

Towards an optimal method for teaching industrial assembly tasks using collaborative robots: teleoperation vs kinesthetic

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Introduction

Introduction

Within the industry 4.0, robots are increasingly exploited in production plants.

With the ambition to introduce robots into assembly lines the need to reconfigure the workspace requires faster modalities for robot reprogramming.

Introduction

Actually, in automotive industry, welding and painting tasks are already highly automated.

Instead assembly tasks are mainly performed manually today and they are absolutely repetitive and they can be constantly changed.

These tasks are mainly:

- pick and place
- peg into hole

Introduction

To facilitate reprogramming of robots, the new paradigm which is used more frequently is *PbD*: Programming by Demonstration.

Pbd is often used with collaborative robots that are installed in industrial environments.

It's a technique for teaching a robot new behaviors by demonstrating the task through a sequence of commands.

Goals

From *PbD* paradigm a comparison between two modalities was made to find the optimal method for teaching industrial assembly tasks.

The two modalities compared were:

- **kinesthetic teaching**: the robot is gravity compensated and the user physically guides the robot within his workspace
- **teleoperation teaching**: the user controls the robot with a **Ps4** pad

Before starting the work some research questions can be done:

- Which mode is preferred for ease of use?
- The two proposed approaches are said to be intuitive, but how much when they are used for assembly tasks in industry?
- There is a correlation between physical characteristics of the users and kinesthetic teaching?
- users who have familiarity with the pad are better teleoperation teaching?

The project

Setup overview

The KUKA LBR IIWA is a robot with collaborative features. It has a 14kg payload and an action range from 800mm to 820mm.

Moreover it has a media flange, with internal wiring that is helpful to attach a lot of different tools.

In our case the tool select is an electric parallel gripper with 2 self-centering two jaw with a total gripping force of 210N.

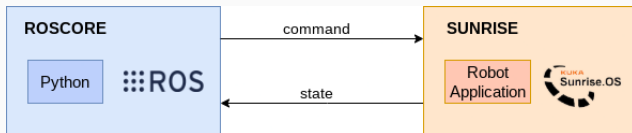


Setup overview

Usually the KUKA LBR IIWA is programmed using the KUKA's Sunrise Workbench platform and its Java API's.

Instead in this work an open source stack compatible with ROS has been uses.

It provides a Java Robotic Application that establishes a point to point connection via ROS to the machine connected via Ethernet to the robot cabinet.



Setup overview

The machine with ROS installed, will be able to send and receive ROS messages to and from the Robotic Application.

The robot can be controlled using Python, C++ or via commands sent from console.

Using ROS there are some functionalities already implemented as service, topic and action.

Project Implementation

One goal of the thesis is to evaluate different modalities to teach quickly and simply assembly tasks in industry.

For each of the two modalities a way to save waypoints and actions on the gripper has been implemented.

The actions were captured and saved in a .csv file. The sequence of waypoints and actions can be replicated by the robot.

Teach by demonstration

As described in introduction, teach by demonstration or also called kinesthetic is a way to move the robot in gravity compensation.

The gravity compensation mode has been implemented using *joint impedance*, then for every joint a stiffness and damping value has been set.

After changing the control mode in joint impedance, the robot seems falls and a small force contrary must be carried out to keep it up.

Teach by demonstration

On media flange there is a button that was dedicated for saving commands.

When the button is pressed according to the duration of the pressure, an action is recorded:

- one click for save a waypoint
- 2 seconds pressure for save the action on the gripper
- 5 seconds pressure to exit from teaching program

Teach with remote control

Remote control, or teleoperation indicates the movement of the robot at a distance. In our case, the KUKA LBR IIWA was controlled with a Ps4pad.

In *full task space* mode the robot will move respect to the base frame using linear and angular velocity on x , y and z :

- with **linear** velocity the robot will move the pose of the robot
- with **angular** velocity the robot will move the orientation of the EE

For these movements, the analogs of the pad were used. Instead, for security, the analogs must be used with the continued use of two deadman buttons.

Teach with remote control

The buttons used to do actions on robot were:

- \times : close or open gripper, therefore save action and the actual pose
- \triangle : save actual pose
- \square : change to control mode from position to cartesian impedance, and vice versa

The possibility to change the control mode to cartesian impedance allows the users to be more relaxed for precise movements.

Therefore, when an external force greater than a preset value is detected the **pad** start vibrating.