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Adaptive Inspection Cell for HMI Consoles

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Abstract. The actual control quality standards require manufacturers to increase the inspection process. Instead of a sampling method, all items should be inspected and different equipment with different characteristics in the inspection cell need an adaptive system and the control quality cells should be enhanced. The presented work describes a self-adaptable robotized inspection cell for HMI consoles. which comprises the image acquisition system with controlled illumination and a force feedback sensor manipulated by a collaborative robot. The developed robotized cell is capable of detecting different HMI consoles and adapting the inspection routines of the manipulator robot according to the specific console. Moreover, the flexibility of the collaborative robot allows to adapt the camera positioning, lighting, and distance in a way that future HMI consoles can be inspected based on learning strategies.

Keywords: Adaptive industrial Inspection, collaborative robots, torque sensing, simulation.

Introduction

Nowadays, the 4th industrial revolution is introducing the cyber-physical systems concept, comprising a network of nodes combining cyber and physical counterparts, aiming to provide intelligence and communication for artificial and technical system that are called smart systems [1]. Those systems, are being developed looking through the increase of the industry values. It means that the volume of manufacturing production must decrease, and a high-mix production in a cost-efficient way [2].

To become the production process as good as possible, multipurpose robots are being used for its adaptability and intelligence, without losing focus on safety, versatility and collaborative [2]. At this moment, the density of robots in the industry is increasing globally and following the concept of "4.0 Industry", these robot are parts of all level of the production and tests [3] [4].

A currently demand faced by manufacturing companies is the need of high products quality, which requires the implementation of more effective inspections tests, applied to all production items instead of using a sampling. These actions will allow the achievement of valuable benefits for the companies, namely to increase their market value and reduce the maintenance and replacement costs.

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So, to follow the 4th industrial revolution and the world commerce needs, it is proposed the creation of a workbench for inspection and cooperative work for general use, that is, it can be used for many purposes and types of work.

This paper presents an adaptive inspection cell for testing the push buttons of HMI consoles, that is composed by a UR3 collaborative robot, a camera and an illumination system controlled by an embedded system. This system allows to adaptably test different HMI consoles as well as run the inspection routines under different operating conditions, e.g., related to the environment illumination.

The rest of the paper is organized as follow: Section 1 contextualizes the related work. On the third section it is presented the system architecture. The following section describes the image process system used to acquire data. After, a section describing the illumination control utilities and improvements are addressed. At sixth section there is a description of the robot, the force sensor characteristics, the algorithm implementation to connect the robot with the system acquisition data and the sensor's feedback. On the seventh section it is presented the system simulation's results. Lastly, the conclusion and future works are presented.

1. Related Work

Different types of quality inspection systems are being studied to demonstrate their importance to improve the process. As examples, some adaptive systems comprise vision and trajectory control [5], others focus on the collaborative work between humans and robots [6], and frameworks for the interaction between inspection and maintenance [7] procedures, e.g., by using Augmented Reality (AR) technology are being deploying and can be found in the literature.

In particular, some research is being devoted to the collaborative work in robotics and methods that allow its application in real cases [8]. An example is the creation of a Human Robot Collaborative (HRC) workplace to decrease the time of new set-up or a cell's configuration [9].

Moreover, security rules, methods and systems are studied to protect humans, avoid accidents and possible damages on the robots during the utilization of collaborative workplaces [10]. Also in this area, studies about estimation of contact forces have been also done to provide security for users [11]. The use of collaborative robots in adaptive inspection cells can contribute to increase efficiency, adaptability and responsiveness in such inspection tasks.

Inspection stations are following the factories way. So, if the production is becoming more variable and adaptive, the quality manufacturing technologies needs to be capable to improve their performance to balance the relation between adaptive production and its quality [12].

Focus on the main objective of the study made, the implementation of the low level programming used on the robot interacts with image system, a force sensor and an illumination control, but a security system will not be applied in this paper what is made by [13].

2. System Architecture

First of all, it is necessary to develop the system architecture (Figure 1), that is, the main process used to perform the processing of image, the illumination control and the communication between the programming and the simulation of the real scenario.

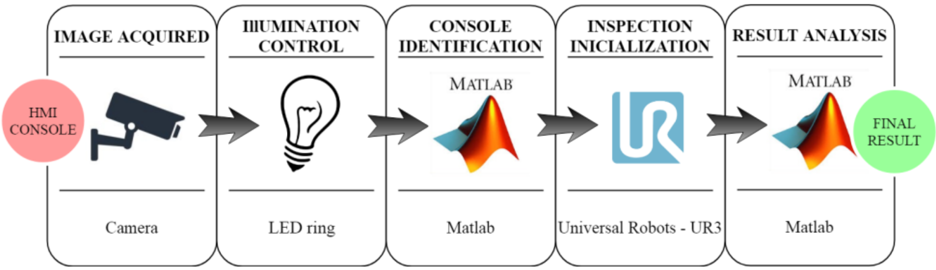

Figure 1: System architecture.

The procedure to simulate the real word task starts by creating the workplace structure using SolidWorks and, on sequence export to V-REP (Virtual Robot Experimentation Platform) to make an offline programming. Then, create a structure of the system functions to associate the offline programming to the real task. It is composed by a sequence of algorithm created to work together with the robot. These codes are responsible for identifying and controlling the systems functions that will inspect the HMI console (Figure 2).

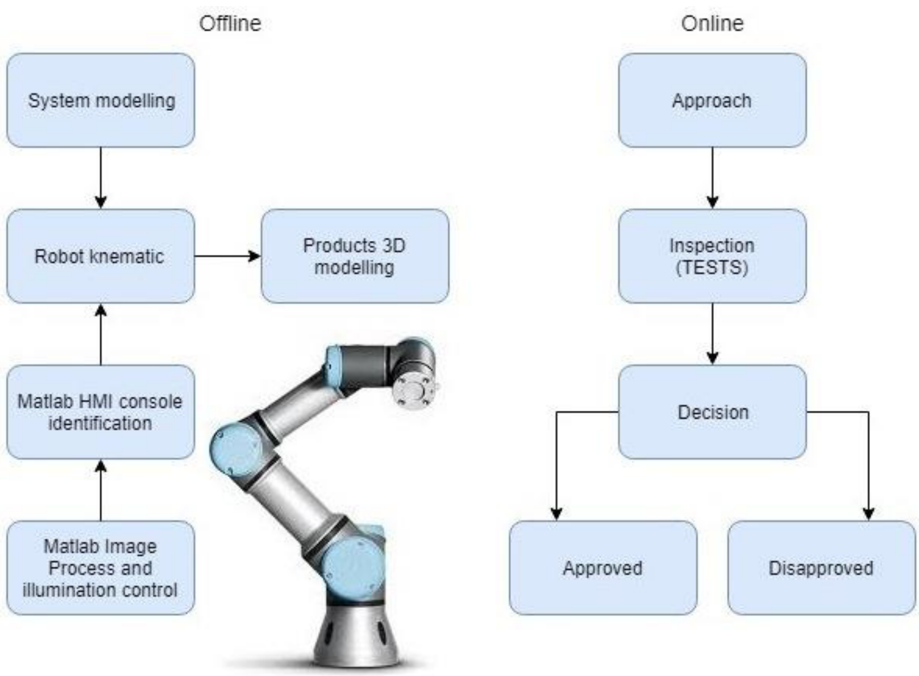

Figure 2: Operation flowchart.

With the 3D models done, it must start the offline simulation of kinematic from the robot that will be setup according to the Matlab's image process response. It sends a message for the network to communicate with the V-REP program. This way the console will be identified and its characteristics are setting up to the inspection test to be done. According to the HMI type, the system needs to get different positions to test the cell and this should be done offline. After the tests, the results are sending to be processed in Matlab that approves or disapproves the console as answer of the maximum and minimum force response of each button, and sends the final result to V-REP (see Figure 3).

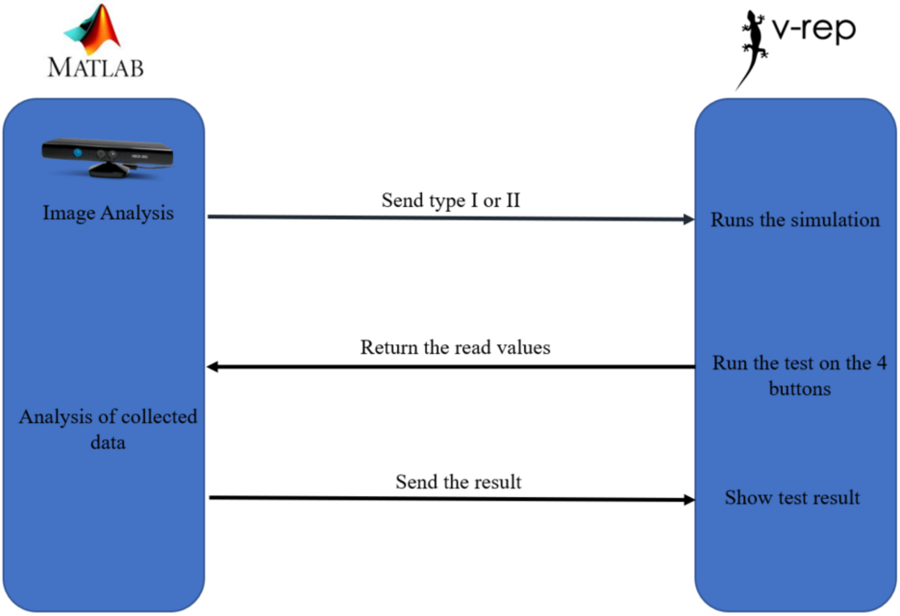

Figure 3: Process sequence made by Matlab and V-REP.

3. Image Acquisition and Adaptive Illumination System

The acquisition of images is done by a camera installed on the robot and further the images are processed by Matlab based on an algorithm used to identify the HMI that is ready to be inspected. The image is processed by a function that made a histogram from the picture obtained. If the histogram shows a low quantity of light, the system activates the illumination control until it stabilizes the illumination to an established level of luminosity, facilitating and improving the image acquisition. Moreover, filtering is done to remove some noise.

The illumination control is related with the image process. Since it is actuated by the Matlab, some data information is being transmitted by serial communication to an Arduino Uno. This controller receives the data and processes it to each LED of light increasing or decreasing it according to the histogram generated. This system is demonstrated in the Figure 4.

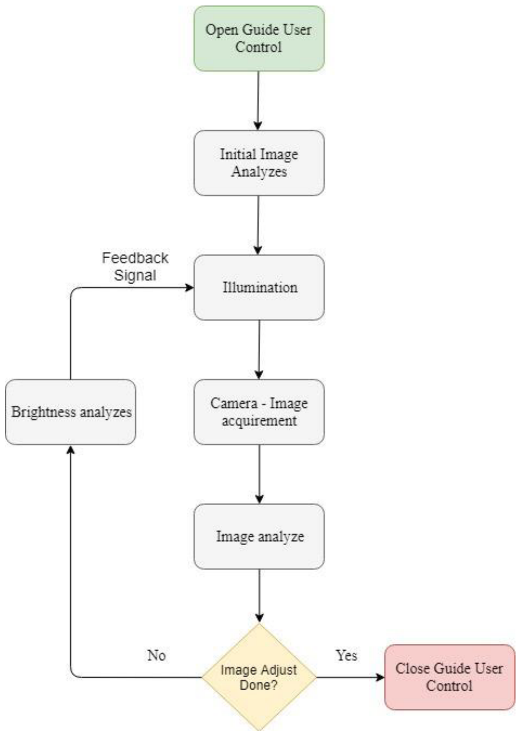

Figure 4: Image analyses and illumination control.

Figure 5: RGB LED ring WS2812.

The illumination is done with a 16-Bit RGB LED ring WS2812 (Figure 5) coupled on the camera according with the image analysis made by Matlab. A string with the RGB values are transmitted for serial communication with the Arduino and set up until the brightness value gets in the Guide user. To analyse the image, a histogram is made and shows the brightness frequency of an image, in grey scale, and it's represented by a one-dimensional array with n elements. These elements contains the value $z = f(x, y)$ that indicates a probability of brightness and are independent of each one's position on the image. So it's only a probabilistic information about the image analysed. This array's values are processed to control the lights' system. Also, in the image process and edge detector is applied to detect abruptly changes of brightness. In this study, it helps to differ the HMI surface from the workbench, reducing false diagnosis [14]. Furthermore, to recognize the objects some Matlab's functions are being used to identify the object according to each characteristics, e.g., area, eccentricity, centroid, etc. All this process is setup to improve the image classification and object identification.

4. UR3 and Force Sensor to Inspection

For the robustness, the excellent repeatability of movement and easy operation a robot from the Danish Universal Robots was chosen, specifically UR3 [15]. By its size and qualifications it is an excellent option to be used on the proposed workplace model. Its workplace extends to 500mm from the base joint but according to the manual it also has a security region of work. Using V-REP the bench is created and linking it to Matlab that will process the images and data received.

The force torque sensor is an FT 300, from Robotiq (Figure 6). It has a specific mechanical coupling for UR3, a force sensing range of ±300 [N] and a resolution of 0.2 [N] on the three axes. Besides it also can be easily connected to USB port [16]. Along with the force and torque sensor there is a tool designed in SolidWorks (Figure 7) to operate the buttons, giving the feedback data.

Figure 6: Robotiq® FT 300, force sensor [16].

Figure 7: Tool to operate the buttons.

5. Simulation and Results

Started by the construction of the system platform on V–REP, it was created to simulate the inspection ambient that is used (see Figure 8 and Figure 9) with the HMI consoles tested (Figure 10). This platform receives data from Matlab system, according to the cell identification and illumination control made together in a Matlab GUI (Guide User Interface) to make its use easier. The interface is composed by a scroll bar to set values of brightness of the image, a real time preview image and button group to turn on and off the illumination and image identification.

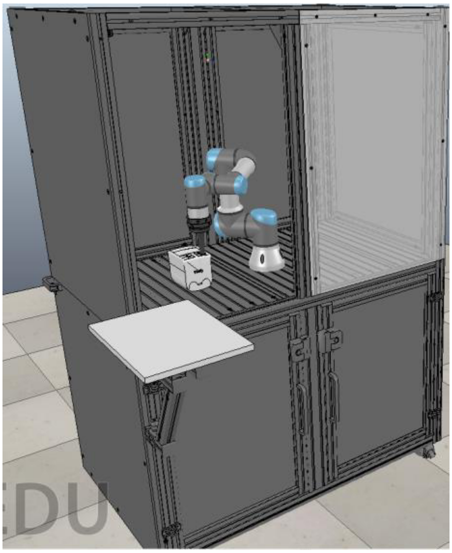

Figure 8: V-REP robot and ambient simulation with console type I.

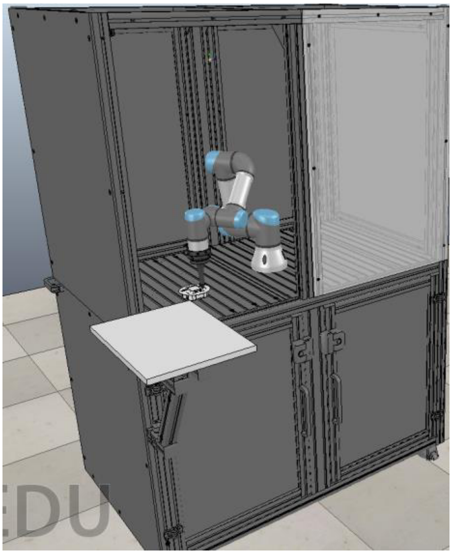

Figure 9: V-REP robot and ambient simulation with console type II.

After the image setup, a process sequence is done to identify the HMI and send data to the V-REP starts the inspection of a specified cell. When the tests are finished the program sends the results of each button to be processed by Matlab, that according to the type of cells may use a specific algorithm to process the results and approve or not the console. The final result is also send to V-REP that shows it and finish the inspection.

In addition, the user also can access some resulting figures from the image process like the red, green and blue histogram in grayscale of each colour plane. Also, provides a final figure with the black and white final image filtered and filled up, and another one with the object identified (Figure 10).

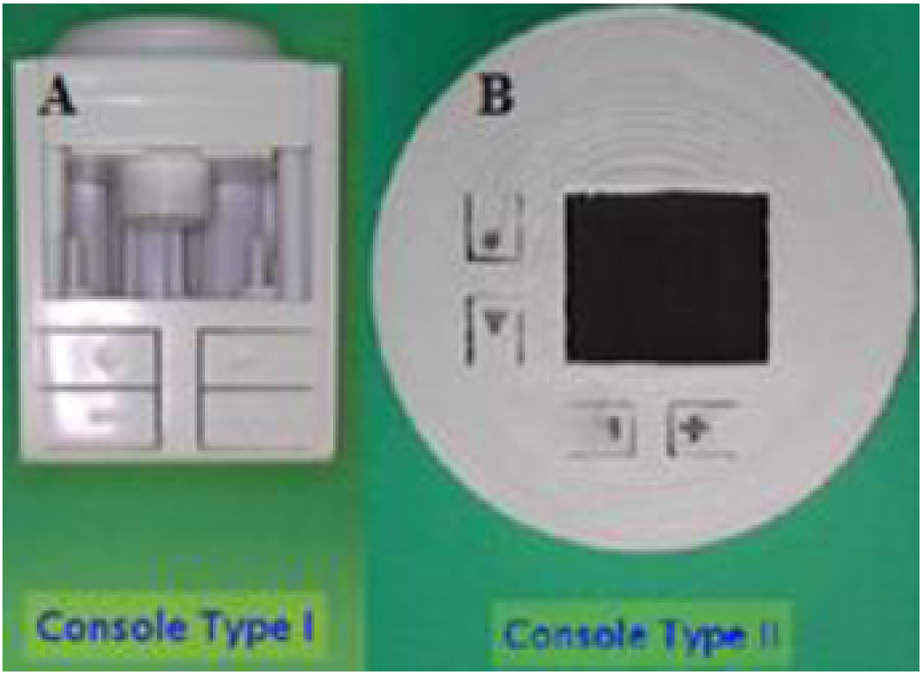

Figure 10: Consoles identified.

With the identification of the HMI done, the net communication is setup and the information is transmitted to V-REP starts the tests that, in these cases, the consoles have four buttons each. When the tests have been finished, the simulation create an array of four positions and sends it to be processed by Matlab. After process, it gives the result of the quality inspection according to the analysis made, then an “OK” signal or “REPROVED” signal is transmitted (Figure 11) to V-REP. In this simulation, to the console be approved, the response of each button should be smaller than 2,0 [N] and bigger than 0,8 [N] but another algorithm can be created according to the necessity. Also, the final results are displayed in the signal monitor to the user follow the procedure.

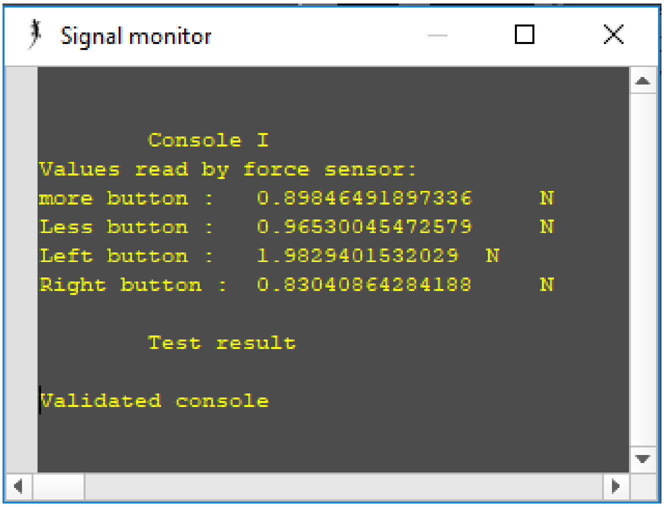

Figure 11: Results displayed on V-REP.

6. Conclusion and Future Work

It was presented a self-adaptable robotized inspection cell for HMI consoles. which comprises the image acquisition system with controlled illumination and a force feedback sensor manipulated by a collaborative robot. The developed robotized cell is capable of detecting different HMI consoles and adapt the inspection routines according to the specific console. The flexibility of the collaborative robot allows to adapt the camera positioning, lighting, and distance.

The system proves to be extremely effective and also has a high capacity of adaptation.

For the future, the construction of a real model of this bench workplace should be done to demonstrate the system adaptation capacity, and move on with a new study about the security system to be installed on the bench. Also an automatic program to act inspecting, positioning, creating and adding new types of consoles together with a machine learning algorithm can be addressed improving the quality results and making it more useful to a real application in industries.

To make a cooperative work, a Kinect sensor is being installed to identify possible movement around the robot avoiding accidents while increasing the security of the users and follow the rules of cooperative robots [17].

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