A GESTURE-BASED ROBOT PROGRAM BUILDING SOFTWARE

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1. INTRODUCTION

With the advent of intelligent systems, industrial workstations and working areas have undergone a revolution. The increased need of automation is satisfied using high-performance industrial robots in fully automated workstations. In the manufacturing industry, sophisticated tasks still require the human intervention in completely manual workstations, even if at a slower production rate [1]. To improve the efficiency of manual workstations, Collaborative Robots (Co-Bots) have been designed as part of the Industry 4.0 paradigm [2]. These robots collaborate with humans in safe environments to support the workers in their tasks, thus achieving higher production rates compared to completely manual workstations. The key factor is that their adoption relieves humans from stressful and heavy operations, decreasing job-related health issues. The drawback of Co-Bots stands in their design: to work side-by-side with humans they must guarantee safety; thus, they have very strict limitations on their forces and velocities, which limits their efficiency, especially when performing non-trivial tasks. To overcome these limitations, our idea is to design **Meta-Collaborative workstations** (MCWs), where the robot can operate behind a safety cage, either physical or virtual, and the operator can interact with the robot, either industrial or Collaborative, by means of the same communication channel [3]. Our proposed system has been developed to easily build robot programs purposely designed for MCWs, based on (i) the recognition of hand-gestures (using a vision-based communication channel) and (ii) ROS to carry out the communication with the robot.

2. SYSTEM EVALUATION

To evaluate the proposed system, we carried out two different experiments:

First Experiment: it was conducted during the ***Meet me Tonight 2019*** event held in Brescia. It was the perfect scenario to test the system with different people and to analyze their reactions. We used a Rethink Robotics Sawyer one arm Collaborative Robot with no gripper equipped to avoid unsafe interactions, and a simplified version of the State Machine. At the end of each demo, users were requested to fill in a survey to collect their insights about their experience with the system. They had to rate (i) how much effort it was required to learn the gesture language (Table 1, first three rows) and (ii) how intuitive they found the communication language (Table 1, last three rows). We had the chance to test 30 subjects equally divided between males and females.

TABLE 1. *Results of the first experiment.*

	Extr. Easy	**Easy**	**Neutral**	**Hard**	**Extr. Hard**
N. of answers	10	15	5	0	0
Average age	25 years old	31 years old	43 years old	0	0
	1 star	**2 stars**	**3 stars**	**4 stars**	**5 stars**
N. of answers	2	1	7	10	10
Average age	40 years old	65 years old	34 years old	26 years old	28 years old

The surveys show that all the participants were generally satisfied with the demo, especially people of age range 14-40. Younger people and people of age range 40-60 presented some difficulties in understanding the correct gesture sequence and sometimes forgot the gestures. Considering the response mean time (Fig. 1), which expresses the time interval between the system request to the user to perform a certain action and the actual response of the user with a valid gesture, it is worth noting that participants of age range 14-40 performed better, adapting really fast to the system interface and language.

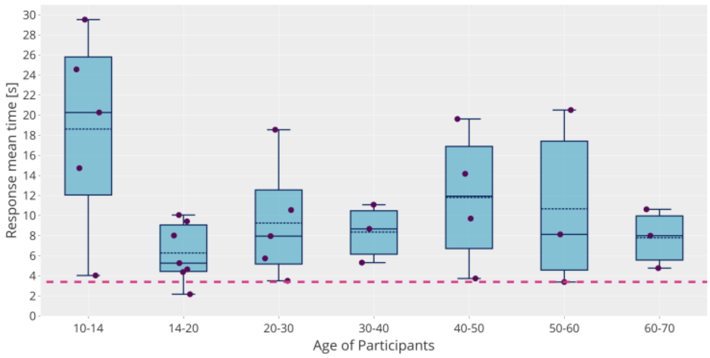

Fig. 1. Response mean time obtained by each participant. The pink dashed line represents the response mean time achieved by an expert user, equal to 3.4 s.

Second Experiment: In this case, we simulated a real-world manufacturing set-up aimed at assembling a moka coffee maker, using a robotic manipulator and a human operator in a MCw. The robot manipulator used for the tests was a Universal Robot UR10 equipped with a ROBOTIQ 2F-85 Adaptive Gripper. The task was to assemble the moka coffee maker (i) by programming the robot using the teach pendant (TP) and (ii) by programming the robot using our system (MC). Seven operators participated to the test and the results of the test are shown in Table 2, along with the personal expertise of each participant and the total number of points used.

TABLE 2. *Results of the second experiment.*

Subjects	Expert user of which modality?		# points	TP total time	MC total time
	TP	MC			
Subject 1	X	-	12	15 min	11 min
Subject 2	-	X	11	12 min	16 min
Subject 3	-	-	12	12 min	9 min
Subject 4	-	-	19	21 min	19 min
Subject 5	X	-	8	12 min	18 min
Subject 6	-	X	10	14 min	12 min
Subject 7	-	-	8	16 min	16 min

Our results show that four participants (1, 3, 4 and 6) took less time to carry out the MC test than the TP test. Among these, three Subjects were non-expert users of the MC modality (1, 3, 4): this suggests that our system interface is easy enough to be used properly even by non-expert users. Subject 4, which was a non-expert user of both methods, is the one with the highest values: this can be related to the high number of used points to build the robot trajectory. It is worth noting that the time required to complete the MC test depends on the wrong predictions of the gestures. Specifically, the high values of the MC test achieved by Subject 2, 5 and 7 are related to the recognition difficulties of the hand-gesture recognition model.

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