Dynamics of Robotic Arm

Abhishek Chavan
Dept. of Computer Engg.,
SITS, Pune

Abhishek Bhuskute
Dept. of Computer Engg.,
SITS, Pune

Anmol Jain
Dept. of Computer Engg.,
SITS, Pune

Neha Shinde
Dept. of Computer Engg., SITS, Pune

M. B. Salunke
Dept. of Computer Engg., SITS, Pune

ABSTRACT
One of the major areas of Research & Development (R&D) that has made a drastic improvement in Computer Science and electronics is 'Automation' and 'Artificial Intelligence'. Autonomous Systems are self-governed and does not require any manual interventions. This paper presents an overview of previous developments and the working of Robotic arms along with its mathematical aspects. Arm assembly is used to supplement the robot's gestures and allows it to grasp and move objects. Arduino-board and other electronic circuits can be used to drive arm actuators by programming. A robotic arm can have a wide range of applications including pick-and-drop, imitating human arm, drawing objects with programmed intelligence, throwing light-weight objects based on mathematically governed functions. Once designed and implemented arm can be mounted to the mobile base so as to allow itself a complete plane of locomotion. The human arm is considered to have rotational ability mainly at shoulder, elbow and wrist. The actuators that control the shoulder and, to a lesser degree, the elbow have to carry the load of the entire arm, hand, and payload. The major simulative actions of robot can be implemented based on 'Learn-and-Improve' baseline which is called as Reinforcement Learning. In nutshell, the robot can perform a task iteratively analyzing errors from its previous attempts and improving in every successive attempt. The algorithms involved in these actions decide complexity of operation.

Keywords
Robotic Arm, Reinforcement Learning, Autonomous.

1. INTRODUCTION
Currently there are many industrial applications which use the rigid, manually operated or programmed robotic systems. But the area of application still remains narrow. The task of handling manual robotic arm is considered tedious as the operations of all the motors should be synchronized. Hence automatic robotic motions are emphasized for industrial applications. That is the system is very less intuitive and this is the knack of the article, that is, to develop the system that would make the existing system more intuitive and user friendly. So the aim of the system design is to explore various possible areas of applications where the human-like robotic arm will prove helpful overcoming strength, speed and robustness limitations. The applications would typically involve imitation of human-arm motion, pick-and-drop action, throwing of object at specified target based on 'Learn-and-Improve' method.

2. LITERATURE SURVEY-

2.1 Early Modern Robots and Robotic Arms:
Now, with the advent of machines, electronics, automation and the incorporation of solid-state transistors instead of vacuum tubes, the evolution of the microcircuit and more rapid computer systems, the stage was set for early modern robotic arm evolution. The first "position controlling apparatus" was patented in 1938 by Willard Pollard. This was a spray finishing robotic arm that had five degrees-of-freedom and an electrical control system. Although Pollard never built his arm, his design and interest in an mechanized application for automated robotic arms would spur on the ingenuity of others. Harold A. Roselund, working for De Vilbiss, developed another sprayer that was indeed manufactured. Both arms were useful and task oriented for their time and every movement at the respective joints in unique ways.

2.2 "The Multiple-Function Intelligent Robotic Arms"
The main design goal of this robotic arm was to present the following functions: Chinese calligraphy, fancy dancing, weightlifting and colour classification. Another design goal was to minimize cost and maximize performance.[1]

Hence it is designed in a way so as to perform many tasks as a human arm. The simplicity of its design gave it the way to perform motion as good as a human arm with improved values of strength and speed.[1]

2.3 "Development of a Robotic-Arm Controller by using Hand Gesture Recognition"
This robotic arm controller is using image processing in the field of Human-Machine Interaction. There are two methods used to control the robotic arm, the main task of them is to get the hand gesture data without using tool that helps the system to extract data easier (ex. glove or wrist band). The first method is comparing of all pre-stored data in the database at the Template Matching Algorithm, the second method is Signature Signal, distance signal between edge of the hand and centre of hand. These necessarily use the gyro-censors as the computation of change in angular values shall be obtained at time of operation.[5]

The subsequent operations are decided based on these changes.[5]

2.4 "The Development of Six D.O.F. Robot Arm for Intelligent Robot"
The aim of this paper is to develop a six D.O.F robot arm for an intelligent robot. As for the base or shoulder part, the harmonic responding drive, which has some advantages, was used to ensure the weight of the whole arm could be supported. This provides a degree of freedom along with supporting the assembly. The kinematic equations of the system have been studied and shown in this. The degrees in which the robotic unit make moves or acquires motion necessarily contribute to improvement of operation. Every

added or updated motion represents ease of operation in certain operating context.[6]

At the end, we investigate some experiments; the computer system based controller can command the robot arm to pick a box through a moving path successfully.[6]

3. LITERATURE REVIEWED

Our system is an autonomous robotic arm which estimates trajectory and plans motion on it. We will be using a new concept called reinforcement learning which will enable our system to learn itself the path and trace it. For this we have reviewed some IEEE papers understanding and using them for our system. Some of the titles of these papers are listed below:

3.1 "Design and Implementation of Robotic Arm based on Haptic Technology"

This involves designing a haptic robotic arm, which can be used to pick and place the4 object. In this paper a robotic arm with four degrees of freedom is designed and is able to pick the objects with a specific weight and placed them in a desired location. To facilitate the lifting of the objects, Servomotors with a torque of 11kg are used. The programming is done on ATMEGA-328 Microcontroller using Arduino programming. The input is given using a remote, which is an arm, made of polycarbonate fitted with potentiometers with a certain angle of rotation. The potentiometers detect the angle of rotation and the signals are sent to the Microcontroller accordingly.

3.2 "Image processing and Recognition System for a Robot Arm Control"

Image processing (IP) and recognition system is based on continuous monitoring of environment with sensors and responding accordingly. These are considered intelligent as their behaviour is completely based on changes in environmental system and triggered associated programmed actions.

3.3 "The Development of Six D.O.F. Robot Arm for Intelligent Robot"

The motion is guided by the manually operated controller or a program that guides the appropriate motion and actions of robot. . The degrees in which the robotic unit make moves or acquires motion necessarily contribute to improvement of operation. Every added or updated motion represents ease of operation in certain operating context.[6]

Hence, the idea that a circular rotatable base may prove very useful as it is less costly and less time consuming for an assembly to rotate rather than to turn it. Care should be taken that this provision doesn't hamper any other DOF previously considered.[6]

4. METHEDOLOGIES

4.1 Throwing and Reinforcement Learning

When we, as humans, think of throwing something to some target, we don't really think much, we just throw. The fact is that, our brain is so used to such things that we don't need to think nor we do any calculation while throwing. But, with deeper observations we realized that, actually throwing is very complex and time critical task. It involves lots of calculations and factors and angular movements of the arm.

All these things, as a human, are very easy and we generally take this intelligence for granted. When it is to throw, we are not much concerned about the object we are holding, we just focus on the target. The brain approximates the force to apply, the angular motion of the hand and the timing to release the object, so that it will hit the target. It is a challenging task to implement this on a robotic arm. The system should be autonomous, taking the target information from the cameras and processing it to map all the necessary factors in place. Also defining and estimating the trajectory on which the object will travel is a critical task, as there is no way to control the object in air, once the object is released from the grip.

We suggest reinforcement learning for doing this task dynamically. The system will learn itself to throw and move towards precision to hit a target. Precise mapping of the data from camera to real world measure is most important. For this we suggest to start with some arbitrary factors and keep the record of the results of every attempt.

Initially, throwing with arbitrary values, the object will either go beyond the target or it may simply fall short. In case the object goes beyond the target set it as F_{max} (Maximum required value to hit the target). In some iteration, when the object drops before hitting target set it as F_{min} (Min required value to hit the target. Now, as you have F_{max} and F_{min}, use binary search to search a perfect scaling factor for mapping. It will take several iterations to get the perfect value. Once you get this perfect factor of scaling and mapping, change the target position, the arm will throw the object and hit the target at first shot. This process involves reinforcement learning in which system learns and improves itself. This makes the system dynamic and can work in various environments.

Application of this includes sorting of objects for industrial or domestic purpose; Also, playing games such as Dart. It will be real fun to play the dart against the robotic arm.

5. MATHEMATICAL MODEL

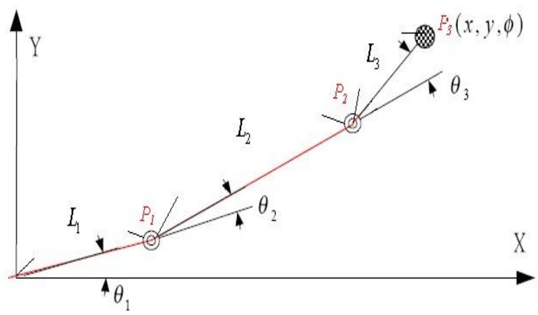

Figure 1

Considering 2-dimensional mathematical model so as to establish relational expression among θ1, θ2 and θ3 are the rotated angles of three links respectively. x and y are the final positions of the multi link system. Φ is summation angle of θ1, θ2 and θ3 displacement, angular displacement and obtained position, following relation can be considered.

L_1, L_2 and L_3 are the lengths of three links. In this case, the rotational matrices are as follows:

$$R_{ix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_1 & -\sin\theta_1 \\ 0 & \sin\theta_1 & \cos\theta_1 \end{bmatrix}$$

$$R_{iy} = \begin{bmatrix} \cos\theta_1 & 0 & \sin\theta_1 \\ 0 & 1 & 0 \\ -\sin\theta_1 & 0 & \cos\theta_1 \end{bmatrix}$$

$$L_i = \begin{bmatrix} 0 \\ 0 \\ l_i \end{bmatrix}$$

$P_1=R_{1x}L_1$

$P_2=R_{1x}L_1+ R_{1X}R_{2x}L_2$

$P_3=R_{1x}L_1+ R_{1X}R_{2x}L_2 + R_{1x}R_{2x}R_{3x}L_3$

Where, P1, P2 and P3 are positions of the links.

6. FUTURE SCOPE

Robotic Arms has a wide scope of development. In the near future the arms will be able to perform every task as humans and in much better way. Imagination is the limit for its future applications.

It can be a real boon for handicapped people, who are paralyzed or lost their hands in some accident. The arm can be trained to listen to the command from a human and perform that task. A Precise gesture controlled system is also possible. Wearable devices can be used to send the command and control the movements of the arm.

Brain Computer Interface (BCI) is an immerging field of research. BCI can be used to acquire signals from the human brain and control the arm. The system can work in the same way as human arm. A person who may have lost his hand in any accident can resume his life like previous by such artificial arms. Robotic arms are versatile and have enormous ways of implementations.

7. CONCLUSION

This paper presents our study on early research and developments in robotic arms. It also explains basic mathematical model of the arms which can be used to implement the arm. Even after many years of research, the applications of robotic arm are restricted to the industries and primarily used in manufacturing units for increasing productivity. These arms are very sophisticated and can manage to make extremely precise movements. The robotic arms have wide variety of general purpose and domestic applications too, which are not much explored. Cost is the main constraint on robotic arms and to bring it down is a challenging issue. High torque servos with high precision are necessary for building these machines. These are the main components which cause the motion of the arm, and are most expensive. Finding alternatives to these motors to bring down the cost is the necessity. Also the material which will be used for the body should be light and durable. The light weight body can improve the performance of the motors and the torque. The shapes and size of the components and parts varies widely depending on the applications. Bringing these machines on product level for general purpose application is a tough job. If these constraints are resolved, soon the robotic arms will be available everywhere to serve as a "helping hand".

8. REFERENCES

[1] The Multiple-Function Intelligent Robotic Arms Rong-Jyue Wang, Jun-Wei Zhang, Jia-Ming Xu, and Hsin-Yu Liu

[2] http://www.pathfindersdesignandtechnology.com/worksheets/build_a_robotic_arm.pdf

[3] A Low-cost Compliant 7-DOF Robotic ManipulatorMorgan Quigley, Alan Asbeck, and Andrew Y. Ng

[4] Design and Implementation of a Wireless Gesture Controlled Robotic Arm with VisionLove Agarwal, Varnika Gaur, Puneet Verma

[5] Development of a robotic-arm controller by using hand gesture recognition Celik, I.B. ; Dept. of Electr. Electron. Eng., Dokuz Eylul Univ., Izmir, Turkey; Kuntalp, M.

[6] The development of six D.O.F. robot arm for intelligent robotJie-Tong Zou ; Dept. of Aeronaut. Eng., Nat. Formosa Univ., Huwei Township, Taiwan; Des-Hun Tu.