Design and Motion Study of a Robotic Palm
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Abstract
Kinematic and dynamic modeling of Robotic Palm is an interesting task but to obtain the best performance of the system, the study of the kinematic both forward and inverse and dynamic mechanism of the system is essential. The kinematic analysis is the relationships between the positions of the links of a manipulator and dynamic analysis is the relationship between force and motion generate on the joints and links. The kinematics separate in two types, forward (direct) kinematics and inverse kinematics and this same for dynamics also but my focus is on to formulate and analyze forward kinematics and dynamics only. In forward kinematics, the length of each link and the angle of each joint is given and we have to calculate the position of any point in the work volume of the robot. In dynamic analysis, to be able to control a robot manipulator as required by its operation, it is important to consider the dynamic model in design of the control algorithm and simulation of motion. The mathematical equations for kinematics and dynamics of Robotic Palm manipulator based on the Denavit-Hartenberg (DH) framework. MATLAB code in the form of several M-files are developed for kinematics and dynamics analysis of two link planar manipulator and results are plotted in the form of graphical representation.

Keywords: D-H coordinate, link, planar, torque, joints.

Key Words: Robotics, D-H Transformation, Motion Study

1. INTRODUCTION
Robotics is a branch of engineering and science that includes electronics engineering, mechanical engineering and computer science and so on. This branch deals with the design, construction, use to control robots, sensory feedback and information processing. These are some technologies which will replace humans and human activities in coming years. These robots are designed to be used for any purpose but these are using in sensitive environments like bomb detection, deactivation of various bombs etc. Robots can take any form but many of them have given the human appearance. The robots which have taken the form of human appearance may likely to have the walk like humans, speech, cognition and most importantly all the things a human can do. Most of the robots of today are inspired by nature and are known as bio-inspired robots. Robotics is that branch of engineering that deals with conception, design, operation, and manufacturing of robots. There was an author named Issac Asimov, he said that he was the first person to give robotics name in a short story composed in 1940’s. In that story, Issac suggested three principles about how to guide these types of robotic machines. Later on, these three principles were given the name of Issac’s three laws of Robotics. These three laws state that:

- Robots will never harm human beings.
- Robots will follow instructions given by humans with breaking law one.
- Robots will protect themselves without breaking other rules.

2. LITERATURE SURVEY
It is bifurcated into two parts. The first part presents the approaches of other researchers in analyzing the kinematics of planar manipulators and specifically, the 2DOF planar manipulator. This section discusses existing forward kinematics analysis methods, outlining the strengths and weaknesses of each of them. The second section examines ways in optimizing design.

A. Forward Kinematics
Forward Kinematics refers to the use of the kinematic equations of a robotic element to compute the position of the end effector from specified values for the joint parameters. So for forward kinematics, the joint angles are the inputs, the outputs would be the coordinates of the end effectors.

B. Inverse Kinematics
On the other hand Inverse Kinematics, the given inputs are the coordinates of the end effectors, the outputs to calculate the joint angle of the end effectors. If we want to place the hand of the robot at the desired location
and orientation, we need to know how much joint angle, or link length of the robot must be such that at those values the hand will be at desired position and orientation.

3. OBJECTIVES OF THE PRESENT WORK

The study of some of the important literatures in the area of robot direct kinematics and dynamics mechanism suggest that there is need to refine the performance and control of Robotic finger. It is desirable to compute kinematics and dynamics analysis with MATLAB. Therefore, the present work is contemplated with the following broad objectives

- To find the mathematical formulation of the 3 link robotic palm forward kinematics and dynamics with the help of D-H convention.
- Simulate that mathematical formulation using the MATLAB for the forward kinematic and dynamic analysis.

4. FORWARD KINEMATICS OF 3 LINK MANIPULATOR

![Figure 1 Shows an outline of the Robotic Finger](image)

<table>
<thead>
<tr>
<th>Link</th>
<th>Link Twist Angle</th>
<th>Link Length</th>
<th>Joint Distance</th>
<th>Joint Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>a1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>a2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>a3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table for DH parameter

\[\theta = [0:5:30]^\circ/180;\]
\[ \theta = [0:2:12] * \pi/180; \]
\[ \theta = [0:3:18] * \pi/180; \]

\[ l_1 = 0.45; \]
\[ l_2 = 0.30; \]
\[ l_3 = 0.22; \]
\[ \alpha_1 = 0; \]
\[ \alpha_2 = 0; \]
\[ \alpha_3 = 0; \]

\[
\begin{bmatrix}
\cos(\theta_1) & -\sin(\theta_1) \cos(\alpha_1) & \sin(\theta_1) \sin(\alpha_1) & l_1 \cos(\theta_1) \\
\sin(\theta_1) \cos(\alpha_1) & \cos(\theta_1) \cos(\alpha_1) & -\sin(\theta_1) \sin(\alpha_1) & l_1 \sin(\theta_1) \\
0 & \sin(\alpha_1) & \cos(\alpha_1) & 0 \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

\[
\begin{bmatrix}
\cos(\theta_2) & -\sin(\theta_2) \cos(\alpha_2) & \sin(\theta_2) \sin(\alpha_2) & l_2 \cos(\theta_2) \\
\sin(\theta_2) \cos(\alpha_2) & \cos(\theta_2) \cos(\alpha_2) & -\sin(\theta_2) \sin(\alpha_2) & l_2 \sin(\theta_2) \\
0 & \sin(\alpha_2) & \cos(\alpha_2) & 0 \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

\[
\begin{bmatrix}
\cos(\theta_3) & -\sin(\theta_3) \cos(\alpha_3) & \sin(\theta_3) \sin(\alpha_3) & l_3 \cos(\theta_3) \\
\sin(\theta_3) \cos(\alpha_3) & \cos(\theta_3) \cos(\alpha_3) & -\sin(\theta_3) \sin(\alpha_3) & l_3 \sin(\theta_3) \\
0 & \sin(\alpha_3) & \cos(\alpha_3) & 0 \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

\[ H = h_1^0 * h_2^1 * h_3^2 \]

As we discussed in the literature review section, that by giving link length and angle of turn, we get coordinates traced by the joints of the robotic finger mechanism. The procedure used was Denavit Hartenberg Transformation. The MATLAB program above shows Forward Kinematics of our Finger mechanism. The Table above shows the inputs in order to conduct Forward kinematic analysis. The coding above is only for the one finger. The outline coding for different fingers are same but values of inputs changes from finger to finger. Below we received the path traced by the joints and tips in the form of a graphical representation.
5. INVERSE KINEMATICS

Inverse Kinematics is exact reverse of Forward Kinematics. In this, we gave the coordinates of the end effector as well as external parameter (Gamma) which is the addition of all the angles made by the extension of the previous link. We gave the coordinates and Gamma as an input to MATLAB coding. We get the angles turned in graphical format by each link at every instant.

\[
x = 10, \quad y = 20, \quad \gamma = 120
\]

\[
x_1 = x \cdot a \cdot \cos \gamma
\]

\[
y_1 = y \cdot a \cdot \sin \gamma
\]

\[
\gamma = \theta_1 + \theta_2 + \theta_3
\]

\[
\theta_2 = \gamma - \theta_3 - \theta_2
\]

\[
r_1 = x_1 + y_1
\]

\[
\theta_1 = \theta_2 - \theta_3
\]

\[
\tan \phi_1 = \frac{y_1}{x_1}
\]

\[
\phi_2 = \tan^{-1} \left( \frac{y_2}{x_2} \right)
\]

\[
a_2 = a_1 + r_1 - 2a_1 \cdot r_2 \cos \phi_1
\]

\[
\phi_2 = \cos^{-1} \left( \frac{a_2 - a_1 - r_1}{2a_1 r_1} \right)
\]

\[
\theta_2 = 180 - \phi_2
\]

\[
r_2 = a_2 + a_2 ^2 - 2a_1 \cdot a_2 \cdot \cos \phi_2
\]

\[
\phi_3 = \cos^{-1} \left( \frac{r_2 - a_2 - a_1}{-2a_1 a_2} \right)
\]
6. SIMULINK MODEL

The thumb and fingers of the human hand can be modeled as a serial link mechanism with three joints. The number of joints and number of d.o.f. of the robot hand were designed to mimic those of the human hand. The thumb and the fingers is actuated by servo motors connected by strings. To perform power-grasps it is absolutely necessary to have a nearly parallel position of the second, third and forth finger. Now with modern software tool we can direct import the complex model inside matlab which can be used for further accurate & effective motion control. The block diagram can be used to simulate the internal mechanics of the hand without actually prototyping the system. The error can be easily identified in the model and can be prevented while actually 3D printing the model. The development of powerful computational platforms for simulating the behaviour of robotic systems constitutes a fundamental tool for researchers of this field to visualize the motions and compute various actuation parameters required for movement of the links.

In the control of the revolute joint we can implement Integral controllers. Integral controllers provide a means for eliminating steady state error in the system. This is because an integrator adds an additional s to the denominator of the transfer function.

During the gripping action of fingers a sophisticated control system is essential. It should be clear that :

1. The response of the robot actuators to a function for motion of the the link should not overshoot.
2. It should rise to the value of the input signal as quick as possible.
3. It should not have any steady state error.
7. CONCLUSION

In this paper, the mathematical analysis for forward kinematics as well as inverse kinematics is achieved. In the forward kinematics modeling of the system, the mathematical equations for the position of end effector with respect to the base frame by using the Denavit-Hartenberg Transformation and homogeneous transformation matrices are derived. D.H parameters are applied to determine the coordinate matrices through their different positions and transformation. For the computational analysis of mathematical formulation of complete forward kinematics and inverse of the system. The simulated results are also produced. Thus various related graphical representation corresponding to stated analysis and calculations have been plotted.

8. REFERENCES