Design of a Low Cost PC interface Six DOF Robotic Arm Utilizing Recycled Materials

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***Abstract*— In this work, a PC-interfaced low cost robotic arm has been designed which can be integrated with modern robotic-arm based light weight lifting applications. Both manual and PC-based controlling system have been integrated with the robotic arm to make the manipulator use-worthy in maximum applications. This designed robotic arm has six degree of freedom (DOF) which is modeled as four-link, with each joint connected with suitable DC gear-motor. Available parts from local market as well as used up elements from industrial machines and household appliances have been used for the implementation of the manipulator to lower the cost. For controlling the robotic arm, microcontroller based manual controlling system with PWM speed control along with relays has been used and DC gear motor has been integrated with PC based on parallel communication for PC-based controlling system. The weight of the complete structure is only 7.363 kg which is capable of lifting up to 1.5 kg. This designed robotic arm costs only $125 including all prices of recycled and fresh materials which is considerably lower than commercially developed robotic arm with same specifications.**

Keywords*— *Robotics, Robotic Arm, Manipulation, Degree of Freedom.

I. INTRODUCTION

Robotics is a growing field with enormous applications in the defense, industrial, and consumer markets. To perform high-precision jobs such as welding and riveting, robots are now widely used in factories. They are also used in special situations that would be dangerous for humans -- for example much production in industry, cleaning toxic wastes or defusing bombs. In modern industries, a special kind of human-size industrial robotic arm called Programmable Universal Machine for Assembly (PUMA) [1], often termed anthropomorphic because of the similarities between its structure and the human arm came into existence.

Manipulation is a very important aspect of robotics, which is necessary for accomplishing simple and complex tasks from painting cars in a factory to lifting victims out of rubble. At first appearance of the industrial robots during the 1960s, the concepts for the usage of the robots were only as manipulator in which to perform pre-ordered commands. After 20 years later during the 1980s, together with the appearance of microprocessor, it marked the beginning of the intense research of the field of robot [2][3]. As the research progressed, robots were recognized not only as simple action performer but as a machine that have diverse and variety of purposes and usages. No ideal solution to manipulation has been identified yet that maximizes robustness and minimizes cost. Industrial robotic arms are robust, yet extremely expensive with many complex parts along with expensive actuators and sensors [4]. Therefore, an inexpensive robust robotic arm would be a very useful development with many potential applications. Increased affordability can lead to wider adoption, which in turn can lead to faster progress [4][5]. However, drastic cost reduction will require design tradeoffs and compromises.

In our proposed robotic system, to design a low-cost robotic manipulator, we have given much attention to the recycling elements from used up industrial and household equipment. The undamaged parts are worth to use for the design purpose. To give a diversified control on the robotic arm, both manual and PC-based control has been integrated in this system. The designed manipulator has 6 DOF (degree of freedom) with four link points which is the modern trends of robotic arm design [4][6]. The elaborate description about the construction of the system has been drawn in section II. Construction and material selection have been presented in section III and IV. Finally operation and necessary calculations have been shown in Section V and VI.

II. CONSTRUCTION OF THE ROBOTIC ARM

In this work, a robotic arm has been designed in such a way that it can utilize for industrial purpose as well as anyone can design this by one's own at home. The whole robotic arm shown in Fig. 1, has designed on an aluminum basement part with screw backup to set the arm on floor or on the wall. From basement part, a stainless steel (SS) pipe has been used to provide a strong support for the upper portion so that the upper portion can move safely without any damage. In this portion, a motor with 3-Spur gear systems have been integrated with the pipe to control the whole movement of the arm with specific speed control system. A baring has been used attached with the SS pipe to provide a free disk. This is the junction point of the basement and upper part. The aluminum structure of the basement part are interconnected with each other using small

Fig. 1. Final outlook of the designed robotic arm.

90 degree angle plate inside with screw instead of soldering which make the design less expensive. The basement structure has been depicted in Fig. 2.

The upper portion of the manipulator has four separate portion with three link point. The first portion nearer to the basement part named as shoulder shown in Fig. 3. In the shoulder portion, 4 motors, 4 gear and 4 timing belts has been used. This portion is the junction between upper-arm and basement part. DC-gear motor along with gear and baring of the basement rotates the shoulder portion on its own axis. The motors of this section have been utilized to control the upper arm and forearm in the up and down direction. It has also provided the rotational control and up-down control to the gripper portion. This shoulder section has aluminum body and the upper arm has been connected with the shoulder though a shaft on which the timing belts are mounted. The upper arm made by aluminum body of the robotic arm next to the shoulder is the link portion of fore arm and the upper arm part through a shaft. The movement of this upper arm is fully controlled by a DC gear motor on the shoulder part and it connected by 1 timing belt with gear. For movement of forearm, motor on the base and 2 timing belt are connected with gears. This portion is only free to move up and down direction along with the fore- arm and the wrist part of the robotic arm.

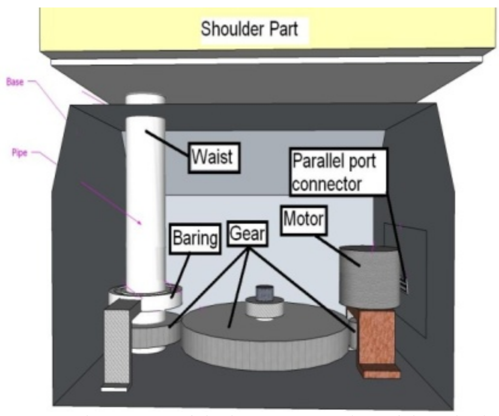

Fig. 2. Internal structure of the basement portion of the robotic arm.

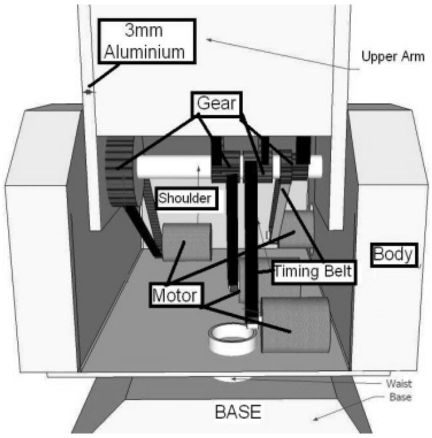

Fig. 3. The internal structure of the shoulder of the robotic arm.

When one part is move then all the other part are maintain their position along with axis. In the fore-arm section depicted in Fig. 4 (left), the aluminum body has a DC-gear motor to control the gripper with worm gear system to move the gripper open and close. There are two motor connected to control the gripper up and down right or left rotate. In this system there are 6 timing belt are connected between motor and bevel gear (shown in Fig. 5). The wrist portion has been connected with this portion with another shaft which has been integrated with the motor system.

The timing belt along with the motor has been provided the mobility to the wrist portion in the direction to up-down and the rotational movement. The uppermost part of the robotic arm has been named as the wrist in Fig. 4 (right side) constructed with aluminum body. The wrist portion has been connected with the fore-arm with a shaft of two shorter radius along with an aluminum bar. The shaft has been placed into the bar through a hole. This bar has been integrated with the fore-arm portion utilizing two other holes perpendicular to the shaft. At the end of the SS pipe the DC-gear motor has been mounted tightly. A shaft along with worm gear has been connected to the rotor of the DC-gear motor. Two gears has been placed besides the worm gear. This portion has a Bevel gear system besides the aluminum bar to provide the rotational movement and the up-down directional movement to the wrist.

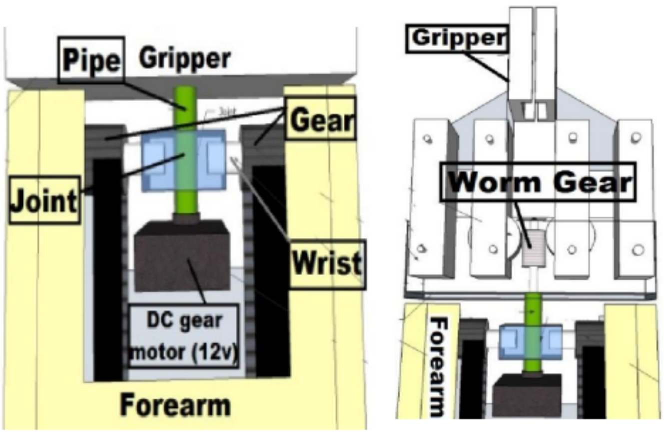

Fig. 4. The internal construction of the forearm (left side) and wrist (right side) of the robotic arm.

Fig. 5. The joint of fore arm and wrist with bevel gear and timing belt along with DC gear motor to control worm gear.

To provide the control over the designed mechanical system of the robotic arm, an electrical section along with software based PC interface has been used in robotic arm. The electrical section has been constructed such a way that the whole system can be run in manual and automatic mode or PC-drive mode. The electrical section has been provided the working basement of the mechanical portion. This section has been designed with a microcontroller along with motor driving circuit elements. The whole system has been run by the input signals having from encoder along with all DC gear motors and touch sensor. In motor driving elements, two ULN2003 and several 12 relays driven at 5 V power source and 12v and 19 v have been used to drive the DC-gear motors. In the electrical section, three voltage levels has been used. Microcontroller unit has been run by 5V which is managed by using mobile charger that have less PWM frequency and 12V and 19V have been utilized for running the DC-gear motor which is mostly managed by a laptop charger. The designed circuit diagram has been illustrated in the following Fig 6.

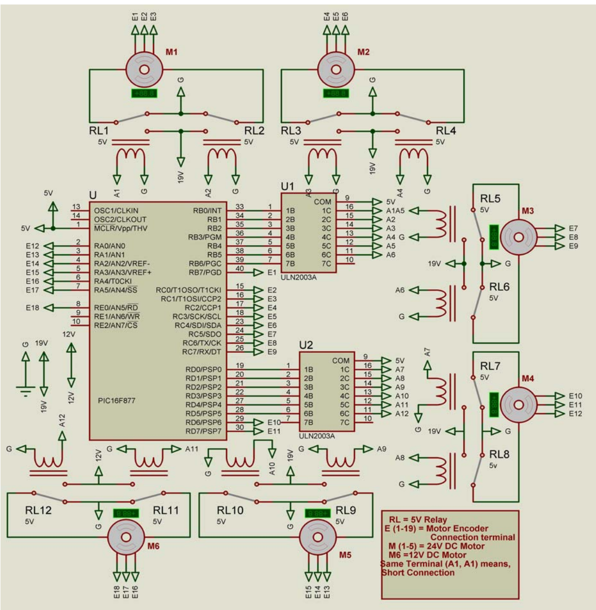

Fig. 6. Circuit diagram of the controlling unit of the robotic arm

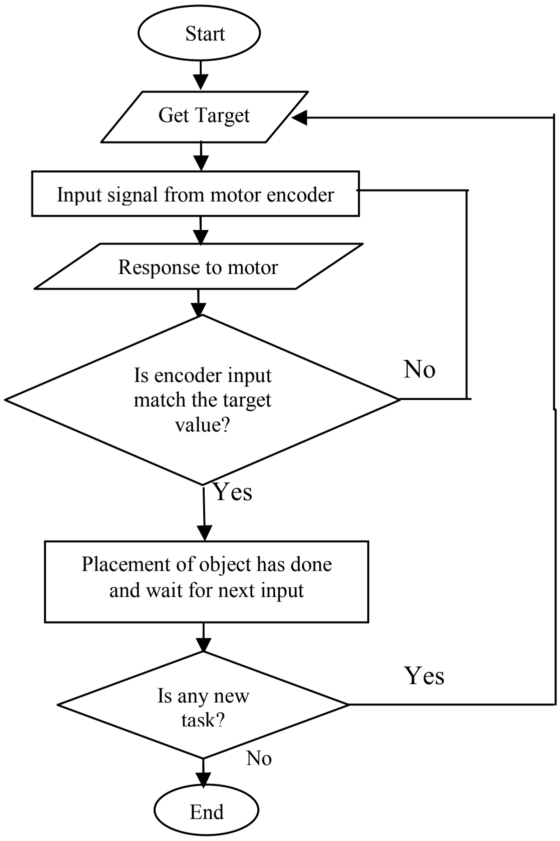

Fig. 7. Flow chart of the operation of the robotic arm.

To provide the PC- based controlling, c++-based program and another is visual basic have been used. The robotic arm has been integrated with the PC through parallel port. The whole system can jump from manual control to PC-based control. The PC-based controlling is 8 bits controlling system. So for controlling the 6 DC-gear motor, 8 bits controlling signal has been sent twice through the communication port. Here some register are used to make serial to parallel signal. The whole operation has been briefly shown with complete flow chart in Fig. 7.

III. MATERIAL SELECTION

In choosing the materials and the shape for the fabrication of the robotic arm, the following factors were taken into consideration [7][9]:

- The ease of manufacturing the parts
- The mode of manufacturing
- Ease of assembly
- Strength and durability of the parts
- Weight of robot
- Cost of the selected materials

To construct the robotic manipulator, aluminum has been mostly utilized to give the main outward structure of the arm.

Some inner structures have been made of iron. Aluminum sheets are collected from unused body of cars and industrial machines. For developing the basement part, one can use wood instead of aluminum as wood can provide hard and reliable structure for the basement portion. For constructing the link point between the different sections, long nut with bolt of different radius have been utilized. These nuts are available in local market as recycled parts which costs lower than new nuts with almost same working capabilities.

Whole robotic arm has been designed with 6 DC-gear motor. In this work, mainly 24 V DC-gear motor has been used. Only in the wrist portion, 12 V DC-gear motor has been used. For the design of the manipulator, mostly spur gears of different radius have been utilized to control the speed of the motors. For controlling the speed and position of the wrist, a bevel and worm gear have been used [7-9]. Using a spring system connected between top of the fore arm to shoulder to increase the lifting weight capacity. All the timing belts have been integrated with the gear system utilizing the slot and teeth system. The timing belt section can be replaced by low weight chain from car with its gear. The chain system lowers the cost but increases the weight. The integration of the whole system has been done by screw along with the knack to make the system more reliable and less expensive. Here, the encoder disk and optocouplers have been collected from the damaged printer.

IV. OPERATION OF THE MANIPULATOR

To operate the whole system, two separate power supply has been used in this robotic arm project. 19V power supply has been taken from a laptop charger and it has been converted into 12V power supply. 5V power supply has been taken from a mobile charger. After providing the power supply, the whole operation has been performed with 12 switches. These switches have been used to control the 6 DC-gear motor in the forward and backward direction. Whole operation has been performed through the microcontroller portion along with the relays. In this work, the designed system is 6 DOF (degree of freedom) system. 6 DC-gear motor integrated with 9 timing belts have been utilized to make the system 6 DOF robotic manipulator. Generally each degree requires a motor, often an encoder, and exponentially complicated algorithms and cost. The timing belt diagram has been shown in Fig. 8. In the figure, it has been illustrated that Timing Belt1 in the shoulder section and the upper arm section has been responsible to provide the movement in the fore-arm section. Timing Belt 4 has been used to move the upper arm. Timing Belt 2 and 3 of shoulder, upper arm and fore-arm have been integrated with each other to control the movement of the wrist section of the robotic arm.

In electrical section, for controlling the speed of the arm, a pot has been used to vary the speed. From the optocoupler sensor and encoder signal, arm continuously check the output of the encoder using PIC microcontroller to achieve the desired target. Besides the manual control, for PC-based controlling, input signal has been sent from c based program [10]. This signal has been sent through the parallel port of the PC. For parallel port communication, Port95nt software has been used.

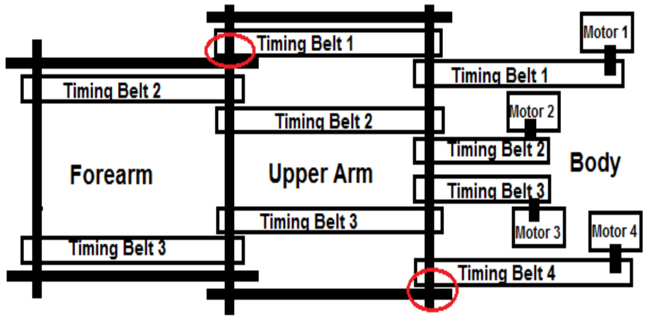

Fig. 8. Timing belt diagram for the designed robotic arm.

The input signal first has been fed into the microcontroller and the rest of the functions have been performed in the above described process. MikroC has been used for the microcontroller code.

V. DATA AND CALCULATION

The design of a robot arm is one of the most mathematically complex robot design [11-14]. In this designed project, to calculate the parameters discussed above, all necessary data and information has been collected. The information of the related parameters have been given in the following table I [11][15][16].

In this work, the way of measurement and calculation of the specification of the robotic arm is slightly different than the discussed process [12][17]. As all the motors are at the basement section and these motors are coupled with the corresponding joint with the timing belt, here it is assumed that the system is well coupled with the timing belt. Weight of the timing belt of the corresponding actuator has been added to that actuator's weight. The weight of the gear and the shaft integrated to the joint has been adjusted with the weight of the respective motor of that joint. In the designed robotic manipulator, weight of all DC-gear motor except the motor of wrist has been obtained as 0.11 kg and the motor of the wrist has 0.06 kg. The weight of the timing belts have been found as 0.075 kg at upper arm section, 0.05 kg at the fore-arm and 0.068 kg at the shoulder portion.

TABLE I. ABBREVIATION OF USED PARAMETERS

Used variable name	Abbreviation
L1	length of arm linked between base to upper-arm
L2	length of arm linked between shoulder to fore-arm
L3	length of arm linked of fore-arm including the wrist
T	Torque
W1	Weight of the base motor
W2	Weight of the arm linkage between base and upper arm
W3	Weight of the motor at joint of shoulder and upper arm
W4	Weight of the arm linkage between base and upper arm
W5	Weight of the wrist motor
W6	Weight of the arm linkage between base and upper arm
W7	Weight of the object

The whole system including all section has been obtained as 7.363 kg. The other calculated data has been illustrated in the following table II. From the calculation, the designed robotic arm is supposed to lift weight of 2.059 kg but practically this robotic arm is capable of carrying 1.5 kg of weight.

TABLE II. COLLECTED AND CALCULATED VALUES OF THE PARAMETERS

Weight Parameters of table 01	**Weight (kg)**	**Length Parameters of table 01**	**Length (cm)**
W1	0.57	L1	24
W2	0.682	L2	19
W3	0.291	L3	23
W4	0.415		
W5	0.141	Motor Efficiency	80%
W6	0.25	Safety Factor	2
W7	2.059		

Using the process mentioned above, the calculated torques have been found as 34.5 Nm in the wrist-forearm joint, 112 Nm at the joint of fore-arm and upper arm and 239 Nm at the joint of upper arm and shoulder. The basement motor's torque has been calculated as 216 Nm. In this project, the output arm accuracy has been obtained as 1.153 cm.

CONCLUSION

Now-a-days, Robot and robotic system has become an unavoidable part of the modern industries. In near future, the uses of the robot and robotics will cover almost every possible field related to human needs. So in this work, the aim has to design a low cost robotic arm with PC interface which can be implemented in all the sector where robotic arms is needed. To fulfil the purpose in the design of the robotic arm several recycling materials have been used to lower the cost of design. The designed robotic arm (manipulator) has 6 DOF (degree of freedom). All sorts of modern features have been integrated in the construction. It has 4 sections: basement (base), shoulder, upper arm, fore-arm and wrist along with a gripper. It has been designed for both manual and auto controlling mode. In manual mode, it has been operated by the signal from encoder connected to the designed electrical circuit portion described in the construction section. For PC-based controlling visual basic based program has been utilized with parallel communication protocol. The weight of the designed system is 7.363 kg and it can lift 1.5 kg safely. To lift the highest payload of this weight, the wrist-forearm junction has run under 34.5 Nm torque, the upper arm and forearm junction has produced 112 Nm torque, 239 Nm torque has been produced by the upper arm and the shoulder junction. The basement section has produced 216 Nm torque for this operation. The operation result shows a satisfactory agreement with other designed robotic system [6][9][17]. This main purpose of this design is to make the system affordable for the third world country where budget is a big issue but necessity is there. So, this design and implementation can utilized in the third world country for their industrial purposes.

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