Module name: Kinesthetic teaching of robot skills

- **Main functionalities**:

Traditional robot programming approaches require the user to guide and program the robot with its controlling interface. By handling either a touchscreen or a joystick, the user moves the robot to a desired position and defines the type of motion to that configuration. This method turns out to be relatively slow and requires a certain proficiency in robot handling. For these exact reasons, modern robots allow for kinesthetic guidance out of the box. Kinesthetic guidance proves to be a considerably more intuitive approach to move the robot during the programming phase.

- **Technical specifications:**

The robot has to be equipped with necessary sensing equipment which enables kinesthetic guidance, i.e. it should enable control in gravity compensation mode. Joint torque sensors or 6-D force-torque sensor mounted at the end-effector are also be beneficial for kinesthetic guidance.

Skill acquisition can be performed kinesthetically by guiding the robot to the desired configurations. A Graphical User Interface (GUI) is provided that facilitates this skill acquisition process. In the developed system, skills are saved in a MongoDB database available in ROS. Acquiring a news skill means making a new entry into the MongoDB database.

Button interface:

To accelerate the process of robot skill acquisition, we provide a custom-made plastic cover with buttons for one of the robot's joints (see Figure 1). The cover houses two buttons and two switchers. The latter have an LED showing their status (in the picture below the switch with the label 1 is turned on). These buttons and switches are programmable and their functions differ depending on the skill acquisition process.

Figure 1: The button interface

Graphical User Interfaces for Skill Acquisition**:**

There are two types of skill acquisition: Single Point Acquisition and Whole Trajectory Acquisition. The first one consists of storing a single point (either in joint or in Cartesian space) to be later used for generating point-to-point movements. The second one consists of acquiring a whole robot trajectory as a dynamic movement primitive (either in joint or in Cartesian space).

- **Inputs and outputs:**

none_Outputs_: the recorded positions and orientations or trajectories in either joint or Cartesian space stored in MongoDB.

Inputs: Trigger signals that mark the start and end of kinesthetic teaching are provided by the button interface. Positions and orientations are recorded (and computed using forward kinematics in case of Cartesian space data) from the robot's internal joint sensors.

- **Interface specification:**

Single Point Acquisition

When the GUI is launched, it assigns some functionalities to the custom-made button interface. At this point, the user should position the robot into the desired configuration and press _Button A_ (blue). A signal will be sent to the GUI indicating it has stored the current robot configuration (both in joint and Cartesian space) into a temporary buffer. The user should now decide if he/she wants to save either the joint or Cartesian space configuration with the Joint or Cartesian space radio button. The final step is writing the name for the database entry in the _Entry name field_ and pressing _Save_ to store the recorded data in MongoDB.
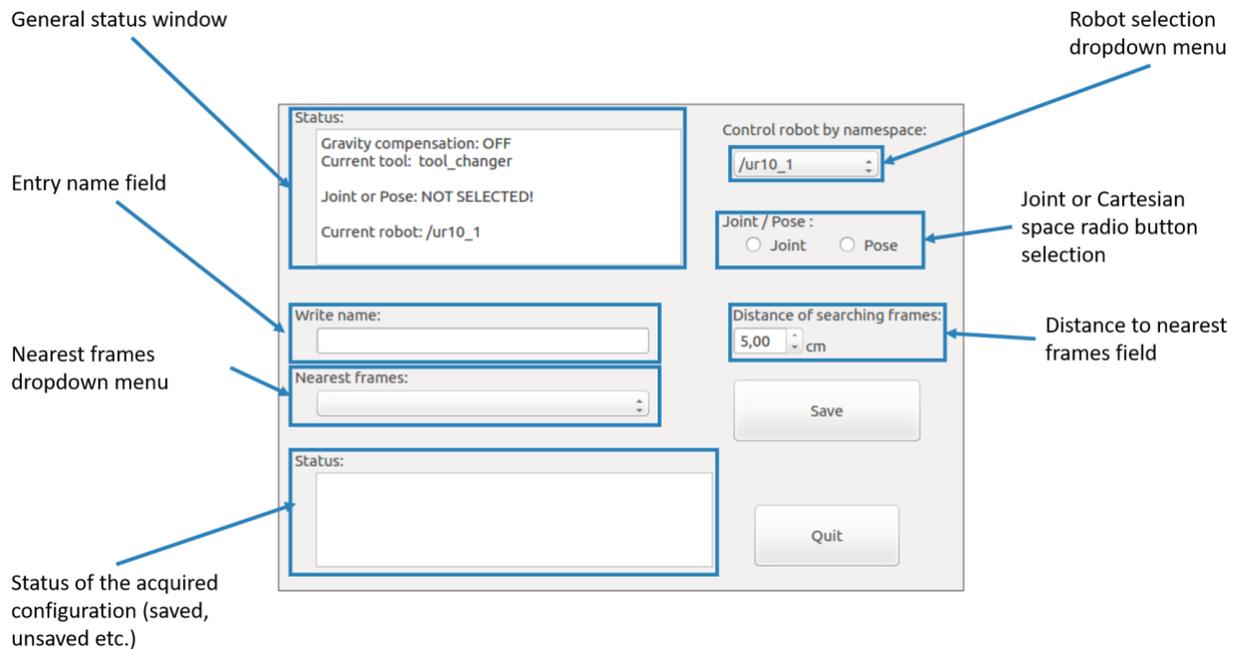

Figure 2: GUI for single point acquisition

Whole Trajectory Acquisition

When the GUI is launched, it assigns some functionalities to the custom-made button interface. This tool is meant to be used for recording whole trajectories during kinesthetic demonstrations. Before starting to move the robot, the user has to fill in the Topic selection field. This field should contain a string to a ROS topic of type _sensor_msgs/JointState_ or _geometry_msgs/PoseStamped.msg_, which

provide the data to record. If the type of the entered topic is adequate, the text will turn green, otherwise it will be red.
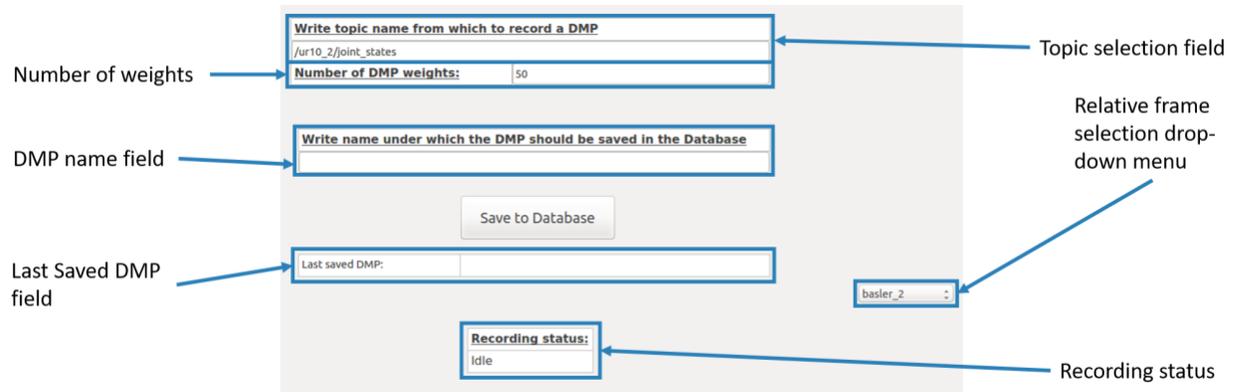

Figure 3 GUI for whole trajectory acquisition

Once the text is green, it means that the GUI has successfully subscribed to the topic. To record a trajectory, the user should first flip the *switch 1* and activate the Gravity compensation mode. The user can now guide the robot kinesthetically. When the user is ready to record a trajectory, she/he should simply flip the *switch 2*. The light on the switch will turn on which means that the robot trajectory is being recorded. The user should then move the robot along the trajectory she/he wants to record. When finished, flip the *switch 2* back so the light is no longer on.

The trajectory is now saved in a buffer. The user should now type the name under which she/he wants the trajectory to be saved in the database in the DMP name field. The trajectory is saved in the database after pressing the *Save* button in the GUI.

- **Formats and standards used**:

MongoDB database where the acquired data is saved, ROS-based robot control system, ROS topics, ROS services, ROS action servers, access to low-level robot control system.

- **Availability:**

The module is provided for UR-10 robots. It can be adapted to different robot systems that support control in gravity compensation mode.

- **Application scenarios:**

Teaching new motions and via points of a production sequence. Calibrating positions of workpieces in the cell. Modifying the existing trajectories.

- **Offered for internal / external use**

The Kinesthetic teaching of robot skills module is available for internal and external use.