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Instrumentation and Automation of Mechatronic

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ABSTRACT

This paper presents the methodology used for the automation of a mechanical system, which will be used to perform scans on tooth surfaces, in this paper the mathematical modeling of the structure for further implementation was carried out in order to get a reconfigurable device using specialized software. To carry out this study various mathematical tools for developing the mathematical model were used, then control routines that allow the manipulation mechanism for each axis independently performed. The implementation was carried out by integrating various electrical, electronic and computer systems for an efficient control of the movement and location of robot systems.

Key-Words: -Automation, model, mathematical, mechatronic system, microcontroller, data acquisition card

I. INTRODUCTION

Currently the development of technology in recent decades has resulted in the ability to perform tasks that require an increasing degree of accuracy and complexity, which generates the need to update and improve the techniques used for this function.

Automation is understood as the integration of various elements applied to a system that perform a specific task, with the least possible intervention.

The automation process is carried out by implementing a control system which monitors the operation of a plant, the field where automation is possible to apply covers human activities involving repeatability, accuracy and reduced operation time are required.

II. DYNAMIC MODEL OF THE MECHANICAL SYSTEM

Since the movement of the robot must be controlled to obtain the accuracy that characterizes this type of mechanism a model is needed, which will abstract the variables that describe the physical movement of each axis of the system.

The use of mathematical tools for describing movements and orientations required by the use of matrix algebra, Denavit - Hartemnberg algorithm (DH) through its parameters (θ, d, α α) allows referencing the length of each axis, the distances and angles between them, and determine factors such as speed and torque required to control each axis.

a) CINEMATIC MODEL

Kinematics is the branch of physics that deals with the study of the laws of motion without addressing the causes that originated them, it is possible to have a mathematical model that will allow the study of the movement and angle of motion of the mechanical system, without considering speeds, forces influencing the same.

To determine the model of the mechanism (Fig. 1) is necessary to analyze each axis individually, in order to specify each of the forces, masses, and accelerations in each axis immersed [2].

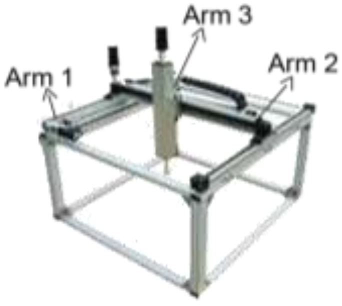

Figure 1. Mechanical structure.

For the study of the Y axis (Fig.2) equations of the forces involved in this reference axis is determined. The following equations illustrate these forces.

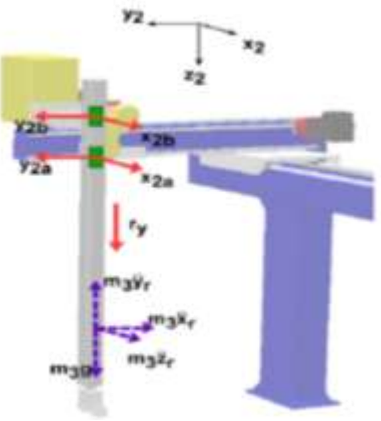

Figure 2. Representation of the physical quantities of the shaft.

$$-x'_2 - x''{}'_2 = m_3\ddot{z}_r \qquad (1)$$

$$y'_2 + y''{}'_2 = m_3\ddot{x}_r \qquad (2)$$

$$r_y + m_3\, g = m_3\ddot{y}_r \qquad (3)$$

$$\frac{a_3}{2}y'_2 - \frac{a_3}{2}y''_2 - b_3r_y + w_3m_3\ddot{x}_r = 0 \qquad (4)$$

$$-\frac{a_3}{2}x'_2 - \frac{a_3}{2}x''_2 - c_3r_y + w_3m_3\ddot{z}_r = 0 \qquad (5)$$

Where:
z_r Z axis position
x_r X axis position
y_r Y axis position
m_3 Mass arm 3
r_y Force transmitted by the rope to Y axis
a_3 Spacing blocks glide.
w_3 Distance between the center of mass of the arm 3 and the center of the union 3.

Balance equations can be solved by finding the five variables of the equations system, Figure 3 shows the free-body diagram of the transverse support arm 2 (X axis), and the equation of arm balance is described by:

$$x'_1 + x''_1 + x'''_1 - m_2g + r_y = 0 \qquad (6)$$

$$y'_1 + y''_1 + y'''_1 + x'_2 + x'' = m_2\ddot{z}_{r2} \qquad (7)$$

$$r_x - y'_2 + y''_2 = m_2\ddot{x}_r \qquad (8)$$

$$\frac{a_2}{2}y'_1 - \frac{a_2}{2}y''_1 - b_2y'''_1 + e_2r_x - u_2m_2\ddot{x}_r + \\ +v_2m_2\ddot{z}_r - c_{23}x'_2 - c_{23}x''_2 + \\ +a_{23}y'_2 + a_{23}y''_2 = 0 \qquad (9)$$

$$-\frac{a_2}{2}x'_1 + \frac{a_2}{2}x''_1 + b_2x'''_1 - d_2r_x - w_2m_2\ddot{x}_r + \\ +v_2m_2g + \left(\frac{a_3}{2} + b_{23}\right)y'_2 + \left(-\frac{a_3}{2} + b_{23}\right)y''_2 + \\ +(c_{23} - b_3)r_y - c_{m3} = 0 \qquad (10)$$

$$-\frac{c_2}{2}y'_1 + \frac{c_2}{2}y''_1 + \frac{c_2}{2}y'''_1 + u_2m_2g + \\ +w_2m_2\ddot{z}_r + \left(b_{23}\frac{a_3}{2}\right)x'_2 + \left(b_{23} - \frac{a_3}{2}\right)x''_2 + \\ +(a_{23} + c_3)r_y = 0 \qquad (11)$$

Where:

m_2 Mass of arm 2
r_x Force transmitted by the rope to axis X
c_{m3} Engine torque arm
u_2 Position of the center of mass of the arm 2 (Component y_1)
v_2 Position of the center of mass of the arm 2 (Component y_1)
w_2 Position of the center of mass of the arm 2 (Component y_1)
a_{23} Distance from the center of mass of the arm 2 (Component y_1)
b_{23} Distance from the center of mass of the arm 2 (Component x_1)
c_{23} Distance from the center of mass of the arm 2 (Component z_1)

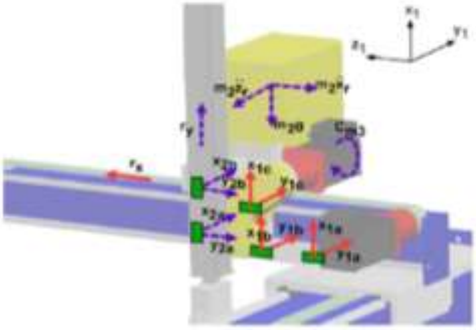

Figure 3. Representation of the physical quantities of the X axis

III. INSTRUMENTATION AND AUTOMATION OF THE MECHANISM.

Subsequent modeling of the mechanical system , the architecture of the instrumentation required for such mechanical systems (Fig. 4), involves the interaction of various modules and it is designed as: distance measurement, sending module data control module speed, power amplifier for each axis angle control module for sample acquisition system and a general control system which receives information about the current position of the robot and generates the necessary instructions to perform a particular task .

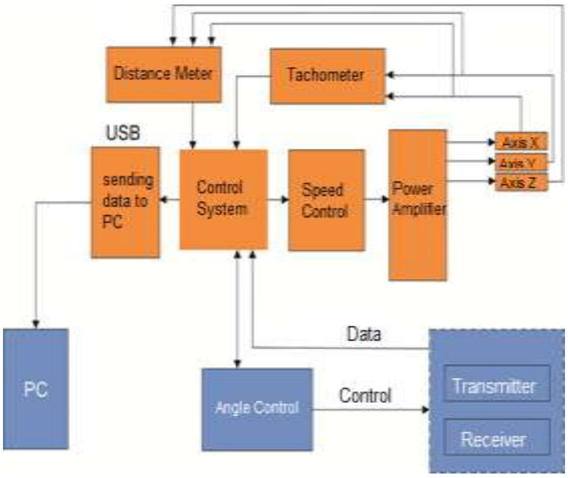

Figure. 4. Block diagram of the system

The development of this system is divided into the design elements of both hardware and firmware design, and finally designing a combinational digital system, the electrical circuit used for automation describes the hardware design which is divided into a power and a control stage.

This diagram shows the connections between the control and power stages of system in addition to indicating the physical connectors on the final circuit board, to facilitate understanding and wiring it.
The automation of this mechanical system is the foundation on which further work will be conducted within, this work is to perform scanning teeth.
Thus if you want to modify the configuration,a simple change in the parameters is needed. No need for full system programming.
To measure the distance of linear ultrasonic sensors, which were characterized as to measure in a range of 1 cm were used 2 m.
To perform this function a mathematical expression (12) takes the time it takes a signal from being issued until the bounce back product with a flat surface was used.

$$distance\ = time * 340\ {}^{km}/_{hr} \quad (12)$$

The module responsible for the measurement of revolutions uses a motor coupled to the shaft, which provides digital pulses for each rotation of the motor, the number of pulses generated in a turn is determined by the sensor resolution sensor typically 20 pulses are generated for each motor rotation.

To determine the motor rpm the mathematical expression (13) which calculates from the pulse generated by the sensor is used.

$$rpm = \frac{sensor\ \ pulses}{60000 * number\ \ of\ pulses\ \ per\ \ spin} \qquad (13)$$

The angle control system is carried out using stepper motors, which need pulses for rotation of the motor, generally four pulse sequences for performing the required movement of the motor, this sequence is repeated 50 times for a complete rotation engine, with this we can make the shift to a desired angle.

For the expression (14) the above stated parameters are used, this term will provide the exact number of pulses to be sent to the motor for rotating the rotor to the desired angle.

$$angle = \frac{desired\ \ angle\,° * 100\ pulses}{180°} \ (14)$$

IV. RESULTS

The results at the end of this work are listed below:

A speed control for DC motors and for a servomotor, which selects the motor to be controlled and its speed is set was designed, you can choose each motor independently.

It was performed with the use of a combinational logic circuit, which serves to select and set between DC motors and motor operating speed.

The tests were made to this system consisted of testing the engine selection system by entering the code for each motor and observing the signals on an oscilloscope with which it was found that the selection stage motor function properly.

Subsequently testing stage speed setting is made, this step was tested by selecting a motor, after this speed was varied from the minimum value to the maximum value, and these ranges are given by PWM module having the microcontroller, which is 8 bits.

These tests were conducted in 2 parts, the first without the connected motors where the output signals were observed on an oscilloscope.
In the second part of this test engines with this operation with the connected and mounted on the engine system it ensured connect.

Meter speed for DC motors, which will provide information about the speed thereof are designed so as to anticipate possible engine failures.

Testing the speed measurement system they were performed with motors without charge and subsequently considering the system load. The results in Table 1 provide information concerning the attenuation factor due to the load.

Table 1. Measurement of revolutions in the system measures

Motor	No-load measurement	Load measurement	Attenuation factor

X	2000 R.P.M.	856 R.P.M.	42.8%
Y Left.	1800 R.P.M.	1010 R.P.M.	56.1 %
Y Right.	1800 R.P.M.	1010 R.P.M	56.1 %

With these data it is possible to obtain information on the status of the engines and the mechanical system, which will be used to detect early failure of the mechanical system and engine.

Angle control for a laser beam and an optical receiver designed. Whose function is to independently position the angle of incidence of the laser beam and the reflection angle of an optical receiver. For the positioning of these motors are employed steps of bipolar type, which are in the mechanism.

Angle control takes as input argument the desired angle to the laser and the optical receiver, which becomes the number of steps to be performed for each stepper motor

The tests were performed at this module consisted of measuring the angle using a compass with which the angle obtained by the mechanism and the actual angle obtained was verified. It was concluded that control angle operating properly for integer values of angles for actual angle values in the real number modulo rounded top, thus creating a maximum error of 0.9 °.

Meter distance to the 3 axes of freedom of the mechanism was designed, this module is designed using linear ultrasonic sensors, which calculates the distance from the bounce time of the signal, the distance meters are designed to provide for required for these interface modules, necessary for the operation of the 4 sensors to the controlling mechanism, and obtaining the distance for each sensor.

Distance measurement tests on each axis verifying this measurement system with the use of a vernier were performed. By testing error with counting system of measurement, which is 0.008 mm, which translates to 8 microns was obtained.

The communication between the PC and the developed card, developed using the built-in module to the microcontroller USB communication was configured for communication in CDC mode, which is characterized by emulating a serial communication port in the USB mode.

Communication tests were conducted between the PC card and satisfactory results in terms of card configuration and data acquisition from the same.

Finally he devised a test routine for the entire system in which all modules described above, subsequently, the performance of electronic systems and, the mechanical system is evaluated they can combine.

A card (fig.5) consisting of a control stage which allows interface sensors and a power amplifier , it provides the system , the energy required for operating the system according to the configurations developed user has a total consumption of 80 watts, the power of this card is obtained from a switching power supply ATX with capacity of 450 W.

Figure 5. Data acquisition card developed

Developed card contains the necessary elements for the regulation of heat generated by H bridges, for which evidence about the required size of heat sinks for electronic components implemented, which are presented in Table 2 were performed.

Table 2. Comparison of size sinks with H bridges behavior

Size sink	H bridge behavior
2.5 cm2	H bridge burned completely.
4.5 cm2	Some components are burned.
10 cm2	Some components showed heating.
15 cm2	The components showed no warming in 24 hrs of use.

V. CONCLUSIONS

This work will benefit the field of dentistry because they provide the tools necessary for the development of studies and work in this area.

It allowed the study of various areas of electronics such as power systems, digital systems, also allowed the deepening programming firmware using a programming language of high level and conducted a study on mechanical systems to meet their operation for further automation.

A problem that arose was the adjustment in the mechanical system, because it had several flaws that caused a delay in terms of estimated development time of this work, these failures were solved using more experienced people in the area, with which it was obtained a better idea of the origin of these failures, for further correction.

The importance of this work lies in the development of electronic instrumentation in the area of digital systems using microcontrollers, which currently represent a response to the need to automate processes in a reliable, fast and versatile way.

As future work modifying the power stage is raised using other switching devices, which reduces board space and occupy fewer elements.

In addition the development of a communication system between the card and the computer acquisition, which would be obtained more data transfer in a shorter time is proposed.

Another modification that arises do future work is the modification, corresponding to the X axis mechanical system, due to the use of a gearbox, which generates reduction in engine speed, for this reason, the modification to the system mechanical contribute to a shorter displacement of the shaft and thus to a reduction in total scan time.

REFERENCES

[1] Robótica, Craig John, J, Pearson, Tercera Edición, México 2006

[2] Dynamic Models For The Re-Engineering High-Speed Cartesian Robot, *Massimo Callegari*, Italia, *2001.*

[3] José Guadalupe Castro Lugo, Juan José Padilla Ybarra, Eduardo Romero A. Metodología Para Realizar Una Automatización Utilizando Plc. Revista Impulso. México. 2008.

[4] Sánchez Carmona Arturo. Automatización Y Flexibilidad De La Industria, México. 2002.

[5] Michael G. Christel, Kyo C. Kang, Issues In Requirements Elicitation, Technical Report, Cmu/ Sei-92-Tr-12, Esc-Tr-92-012, September, México, 1992.

[6] Baca Urbina Gabriel. Evaluación De Proyectos. Quinta Edición, Mc Graw Hill, España, 2005.

[7] Bobadilla Díaz, P., Del Águila Rodríguez, L. Y Morgan, M. De La L. Diseño Y Evaluación De Proyectos De Desarrollo. Lima-Perú, 1998.

[8] Faber, Industrial Technologies. Gantry Robot Systems And Linear Modules, High SpeedAutomation. Belt Driven Modules, Estados Unidos, 2003.

[9] Fraile Mora Jesús. Máquinas Eléctricas, Madrid. Mcgraw-Hill, España, 2008

[10] Manzano Juan. Máquinas Eléctricas. España, 2010.

[11] Wildi Theodore. Máquinas Eléctricas Y Sistemas De Potencia. México, 2007.

[12] N. Mohan, T. M. Undeland, W. P. Robbins, Power Electronics,Converters, Applications, And Design. Second Edition, John Wiley & Sons, Estados Unidos, 1995.

[13] Muhammad H, Rashid. Electrónica De Potencia, Circuitos, Dispositivos Y Aplicaciones. Prentice Hall, México, 1993.

[14] Han-Way Hunag. Pic Microcontroller: An Introduction To Software And Hardware Interfacing. Thomson, Argentina, 2005.

[15] Luis Felipe De La Hoz Cubas, María Ilse Dovale Pérez, Fabio García Rodríguez. Estudio De Las Características De Un Motor De Corriente Continua. Departamento De Ingeniería Eléctrica Y Electrónica - Electrónica I Laboratorio 1 – Agosto, Guadalajara, 2008.

[16] Conti Francisco. Motores Paso A Paso. Alsina, 2005.

[17] Paul Acarnley. Stepping Motors A Guide To Theory And Practice. The Institution Of Engineering And Technology, 4th Edition, London United Kingdom, 2007.

[18] John Iovine. Microccontroller Project Book. Tab Editorials, Second Edition. Estados Unidos, 2004.

[19] Carlos Elías Sepúlveda Lozano. Servomotores, La Misma Potencia Con Ahorro Para La Industria. Acme Centro De Servicios Del Acero, Tecnología Y Precisión Para La Industria Y La Construcción, Venezuela, 2005.