developed by third-party SME), then a software developer can perform automated text recognition tasks, detect objects on an image based on their color and implement movement algorithms along optically detectable tracks on the ground, respectively.
The module is already available in source code and as a part of a standalone desktop application by contacting the authors of this description.
The module as a source code is available both for internal and external use.
The typical application scenarios for this module are the following:
• Automated text recognition,
• object detection,
• optical line following
• intralogistics.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Technical specifications

This module is created entirely with LabVIEW™ software. OCR is the process where the machine vision software recognizes text or characters in an image. This sub-module is based on the OCR template created with LabVIEW™ software and modified to recognize only the text appropriate for the task at hand. The sub-module uses a so-called Character Set File, in which the character templates are stored.

The Object detection by chromatic discrimination sub-module doesn't require any hardware. This sub-module uses the HSL color space and calculates the position (X and Y coordinates) of the center of mass of the group of pixels represented with the desired color on a camera image. The Optical line following sub-module requires the Festo Robotino® v2 mobile robot hardware equipped with 2 optical proximity switches.
The optical proximity switches should be mounted on the base plate of the Robotino®, facing downwards with relative distance between them matching the width of the track. The sensors should be connected to the DI0 and DI1 inputs of the input and output port of the Robotino®. The sub-module can operate on a bright floor with dark track and on a dark floor with a bright track also.

Inputs and outputs

OCR

- Inputs: grayscale image in JPG format, Character Set File, text to be recognized.
- Outputs: Recognized text in ASCII string format.

Object detection by chromatic discrimination

- Inputs: image, HSL parameters of the desired color, minimum number of pixels.
- Outputs: the desired color is found, the position of the center of mass, segmented image highlighting the group of pixels represented with the desired color

Optical line following

- Inputs: State of the optical proximity switches.
- Output: movement speeds for the Robotino®.

Formats and standards

The JPEG image format, ASCII string format, HSL color space representation is used in this module.

Owner (organization)

Budapest University of Technology and Economics

Trainings

Training material is under development.

MOBILE ROBOT MOTION CONTROL

Main functionalities

This module consists of two sub-modules, each performing different motion control tasks. Open-loop motion control: the main functionality of this sub-module is to perform different pre-programmed or time-controlled movement patterns.

Machine vision-based closed-loop motion control: the main functionality of this sub-module is to implement closed-loop motion control algorithms based on machine vision calculations executed on images.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

In case this module is in operation, i.e., the robot control software for the use case demonstration is operated by the end-user, then the end-user cannot perform any modification on this module since this module is part of the robot control software. In case this module is included in another robot control software (developed by third-party SME), then a software developer can implement movement algorithms using open-loop or closed-loop control.

The module is already available in source code and as a part of a standalone desktop application by contacting the authors of this description.

The module as a source code is available both for internal and external use. The typical application scenarios for this module are the following:

- Motion control of mobile robots.
- Intralogistics.

Technical specifications

This module is created with LabVIEW™ software.

The Open-loop motion control sub-module doesn't require any hardware. The Machine vision-based closed-loop motion control sub-module requires the Festo Robotino® v2 equipped with 3 optical proximity switches. Two optical proximity switches are the same optical proximity switches as in the Optical line following sub-module and one additional optical proximity switch is required to be mounted on the front of the Robotino® and connected to the DI2 input of the Robotino®. The Machine vision-based closed-loop motion control sub-module requires the Object detection by chromatic discrimination sub-module.

Inputs and outputs

Open-loop motion control

- Inputs: rotational and linear speeds, the amount of time while the module is executing.
- Outputs: movement speeds for the Robotino®.

Machine vision-based closed-loop motion control

- Inputs: image, HSL parameters of all objects to be detected, HSL parameters of the targeting markers, minimum number of pixels, DI0:3 inputs from the Robotino® (see 8.4.1. Figure).
- Output: movement speeds for the Robotino®.

Formats and standards

The JPEG image format and the HSL color space representation is used in this module

Owner (organization)

Budapest University of Technology and Economics

Trainings

Training material is under development.

Queued message handler software architecture

Queued Message Handler Software Architecture

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

The main functionality of the module is to organize the whole software in separate tasks (modules) and execute them in parallel at different execution rates.

This module is the interface between the end-user and other parts of the software. An end-user can operate the software through a user interface. The QMH template is useful for applications where multiple tasks occur in parallel, often at different execution rates, but the application requires a responsive user interface; that is, users should be able to click buttons even while the application is executing another command. The demonstration is available both for internal and for external use.

Technical specifications

The implemented Queued Message Handler is based on the Queued Message Handler Template software architecture, and it is custom-tailored for the Use Case demonstration. The complete software is made with National Instruments LabVIEW™ graphical programming language.

The QMH template facilitates multiple sections of code running in parallel and sending data between them. Each section of code represents a task, for example, acquiring, or processing data. Each task is designed similarly to a state machine. Because of this design, each task can be divided into states. The QMH template is a version of the Producer/Consumer design pattern, where the user interface (producer) produces messages and the tasks (consumers) consume them.

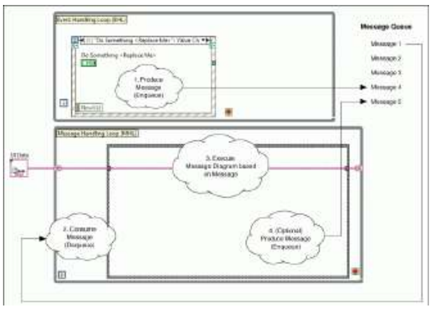


Figure Overview of the Queued Message Handler software architecture

The software can be used with any computer that complies with the LabVIEW™ system requirements . The demonstration in the prototype phase is already available in source code and as a standalone desktop application by contacting the authors of this description.

The software for the use case demonstration itself is free of charge, but if used as a source code, the LabVIEW™ software is to be purchased. If used as a standalone desktop application, no further purchase is required.

Inputs and outputs

No inputs and outputs are required.

Formats and standards

QMH design pattern was used as a standard.

Owner (organization)

Budapest University of Technology and Economics

Trainings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Training material is under development**.**

Robotino® communication

Main functionalities

The main functionality of the module is to communicate with the Robotino® . The Robotino® is a mobile robot platform for research and education developed by Robotics Equipment Corporation GmbH and distributed by Festo Didactic.

In case this module is in operation, i.e., the robot control software for the use case demonstration is operated by the end-user, then the end-user cannot perform any modification on this module since this module is part of the robot control software. In case this module is included in another robot control software (developed by third-party SME), then a software developer can implement algorithms for communication with the Robotino® using this module.

The typical application scenario for this module is to implement communication algorithms with Robotino®.

The demonstration is available both for internal and for external use.

Technical specifications

This module is an adaptation of the qDSA protocol of the API1 for Robotino® v2, made in native VIs for use with LabVIEW™ software without the need to call external code.
Hardware requirements of the module: Festo Robotino® v2 (Firmware 670, OS Date: 11.02.2011), Wi-Fi access point (AP) (factory standard accessory), UVC standard Webcam (factory standard accessory).

Figure Robotino® v2 mobile robot for education and research

The module consists of two continuously running parallel loops (tasks). One task is dedicated to the keep-alive type communication of the Robotino®, where the Robotino® continuously sends data to the host computer and expects data in response. The other task is the receiver of the camera images, continuously sent by the Robotino® if the camera is enabled.

The module is already available in source code and as a part of a standalone desktop application by contacting the authors of this description.

Inputs and outputs

Inputs:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

State of 8 digital outputs
State of 2 relay outputs
Motor speed set-points in RPM for each motor
Reset Position for each motor
Break for each motor
On-board PID controller parameters for each motor
Odometry (Position of the robot)
Set Odometry switch
Camera enable switch
Shutdown switch
IP address of the Robotino®
Constructional parameters of the Robotino®
Outputs:
State of 8 digital inputs
State of the collision detection switch
State of the power button
Sequence number of the communication
Readings of 8 analog voltage inputs
Current readings of each motor
Actual position of each motor
Actual speed of each motor
Actual Odometry (Position of the robot)
Readings of 9 IR distance sensors
Reading of the battery voltage
Is the Robotino® connected switch
Kinematics and inverse kinematics matrices of the Robotino®

Formats and standards

The qDSA protocol of the API1 for Robotino® v2 is used in this module

Training material

undefined

Owner (organization)

Budapest University of Technology and Economics

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 50: Digitalisation Of A Production Environment

1. Basic information

Name of demonstration

Digitalisation Of A Production Environment

Main objective

This demonstrator illustrates how to create a digital copy of a production environment. It will also show how robots and other machines can be connected and controlled from the same industrial information server.

Short description

Factories of the future will face increasing demands for non-stop production, accompanied with high flexibility and safety requirements. This implies an important future market, for instant services dealing with support, error diagnostics and reconfiguration of industrial robot systems. These advances can be achieved by utilizing IoT in every stage of the production process in a factory. Based on the collected data, decisions can be made even from distant locations.

Owner of the demonstrator

The Arctic University of Norway

Responsible person

Scientific fellow. M.Sc
Halldor Arnarson
Department of Industrial Engineering
UiT the Arctic University of Norway
HALLDOR.ARNARSON@UIT.NO

NACE

C33.2.0 - Installation of industrial machinery and equipment

Keywords

Simulation software, IoT, Digital twin, Remote control , VR robotic programming.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

2. Innovation

Potential users

Production systems, Factories

Benefits for the users

– The main benefits of the demonstrator revolve around increased flexibility by digitalising a production environment and connecting robots and other machines together.
– A digital twin can be used for testing, validating, and refining assumptions, which leads to …
– Data from a production system can give an enhanced insight into the performance of the system for improved visualisation.
– It creates a unified method for robot programming which simplifies and standardises the procedure of robot programming. Which again creates a friendly and simple environment for training of employees.
– The system is made to be flexible and scalable, where robot arms, mobile robots and other machines can be added or removed to the IoT system without compromising the current system.
– The use case creates an agile method for connecting robots and other machines together through a standardized industrial information server (OPC UA standard).

Innovation

This demonstrator allows for machine-to-machine communication which allows for collaboration between robots and other machines from different brands. Instead of going to each robot controller and programming the robots separately. This demonstrator creates a unified method of robot programming, as well as using new methods for programming.
A digital model of a production environment can be used for optimisation and modification of the environment.

Risks and limitations

- Some robots have closed system and don't allow for control from an external computer. This demonstrator requires an open robot controller.
- Since robots are connected through the internet, extra work and consideration on cybersecurity should be done.
- The mobile robot used to scan the production environment does not have the highest accuracy and therefore the digital twin module does not produce the highest accuracy.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Aerospace, Automotive, Manufacturing, Supply chain and logistics.

Potential sectors of application

Production and Healthcare

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Patents / Licenses / Copyrights

The module is made for the purpose of providing a proof-of-concept. The designed structure, upsetting, and its associated files are free of charge for internal and external use during the project period. The software and other related files are under the standard MIT license: Copyright 2021 The Arctic University of Norway (UiT) Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions: The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software. THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

Hardware / Software

Hardware:

Industrial robot

Robot arm

External computer

Software:

Visual Components premium 4.2

OPC UA

Visual Components Experience

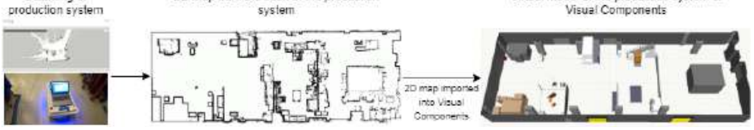
Steam VR

Trainings

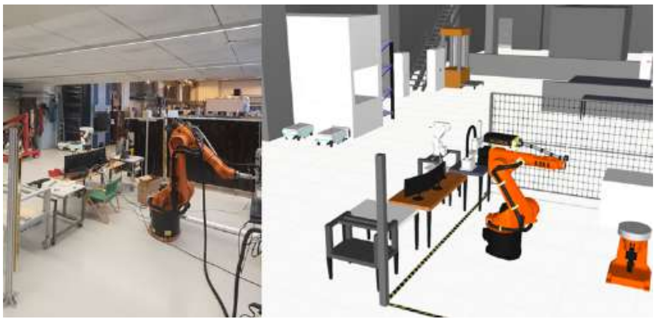
The training material is under development: http://heinlein.mech.upatras.gr/trinity/use-case-6/

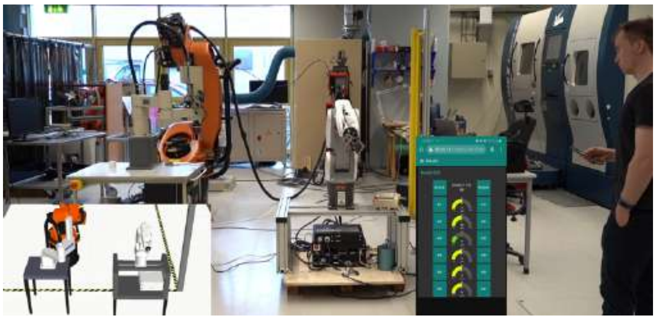
4. Media

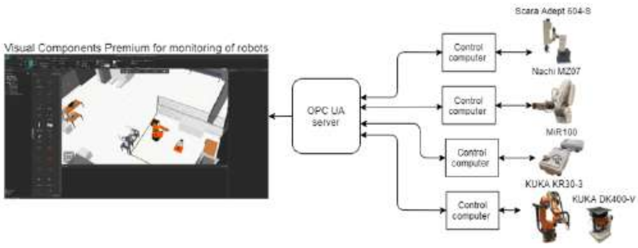
Photos



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196







Video

Demonstration video 3of the use case

HTTPS://WWW.YOUTUBE.COM/WATCH?V=ZNG89UHOR4C

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 51: Automated Robotic Welding

1. Basic information

Name of demonstration

Automated Robotic Welding

Main objective

The objective of the demonstrator is to showcase how an industrial robot can be used for robotic welding and wire arc additive manufacturing (WAAM).

Short description

The industrial robot has an important role in the automation of the manufacturing industry and has considerably contributed to the improvement of profitability and working environments. However, there are still many tasks in the manufacturing industry that requires heavy work, such as welding and additive manufacturing based on welding.

Owner of the demonstrator

The Arctic University of Norway

Responsible person

Scientific fellow. M.Sc
Halldor Arnarson
Department of Industrial Engineering
UiT the Arctic University of Norway
HALLDOR.ARNARSON@UIT.NO

NACE

C25.1.1 - Manufacture of metal structures and parts of structures

Keywords

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Wire Arc Additive Manufacturing, WAAM, Additive manufacturing with industrial robot, Robotic welding, IoT.

2. Innovation

Potential users

Manufacturing Industry, Automotive and Aerospace Industry

Benefits for the users

– The demonstrator exploits an industrial robotic arm to automate repetitive welding jobs that result in more consistent welds and fewer mistakes.
– Remote programming of the system (offline programming). This allows for verification of the welding program before running it on the physical robot and you can program the system without interrupting the current production which can save costs.
– Using robotic welding releases humans from the labor-intensive and hazardous work environment.
– The system can be used for additive manufacturing, to repair broken parts or 3D print parts. This can be a fast and cost-effective method to create or fix damaged parts.

Innovation

Robots are usually programmed with a robot controller and the physical robot to teach positions. This demonstrator uses a simulation software as a programming tool and a digital twin copy of the physical robot for robot programming.

The system allows for remote programming and configuration without being physically in the production environment. This creates a flexible method for re-programming and the possibility to test the program in the simulation software before executing it on the physical system.

Risks and limitations

- Welding induces a lot of stress on the welded part. This has to be considered when using the system for additive manufacturing with a TIG welder.
- Since robots are connected through the internet, further consideration on cybersecurity should be done to avoid cyber attacks.
- Using TIG welding for additive manufacturing produces considerable heat, which requires a lot of cooling.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Aerospace - the parts created from the demonstrator have strong features, Automotive - the demonstrator has significant use as a single car can require thousands of welds in assembly, Manufacturing - performing repetitive work which can easily be automated with a robotic welder, Petroleum industry - welding oil and gas pipelines.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Potential sectors of application

3D printer for Aerospace and Automotive industry

Patents / Licenses / Copyrights

The module is made for the purpose of providing a proof-of-concept. The designed structure, upsetting, and its associated files are free of charge for internal and external use during the project period.

The software and other related files are under the standard MIT license: Copyright 2021 The Arctic University of Norway (UiT) Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions: The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software. THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

Hardware / Software

Hardware:
KUKA robot

Software:
Visual Components Premium

OPC UA

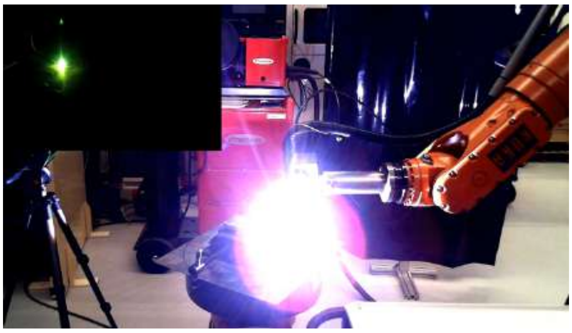
Python

Trainings

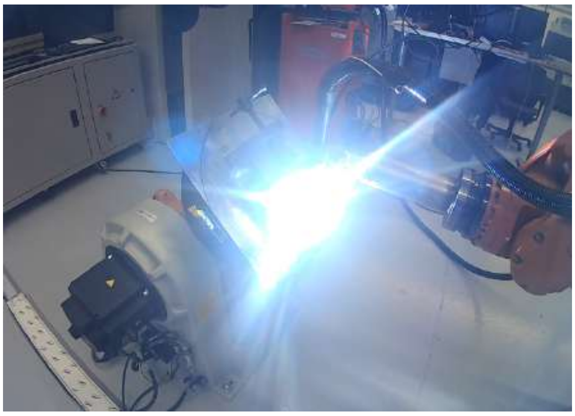
The training material is under development: http://heinlein.mech.upatras.gr/trinity/use-case-5/

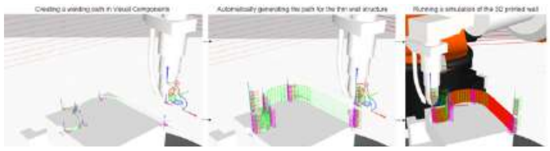
4. Media

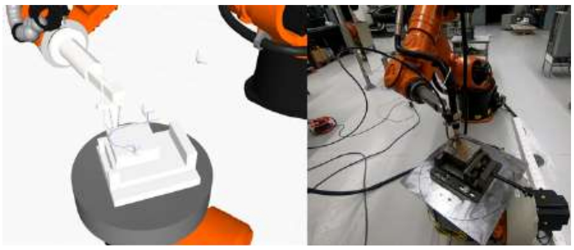
Photos



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196







5. Modules

Additive tig welding

Main functionalities

The module uses a KUKA robot to perform metal additive manufacturing of thin wall structures using TIG welding. It uses the simulation program Visual Components as a programming interface and allows for advanced programming functions/commands to be executed on the KUKA robot and rotary table.
The program works by first creating a robot movement in Visual Components. From the movement, multiple layers are automatically generated with a specific height increment and number of layers. This creates a program that can be executed on the KUKA controller to weld thin-wall structures. The movement can be created with either a liner, point to point or path movement.

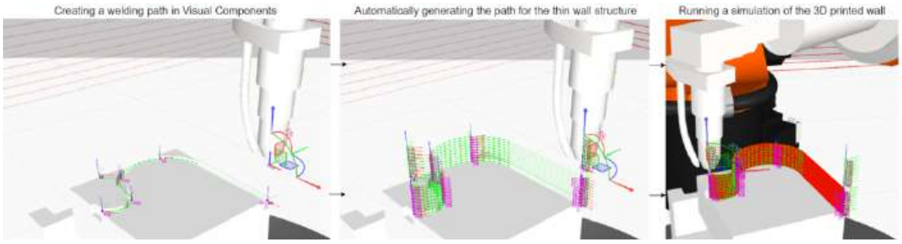
Benefits of the system:
Flexible system for 3D printing of metal parts
TIG welding has fewer metal properties requirements comparing to MIG welding. (TIG welding supports two different metals welding)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Can create thin-wall structures welding
Being able to repair parts (ex: broken gear wheel) (coming very soon video demonstration).
Significant cost-saving due to, i.e., reduced material used, reduced production time and reduced number of parts in assembly.

Technical specifications

The system consists of an industrial KUKA Robot and a rotary table coupled to the same KUKA controller (KR C2). A Fronius MagicWave 5000, a completely digitized TIG welder, is connected to a PLC and then to the KUKA controller as shown in Fig 1. With the KUKA controller It is possible to set welding parameters and control the welding machines. For this reason, the system is setup with an external computer connected to the KUKA controller, which can control the KUKA robot, rotary table and welding equipment in real time.
To be able to generate the path, Visual Components premium is required.
Visual Components is used to generate a path for the first layer. A python script replicates the first layer with a specific height increment and number of layers.



How the 3D structure is generated in Visual Components

Inputs and outputs

Input: Input the welding plate and program the robot and rotary table movement in Visual Components.
Output: A 3D printed thin wall structure

Formats and standards

Visual Components Premium 4.2 (simulation/programming tool), OPC UA standards (Connecting robot and simulation software), translator from Visual Components to the robot and rotary table (made in Python) and KUKA controller with the Robot Sensor Interface (RSI) add-on for real time control of the robot and rotary table.

Owner (organization)

The Owner of the demonstrator is: The Artic University of Norway (UiT) https://en.uit.no/startsida
The Arctic University of Norway is a medium-sized research university that contributes to knowledge-based development at the regional, national and international level. UiT is the third largest university in Norway and northernmost university in the world. UiTs study portfolio covers all classical subject areas from Health Sciences, Social Sciences, Education and Humanities, Science and Technology to Economics, Law, Social Work, Tourism, Sports and Fine Arts. While the key research areas cover the polar environment, climate research, indigenous people, peace and conflict transformation, telemedicine, medical biology, space physics, fishery science, marine bioprospecting, linguistics and computational chemistry.

Trainings

The training material is under development.

Simulation welding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Main functionalities

The main functionality of the module is to use a simulation software to program a welding path by creating a connection between the simulation software (Visual Components), the industrial robot and rotary table (KUKA).

The system works by having a translator between the simulation software and the industrial robot. The translator takes the data from the simulation and uses the data to control the robot with the parameters from the simulation software.

Benefits of the module:

Creates a simple method for re-programming and configuration of the welding system

Offline testing of welding program

Verification of welding program before running it on the physical robot.

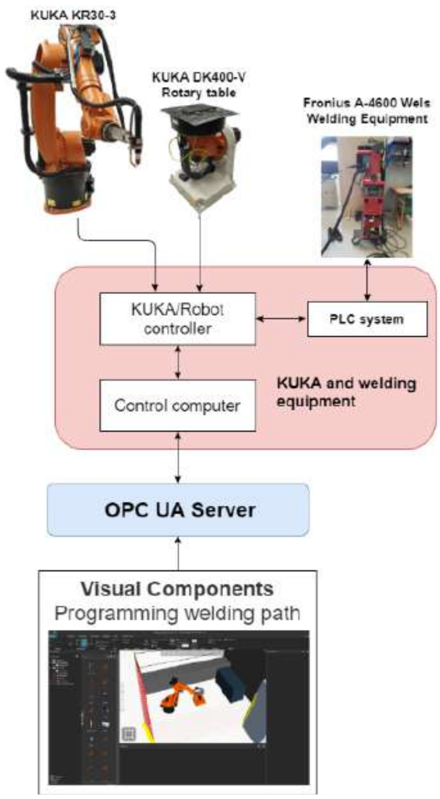
Being able to program the robot while not being in the production environment. Remote programming.

Monitoring of the system

Release humans from labor-intensive, heavy work, or hazardous work environments.

Technical specifications

The system consists of an industrial KUKA Robot and a rotary table coupled to the same KUKA controller (KR C2). A Fronius MagicWave 5000, a completely digitized TIG welder, is connected to a PLC and then to the KUKA controller as shown in Fig 1. With the KUKA controller It is possible to set welding parameters and control the welding machines. For this reason, the system is setup with an external computer connected to the KUKA controller, which can control the KUKA robot, rotary table and welding equipment in real time.



How the 3D structure is generated in Visual Components

Inputs and outputs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Inputs: The robot and rotary table are programmed in Visual Components to generate robot motion data. Output: Data to the KUKA robot, rotary table and welding equipment.

Formats and standards

Visual Components Premium 4.2 (simulation/programming tool), OPC UA standards (Connecting robot and simulation software), translator from Visual Components to the robot and rotary table (made in Python) and KUKA controller with the Robot Sensor Interface (RSI) add-on for real time control of the robot and rotary table.

Owner (organization)

The Owner of the demonstrator is: The Artic University of Norway (UiT) https://en.uit.no/startsida
The Arctic University of Norway is a medium-sized research university that contributes to knowledge-based development at the regional, national and international level. UiT is the third largest university in Norway and northernmost university in the world. UiTs study portfolio covers all classical subject areas from Health Sciences, Social Sciences, Education and Humanities, Science and Technology to Economics, Law, Social Work, Tourism, Sports and Fine Arts. While the key research areas covers the polar environment, climate research, indigenous people, peace and conflict transformation, telemedicine, medical biology, space physics, fishery science, marine bioprospecting, linguistics and computational chemistry.

Trainings

The training material is under development.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 52: Integrating digital context to the digital twin with AR/VR of the robotized production

1. Basic information

Name of demonstration

Integrating digital context to the digital twin with AR/VR of the robotized production

Main objective

To showcase the use of digital context data in manufacturing. Integration of robot trajectory data into product design provides an agile way for automating manufacturing processes and speeds up the design-production timeline. Complete VR/AR environments can be built and used for flexible monitoring, support, training, safety and maintenance.

Short description

The use case demonstrates the possibilities for utilizing digital context data into production of manufacturing companies, which provides an agile way for automating manufacturing processes. The use case involves utilizing BIM, VR/AR technology and a digital twin of a robotic production cell. These methods can be used for flexible monitoring, operational support, training, safety and maintenance purposes of the production cell.

Owner of the demonstrator

Centria University of Applied Sciences

Responsible person

Senior Research Scientist Sakari Pieskä
SAKARI.PIESKA@CENTRIA.FI Tel.: +358 44 449 2564

NACE

C28.2 – Manufacture of other general-purpose machinery

Keywords

Virtual reality, Augmented reality, Digital twin, Automation, Digital design

2. Innovation

Potential users

Robot and automation integrators, Manufacturing companies, SMEs providing or utilizing augmented reality interaction

Benefits for the users

Design-to-production time reduction: shortening of product's design-production time span in manufacturing by introducing advanced product design e.g. robot trajectories to digital models already at the design phase.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Operational information: digital twins provide information of the real world enabling advanced monitoring if the system is performed as designed. Additionally, digital twins allow information flow from the real world to the digital allowing to update digital models if necessary. In addition, AR allows flexible and agile maintenance.

Advanced training: operational and safety training can be performed safely in virtual environment with the presence of instructor. Challenging conditions such as fire, toxic gas, dust, smoke etc. can be safely simulated in virtual environment.

Advanced risk assessment: Using virtual models of fully functional robot cells, risk assessment can be performed safely including visual inspection of robot cells, precise distance measurement, and testing of safety equipment.

Innovation

The use case innovates the existing product design capabilities along with robot maintenance and operational training measures by utilizing digital twins and AVR models in the production and robot integration. The use of digital twin and virtual environment of robot cells provides a safe, easily adaptable environment for the precautionary risk assessment in the integration phase, or for the operational and safety training on the robot cell tending. For example, as a result of a virtual environment training, newly trained operators will:

– learn to operate machinery in a safe and efficient way,
– learn to react proactively and safely to tasks that require a human interaction, and
– receive concrete information on safety measures in the robot cell (safety devices, first aid kits etc.).

The use case also innovates the product design during the design phase of new workpieces. A product design engineer can include the robot trajectory data into the product data at an early product design, and this information can be used by production engineers for robot programming at the production starting phase. This reduces the design-production time and leads to less faulty workpieces at the starting phase, which both lead to more agile robotized production and increased productivity.

Risks and limitations

Lack of incompatible specific software needed in integration may be a limitation.

Technology readiness level

6 – Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

AUTOMOTIVE INDUSTRY, CONSTRUCTION, ELECTRICAL AND ELECTRONIC ENGINEERING INDUSTRIES, FOOD AND DRINK INDUSTRY, HEALTHCARE INDUSTRIES, MARITIME INDUSTRIES, MECHANICAL ENGINEERING, SPACE INSUTRY.

Potential sectors of application

EDUCATION

Patents / Licenses / Copyrights

Digital Design Content Based Robot Trajectory Generation: Usage of module is free excluding SolidWorks, Unity, Vuforia and RoboDK which are commercial software and licensing has to be negotiated with them.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Blender is released under GPL.

Other software developed at Centria is released under MIT license.

Hardware / Software

Hardware:

Virtual reality headset: e.g. HTC Vive includes base stations to track user movements in a real environment and hand-held controllers for user interaction. These devices together with a VR platform enable a full VR experience.

Indoor positioning system: e.g. Quuppa Intelligent Locating System. This can be utilized to improve the safety of robotized environments by tracking either mobile robots or people in the environment.

Software:

Simulation and programming framework: e.g. RoboDK. A developmental platform for industrial robot offline programming and simulation. RoboDK includes support for an online connection of robot systems and connection to SteamVR platform.

VR software: e.g. SteamVR. Publishing and distributing platform for VR software providing a connection between VR software and hardware.

SolidWorks: a solid modelling computer-aided design and computer-aided engineering utilized to include information needed for robotized production to digital design content.

Unity: game engine for building AVR-experiences on multiple platforms.

Vuforia: augmented reality software development kit. Key features of Vuforia include real-time 3D object detection and planar surface design tools, which in combination with AR equipment may be used in AR environment for design and manufacturing purposes.

Blender: free and open-source 3D computer graphics software utilized for building and modifying 3D-model files for Unity.

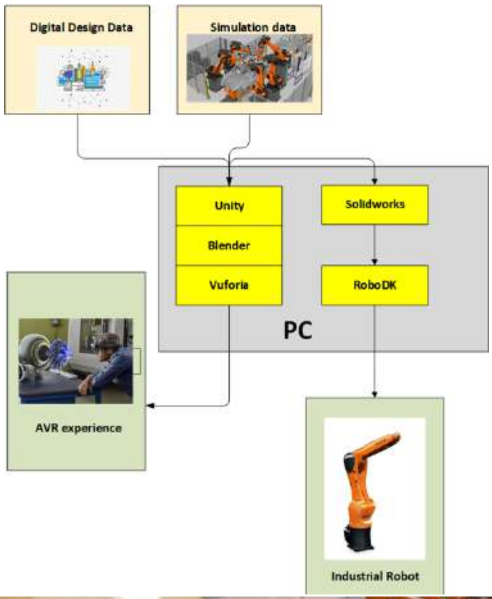
Trainings

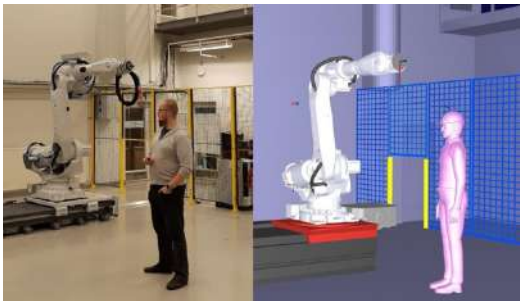
Online training material is available through the TRINITY training platform that contains separate training material for use cases and modules.

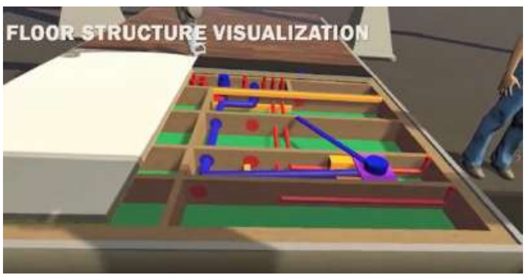
4. Media

Photos

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

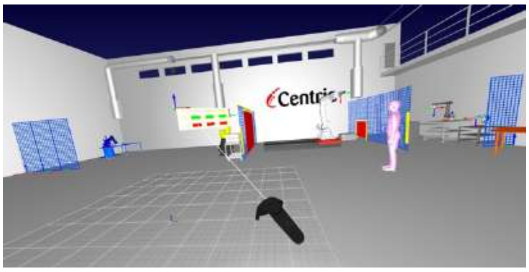


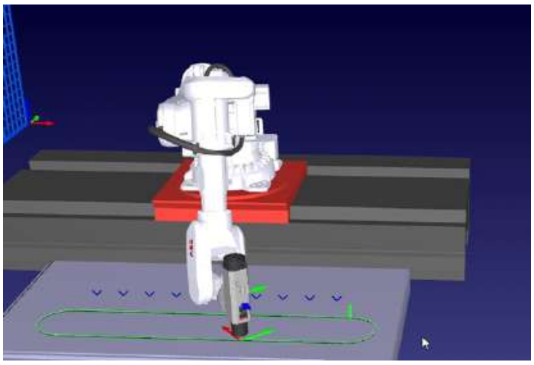




This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

trinity





5. Modules

Robot trajectory generation based on digital design content

Main functionalities

Speeding up robot simulation and programming: by using data from digital design data, such as Building Information Model (BIM). Utilizing digital design information for robot simulation and offline programming. Existing digital design data from a CAD model can be utilized to generate trajectories for robotized tasks such as milling at an early phase of development, which shortens design-to-production time and, in turn, significantly eases integration of new workpiece production.
Rapid AR/VR models: utilizing design data to create AR/VR models. The goal is to speed up the creation of AR/VR models or virtual twin models by using data from the digital design data. This module can be utilized in training, safety and production planning purposes.

Technical specifications

Hardware:
HTC Vive or similar virtual reality headset
Desktop PC with Windows 10
Sufficient hardware for VR applications

Software:
RoboDK
SolidWorks or similar CAD software
Unity
SteamVR

SolidWorks or similar CAD software is used to integrate robot trajectory data into the product's design data, which is preserved in the form of curves or points. This data can then be utilized in robot simulation or offline programming in a robot simulation or programming framework such as RoboDK. Data can also

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

be utilized with Unity and SteamVR for creating AVR-experiences of production for training and marketing purposes.

Inputs and outputs

Inputs of this module are simulation data files and digital design data files provided in STL, STEP and BIM formats. These inputs can be utilized with 3D development platforms, such as Unity, Blender or Vuforia to create an AVR-experience for training purposes, or with RoboDK simulation software in order to create robot trajectories. Keypoints for robot trajectory generation can be integrated into the design data using CAD software such as Solidworks. Outputs of this module are robot trajectory files or AVR-executables.

Formats and standards

Digital design file formats: STL, STEP

Owner (organization)

Centria University of Applied Sciences https://tki.centria.fi/en

Trainings

Online training material is available through the TRINITY training platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Annex 53: Collaborative Robotics In Large Scale Assembly, Material Handling And Processing

1. Basic information

Name of demonstration

Collaborative Robotics In Large Scale Assembly, Material Handling And Processing

Main objective

Main objective of this use case is to demonstrate the possibilities of large-scale industrial robotics in collaborative tasks. This use case demonstrates a novel combination of safety sensors and additional devices that make true human-robot collaboration possible, while still following safety regulations and standards. In addition, dynamic and flexible robot trajectory generations are demonstrated.

Short description

An agile industrial robotization of a large-scale material handling, processing or prefabrication where robots and people will process components collaboratively is demonstrated. The working zone is monitored dynamically and information is provided to both parties: the human worker and robot. Different multimodal human-computer interaction methods are evaluated. This ultimately leads to more agile robotized production, where humans and robots may work together in tasks such as large-scale assembly, material handling and processing

Owner of the demonstrator

Centria University of Applied Sciences

Responsible person

Senior Research Scientist, Sakari Pieskä
SAKARI.PIESKA@CENTRIA.FI
tel.: +358 44 449 2564

NACE

C33.2 - Installation of industrial machinery and equipment

Keywords

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Industrial robot, Collaborative robot, Robot safety, Robot trajectories.

2. Innovation

Potential users

Robot and automation integrators: companies that program and deploy industrial robots for automated manufacturing tasks can use the demonstrated systems in realised robot cells. Companies dealing with large-scale materials: companies carrying out large-scale material handling, processing or component pre-fabrication. Typically the robot integration is bought as a service from the aforementioned operators.

Benefits for the users

Enhanced and dynamic safety: more flexible production and operations related to robotics.
Human-robot-collaboration: HRC using industrial size robots.
Saved space: smaller factory footprint and therefore lowered costs due to fenceless robot cells.

Innovation

Conventionally, industrial robots have been isolated by fences to prevent accidents and as a result, tasks involving large-scale workpieces and human interaction have been challenging to implement into robotized production. While still following regulations and standards, it is possible to implement safe fenceless industrial robot cells that allow a true human-robot collaboration. This demonstration is a novel combination of multiple safety-related sensors of which some are safety-approved and others are additional sensors increasing agility, flexibility and safety of the manufacturing process.

Risks and limitations

Lack of incompatible specific software needed in integration may be a limitation, especially for aged industrial robots. Every robot needs a safety software (e.g. ABB SafeMove, KUKASafety) to assure safe and reliable operation. For aged industrial robots the modern software is not necessarily available.

Technology readiness level

6 - Safety approved sensors and systems are commercially available

3. Exploitation

Sectors of application

Construction, Mechanical engineering.

Potential sectors of application

Maritime industry and Automotive industry

Patents / Licenses / Copyrights

Individual HW components are commercial off-the-shelf products.

Usage of modules is free excluding AutoMAPPPS, which is property of Convergent IT.

CloudCompare is released under GPL.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Other software developed at Centria is released under MIT license.

Hardware / Software

Hardware:

Safety laser scanner: e.g. Pilz PSENscan or Sick S300 safety scanner for spatial robot cell safeguarding.

Microwave radar: e.g. Sick SafeRS microwave radar that operates in challenging industrial environment containing dust, smoke, darkness, steam etc. for person detection.

Indoor positioning system: additional safety system of RF tracking or other precise indoor positioning system such as Quuppa Intelligent Locating System.

360 camera: e.g. 360Fly as an additional safety system that together with artificial intelligence can be used for person detection.

3D point cloud creation hardware: 3Dcamera: e.g. 3D Kinect, Intel RealSense, Orbec or LIDAR or 3D Scanner e.g. PhotoXi or Artec Leo 3D Scanner. Used for robot trajectory generation

Software:

ROS and/or ROS-Industrial: dynamic trajectory programming

AUTOMAPPPS: reactive (online) robot trajectory programming

CloudCompare: 3D-point cloud processing

RoboDK: dynamic trajectory programming, robot programming in general, and simulation

CDS Config and diagnostic software: configuration and diagnostic software for SICK safety products

SICK safeRS Designer: configuring and diagnostics of safe radar sensor(s)

Quuppa Positioning Engine (QPE) or similar for indoor positioning: used to calculate tracking tag locations based on information tags are transmitting to the server

Custom software for other additional sensors: accessing and analysing data from 3D cameras, 360 cameras, LIDARS and 3D scanners. machine learning framework such as PyTorch

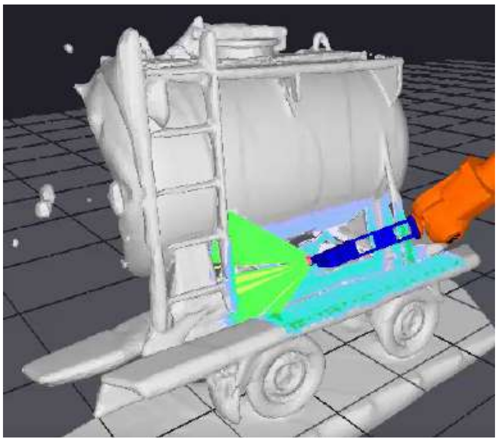
Trainings

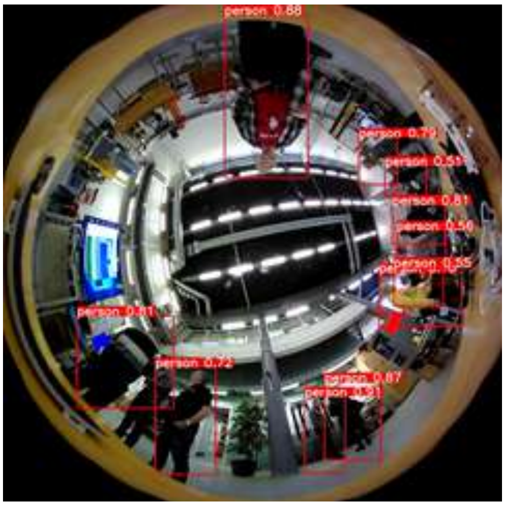
Online training material will be available through the TRINITY training platform that contains separate training material for use cases and modules

4. Media

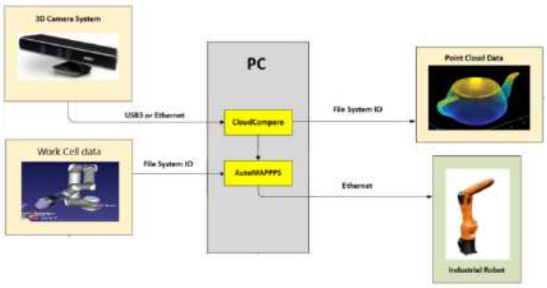
Photos

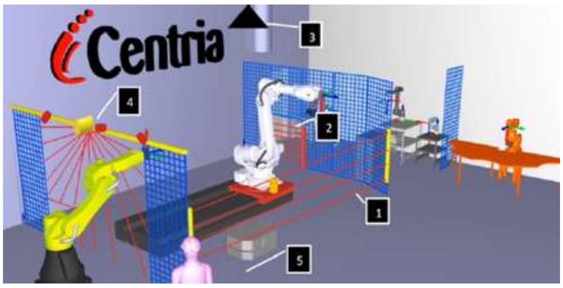
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196





5. Modules

Dynamic robot trajectory generation based on information from 3d camera

Main functionalities

This module provides a flexible and adaptive way to create robot trajectories dynamically based on point cloud data created automatically with 3D-camera. Module can be utilized in processing of work objects with varying physical characteristics to create robot trajectories dynamically for processes such as painting, sandblasting and pressure washing. Camera may be mounted onto the robot arm or installed in a stationary manner. Secondary functionality is to provide point cloud data of scanned object to be saved as 3D-model file.

Technical specifications

Hardware:
3D camera system (Microsoft Kinect V2, Intel Realsense D435)
A laptop/desktop computer with Windows or Ubuntu 18.04

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Software:
AutoMAPPPS
CloudCompare or similar point cloud data processing software
AutoMAPPPS is a family of robot programming software tools developed by Convergent Information Technologies GmbH. The software allows for fast computing of collision-free robot trajectories and program upload to robot controller for execution.
CloudCompare is a 3D point cloud and triangular mesh processing software. The software is originally designed to perform comparison between two dense 3D point clouds or between a point cloud and a triangular mesh. The software has since been developed suitable for more advanced point cloud processing, including algorithms for resampling, scalar fields handling and more.

Inputs and outputs

The input format is depth-map data provided by 3D-camera to CloudCompare and AutoMAPPPS in PLY format. This input data is used to generate a mesh model file of work object in STL or STEP format using CloudCompare, and dynamic robot trajectories are created using AutoMAPPPS.

Formats and standards

Point cloud and 3D model data formats: PLY, STEP, STL

Owner (organization)

Centria University of Applied Sciences https://tki.centria.fi/en

Trainings

Online training material is available through the TRINITY training platform.

Online trajectory generation with 3d camera for industrial robot

Main functionalities

this module provides depth-based real-time information of workspace for generating dynamic trajectories for the robot. The module offers a flexible and adaptive way of generating robot trajectories for human-robot collaboration based on information from 3D-camera(s). The module can be utilized in example with bin picking applications including workpieces with varying physical characteristics and random orientation. Another way of utilizing module is processing task including processing targets of varying locations in example assembly.

Technical specifications

Hardware:
3D camera (e.g. Microsoft Kinect V2, Intel Realsense D435)
A laptop/desktop computer with Ubuntu 16.04 – 20.04

Software:
ROS
ROS-Industrial
Packages for camera data processing and robot programming

3D cameras (or other peripherals that can produce a point cloud) are used to image/scan the object/scene. After scanning the data can be converted to point cloud and saved for later purposes or utilized online by AutoMAPPPS or ROS to create trajectories for robot.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

ROS (Robot Operating System) is a set of open-source software libraries and tools that simplifies complex robot tasks by using hardware abstraction, drivers, libraries and simplified process communication. ROS was originally developed to create a universal platform and user support base for manufacturer-independent robot programming.

ROS-Industrial extends the advanced capabilities of ROS software to industrial relevant hardware and applications, such as industrial robots and sensor data processing. ROS and ROS-Industrial together provide a high level of adaptability to a wide variety of robot manufacturers, which significantly eases project implementation on different device structures.

Inputs and outputs

Input of this module is RGB-Depth data provided by 3D camera to a suitable ROS module for camera data processing, such as depth_based_collaboration. This node recalculates robot trajectories if necessary, based on information provided by 3D-camera. Recalculation is needed, for example, if obstacles are placed in robot path or work piece is misaligned.

As output, the module provides calculated trajectories and translated program code for robot controller. The programming language depends on the manufacturer of the used robot. For example, KUKA robots run programs written in KRL and ABB robots run RAPID code. The resulting program code is directly transferred to the robot controller without user interaction using a ROS hardware interface module, such as kuka_eki_hw_interface

Formats and standards

File formats: KRL, PLY

Owner (organization)

Centria University of Applied Sciences https://tki.centria.fi/en

Trainings

Online training material is available through the TRINITY training platform.

AFE HUMAN DETECTION IN A COLLABORATIVE WORK CELL

Main functionalities

Creating safety areas: flexible and adaptive creation of dynamic safety areas is based on information from safety approved safety equipment such as laser scanners, microwave radars, and additional safety equipment such as RF indoor positioning and 360 cameras. The aim is to create a safe collaborative working cell for robots and employees performing tasks such as collaborative assembly. The hardware of the solution is based on off-the-shelf commercial components.

Technical specifications

The system consists of safety-approved systems and additional systems for increased safety. Any suitable combination for the application can be used. The system is able to observe/detect people around the robot cell and the robot can be controlled correspondingly. The robot can be slowed down or stopped depending of the distance from a human to the robot. The dynamic safety system can use laser scanners, light curtains, microwave radars, indoor positioning, and 360 cameras.

Inputs and outputs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196

Data from each sensor is transferred to the robot controller as a digital signal, which in configuration with the inputs on the industrial robot may be used to slow or stop the robot's motion, depending on the type of safety zone violation. The safety zones may be reconfigured as preset settings, which makes it possible to dynamically reconfigure safety solution combinations for different scenarios. The sensors also feature configurable inputs and outputs for basic functionality and interoperability.
SICK S300 Standard Series safety scanner, Pilz PSENscan, and SICK saferRS connect straight to appropriate inputs on robot controller or to a separate PLC. Safety scanners use different outputs for different signalling purposes, such as warning zone violations or lens contamination. These signals can be used in great variety, depending on the production cell's requirements. SICK saferRS safety radar sensors operate on two states: motion detected or motion not detected where the state information is transmitted

Formats and standards

ISO 10218-1:2011, Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
ISO 10218-2:2011, Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration

Owner (organization)

Centria University of Applied Sciences

Trainings

Online training material is available through the TRINITY training platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825196