Oct 30th, 12:00 AM - 12:00 AM

Cost Oriented Control Unit for Robotic Arm Mitsubishi MoveMaster II

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Abstract. One of the main reasons for robotics development was always making human life easier by assisting or even replacing humans in hazardous environments. But in order to get robotics at that level, a lot of development and research was needed in order to solve the barriers and challenges that appear along the way. Solving problems, especially engineering ones usually accompanied by complex tech which is in most cases expensive to implement, and by that, a new challenge is appearing: high cost. In order to get robotics to help humans, especially in daily tasks, the cost of robotics needs to drop but without affecting its functionality, which is one of the main problems that we will try to solve or at least contribute with our research to help to solve that. In this paper we will focus on developing and implementing a new control unit for an old Mitsubishi MoveMaster II by replacing its old and expensive control unit which is also out of function. For developing such a unit, we will use low-cost parts like L298N motor drive and Xtensa LX7 dual-core microprocessor as main controller. By implementing this controller, not only the overall cost of the robot is reduced but it also became much easier to manipulate with.

Keywords: Low-cost, robotic arm, embedded systems, Xtensa LX7 dual-core.

1 Introduction

The slow pace of the gradual progress in the incorporation of robotics to manufacturing industry is finally coming to an end. Today, six decades after the introduction of robotics in industry which occurred in the early 60s, modern manufacturing, maintenance, services and research is considered incomplete if it does not include robots that execute various functions, communicate remotely and in some cases even improve themselves autonomously. Less costly, more precise and more flexible robot bodies designed for various functionalities are under continuous development. Developers are parallelly working on new control systems as well

[1][6]. The effective means of providing both efficient and compatible robotic systems is the topic of concern in this research paper. The paper is focused on a physical implementation; a classic arm has been revitalized by substituting the outdated control module with a new system containing items selected on the basis of cost, without compromising functionality and quality-based goals.

This paper provides a description for the modification and revitalization of a relatively old robotic arm by substituting the control system entirely and creating a low-cost solution using a readily available decommissioned robot and adding other functionalities based on contemporary needs, like remote control through a local wireless network using IoT enabling technologies. In addition, it sets the basis for extensive work in the future, leaving space for new innovative implementations by incorporating even more state-of-the-art technologies. However, the aim of this paper at this point in time is an easy and efficient method to implement a functional remotely controlled robotic arm with six degrees of freedom. We have tried to use the less costly and most easily accessible components and the fastest and easiest ways of programming and configuration techniques.

In the following section of this paper, we will start off by giving a brief description on the aims of the project and expected results. In the third section, there is a review on five case studies concerning the topic of this paper and several other topics that are related to the project in one way or another, all the references are published papers that share the main aim criterion with this project, which is low-cost implementation. The fourth section presents the results including an explanation on flaws and inaccuracies whereas the final section concludes the project by recapping the key points and laying out proposals for future research.

2 Problem statement

During the process of lowering the cost of older robots and making them easier to use by everyone, not only engineers and scientists we need to try to solve problems that are expressed through the following questions:

Can we lower the cost of the old robotic arm just by creating a new cheaper control unit for it?

Controlling small robots with cheaper control units is easy because the hardware part is usually easily compatible with developed software [1]. But if we aim to create controllers for industrial or professional robots like Mitsubishi MoveMaster II, we need to carefully design the control unit so it is not only low-cost but also reliable. Based on this, we will be focusing on finding the best solution to the problem of keeping a balance between affordability and reliability of the control system with this type of robot.

Is it possible to improve the Human-Robot Interface with this new control unit?

If we want to bring robotics into our daily lives, besides lowering the cost we also need to make robots more user-friendly, especially for people who don’t have a technical background and when robots have an outdated interface. In order to make this happen, we need to improve the human-robot interface which can sometimes increase the general cost of the robot. We will try to create a software solution in this case by implementing it in cheap but reliable hardware which will be described in the results chapter of this paper.

Can we increase functionality of the robotic arm with new technologies and simultaneously keeping it low-cost?

If we are able to solve the first two stated problems, the third one will probably be easier to address. Basically, by implementing a new control unit for the robotic arm, it gets a technology update that increases its functionality. However, what we want to analyze is whether we can add functions the robot has not had before. In that case, beside the new control unit, the robot would also provide more functionality at a low price.

In this paper, we aim to solve the problems stated above by creating a new control unit, using the latest technology that is available at low cost and then analyzing the results we get.

3 Literature review

Based on the problems we set to solve, we researched related work what others contribute in similar fields. We mostly find that when a cost-oriented robotic arm is included as a topic, authors try to develop both mechanical construction and control unit in order to lower the overall cost of the robot [3]. Other authors try to focus more on the software solutions by developing more complex algorithms without focusing on hardware in order to reduce cost without implementing expensive parts like high-end motors or expensive drivers [5]. Some examples of low-cost research projects are described in the following part of this section in order to give a perspective on what is currently being worked on in this direction.

3.1 State of the art

A worth-mentioning embedded software implementation of a robot localization system has been presented in the IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems held in Tunis, Tunisia in 2019 [2]. A double-core Pandaboard ES with Ubonto 21 operative system as computing unit, a web camera for image acquisition and the RS232 protocol for communication with the robot have been used for the software solution which executes in a parallelized way, where one thread takes care of position detection and the other thread for orientation detection. The image processing algorithm has been implemented in C++ without using the OpenCV libraries.

In an article published in the Elsevier journal [3] a robot arm with two degrees of freedom which is remotely controlled and designed to be used for educational purposes in time of pandemic has been presented. Developers have used an ESP32 microcontroller for internet connection and control which along with two servo-motors is connected to a single 6V power supply. The body of the robot is 3D printed in PLA material. The total cost of this robot adds up to about 60$ per unit.

The paper presented in [4] demonstrates an autonomous low-cost pole climbing robot which is intended to be multi-functional and execute various tasks like cleaning, inspection, surveillance, maintenance and even coconut harvesting in trees. It has been developed using an Arduino Mega 2560 development board, five stepper motors for the robot mechanism and two infrared sensors to detect the top and the bottom of the pole. It can climb upwards and descend downwards thanks to its servo-controlled gripping mechanism.

Raspberry Pi, a low-cost computer is also quite widely used for low-cost solutions in modern era robotic applications. A low-cost automation system for gravity compensation in a robotic arm is presented in [5] where developers have aimed to achieve a better solution for control systems that are based in algorithms which use forward and inverse kinematics. A drawback in these algorithms is the high dependence of the end-effector position accuracy on joint position accuracies. Using the ROS operating system implemented in Raspberry Pi 3, this drawback has been eliminated by applying the gravity compensation technique. The technique has been tested in a 5-degree-of-freedom Kuka youBot manipulator, showing higher accuracy and smaller delay.

A recent publication [6] shows how developers have used the Arduino platform and Arduino IDE for robot control and programming, Bluetooth for wireless communication and a smartphone app created with the open-source simplified online tool AppInventor. The aim was to create a control system for improving the performance of the robot by comparing the 6-degree-of-freedom robot arm motion with a camera image space, identifying errors on each joint through the inverse method for decoupling and then send data remotely for analytics.

4 Results

In the previous chapter, we discussed about the latest developments in the field of low-cost robotics and what other researchers have been working on in the last decade. Unlike other research cases, we have used an old industrial robotic arm instead of making a new one ourselves. The robotic arm used in this project is the Mitsubishi MoveMaster 2 which was developed and released in 1983 by Mitsubishi and came along with a drive unit (40Kb ROM and 32kB RAM, expandable with EPROMs) [7]. Usually, older industrial robots are limited and not very user-friendly, especially in the control part, so replacing the control unit with new ones is usually very expensive. What we aimed to achieve in this paper was not developing a cost-oriented robotic arm from zero but rather functionalizing an existing one by reverse engineering it in order to adapt the new control unit. This has brought possibilities to explore new implementations for upgrading the functionality of the robot. As the main processing unit, we have selected the ESP32 development board for a number of reasons, two of the main ones are wi-fi and Bluetooth connectivity. Two other major advantages are better SRAM (520 KB of SRAM, 448 KB of ROM) and a powerful microcontroller (Dual-Core 32-bit LX7 Microprocessor with clock frequency up to 240 MHz). As a motor driver, we picked the L298 model which has a low cost and is reliable for DC motors. By developing a new control unit, we were able to replace the old control unit which is three to four times bigger in size and uses older technologies that are usually not compatible with today's methods and applications.

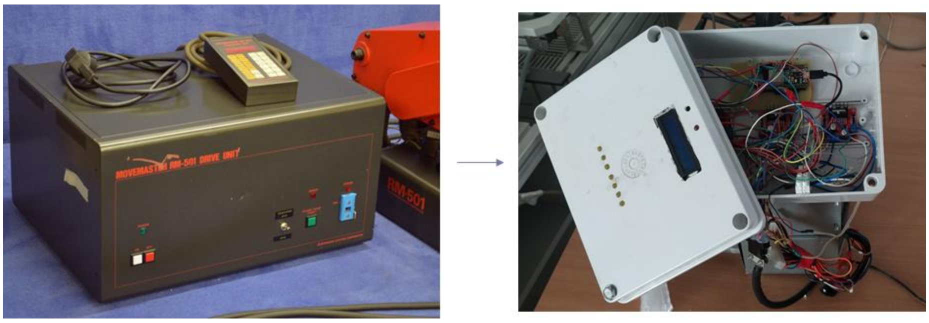

Figure 1. *Comparing the old control unit (on the left) with the new control unit (on the right)*

In the figure 1 the new control unit is shown in an opened enclosure where we can see the ESP32 development board and the motor drivers connected. At the top of the enclosure, we have an LCD panel that shows the IP address used for connecting with the robot, while at the bottom, we can see an old computer's power supply which has been used to power up the entire control unit. An IP address is required to be able to use the IoT feature of EPS32 and developed. We have also created a web-based interface which makes it much easier to control the robotic arm via smartphone, tablet, or PC/laptop simply by connecting it to the IP address shown on LCD screen.

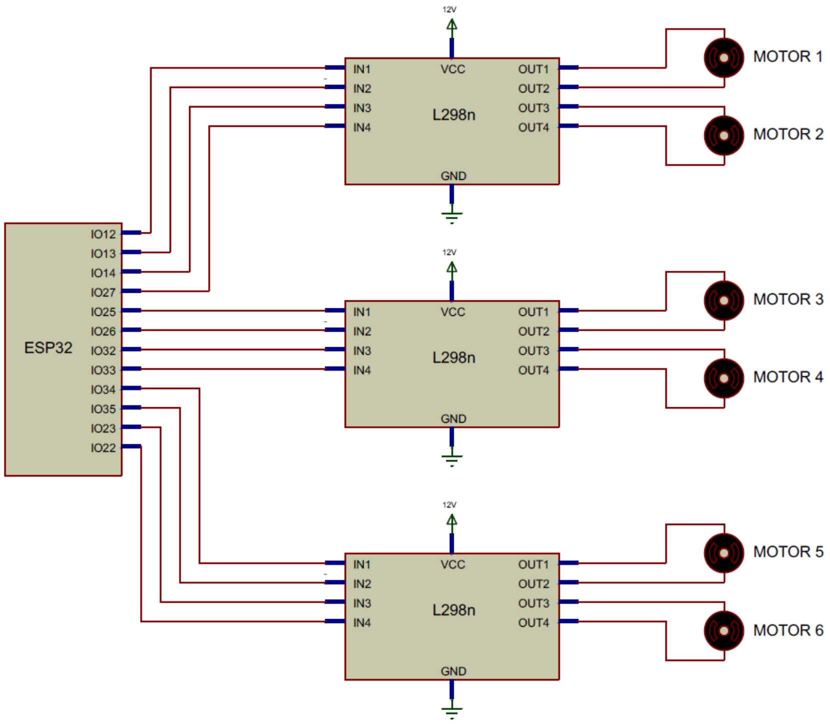

Figure 2. *New control unit circuit*

In figure 2 we can see the circuit of the drive which is inside the enclosure. Every motor is controlled individually through L298N drive which can control the direction and the speed of the motor. In the end, every drive is connected to EPS32 which is the main processing unit for each motor drive and consequently for each motor.

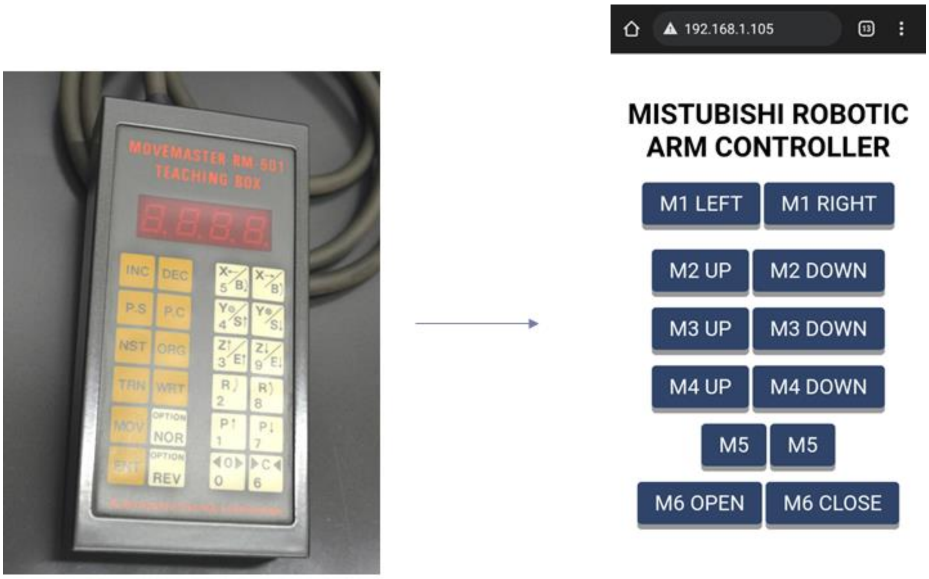

Figure 3. *Old control interface (on the left) vs new web-based control interface (on the right)*

As we can see in figure 2, the new interface gave us full control of each motor and it is much easier to understand which motor you are controlling and in which direction. Also, it makes it possible to control the robot wirelessly, thus not limiting us in the aspect of distance and mobility.

After successfully implementing the new control unit and interface we tested functions of the robot such as accuracy and repeatability. After several tests, we notice that there is a slight issue with repeatability. Unfortunately, the old control unit of the robot is not working at all, so there is no possibility to compare the movement data from the old one.

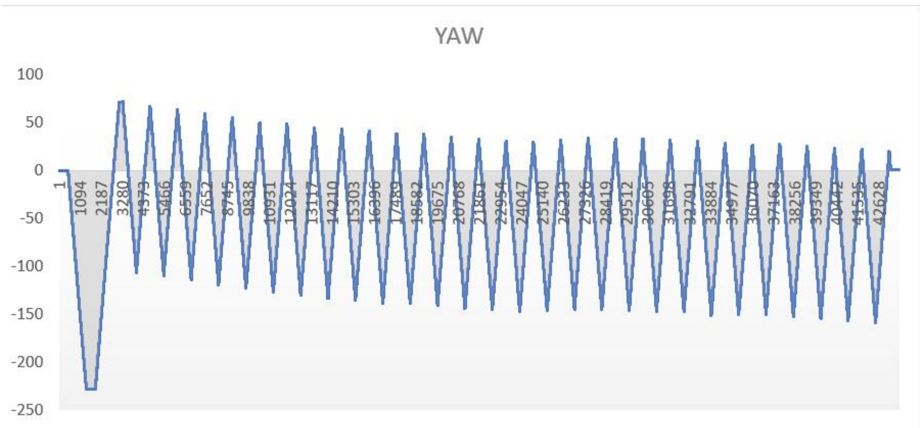

Figure 4. *Measured data of YAW angle from external gyroscope in robotic arm*

We placed an external gyroscope at the top of the robotic arm and then programmed the robot to repeat the same movement for several minutes. By tracking movements through the gyroscope, we can see the spikes in the diagram, that represent an end-to-end position of the robot during movement. As can be noticed, they shift slightly after each period, this implies that the robot is not stopping at the same position on each step even though we programmed it to behave that way. The main reason behind this unwanted behaviour is that we did not use the motor encoders due to lack of documentation on schematics of the robot, which made it impossible for us to find the connection of the motor encoders. Repeatability will most likely improve significantly if encoder data is added to the control system because with data from encoders, we can know the exact position of the motor and as a result of the robot also.

Now if we compare the cost of a new control unit which is shown in figure 1 (the right one) with the old control unit (the left one) we can see a noticeable difference. A new control unit including all components we mentioned cost around 40€. On another side, the old control unit, unfortunately, isn't in sale anymore because the robot is not produced anymore. But there are still online sellers that sell used old control units and the price is around 600€ to 700€ and when you add shipping cost it goes usually more than 1000€ (shorturl.at/wBHLT). So, besides the fact that we can lower the price by implementing a newly developed unit compared to buying the used one, it is also much more practical in many aspects like size, usability, functions, etc.

5 Conclusions

This research paper recommends lowering the cost of robots by developing a new control system. As robots are usually modular and are compatible to various types of parts, achieving this purpose is most of the time feasible and can be done with a relatively low effort. We have used a Mitsubishi MoveMaster II robot to demonstrate a working model that successfully achieves this goal. Our approach is to substitute the outdated control system with a contemporary one by using ESP32 development module which is based on an Xtensa LX6 microprocessor. Furthermore, we have added functionalities like robot control via a smartphone app using IoT enabling technologies. This approach resulted in a working system with an exceedingly acceptable performance, although repeatability issues have been observed while testing the system. Besides that, we see in the results that difference in cost between new control unit and old used one is something between 550€ to 950€.

Advancing the control system so it fully complies to the industry standards is our main recommendation for future work. Nevertheless, industrial robots require high reliability, therefore it is imperative that extra care is taken when intervening in their physical structure and programmatic functionality. For this reason, balancing low-cost and reliability would add to the complexity of this process. Moreover, we also recommend working on a user-friendly version by applying software solutions as robots provided for everyday use that will be managed by users that lack sufficient knowledge in robot operation are becoming ever more present in the market. Finally, the modular construction and programmability offers potential in adding a number of other functionalities, including machine learning capability.

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