Diseño Mecatrónico y Simulación de un Robot Manipulador Móvil para la distribución de instrumentos en un ambiente hospitalario

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***Abstract*— In recent years, the health and well-being of the world has been compromised by a virus that does not distinguish borders, race or gender. The entire population is affected by the high rate of infections and the saturation of health systems. In a constant fight and in the area of greatest risk of contracting the disease, there are health personnel who are in constant interaction with different patients, which increases the number of infected, in a proven way. All this is the reason for the present research to reduce time pressure on medical personnel, reduce the need for social interactions and reduce the risk of contagion in health centers. It is proposed to use a medical robot for the distribution of surgical instruments, supplies and medical devices, among others. This mechatronic design consists of a mobile robot as a base, a shelf structure on top of the mobile robot and a centrally located UR 6 DoF (Degrees of Freedom) serial robot that allows the serial robot free movement of its joints and maintain the stability of the complete structure. Considering as a tool a Gripper that has the holding capacity for different objects and a coupling for a programmable camera which must recognize and identify each tool. Finally, the simulation results show the kinematics of the mobile robot, the tracing of its trajectory and the patterns of the different objects, as well as its recognition and identification of them.**

Keywords*— *Mechatronic design, serial robot, Denavit-Hartenberg, kinematic analysis, neural networks.

I. INTRODUCTION

Currently, the prevention of accidents and occupational diseases is one of the main concerns in mining. According to Osinergmin's statistical sources for mining industries [1], 65% of accidents belong to underground mines, while 35% belong to open-pit mines, likewise, in the classification of mortal victims by accident type, 17% are produced by ventilation and poisoning incidents inside the internal mining facilities [1], [2].

The incidents related to ventilation and degenerative diseases among mining workers are caused by the exposure to environmental pollution conditions including chemical, physical and biological agents. Among the most common chemical and physical agents; extreme temperatures, gas poisoning and prolonged work in highly polluted environments with dust may cause pneumoconiosis.

According to the statistical analysis of the Ministry of Energy and Mines of Peru [2], the chemical agent that produces the greatest amount of diseases among the mining workers is *Silica Dust*, positioning in the second place as the causal of occupational diseases in underground mines. In years 2015 and 2017, accidents due to gas intoxication were reported by Osinergmin [1], in the mining units of Minera Aurífera Retamas S.A., and Compañía Minera Ares S.A.C. companies respectively.

Therefore, in order to improve the environmental safety and occupational health levels and to reduce the mortality rate within the operations in underground mines, a terrestrial mobile robot "MineBot" was developed, capable of detecting and monitoring the environmental information, remotely controlled made of open source teleoperation technologies, as shown in Fig. 1.

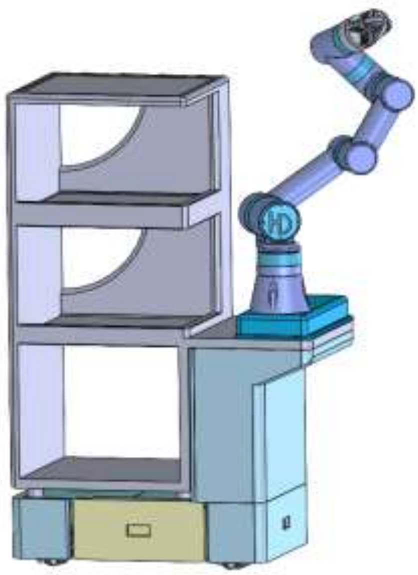


Fig. 1. Robotic Arm mounted on electric wheelchair.

II. MATERIALS AND METHODS

A. Mechatronics Design of Mobile Manipulator Robot

Para la realización de este proyecto, se inició con el diseño de cada una de las piezas del robot manipulador móvil, con el software SolidWorks.

Base móvil del Robot: para la parte móvil del robot se diseñó un chasis para robot móvil con espacios para los circuitos, sensores y con acoplamientos para una configuración de 4 ruedas *Mecanum* las cuales nos permiten una traslación omnidireccional en nuestra base móvil.

Fig. 2. Ruedas Mecanum y Ensamble de la base móvil del robot

Manipulador del Robot: como manipulador se utilizó un robot colaborativo UR el cual cuenta con 6 DOF, el diseño de este consta de eslabones y articulaciones específicas para el ingreso del motor de paso NEMA17, un sistema planetario de engranajes el cual funciona como acople entre eslabones y articulaciones al igual que incrementa el torque en cada articulación, en el extremo del robot tenemos unas pinzas cuyo diseño cuenta con 4 enganches y un acople para la última articulación del robot.

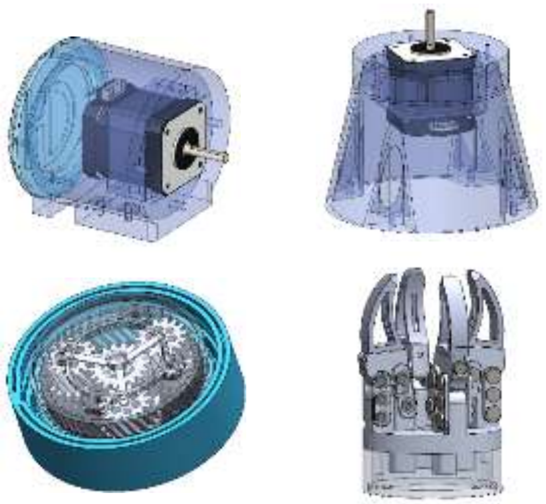


Fig. 3. P Diseño de Eslabón, Base, Sistema Planetario y herramienta del robot manipulador

1) Mechanical System

Fue diseñado en SolidWorks con el propósito de ser implementado utilizando filamento ABS, ya que tiene la máxima resistencia a la tracción (41 a 45 MPa) y se fabricará utilizando una impresora 3D. Además, está compuesto por 6 eslabones: base, hombro, parte superior del brazo, parte inferior del brazo, 1 pinza como herramienta y 6 articulaciones ($\theta_1,\theta_2,\theta_3,\theta_4,\theta_5,\theta_6$). La Fig. 4 muestra los parámetros de Denavit Hartenberg (D-H) del brazo robótico colaborativo 6 DoF.

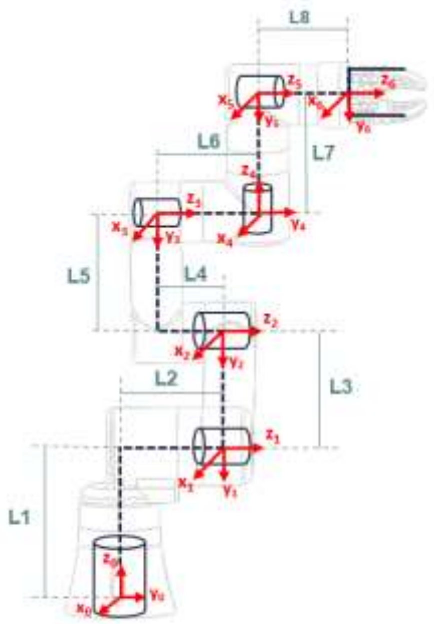


Fig. 4. D-H Parameters

Besides, the structural calculation, torques and maximum energy consumption were carried out, considering a maximum load of 1 Kg. Which generated results between 0.071 to 59.32 Kg-cm of torque and 0.02 to 5 Watts of power consumption. In addition, in Fig. 5 the Control Box of the robotic arm is shown, which is composed of a joystick and 2 buttons that allow the dynamic motion in order to develop some tasks showed in Test and Results section.

Link (i)	Kinematic Parameters			
	θ_i	d_i	α_i	α_i
1	q_1	l_1	l_2	-90°
2	q_2	0	l_3	0
3	q_3	l_4	l_5	0
4	q_4	l_6	0	90°
5	q_5	l_7	0	-90°
6	q_6	l_8	0	0

Fig. 5. Parámetros de Cinemática

2) Control and Hardware

Fig. 6 shows the Control Box functions of each button and joystick. The B1 button allows changing the control of the joints (A1, A2, A3, A4) with the axis X and axis Y of the joystick. Button B2 allows the gripper tool (A5) to be opened and closed, and the robotic arm to be placed in the initial position.

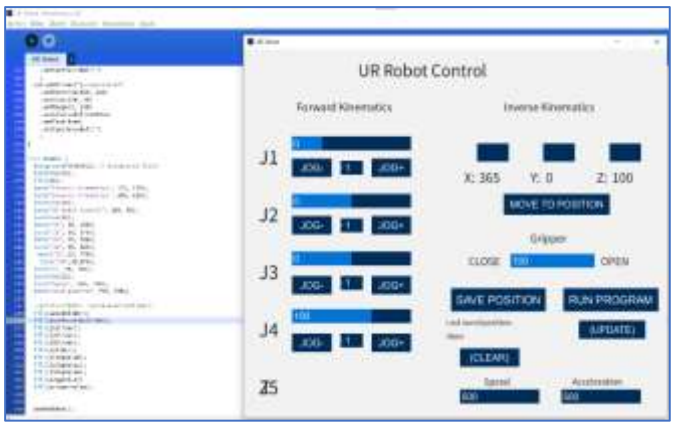


Fig. 6. Control Box functions

3) Electrical and Electronic System

The total energy consumption of 8.4 Watts/hour, considering a continuous operating time of 8 hours and the total power consumption of approximately 74 Watts were analyzed. This was calculated through a motion study tools of SolidWorks. In the other hand, Arduino Micro was chosen as a development board due to size and portability, which allowed the compact hardware design of the Control Box. Also, Fritzing was used to design the schematic diagram.

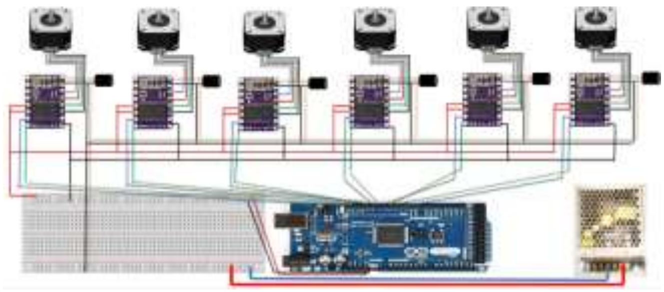


Fig. 7. Electrical-Electronic Schematic Diagram design

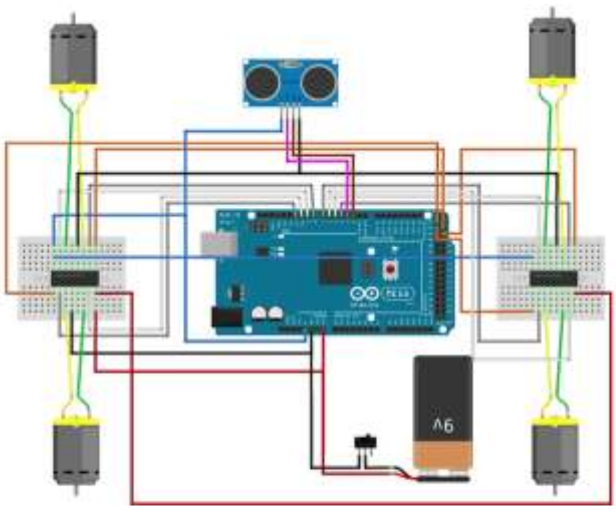


Fig. 8. Electrical-Electronic Schematic Diagram design

4) Mathematical Modeling and Simulation

Table I shows the parameters for all joints, calculated using Denavit-Hartenberg (D-H) that are intended to describe the location of the end effector.

TABLE I. D-H PARAMETERS

Cinemática Directa 6 DOF

```
syms theta1 L1 L2 theta2 L3 theta3 L4 L5 theta4 L6 theta5 L7 theta6 L8
PI=sym('pi')

% --------- Tabla ----------
T01=DH(theta1,L1,L2,-PI/2)
T12=DH(theta2,0,L3,0)
T23=DH(theta3,L4,L5,0)
T34=DH(theta4,L6,0,PI/2)
T45=DH(theta5,L7,0,-PI/2)
T56=DH(theta6,L8,0,0)

% Hallamos T la multiplicación de todas las matrices
T07=simplify(T01*T12*T23*T34*T45*T56)

% Posición (desplazamiento)
X=simplify(T07(1,4))
Y=simplify(T07(2,4))
Z=simplify(T07(3,4))
```

In order to build the mechanisms, the ABS - 3D printed material was selected. Besides, the analysis of stress, torques and power consumption were carried out using maximum load of 1 Kg to calculate the maximum values required by the servomotors [28], [29].

```
% *****************************************************************
% ***********************CONTROL DE TRAYECTORIA*********************
% *****************************************************************

%Condiciones de tiempo
clc; clear all; close all;
ts=15;            %[s] Tiempo de simulación
avance=0.05;      %[s] Intervalo de tiempo
t=[0:avance:ts]; %Vector tiempo

%Variables globales
global r L l

%Posicion inicial
xp(1)=0.8;          %[m]
yp(1)=-0.7;          %[m]
wo=180*pi/180;  %[rad]

%Posición deseada
xd=2*cos(t);    %[m]
yd=1.5*sin(2*t);  %[m]
wd=0*t;       %[rad]

%Velocidad deseada (Derivada de la posición)
vxd=-2*sin(t);  %[m/s]
vyd=3*cos(2*t); %[m/s]
vwd=0*t;      %[rad/s]

%Parámetros del robot
r=0.03;       % [m] radio de las ruedas
L=0.09;       % [m] distancia vertical desde el eje inercial al centro de las ruedas
l=0.095;      % [m] distancia horizontal desde el eje inercial al centro de las ruedas

n=length(t);    %Longitud del vector tiempo

%Condiciones iniciales del sistema
hx(1)=xp(1);
hy(1)=yp(1);
hw(1)=wo;
```

A) Programa en MATLAB para el trazado de trayectoria para un robot móvil omnidireccional

To estimate the maximum torques and power consumption corresponding to each servomotor of the robotic arm, SolidWorks motion study tool was used, for this, the robotic arm was assembled, material properties were assigned to each component, also movement sequence was configured. Fig. 9 shows the curve of the torque and Fig. 10 shows the power curve in Watts required by the servomotor during movement, the respective maximum value being 5817 N-mm. and 5 Watts.

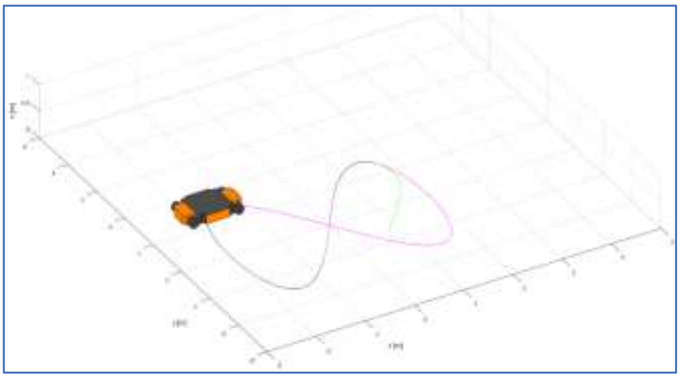


Fig. 9. Torque curve by Servomotor 2 (Joint 2)

Table III shows all the power consumption and maximum torque results of all the servo motors of the robotic arm. Where the shoulder shows the maximum values.

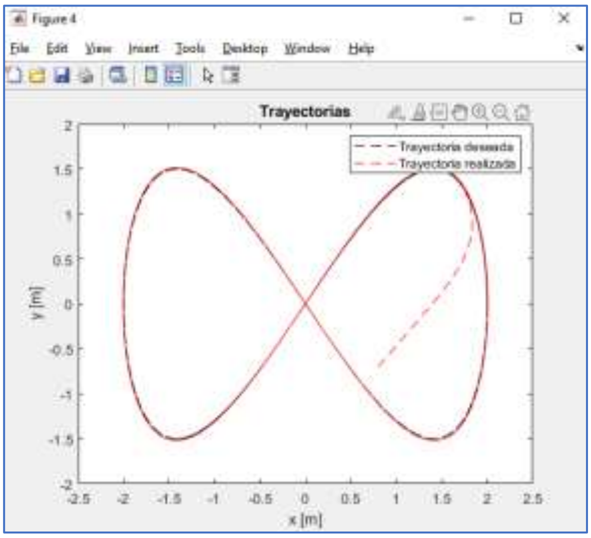
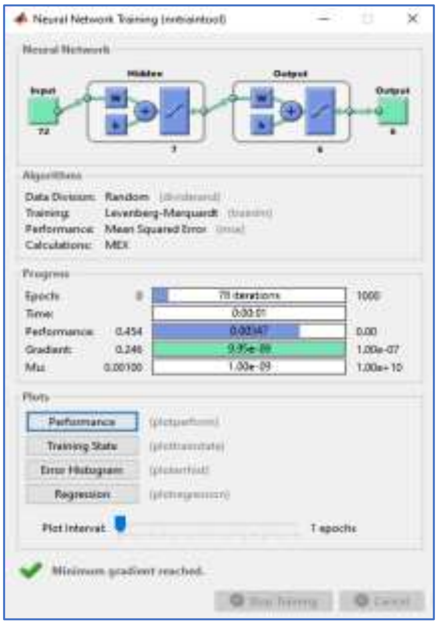


Fig. 7. Trayectoria del robot móvil

B) Red Neuronal en MATLAB para configurar patrones e identificar objetos mecánicos con formas mecánicas

The Data Acquisition System is comprised of two parts, based on IoT characteristics. The First one, receives information from the main sensors through an Arduino ADK [11]. The Second one, which is a modular master-slave configuration that allowing flexibility to add or remove a sensor without impacting the global data acquisition system.



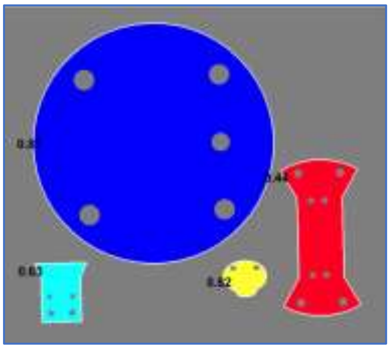


Fig. 7. Navigation Control System.

VII. Conclusion and Further Work

The Terrestrial Mobile Robot: "MineBot" made of Open Source Teleoperation Technologies was successfully designed and implemented, along with the ability to detect and monitor the environmental parameters inside Underground Mine Analogues. The robot has been tested to move on slopes of up to 20° on irregular and unstable terrains [21] and its locomotion system based on tracks allows the improvement of the traction system. Likewise, the measured parameters proved to be very helpful in the analysis of Environmental Analytic Reports, as well as the identification of safe areas [22]. Future work suggests the utilization of commercial clouds such as Google Cloud Platform, Amazon Web Services and Azure (IoT Platforms) with the purpose of a flexible and high availability access to information from any place of the world [23].

The full Project Documentation was published by his author: Cesar J. Muñoz Martinez at the Ricardo Palma University [8].

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