Design and Investigation of Social Robotic Coworkers in Factories

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***Abstract*— Collaborative robots or co-bots combine the strength of the human (dexterity and problem-solving ability) and the robot (precision and strength) to implement tasks that cannot be fully automatized and reduce the workload of human workers. In this paper, the results of the ClaXon project are presented whereby a fully operational collaborative robot was integrated in the manufacturing line of the Audi Brussels production plant. Social studies were realized with factory workers to investigate the human-robot interaction and assess the acceptance of co-bots.**

I. Introduction

Current industrial robots are programmed to achieve repetitive and dangerous tasks. They are separated from human workers by cages for safety reasons. Collaborative robots (co-bots) are a new generation of robots that are designed to work together with humans without a safety fence. The human-robot collaboration combines the complementary skills of the robot (precision and strength) and the human (dexterity and problem-solving ability) to perform tasks that cannot be fully automatized. The use of collaborative robots allows to improve the production's quality while at the same time reduce the workload of human workers. Recently, several tools have been developed and investigated to enhance the human-robot collaboration such as actuators, sensors, safe control methods [3] and architectures [2]. However, research about the acceptance of collaborative robots in factories is limited. Social studies are often realized in labs with students. The current challenge is to involve people from the manufacturing industry and investigate the opportunities of human-robot collaboration in their environment.

This paper presents the research results of the ClaXon project. The project unified complementary expertise to investigate and improve the interaction between people and collaborative robots in factories. Technologies were developed for safety, human-robot interaction and robot-product interaction. Aside from the technical advances, social studies were realized to investigate the acceptance of collaborative robots. During the project, a use case at the Audi Brussels production plant seemed suitable to be addressed in the short-term. This led to the integration of a fully operational co-bot and allowed unique insights along the full implementation process of a collaborative robot in a real factory setting.

II. Use Case

The use case at Audi Brussels is a gluing application where the worker applies stripes of glue on the reinforcement plates of car roof's racks. The worker's job consists then in attaching the plates to the side panel of a three-door or a five-door car from two assembly lines. Fig. 1 shows the glued metal piece. Since the gluing is done manually, the quality is not optimal. The applied glue stripes on the metal pieces are not uniformly distributed along the plate.

Figure 1. Example of a manually glued reinforcement plate. The applied glue stripes are not uniformly distributed along the plate.

Other factors influence also the quality of the process such as the temperature and the worker's skills. The use of a collaborative robot in this context allows to achieve a better production quality while taking over the repetitive and dirty tasks of the worker. This use case is also the basis to demonstrate the technologies developed during the ClaXon project.

III. Human-Robot Interaction

Currently, the human-robot interaction with classical industrial robots is mainly done via buttons or graphical user interface. Interactions with collaborative robots is meant to be more intuitive by using communication means similar to humans such as speech and gestures. However, due to the noise often present in industrial environments, speech communication is not possible. Therefore, gestures are used for human-robot interaction. During the project, multimodal human-robot interaction was investigated whereby the information from multiple sensors are combined. "Hasselt User Interface Management Systems" [1] was utilized to setup the human-robot interaction in two collaborative robot setups. In one proof-of-concept, Hasselt was combined with fusion of

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3D, thermal and RGB data allowing recognized operators to program flexible, intelligible trajectories of an industrial robot arm using gestures.

IV. Safety

Since collaborative robots operate without a safety fence, it is important to control the robot's motions and forces by using appropriate control algorithms. Classical industrial robots generally employ PID controllers with high gains a high accuracy and disturbance rejection. However, this leads to a fast and potentially dangerous motion in case of a deviation from the robot's reference trajectory. A novel controller [3] was developed for a safe and performant control. The controller allows to achieve various interaction levels by adjusting two parameters, namely the torque limit and the expanding factor of the variable boundary layer while conserving good overall tracking performances.

V. Robot-Product Interaction

A set of 2D and 3D cameras were integrated with the co-bot system to obtain a visual feedback during the gluing process. This setup allowed to detect the reinforcement plates on a rack. An unactuated beam was used as attachment support for the cameras. The latter was designed to move loosely together with the robot to prevent collisions. This intelligent support was not only used for part and glue detection but also to find the rack holding the parts independently from its position and pose.

VI. Social Acceptance

Research on social acceptance of collaborative robots outside the lab is limited but growing. We conducted experiments with real factory workers at Audi Brussels using multiple methods (surveys, experiments and interviews). These were used to investigate the human-robot interaction using gestures and assess the importance of social cues [4]. Results have shown that factory workers are more willing to work with a co-bot when showing more social cues such as head nodding and eye gaze (Fig. 2). Another study [5] found that factory workers expressed concerns of robots taking over their jobs while at the same time believing that co-bots can be of great help for physical demanding tasks.

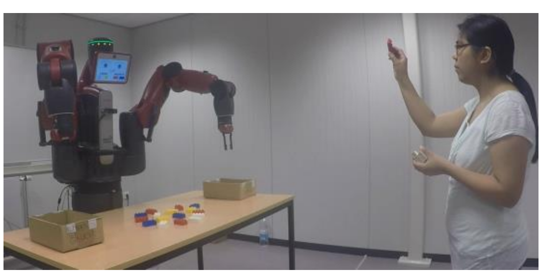

Figure 2. Social experiments where the Baxter robot is used to investigate gestures and social cues.

VII. Implementation

The ClaXon project led to the implementation of a fully operational collaborative robot "Walt" at the Audi Brussels production plant. Fig. 3 shows the integrated MRK-System robot for the gluing application and the interaction with factory using gestures (thumbs up/down, left/right finger pointing, 4/5 fingers). The robot works in close proximity of humans without a safety fence. An actuated robotic head was developed by Robovision to communicate with human workers and express emotions. The robot integrates a safety skins that detects collisions with humans and complies with the safety requirements of the standard ISO 10218-1 (controlled work envelope, speed and forces). The glue gun (point-shape) at the end-effector is framed by a plastic case to achieve the required safety level. Along with gesture recognition, face recognition and fingerprint scanning were for operator identification.

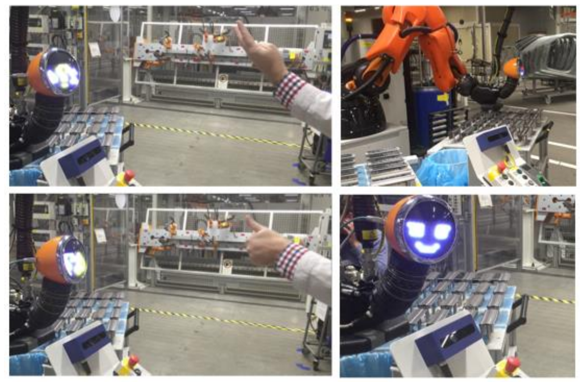

Figure 3. Collaborative robot "Walt" implemented at the Audi Brussels factory. Interaction is done via gestures. A robotic head was designed to communicate with human and express emotions.

VIII. Conclusion

The ClaXon project has studied and implemented technological tools relative to collaborative robots such as human-robot interaction and robot-product interaction. Social studies were conducted to assess the acceptance of co-bot by factory workers. The project has led to the implementation of a co-bot in an operational car manufacturing line.

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