Microcontroller Based Robotic Arm

Operational to Gesture and Automated Mode

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***Abstract*—Robotics has been a tremendous successful field of research in last few decades. Regarding the development of robotics, many developed robotic arm has been deployed in industrial purposes like automation, sophisticated fabrication etc. This paper is an initiative to patronize the robotic arm for hazardous situation people who can use his hand to move object within certain range to carry out that job. This project is meant to designing and developing of a microcontroller (ATmega) based robotic arm. The project delivers a combined implementation of Electrical, Electronic as well as Mechanical gen. The robotic arm responds to the gesture as well as can be programmed to go along a definite path and task.**

The system senses the movement of user's arm and robotic arm replicates the given input gesture. The gesture is sensed by a number of potentiometers which are embedded onto a glove or other structural attachment. The movement in potentiometer determines the position for the servo motors driving the parts of the arm.

Keywords—Robotics; SCARA; DOF; ATmega;

I. INTRODUCTION

In the modern world, robotics has become popular, useful, and has achieved great successes in several fields of humanity. Robotics has become very useful in medicine, education, military, research and mostly, in the world of manufacturing. It is a term that has since been used to refer to a machine that performs work to assist people or work that humans find difficult or undesirable. Robots, which could be destructive or non- destructive, perform tasks that would have been very tedious for human beings to perform. They are capable of performing repetitive tasks more quickly, cheaply, and accurately than humans. Robotics involves the integration of many different disciplines, among them kinematics, signal analysis, information theory, artificial intelligence, and probability theory. These disciplines when applied suitably, lead to the design of a very successful robot.

The most common types of robot technology that have evolved for different purposes are Robotic Arms. The Robotic arms are mechanically controlled devices designed to replicate the movement of a human arm. These are used for lifting heavy objects and carrying out tasks that require extreme concentration and expert accuracy. The design of a robot arm can vary depending on what it is intended to do. A Robotic arm consists of the following elements- controller, robot arm, end effector, drives, sensors; which are integrated together to form a whole that all contribute to making it properly function [1]; Controllers-these are the main processors of the robotic arms and act as their brains. They can either act automatically as programmed or allow for manual operation by outputting instructions directly from a technician. Robot Arms-The arm is the main section of the robotic arm and consists of three parts: the shoulder, elbow and wrist. These are all joints, with the shoulder resting at the base of the arm, typically connected to the controller, and it can move forward, backward or spin. End Effector-acts as the hand of the robotic arm. This part comes in direct contact with the material the robot is manipulating. Some variations of an effector are a gripper, a vacuum pump, magnets, and welding torches. Drives - the mechanical systems that move the robotic arm into place [2]. The drives are typically located between the joints and are responsible for motion and placement. Sensors-are used in advanced robots. Some are riddled with sensors that allow them to sense their environment and react accordingly. Six major categories of robotic arm [2] by their mechanical structure we have used SCARA (Selective Compliance Articulated/ Assembled Robot Arm) Robotic arm, which will be controlled using gesture of our replica arm. Robotic arm will be made of Aluminum pipes, which are attached with servo motors to drive the arm. Gripper hand will be used as end effector. We use microcontroller to interact with the servo-motors with gesture. The microcontroller can be programmed to Gesture (Shadow) mode as well as Automatic mode. Fig. 1 shows below the proposed robotic arm and Fig. 2 shows the flowchart.

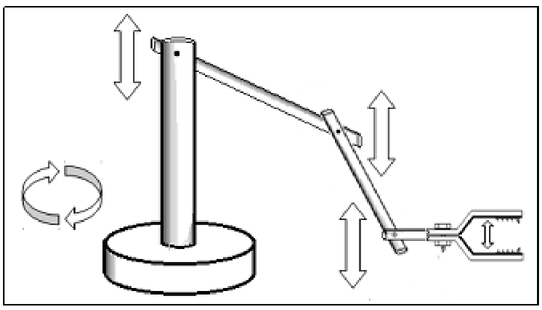

Fig.1. Proposed Robotic Arm

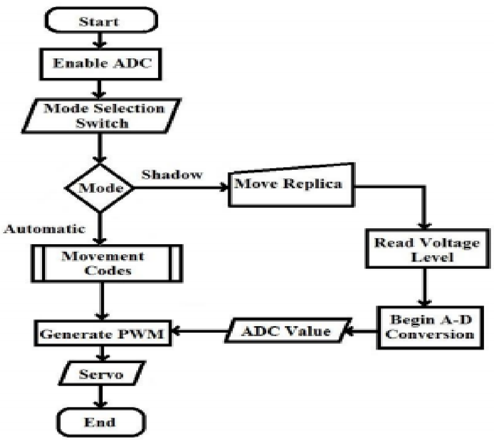

Fig.2. Flowchart of the proposed robotic arm

In Fig. 2 the process starts with enabling the ADC (Analog to digital conversion) later the command flow line checks for the mode selection by the user. Two modes can be selected, either ***Shadow Mode*** or ***Automatic mode***.

Shadow Mode: In case the selection bit resembles shadow mode, every time the replica arm is moved the change in the potentiometer position causes change in voltage levels which through ADC is convert to certain ADC values. These ADC values are then interpreted by the MCU in terms of equivalent varying pulses; PWM. Thus generated PWM can be fed to the servo motor control input which causes a desired deviation as that of the replica arm. The servo movement can be calibrated to meet the replica arm movement finely.

Automatic Mode: The robotic arm when selected for automatic mode reads some predefined movement, interpreted in codes, which the robotic arm repeats on and on. The movements can be coded as required.

II. CIRCUIT DIAGRAM & DESCRIPTION

SCARA robots have two parallel rotary joints to allow full movement throughout a plane, typically for pick-and-place work. From Fig. 2 we can understand there should be a smooth and accurate signal transition throughout the whole operation in order to pick-and-place work. The whole basic operation will be conveying by our circuit based of microcontroller ATmega8A. This Atmel ATmega8A is capable of processing 16MIPS and consists of 6 ADC channels of 10-bit accuracy.

Movement of arm operated by motors especially servo motors. Servomotors are generally used as a high performance alternative to the stepper motor. Stepper motors have some inherent ability to control position, often allows them to be used as an open-loop position control, without any feedback encoder, as their drive signal specifies the number of steps of movement to rotate. This lack of feedback though limits their performance, as the stepper motor can only drive a load that is well within its capacity, otherwise missed steps under load may lead to positioning errors [3].

A. Control Circuit for Servo Motors

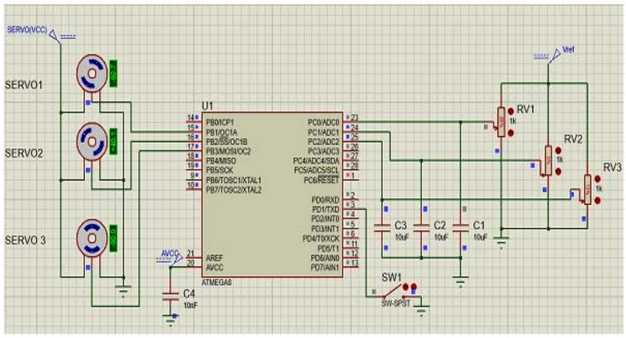

Fig.3. Circuit diagram for controlling three Servo motors using three Potentiometers

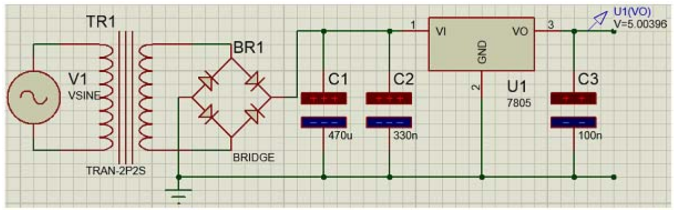

Fig.4. Regulated Power Supply

The circuit in the Fig. 3 is for handling only 3 of the motors. In case a greater number of motor is to be handled another similar circuit can be used. This circuit can even be developed into a module which can be used to control number of motors of factor of 3 i.e. each module would be capable of increase the DOF (Degree of Freedom) of the robotic arm by 3. But later we developed 5 DOF to finalize the prototype using same principle.

The power supply unit consisted of a regulated power supply using 7805, circuit shown in Fig. 4, and an adapter supply for the servo motors. The adapter was chosen to meet the power required to drive the servo motors efficiently. The regulated supply comprised of a step down transformer (220:12V). The output of transformer is fed to the bridge rectifier where full rectification takes and D.C. is obtained. This D.C. comes with a lot of ripples which is mitigated using capacitors. A capacitor is connected at the rectifier output and a D.C. voltage with fewer ripples is obtained across the capacitor [4].

The voltage was regulated to 5v using 7805 IC. The circuit in Fig. 3 and Fig. 4 were drawn in Proteus 8 Professional and simulated. For further development of the circuit; physically, the hex file was load into the microcontroller for simulation. When the circuit's performance was up to mark and met the output requirements, it was developed into a Printed Circuit Board (PCB).

As we know, the servo motors can be controlled using PWM. Hence the microcontroller has been programmed to generate pulses or different width as control signal depending on the wiper position of the potentiometer. The two extremities of the potentiometer are connected to Analog reference voltages AVCC and AVREF and the middle point is fed as input the ADC channel of the microcontroller.

TABLE I. Voltage Reference Selections for ADC

REFS1	REFS0	Voltage Reference Selection
0	0	AREF, internal V_{ref} turned off
0	1	A V_{cc} with external capacitor at AREF pin
1	0	Reserved
1	1	Internal 2.56V Voltage Reference with external capacitor at AREF pin

These bits select the voltage reference for the ADC, as shown in TABLE I. If these bits are changed during a conversion, the change will not go in effect until this conversion is complete (ADIF in ADCSRA is set). The internal voltage reference options may not be used if an external reference voltage is being applied to the AREF pin.

B. Parallelogram joints & Counter Weight Determination

The limbs were coupled using the parallelogram technique. As shown in the Fig. 5 the rotating horn of the servo motor attached onto a limb was controlled the moved of other limb attached to it by means of two brackets, on either side of the horn at equal distance i.e. 'y' from the center of horn. As in the Fig. 5 Limb1 and Limb2 are pivoted and Limb2 hosts the servo with two parallel brackets joining Limb1. The brackets at Limb1 may be attached at distance equal to that of the horn i.e. x=y or it may differ. In case x>y, torque will be greater but displacement will be smaller while x<y displacement will be greater whereas torque will be reduced. We have chosen x=y for all the joints except for that of base, where x>y. This has been chosen so because the base bears the entire weight of the arm which would require greater torque for movement.

Initially, when the servo motor is at mean position, let Limb1's position be Position1. When the servo motor rotates, the upper and lower brackets displace equally but in opposite direction. This cause a push-pull effect on Limb1 thus rotating it by an equal angle of deflection by the servo horn and Position2 is achieved. We chose this technique of coupling so that the motors could be kept at a suitable place in order to reduce the lever-effect.

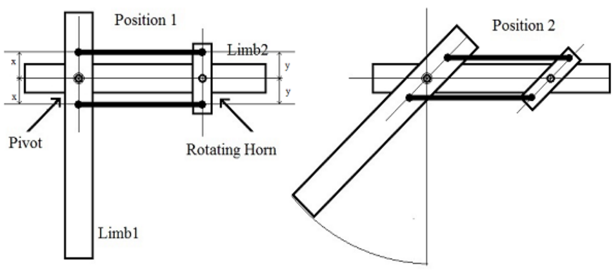

Fig.5. Parallelogram joints at different positions

Counter weight determination is important to grab any object by robotic arm. The slightest weight of motor and other attachments on the extremities of the limbs could cause a greater torque, in short lever effect. In case this torque becomes greater than the stall torque of the motor, the motor won't be able to operate. Thus, cancellation of this opposing torque, for better operation a counter weight needs to be added on the other end. This can be well understood from the following illustration.

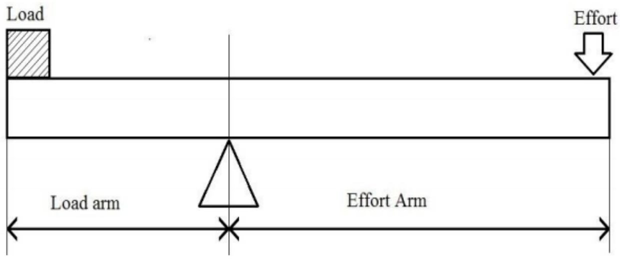

Fig.6. Counter weight determination

The counter weight can be easily determined. Suppose the distance from the pivot to 'Load' be 'Load Arm' and 'Effort' or counter weight be 'Effort Arm'. Thus, use "(1)"to determine the counter weight.

$$load \times load\ arm = Effort \times Effort\ arm \tag{1}$$

III. DEVELOPPED PROTOTYPE

Our developed prototype has 3 DOF at initial stage and later it has to 5 DOF as mentioned earlier. So, the hex code was modified to suit the 5 Degree of Freedom for the arm. The code was ciphered to hex and then burnt on the MCU chip using AVRpal.NET and AVRDEV Tool. The finished prototype appeared as like in Fig. 7. The arm was physical structure was built using aluminum plates and pipes. The robotic arm was able to work under both modes i.e. Gesture (Shadow) mode reading the wooden replica arm and Automated mode.

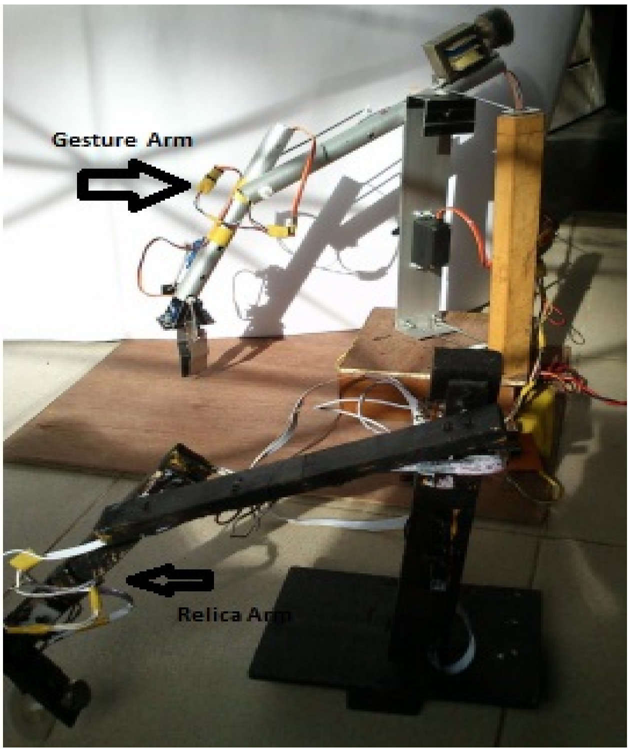

Fig.7. Complete prototype with replica

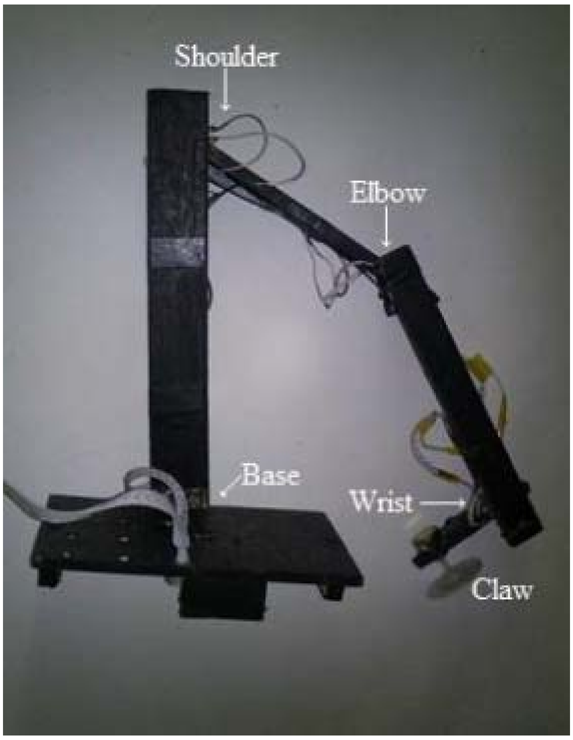

Fig.8. Replica Arm

A. Replica Arm

The replica arm was made up of wood which was hinged at joints by means of potentiometer. The potentiometers were fed to the ADC input lines. As the replica arm is moved the potentiometer's knob rotates resulting in change in the voltage levels using voltage divider rule. The change in voltage level is read by the ADC channels as the change in ADC values. These changes in the ADC values are read by the microcontroller and which eventually cause the change in the PWM pulse of the output. These varying pulse widths are fed to the servo motors which control the servo position. The replica arm is capable of making the robotic arm work only in the Shadow mode. Meanwhile it is of no control in automatic mode. The developed replica arm is showing in Fig.8. Here we are mentioning the parameter of the prototype:

Number of Axes: 3

Degree of freedom: 5

Power source: Electricity

End Effector Max^{m} Opening: 10 cm

Max^{m} Arm Stretch: 30 cm

Max^{m} Payload: 50gm

Type: SCARA (Selective Compliance Articulated/ Assembled Robot Arm)

B. Discussion

- The finished project was capable of dealing with a demonstrating pay load. However this can be further developed using servo motors of greater torque to meet heavier demands. And the movement can be made sophisticated by simply adding greater number of Degrees of Freedom, not to mention, which would certainly approach with further problems to be taken care of. The output for the prototype was as proposed i.e. it was capable of working at both Shadow and Automatic Mode.

C. Shadow Mode Output

The completed prototype of the robotic arm was able to replicate the movement of the wooden replica. In case the shadow mode is not exact, it would require calibration with the generated ADC equivalent PWM signal. Using this mode various tasks can be done. If the prototype is developed with wireless control it would help the bomb squad for bomb disbarment. Likewise, it can be used in rovers sent in space expedition for sample collection and other jobs, etc.

D. Automatic Mode Output

When the mode selection switch was slide to the automatic mode the robotic arm would no more replicate the movement of wooden replica. Rather, it would go on repeating the number of instructions for definite positions; as coded into the microcontroller. This mode can be programmed to be activated at certain triggers such as when a finished product in a production line reaches the end; the robotic arm can be triggered to transfer the product to the packaging zone.

E. Real-life Implementation aspect, complexity and study of cost

The aim of this prototype was to handle situation like human assignation is hazardous or accuracy of some task. For example, bomb, explosive, mine or detonator now-a-days handled by some squad where most of the times they need to deactivate those dangerous things by hand. If we can use such robot, which can act like a human hand and can work through remotely it can save life. From this point of view, this prototype was developed and further improvement of this robotic arm can be helpful in this area. Although, few bomb disposal robot has been made already in different area of the world, but here we have tried to make this prototype in a cost effective way [5], [6]. Though this prototype was functional but it had some inadequacies in reaching full swing of arm. For this reason, it can't give full value of DOF. As a result, for practical implement this arm we need to use precision actuator to avoid unwanted swing and movement. Gesture reading position was not that interactive as expected and we can avoid this complication using flex sensors or hall elements. But due to cost minimization we did not used that. Now, the total cost to make this prototype was almost 1200 BDT. But most of the robotic arm (based on microcontroller) prototype developed around the world is costly [5], [6], [7]. But the features of each prototype are unique and specific object oriented. So, it is not easily comparable all of them with respect to cost. Nevertheless, based on approximation of these prototypes [5], [6], [7] and our developed one is in minimum cost.

IV. CONCLUTION

In this paper, we have developed a microcontroller based robotic arm where ADC conversion and PWM generation for controlling and two modes to operate that arm shadow or automatic. As per the selected mode the further actions are carried out. For the shadow mode the robotic arm replicate the movements of the Replica Arm and in Automatic mode, the robotic arm went on and on with the predefined steps. As the project is based on gesture movement, with a proper blend of AI (Artificial Intelligence) concepts and powerful components it may be developed into highly interactive robot.

ACKNOWLEDGMENT

We would like to thank all the teachers and technical stuff of our university for their unequaled support. We also thank to our friends to inspire us to finish this robotic arm. We are grateful to our supervisor Mr. Ahsanul Hoque, Lecturer, EEE, IIUC for his continuous support and assistance in whole project.

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