

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

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- **Motivations:** within the Industry 4.0, collaborative robots with advanced features, more flexibility and safety are increasingly exploited in production plants. Cobot requires new reprogramming techniques, such as kinesthetic and teleoperation.
- **Goals:** this work proposes a new teleoperation modality using a common pad for console for teaching assembly tasks. Therefore, with an user experiment, the work wants to highlight the differences between the two modalities.

We formulate some preliminary questions:

- Which mode is preferred for easy of use?
- The two proposed approaches are said to be intuitive, but how much when they are applicable for industrial assembly task programming?
- Are the physical characteristics of the users impacting on kinesthetic teaching?
- Are users who are familiar with the pad better in teleoperation than the other users?

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# Introduction

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In automotive industry welding and painting tasks are already highly automated, while assembly tasks in industry are mainly performed manually today.

For those tasks that are performed by robot, the default modality for teaching assembly tasks is kinesthetic teaching.

The use of a collaborative robot such as Kuka LBR IIWA and kinesthetic teaching doesn't allow us to fully use the collaborative features.

For these reasons and inspired by other works, a new modality for teaching assembly tasks was implemented.

Teleoperation teaching provides a way to control robot using a **PS4 pad** that allows us to have more control options.

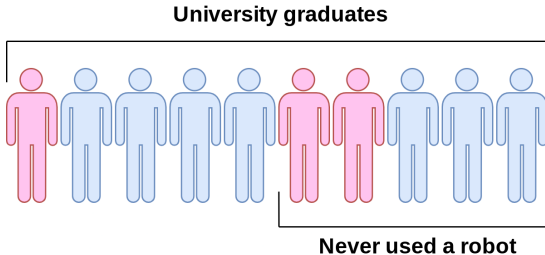
It allows to have a safe remote control of the robot through the use of buttons and analogs. It also have a force feedback feature.





# Experimental design

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To obtain better and diversified results among the participants, half of them started with teleoperation teaching, while the others with kinesthetic teaching.

## Experimental design

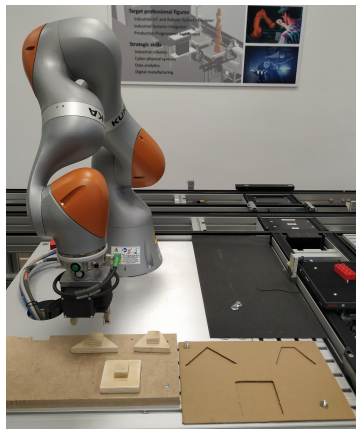
Before the experiment, was asked to the users to take confidence with both the modalities. Every user performs this phase without seeing other users do the same.

The experiment consists in two tasks in ascending order of difficulty repeated for three times. These tasks were repeated in kinesthetic and teleoperation and the users were rated with the data collected.



# Experimental design

In this figure the setup overview is shown: the Kuka LBR IIWA and the shapes used for the task.

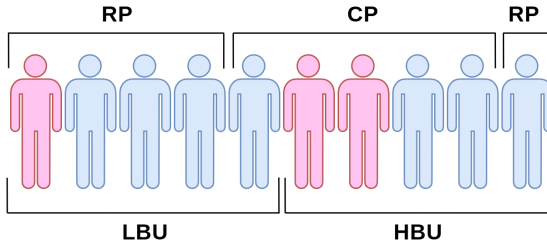


## Results discussion

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## Results discussion

For the analysis the users were divided into groups and their characteristics were analyzed.



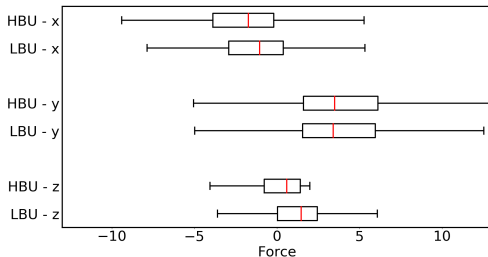
For reasons of time, in this presentation only two of the research questions are demonstrated through data. For a more complete and in-depth explanation, you can refer to the thesis.

### Are the physical characteristics of the users impacting on kinesthetic teaching?

- An analysis on the forces applied on the EE by the users of the two groups was made.
- Therefore, the questionnaire asked the *physical effort* required by users to perform the tasks.

## Results discussion

This figure shows the difference of the forces applied by the groups while they were performing the tasks in kinesthetic teaching. The force is in  $N$ .





## Results discussion

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Therefore, the previous concept is supported by the answers in the questionnaire.

The averages of the physical effort of the users are: 5,4 for **LBU** group and 3,8 for **HBU** group.

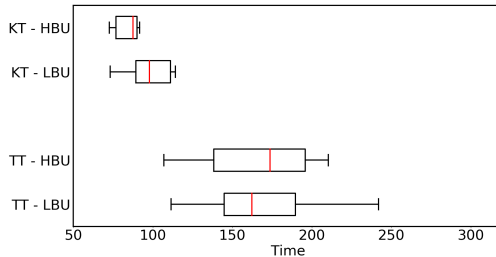
Both personal opinions and scientific data show us that there is a correlation between kinesthetic teaching and physical characteristics.

**Are users who are familiar with the pad better in teleoperation than the other users?**

- Time and distance to complete the tasks for both groups were analyzed.
- Therefore, the answers to the question regarding the *mental effort* required by the users to perform the tasks were analyzed.

## Results discussion

Only the times (in *seconds*) about task  $t_1$  are shown, for task  $t_2$  the values are similar.



## Results discussion

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The concept of time and distance to complete the task is also related with the concept of ratio and precision of waypoints.

The mental efforts in teleoperation teaching are: 5, 6 for **LBU** and 6 for **HBU**. Also, the data show us how users confident with the pad are better in teleoperation.

Furthermore, from the previous figure it's possible to notice how teleoperation teaching is always slower than kinesthetic teaching.

## Conclusions

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# Conclusions

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As mentioned, many aspects were considered and it isn't easy to find the best modality.

Kinesthetic highlights the physical differences between users.

Furthermore, thanks to its simplicity kinesthetic teaching can be used when an user wants to teach simple tasks.

To overcome the problem of different physical characteristics, teleoperation is used because unifies the differences.

Furthermore, the abilities of the users can be reused and trained for better performances.

We can for this reason say that teleoperation teaching can be used for difficult tasks that require precision as it offers the possibility to exploit more functionalities of the collaborative robot.

Thank you for your attention.