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Demonstrative Learning 5 Axis Robotic Arm

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ABSTRACT**:** This paper proposes the concept of Demonstrative learning , task level learning and planning for robotic applications that involve object manipulation. Pre-programming robots for execution of complex industrial tasks, as the identical order of sub-tasks cannot be done while previously assigned task is in operation. This paper aims to pre-program the Industrial Robots using Demonstrative Learning algorithm, so that the task changed will be easily adoptable for Industrial Robots. For few tasks, there are underlying constraints that must be fulfilled, and knowing. The Human tutor can directly teach or demonstrate the Robots about the underlying constraints and the required task to be done. It will be stored, analysed and reproduced during the actual execution of task by the Robots. Thus the Industrial Automations like Pick and place task can be achieved.

KEYWORDS: Demonstrative Learning, Robotics, learning by Demonstration, Industrial Automation, Articulated robot.

I.INTRODUCTION

In this Modern era, the Industrial Automation is inevitable and Robots are playing major role for it. Industrial automation can be simply explained as, employing Robots to perform the operations, which were previously done manually [1]. The known fact is that, Robot is simply a dumb machine, until it is programmed something to make it perform certain task. The Robots once programmed, will perform a set of tasks alone. Other than the programmed task, Robots cannot do any other task. In other words, Robots will not perform any additional or new tasks, which were not pre-programmed. In order to use any robot for different task or application, Reprogramming is necessary. But for any manufacturing industries, which are operating continuously or at higher rate, the Reprogramming takes more time and also programmer availability and cost to pay them is big deal. In-order to avoid such problems, Demonstrative Learning concept is introduced for Robotic arm used in Industries, which will learn new tasks by demonstrating it with the help of a human Tutor [7]. This learning methodology will cope up the time constraint and programmer constraints, for Industries.

In this paper, the concept of Demonstrative Learning is implemented for 5 axes Robotic arm, which can be used for Industrial Automation. The Robotic arm is operated using Analog Feedback Servo motors, which can take angular inputs, while moving them mechanically and also produce angular motion while providing them PWM signals. The Tutor will demonstrate the motion of the robots by touching and moving it physically. The motion demonstrated by the tutor will be obtained as angular inputs in a sequence and then converted as respective PWM signals and they are stored. While execution of the motion by the Robotic arm, the PWM signals will be converted into respective angular motion in sequence. Thus Demonstrative learning and its outcome can be achieved by the proposed system.

II.PROPOSED SYSTEM

The Major components of the proposed system are Analog Feedback Servo Motors, Microcontroller, Mechanical structure of 5 Axes Robotic arm and Power supply. The Block diagram, shown in Fig.1, illustrates the working flow of the proposed system.

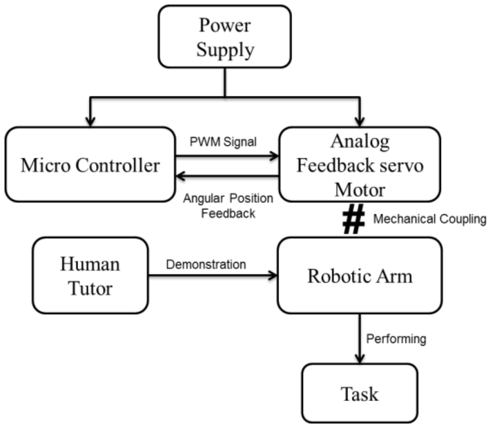

Fig.1: Block Diagram

The Shafts of the Analog Feedback Servo Motors are mechanically coupled with Robotic Arm. The Analog Feedback Servo Motors are interfaced with Microcontroller. Power supply is required for operation of Microcontroller and Analog Feedback Servo Motors.

III.HARWARE REQUIREMENTS

3.1 Analog Feedback servo Motor

The Analog Feedback Servo Motor is used in the proposed system to produce angular motion by getting PWM signals from Microcontroller, as well as to receive the angular position as feedback to the Microcontroller. There are two types of Analog Feedback Servo Motor: 180 degree Servo and 360 degree Servo. The circuit block diagram of Analog Feedback Servo Motor is shown in Fig.2

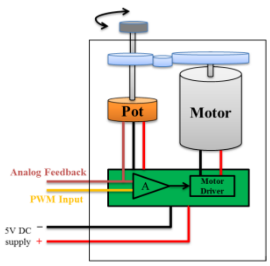

Fig.2: Circuit Block of Analog Feedback Servo Motor

The Analog Feedback Servo consist of DC power supply lines, PWM input line and Analog Feedback Line. The Analog Feedback line is to give the angular position feedback to the microcontroller, which is used during the Demonstrative Learning process to record the motion demonstrated by Tutor to the Robotic arm. For reproducing the motion taught to the Robotic arm, the PWM signal will be given as input to Servos.

3.2 Microcontroller

The Microcontroller chosen and used for this system is ATmega2560. It is a 8-bit microcontroller. It is a SMD TQFP package 100 pin IC. It has 256KB on-chip In-system programmable Flash memory for program storage, 8KB SRAM and 4KB of EEPROM. Further memory requirement can be met by External memory interface. The clock frequency of ATmega2560 is 16MHz, which is provided by an external Crystal oscillator. It is capable of executing 1 million instructions per second per mega Hertz.

3.3 Robotic Arm

The Five axis Robotic Arm, i.e. Degree of freedom is five (5-DOF), which is similar to a human hand [2] [5]. It consists of Gripper, wrist, Elbow, Shoulder and waist structure [2] [4] [5], which are made of Poly Vinyl Chloride (PVC) material. The Robotic Arm will be used for all kind of Industrial Automation tasks, like Pick and place, Lifting and Holding objects, Welding, cutting, and etc [1].

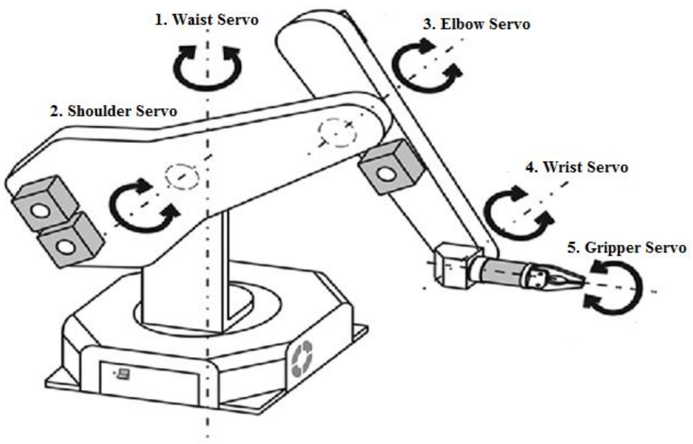

Fig.3: Working Diagram of Robotic Arm

There are 5 Analog Feedback Servo Motors fixed at 5 joints of Robotic Arm. The First servo is for 360 degree rotation of entire Robot, acting as a waist for Robotic Arm. Other four Servos are capable of 180 degree angular movement, which are acting as Shoulder, Elbow, wrist and Gripper of Robotic Arm.

3.3.1 Mechanical Design of Robotic Arm

The Five Axis Robotic arm has to perform operations done in Industrial Automation like Pick and place, lifting and holding loads etc. In-order to determine what kind of load and how much torque required for the motors going to be fixed with it, mathematical analysis is required to be performed, for determining the Maximum Required Torque. The simple mechanical layout of Robotic Arm is shown in Fig.4.

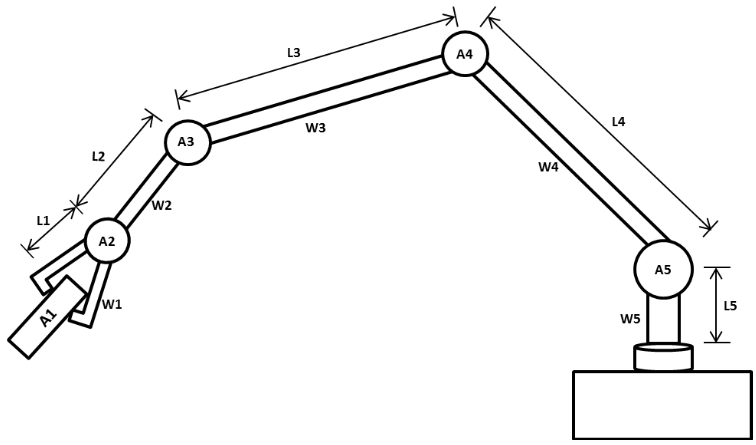

Fig.4: Simple Mechanical Layout of Robotic Arm

In Fig.4, the L1, L2, L3, L4 and L5 are lengths (in cm) of Gripper, Wrist, Elbow, Shoulder and Waist part of the Robotic Arm.W1, W2, W3, W4, W5 are the weights (in Kg) of Gripper, Wrist, Elbow, Shoulder and Waist part of the Robotic Arm. A1 is the weight (in Kg) of the Load lifted by Robotic Arm. A2, A3, A4 and A5 are the Weights of the Servo motors fixed at Gripper, Wrist, Elbow, and Shoulder joints respectively. The Maximum Load, rating of Servo Motor, Robotic Arm material and structure are determined using the following Torque equations.

$T1 = (L1 * A1) + (0.5 * L1 * W1)$

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T2 = ((L1 + L2) * A1) + (((0.5 * L1) + L2) * W1) + (L2 * A2) + (0.5 * L2 * W2)
T3 = ((L1 + L2 + L3) * A1) + (((0.5 * L1) + L2 + L3) * W1) + ((L2 + L3) * A2) + (((0.5 * L2) + L3) * W2) + (L3 * A3) + (0.5 * L3 * W3)
T4 = ((L1 + L2 + L3 + L4) * A1) + (((0.5 * L1) + L2 + L3 + L4) * W1) + ((L2 + L3 + L4) * A2) + (((0.5 * L2) + L3 + L4) * W2) + ((L3 + L4) * A3) + (((0.5 * L3) + L4) * W3) + (L4 * A4) + (0.5 * L4 * W4)
T5 = (L5*(A1+A2+A3+A4+A5+W1+W2+W3+W4)) + (0.5*L5*W5)
Here, T1, T2, T3, T4 and T5 are the Torques in (Kg-cm) of Servo motors fixed at Gripper, Wrist, Elbow, and Shoulder joints respectively.

3.4 Power Supply

The nature of power supply required is DC. The Microcontroller requires 5V supply voltage and the Analog Feedback Servo motor also requires 5V supply voltage. The Most generically available Power adapter provides 12V DC supply. So a 12V DC adapter and a 12V to 5V Buck converter, which supports for the maximum current rating, will be used for providing power to Analog Feedback servo Motors and Micro controller.

IV.SOFTWARE REQUIREMENT

The ATmega2560 Microcontroller can be programmed using Arduino IDE or Atmel Studio with Embedded C. Embedded C uses most of the syntax of standard C language such as Functions, Variable declaration and definition, Data type declaration, Conditional statements, Loop statements, Arrays, Strings, Structure and Union, Bit-wise operation and Macros. Embedded C has features such as Fixed-point Arithmetic, Named address spaces and Basic I/O Hardware addressing, which are not available in standard C.

V.METHODOLOGY

The proposed system consists of two operating modes: 1.Learning Mode and 2.Action Mode (default). For switching the operating mode, respective button has to be pressed to select the mode manually.

5.1 Learning Mode

When Learning Mode is enabled, the Human tutor can start demonstrating the Robotic Arm [7]. Human tutor will hold the Robotic Arm and move it, at the time, the angular positions of the Analog Feedback Servo Motor attached 5 joints of it will get changed continuously. The angular positions of all Analog Feedback Servo Motors will be sampled by Microcontroller at every 50 milliseconds. For examples, if 500 samples of angular positions are collected, the movement for 25 seconds (maximum) can be learnt and stored. So tutor has to ensure that, the movements to be taught to the Robotic Arm is less than or equal to 25 seconds. Once the Demonstration is finished, the Action button is to be pressed for ending the learning and switching the Robotic Arm to Action Mode.

5.2 Action Mode

The Action Mode will be enabled by default. If Robotic Arm is in Learning Mode and then the button for Action mode is to be pressed for switching the Robotic Arm to Action Mode. In Action Mode, the movements, which were taught during the last Learning operation, will be performed by the Robotic Arm. The Angular positions which were sampled during the Learning operation, is converted in to respective PWM signals by Microcontroller. Then Microcontroller will apply these PWM signals the Analog Feedback Servo Motors in sequence. Each PWM signal will be applied for 50 milliseconds once, which is equal to the sampling time, So that the movements will be performed at the same rate as it was taught by the tutor.

5.3 Pause and Resume

The additional control operations available in the proposed system are: 1.Pause and 2.Resume. For pause and resume, individual buttons are provided. While pressing the pause button, an interrupt signal will be generated, which freezes the operation of Robotic Arm, either Learning or Action. When Resume button is pressed, an interrupt signal will be given to controller, which will again make the controller to continue the operation from where it has left.

VI. RESULT AND DISCUSSION

The prototype for the proposed system has been made and underwent for experiment. The Fig.5 shows the Demonstrative Learning for prototype, i.e. Learning mode, in which human tutor is demonstrating set of motion to the Robotic arm.

Fig.5: Demonstrative Learning of Pick and Place Operation (Learning Mode)

Fig.6: Execution of Pick and Place operation (Action Mode)

The Fig.6 shows the prototype performing the taught actions to it, i.e. Action Mode. Thus the experiment done using the prototype acts as proof of concept for the proposed system.

VII.CONCLUSION

Thus the proposed system makes a Robotic Arm to learn and perform basic Industrial Automations like pick and place of light weighted objects. In addition to that, it can also learn and perform some basic patterns for drawing, writing alphanumeric characters and other symbols of limited number of characters (say less than 5). The Robotic arm learns set of motions for one particular operation for one time and it executes the learned motion for n number of times in a continuous loop. Thus the proposed system achieved the demonstrative learning for Industrial Automation.

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