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An Investigation For Control Aspect Towards Modeled Dexterous Hand System

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ABSTRACT
The research domain of prosthetic technology has always remained a dialectic zone of creativity, yoking together technology and biomedical necessity. Any part of the human body replication procedure commences the prosthetic control science. Dexterity, adroitness in using the hands or body, is the prime or essential aspect in modeling dexterous hand. Simulation procedure implies to build up stability of the reference transfer function of Dexterous Hand. The present work deals with the discussion of stability criteria and simulation in discrete domain of Dexterous Hand.
Keywords – Dexterous Hand, Control Strategy, Stability Analysis, Simulation and Numerical Approach.

I. INTRODUCTION

"Dexterity" means the capability of end-effectors to autonomously perform tasks with a certain level of complexity operated by a suitable robotic system [7]. So many researches have been done to construct the control model of Dexterous Hand. The approach of modern control systems are implemented digitally. The man machine interface process is easier to theorize but its practical implementation tends to be much tougher. This work, directly related to the handicapped patients makes it a potential aid for the society. Apart from continuous deterministic test response (step, ramp, impulse etc.) the study of discrete deterministic test response for a system retains the special aspects of modern control system [8, 9, 10]. In essence, this device makes the prosthetic limb to mimic a real limb, restoring the associated functionalities and efficacies of natural arm movement [4][5].

II. TECHNOLOGY SURVEY BEHIND PROSTHETIC ARM

The main technical concept, behind this starts from taking the signal from the movement of our limb and with the help of microcontroller program of the signal; we are able to create the movement of the artificial arm. New technique that capitalizes on the movement of remaining nerves allows amputees to intuitively control their prosthetic limb, providing them with a much better level of control than traditional prosthetics. The rerouted nerves growing in the muscle, amplified the messages once sent to muscles in the arm. These signals are read by sensors on the prosthetic limb and translated into movement.

III. BLOCK DIAGRAM REPRESENTATION

Fig.1a and 1b represents a dexterous hand in rest and in grasping condition respectively.

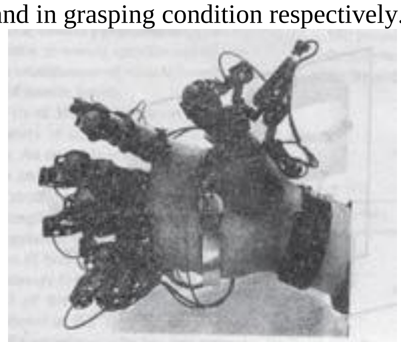

Fig. 1. (a) The Dexterous Hand Model [11]

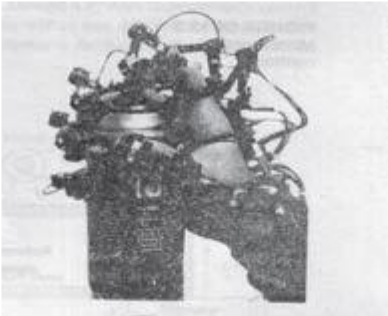

Fig. 1. (b) The Dexterous Hand Model in action [11]

To analyze the above two models, the control block and the transfer function of dexterous hand have been developed.

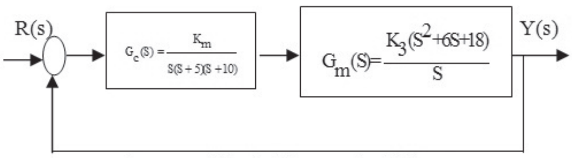

Fig. 2. Control Block of Dexterous Hand [11]

Here Gc(s) represents the controller and Gm(s) is defined as Motor and Joint. Now the overall transfer function T(s) =Y(s) / R(s)

$$T(s) = \frac{(s^2+6s+18)k_m k_3}{s^4+15s^3+(50+k_m k_3)s^2+6k_m k_3+18k_m k_3}$$

Considering

$k_m k_3 = k$

$$T(s) = \frac{(s^2+6s+18)k}{s^4+15s^3+(50+k)s^2+6ks+18k}$$

Using R-H Criterion Getting k=83.33=83 (Approx.)

$$T(s) = \frac{83s^2+498s+1494}{s^4+15s^3+133s^2+498s+1494}$$

IV. SIMULATION ASPECT OF TRANSFER FUNCTION

A system is said to be stable if any oscillatory setup is damped out with respect to time in consequence to Application of an input.

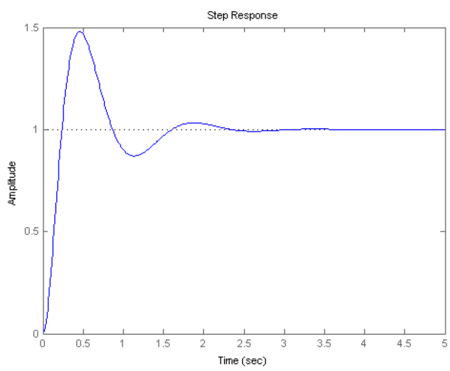

Fig. 3. Step Response

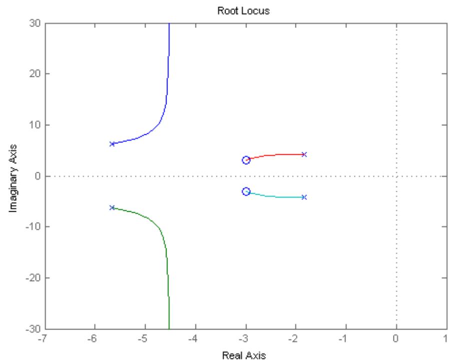

Fig. 4. Root-Locus Plot

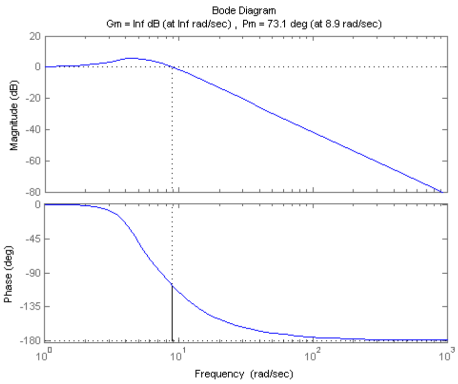

Fig. 5. Bode Plot

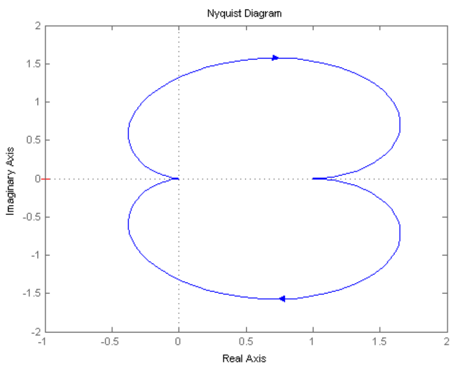

Fig. 6. Nyquist Plot

It is already initiated by optimization that for K= 83, the system is stable. In reference to fig. 4 all the roots are on the left hand side (L.H.S) of the s-plane. Thus the system is perfectly stable. In Fig. 5 GM (infinite dB) is greater than PM (73.1 dB) and gain margin is infinite, so the system is stable but practically not feasible. Now according to fig.6 N (the number of encirclements of the (-1, 0) point) = 0, P (the number of poles on the real axis) = 0. Therefore, Z = P-N, Z = 0. Thus the system is perfectly stable.

V. ULTIMATE LINEAR DOMAIN ANALYSIS BY LYAPUNOV TEST

The Lyapunov method is known to be a very useful tool of assessing stability of a system without solving the system dynamic equations in nonlinear domain [1].

Following Steps are involved to solve system stability in nonlinear domain:

a. Find State Space Matrix of given transfer function.

b. All the element of matrix must be grater then zero.

c. 3*3 matrix determinants must be grater then zero.

d. 2*2 matrix determinants must be grater then zero.

a.

$$\begin{matrix} -498 & -1494 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{matrix}$$

b. From matrix observed that all element of matrix not greater than zero. So, condition failed.

c.

$$\begin{matrix} -498 & -1494 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{matrix}$$

$\text{det of } 3*3\text{Matrix} = 0$

Condition Failed.

d.

$$\begin{matrix} -498 & -1494 \\ 1 & 0 \end{matrix}$$

$$\text{det. of } 2*2 \text{ Matrix} = 1494 \ > 0$$

Condition satisfied.

System is conditionally stable observed from Lyapunov Test.

VI. DISCREET DOMAIN ANALYSIS BY JURY TEST

Jury's technique is one of the best suited tools in discrete domain which is being applied widely to determine the stability of discrete system. Technologists have segregated these special cases in which the stability of biological system can be established by the application of the Jury's stability testing. The authors have devised an algorithm to determine the stability of biological system through Jury's testing [6][2].

Z- Domain Representation by ZOH we obtained

$$T(Z) = \frac{0.8284\,Z^3 - 0.3138\,Z^2 - 0.1446Z + 0.1309}{Z^4 - 1.132\,Z^3 + 0.78Z^2 - 0.1972Z + 0.04979}$$

Characteristic polynomial:

F (Z)=

$$Z^4 - 1.132Z^3 + 0.78Z^2 - 0.1972Z + 0.04979$$

F (1)= 0.50059 [F(1)>0; Satisfied]

$(-1)^4$ F(-1)= 3.15899 [$(-1)^4$ F(-1)>o; Satisfied]

Table 1. Table of Jury Test:

ROW	Z^0	Z^1	Z^2	Z^3	Z^4
1	0.049	-0.19	0.78	-1.13	1
2	1	-1.13	0.78	-0.19	0.049
3	0.99	1.12	-0.74	0.14	
4	0.14	-0.74	1.12	0.99	
5	0.975	-1.015	0.581		
6	0.581	-1.015	0.975		

Table 1 represents the Jury format of dexterous hand Transfer function. From Table 1 the sufficient conditions for stability are obtained.

$|0.049| < |1|$, Satisfied

$|0.99| > |0.14|$, Satisfied

$|0.975| > |0.581|$, Satisfied

So the transfer function is appropriate for the system.

From Controllable and Observable matrix we get the above transfer function are fully Controllable and Observable.

VII. CONCLUSION

Artificial or prosthetic human organs can be classified into three general types: Internal Organs, Sense Organs and External organs. Though research work is going on rapidly on each of these types, it is very difficult to facilitate proper interpretation and designing of Sense organs. Dexterous Hand is the important sense organ which is a very challenging and growing research area in the field of prosthesis. In this paper, the simulation approaches for efficient modeling of a prosthetic Dexterous Hand has been carried out. Further, from the appropriate control model development of those prosthetic Systems an effective performance study has been furnished. In our future works, the practical approaches for generating a hardware implementation of prosthetic organs will be carried out regarding to the performance and stability analysis for a Dexterous Hand. The development of the work is enriched the interdisciplinary knowledge of engineering and Biomedical sciences.

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