A Quest Towards Safe Human Robot Collaboration

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Abstract. In the upcoming industrial revolution (Industry 4.0) automation and robotics play a central role. Humans and robots are expected to share the same workspace and work safely side by side. Consequently, various collaborative robots have been introduced to the market. Nevertheless, those robots are still limited in their reactions. In some cases they are restricted to reducing their working speed as a response to the proximity of humans or they initiate an emergency stop, particularly if a contact is detected. In this paper, our work on real-time human robot collision avoidance is presented. Unlike the existing solutions, in our method the robot is provided with agile reactivity to human presence. The system is engineered to achieve natural collision avoidance behavior. As a result, the robot acts with smooth avoidance motion upon the proximity of human, giving him/her the space required to do his/her work in shared tasks between a human co-worker and robot.

Keywords: Human robot safe collaboration · safe coexistence · Industry 4.0.

1 Methodology

We are living in a dynamic and competitive world where change is touching every aspect of our lives, including industry. The paradigm of manufacturing is shifting towards flexible production. In such a case, multi-functional programmable machines (mainly robots) along with skilled manpower offer this flexibility, by combining the cognitive power of humans with robots' ability to perform tedious and repetitive tasks. To achieve this quest humans and robots are required to work with proximity, sometimes in the same workplace collaborating with each others. In such a case, having safe human robot collaboration poses both safety and technological challenge to existing solutions. Yet, the field of human-robot collaboration is still in its infancy. Most industrial robots are still posing safety risks to humans, such that they are confined behind steel fences on the factory floor. To tackle this issue, collaborative robots are introduced into the market, due to their safety-centered design they are allowed to work side by side with humans. Those machines are provided with advanced mechatronic components, but their full potentialities are not fully realized. Existing collaborative solutions tend to reduce robot's velocity with human's proximity, or to stop the robot altogether [1]. Such behaviors seem un-natural and cause interruptions when human and robots are performing shared tasks. For example, the existence of robot in the workspace might deny acceptability to the worker, reducing the robot's velocity or stopping it might not solve this issue. One solution is to give the robot an ability to perform safe collision avoidance motion, by endowing the robot with human like reflexes and more autonomy. In our proposed solution, the robot senses the proximity of the human through external sensors attached to his/her body [2]. Then, sensors data are used to capture the configuration of the human (approximated by capsules), the structure of the robot is also approximated by capsules. The minimum distance between both, human and robot, is calculated using the method in [3], that is used as an input to our custom collision avoidance algorithm based on the potential fields method [4].

2 Tests and results

Figure 1 shows the experimental setup used for testing the proposed real-time collision avoidance system. The robot used is an industrial collaborative manipulator KUKA iiwa 7 R800. An external computer is also used to implement the control algorithm and to process sensors data in real-time. The robot was controlled from MATLAB through TCP/IP connection using the KUKA Sunrise Toolbox KST [5].

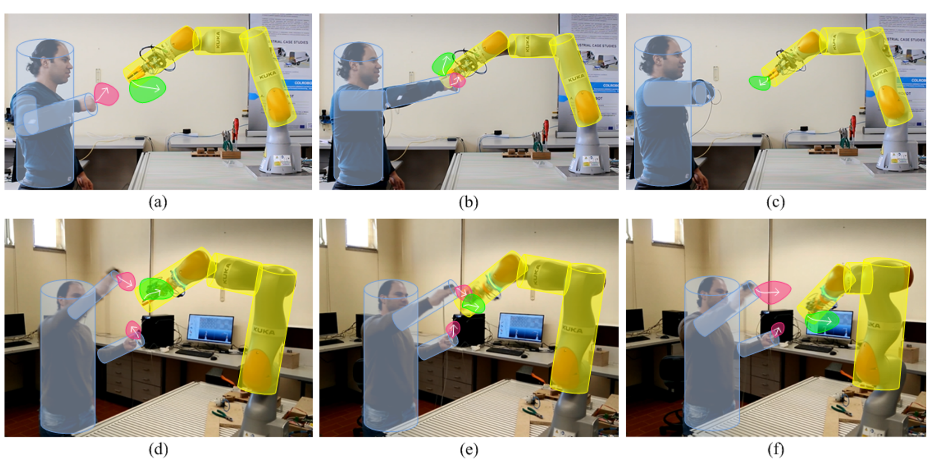

Fig. 1. Human robot collision avoidance, the human is trying to touch the robot causing the robot to maneuver in a collision avoidance motion.

In the proposed experiment a human is performing random motions around the robot with the two arms, causing a reactive motion of the robot as it avoids collision with him/her. Figure 2 at the left shows various data recorded during the experiment regarding the end-effector (EEF), its velocity and position in Cartesian coordinates, as well the minimum distance (d1 and d2) between each human arm and the robot. Figure 2 at the right shows the path of the EEF in 3D space during the maneuvering motion. The results demonstrated that the robot avoids collisions by reacting quickly and smoothly. Such behavior was achieved due to accurate sensing, efficient calculation of minimum distance and fast computations of collision avoidance algorithm which allow controlling the robot at a frequency of 275 Hz. A video demonstrating the experiment is available in [6].

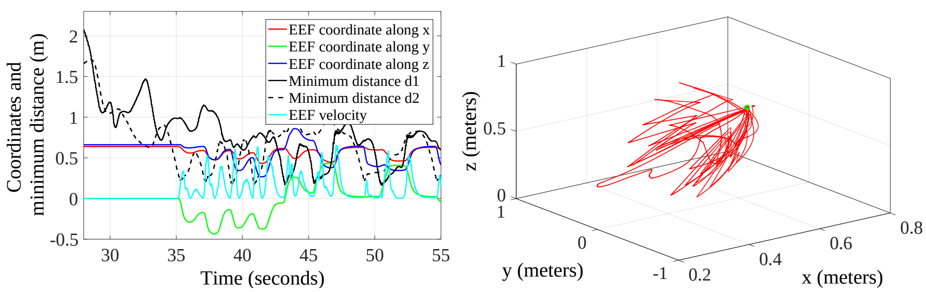

Fig. 2. Minimum distance, EEF velocity and position (Left). Collision avoidance path of EEF in 3D space (Right).

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