Augmented Reality for Robot Control in Low-cost Automation Context and IoT

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***Abstract*—Augmented Reality (AR) is one of the key technology in the Industry 4.0 development. The robotic manufacturing is very useful because of their versatility and repeatability in industrial tasks. However, as technologies advance, complex and high-cost control systems are required, hence the need to create low-cost and efficient control systems, with low complexity when operating them. A virtual control proposed in Unity 3D allowing the application to be much more interactive and very easy for the user. The authors describe the working scenario, the overall architecture, communication protocol in the context of the Internet of Things (IoT) and give design and implementation details on the AR application.**

***Index Terms*—Augmented Reality (AR), Internet of Things (IoT), Low-cost automation, Robotic assembly, Manufacture.**

I. Introduction

Today, the evolution of production systems is the basis of the competitiveness, improvement, economic and social development of industrial organizations worldwide. The fusion of industrial automation and computing has given rise to technical innovation known as Industry 4.0 [1]. Industry 4.0 is characterized by increasing reliance on system automation and interconnection due to the need to increase efficiency, autonomy and process customization at a low cost, and thus robotic systems become an important tool that has an increase in demand year after year within the global industry [2].

The applications that are developed in Virtual Reality (VR) or Augmented Reality (AR) can be oriented to the processes of teaching-learning [3], [4], in the academic part and to the training - qualification in the industrial scope, these processes previously mentioned can be applied individually or in collaborative works between users, for which it is considered: (i) environments with a user in which tasks that can be performed individually are considered such as assembly of mechanical parts, doors [5], spot welding, precision welding [6], [7], electronic control units [8], electric motors, among others.

In the current context of the technological world, robotic systems have had a significant advance in cost and implementation, with the emergence of low-cost Single Board Cards (SBC) that can be developed efficient control systems for robotic automation to really low prices compared to the systems that are handled in the robotics and automation market [9], [10]. However, despite being a major breakthrough, these new technologies have only taken place in the major world powers, there is limited knowledge of them in less industrialized countries.

The main goal of this research is the development of an Augmented Reality (AR) platform for the control and handling of a robotic manipulator such as the Scorbot ER 4U, using low-cost microcontrollers or so-called low-cost embedded cards. The first step is performed the cinematic analysis of the robotic arm, and thus define the method of control of the manipulator, which will be designed in an AR environment using the Unity 3D engine, together with the Meta 2 glasses increases for interaction with the user, finally, the users can send messages to the embedded card using the Message Queuing Telemetry Transport (MQTT) protocol, and in turn, the low-cost controller card controls the robotic arm, finally, these messages will be validated checking that the robot's movement is the desired one.

The design of the document is as follows. Section II illustrates a case study of AR for industrial training. The proposed solution for the case study is presented in Section III. Finally, some conclusions and future work are established in Section V.

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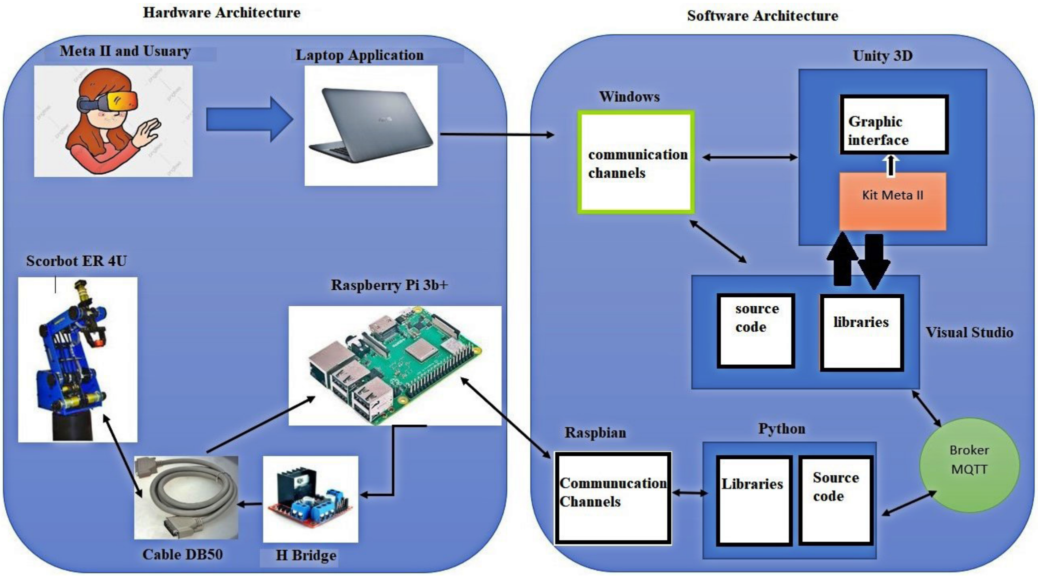

Fig. 1. Software and Hardware Architecture

II. Case Study

The hardware architecture is the conceptual design and the fundamental operational structure of the system. It is the physical support where the software resides. The hardware architecture consisting of a Meta 2 glasses [11] as the AR device. Meta 2 is a stand-alone device that has an own graphic processor that runs the processes natively on its hardware. These glasses provide real-time tracking, stable and accurate.

Meta 2 glasses are connected to the computer through communication cables that will allow interaction with the developed AR system. As shown in Fig. 1, once a precise location of the space is achieved and maintained, the user just by putting on the viewer will already have the reach to the virtual objects and the virtual training sequences that will be overlaid on the real environment through the computer that contains the application and because the device maps the environment and tracking the user's actual location, the user can use defined hand movements to interact with the 3D images.

The main goal of this research is the development of a control system for the Scorbot ER 4U robotic arm, from an augmented reality environment platform created in Unity 3D and with the use of Meta II augmented reality goggles, a low-cost arm controller is designed used the RPI card which interacts with the robotic manipulator through the GPIO inputoutput pins. The MQTT communication protocol is used for communication between the virtual environment and the controller.

The software architecture provides a general reference necessary to guide the construction of the augmented reality system for user training, allowing all application objectives and restrictions to be covered.

III. Implementation of the Solution Proposal

This stage presents the design of the system architecture both at the hardware and software level, describes all the components that will be part of the control system, for the description Unified Modelling Language (UML) diagrams, are used.

A. Hardware Architecture

The hardware architecture consists of the design of a physical communication network that allows the interaction of all hardware components of the system supported in the software. Fig. 2 has a diagram of components of the hardware that are part of the proposed control system.

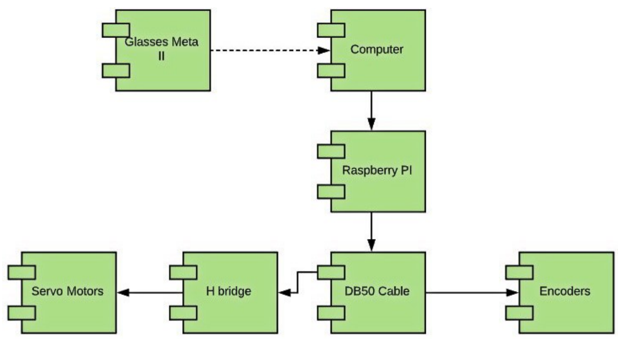

Fig. 2. Diagram of Physical Components Control System Scorbot ER 4U

For user interaction with the system the Meta 2 augmented reality goggles is used, these smart glasses offer the ability to track in real-time, stable and accurate, provide a mapping of the environment and follow the actual location of the user. The glasses interact with the virtual world through the computer by using communication channels such as the HDMI port and the USB3.0 port. In this way the user when placing the virtual reality glasses will be able to visualize the Scorbot robot in 3D, having the possibility to change the position of the effector of the robot indicating where it should go simply by moving its hand.

RPI interacts with the Scorbot arm to drive the servo motors and receive the signal coming from the encoders, for such interaction the boards use the GPIO input/output pins. The embedded card is also connected to the virtual world via the computer, through the ethernet or wifi communication ports and supported by the MQTT data transmission and reception protocol receives all the signals coming from the PC where the META 2 goggles are connected.

Fig. 3 provides the hardware architecture between RPI and the Scorbot manipulator arm.

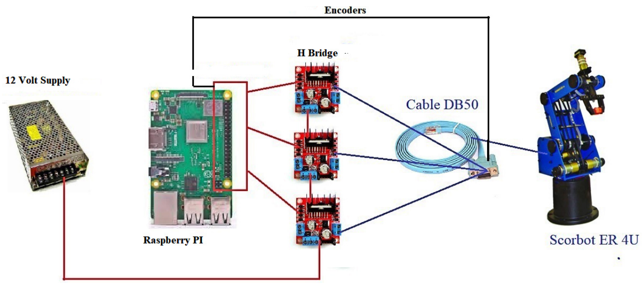

Fig. 3. Raspberry pi and Scorbot hardware architecture proposed

IV. SOFTWARE ARCHITECTURE

It consists of two levels of assembly, the first, is developed in Visual Studio and allows the coding of the instructions in the languaje C# for the control and movement of the 3D model of Scorbot which was previously designed, instructions to communicate under the MQTT protocol and code to interact with the META 2 glasses, in addition, at this level also add all the libraries necessary for the user interface, control of objects in the workspace and communications.

The second level of assembly is developed in the Thonny Raspbian IDE which is a code manager for Python language, in this assembler are encoded the instructions for sending and receiving signals through the GPIO pins, thus managing to interact with the robot Scorbot. Also, there are a C# code to establish communication through the MQTT broker, and finally, all the libraries necessary for the use of raspberry GPIO pins and MQTT libraries are added.

A. Human-Robot Interface (HRI) Design

It bases its operation on the manipulation of 3D objects, which are contained within a scene, in order to manipulate the objects that require script coding C# Sharp language. These scripts implement a class with attributes and methods. For the development of the proposed control system, scripts have been developed for both the control and handling of the robot and for communication with the embedded card. This interface is programming used 5 different classes which are detailed below:

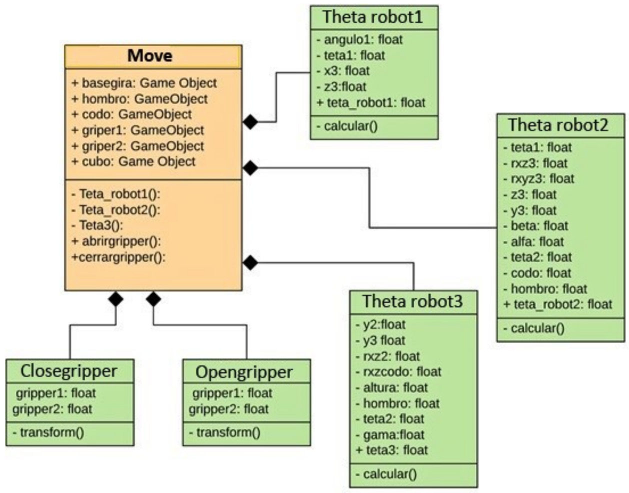

Fig. 4. Scorbot Movement Class Diagram

1) Scorbot ER 4U Movement Design: Fig. 4 shows the classes used for Scorbot arm control, each class has their attributes and methods.Furthermore, there is a composition relationship between the classes. As the ”movement” class can be observed predominates over the others i.e. without the ”movement” class the others cannot continue to function independently.

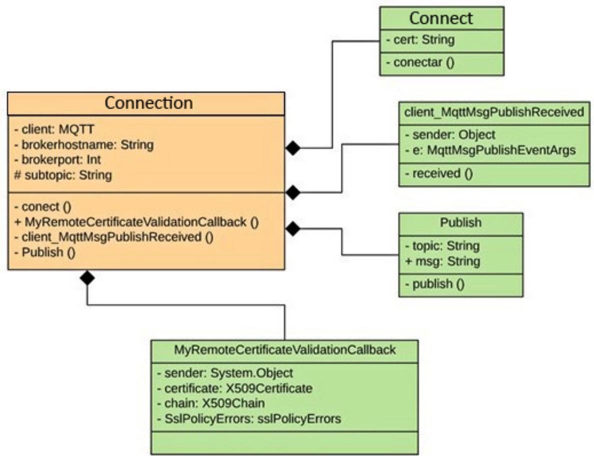

Fig. 5. Scorbot Movement Class Diagram

2) Communication Implementation in Unity 3D software: Fig. 5 shows the classes that are used for MQTT communication protocol implementation in Unity 3D software. The MQTT communication stack used is Mosquitto Broker. Each class has their respective attributes and methods, it is important to note that there is a composition relationship between the ”communication” class and the other classes, i.e. the classes they cannot function independently without the ”communication” class.

3) Main scene class diagram: Fig. 6 shows the classes that are used for the main scene, each class has their respective attributes and methods, it is important to note that there is a composition relationship between the "main" class and the other classes, the classes do not can operate independently without the "main" class.

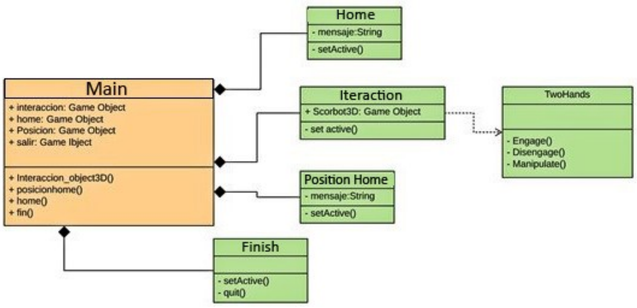

Fig. 6. Scorbot Movement Class Diagram

B. Interface development in Unity

Within the virtual environment should be positioned the 3D model of Scorbot which is built in the Blender software. With the model already in the workspace, the authors proceed to give physical and kinematic characteristics for the movement of each part of the robot. In addition, is inserted into the scene a small white cube that is a pointer that indicates where the end of the robot should be placed. Finally, buttons and labels are created that will be inside the scene, a background image has also been added to give the scene a pleasant look according to the situation. Fig. 7 shows the design of the virtual environment.

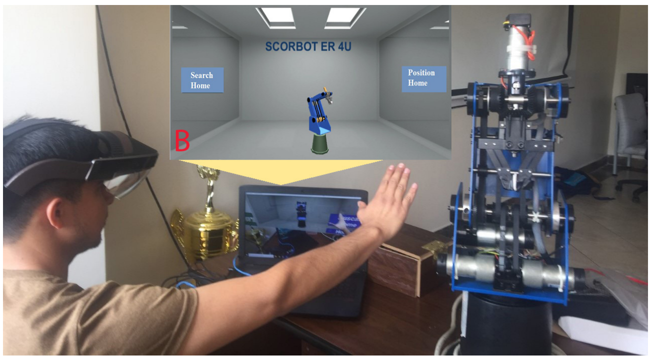

Fig. 7. HRI Virtual Environment Evaluation by Users; B) HRI Virtual Environment

V. Conclusions and Future Work

The use of the Raspberry Pi card as the controller of the Scorbot ER 4U robotic arm is an effective means of giving movement and control to the manipulator, as it adapts perfectly to the vast majority of communication protocols and thus interacts with different platforms and environments.

Establishing communication with the controller under MQTT parameters ensure success in the control system of the Scorbot manipulator,the use of this communication system makes that the goal achieve successfully because it provides security and quality in the transmission of the message from the virtual environment to the controller card.

Future works will be the development of applications for monitoring parameters in real-time control systems since integrating AR can be displayed on the work screen important information, in addition, these applications can be able for handling loads through robotics arms in hazardous environments.

Acknowledgment

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