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Procedia Engineering 69 (2014) 464 – 468

Procedia Engineering

www.elsevier.com/locate/procedia

24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013

Human-Robot Interaction Based on use of Capacitive Sensors

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Abstract

In industrial assembly processes nowadays there is a trend of incorporating robotics and automation in more fields of human activity. The objective is to alleviate the work process for human operators and improve operations with the ultimate goal of increasing precision, shortening the cycle time and reducing risks. However current limitations of technical systems still dictate that human operator takes part in the process and also provides necessary support to the system. Development of advanced interaction models could simplify the role of human operators mainly in complex tasks. Robotic assistants, in form of an industrial robot, completely replace human operators in processes they are fit to perform or assist and hand items to them when they are not. When working together the robot´s priority is not to harm the human. Also it is important the human can convey desired actions of the robot in an intuitive manner. The goal is to apply human robot interaction models based on tactile stimulus. A simple capacitive sensor field has been developed for aiding the human-robot interaction in industrial applications. The sensor is connected to Arduino controller and mounted on the robot. When the human operator is in contact with the robot the change of capacitance is detected. The robot responses appropriately based on the input.

Selection and peer-review under responsibility of DAAAM International Vienna

Keywords: robotics; human-robot interaction; haptics

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1. Introduction

With development of technological solutions, computer processing power and all kinds of control software the field of human interaction with all forms of technology expanded. But development also leads to new problems. Due to increase of system complexity there is a higher demand for expertise of the user. So an issue arises how to interact

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Selection and peer-review under responsibility of DAAAM International Vienna
doi:10.1016/j.proeng.2014.03.013

with ever more complex systems. Whether to simplify control, thus making it is easier and more intuitive for the user, or to allow the user to control every part of the complex system so it is impossible to use without prior training. The simplifying interaction issue spans across many fields of technology including robotics. Human robot collaboration is considered one of mayor research challenges [1]. Intuitive human robot interaction was a topic strictly related to service robotics but nowadays it spreads in all application including ones where classic forms of robot control are dominating. Recently industrial robots are widely employed in various fields [2]. There are multiple architecture approaches spanning from single robot cells to complex multi-agent setups [3,4]. Regardless of system complexity there is an exchange of information between the environment, robot and human. Therefore every form of interaction is established on performing action based on any sort of perception. Types of instruction a human can issue can be roughly divided on voice commands, visual gesticulation, touch and use of all kinds of buttons. Each approach delivers benefits and disadvantages. This research is based on use of touch as a mean of interaction. When considering types of sensors intended for use on the robot and able to detect touch there is a limited choice. A force/torque sensor mounted on the flange of the robot is limited to sensing forces only on the tool part of the robot. Measuring current in all the motors is a plausible approach to determine external forces but it will yield slow response times and insufficient sensitivity therefore posing a risk in interaction. New technologies, like the Kuka lightweight robot, enable torque measurement in all joints at very high frequencies and can produce adequate compliant behavior [5]. Though this technology is still developing it is suitable for human robot interaction. However this article proposes use of a simple capacitive sensor as a mean of interaction based on previous work in the same field [6]. Outfitting the robot arm with flexible sensors as sort of "skin" enables the system to register human touch. With a sort of primitive tactile language it is possible to control the robot with a light touch making it an intuitive form of interaction.

2. System setup

For this technical solution an Arduino microcontroller [7], MPR121 Capacitive Touch Sensor Breakout Board [8] and developed sensor are used. Capacitive sensing is simple in concept. Every object has its own capacitance. This capacitance is an objects ability to hold a charge, and when a person comes in contact with an object the capacitance changes. The MPR121 registers these changes in capacitance. The MPR121 has an I2C interface with IRQ interrupt output to report electrode status changes. I2C devices uses two bidirectional "open drain" lines Serial Clock (SCL), and Serial Data Line (SDA). SCL is the clock line, used to synchronize all data transfers over the I2C bus, and SDA is the data line. The SCL and SDA lines are connected to all devices on the I2C bus. A third wire is needed for ground or 0V. There may also be a positive wire if power is being distributed to the devices. Typical voltages used are +5V or +3.3V. Pulling the line to ground indicates a logical zero, while letting it float to +V is considered a logical one. Only one set of pull-up resistors is required for the whole I2C bus, as shown in Fig. 1.

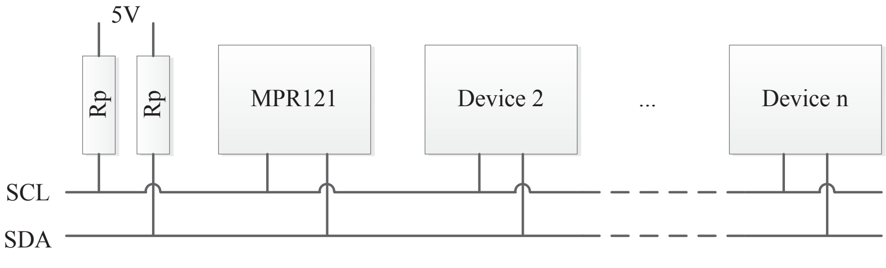

Fig 1. I2C bus.

This means that the MPR121 can drive its output low, but it cannot drive them high. For the line to be able to go high a pull-up resistors to the +3.3V supply must be provided. There should be pull-up resistors for both the SCL and the SDA line. Arduino micro controller has internal pull-up resistors, so MPR121 breakout board can be connected directly to analog pin 5 (SCL), and analog pin 4 (SDA) for communication. When the MPR121 senses a change, it pulls an interrupt pin (IRQ) low. Code is checking IRQ pin to see if it is low during program loop. For this action sensor needs access to digital input pin (IRQ), and in this case digital pin 2 is used. Also there is connection to +3.3V and ground.

Sensing part of the MPR121 consist of 12 capacitance sensing electrodes with integrated independent calibration for each electrode input. It can measure capacitance ranging from 10pF to over 2000pF with a resolution up to 0.01pF. There are also separate touch and release thresholds for each electrode, providing electrode independence [9]. Threshold values are very important for eliminating false or no positives representation of touch states. Also they should be calibrated in accordance to sensor design, and size. There is a small change in capacitance even as an electrode is being approached through the air. If the touch or release thresholds are set low, the trigger signal can be noticed even from a few inches away.

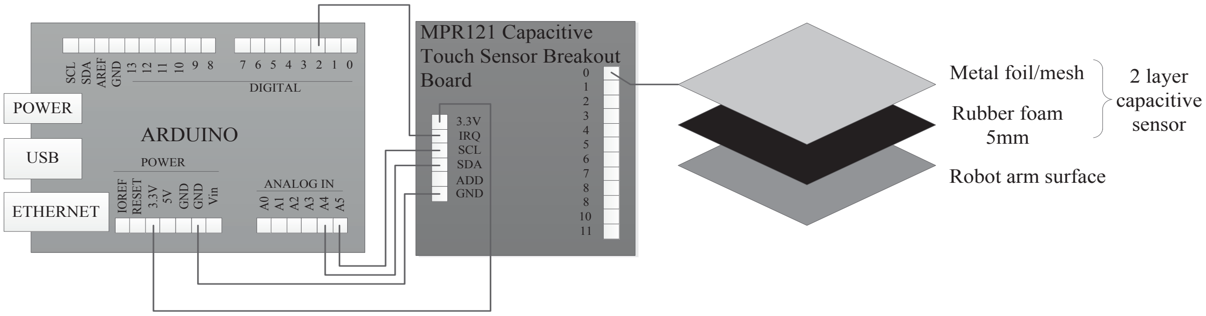

Fig 2. Capacitive sensor.

The capacitive sensor is a soft and flexible two-layer "skin" as shown in Fig. 2. It is shaped in regards to robot casing so it appropriately covers all larger and potential contact areas on the robot as shown in Fig. 3. The two layers it consists of are a metal foil/mesh and rubber foam. The metal foil/mesh is the sensing part connected to MPR121 that reacts to changes in environment. Rubber foam is used as an insulator between the metal foil and surface of the robot arm to eliminate any interference. Change of capacitance on the metal part of each sensor is measured and processed in MPR121. Arduino processes sensors information using Wire Library and developed programs. Once the sensory information is processed an associated message is sent to the robot. All messages between Arduino and the robot are exchanged via TCP/IP communication (socket messaging). The received message is then interpreted in the robot controller and adequate behavior is exhibited.

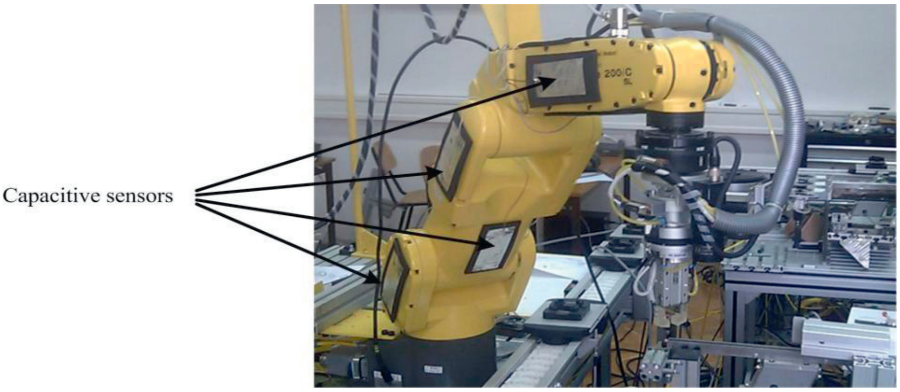

Fig 3.Sensor layout on the robot arm.

3. Implementation

In the developed application the human operator is able to interact with the robot. Touching any of the twelve sensors mounted on the robot or their different combinations results in desired behavior and very intuitive interaction model. The Arduino controller and MPR121 measure change in capacitance and associated instructions are sent to the robot as shown in Fig. 4.

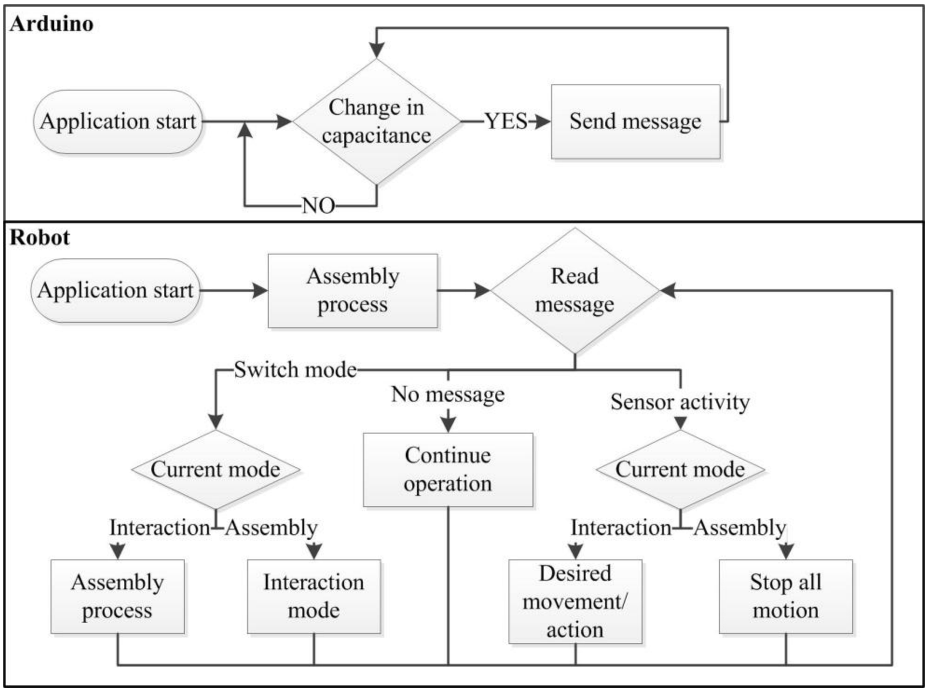

Fig 4. System flowchart.

Depending on the current mode of operation the robot behaves in response to different stimuli. There are two main mode of operation. First mode is assembly which is a predefined process programmed previously. Any conventional robot programming method can create this process. When the robot is in assembly process mode and any sensor is triggered the robot is issued a stop command. This is intended to prevent any damage to the human operator that enters the robot working area. Once the operator let´s go of the robot the process is continued. This is the primary mode of operation as the intention is the robot works uninterrupted. To activate the second mode of operation it is simply necessary to touch the "shoulder" sensor, which switches the mode of operation from automated task to manual guidance of the robot. This is a reflection from human social interaction patterns. As a human worker would tap a colleague on the shoulder to get his attention or communicate a message so the robot responds in a similar way. The second mode of operation is interaction mode where the robot responds with desired movement and action in accordance to active sensors. For example when operator pushes the robot away from the left side of the robot a sensor on the left side is activated and results in movement to the left. Analogously all the sensors respond in an intuitive manner. This enables the operator to move the robot away in order to access the desired area. Also this mode of interaction enables simple way of programming the robot. Instead of navigating the robot through space and recording points using a teach pendant the operator can replicate the same using capacitive sensors. Guiding the robot manually and activating specific sensors on the robot arm a new assembly program can be created or a previously created one can be modified.

4. Conclusion and future work

A simple capacitive sensor array has been developed in order to improve human robot interaction. Presented application utilizes an improvised two layer sensor as sort of robot "skin", Arduino controller and MPR121 Capacitive Touch Sensor Breakout Board in order to enable interaction. Developed model of interaction provides a safer working envelope of the robot due to the activation of stop command on any contact with a human. Also it provides a touch-based movement of the robot so an operator can simply hand guide the robot in any direction. This can serve as a foundation to simplify robot programming. The developed modules can be used on any robot that supports socket messaging.

Further work will concentrate on developing the capacitive sensor array and expanding control modules of the robot in order to cover a wider field of potential applications. Intuitive interaction eliminates the need for expert training in robotics of the end user. Due to simplicity robotics could find application in all sorts of task that could be further improved with use of robot. Numerous fields have the potential from every day service robotics to very specific fields that would benefit from high precision of robots, like neurosurgery and other minimally invasive surgical procedures. Also there is a need for deeper understanding of a plausible tactile language for human robot interaction. It has become recently apparent that social and interactive skills are necessary requirements in many application areas and contexts where robots need to interact [10]. This requires a cross section of multiple scientific directions from technical, medical and social studies to better comprehend human communication patterns and embed them in control modules. As this is an interdisciplinary field the research potential is immense and widely applicable.

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