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# Virtual Human-Robot Collaboration: The Industry's Perspective on Potential Applications and Benefits

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**Abstract.** Two keystones of Industry 4.0 are the increased use of autonomous robots and advanced simulation software. Human-Robot Collaboration (HRC) combines the strengths of humans and robots, opening up application areas that previously could not be automated. However, the realization of HRC on industrial shop floors is held back by several challenges: safety, trust, the need for intuitive interfaces, and design methods. This study investigates the automotive industry's perspective on relevant application areas and potential benefits of HRC. The data were collected through a survey of 185 participants from a variety of working roles in the automotive industry. The results of the study indicate that participants from the automotive industry consider that the areas best suited to the implementation of collaborative robots are material handling, assembly, and quality control, with potential benefits in ergonomics, efficiency, and quality. The results can be used for the development of a future virtual HRC simulation model.

**Keywords.** Human-Robot Collaboration, Virtual Simulation, Industrial Perspective.

## 1. Introduction

The fourth industrial revolution and the digitalization of industry for more flexible and automated production systems are ongoing where two of the nine key factors for competitiveness are the adoption and use of advanced simulation software and autonomous robot [1]. Industrial robots have been around for a long time, but they have been separated from humans by physical barriers. Removing these barriers opens up possibilities for manual tasks, previously restricted to human labor, to be performed by efficient human-robot teams. Villani, et al. [2] state that by allowing concurrent robot and human work inside a collaborative workspace, human qualities such as flexibility and cognitive skills can be combined with robot qualities such as repetitiveness, accuracy, and speed. However, they acknowledge that Human-Robot Collaboration (HRC) is held back by several challenges, including safety and the design of intuitive user interfaces that allow for simple programming, as well as design methods including planning and allocation of work tasks. The literature shows that a few HRC

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applications start to emerge, where the vast majority focus on assembly applications [3-5]. Hancock, et al. [6] suggest that trust is one of the critical elements for HRC. Their work concludes that performance-based factors, such as robot behavior and reliability, are the largest current influences on perceived trust in human-robot interaction; environmental-based factors such as type of the task performed are the second largest influence.

The long-term goal of this study is to create a Virtual Human-Robot Collaboration (VHRC) simulation model that can function as a safe platform for training, design, task planning, and improvement work. We believe that this simulation model could bridge the gap toward realizing HRC on industrial shop floors on a larger scale (Figure 1).

According to Banks et al. [7], the first step in any simulation study is a clear statement of the problem. Therefore, this study will investigate possible application areas, potential benefits, and the general level of support for HRC among the personnel of the automotive industry, and later use the results to clearly state the problem in the creation of the VHRC simulation model. Of special interest is to investigate possible application areas, beyond just assembly tasks, in order to potentially increase the utilization of the robot as a motivation for investment by the industry.



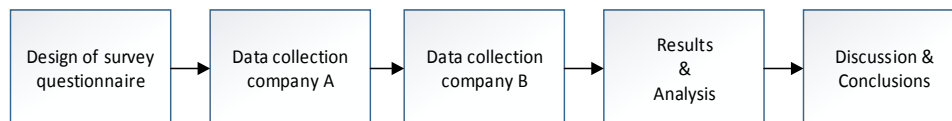
**Figure 1.** The literature shows that the realization of HRC is held back by several challenges.

Developing an HRC application and evaluating its safety requires human interaction, which itself can be highly unsafe. Operator training is required to reach sufficient trust to be able to safely interact with the robot. We believe that this interaction can be performed in a safe virtual environment representing the real system.

The next chapters of this paper show the methods used in the project followed by results and finally discussion and conclusions.

## 2. Methods

A questionnaire-based survey was used as a research strategy and data collection technique to investigate the general opinions of automotive industry personnel on the subject of collaborative robots. Figure 2 illustrates the methods used in the project.



**Figure 2.** A flowchart overview of the project method.

### 2.1. Design of Survey Questionnaire

It was decided to use the general population of the automotive industry as the scope of the sample frame. All the respondents were randomly chosen. To avoid a biased result, the questionnaire was self-administered and anonymous. The questionnaire was designed to generate qualitative data and contained five short questions with closed multiple choice answers (table 1).

**Table 1.** Survey questionnaire questions and answers.

Question.	Choice of answers
1. What is your working role?	Machine operator, leader, other
2. Do you think collaborative robots could be useful in your particular work?	Yes, no, don't know
3. In what application areas do you think collaborative robots can be beneficial?	Assembly, processing, quality control, material handling
4. What benefits do you think the use of collaborative robots can lead to?	Ergonomics, cost reduction, efficiency, quality
5. Would you feel safe working with a collaborative robot?	Yes, no, don't know

### 2.2. Data Collection

Data was collected by asking the personnel from two Swedish automotive manufacturers to fill out the questionnaire. This was done on two separate occasions in 2018. Prior to this, all participants attended an introductory presentation on the subject of collaborative robots. The information included:

- Differences between human-separated industrial robots and collaborative robots.
- Levels of HRC, ranging from utilizing the same space to full collaboration.
- Safety aspects and the four safeguard modes described in ISO/TS 15066:2016.
- Basic lead-through programming.
- A demonstration of an HRC assembly application.

Acquired quantitative data sets were organized in bar charts, one for each question, with data sorted into the categories: Operator, Leader, and Other. A mean value was also calculated and constitutes a fourth category.

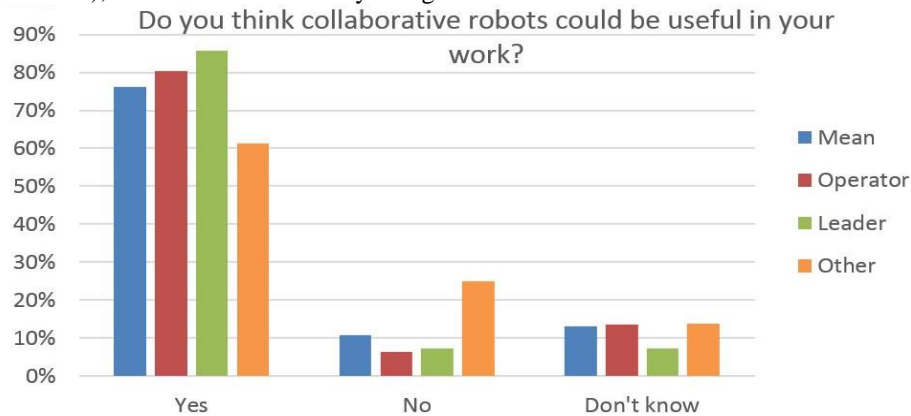
## 3. Results

185 out of a total 230 participants, answered the questionnaire. The majority of company A respondents consisted of machine operators and leaders of machine operators, while company B was mainly represented by other roles (Table 2).

**Table 2.** A sample of the roles in the three respondent categories

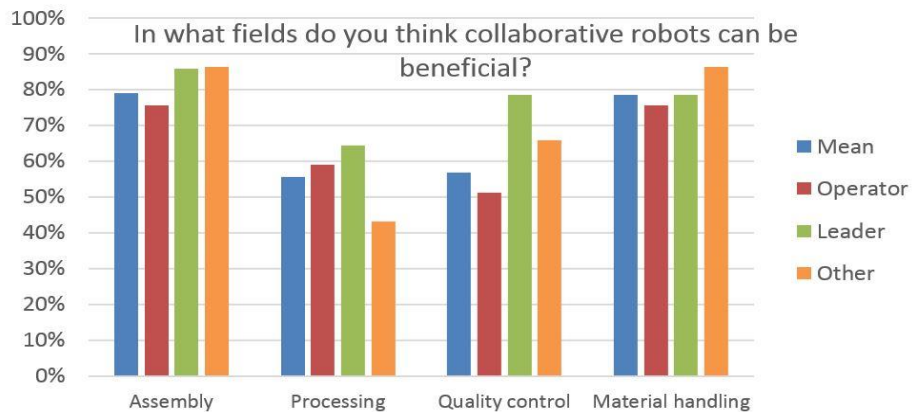
Participants (185)		
Operator (127)	Leader (14)	Other (44)
Processing machine operators	Leaders of operators	Project leaders Production technicians Product processors Measure technicians Supporting roles Maintenance

Figure 3 shows that the majority believe that collaborative robots could be useful in their particular work, but the numbers are significantly lower in the “other” category. This is probably due to the nature of this group’s work (e.g. administration or data collection), which is not necessarily a target for robotics.



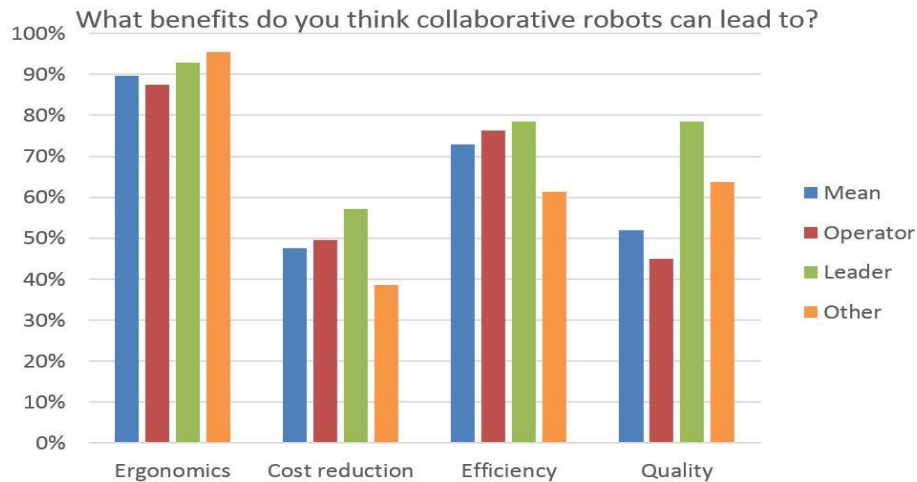
**Figure 3.** Questionnaire question 2: Do you think collaborative robots could be useful in your particular work?

Figure 4 shows that *assembly* and *material handling* have the highest support of the suggested application types that could benefit from collaborative robots. The leaders believe that *quality control* could be a good application, but this category has less support from the operators. Even though a majority of the participants think that *processing* can be a target for collaborative robots, it is the least supported application area.



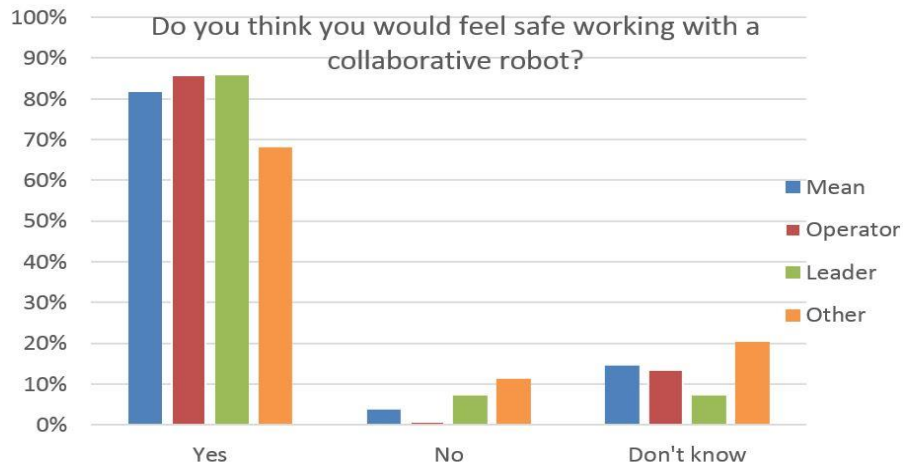
**Figure 4.** Questionnaire question 3: In what application areas do you think collaborative robots can be beneficial?

Figure 5 shows the result of the question regarding the production benefits of using collaborative robots. Ergonomics is supported by almost all participants, followed by a moderately high support for efficiency. The leader and “other” categories – but less so the operators – also think that increased quality can be a result of using collaborative robots. Cost reduction is the least supported potential benefit, which might be due to the investments that were expected to be required for the implementation.



**Figure 5.** Questionnaire question 4: What production benefits do you think the use of collaborative robots can lead to?

Figure 6 shows clearly that the participants would feel safe working together with a collaborative robot, with slightly less support from the “other” category.



**Figure 6.** Questionnaire question 5: Would you feel safe working with a collaborative robot?

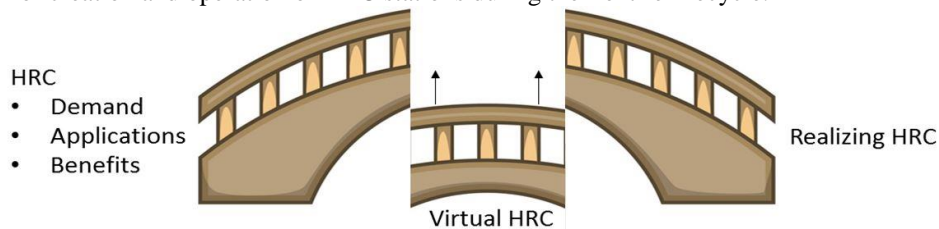
#### 4. Discussion and Conclusions

We conducted a questionnaire-based survey to investigate the general industrial perspective on HRC. We found that the application areas best suited for HRC are *material handling*, *assembly*, and *quality control*, with potential benefits in ergonomics, efficiency, and improved quality. These results provide insights in which application types can be incorporated in a future highly utilized HRC. We also found that the majority of the respondents think they could use, and would feel safe working together with, collaborative robots.

A strength of our study is that it investigated the opinions of two different automotive manufacturers with respondents from a broad variety of working roles (Table 1). A limitation is that it only targeted Swedish companies, implying that the possibility of cultural bias cannot be ruled out. We propose future studies to expand and validate the results, for instance by including global manufacturers from other industries to investigate a broader general view.

In a related study Charalambous, et al. [8] performed an exploratory study of trust in HRC by collecting the opinions of university students and staff. In contrast to our study, the majority of the participants did not have any prior experience of industrial robots or automation. The qualitative analysis of their interview data showed that human trust in robots was affected by awareness of safety features, prior experience with industrial robots, fear of being hit by the robot, robot appearance, and the complexity of task. These aspects, together with the aspects identified in our own study, will be considered in the simulation to be developed.

We believe that VHRC is a potential key to bridging the gap toward realizing HRC on industrial shop floors by providing a safe development and training platform. Potential uses include evaluation and design of safety measures, development of user interfaces, task planning and allocation, and improvement work (Figure 7). The results of this study will be used for problem formulation in the development process of an interactive VHRC simulation, with the long-term goal to create a holistic framework for creation and operation of HRC stations during their entire lifecycle.



**Figure 7.** Virtual HRC may be the missing piece toward realizing HRC on industrial shop floors.

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