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Modeling, Simulation and Control of 2-R Robot

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Abstract

This article presents a study of Three PID controller technique of a 2-Revelutejoint robot. First we present Denavit- Hartenberg parameters for 2-R robot. Then we studied the dynamics of the 2-R robot and derived the nonlinear equations of motion. A PID controller has been implemented for three types of modeling technique: model based on linearization about equilibrium point, model based on Autodesk Inventor and Matlab/Simulink software?s, and lastly model based on feedback linearization of the robot. A comparison between the three controllers is presented showing the effectiveness of each technique.

Index terms— robotics, 2-R robot, dynamic, modeling, simulation, control and PID.

1 Introduction

obotics is the science that deals with robot's design, modeling and controlling. Nowadays robots are used everywhere in everyday life. It has accompanied people in most of industry and daily life jobs. (Gouasmi, Ouali, Fernini, & Meghatria, 2012).

The range of robot utilization is very wide. A large family of robots is used in industry and manufacturing. Robots are used in supplying the motion required in manufacturing processes such as pick and place, assembly, painting, milling, cutting, welding, drilling, etc.

Because of different types of tasks different manipulator configurations are available such as rectangular, cylindrical, spherical, revolute and horizontal jointed (Gouasmi et al., 2012).

A two revolute joint robot configuration with two degrees of freedom is generally well-suited for small parts insertion and assembly, like electronic components. Although the final goal is to design and manufacture real robotics, it is very useful to perform simulations prior to investigations with real robots. Simulations are easier to setup, less expensive, faster and more convenient to use. it allows better design exploration and helps you enhance your final real robot by selecting suitable parameters for the system you want to design **??**?lajpah, 2008).

There are many control techniques used to control a robot arm. The most used ones are the PID control, optimal control, adaptive control and robust control. "There are many kinds of controllers that can be used to cause a designed robot arm to move along a desired trajectory" (Sukvichai, 2008). The simplest which we used in this paper to control the robot arm is the PID controller. **??**he (D-H) parameters for the 2-R robot will be defined as in the table below. The initial position (at t = 0) from the homogeneous transformation matrix where ? 1 = 0 °?2 = 0 ° are shown in figure (2).

2 II.

3 Problem Formulation

4 Robot Dynamics

Description of x and y in terms of ? 1 and ? 2 in term of linear displacement:?? 1 =?? 1 sin?? 1 ?? 1 =?? 1 cos?? 1 ?? 2 =?? 1 sin?? 1 +?? 2 sin (?? 1 +?? 2) ?? 2 =?? 1 cos?? 1 +?? 2 cos (?? 1 +?? 2)

So, Kinetic Energy could be formed as:KE = 1 2 m 1 v 1 2 + 1 2 m 2 v 2 2 + 1 2 j 1 ? 1 2 + 1 2 j 2 ? 2 2 (1)

Substitute for v1 and v2KE 1 2 m 1 l g1 2 ? ?1 + 1 2 m 2 ?l 1 2 ? ?1 + 2l 1 l g2 ? ?1? ? ?1 + ? ?2? cos ? 2 + l g2 2 ? ? ?1 + ? ?2? 2 ? + 1 2 j 1 ? ?1 + 1 2 j 1 ? ? ?1 + ? ?2? 2 (2)

And Potential Energy isPE = m 1 gl g1 sin? 1 + m 2 g(l 1 sin? 1 + (l g2 sin (? 1 + ? 1))**(3)**

a) Equations of motion

The Lagrangian of a dynamic system is defined as the difference between the kinetic and potential energy at an arbitrary instant (N.Jazar, 2010).

5 L = KE ? PE So, by Lagrange Dynamics, we form the Lagrangian

? = l g1 2 ? ?1 + 1 2 m 2 ?l 1 2 ? ?1 + 2l 1 l g2 ? ?1? ? ?1 + ? ?2? cos ? 2 + l g2 2 ? ? ?1 + ? ?2? 2 ? + 1 2 j 1 ? ?1 + 1 2 j 2 ? ? ?1 + ? ?2? 2 ? m 1 gl g1 sin? 1 ? m 2 g(l 1 sin? 1 ? (l g2 sin (? 1 + ? 2))**(4)**

Using Lagrange to form generalized equations of motion in matrix form as:? m 1 l g1 2 + m 2 l 1 2 + j 1 m 2 l 1 l g2 cos(? 1 ? ? 2) m 2 l 1 l g2 cos(? 1 ? ? 2) m 2 l g2 2 + j 2 ? ? ? 1 ? 2 ?? ? ?m 2 l 1 l g2 g sin(? 1 ? ? 2 ? ? ? 1 ? 2 ?? + ? (m 1 l g1 + m 2 l 1) g cos? 1 m 2 l g2 g cos? 2 ? = ? M 1 M 2 ? (5)

And the general form is:H(q?) + C (q? , q) + g(q) = M IV.

6 Pid Controller based on Linear Model

We define new variables in order to convert the 2-R robot to an equivalent linear model.x 1 = ? 1 x 2 = ? 2 x 3 = ? 1 ?x4 = ? 2 ? ???1 = ? 1 ?= x 3 ???2 = ? 2 ?= x 4 ???3 = ? 1 ????4 = ? 2 ?

Rewrite the equation of motion using these variables, and use new constants c 1 to c 6 function of robot specifications to make equations in simple formx 4 ?= M 2 c 5 ? c 2 M 2 c 5 cos(x 1 ? x 2) + c 3 c 5 sin(x 1 ? x 2) x 4 ? c 6 c 5 cos x 2 (6) ?c 1 ? M 2 c 5 cos 2 (x 1 ? x 2)? x 3 ?= M 1 ? c 2 M 2 c 5 cos(x 1 ? x 2) ? c 2 c 3 c 5 cos(x 1 ? x 2) sin(x 1 ? x 2) x 4 + c 2 c 6 c 5 cos(x 1 ? x 2) cosx 3 ? c 4 cos x 1**(7)**

x 1 ?= x 3 (8)x 2 ?= x 4**(9)**

Y=?1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 ? ? ? x 1 ? x 2 ? x 3 ? x 4 ? + [0][D] a) Linearized model

We substitute values of constants c 1 to c 6 into the state-space model to get the state space matrices:

7 H

Now we can write the state-space model using linearization about the equilibrium point:? 1 = ? ? 2 ? 1 ?= 0? 2 = ? ? 2 ? 2 ?= 0 M1= 0 M2= 0

We Perform Taylor series expansion of the nonlinear functions and neglect high-order terms, to get the linearized model. At equilibrium point: Linearization of the variable x 1 with respect to other variables:?x 1 ?x 1 = 0 ?x 1 ?x 2 = 0 ?x 1 ?x 3 = 1 ?x 1 ?x 4 = 0

Linearization of the variable x 1 with respect to other variables:?x 2 ?x 1 = 0 ?x 2 ?x 2 = 0 ?x 2 ?x 3 = 0 ?x 2 ?x 4 = 1

Linearization of the variable x 1 with respect to other variables: Linearization of the variable x 1 and x 2 with respect to input torques:?x 1 ?M 1 = 0 ?x 1 ?M 2 = 0 ?x 2 ?M 1 = 0 ?x 2 ?M 2 = 0 ?x 3 ?M 1 = c 5 c 1 c 5 ? M 2 ?x 3 ?M 2 = ? c 2 c 1 c 5 ? M 2 ?x 4 ?M 1 = 0 ?x 4 ?M 2 = 1 ? c 2 c 5

We can write the state-space model: ? ?x 1 ?x 2 ?x 3 ?x 4 ?? = ? ? ? ? ? ? 0 0 c 4 c 5 c 1 c 5 ? M 2 0 0 0 c 2 c 6 c 1 c 5 ? M 2 ? c 6 c 5 1 0 0 0 0 1 0 0 ? ? ? ? ? ? ? ? x 1 ? x 2 ? x 3 ? x 4 ? + ? ? ? ? ? ? 0 0 c 5 c 1 c 5 ? M 2 0 0 0 ? c 2 c 1 c 5 ? M 2 1 ? c 2 c 5 ? ? ? ? ? ? ? ? M 1 ? M 2 ?

8 Pid Controller based on Feedback Linearization

Having system's equation H(q?) + C (q? , q) + g(q) = M q?= H ?1 [? C (q? , q) ? g(q)] + M ? While:M ? = H ?1 MAnd, M = H ?1 M ?

This way, we decoupled the system to have the (non-physical) torque input:M ? = H ?1 ? M 1 M 2 ?

However, the physical torque inputs to the system are:M = H ? M ? 1 M ? 2 ?

To design the feedback PID controller, error signals are assumed to be: We notice that the response is following the control signal with relatively good manner. And errors of ? 1 and ? 2 are equal to zero in a short time.

9 VII.

10 Conclusion

The main content of this paper is about modeling a 2-R robotusing two methods: first is mathematical modeling using Lagrange dynamic equations and the second is using Autodesk Inventor and Simulink software's to develop the model. After that we used PID controller to validate the models and to notice the difference in accuracy achieved by each technique. Linearization about working point is valid in one point only, while it is no longer

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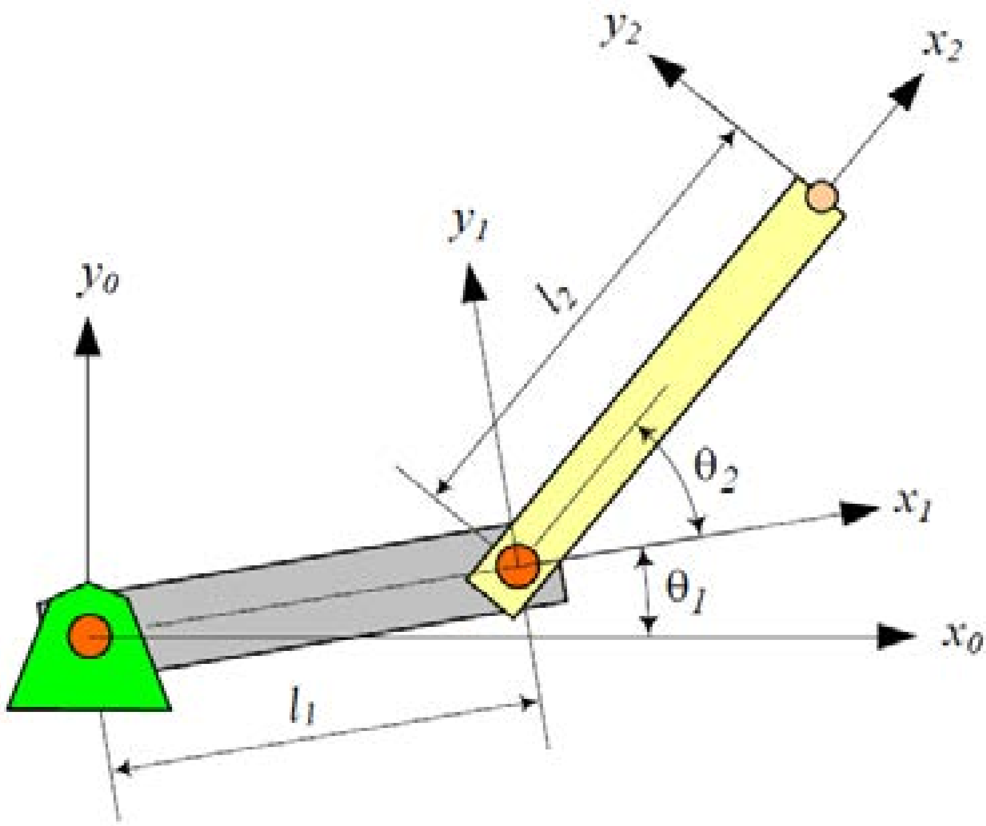
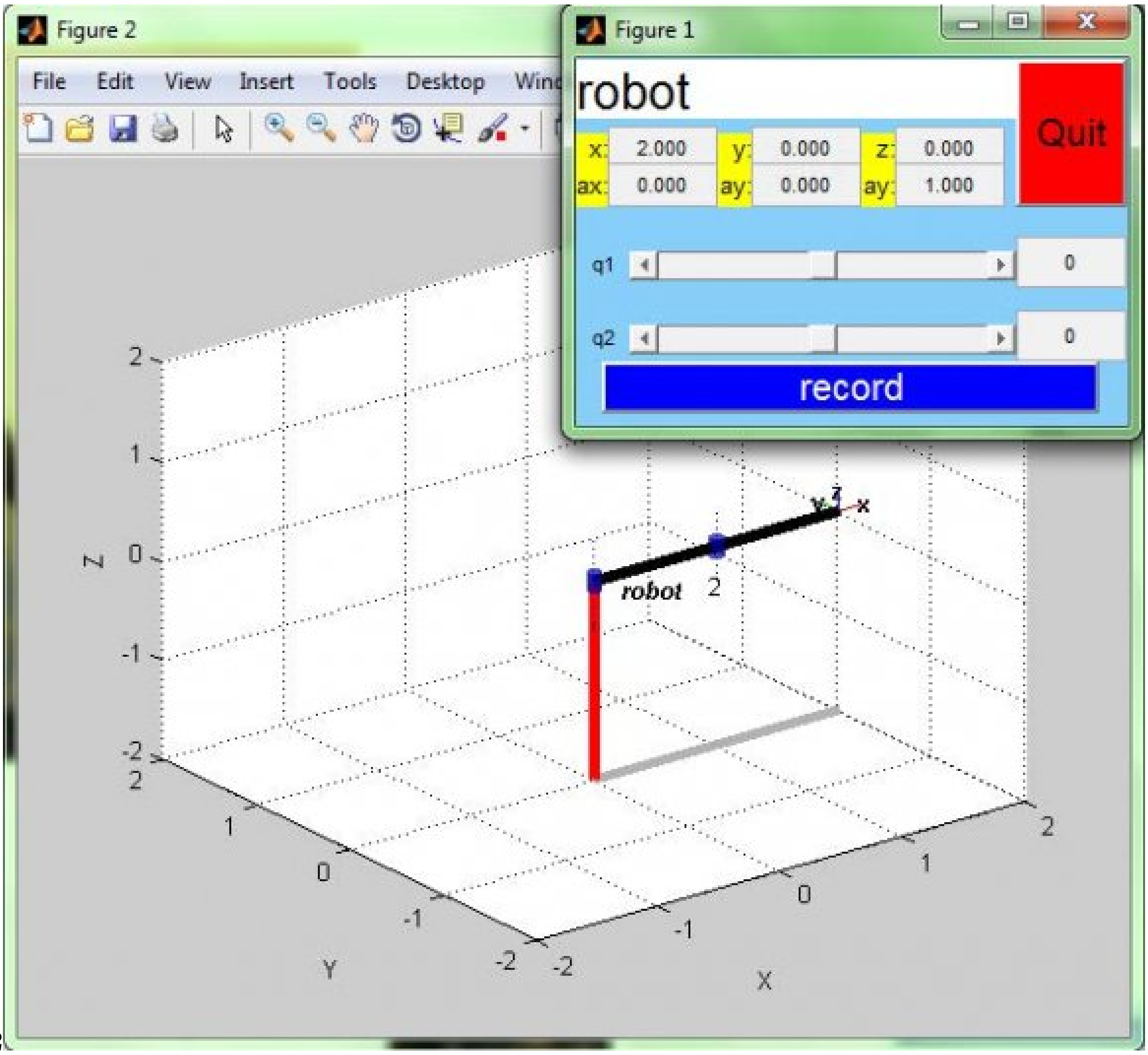
Figure 1: ?"¨ 1 ?"¨ 2



1

Figure 2: Fig. 1 :



2

Figure 3: Fig. 2 :

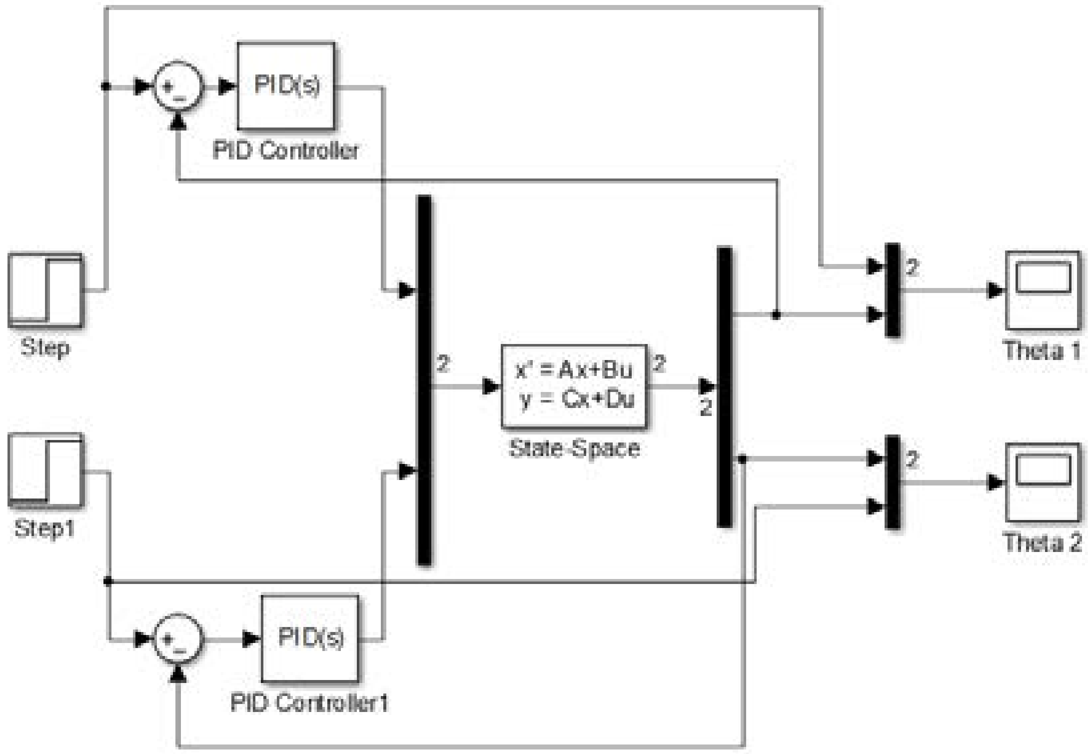
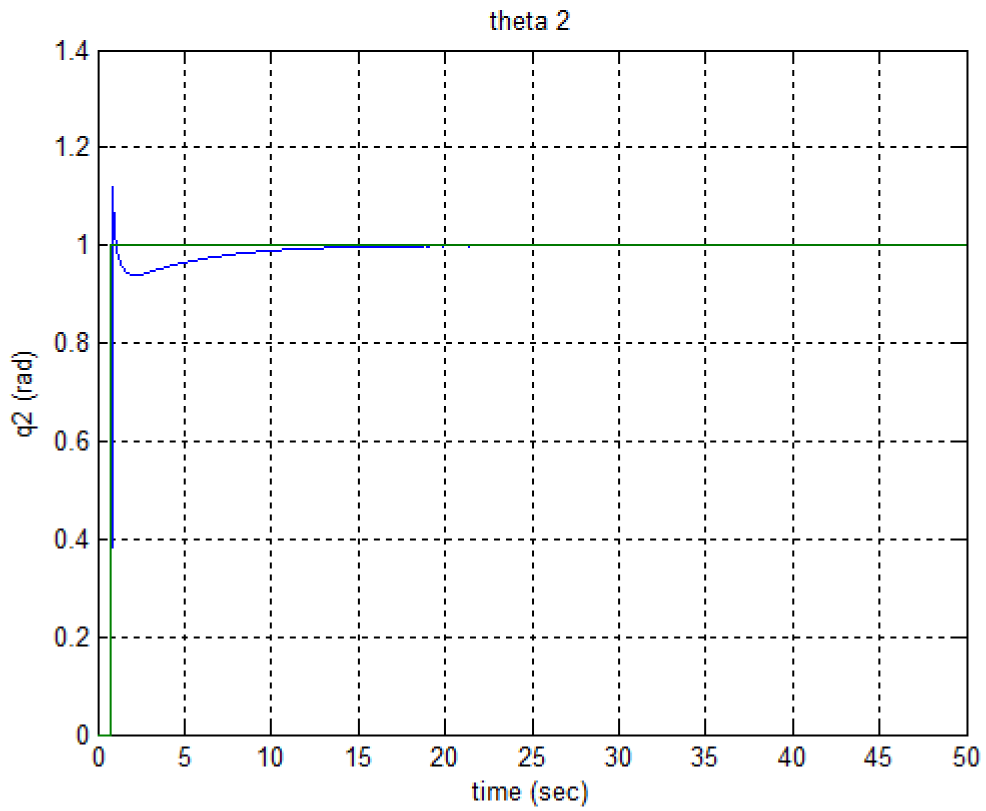


Figure 4:



3

Figure 5: Fig. 3 :

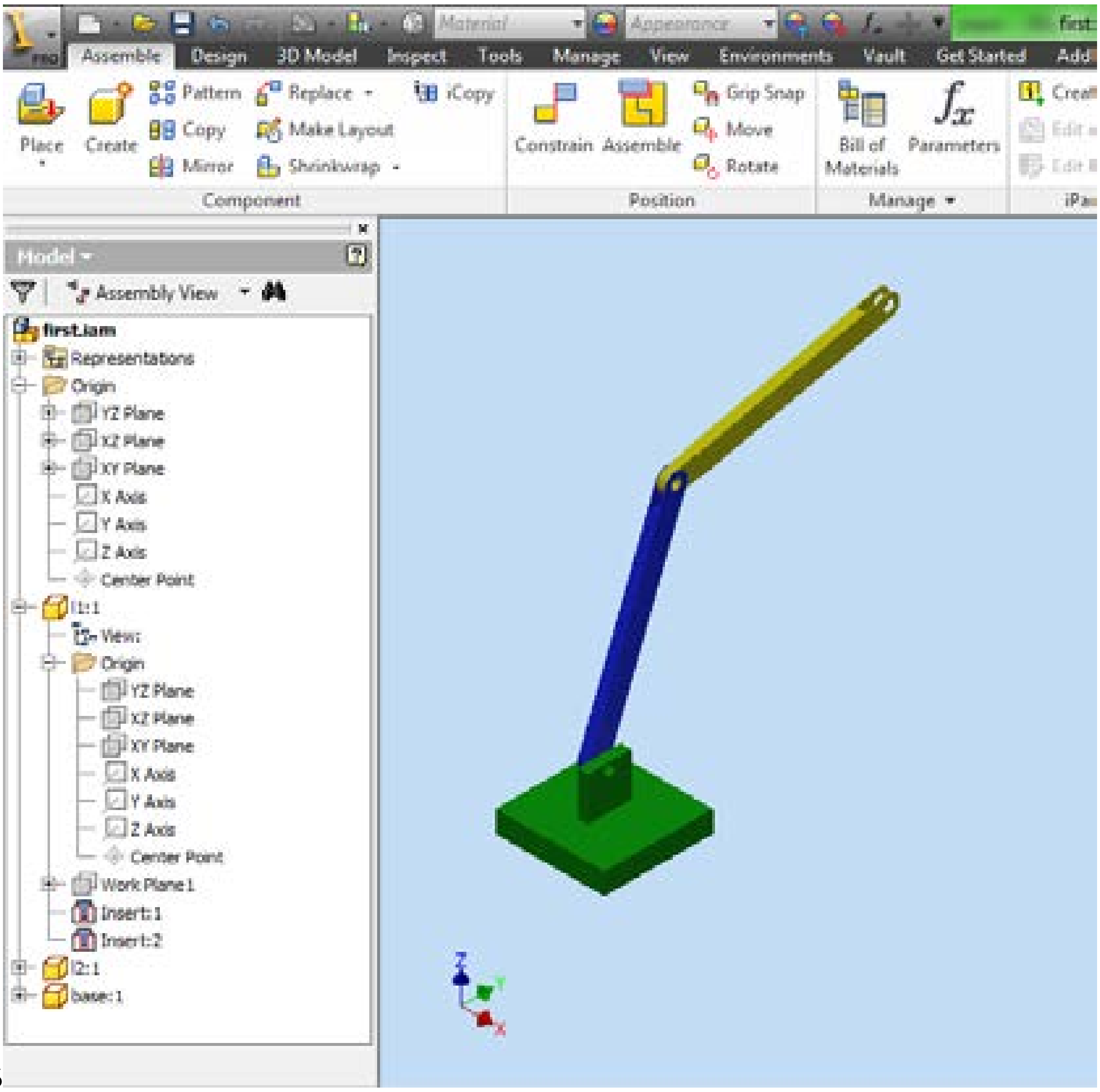


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Figure 6: Fig. 4 :Fig. 5 :

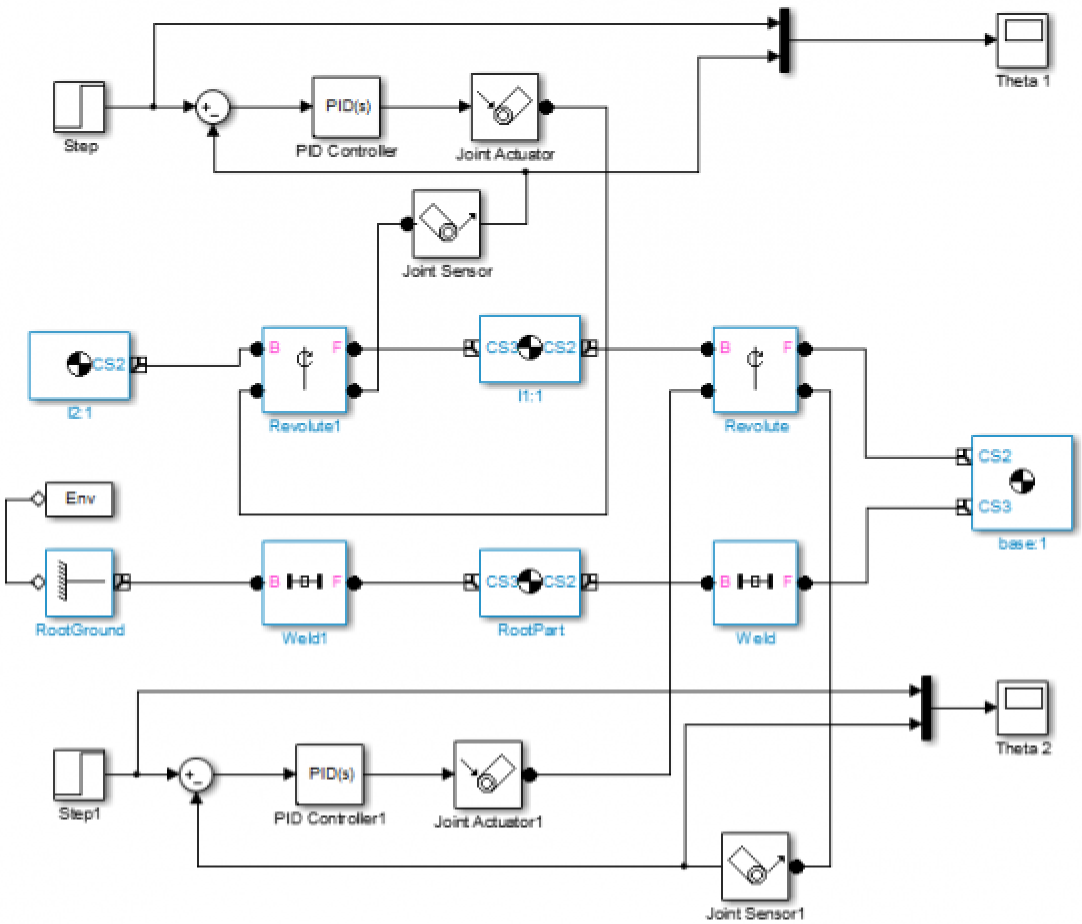

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Figure 7: Fig. 6

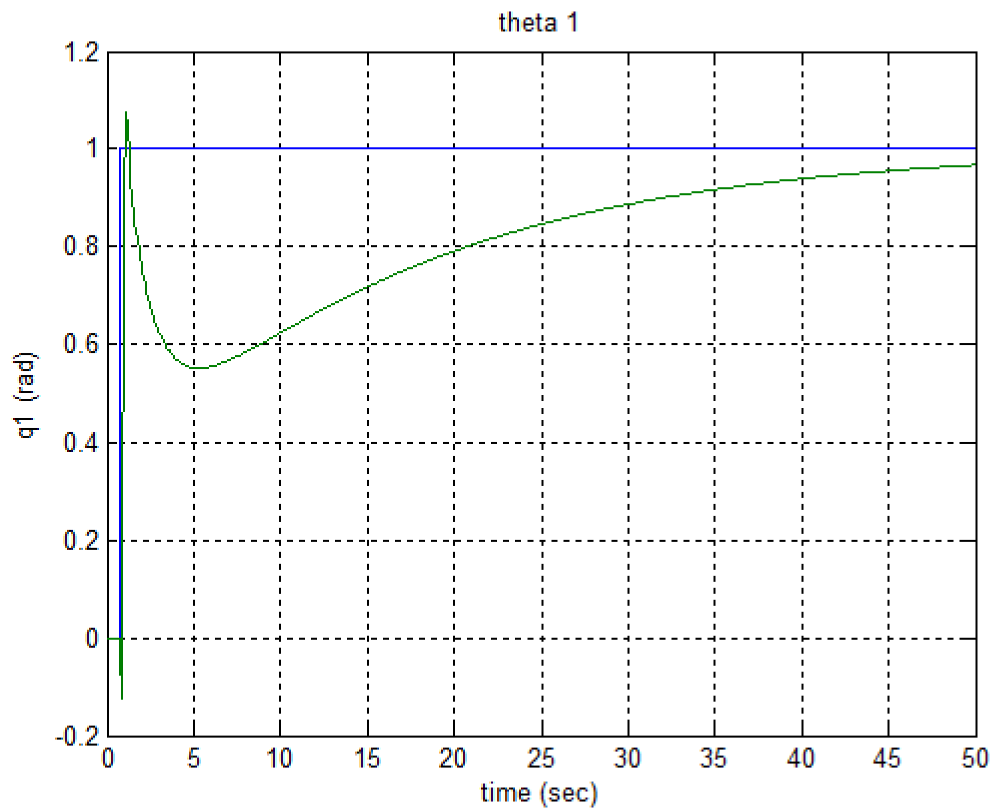

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Figure 8: e? 1 = 4 , ? 2f = pi 4

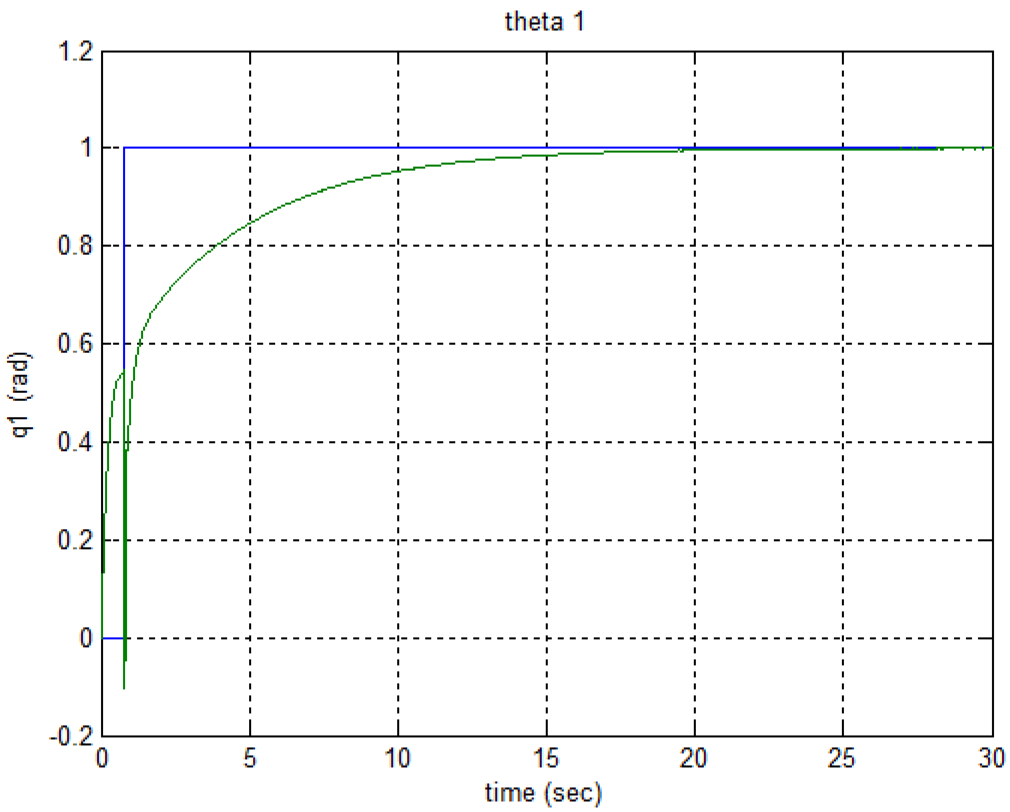

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Figure 9: Fig. 11 :

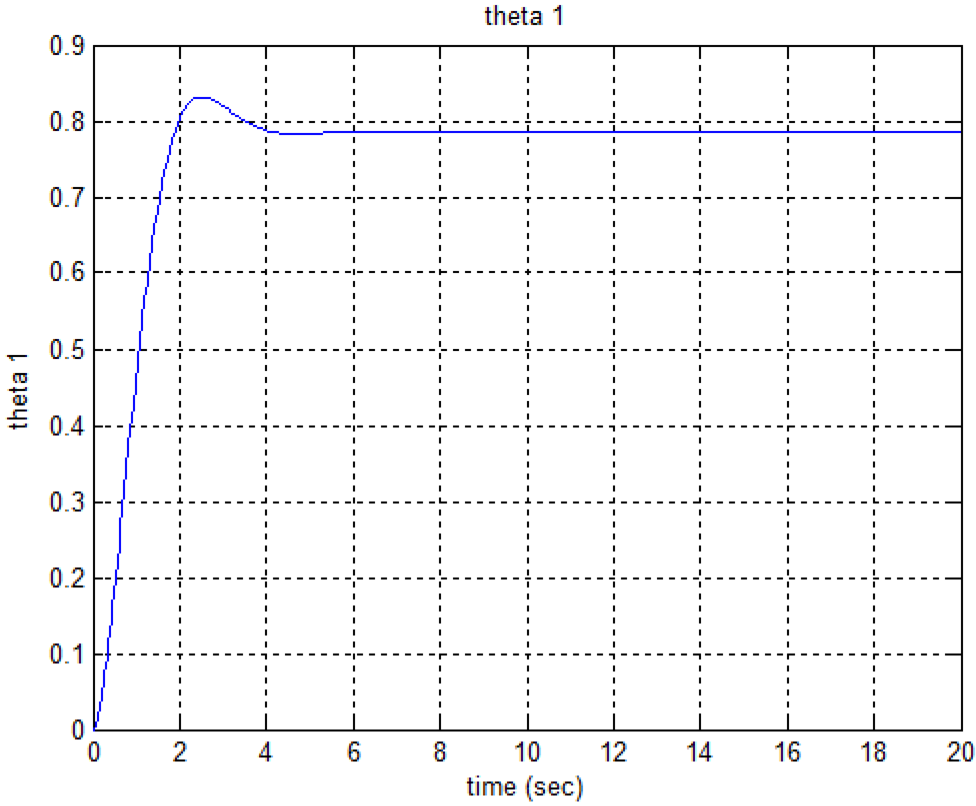

Figure 10:

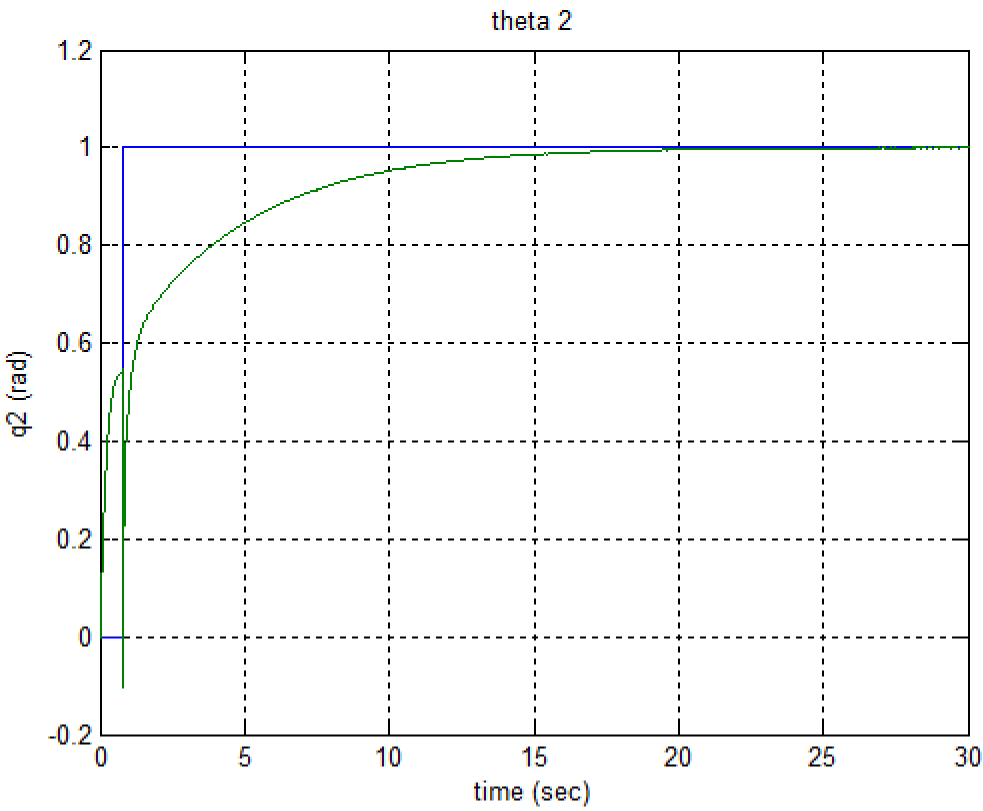

Figure 11:

1

	D-H parameters of 2-R Robot			
Frame No.	?? ??	?? ??	?? ??	?? ??
1	L 1	0	0	? 1
2	L 2	0	0	? 2

Figure 12: Table 1 :

valid for other points. The model designed from Autodesk Inventor and Simulink software's is giving better and reasonable response. Good results are found when using feedback linearization. [1] [2]

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