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is presented to

the

IEEE Student Branch

at

Universidad Nacional del Sur

in recognition of

its outstanding project proposal

entitled

Control and Modeling a Very Flexible Single Link Manipulator

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1ST REPORT OF THE
IEEE VINCENT BENDIX AWARD

TITLE :

CONTROL AND MODELING A VERY FLEXIBLE SINGLE LINK MANIPULATOR

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ABSTRACT

This work presents preliminary results in structure and parameter identification of a very flexible single link manipulator. The experimental part was done with a Data Acquisition Software package specially design for the experiment at *Universidad Nacional del Sur*.

The results obtained will be very useful for the second part of the research. This consist of on-line identification.

INTRUDUCTION

The need to study this particular structure can be justified by looking at some of the areas in which these manipulators outperform the rigid based robots:

1.- Speed response. Lighter robots will be able to move at faster speed.

2.- Smaller actuators. These manipulators will not need bigger motors to move themselves around the field of operation. The actuator may be designed based mostly on the load it has to handle.

3.- Lower energy consumption. This property makes the flexible manipulator attractive for environments in which energy efficiency is a must.

4.- Less bulky design and smaller overall mass.Today´s industrial manipulators have a workspace bigger than $1m^3$ requiring powerful motors to move maximum payload that are usually between 3 and 6% of its total weight.

5.- Lower overall cost.

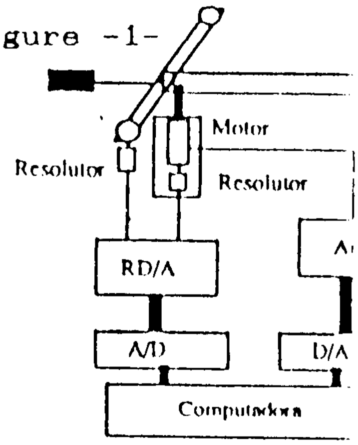
MANIPULATOR DESCRIPTION

The manipulator consist of a thin cantilevered beam of approximately 1 meter long, 3 cm. width and 1 mm. thick. Attached to the hub is a counterweight which provide a mechanical low pass filter as well as decrease the dumping effect; this characteristics make the control task more difficult.

The actuator is a DC motor and is driven by a power amplifier using current feedback. To convert the input voltage command to current for the motor.

The position information is provide by a pair of synchros. One is used to detect the position of the hub and the other to measure the flexion of the arm.

The overall hardware description is shown in figure -1-



Base Model Identification

It has been shown that the transfer function of the system has the following form:

$$\frac{\theta_{hub}}{T} = \frac{1}{I_T \cdot s^2} * \prod_{i=1}^{\infty} \frac{s^2 + 2\zeta_i \Omega_i + \Omega_i^2}{s^2 + 2\zeta_i \omega_i + \omega_i^2} \qquad -1-$$

where ω_i = resonant frequencies

Ω_i = anti resonant frequencies

ζ_i = dumping

I_T = total moment of inertia

1- Resonant and Antiresonant Frequencies

To determine the values of Ω_i and ω_i the following experiment was performed. A sinusoidal voltage is fed to the DC amplifier and the frequency swept from 0-10Hz. The resonant frequency is determined when the sensor output reaches its maximum amplitude with a 90° phase shift from the input. The antiresonant frequency is determined when the sensor reached its minimum output with a 90° phase shift.

Applying this technique we obtained the parameters shown in table 1:

TABLE 1

mode	ω_i	Ω_i
1	1.6Hz	0.8Hz

With on-line identification we will try to identify the parameters correspond to mode #2.

2- DETERMINATION OF THE DAMPING COEFFICIENT

This parameter is very important to design the controller. In order to determine the coefficient ζ_i the following experiment was performed. A constant sinusoidal current is fed to the motor during a period of time long enough in order to make the transient effect negligible. The frequency of the input is get equal to the mode corresponding to the dumping coefficient we would like to determine. Then we abruptly disconnect the input and plot the speed response of the system. With figure -2- the value of ζ_1=0.027 was determined.

3- DETERMINATION OF MOMENT OF INERTIA

From equation -1- we can see that at low frequencies, 50 mHz, the arm behaves as a rigid arm. Assuming this frequency the TF can be simplified:

$$\frac{\theta hub}{T} = \frac{1}{I_T . s^2} * \prod_{i=1}^{\infty} \frac{\Omega_i^2}{\omega_i^2} \cong \frac{1}{I_T . s^2} * \frac{\Omega_1^2}{\omega_1^2} \qquad -2-$$

because $(\Omega_i / \omega_i)^2$ is $\cong$ 1 for i>1

In terms of angular velocity the TF is

$$\frac{V}{I} = \frac{k_t \times k_f}{I_T \times s} = \frac{K \times k_f}{s} \quad : \quad k_f = \frac{\Omega_i^2}{\omega_i^2} \qquad -3-$$

when I is the current through the motor and k_t is the torque constant. With input signal equal to:

$$I(t) = A \sin(\omega t) \quad (\omega = 2 \times \Pi \times 0.05 \text{ rad/sec}) \qquad -4-$$

then
$$I(s) = \frac{A\,\omega}{s^2 + \omega^2} \qquad -5-$$

and
$$V(s) = \frac{A\,\omega\,K\,k_f}{s\,(s^2 + \omega^2)} \qquad -6-$$

$$V(t) = \frac{A\,K\,k_f}{\omega} \times (1 - \cos(\omega t)) \qquad -7-$$

From last equation we can see that only unknown is I_T. Then measuring the amplitude of the velocity we can valued:

$$K = \frac{k_t}{I_T} \cong 0.5$$

Finally the TF of the system become

$$\frac{\theta}{T} = 0.5 \times \frac{1}{s^2} \times \frac{s^2 + 0.275\,s + 25.2}{s^2 + 0.55\,s + 101.0}$$

On-Line Identification and Model Validation Techniques

The students working in the project are actually taking a course on Identification and Adaptive control. In this class they can get enough material to implement on line identification algorithm like RLS, ELS, and RML. This will be of fundamental importance to complete the last part of the project, which total length was initially estimated in 7 to 10 month.

The data acquisition software was completely developed and is being tested with the implementation of identification algorithms. The shell was developed in 'C' language and optimized with in-line machine code. We have obtained several experimental results. We are mailing part of them on a separate package this week.

CONCLUSION

The past few month were mainly invested implementing the experimental arm, developing acquisition software and getting enough theoretical background in the area.

The founds provided by the IEEE-Vincent Bendix Award, joined with the 500 U$S supplied by the department of EE (UNS) helped to buy a PC-AT 25 MHz. IBM compatible computer. This hardware is used by the students involved in this work.

We expect to finish the proposal and submit the final report in approximately five month, as scheduled in the original presentation. It is very important to mention the interest that the project have originated to our students bringing new members to the branch.

PS: PLEASE, REDIRECT THIS FAX PROPERLY IF NECESSARY

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