Design and Fabrication of L-Shaped Automated Pick- and-Place Robot Arm With Punching Operation

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Abstract:

In several circumstances, independent robots can offer operative solutions to demanding jobs. In this situation, it is necessary to generate an independent robot that can recognize objects from the conveyor belt and transfer them if the object meets definite standards. Handling a large number of products is very tedious manually hence this type of robotic arm is an excellent solution for the existing problem. In this work a robotic arm model with 3 degree of freedom has been designed to meet the industrial application by using CATIA which run with embedded C programming principle. Fabricated model uses a picking arm which runs with micro controller motor to pick the specific object from the conveyor belt and place it on the other conveyor belt by sensing the object. This work also includes a die which give the labeling on the specified objects. Fabricated model can able to lift the objects upto 150gms and can be positioned for required angle. Positioning and orientation of the robotic arm has been evaluated numerically using DH notation algorithm in forward kinematic manipulator. Hence this type of models can be used in small scale industries like packaging, parts delivery with labeling etc.

Index Terms – Manufacturing industries, degree of freedom, conveyor belt, etc**.**

I. INTRODUCTION

Different methods such as fork lifting, use of bucket elevators, conveyors systems, crane, etc. has been identified for lifting or transporting bulk materials or products from one place to another in the manufacturing industries depending on the speed of handling, height of transportation, nature, quantity, size and weight of materials to be transported. Conveyor system is a mechanical system used in moving materials from one place to another and finds application in most processing and manufacturing industries such as: chemical, mechanical, automotive, mineral, pharmaceutical, electronics etc. [1].

It is easier, safer, faster, more efficient and cheaper to transport materials from one processing stage to another with the aid of material handling equipment devoid of manual handling. Conveyor systems are durable and reliable in materials transportation and warehousing. Based on different principles of operation, there are different conveyor systems namely: gravity, belt, screw, bucket, vibrating, pneumatic/hydraulic [2], chain, spiral, grain conveyor systems etc. The choice however depends on the volume to be transported, speed of transportation, size and weight of materials to be transported, height or distance of transportation, nature of material, method of production employed. Material handling equipment ranges from those that are operated manually to semi-automatic systems and to the ones with high degree of automation. The degree of automation however depends on handling requirements [3].

A robot, according to the Robot Institute of America, is ―A reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks.[5]Therefore, because of their re-programmability and adaptability, robots are suited to many requirements or applications associated with industrial tasks [4]. In fact, robots are particularly useful in many industrial applications which are laborious, boring, and hazardous. And several types of robot manipulators have been developed in times past; examples of these are the The Tomorrow Tool (T^3),

This robotic arm is electrically actuated by using DC servo motors for achieving three rotational motions and one DC geared motors for linear vertical motion. These motors are controlled by C-programming language in Arduino Genuino[6] 1.8.5 Software as required for pick and place operation of object having dimensions 50x50x60mm. To command the robotic arm by using mobile android app, Bluetooth module HC05 is used which make it user friendly and ease of giving task. The required task is specified to pick up the object from one place to another place and to find the robot position and orientation of the object.

2. LITERATURE REVIEW

Antonio J. etal. [1]: This paper described about programming robot tool with graphical CAD systems has been implemented within the research line in robot programming in the Robotic Systems and Robot Programming Laboratory of the Department of System Engineering (DISA) in the Polytechnics University of Valencia (UPV). The experimental hardware used in this work is composed by local computer network system, robot-arm system, vision system and distance sensor system.

Vishakha Borkar etal.[2]: This paper described about the microcontroller operate the task such as forward, reverse, left, right. It also performed bottle filling and pick and place operation. User sends the signal through RF module. Receiver circuit is interfaced to microcontroller to received it and execute the instruction according the programming.

Abhishek Kumar etal [3]: This paper described about the infrared sensor detected the block; it was picked up at the other end of the conveyer belt by a gripper connected to the end of a two-link arm. The double link arm was controlled using Proportional Integral Derivative Controllers on the joint angles. The desired arm angles values are calculated using the Infrared Sensor value to figure out the desired gripper position. This position can then be translated in corresponding angle values using inverse Kinematics.

S.D Rajgure etal [4]: This paper described about the end effectors of robotic hand can be designed to perform any desired task such have welding, gripping, spinning etc. Gripper is a device which involves parallel or angular motion of surface. It is provided with the jaws to pick and place the objects. The air is provided to produce the grasping force. Gripper is capable of lifting very small object as well as large objects like engine blocks of vehicles.

Hardik A. Modi etal [5]: This paper described about the movements of robot arm. The robots movement can be divided into two general categories: arm and body motions, and wrist motions. The individual joint motions associated with these two categories are sometimes referred to by the term "degrees of freedom", and a typical industrial robot is equipped with 4 to 6 degrees of freedom.

Enrique Hortal etal [6]: This paper presented a multimodal Human-Machine Interface system that combines an Electrooculography Interface and a Brain-Machine Interface the EOG interface is applied to control planar movements and to operate the gripper. The BMI is used to control the height of the gripper through two mental tasks. The results prove the feasibility of the system in the performance of these tasks.

Tomas Lozano-Perez etal [7]: This paper described about A task-level robot system named Handey, which is under development, is described. The current system is limited to pick-and-place operations, and it has successfully carried out dozens of such operations involving a variety of parts in relatively complex environments. The pick-and-place problem is described, and approximate approaches to the problem are examined.

Tian Huang etal [8]: This paper dealt with the conceptual design and optimal dimensional synthesis of a novel 2-DOF translational parallel robot for pick-and-place operations. The kinematic optimality of the 2-DOF translational parallel robot is achieved by minimizing a global and comprehensive conditioning index subject to a set of appropriate constraints. The kinematic optimality of the 2-DOF translational parallel robot is achieved by minimizing a global and comprehensive conditioning index subject to a set of appropriate constraints.

Carlos Blanes etal [9]: Nowadays robots are cheaper, can work in hostile and dirty environments and they are able to manipulate products at high speed. High speed and reliability and low robot gripper costs are necessary for a profitable pick and place (P&P) process. Contact grippers with under actuated mechanism and suction cups could be a promising approach for the manipulation of fresh fruit and vegetables. The characteristics and handling requirements of fresh fruit and vegetables in order to design grippers which are suitable for correct manipulation, at high speed, in profitable P&P processes for industrial applications.Manjula etal

Manjula vs, karamagi Ri [10]: This paper described about a robot arm is fixed to a base and operates in its workspace to achieve the migration towards its pick location. It opens its gripper upon arrival to grasp the object and move with it to the depot location. Upon arrival at the destination it opens its claws to release the object.

3. MODELING AND FABRICATION

Design of 3D model in CATIA:

CATIA is an acronym for Computer Aided Three-Dimensional Interactive Application. It is the most proficient, powerful and highly popular CAD i.e. computer aided design software. It is created, developed and owned by Desalt Systems of France. IBM was the leading marketer of CATIA till 2010.

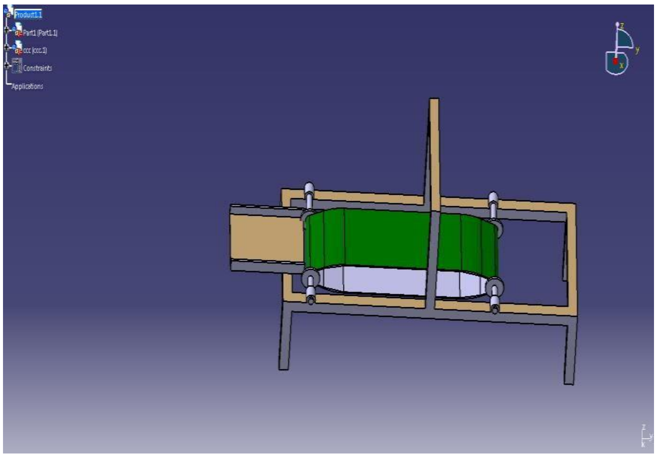

Fig: 3.1: Conveyor belt 1

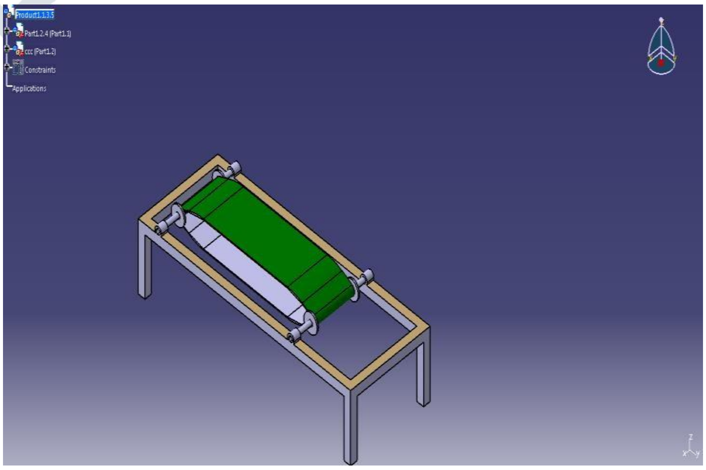

Fig 3.2: Conveyor belt 2

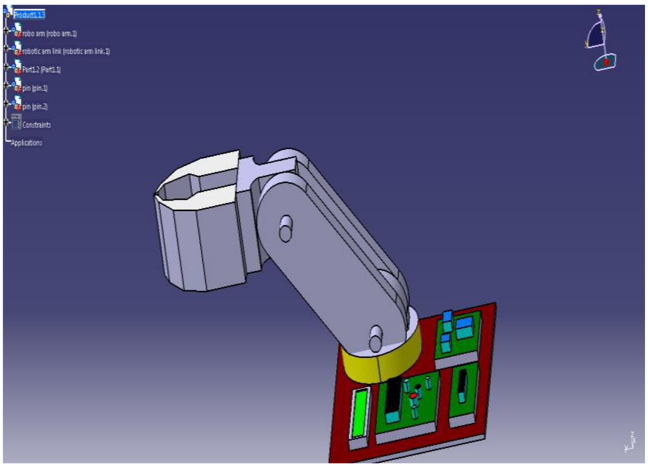

Fig 3.3: Robot Arm Model Representation

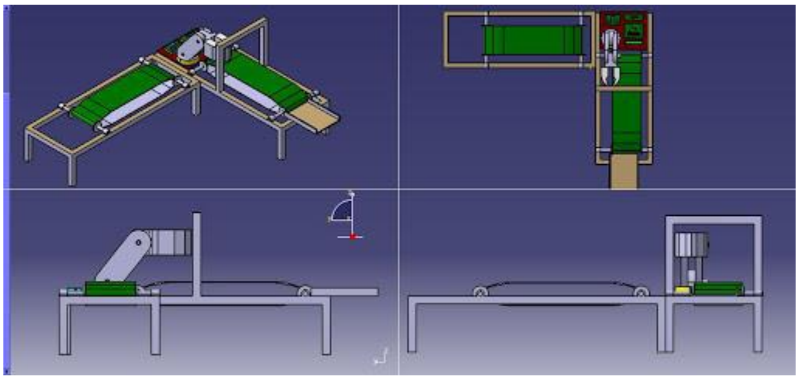

Fig 3.4: Orthographic views

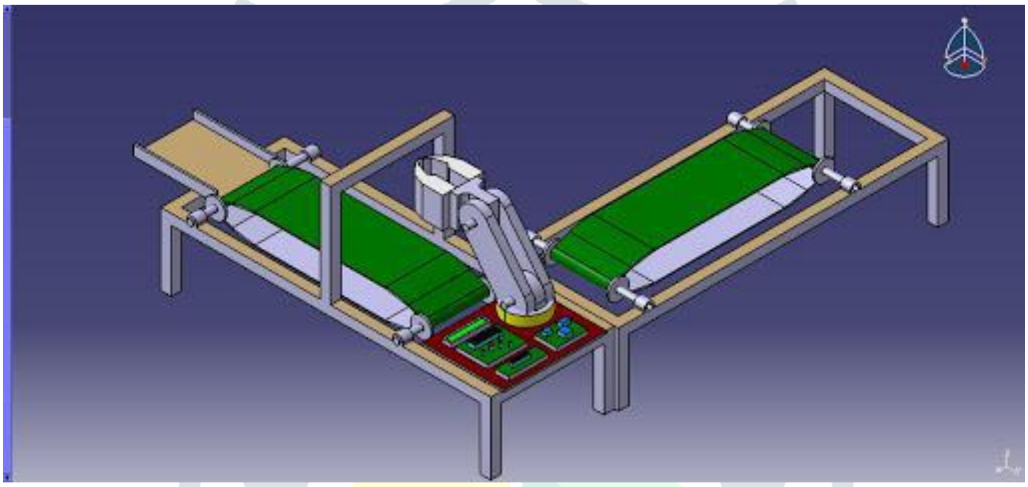

Fig: 3.5 Assemble View of L-Shaped Automated Conveyor Belt with Robot Arm

FABRICATION OF MODEL

The following components are used to prepare the experimental setup

- Two conveyor belts(conveyor belt 1,conveyor belt ,Two Infra-red (IR) sensors(IR 1 ,IR 2)
- Electrical Linear actuator, DC motors, Robot manipulator, Liquid crystal display(LCD)

DESCRIPTION OF COMPONENTS

Robot arm

The work space of this arm in which it Rotates 90 degrees to pick and place the job and position itself. The base of the arm is provided with a dc motor to rotate the arm; the motor rotates in both clockwise and anti-clockwise directions to place the job. The motor is interfaced with the microcontroller. The robotic arm movements are controlled by the DC motor of 10 rpm. Here micro controller controls the movement of the arm depending on the of the object placed the microcontroller drives it that is it supplies power to arm. the robotic arm moves towards its path and releases the job at a specified place or may be releases it onto another conveyor moving the job to packing shop or a paint shop used in manufacturing units. Once it releases the job, the robotic arm automatically comes back into its initial position. To pick up another object.

Gripper:1 V, 10 rpm, DC motor is used to control the gripper movement, for opening and closing of the gripper. The DC motor receives its signal from the controller for performing gripping and dropping operations. The gripper has been specially designed in order to grip rectangular, square or circular objects from the running conveyor and dropping them at programmed locations.

Conveyor belt:

Belt conveyor is one of the basic tools in material handling industry; these are most commonly used in transportation of bulk materials (grain, salt, coal, ore, sand, etc.).

Belt conveyor systems consist of two or more pulleys. An endless loop of carrying medium the conveyor belt rotates about them. To move the belt and the material it carries forward, one or both pulleys are powered. The powered pulley is called “drive pulley,” the unpowered one is known as “idler pulley.” Belt conveyors in general material handle such as those moving boxes along inside a facility form a different class of belt conveyors from those that are used to transport large volumes of resources and agricultural materials.

LCD (Liquid Cristal Display) AND IR

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. Each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through the other.

An Infrared sensor is an electronic device that measures infrared (IR) light radiating from objects in its field of view. IR sensors are often used in the construction of IR-based motion detectors apparent motion is detected when an infrared source with one temperature, such as a human, passes in front of an infrared source with another temperature, such as a wall. It is the same principle in all Infra-Red proximity sensors.

ELECTRICAL LINEAR ACTUATOR

A linear actuator is an actuator that creates motion in a straight line, in contrast to the circular motion of a conventional electric motor. Linear actuators are used in machine tools and industrial machinery, in computer periphaperls such as disk drives and printers, in valve sand dampers, and in many other places where linear motion is required. Hydraulic or pneumatic cylinders inherently produce linear motion. Many other mechanisms are used to generate linear motion from a rotating motor. Linear actuator is used to punch or stamp the objects which are moving on conveyor belt. The basic working principle of electric linear actuator is to convert the rotary motion into a linear motion. This conversion of motion is done with the help of a gearbox and a lead screw. These are the two most important electric linear actuator parts.

Controller software:

The robot software can be regarded as the soul of the robot manipulator because it directs and coordinates the entire robot operation. There are many possible choices for the programming language platforms to employ in the development of the robot software, but use is made of the Arduino board here for ease of operation. The code is written within the Arduino IDE. The a flowchart that describes the software algorithm

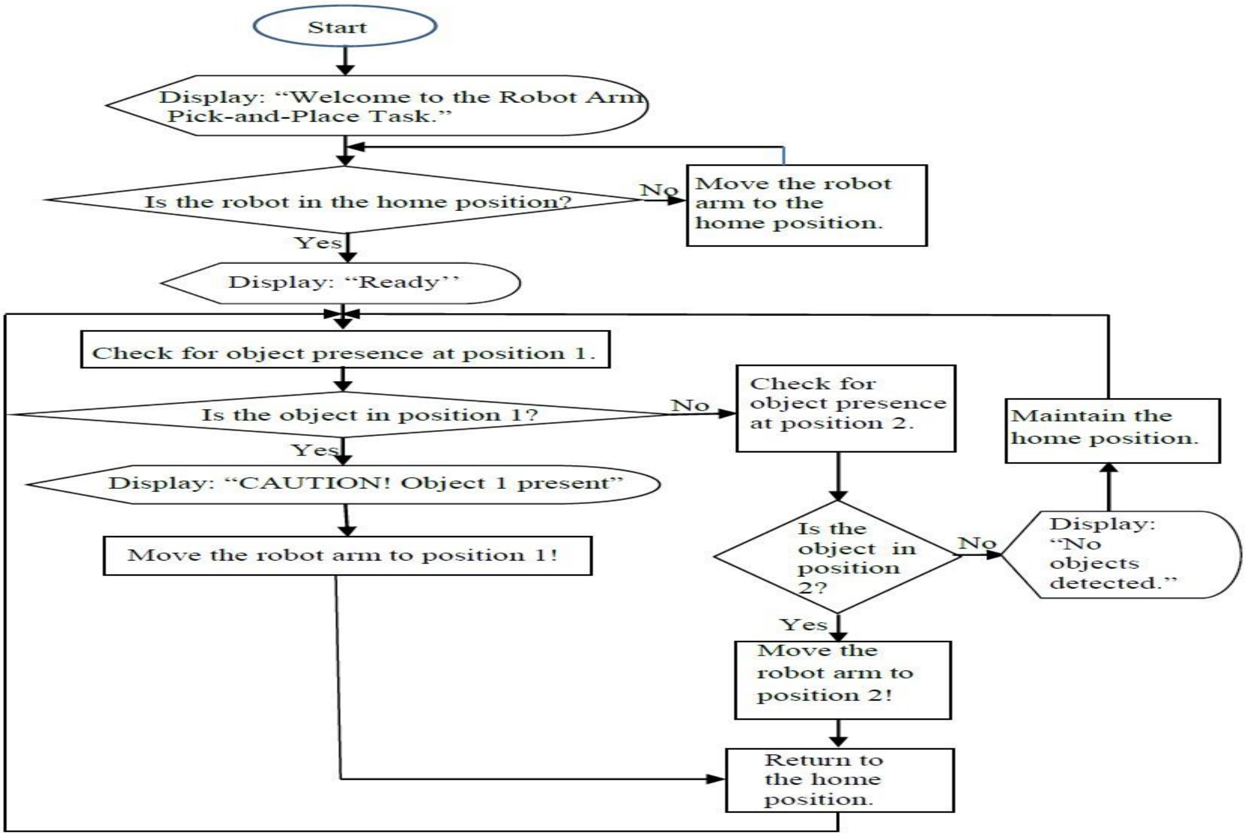

Fig :3.6 flow chart

Fig 3.7:Design and fabrication of L-shaped automated pick-and-place robot arm with punching operation

4. Position and orientation of the pick and place robot arm by using D-H notation

Kinematic modeling of the manipulator:

This model is the analytical description of the spatial geometry of motion of the manipulator with respect to fixed reference frame as a function of time. The relation between the joint- variables and the position and orientation of the end effector is the kinematic model. The kinematic models are two types

1. Forward kinematic system.
2. Inverse kinematic system.

Denavit –Hartenberg notation for forward kinematic manipulator:

The definition of the a manipulator with four joint –link parameters for each link a systematic procedure for assigning right –handed orthonormal coordinate frames, one to each link in an open kinematic chain 4*4 homogeneous transformation was proposed by Denavit and Hartenberg(1955) and is known as DH notation.

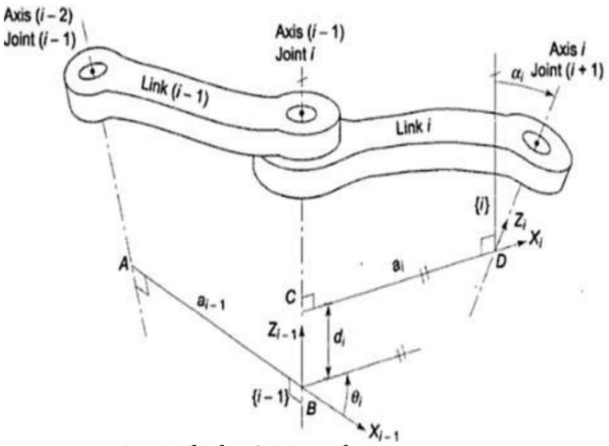

Fig:4.1 links &joints their parameters

To find the transformation matrix relating two frames attached to the adjacent links, consider frame {i-1} and frame {i}.the kinematic joint-link parameters involved (d_i, θ_i, α_i, a_i)are shown 3.8.
The transformation of frame {i-1} to frame {i} consists of four basic transformations

(a) A rotation about z_{i-1}-axis by an angle θ_i ; ($T_{z-\theta i}$)
(b)Translation along z_{i-1}-axis by a distance d_i ; (T_{z-di})
(c)Translation by distance a_i along x_i- axis (T_{x-} a_i)
(d)Rotation by an angle α_i about x_i- axis (T_{x-} α_i)

The composite transformation matrix which describes frame {i} with respect to frame {i-1}

$^{i-1}T_i = (T_{z-\theta i}).\ (T_{z-di}).\ (T_{x-}\ a_i).\ (T_{x-}\ \alpha_i)$

The matrices associated with these operations are:

$$Trans_{z_{n-1}}(d_i) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_n \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Rot_{z_{n-1}}(\theta_n) = \begin{bmatrix} \cos\theta_n & -\sin\theta_n & 0 & 0 \\ \sin\theta_n & \cos\theta_n & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Trns_{x_n}(r_n) = \begin{bmatrix} 1 & 0 & 0 & r_n \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Rot_{x_n} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha_n & -\sin\alpha_n & 0 \\ 0 & \sin\alpha_n & \cos\alpha_n & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

That gives:

$$^{n-1}T_n = \begin{bmatrix} \cos\theta_n & -\sin\theta_n \cos\alpha_n & \sin\theta_n \sin\alpha_n & r_n \cos\theta_n \\ \sin\theta_n & \cos\theta_n \cos\alpha_n & -\cos\theta_n \sin\alpha_n & r_n \sin\theta_n \\ 0 & \sin\alpha_n & \cos\alpha_n & d_n \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} R & & & T \\ & & & \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

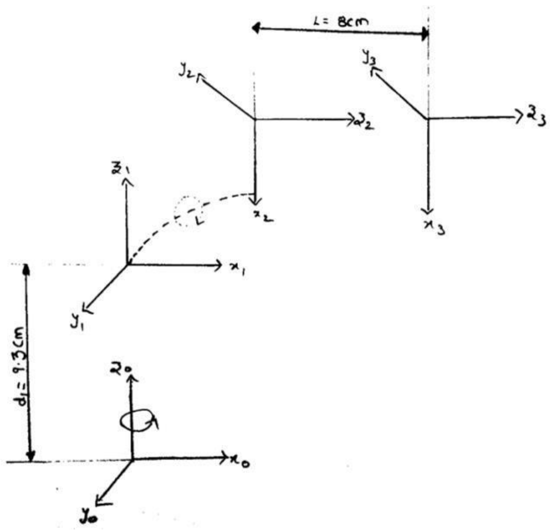

Fig:4.2 Frame assignment for denavit hartenberg notation

Where *R* is the 3×3 sub matrix describing rotation and *T* is the 3×1 sub matrix describing translation.

Table:

Joint i	(T_z, D_i)	$(T_z\ \theta_i)$	$(T_x\text{-}a_i)$	$T_{(X\text{-}\alpha i)}$
	Joint parameters		**Link Parameters**	
	$d_{i(cm)}$	θ_i	a_i	α_i
T1	9.3	90	0	0
T_2	0	35	8	90
T_3	0	0	2.5	0

$${}^{i-1}A_i = T(z-d_i)*T(z-\theta_i)*T(x-a_i)*T(x-\alpha_i)$$

$$\begin{bmatrix} \cos\theta_i & -\sin\theta_i & 0 & 0 \\ \sin\theta_i & \cos\theta_i & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & d_i \\ 0 & \cos\alpha_i & -\sin\alpha_i & 0 \\ 0 & \sin\alpha_i & \cos\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^{i-1}A_i = \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & -\sin\theta_i - \sin\alpha_i & \cos\theta_i a_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & \cos\theta_i - \sin\alpha_i & \sin\theta_i a_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^{0}T_1 = \begin{bmatrix} \cos(90) & 0 & \sin(90) & 0 \\ \sin(90) & 0 & -\cos(90) & 0 \\ 0 & 1 & 0 & 9.3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{1}T_2 = \begin{bmatrix} \cos(35) & 0 & \sin(35) & 0 \\ \sin(35) & 0 & -\cos(35) & 8\sin(35) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{2}T_3 = \begin{bmatrix} \cos(0) & 0 & \sin(0) & 2.5\cos(0) \\ \sin(0) & 0 & -\cos(0) & 2.5\cos(0) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{0}T_3 = {}^{0}T_1 \times {}^{1}T_2 \times {}^{2}T_3$$

$$^{0}T_3 = {}^{0}T_1 * {}^{1}T_2 * {}^{2}T_3$$

$$= \begin{bmatrix} 0 & 0 & -1 & 0 \\ 0.819 & 0.573 & 0 & 2.04 \\ 0.57 & -0.81 & 0 & 6.01 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} n_x & o_x & a_x & d_x \\ n_y & o_y & a_y & d_y \\ n_z & o_z & a_z & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$n_x = 0$ $o_x = 0$ $a_x = -1$ $d_x = 0$

$n_y = 0.819$ $o_y = 0.573$ $a_y = 0$ $d_y = 2.04$

$n_z = 0.57$ $o_z = -0.81$ $a_z = 0$ $d_z = 6.01$

Where n_x = Normal vector in n_x, n_y, n_z direction;
o_x= Orientation vector in o_x o_y o_z direction
a = Approach vector in a_x, a_y, a_z direction

Conclusion:

The design and fabrication of pick and place robot has been carried out. A prototype was established practical working of robot system. This system would make it easier for human beings to pick and place the risk of holding doubtful objects, which could be risky in its present environment and workplace. Difficult and complex duties can be accomplished quicker and more exactly with this design. The fabrication of a robot arm for simple pick-and-place actions has been considered in this paper. The system hardware and software have been emphasized, and trials conducted on the whole assembly shows that the execution is adequate. However, to obtain highest grip pressure on the target object, it is suggested that a pressure sensor be merged and connected on one of the end-effector's fingers. Besides, a video camera and a computer with image processing capability can be used to give subjective positions of the object (instead of the pre-programmed positions employed in this work). Thus, to make the manipulator more exact and specific, the authors are presently considering computed torque control method.

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