Metrics for Evaluation of Mixed Reality Technologies for Robotic Assembly of Manufacturing Tasks

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ABSTRACT

Robotic tasks in manufacturing environments are frequently conducted by recording multiple robots poses and configurations throughout the expected task implementation and then executing the recorded task. With the rise of mixed reality interfaces, including Augmented Reality (AR) and Virtual Reality (VR), metrics and test methods to study the human-driven teaching of robotics are becoming more important. This research aims to study test methods and metrics for quantifying user interfaces for human-robot interaction (HRI) in industrial settings. Through assembly of a modified NIST competition task board using the native Teach Pendant (TP), AR, and VR interfaces, HRI metrics are explored to capture the social and industrial characteristics inherent to manufacturing processes. This paper discusses the nature of the tasks to be conducted, an overview of the user interfaces, and preliminary results.

CCS CONCEPTS

• HCI design and evaluation methods • Interaction devices • Visualization systems and tools • Interactive systems and tools

KEYWORDS

Human-Robot Collaboration, Robotics, Manufacturing, Augmented Reality, Virtual Reality, Assembly, Extended Reality

1 Introduction

Collaborative robots, also called cobots, have become increasingly popular since the 2000's in the industrial and academic sectors [1]. Cobots are used in various applications, from manufacturing to medicine and workforce training [2]. However, human observation and programming are necessary to operate cobots. Studying Human-Robot Interaction (HRI) helps to understand the cognitive psychology of humans interacting with robots to promote safe and effective work environments [3-4]. Traditionally, programming via the Teach-Pendant (TP), the robot's native controller, is widely used to control the cobot. However, the method demands physical and mental effort, requiring simultaneous dexterity and observations, thus limiting the accessibility of cobots to the wider population. To facilitate efficient and productive collaboration between robots and humans, researchers aim to use advanced technology such as Augmented Reality (AR) and Virtual Reality (VR). Thus, the goal of this research is to develop methods to quantify the cognitive workload and task metrics associated with human programming and control of cobots for accessible HRI.

2 Methodology

This research involves assembling a NIST task board[1] (Figure 1), which is a modified/scale down version that consists of nine manufacturing individual sub task such as rods/bars peg in hole, fitting of gears, nut, electrical connector and USB. The components are arranged on a starting board and the participant will be asked to drive the robot to pick the components from the starting board using a gripper and fit them on the assembly board. Also, they will be asked to control the robot with one of the user interfaces (the order of TP, AR, and VR are ran-

[1]https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-assembly/robotic-grasping

domized). The participants will be asked to complete the assembly board within a certain time limit. Participants can choose to proceed or terminate after the time limit, and the board will be reset to use the other two remaining interfaces.

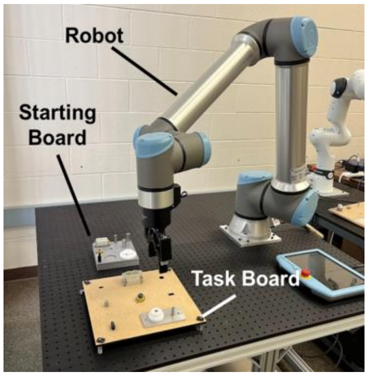

Figure 1: Experimental setup for assembly of task board.

Before conducting the tasks, pre-task metrics will be collected documenting the participants' experiences in computing and robotic technologies. During the task, metrics will be collected, including video and assembly observation. After completing the assembly board, post-task metrics will be collected through participant surveys. Thus, this study aim is to compares participants behavior when controlling a cobot with a TP versus using AR and VR for the same tasks. Both qualitative and quantitative analysis will be conducted to compare the user interface.

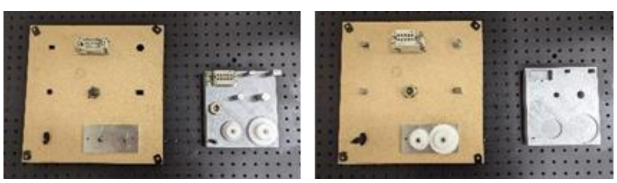

Figure 2: Unassembled (left) and assembled (right) task board.

3 Metrics and Preliminary Results

To conduct quantitative and quantitative analysis, the participants will be provided with the pre-task survey questions consisting of multiple-choice questions based on experience scale or familiarity with the following technologies: (1) tables/smartphones, (2) personal computers, (3) immersive cinema, (4) Computer/console video games, (5) tablet/smartphone video games, (6) virtual reality, (7) home automation, (8) instructional writing, (9) industrial machine tools, (10) industrial robots, and (11) remote control of vehicles. The researchers have carried out preliminary TP experiments manually in real time without any assistance. They evaluated the time taken by each component of assembly and observations were recorded before conducting full-scale human-subject studies. The first attempts were mostly unsuccessful due to inexperience of the operators and lack of knowledge of required gripping force to grasp the objects. Therefore, the second attempts were also recorded. Figure 3 shows the amount of time each sub task was required for both attempts. Furthermore, post-task survey question including NASA-TLX [5] will be provided to the participants after conducting experiments with each user interface (TP, AR, and VR).

4 Future Work

Future work involves demonstrating successful assembly of the board to participants to reduce the likelihood of failure on first attempt. Pre-task and post-task surveys may need to be revised in the future depending on preliminary results for the AR and VR interfaces. Additionally, the use of Extended Reality (XR) could enhance the operator's ability to visualize clearly, reduce dexterity and perform teleoperation efficiently for accessible HRI. This could reduce human cognitive workload to do manufacturing task and improve safety and trust by providing immersive and intuitive environment.

Part type	**Time 1st Attempt (min:sec)**		**Feedback/Observations from 1st attempt**	**Time 2nd Attempt (min:sec)**	
12mm Bar	3:30	✗	Aligned part stuck to gripper, moves wrong when open.	2:50	✓
12mm Rod	3:59	✗	Difficult to align the rod with the hole due to precision.	2:20	✗
16mm Bar	3:02	✗	Matching the pocket to the bar was challenging.	2:25	✗
16mm Rod	2:11	✗	Aligned part stuck to gripper, moves wrong when open.	2:25	✗
16 mm Nut	4:10	✗	Threads were not able to catch.	5:38	✗
Large Gear	6:05	✗	View of the gear hole was obscured by the boss.	3:04	✓
Small Gear	3:31	✗	Simultaneous observation of the TP and task was difficult.	2:30	✓
Electrical Connector	5:11	✗	Lack of confidence in ensuring the connector would not break.	4:50	✓
USB-C	5:01	✗	Did not mate completely due to lack of insertion knowledge.	4:04	✗

Figure 3: Table shows the completion time and observation attempts to complete assembly tasks using TP. Red and green denote the failure or success of the task, respectively.

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