Communication Between Human and Robots Within a Collaborative Workspace

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Abstract. Human-Robot collaboration is expanding to new application areas. In this paper, a solution is developed to join safety, efficiency and collaboration between humans and robots. The focus has been set in creating a functional simulator of a collaborative zone, including a Universal Robot (UR10) and a collaborator. The virtual robot is controlled from an external simulator and the collaborator will be controlled either by the simulator (as in a computer game) or by an external sensor.

Keywords: Co-bots · Automation · Augmented reality · Robotics · Collaboration

1 Introduction

Since the industrial revolution, automation and robotization has been helping workers in the industry. Robots were able to do more and more complicated tasks and free the workers from doing difficult and repetitive tasks. They are efficient, but humans are still needed for complex or unpredictable tasks. To be able to take the best from the two, collaborative robots (co-bots) [1] has been developed. This term defined the collaboration between robots and humans, especially for the industry. This collaboration can prevent the worker from doing annoying tasks and carrying heavy loads. Nonetheless, powerful robots can also be dangerous for the worker due to the absence of fence between the robots and the collaborators. Therefore, many safety rules and standards has been set; they especially set some safety distances and speed limits.

With regards to efficiency in the industry, these limitations are problematic. To have a safe environment with robots working fast next to safe human workers, a virtual collaborative workspace was developed. This simulator both aim to help developing the hardware and software needed to allow the robots to move in a fast and safe mode, but also to test the impact of this new technologies on the collaborators (feeling, stress, etc.). The paper is organized the following way: firstly, a brief description of the idea and its constrains are presented. Then the explanation of the collaboration requirement and the safety standards that must be respected will be presented. This will allow to set

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a bench of requirements for the simulator to then go through the different features that have been implemented. Finally, the choice of sensor to locate the collaborators and the future work will be discussed.

2 Background

To overcome the safety limitations, the goal is to develop sensors that can locate the collaborators and communicate in real time with the robots. Thanks to the data gathered, robots can adapt their actions and movement to act in a safe manner for the humans next to them. For example, if a robot wants to move from one place to another and there is no one on its way, then it can do it quickly. But if during his movement, sensors detect an approaching human, and a collision become likely, then the robot will reduce its speed to a potential stop. In this case, the robot would be able to either change its direction and try to move around to obstacle, or to completely stop to stay in a safe state. However, a safe and convenient implementation of these new features requires the creation of a virtual collaborative workspace. The first step is to implement this on a Universal Robot and a collaborator in the same zone. Both should be able to move according to external data (simulators or sensors). The collaborator should also be movable directly through the simulator to ease the evaluation of how the robot is reacting to collaborator actions. Therefore, the virtual workspace will both be a simulator to test the robot and an Augmented Reality [2] system.

The reference implementation is called Local Observing and Communication Device (LOCDev) a because the sensors, which can be considered as the eyes of the robots will stand on some poles. The architecture has three layers of implementation [3]. First, one LOCDev alone and its local environment which does human and object recognition. This LOCDev may have the possibility to communicate by sounds with the collaborators, both speaking and understanding. It uses visual displays to show where it is safe to be and where it is dangerous to stay. Then, inside a collaborative zone, it will be several poles. They all communicate together, with the robots and with the workers to ensure safety regarding robots' movements. Finally, these LOCDevs will communicate with a global server in the factory that gather all the data, giving a global feedback of the factory health. Some relevant decisions can be taken according to this information to increase the global performances of the factory and decrease the pressure on the workers.

Having a safe system is not enough; trust and communication between robots and operators are essential. When people work together, they can talk to each other, do some gestures, face mimics and more. It is easy to understand what another human aims to do, and so they feel safe to work with [4]. But when people are working next to robots, they do not know anything about what the robots intend to do. They cannot get eye-contact. Therefore, one must keep in mind that people will not necessarily feel safe in this new kind of environment, even if it is designed as safe.

3 Collaboration Between Human and Robot

Technical committee: ISO/TC 299 [5] explains that a collaborative operation is a state in which a purposely designed robot system and an operator work within a collaborative workspace, which in turn is a space within the operating space where the robot system (including the workpiece) and a human can perform tasks concurrently during production operation.

In case of uncertainty and vulnerability, trust can be partly rational, but sometimes trust is largely irrational, especially when it comes to non-dangerous situations. Even though the robots are designed in a way to be safe to work with, they can be perceived dangerous. Thus, the transition from working without collaborative robots to the work with them may be difficult, and feedback from workers is needed to design a trustable system.

Yet, to ease the transition, a good communication between robots and humans is needed. Since communication is used to being implicit between two humans, it would be relevant that robots can understand human body language. The robot could therefore adapt his comportment, and indicate good intentions such as sounds, lights or decreasing speed to indicate that it is safe to work with.

Therefore, in contrary to a factory with workers only, or robot only, collaboration create the need of psychological requirements which should not be underestimated [6].

Safety, on the other hand, is difficult to ensure. A new workspace must get its possible hazards and the risks associated to the robot and its application identified [7]. Afterward, it is possible to select and design appropriate safeguarding measures to adequately reduce the risks.

However, whatever the context is, these are some performance requirements [8]. For instance, a single fault in any of the safety related parts of control system must not lead to the loss of the safety function. When the single fault occurs, the safety function is always performed, and a safe state shall be maintained until the detected fault is corrected. Also, the collaborative workspace where the operators can interact directly with the robot, shall be clearly defined (e.g. Floor marking, signs, etc.). In the same time, robots designed for collaborative operation shall provide a visual indication when they are in collaborative operation. The robot shall stop when a human is in the collaborative workspace, alternatively, the robot may decelerate, resulting in a category 2 stop in accordance with IEC 60204-1. Then the robot must have a reduced speed of maximum 250 mm/s.

4 Requirements and Implementation

4.1 Virtual and Physical Robot

Universal Robot company is proposing a simulator of their robots through a virtual machine. This enable to test programs of the robot in a safe way, remotely. The number of developers is not limited by the number of robots and they can work wherever they want. So, the created simulator is be able to communicate with this robot simulator. However, simulations are never perfect and we want to be able to test the real robot dynamics. Therefore, the collaborative workspace also needs to be able to directly control the robot (as shown on Fig. 1).

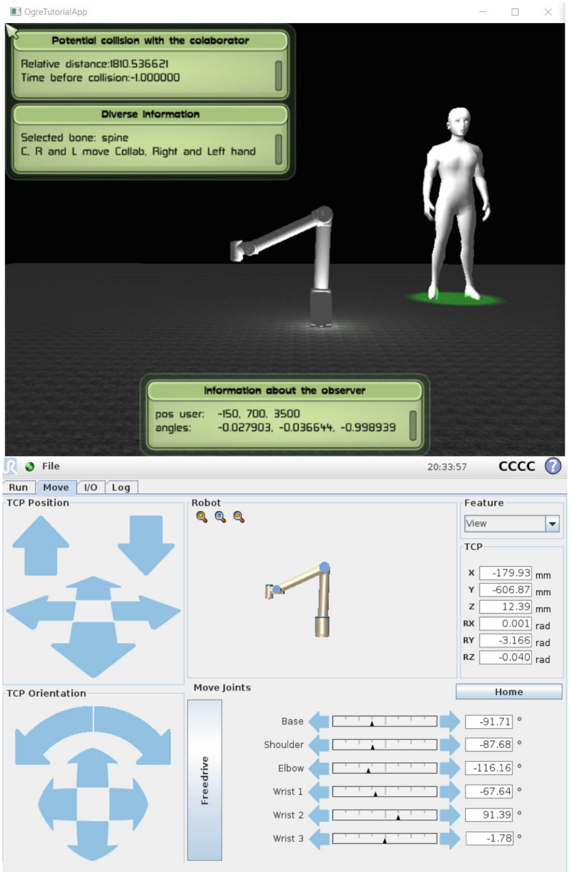

Fig. 1. Simulated robot follows the external simulator data

4.2 Human Collaborators

Human safety is primordial and so nobody should be in the collaborative workspace during its development. Therefore, when the robot dynamics will be tested out with the real robot, having a virtual collaborator is compulsory. The latter tests will be eased by the implementation of controls for the virtual collaborator through a simple keyboard. The designers should be able to place and move the virtual collaborator however they want in the virtual collaborative workspace while the robot will be performing its actions and being tested. Nonetheless, feedback from the collaborators are crucial to know how it feels to be in the workspace and to collaborate with the robot. In that case, sensors can detect someone's movements and transmit them to the simulator. This person would be wearing a head mounted device that would diffuse the simulator in

Augmented Reality. They will then see the virtual robots moving around us, hear sounds and see some visual information that is shared by the installation. They will then feel how it is to be in such an environment.

4.3 Human and Robots Within a Collaborative Workspace

The collaborative workspace has been designed, so that the setup can be tested and confirmed as safe to collaborate with. In that case, the collaborator would still wear the head mounted device to get the information shared by the workspace through the Augmented Reality. Semi-transparent glasses display coloured markings and text to warn the collaborators or to make them feel safer. For example, if a robot arm is approaching from the right to a collaborator, we can display on the right of the glasses an arrow with "watch the approaching robot". This would also mean that the robot has seen the collaborator and that it will take care of them. Thus, this simple message would aid the collaborator's feeling of safety and help them perform safe actions and freely focus on their task (as shown on Fig. 2).

Finally, the simulator will make sure that it is easy to observe what is happening from wherever we want to catch all the details the designers would need. To do that, an external camera is implemented and can navigate all over the scene through a computer keyboard.

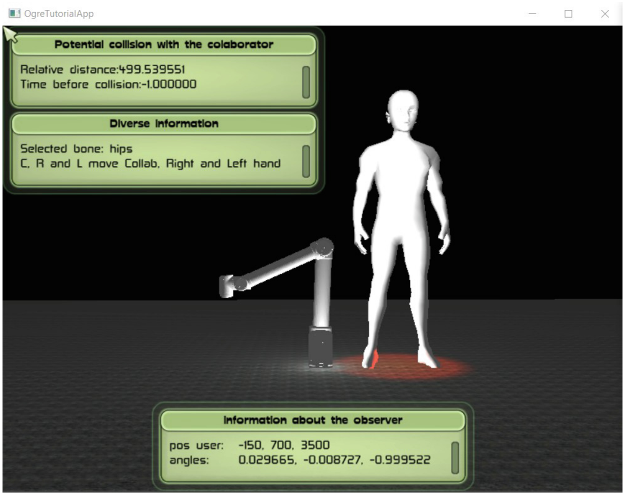

Fig. 2. Safe human has a green light underneath

5 Conclusion and Future Work

The developed simulator presents one Universal Robot and a collaborator. Both can be moved independently. Some of the bones do not rotate around the bone base which create some weird deformation of the collaborator body. More generally, the representation on the simulator can be improved with a more complex dressed mesh. Afterwards a communication back to the robot has to be implemented so that the robot can decrease his speed limit and even stop if it get too close from people. Then, the collaboration and communication between the worker and the robot should be improved. It can for example be done through labels on the floor where actions could be triggered in the robot, such as "stand here to start the robot's program".

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