Development of Embedded Control for a Repetitive Pick and Placed Robotic Arm

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ORIGINAL RESEARCH

Abstract- Manual execution of tasks is usually strenuous and exhaustive, some tasks may be repetitive in nature such that it requires full concentration. Nowadays, the integration of robotics into commercial and industrial activities to perform repetitive, dangerous, and difficult is becoming a norm. This work focuses on the implementation of a robotic arm. The robotic arm was designed to have six degrees of freedom. The control circuit includes an embedded Atmega328P microcontroller interfaced with servomotors and other glue electronic components such as sensors and buttons. The system is structured and programmed to operate automatically, performing a repetitive routine. The rotation and orientation of the device were tuned by sending required pulse width modulation (PMW) signals to different servomotors, such that they rotate as desired. The system employs six potentiometers in varying the duty cycle generated by the microcontroller. The system is structured such that three servomotors manipulate the motion of the body, the shoulder, the arm elbow, and the base. Manipulations of the end effector were also carried out by another three servomotors, each one controlling the gripper pitch, the movement of gripper spin, and that of the gripper itself. The constructed robotic arm gives a good response when tested for repetitive picking of objects. A similar acceptable performance was repeated in the autonomous lifting and dropping of objects items.

Keywords- Manipulator, Microcontroller, Robot, Servomotor.

1 Introduction

Robots can work where humans cannot, and this constitutes a great benefit to mankind. They are electromechanical device that does not require breathing, drinking, or worrying about their internal feelings. Ideally, they are designed and sometimes constructed to look like and mimic humans. They can compose of features such as feet, arm, fingers, and human intelligence (Dylan et al., 2004).

Hence, robots are increasingly being tasked with delicate, repetitive and complicated operations in manufacturing industries, transportation, mining, media and the health sector (Ashutosh & Rajiv, 2013; Khairul, 2009). They find applications in several machines and equipment such as land movers, industrial automation, and even toys (Hanafi et al., 2013; Liu et al., 2022). They primarily use the end effector in operations related to gripping items, trenching, digging, lifting, pushing, and hitting. Usually, they require human personnel for operations and manipulation of their various movement (Ghadge et al., 2018; Hanafi et al., 2013; Jabir et al., 2015; Olawale et al., 2007). Controlling a robot can be done manually and sometimes mechanized to be autonomous (Liu et al., 2022; Olawale et al., 2007; Siti, 2011). Notable control techniques include the computer terminal where commands are written to execute a control action. The use of joysticks is another technique, it seems to be more convenient than using the terminal.

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Section B- ELECTRICAL/COMPUTER ENGINEERING & RELATED SCIENCES
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Some robots are controlled via a purposely designed graphical user interface (GUI). The use of sensors such as accelerometers is another notable technique. Recently, interfacing robots with the internet is the pursuit of any developer and a part of the current trend of IoT (Adiputra & Setiawan, 2017; Krishna et al., 2012; Meng et al., 2016). Other control techniques are haptic technology, electromyography, and the human mind (Bhanu et al., 2012; Florentinus & Ricky, 2016; Gohil et al., 2013). Robotic control using a hepatic sensor was proposed in Aishwarya et al. (2016). A locomotive robot was designed and controlled by human gestures. This can help to magnify human effort or support the disabled.

Faravar (2014) implemented a five-degree-of-freedom robotic arm using PIC16F877A. The work also presented a generic mathematical formula that aided the motion control of robots. Similarly, Ndwiga (2018) designed and constructed a five-degree-of-freedom robotic arm. The embedded control was built around the PIC18F4550 with the help of PICkit3 and MikroC Pro compiler. A wooden base and stand were fabricated for the robot to maintain stability. A robotic firefighting vehicle was explored in the work of Olugboji et al. (2019). A prototype of a quasi-robot was developed around a dc motor and wooden support that carries water. The system consists of a Bluetooth sensor that enables wireless control over a distance. Dandago et al. (2021) presented the state estimation of a pick-and-place robotic arm developed by Quanser consulting incorporation. A parametric model of the robot was obtained using LabView, from which the five state estimators were extracted. The model becomes useful in studying the dynamics of the system and developing different control techniques for the robot. From the available literature reviewed in the course of the work, the control of a robotic arm is not autonomous. Most require an interface with a digital device or sensors in executing a given task. The control also seems to be complicated with more advanced equations, big-size microcontrollers, dedicated programmers and more difficult programming.

The work attempts to introduce repetitive control, once the trajectory has been determined for the first time, the robot having six degrees of freedom can repeat the action until it is been interrupted. The controller is also based on the rugged, cheap, and readily available Atmega328p. It is easy to program in the less complicated Arduino IDE.

2 METHODOLOGY

To develop a robotic manipulator that takes a piece of an object from one position to another records its movements and replays the action, the work devolved into two parts: the mechanical chassis and the embedded control. The mechanical chassis consists of the robot base, the shoulder, the elbow, the wrist, and the gripper. This chassis can be fabricated locally or from a 3-D printer. A factory-fabricated chassis was obtained; thus, this work focuses on the development of embedded control for the servomechanism in the robot base, the shoulder, and the elbow. In addition, there is a provision to control the movement of the end effector which includes the gripper pitch and the gripper spin. The realization of the control circuit is based on generating an equal pulse width modulation (PWM) signal and send to the six servomotors. An Atmega328P microcontroller unit (MCU) was chosen in the circuit of the control unit. Control instructions were written through the Arduino IDE since it enables easy compilation of C++ programming language.

Figure 1 is a block diagram showing the interface of the servomotors and the connection to the microcontroller. The servomotors were powered from a 5.5V source. The microcontroller's internal analog-to-digital converter (ADC) is enabled such that the 6 potentiometers control each servo interfaced with the MCU, hence the duty cycle of the PWM signal can be controlled.

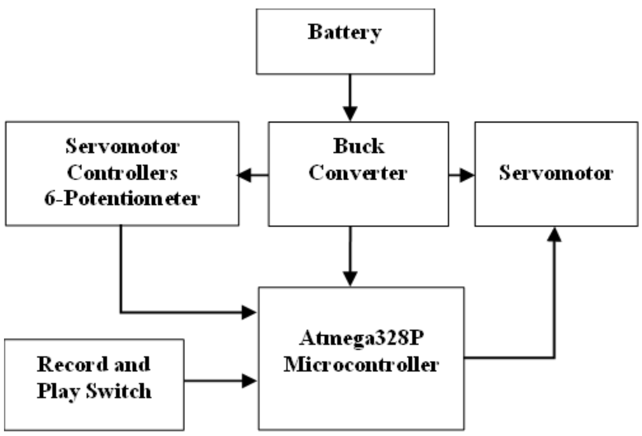

Fig. 1: Block Diagram of the Robotic Arm

The Proteus 8 professional software was used for designing and drafting the electronic circuit. Some parts of the circuit were also simulated after being written in the Arduino IDE programming environment. Considering the size and ruggedness, the MG996R servomotor of Figure 2 was chosen for this work. It operates at a voltage of +4.8V to +6V, typically a current of 2.5A, and a stall torque of up to 9.4 kg/cm at 4.8V.
The MG996R motor is characterized by gears and a potentiometer. The potentiometer is needed for the position feedback, derived from the potentiometer voltage. Normally, the servomotor's shaft can rotate from 0 to 180° but it can be reprogrammed for a continuous rotation.

A dedicated power supply was designed using a battery, MT3608 boost converter and LM2596 buck converter adjustable voltage regulators. The battery was connected to the buck and the boost converter in series-parallel mode. The 12V DC from the battery was fed to the MT3608 boost converter to supply 5V to the MCU and LM2596 voltage regulators to supply 5.5V to each servomotor.

Fig. 2: MG996R Servomotor

Figure 3 presents the movement of the servomotor in response to the PMW signal. For a clockwise rotation, a pulse duration of 2ms is sent to the motor. Under this condition, the motor rotates at its full speed. On the other hand, a 1ms pulse duration will rotate the servomotor counter-clockwise, also at full speed. If the pulse duration is 1.5 ms, the motor stops or returns to its initial position.

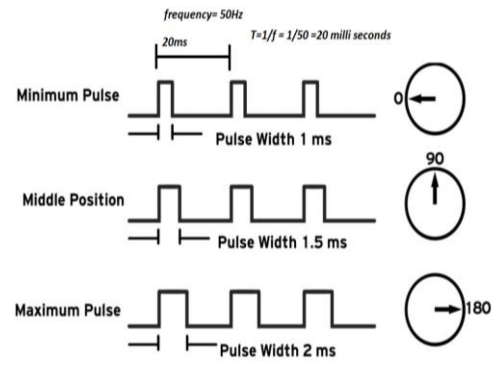

Fig. 3: Servomotor PWM Duty Cycle

As earlier said, the processing unit is built around an Atmega328P microcontroller. It is a 28-pin microcontroller, it is capable of handling complex tasks such as found in robotics dynamics. The control circuit comprises the main MCU to control the entire system. The MCU receives the continuous voltage from each potentiometer and converts the signal to a digital form. The digital signal is further converted to PWM of different

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levels ranging from 1ms – 2ms. The PWM determines the orientation of the arm. Since microcontrollers require an oscillator for proper communication between the interfacing components and the PMW signals, a crystal oscillator of 16MHz was chosen and connected between the OSC1 and OSC2 pins of the microcontroller. The crystal is biased by two numbers of 22pF capacitors. The complete circuit diagram is shown in Figure 4.

3 Results and Discussions

The circuit was constructed and tested in the previous section. Pictures of the control unit and the robotic system are presented in Figures 5, 6, and 7. Figure 5 presents the six potentiometers connected to give different continuous voltages ranging from 0V – 5V to the analog input pin of the microcontroller. Potentiometer 1 controls the gripper of the chassis, potentiometer 2 controls the gripper-spin of the chassis, potentiometer 3 controls the gripper-pitch of the chassis, potentiometer 4 controls the elbow of the chassis, potentiometer 5 controls the shoulder of the chassis, potentiometer 6 controls the base of the chassis.

In Figure 6 all other peripheral components interfaced with the Atmega 328 to get the entire system to work. The constructed robot is shown in Figure 7 carrying an object weighing 1kg from one position to another.

The servomotors were tested to observe their response to the control signal. Each of the servomotors was stable to PWM signals as the angle of rotation increases in proportion to the increase in the PWM. Figure 8 presents the variation of the rotational angle in response to the PMW signal sent; the angle varies from -90° to +90°. Since metallic servos were used to control the arm and they can work within the range of angles from 0 to 180 degrees. Table 1 presents the range of rotation of each part of the robot. The current consumption of the servomotor depends on the load and the position of the object. The higher the weight of the object it carries, the higher the torque needed to get work done. Table 2 presents the load versus current consumption of the servomotor.

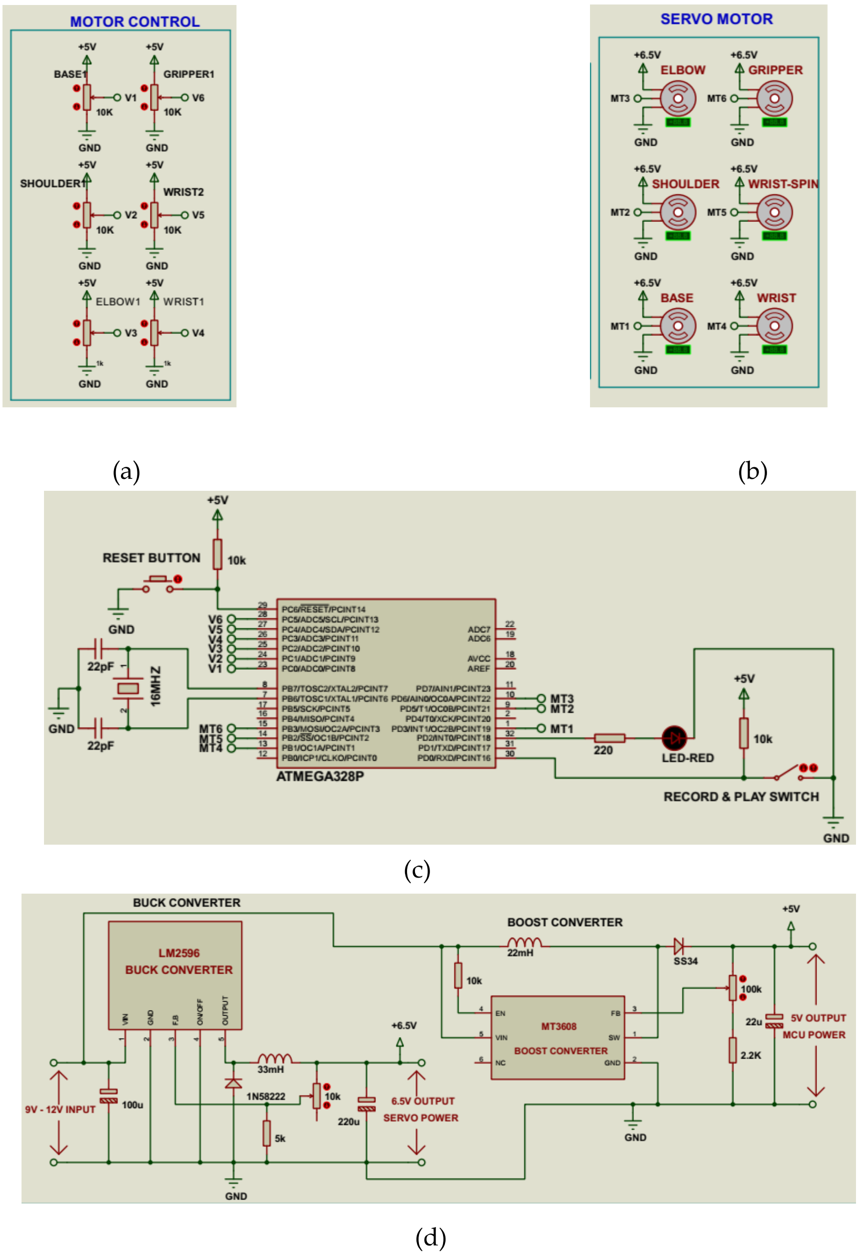

Fig. 4: Circuit Diagram of the Robotic Arm Controller: (a) Motor Control (b) Servo Control (c) Microcontroller Section (d) Buck-Boost Converter

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Fig. 5: The potentiometer control section

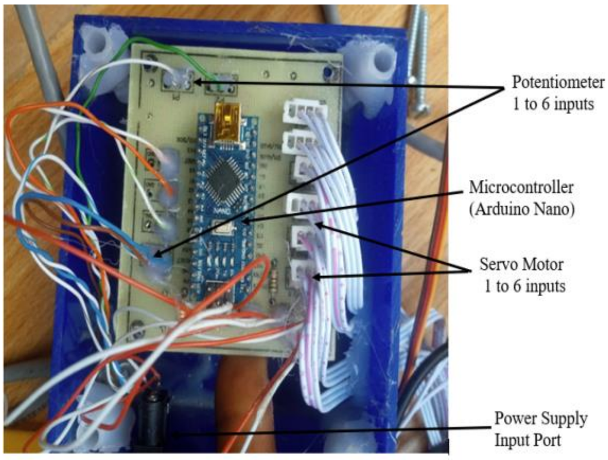

Fig. 6: Peripheral component interfaced with Atmega 328p

Fig. 7. Robotic Arm Manipulator

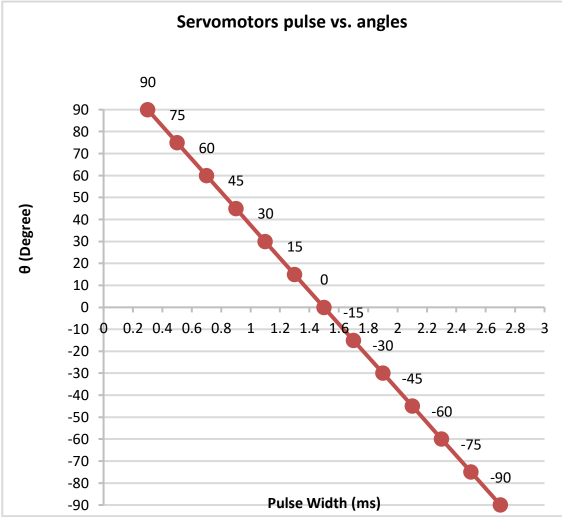

Fig. 8: Servomotors pulses vs. angle

Table 1. Servomotor movement range

Angle	Range Degrees
Gripper	0-90
Gripper spin	0-180
Gripper pitch	0-100
Elbow	0-160
Shoulder	0-150
Base	0-180

Table 2. Load vs current consumption

Load (g)	Current consumption(mA)
100	Low (0-200)
250	Normal (200-500)
350	Normal (500-800)
550	High (800-900)
1750	Overloaded (above 900)
2000	Overloaded (above 900)

4 Conclusion

The development of a control circuit for a robotic arm has been presented. The circuit is designed to send appropriate signals to selected servomotors such that it responds with the required angles and orientation. The robotic arm takes an object from one point to the other, saves the movement in memory, and repeats the action for as long as desired by the user. The control is built around the rugged, cheap and readily available Atmega328p. It can easily be programmed in the Arduino IDE. This work is applicable in areas where a high level of accuracy is demanded: like automobile industries for coupling of cars, welding of parts, and lifting of heavy equipment.

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