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Design and Implementation of a Remote Controlled Robotic Arm Based on Industrial Application Perspective

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Abstract

This paper describes an implementation of a remote controlled robotic arm with six degrees of freedom which is able to pick an object with a specific weight and can place them in a desired location. The method of design of the remote controlled robotic arm consists of two stages. First stage is the construction of the mechanical structure following modular concept with six degrees of freedom and the second is to design the interface of components of the robotic arm to control it via a wireless joystick. To ensure ease of use, wireless system is introduced in this robotic arm. This kind of the arm can be applied in industrial sectors where automaton is profoundly needed.

Keywords: Automation, AVR Microcontroller, Arduino, Mobile robot, Ease of use, Modular design, Ease of maintenance, Wireless, Joystick.

1. Introduction

As technology increases, robots not only become self-sufficient through autonomous behavior but actually manipulate the world around them. Robots are capable of amazing feats of strength, speed, and seemingly intelligent decisions; however, this last ability is entirely dependent upon the continuing development of machine intelligence and logical routines [1]. Industrial robots should perform complex tasks in the minimum possible cycle time in order to obtain high productivity. Robotic arm is one of the key developments in the field of industrial robotics. This paper describes design and implementation of a remote controlled robotic arm with six degrees of freedom which is able to pick an object with a specific weight and can place it at a desired location. The programming of the arm is done on an ATMEGA-328P Microcontroller using Arduino programming. The input is given using a wireless joystick that is also programmed with an ATMEGA-8 Microcontroller. To ensure ease of use, wireless system is introduced in this robotic arm. The wireless system is implemented using wireless transceiver.

2. Design of the Robotic Arm

The design methodology of the remote controlled robotic arm consists of two stages. First stage is the construction of the mechanical structure following modular concept with six degrees of freedom and the second is to design the interface of components of the robotic arm to control it via a wireless joystick. The robotic arm movement depends upon the angular movement of the joint. Joint movement determines the required power. The joint movement must be adjusted to stay within the power available on the robotic system to be used. Friction must also be considered in relation to robotic arm movement [2].

2.1 Mechanical structure of robotic arm

The robotic arm described in this paper consists of two basic elements, a basic structure and a wrist. The basic structure consists of base, waist, shoulder, arm, elbow and forearm which are the first five links (bodies) of this robotic arm and the other link is called its wrist or hand (Figure 1). A robot link is a solid mechanical structure which connects two joints. The main purpose of robot links is to maintain a fixed relationship between the joints at its ends [3]. A robot manipulator consists of links connected by joints driven by separate motors. The wrist is designed for orienting the end effector to do a task or to grasp an object. Rotating motion of wrist enables this robotic arm to grasp an object from different angle.

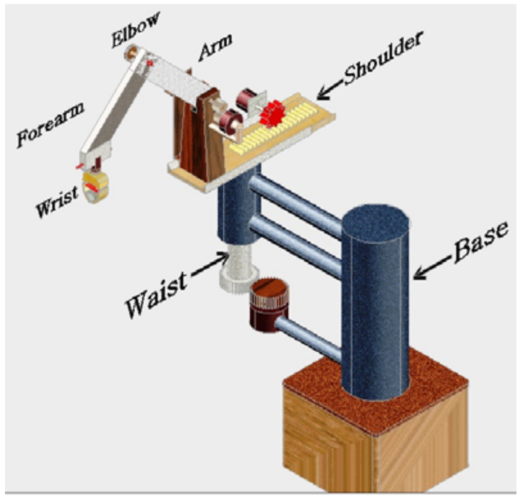

Fig. 1. Basic structure of the robotic arm.

It is shown that maintenance difficulty arrives seriously after completing the manufacturing process of a robotic arm for the absence of modular concept in its design. Modular design is a form of standardization. Modules represent groupings of component parts into subassemblies, usually where individual parts lose their separate identity. One advantage of modular design of equipment compared with nonmodular design is that failures are often easier to diagnose and remedy because there are fewer pieces to investigate. Similar advantages are found in ease of repair and replacement; the faulty module is conveniently removed and replaced with a good one [4].

2.2 Degree of freedom

Robotic systems are characterized by their degrees of freedom (DOF) [2]. Each degree of freedom is a joint on the arm, a place where it can bend or rotate or translate. One can typically identify the number of degrees of freedom by the number of actuators on the robot arm. Each degree requires an actuator, often an encoder, and exponentially complicated algorithms and cost. The robotic arm described in this paper has six degrees of freedom as shown in figure 2. Link 1 (J_1) allows waist rotation (Θ_1) about y-axis, link 2 (J_2) allows arm rotation (Θ_2) about an axis which is perpendicular to the y-axis that means z-axis, link 3 (J_3) allows rotation (Θ_3) of forearm along elbow about an axis which is parallel to the z axis, link 4 (J_4) allows rotation (Θ_4) of wrist along y-axis, link 5 (J_5) allows a linear movement (L_1) of shoulder along x-axis and link 6 (J_6) allows upward and downward movement (L_2) of base along an axis which is parallel to the z-axis.

2.3 Overview of links

- Link 1: At J_1, waist is adjusted into the hollow cylindrical portion of base. Two tapered bearing has used to facilitate the rotation of waist into the hollow cylinder.
- Link 2: At J_2, two gears are coupled. A motor has used for the angular movement of arm using gears as power transmission medium.
- Link 3: At J_3, for the angular movement of forearm, power is transmitted through chain & sprocket system. The motor which is used for the angular movement of forearm, has been in such a way that it's shaft meet at the same level to the motor shaft which is used for link 2.
- Link 4: At J_4, wrist can be rotate as requirement to grasp an object. A small ball bearing has used here to facilitate wrist rotation.
- Link 5: At J_5, shoulder can be moved through the waist with sliding motion. Here rack & pinion are used as

the power transmission medium.

- Link 6: At J_6, base can be moved to upward and downward direction along with slots into the rectangular box. To facilitate this vertical motion an automotive lifting system has used at J_6.

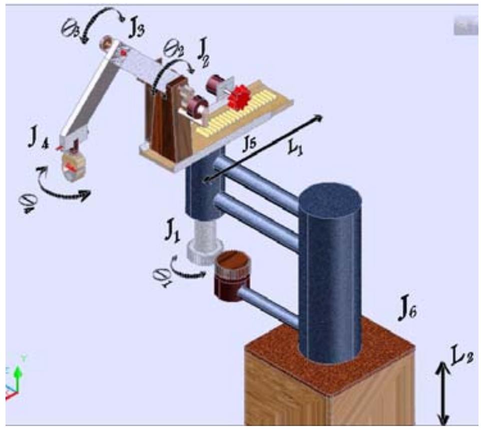

Fig. 2. Robotic arm with six degree of freedom

2.4 Robot workspace (Work Volume)

The robot workspace (sometimes known as reachable space) is a collection of points that the end effector (gripper) can reach. The workspace is dependent on the DOF angle/translation limitations, the arm link lengths, the angle at which something must be picked up at, etc. The workspace is highly dependent on the robot configuration. The table below describes the workspace for the designed robotic arm.

Table 1. Movement range of basic structure

Structure	Movement type	Maximum allowable movement
Waist	Rotation(Θ_1)	$0<\Theta_1 \leq 360°$
Arm	Rotation(Θ_2)	$0<\Theta_2 \leq 180°$
Forearm	Rotation(Θ_3)	$0<\Theta_3 \leq 200°$
Wrist	Rotation(Θ_4)	$0<\Theta_4 \leq 360°$
Shoulder	Linear(L_1)	$0<L_1\leq 8$ inch
Base	Linear(L_2)	$0<L_2\leq 12$ inch

2.5 Ease of maintenance

During operation with heavy load any portion of this robotic arm may be hampered or needed to be upgraded. Because of modular design every portion of the structure of this robotic arm is independent. As a result skilled person is not necessary for the reassembling or assembling the total structure of this robotic arm. For these reason it is very easy for someone to work with any portion of the structure without disturbing other portion. Efficient design of this robotic arm enables one to lubricate it properly without any complexity. The design of this robotic arm also facilitates the scope if any upgrades are needed for the robotic arm to cope with any new advanced process layout or to facilitate production work [10].

3. Implementation Process

The implementation process consists of two parts, the first one is designing the motherboard for the robotic arm to control the motor and the second one is designing the wireless control interface for the wireless joystick to operate the robotic arm remotely.

3.1 Robot motherboard

The theory behind control systems and how they control motors and other devices is the foundation of all modern electromechanical systems. Using control system mathematics and theory, we can design systems that do nearly anything we want, to the granularity that we desire, in the amount of time that we desire. Control system theory can be broadly broken up into two major categories: open loop control and closed loop controls. Open loop control is by far the simpler of the two types of control theory. In open loop control, there is some sort of input signal (digital or analog), which passes through amplifiers to produce the proper output and then it passed out from the system. Open loop controls have no feedback and require returning input to zero before the output return to zero. In general open loop control means send electrical signals to an actuator to perform a certain action, like connecting a motor to a battery. In this scheme of control, there is no any other mean for controller to make sure that the task was performed correctly and it often needs human intervention to obtain accurate results. A very simple example of open loop control is the remote controller of an RC toy car. The human have to constantly check the position and the velocity of the car to adapt to the situation and move the car to the desired place. We have employed the advanced close loop control system [7] to operate the motors for our robotic arm. Closed- loop control system is implemented using a common communication medium (wired or wireless), network quality strongly influences the performance of the control solution. Specifically, time delays governed by deterministic and stochastic processes are often introduced by the network [8]. In closed loop control, the system is self-adjusting. Data do not flow one way. It may pass back from a specific amplifier (such as velocity or position) to the start of the control system, telling it to adjust itself accordingly .Many physical systems have closed loop control at the lowest level since the data about velocity and current position modify the output (also position) at a consistent rate. We need some mean of gaining information about the rotation of the shaft like the number of revolutions executed per second, or even the precise angle of the shaft. This source of information about the shaft of the motor is called "feed-back" because it sends back information from the controlled actuator to the controller. It is clear that the closed loop system is more complicated because it needs a 'shaft encoder' which is a devise that will translate the rotation of the shaft into electrical signals that can be communicated to the controller. Ploplys et al.[9] Implements a closed- loop control solution for an inverted pendulum using a wireless sensor network communicating upon the IEEE 802.11 b communication standard.

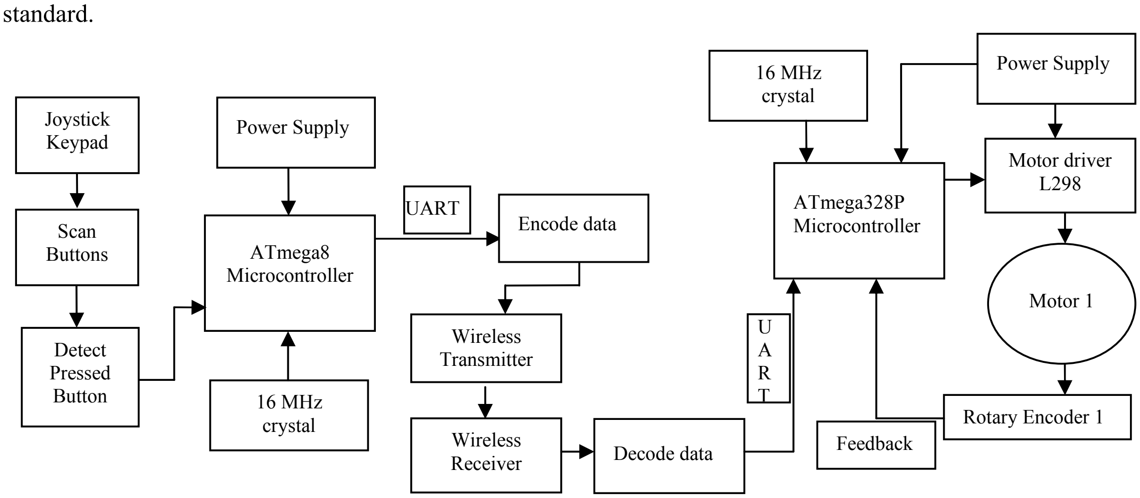

Fig. 3. Closed loop motor control via wireless joystick.

The close loop motor control block diagram is shown in the figure 3 above. The heart of this control system is the ATmega328P microcontroller. The wireless receiver module receives the wave signal transmitted by the wireless joystick transmitter module. Then the module decodes the wave signal and sends to the ATmega328P microcontroller through UART. UART is stands for Universal Asynchronous Receiver Transmitter. It is widely used as protocol for communicating with the microcontroller. Then the microcontroller sends the motor controlling signal to the L298 motor driver IC according to received wireless signal. The motor control circuit is shown in figure 4. The rotary encoder is attached with each motor, which sends clock pulse to the microcontroller when the motor shat rotate. The number of pulse send by the rotary encoder for each motor in one revolution of motor shaft is fixed. By counting the number of pulse the microcontroller calculate the current position of the arm internally and if any error found with the position of the arm and receiver module received position then the position is fixed by sending the necessary signal to the motor driver. In this way the close loop control system is applied effectively to control the position of the arm.

3.2 Programming platform

Arduino, an open-source electronics prototyping platform, has been used for Programming the robotic arm and the Arduino UNO board has been used for our Robotic arm motherboard. The Arduino Uno is a microcontroller board based on the ATmega328P [5]. It has 14 digital input/output pins of which (6 can be used as Pulse Width Modulation (PWM) outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. There is also a free Arduino IDE for Programming the Arduino board that has been used for compiling and uploading the hex code to the microcontroller. The Programming language used in Arduino IDE is C++.

3.3 Wireless joystick

Joystick circuit diagram is shown in figure 5. Radio Frequency (RF) Transceiver Module has been used for wireless communication. A RF Module is a small electronic circuit used to transmit and/or receive radio signals on one of a number of carrier frequencies. RF Modules are widely used in electronic design owing to the difficulty of designing radio circuitry and it is very cheap to buy from market. Good electronic radio design is notoriously complex because of the sensitivity of radio circuits and the accuracy of components and layouts required achieving operation on a specific frequency [9].

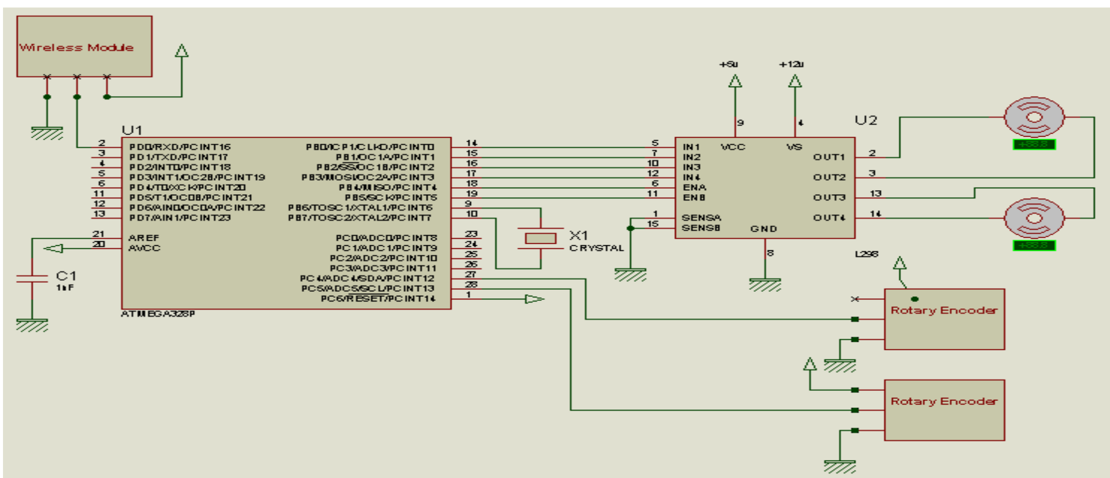

Fig. 4. Motor control circuit diagram.

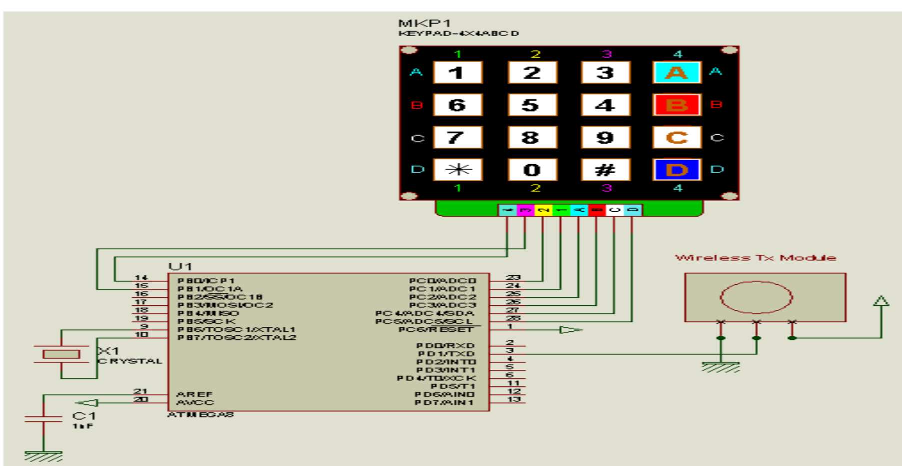

Fig. 5. Joystick circuit diagram.

ATmega8 microcontroller is used in joystick to send the wireless signal to the robot [5] [6]. The microcontroller scans continuously the keypad and detects the pressed button. The joystick is able to detect multiple key presses at the same time. . After detecting the buttons which are pressed down, microcontroller encode the key pressed data and send it to the wireless transmitter module. The transmitter transmits the data in the form of wave.

4. Results & Discussions

The photographic view of our implemented remote controlled robotic arm is shown in figure 6. It is able to lift the objects of medium weight up to 1.6 pound. Three contributions of our work are: (i) This can be employed in places where precision and accuracy is required, (ii) This robot can also be employed where human hand cannot penetrate. (iii) These robots have a wide range of applications such as pick and place.
This robot arm can be used for various applications, few of them are: (i) To lift objects, (ii) To lift nuclear wastes without harming the humans, (iii) Prototype for a Bomb disposal robot.

Fig. 6. Robotic arm lifting objects of average

5. Conclusion & Future work

Our robot developed with an implementation of Arduino Uno microcontroller board based on the ATmega328P, can be guided with six degrees of freedom. We used geared motors for their high torque at low speeds, in exchange for a highly-reduced brushless or brushed motor. These design tradeoffs were chosen for the envisioned target application of robots interacting with unstructured environments such as a typical home or workplace, where the safety of intrinsic mechanical compliance is an important design consideration. These robots have a wide range of industrial and medical applications such as pick and place robots, surgical robots etc. This robotic arm so far designed is able to lift the objects. In order to extend it to some extent, more advanced tools and material are to be used for mounting the tools which are grasped by mechanical grippers include the spot or arc welding gun, spray painting gun, drilling spindle, grinder wire brushes, and heating torches. Then it will be fit for paints, ceramics, and foundry shop as well as for automotive industry.

6. References

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