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Assessing Instructions in Augmented Reality for Human-Robot Collaborative Assembly by Using Demonstrators

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Abstract

Robots are becoming more adaptive and aware of their surroundings. This has opened up the research area of tight human-robot collaboration, where humans and robots work directly interconnected rather than in separate cells. The manufacturing industry is in constant need of developing new products. This means that operators are in constant need of learning new ways of manufacturing. If instructions to operators and interaction between operators and robots can be virtualized this has the potential of being more modifiable and available to the operators. Augmented Reality has previously shown to be effective in giving operators instructions in assembly, but there are still knowledge gaps regarding evaluation and general design guidelines. This paper has two aims. Firstly it aims to assess if demonstrators can be used to simulate human-robot collaboration. Secondly it aims to assess if Augmented Reality-based interfaces can be used to guide test-persons through a previously unknown assembly procedure. The long-term goal of the demonstrator is to function as a test-module for how to efficiently instruct operators collaborating with a robot. Pilot-tests have shown that Augmented Reality instructions can give enough information for untrained workers to perform simple assembly-tasks where parts of the steps are done with direct collaboration with a robot. Misunderstandings of the instructions from the test-persons led to multiple errors during assembly so future research is needed in how to efficiently design instructions.

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1. Introduction

1.1. Current industrial challenges

Customers are becoming more and more individualistic, products are getting more variation and the global market drives for shorter lifecycles for products [1-4]. This puts a demand on the industry to deliver more variants on their products and to introduce new products more often. Robots are becoming more flexible but are currently not flexible enough to cost-effectively replace all human workers [5]. A limitation that currently exists for a large part of robotics implementations is safety-concerns for humans [6]. Robots have traditionally needed large areas to work to allow for safety precautions such as safety-fences [7] but are currently being taken out of the fences to interact with human workers.

If robots can become safe enough for humans to efficiently interact with them in the manufacturing industry, there are great advantages to be had with the flexibility, precision, and quality skills of humans and the endurance and strength of robots [8]. Robots can now work in collaboration with humans and currently there is a lot of research into making robot interaction more dynamic and efficient without creating risks for humans [9, 10].

The aforementioned demands from the market combined with future collaborative robots means that future human operators are likely to face an increase in product variation, shorter life-cycles of products (and thereby more relearning) and collaboration with robots. This puts an increased demand

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on workers to learn more operations simultaneously and learn new products more often. How can this be achieved without reducing quality and efficiency? This paper has two aims. Firstly it aims to assess if demonstrators can be used to simulate human-robot collaboration. Secondly it aims to assess if Augmented Reality-based interfaces can be used to guide test-persons through a previously unknown assembly procedure.

1.2. Augmented Reality

Augmented Reality (AR) makes it possible to present virtual information in a direct connection with objects in the real world [11]. AR works by connecting the real world with the virtual, for instance with specific patterns that are pre-known. When a camera captures and digitalizes what is seen in front of it software can recognize the pattern and it can use the information of where the pattern was recognized to superimpose digital information on top of the rendering from the camera, thereby creating a mix between virtual and real information. This means that AR can show digital information in a real setting and in a specific context, for instance by highlighting real objects. As a result there have been many studies on how to use AR to present assembly instructions that has shown positive results [12]. But although there are positive results there is still more studies needed regarding how the instructions should be presented and how to comparatively evaluate them [12].

2. Demonstrator

2.1. Demonstrator as test-bed

To our knowledge there is no factory that currently have implemented Human-Robot Collaboration combined with Augmented Reality in production. A demonstrator was therefore created where a person will collaborate with a Human-Robot Collaborative robot, a UR3 robot from Universal Robots. A simplified car-model that can be assembled and dis-assembled by hand was developed and can be seen in Fig. 1.

The greatest advantages of using a demonstrator in user-tests are the authenticity and the modularity. The demonstrator allows a test-person to interact directly with a real HRC-robot in an assembly-scenario and thereby simulates a real situation. It is not as believable as real industrial assembly but it does not need to disrupt any real industrial assembly either. The currently developed demonstrator is limited to one test-person and one workstation and is thereby limited in comparison to industrial assembly that is mostly done with close connectivity between workstations and operators. Since the demonstrator is fully developed for experimentation it is also modular and can be changed depending on what needs to be tested. Together these two advantages means that the demonstrator can put a test-person in a semi-authentic situation and, depending on complexity of needed modifications, it can also be modified depending on findings within minutes or hours.

In the first iteration, the car-model was created with wood and the pieces were held together with friction between the pieces. A drawback with this model was that test-persons only had to identify, orient and position the individual parts; there was no need to fasten any pieces with anything else but friction. To make the car-model similar to more generic assembly, a new model was created. The pieces were 3D-printed which allowed for more detailed parts to be created. The new car-model had increased complexity in that thumbscrews were now needed to fasten some parts.

Fig. 1 First iteration of demonstrator.

2.2. Augmented Reality Interface

To present the instructions for the test-persons a spatial top-view Augmented Reality system was created. The platform for the system was the game-engine Unity-3D. In the first iteration AR was implemented with the help of the Vuforia AR-system for Unity. The AR-system was built for Android and launched on an Nvidia Shield Tablet that can be seen at the top of Fig. 1. This tablet was chosen since it has both a USB-connection and mini-HDMI connection which was necessary to both have communication between the AR-system and the Robot Control system and to be able to project the visual information on a screen for the test-person to see. Test-persons worked with the table seen in Fig. 1 in front of them. This set-up meant that they had the work area in front of them, pieces to assemble at their sides, a screen giving the test-persons AR-instructions and a UR3 robot to their left that they had to collaborate with to assemble the car.

2.3. Second iteration of interface

Two big drawbacks with the chosen version of the AR-system was the low battery-life of a tablet that has to continuously have an active camera and the mixing of two