A distributed proximity sensor for safe human-robot interaction

Giovanni Buizza Avanzini, Nicola Maria Ceriani, Andrea Maria Zanchettin, Luca Bascetta, Paolo Rocco

I. INTRODUCTION

The industrial state of the art prescribes a physical separation of robotic manipulators and human workers by means of safety barriers, in order to prevent risks of collisions. This separation has a clear negative influence on the widespread use of robotic technology in shopfloors. On the other hand, the removal of protective barriers gives rise to safety issues, that can be addressed with a combination of approaches, e.g. with a reactive control based on exteroceptive sensors measurements. In this work we developed a distributed distance sensor prototype, that can be mounted on an industrial manipulator in order to detect humans in the robot workspace. The optimal placement of such sensor “spots” is discussed, taking into account detection capabilities and safety enhancement. Experiments exploiting an ABB IRB 140 robot and off-the-shelf distance sensors as spots are presented, integrating the prototype in a control scheme aimed at enhancing human safety.

II. DISTRIBUTED SENSOR SIZING AND OPTIMAL PLACEMENT OF SPOTS

To interact with humans, robots must have the capability to react to modifications of the environment: exteroceptive sensors able to perceive such changes have to be used. Among all possible solutions, we focused on onboard sensors, that present several advantages, in terms of ease of deployment, calibration, and absence of occlusions. In particular, we referred to the concept of a “sensitive skin” covering the robot surface [1]. In our approach, the sensitive skin is a distributed sensor, made up of a multitude of distance sensors called “spots”. A method to define the arrangement of such spots has been developed, guaranteeing the detection of objects of predefined size and position. The use of the distributed sensor when only a limited number of spots is available has then been considered, developing an optimization procedure that determines the best placement of the spots on an industrial robot surface. The result has been experimentally verified exploiting off-the-shelf IR-LED sensors and an ABB IRB 140 industrial robot [2]. The probability of detecting a human in the robot proximity when using 20 spots was proved to be about 90% (Fig. 1).

III. REACTIVE CONTROL SCHEME

The distributed sensor has been used as part of a reactive control scheme for industrial manipulators. The distance measurements were exploited to determine the level of danger induced by the robot in the detect points. On the basis of such measurements, a virtual torque that steers the robot away from the detected obstacles has been designed, in this way decreasing the level of danger. Experiments involving humans sharing the workspace of the sensorized ABB IRB 140 have been carried out (Fig. 2), demonstrating the feasibility of our approach within a realistic industrial scenario.

Fig. 1. Number of sensors simultaneously detecting the obstacle and corresponding detection time percentage over the experiment duration: the obstacle is not detected for 10% of the time, while for the remaining 90% up to 6 sensors at the same time detect the obstacle.

Fig. 2. The ABB IRB 140 covered by the distributed proximity sensor avoids collision with a humans while performing a pick-and-place task.

REFERENCES