Exploring Human Robot co-Production

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Abstract—Recently, robots are making their way towards the small and medium enterprises at a quick pace. This is due to market demand and enabled by reduction in costs of robot systems. If robots can be introduced strategically in existing production workflows, productivity could be increased. However, the task division and interaction between human and robot co-workers need to be optimized in order to achieve this. This work-in-progress paper presents a pilot setup to explore such scenarios. We discuss early findings and we present our vision for the future of human robot coproduction.

Keywords—Workflow; co-production; HRI group dynamics; collaborative task; robotic assistant

I. INTRODUCTION

Due to technological innovations robots in various forms are penetrating everyday life. Over the last decennia, service robots have already been introduced in environments where they function next to humans. However, conventional production robots have always been behind fences due to their potential for inflicting serious injuries and damage. Due to recent advancements in sensing and dynamic path planning these larger robots will have the potential to collaborate safely in close vicinity of humans[1].

Such novel robotic systems would be very beneficial in the context of Small and Medium Enterprises (SME). Nowadays, these organizations are increasingly required to deliver customized products, in flexible quantities and do this faster than ever before. By strategically implementing robotic systems in key tasks, next to humans, these demands would be easier to achieve. Nevertheless, we believe that these systems can only handle these demands through seamless integration with their human co-workers. This means that they need to be capable of executing tasks and afford humans to interact with them. Human-Robot interaction has been studied in various contexts (manufacturing[2], healthcare[3], teaching[4] etc.) and from both perspectives (humans[5], computers[6]). As alluded in Figure 1, the context of manufacturing shows increasing attention towards including robots in various ways and work in teams with humans in accomplishing tasks ([7], [8],[9]).

The purpose of this research project is to explore the performance of human-robot collaborations and understand how suitable interfaces can be designed for creating successful production workflows. In this paper, we explore a pilot setup in which we can allow humans and robots to collaborate. For starters, we let the robot execute exactly the same task as the human is executing. In later stages of this research, we aim to design a tool for simulating various workflows of similar kind as well as to develop a language to be used during the design of such workflows.

II. PILOT SETUP

To be able to simulate and study the targeted context, a pilot setup was built. The main goal of this setup is to be able to compare the performance of various collaboration scenarios and to observe the reactions of co-workers to unexpected situations caused by the robot. Therefore, the setup is designed to allow for the simulation of coproduction with humans only and with humans and robots. In section A, the overall setup is explained and the components are listed. In section B, the pilot task is presented.

Fig. 1. Humans and robots working together on a packaging line
A. Setup configuration

Figure 4 shows key elements that we selected of a generic manual packaging line, such as, roller-conveyors (1), empty cardboard boxes (2) and products to be packed (3). For studying the situation a professional CCTV system consisting of cameras (4), portable microphones, control devices and digital recording equipment (5) has been installed. For studying the scenario when a robot is introduced into the workflow, a 6-axis Universal Robots UR5 (6) is used. Furthermore, as additional automation components, 2 light-gates and 2 pneumatic gates were installed onto the roller conveyors. The system is further constructed using aluminium construction profiles.

B. Pilot

During an initial pilot a human-only (Figure 2) and a robot-human workflow (Figure 1) were tested. The tasks that were targeted at the human and the robot can be seen in Table 1. The test participants were three graduate students. The test setup was located inside a common laboratory space inside the faculty building.

The task that was being simulated was representative of a so-called re-packaging scenario where individual products are taken from their boxes and placed in a separate box (size: 300mm x 280mm x 200mm) in which they are combined with other products. Product types and sizes are as follows:

- P1: Boxed juice, 120mm x 50mm x 38mm
- P2: Choco waffles (per 3) 95mm x 57mm x 37mm
- P3: Boxed sweets 61mm x 43mm x 18mm
- P4: Coffee milk (per 2) 78mm x 40mm x 19mm
- P5: Cotton buds (boxed) 110mm x 90mm x 45mm
- P6: Canned tomato paste, 55mm(diameter) x 77mm (height)
TABLE I. WORKFLOW

<table>
<thead>
<tr>
<th>Task</th>
<th>Condition 1</th>
<th>Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick empty box</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Place on roller conveyor</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Pick product 1 P1 from location 1</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Place P1 in box</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Pick P2 from L2</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Place P2 in box</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Pick P3 from L3</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Place P3 in box</td>
<td>Human 1</td>
<td>Human 1</td>
</tr>
<tr>
<td>Move box to the next location</td>
<td>Human 1</td>
<td>Robot</td>
</tr>
<tr>
<td>Pick P4 from L4</td>
<td>Human 2</td>
<td>n/a</td>
</tr>
<tr>
<td>Place P4 in box</td>
<td>Human 2</td>
<td>n/a</td>
</tr>
<tr>
<td>Pick P5 from L5</td>
<td>Human 2</td>
<td>Robot</td>
</tr>
<tr>
<td>Place P5 in box</td>
<td>Human 2</td>
<td>Robot</td>
</tr>
<tr>
<td>Pick P6 from L6</td>
<td>Human 2</td>
<td>Robot</td>
</tr>
<tr>
<td>Place P6 in box</td>
<td>Human 2</td>
<td>Robot</td>
</tr>
<tr>
<td>Move product off the roller conveyor</td>
<td>Human 2</td>
<td>Robot</td>
</tr>
<tr>
<td>Pick filled box and move to storage location</td>
<td>Human 3</td>
<td>Human 3</td>
</tr>
<tr>
<td>Refill products in locations 1 till 6</td>
<td>Human 1</td>
<td>Human 3</td>
</tr>
</tbody>
</table>

Condition 1: The participants were positioned in their respective places around the production line. Human 1 had the task to pack the products in locations 1, 2 and 3. Human 2 had the task to pack the products from locations 4, 5 and 6. They both had the task to move the product box along the conveyor to the next workstation. Human 3 had the task to take away packed boxes and refill products in product locations.

Condition 2: The participants were positioned in their respective places around the production line. However, this time, at the location of Human 2 from the previous condition, a robot was placed. Human 1 had the task to pack the products in locations 1, 2, 3 and move the box towards the robot. The robot had the task to pull the box closer towards its workspace, pack products from locations 5 and 6 and push the box further down the conveyor.

III. PRELIMINARY RESULTS

Up to this day, only one test session has been performed using the setup in order to validate its working. During this session, Condition 1 was performed twice and Condition 2 was performed once. During the performing of Condition 2, the robot stopped functioning, causing the termination of the test. Yet, we will elaborate on the part of the test that was performed.

Looking at the performance in both conditions in Table 2, we see that the performance of the operation during condition 1 is significantly higher than that of condition 2.

TABLE II. PERFORMANCE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Boxes</th>
<th>Products</th>
<th>Time</th>
<th>Time per product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1, run 1</td>
<td>48</td>
<td>288</td>
<td>8min. 18 sec.</td>
<td>1.72 seconds</td>
</tr>
<tr>
<td>Condition 1, run 2</td>
<td>48</td>
<td>288</td>
<td>7min 20sec.</td>
<td>1.52 seconds</td>
</tr>
<tr>
<td>Condition 2, run 1</td>
<td>28</td>
<td>140</td>
<td>10min. 4sec.</td>
<td>4.32 seconds</td>
</tr>
</tbody>
</table>

As mentioned before, the pilots were executed as validation for the setup. Therefore, next to performance related quantitative data, there are several qualitative findings from which we can get valuable information.

Robot failures: The robot controller sometimes stops the process with a warning. Two warnings have been observed; a torque limit violation and a joint violation. These errors occur on movements of the robot that have previously been performed successfully without any issues. While the robot can function 100 times faultlessly it will may start to display errors randomly. The impact of the error is that the process is completely stopped and in order to continue the pilot, the program has to restart, effectively restarting the entire pilot.

Continuing process after stop: Upon an emergency stop of the robot, the program has to restart from its beginning. This means that the robot wants to be moved back to its start position, and that a number of variables are reset.

Path planning: We have found that we are experiencing bugs with the path planning of the robot.

Lack of sensors: The pilot system is not aware of the output area after the robot workstation. This means that the robot will continue even if the workstation after it cannot keep up.

Lack of actuators: The robotic arm is used for every automated action. For many actions, this is not ideal, for example moving the boxes across the roller belt. This greatly reduces the potential output of the robot.

Workload balance at stations: The robot station was not capable of keeping up with the regular performance of the human co-worker. influences the behavior of participants, where they may pause and wait for.

Staring video capture: Initiating the capturing of the video is done through a computer web-interface which results in a delayed start of the capture.

Position of cameras: Three cameras are now placed on tripods. These tripods require quite some space and may shift if hit. Also one camera is on a ledge. This means it has to look down. However the angle to look down is limited what reduces the area it can capture.

IV. DISCUSSION

From the initial results and findings of the pilots, we observe that several fields of interest are emerging. We believe that these fields and the relation between them can be summarized as depicted in Fig.5. With this model, contexts of collaborations can be captured by observing it from the three perspectives of Product, Process and Person.
A. Process:
During the test, the robot was located next to the human co-worker and was programmed to execute a similar task in a very similar fashion to the human. Together, they were collaborating in accomplishing a packaging task. This is representative of a very basic generic manual packaging scenario. However, in order to verify if the test setup is capable of allowing the simulation of human-robot collaborations, attention needs to be paid towards what is regarded as collaboration. What parameters define collaborations? The current setup may need to be reconfigured and extended in order to achieve this.

B. Product:
The products that were used were regular household products purchased in a grocery store. However, they were not randomly chosen, although attention was paid towards having a variety of products with different sizes, shapes, weights and packages. Most of the products were selected so that they were suitable for picking up with a vacuum gripper attached to the robotic arm.

C. Person:
The persons that participated in the test were graduate students at a University. They were all male, had similar education level and were in their 20’s. This is not representative of real life production staff. In a real situation, the mix of persons and their competences would be much more diverse.

V. CONCLUSION & FUTURE WORK
Based on new advances in robotics, coproduction i.e. collaboration between humans and robots, is getting feasible. To explore this, we conducted a pilot in the domain of packaging with 5 different types of products. Both in development and execution of this task, challenges were experienced in robot infrastructure, workflow planning, and process observation. As a result, the robot performed worse than expected. Therefore, we will be exploring similar situations in order to gain an understanding in and document the various elements and influences inside these contexts.

Furthermore, in our research we will also be focusing on the usability of determining the workflow and subtasks of such robots in a coproduction context.

Thirdly, we will investigate which skills of robots and competences of humans can be best combined in order to compose a successful workflow.

VI. REFERENCES


