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ELECTROTECHNICS, ELECTRONICS, AUTOMATIC CONTROL, INFORMATICS

REMOTE-CONTROLLED GESTURE BASED ROBOTIC ARM

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Abstract: The project aims to implement the functionality of a robotic arm able to be guided through a web page, with the purpose to move an object from point A to point B. Also, the robotic arm can work in an automated way, in which the initialization phase is executed.

Keywords: Robotic Arm, Rapsberry PI, Mbed, FRDM KL25Z, Human Hand Robotic Emulation, Hall Sensors, Android.

1. INTRODUCTION

A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the total sum of the mechanism or may be part of a more complex robot. The robotic hand, can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. For example, robot arms in automotive assembly lines perform a variety of tasks such as welding and parts rotation and placement during assembly. In some circumstances, close emulation of the human hand is desired, as in robots designed to conduct bomb disarmament and disposal.

The authors propose an implementation of a robotic arm which can be remotely guided through a web page. The robotic arm can do several actions, eg. moving an object from based location to a new one etc. Thereby, it doesn't matter in which position the arm is found when it is powered on because it can be restored to the initial position. The communication will be accomplished either from the proximity of the robotic arm, either from distance via a web page from which the commands will be retrieved to a Rapsberry PI.

Thus, the project can be applied in an industrial environment with the purpose to transport the objects that represents a danger to human health. The arm can be set to function in an autonomous mode or in manual way and can be upgraded with a web cam in front of it that will track in real time if a defection occurs. Another area of use is the academic environment. With the help of an accelerometer, through the device Mbed FRDM KL25Z, the user can move the robotic arm in a way resembled with the motion of human hand.

2. APPLICATION DESCRIPTION

For the movement of the robotic arm can be used either engines with direct current, either servo engines, with establishment of a PWM factor, which will simplify the project. To increase the complexity and creativity we will use engines with direct current, watching to find a way to limit the displacement distance once the robotic arm reaches his end.

The solution to this problem consists in stopping the current, once the arm gets in final position, with the help of micro switches or, better, with Hall sensors. Thereby, the chances of a failure at the contact with the micro switch is reduced, because it is fragile and can be easily broken down.

Hardware resources:

- Raspberry PI 3
- FRDM KL25Z
- 5x engines with direct current
- 2x H bridges
- Module with Hall sensor A44E
- 4x battery D (1.5V), 1x Battery 9V
- Voltage stabilizer
- Bluetooth HC-05 module
- Camera V2 module for Raspberry PI

Software resources:

- Compiler- Mbed (fom web browser): to program the FRDM KL25Z platform
- Raspbian operating system
- Apache web server

The general algorithm for the control of the robotic arm:

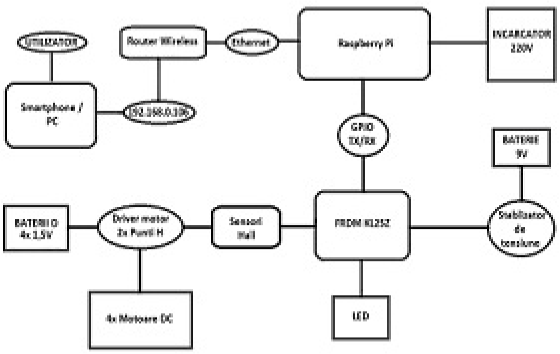

Fig. 1. Algorithm Description

The robotic arm is basically an intelligent system because there are mechanical components (engines with direct current) interfaced with electronic components (bridge H) and with the help of FRDM KL25Z platform and Raspberry PI, it provides a optimal development environment for the programming at the microcontroller level as well as to the Raspbian operating system. The robotic arm can be used in a wide area. It can be implemented in industrial environment with the purpose to transport objects that represents a danger to human health or in the assembly lines of the vehicles. In the first place, the robots can be classified depending of the nature of their application and in the second place, in the way in which they move. In the first category I will treat the way in which robots based on application nature woks. The robots are used in wide areas and the number of jobs for those who are passionate about robots is growing.

Industrial robots types and applications:

- Industrial robots – those robots are used in the process of fabrication; usually there are used articulated arms, specially developed for tasks like welding, handling materials, painting and others; this category includes robots with automatic guidance that executes tasks of a predefined number of times.
- Domestic robots/ for household – robots used in houses; this category includes a wide area of devices, like vacuum cleaners, robots used for pool cleaning, sweeping, sewer cleaning or others category of robots used to do housework. Also, in this context, some surveillance robots can be considered household robots.
- Medical robots – robots used in medical institutions, hospitals. First and foremost – surgical robots. Also, some vehicles automated guided, like robots for assets pick up and transportation.
- Services robots – robots that aren't part of others categories of use. Those can be robots for data acquisition, robots that present some technologies, robots used for research, etc.
- Military robots – robots used in the army. Those kind of robots includes bomb defusing, robots for transportation, drones for reconnaissance. Most times, the robots created in military field can be used by force orders, search and rescue or in others similar areas.
- Entertainment robots – those robots are used in a wide area of categories, among which toy robots, for example: Robosapien or "running" alarm clock and robots with articulated arm used in movement simulation.
- Spatial robots – robots used on International Space Station and on special ships, rovers that travel Mars.
- Robots of passion/ competition – robots created by those who want to learn more, and present the following features: movement on a certain line, sumo robots, robots for fun or with competitive spirit.

The degree project has at its base 2 development platforms: micro controller FRDM KL25Z and computer with operating system Raspberry PI 3. Although on Raspberry PI can be realized both tasks, there will be a lot of lost time with the management of direct current engines, because those, at processing time, go through an additional layer represented by the operating system.

Thereby, the microcontroller realize the real time tasks and manages the accelerometer sensor. But to control the robotic arm from distance it is necessary a web server, which involves the presence of an operating system with TCP/IP stack for the network.

The robotic arm is interfaced with Hall sensors that establish the maximum distance that it can travel on the arm coordinate axis. The use of Hall sensors brings an advantage compared to micro switches because it doesn't require direct contact with the robotic arm but, instead, they make use of the propriety of electromagnetic field to find the presence of a magnet. In this way we avoid failures of device touching.

On the gripper a web cam is mounted which allows for image acquisition and their visualization from distance with the help of web server, hosted by Raspberry PI. Inside the box, which can be seen as blackbox, there are components (hardware and software) that support the execution of the project and his functionality as a whole.

Fig. 2. Robotic Arm

<u>Hardware components</u>:

MKL25Z128VLK4 microcontroller;

- Capacitive tactile surface;
- MMA8451 accelerometer;
- RGB LED;
- power supply: through USB or external source;
- online compiler;
- UART interface with programmable baud rate;
- reading/writing speed between 9600 and 56000 bps;
- low energy consumption: 1.8V on operation, (1.8-3.6) V I/O;
- automated connection at last used devices;

Raspberry PI is a computer with the dimension of a credit card and it can be connected to a mouse and a keyboard, having 4 USB ports. Raspberry PI presents a wide area of application, like its use as a PC, notebook, web server, FTP, etc.

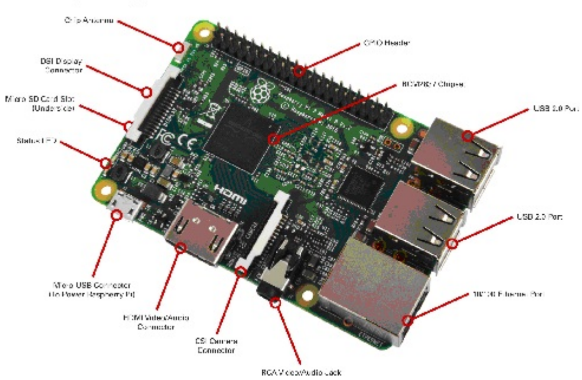

Fig. 3. Raspberry PI

<u>Camera module V2 for Raspberry PI</u>

For identification of malfunctions or for checking the accurate work process, the user can realize captures with the help of the webcam which is compatible with Raspberry PI. Those will be saved and uploaded on the web page available for everyone who has access.

<u>Technical specifications</u>:

- Compatible with Raspberry PI;
- Photo resolution: 8MP;
- Video resolution: 1080p 30fps, 720p 60fps, 640x480p 60/90 fps;
- CSI connection (camera serial interface);

<u>Hall A44E module sensor</u>

Hall A44e module sensor is a simple one, but of high performance. It can generate an analogic or digital output, using the LM393 comparator. Supply voltage is of 5V. The comparator output can generate to 20mA and can be used to control relays or other transistors

<u>Software components</u>

Mbed compiler is an online editor which offers a flexible and easy environment in which the user can program in a language similar to C/C++ and can compile the resulted code in a binary file, after which it can be saved on any development platform it is needed.

Web Apache server is a known web application with elementary functions like hosting web pages in HTML files through HTTP. Support for the PHP web pages can be easily added. Raspberry PI is one of the most used system on the market at this date because of his ability to process a huge amount of data at a relatively low power consumption. Some advantages of its usage is the possibility to perform computations with floating point, the executions of concurrent operations at a critical resource and the communication capability with the external medium using TCP/IP, respectively UDP.

Displaying of the web page through protocol 8080 considered the implementation of a web server. Within the project I chose the web server Apache. Web page is a file of HyperTextMarkup Language(HTML) type, the content of the file being able to be open and interpreted by a browser updated to the last technology launched. The server has to manage files of type HTML, but also and requests from users.

3. APPLICATION IMPLEMENTATION

For the use of the robotic arm there are given 2 was of interaction: from proximity and from distance. In the first case, in the blackbox of the robot are inserted buttons with the help of which the user can control the movement of the robotic arm. In the second case, the command can be realized from distance, based on the Bluetooth technology and web server Apache. Those are base technologies that define an intelligent system.

To realize the web server, Raspberry PI platform has a WIFI module integrated that can facilitate the control of the robotic arm from distance, when it is connected.

Within the project, a smartphone was used (Samsung Galaxy S3) through which was created a hotspot (a local network), at which the Raspberry PI is connected and , also, the rest of the users who wants access to the web page. Both the Raspberry Pi and the smartphone have an operating system, which assures the communication in network at the level of TCP/IP stack.

Smartphone has Android as operating system and Raspberry Pi uses Raspbian. Both systems are known by most developers and have the necessary resources and a well developed documentation. To avoid bugs that were previously fixed and to assure an actual functionality, both operating systems will be actualised.

Therefore, the robotic arm doesn't require a software application when it is controlled from proximity, his movement being executed just hardware. Regarding the control of the robotic arm from distance the web page is accessed connection to the IP address allocated to the Raspberry Pi by the users connected in the same network.

<u>The electric scheme and wires used to interconnect and power the modules</u>

The connection board has the purpose to interconnect the FRDM KL25Z platform with the 4 H bridges, Hall sensors, keyboard that allows for manual control of the robotic arm, and the HC-05 Bluetooth module.

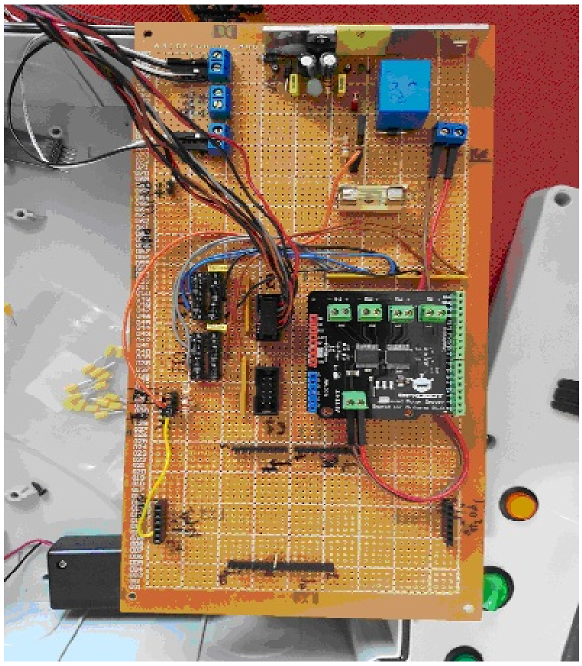

Fig. 4. Application Hardware Board

Electric scheme of interconnections and powering of modules is presented next:

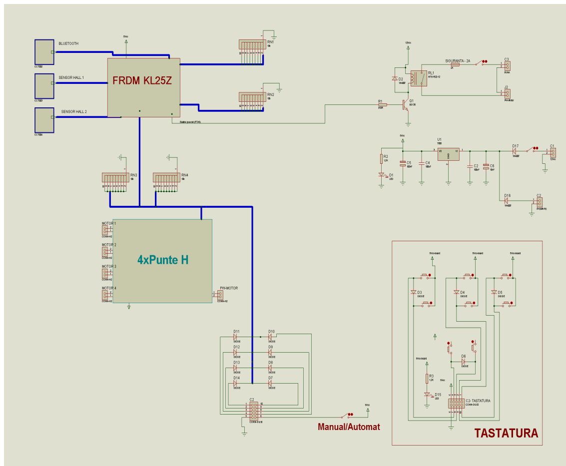

Fig. 5. Electric Scheme of Interconnection

The whole system is encapsulated in a blackbox. For the user interface there are used 3 switches. In fig. 4, on the right can be seen the switch that powers the whole command circuit. In the middle there is a switch used to power the direct current engines and has the emergency role in the case in which there are uncontrolled movements of engines. The last button has the function to switch between manual control, represented by the keyboard, and automatic control represented by the FRDM and H bridges

4. APPLICATION TESTING AND EXPERIMENTAL RESULTS

Following, we will present the functionality of the robotic arm from the perspective of 5 test scenarios.

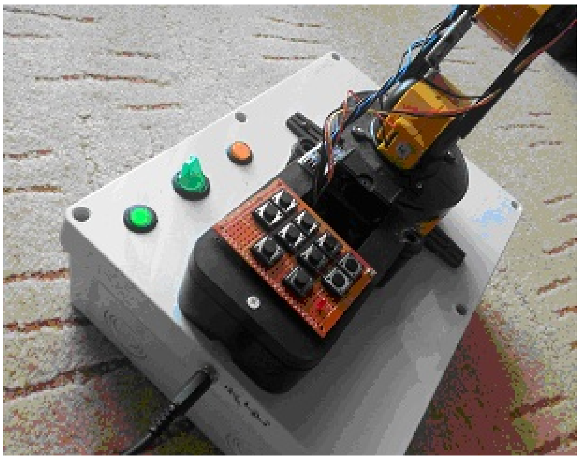

Fig. 6. Robotic Arm Overview

First test scenario - we decided to test the functionality of the keyboard for the manual control of the robotic arm.

As it can be seen in fig. 6, although the supply cable is connected and the green switch is closed, the keyboard indicator led isn't powered on. This is because, on one hand, the orange led associated to the exchange between manual module and automated module is powered, and on the other hand, the middle switch associated with the DC engines is also powered.

Second test scenario - to control the robotic arm from smartphone, a pairing will be made with the Bluetooth module and the commands will be sent from terminal or from the graphic interface, fig. 7.

Fig. 7. Android Graphic Interface

A third test scenario - is represented by the functionality of the initialisation of the robotic arm. For execution there are 2 Hall sensors needed. At the displacement limit, through Hall sensors we are warned of the presence of magnetic field generated by the magnet placed on the robotic arm.

In fig.8 there is presented the detection of movement by height. Once detected, the engine responsible for the upwards movement changes polarity and decreases for aprox. 2 seconds.

Fig. 8. Detection of Movement

To detect the limit of displacement on horizontal, the robotic arm is mobilized to left until it meets the magnetic field generated by the magnet placed on his motherboard.

Fourth test scenario - is represented by the control of the robotic arm from a web page using Raspberry Pi. In fig. 9 can be see the content of the web page. It has some buttons that allow the interaction with the robotic arm from distance.

To control the robotic arm it is necessary to initialize it. The initialization has the purpose to bring the robotic arm in the initial position. Also, the robotic arm can be controlled using the buttons of left, right, up, down. The gripper helps catching or releasing an object.

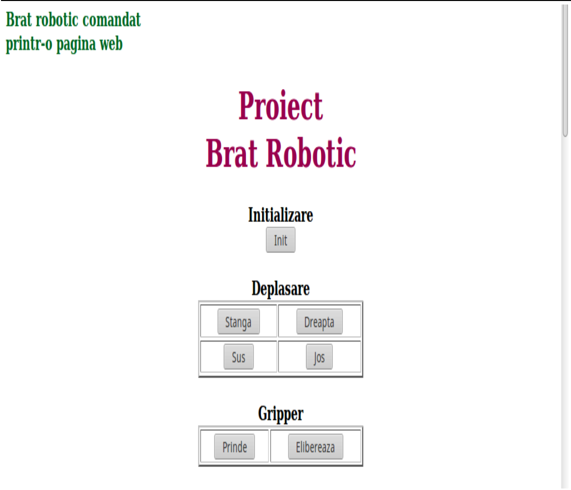

Fig. 9. Web Page Style and Information

Fifth test scenario – the acquired data are using a webcam compatible with Raspberry PI. The webcam can capture images with a photo resolution of 8MP and the video resolution can get to 30fps at 1080p. In fig. 10 it is presented the picture and video acquisition from the web page. The 5 seconds video was chosen, instead of a stream, because the stream is realized with a significant delay.

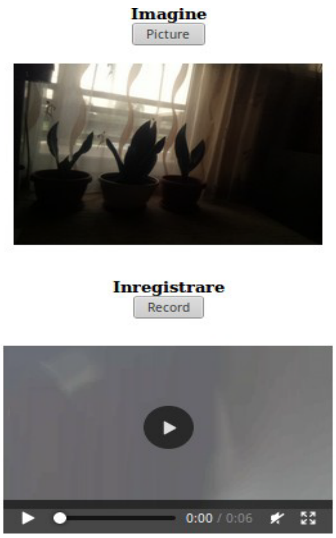

Fig. 10. Phot & Video Acquisition

5. IMPROVEMENT DIRECTIONS AND FURTHER DEVELOPMENTS

The robotic arm can be improved with a series of further upgrades.

In the first place, the robotic arm was projected in an user friendly manner. As it can be seen in previous pages, the electric and the wire part were encapsulated and the user has access only to the three power buttons, a manual interface with buttons and, in automated mode, it can use a smartphone and a specific application or a web page in local network for a simple experience. Consequently, the user can’t interact with the complex implementation of the robotic arm, thus he can’t risk to damage it. That being said, the robotic arm can be distributed and used in domestic applications and, in case it is malfunctioned, the damaged parts can be easily replaced because there are in a large number on market thanks to their use in different projects.

The robotic arm can also be used in the military environment. Adding a movement system, it can be used by force orders for bomb defusing.

Regarding the use of the robotic arm from distance, if it isn’t in the working range, a GSM module can be used to have a connection in the less accessible areas.

Also, through smartphone, a hotspot can be realized and with the use of mobile data, the robotic arm can be controlled from anywhere in world.

Another upgrade consists in finding a way to do streaming video without losing too many frames per second. Thus, a robot arm can be implemented which has as an attribute a surveillance camera.

Besides what was mentioned before, the robotic arm can be scaled and used in an industrial environment. Using the pipeline procedure, the robotic arms can interact with each other in a local network and at the end of one task, it can communicate with the next one to do his task.

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