A tactile sensor for human robot interaction on complexly-shaped industrial robots

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I. Introduction

Long banished behind fences and safeguards, robots are now increasingly finding their ways into new fields of application as service robots or assistance systems. New strategies for human-robot collaboration are erasing the boundaries between workspaces. However safety and protection of humans remains fundamentally important when humans and robots collaborate directly or come into physical contact. State-of-the-art robot control systems offer safe limiting of robot speed and position, whereas safety-rated limitation of forces is currently not a feature of industrial robots. Thus, we propose the integration of an artificial skin into the overall safety concept for collaborative robots with the purpose of providing safety-rated information about contact.

II. Our Approach

We have developed a tactile sensor system for the UR5 from Universal Robots (Figure 1) based upon a piezoresistive transducer technology whose patented matrix transducers can be easily adapted to complex 3-dimensional geometries by thermoforming. This allows us to create tactile transducers that are perfectly adapted to the robots geometry. To reduce the risk of dangerous injuries in case of a human-robot collision we integrated an additional cushioning layer into our sensor setup. This reduces impact forces and absorbs the braking distance of the robot while maintaining the sensors ability to measure interaction forces and represent them spatially and quantitatively resolved (Figure 2).

Figure 1. UR5 with artificial skin

Figure 2. Example of Visualization

The tactile sensor system of our UR5 consists of 16 tactile transducers, covering the entire robot. Each tactile transducer incorporates a matrix of 6 to 8 individual sensing elements. In total we have integrated 100 individual sensing elements on the robot.

Each joint of the robot has been equipped with a PCB containing the electronics to obtain sensor data from the tactile transducers related to the particular joint. (Figure 3).

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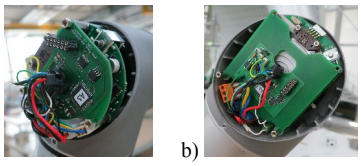

Figure 3. PCBs with sensor electronic, a) small joint, b) big joint

The electronic contains microcontroller-based circuits that scan and sample the tactile transducers by an integrated ADC that serves a resolution of 10 bit at about 20 kHz.

III. Experimental Evaluation

In a first set of experiments we investigated the basic performance of our tactile sensor system. Exemplary shown for these experiments is the response of a single sensor element to forces applied to the sensor (Figure 4).

In a second set of experiments we investigated the tactile sensors ability to be used as a collision detection device. Therefore we integrated the tactile sensor into the emergency stop circuit of the UR5. If the force applied to the sensor exceeds a given threshold the robot should stop its movement.

At first we investigated the system behavior according to the contact area. Therefore we used different test objects and measured the static force required to activate the emergency stop circuit (Figure 5).

Afterwards we investigated the dynamic behavior of our tactile sensor system through collision experiments. For these experiments we used a biofidel collision test set-up that is able to simulate the physical properties of a human. In Figure 6 a typical time response of a collision is shown.

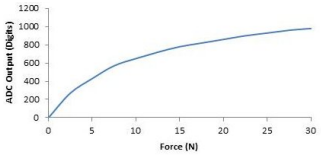

Figure 4. force response curve of a single sensor element at 20% gain

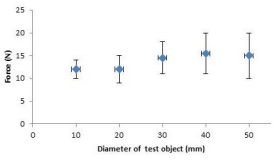

Figure 5. activation force in dependence of test object diameter

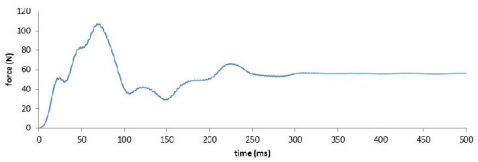

Figure 6. examplarly time response of a collision at 200 mm/s

IV. Future Works

Future work will focus on integrating the tactile sensor into the robot's motion control system to allow force based interaction and motion control in industrial applications.