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Robot Humanoid Design & Prototype with Artificial Intelligence

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Abstract–This project addresses issues of design and development of a prototype of a humanoid robot with interactive movements, feedback control, and detection systems based on the open-source platform of Inmoov. The robot is designed in a way that can perform fluid movements naturally in the arms, fingers, and neck. By integrating advanced technologies such as artificial intelligence through OpenAI's GPT, the robot achieves computer vision capabilities using a stereo camera with depth sensing, specifically the Oak-D with Depth AI. These different technological supports allow the robot to recognize, identify and manage to respond to its environment with interpretation and reading of gestures, voice commands, thus offering a more rewarding experience as a fluid interaction in a personalized way. All the complementation of work implementing a customized and efficient control system for the management of servo motors using programmable modules such as PCA9685 optimizing the accuracy of movements, good skill with care to perform the calibrations.

Key Words-- Humanoid Robotics, Artificial Intelligence, Recognition, Open Source, Neural Networks.

I. Introduction

This project develops an Inmoov robot prototype, arm, neck and finger movement capabilities as a simulation of natural movements by means of controllers for servomotor drive [20]. The integration of artificial intelligence based on ChatGPT with environment recognition with gestures using the Oak-D camera with Depth AI [8]. The project brings together knowledge and technologies of robotics, AI and computer vision for a breakthrough in robotics. It is a technical challenge with certain limitations of many open-source applications with little information and a need to opt for new and creative accessible solutions to make it work the right way in various environments [14]. The project intends to address a broad knowledge from robot design to mechanical operation, programming and fully functional electronics. By overcoming these challenges, the project provides insights into improving affordability and functionality in humanoid robotics for versatile applications [18].

The project aims to optimize the power supply connections always following the attributes of electrical resistance, device control, correct handling of actuators, data flow to improve the efficiency of the system [10]. Addressing challenges with the calibration of servomotors and synchronization of movements with programming [6]. It is intended to make an interactive prototype with natural and fluid movements with the environment in which it is located as a good solid base for future applications and improvements in the future [15].

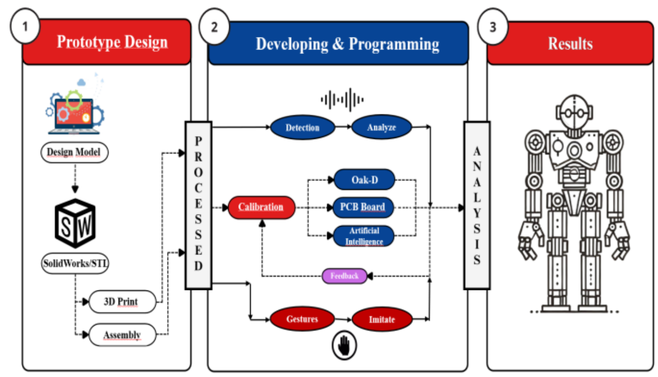

Fig. 1 Shows the full development cycle of a robotic system, starting with prototype design using CAD and 3D printing, followed by programming and integration of components like sensors, AI, and calibration, and ending with the final result: a fully functional robot.

Nowadays, technological advances have improved the levels of automation and improved sporadic transparency with human interactions. A very important design consideration for robots is the addition of transparency with elderly people and the ability to offer them support services based on human guidelines and activities [15]. In special cases, robotic mimicry-oriented algorithms have been developed to imitate on human behavior such as the analysis of officials in an environment have been developed. Currently, proactive robots with human behavior perception can replicate human characteristics with physical aspects of movement, word movements, identification of facial expressions that evolve with the adaptive environment [14].

II. Method

The arduous research of this project is based on the complex development of a humanoid robot with a complex design and functionality trying to mimic movements, as well as significant advances in recent years [7]. In computational systems studies, the research process of acquiring a computational view of the real world for incorporation into a robot can be done in different ways based on different degrees of complexity. The incorporation of an environment recognition camera such as the OAK-D gives an open view and various possibilities of being able to detect gestures, movements in the form of greetings and interaction with the environment itself.

A. V Model

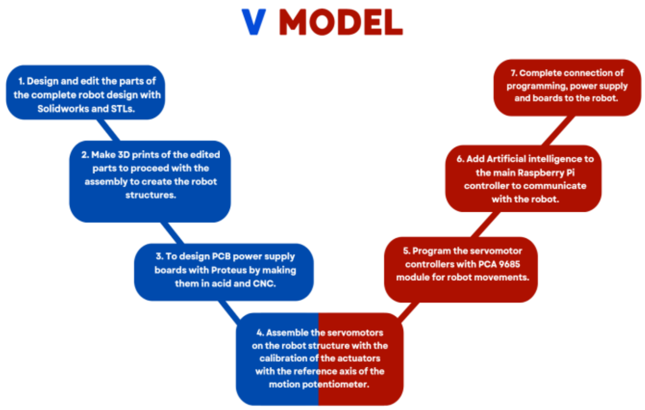

Fig. 2 Outlines the structured development process of a robotic system using the V model, starting with the design and 3D printing of robot parts, followed by PCB board creation, actuator assembly, and calibration. It then transitions to programming controllers, integrating artificial intelligence, and finalizing the complete connection of components to deliver a fully functional robot.

It should be noted that with the support of the open-source platform Inmoov is able to facilitate the research, as well as the electronic components and control systems for the implementation of movements [9]. However, part of its purpose lies in the recognition and interaction with users around it with an open gap to better and add new technical challenges to the project [14].

It was based on the V-model at the time of applying the whole process of creation of the robot, from the idea to the final product [15]. The V-model as a study methodology is based on engineering applications for the development and validation of projects to be carried out, characterized by the structured approach and monitoring of the main stages of development. Everything starts from the definition of initial specifications such as identifying the need for the project and the possible control systems for it [3]. Develop the design of how the system architecture will be, subsystems, components, materials, controllers, sensing modules, actuators and more. The intermediate stage is the phase of construction and prototyping from the construction or printing of parts, procurement and verification of components, making control modules, creating the robot itself [1]. The last stage is the phase of testing and operation of the product.

B. Techniques and Instruments Applied

- SolidWorks: The project started with the design part, modeling, making an idea and putting it into a computer aided digital design software, among them is SolidWorks, which is the design program used [15].
- Arduino IDE: It is a platform designed to perform programming for modules, sensors, controllers of the Arduino brand and even an open chain of electronic components for the facilitation of microcontroller programming [1].
- Prusa Slicer: All the part of the physical component, the designs made, all the pieces to assemble in 3D are made with the configuration of the printer that we are going to use to print all the pieces such as the Prusa MK4 printers [14].
- Proteus Professional: Because we make PCB boards for robot control, we use specialized digital and electronic design software [19].
- Visual Studio Code (Python): A high-level programming language used by many users for various general purposes with an accessible syntax and different versatility used in a wide range of applications from data science, artificial intelligence, education, electronics and process automation [2].

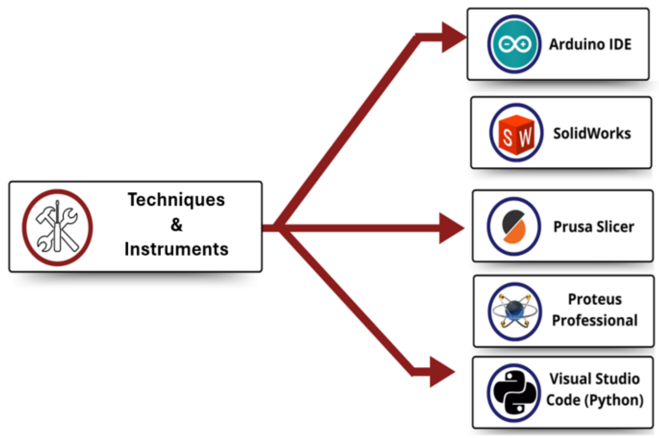

Fig. 3 Techniques & Instruments used in the process

C. Materials

- PLA Filament: The main material by which the physical base is made and all the material by which it is composed is PLA (Polylactic Acid) type filament which is used in 3D printers to make the parts modeled in SolidWorks in physical 3D format [5].
- Servomotors: The movements to be performed on the robot such as arm, finger, neck and wrist movements [10].
- 12V and 24V Power Supply: It is an electronic device whose purpose is simple as to supply electrical energy by converting the alternating current (AC) of the electrical network of an installation into direct current (DC) for a voltage of 12v and another source of 24v [16].

- 12V and 24V Voltage Regulators: It is an electronic device to moderate the voltage obtained from a power supply source [19].
- PCB Boards: These are boards with a structure designed to connect and support electronic components in a physical, mountable and electrical function [1].
- PCA9685 module: It is an Arduino module used to control the PWM (Pulse Width Modulation) signals that indicate which position the servomotors will be moving with guided programming support [13].
- Arduino Uno and Mega (2560): It is a device as a hardware platform with open-source programming software to facilitate the creation of projects of different levels of complexity and magnitudes of interactive projects with electronics [1].
- Oak-D lite: An adaptive interface recognition camera with Depth Al designed with advanced technologies for robotic subjects.
- Raspberry PI: It is a device with a low-cost computer-like capability, capable of performing various electronic, personal, educational and industrial applications in different jobs and projects [2].

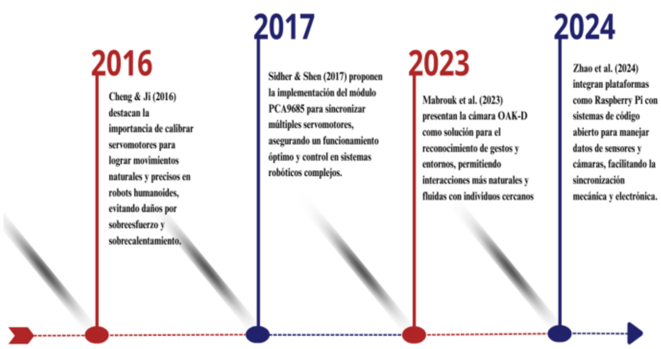

Fig. 4 Background of the topic

In the development of robots with humanoid features with the intention of mimicking human movements as the example of the open source Inmoov for which it faces a series of obstacles to achieve the integration and configuration of servomotors for the function of movement of arms, neck with head and fingers of the hand. Along with devices and controllers such as the recognition camera known as Oak-D that recognizes gestures and movements identified connected to a Raspberry PI [4]. The configuration for the synchronization of the servomotors and the module to control the servomotors which is the PCA9685 must be done as a complex and not very accessible task limited by the different open-source applications and connection models as well as the way of operation. It is required solutions with moderate cost due to the magnitude of work with the due quality that emits as difficulty in diverse environments [11]. The project seeks to realize a more interactive operation with the environment and as a functional robot at an accessible and effective scale with its environment.

When working with humanoid robots, which in recent years has been a point of interest in the industry and technological advances allowing the creation of research programs, development of projects, prototypes and platforms such as Inmoov with years of experience in creating an open-source robot for development in various applications, educational systems and research in the field of robotics [18]. It should be noted, the integration of a system to control certain movements such as arms that must be in a specific position and adjust it with programming. Taking into consideration that another challenge is the part of recognizing an environment and interacting with it being one of the technical challenges to find accessible and adaptable solutions [6].

1) Direct Kinematics: It is used to calculate the position and orientation of the robot end (hands, fingers and neck) based on the angles of the joints.

$$\mathbf{T}_n^0 = \prod_{i=1}^{n} \mathbf{T}_i^{i-1} \tag{1}$$

$$\mathbf{T}_i^{i-1}$$

$$\begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & \sin\theta_i\sin\alpha_i & a_i\cos\theta_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & -\cos\theta_i\sin\alpha_i & a_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

$$x = L_1\cos(\theta_1) + L_2\cos(\theta_1+\theta_2) + L_3\cos(\theta_1+\theta_2+\theta_3)$$

$$y = L_1\sin(\theta_1) + L_2\sin(\theta_1+\theta_2) + L_3\sin(\theta_1+\theta_2+\theta_3)$$

Lengths: $L_1 = 0.29\,\text{m}$, $L_2 = 0.285\,\text{m}$, $L_3 = 0.19\,\text{m}$.

$$\theta_1 = 50^\circ = 0.873\,\text{rad}$$

$$\theta_2 = 60^\circ = 1.047\,\text{rad}$$

$$\theta_3 = 0^\circ = 0\,\text{rad}.$$

Calculating X:

$$x = 0.29\cos(0.873) + 0.285\cos(0.873+1.047) + 0.19\cos(0.873+1.047+0)$$

Calculating each term:

$$L_1\cos(\theta_1) = 0.29\cdot\cos(0.873)$$

$$L_2\cos(\theta_1+\theta_2) = 0.285\cdot\cos(0.873+1.047)$$

$$L_3\cos(\theta_1+\theta_2+\theta_3) = 0.19\cdot\cos(0.873+1.047+0)$$

First Term: $0.29\cdot\cos(50^\circ) = 0.186$

Second Term: $0.285\cdot\cos(110^\circ) = -0.097$

Third Term: $0.19\cdot\cos(110^\circ) = -0.064$

Result: $x = 0.024\,\text{m}$

Calculating Y:

$$y = 0.29\sin(0.873) + 0.285\sin(0.873 + 1.047) + 0.19\sin(0.873 + 1.047 + 0)$$

Calculating each term:

$$L_1\sin(\theta_1) = 0.29 \cdot \sin(0.873)$$

$$L_2\sin(\theta_1 + \theta_2) = 0.285 \cdot \sin(0.873 + 1.047)$$

$$L_3\sin(\theta_1 + \theta_2 + \theta_3) = 0.19 \cdot \sin(0.873 + 1.047 + 0)$$

Fist Term: $0.29 \cdot \sin(50^\circ) = 0.222$

Second Term: $0.285 \cdot \sin(110^\circ) = 0.267$

Third Term: $0.19 \cdot \sin(110^\circ) = 0.180$

Result: $y = 0.669\,\mathrm{m}$

2) Inverse Kinematics: It is used to determine the joint angles required to achieve a desired position.

$$\theta_i = f(x, y, z) \tag{3}$$

For θ2:

$$\cos(\theta_2) = \frac{x^2 + y^2 - L_1^2 - L_2^2}{2L_1L_2}$$

For θ1:

$$\theta_1 = \arctan\left(\frac{y}{x}\right) - \arctan\left(\frac{L_2\sin(\theta_2)}{L_1 + L_2\cos(\theta_2)}\right)$$

$$(x = L_1 + L_2 + L_3)$$

$$x = 0.5\ \mathrm{m}$$

$$y = 0.2\ \mathrm{m}$$

$$L_1 = 0.29\,\mathrm{m}, L_2 = 0.285\,\mathrm{m}$$

Calculating Cos (θ2):

$$\cos(\theta_2) = \frac{0.5^2 + 0.2^2 - 0.29^2 - 0.285^2}{2 \cdot 0.29 \cdot 0.285} = 0.754$$

Calculating θ2:

$$\theta_2 = \arccos(0.754) \approx 41.04^\circ$$

Calculating θ1:

$$\theta_1 = \arctan\left(\frac{0.2}{0.5}\right) - \arctan\left(\frac{0.285 \cdot \sin(41.04^\circ)}{0.29 + 0.285 \cdot \cos(41.04^\circ)}\right) \approx 1.47^\circ$$

θ_1: 1.47°

Results: θ_2: 41.04°

3) Dynamics: To analyze the forces and torques required to move the joints.

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = \tau_i \tag{4}$$

$$F = m \cdot a$$

Momento of Inertia:

$$I = m \cdot r^2$$

Torque:

$$\tau = I \cdot \alpha$$

Fingers

Mass: 0.3kg

Radio: $r = \frac{L_3}{2} = 0.095\,\mathrm{m}$

Force: F=0.3·6.67=2.001N

Moment of Inertia: I=0.3·0.0952=0.00271kg\m2

Angular Acceleration: $\alpha = 6.67/0.095 = 70.21\,\mathrm{rad/s^2}$

Torque: $\tau = 0.00271 \cdot 70.21 = 0.19\,\mathrm{Nm}$

Forearm

Mass: $m = 1.0\,\mathrm{kg}$

Radio: $r = \frac{L_2}{2} = 0.1425\,\mathrm{m}$

Force: $F = 1.0 \cdot 6.67 = 6.67\,\mathrm{N}$

Moment of Inertia: I=1.0·0.14252=0.02029kg\m2

Angular Acceleration: $\alpha = 6.67/0.1425 = 46.83\,\mathrm{rad/s^2}$

Torque: $\tau = 0.02029 \cdot 46.83 = 0.95\,\mathrm{Nm}$

Humerus

Mass: $m = 1.2\,\mathrm{kg}$

Radio: $r = \frac{L_1}{2} = 0.145\,\mathrm{m}$

Force: $F = 1.2 \cdot 6.67 = 8.004\,\mathrm{N}$

Moment of Inertia: I=1.2·0.1452=0.02526kg\m2

Angular Acceleration: $\alpha = 6.67/0.145 = 46.03\,\mathrm{rad/s^2}$

Torque: $\tau = 0.02526 \cdot 46.03 = 1.16\,\mathrm{Nm}$

4) Control PID: For the control of servomotors and closed-loop systems.

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t) \quad (5)$$

Proportional Gain:

$$K_p = 0.6 \cdot K_u$$

$$K_u = 0.5$$

$$K_p = 0.6 \cdot 0.5 = 0.3$$

Integral Gain:

$$K_i = \frac{2 \cdot K_p}{T_u}$$

$$T_u = 1$$

$$K_i = \frac{2 \cdot 0.3}{1} = 0.6$$

Derivative Gain:

$$K_d = \frac{K_p \cdot T_u}{8}$$

$$K_d = \frac{0.3 \cdot 1}{8} = 0.0375$$

5) Power and Energy: For calculate the energy consumption and efficiency of the motors.

$$P = \tau \cdot \omega \quad (6)$$

$$E = \tau \cdot \omega \cdot t$$

τ=80kg\cm=80·9.81·0.01=7.848Nm

Angular Speed: $\omega = \frac{\pi}{t} = \frac{\pi}{0.54} = 5.83\,\mathrm{rad/s}$

$$t = 0.54\,\mathrm{s}$$

Substituting:

$$E = 7.848 \cdot 5.83 \cdot 0.54 = 24.66\,\mathrm{J}$$

6) Visual Recognition and Neural Networks: Using the Oak-D camera, detection of gestures with the camera.

$$I'(x', y') = T(I(x, y)) \quad (7)$$

III. Results & Analysis

The previous board design shown previously is the analysis and track management of a PCB board, it is also the second control and power board that is being used for the operation of the robot [1]. The path to be used is very important from the design to the thickness of the tracks due to, as previously stated for consumption, and that the copper path is not lifted by the large amount of amperage consumed [19].

A. PCB Modeling

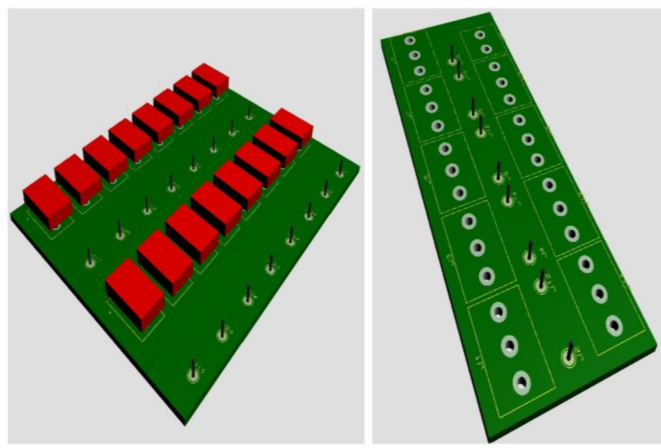

Fig. 5 PCB Design

A very important part are the electronic PCB boards that in this case we divided the power supply board due to the difference in the consumption of the servo motors, as we have large and small servo motors whose power supply is different [10]. Therefore, it is extremely important to divide the power supply on the PCB boards to avoid any problem in the commissioning [17].

The position of the servo motor has a unique feature compared to the rest of the robot: it is the only motor that is completely oriented downwards and, moreover, rotates together with the neck. Because of these characteristics, it is imperative to use a high-quality servomotor and to ensure that it operates with the correct voltage and current [7]. If these requirements are not met, the neck experiences excessively slow motion, affecting the functionality of the system. Since the mechanism uses gears, it is critical to properly grease them. This not only allows for smoother movement, but also reduces wear between parts, thus prolonging the life of the mechanism. In terms of operation, the mechanism is like that implemented in the wrist [9].

Open AI is the source we use for communication as an organization for thematic research of artificial intelligence used in research formats [5]. The objective of this organization is to promote artificial intelligence for further expansion of knowledge, applications, and different utilities that can be given to provide better benefits for technological advances in humanity. Artificial intelligence ensures a safe [15].

B. Dataset

For research, arm movements, due to limits and specific movements that must not exceed excess drive without damaging the robotic arm [17], the potentiometer of the servomotor is extracted, and a physical coupling is made in the robot arm gear as a reference axis for the movements to be performed. Each motor in which the potentiometer was disassembled was tested to find the set point with the 0 point of movement [6], we can denote if this is done correctly if the motor slows down and can make the change in rotation orientation [5].

A very important base in the electronics to have feedback in the control system is the programmable part that we send to call the pin where the servomotors are connected [7].

In the development of the project with the humanoid robot prototype that is based on the open source Inmoov platform posing several technical challenges and mechanical aspects to consider during its assembly process and power supply is why comprehensive solutions are required [12]. Due to the control systems with the main difficulties with the accuracy of motion control and synchronize these movements with the allowable limit that have the servomotors. The solution is to implement a control module such as the PCA9685 module for simultaneous and automatic handling of the robot [3].

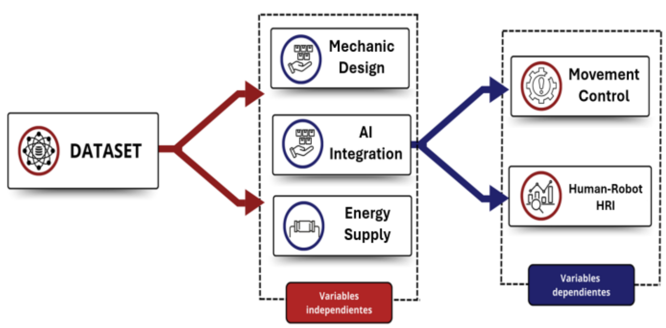

Fig. 6 Dataset Design the structure of a robotics dataset, where independent variables—such as mechanical design, AI integration, and energy supply—are used to influence and predict dependent variables, including movement control and human-robot interaction (HRI), enabling comprehensive system analysis and optimization.

C. Artificial Intelligence and Programming

A control system was implemented that allows interaction between the robot and a Python program, with the ability to receive voice commands, process them, and execute specific movements [17]. This system ensures that the movements are precise, synchronized and respond appropriately to the commands received by the user [13].

Extensive testing was performed to ensure synchronization between the Python-generated voice response and the physical movements of the robot [11]. The system was tested with different commands and timing was adjusted to achieve fluidity in movements and interaction [15]. The part of voice recognition that the audio input to be the microphone that in our case we use a microphone of the shure brand with support to hold it that is banked, it should be emphasized that the microphone represents the user's voice [13].

The project is composed by synergic union as the aggregation of artificial intelligence to make a more interactive robot and its HRI interaction more advanced and natural [12]. The artificial intelligence we are working with is the use of reference code to call ChatGPT to establish an assertive communication with the robot using speakers and a recognition microphone [4].

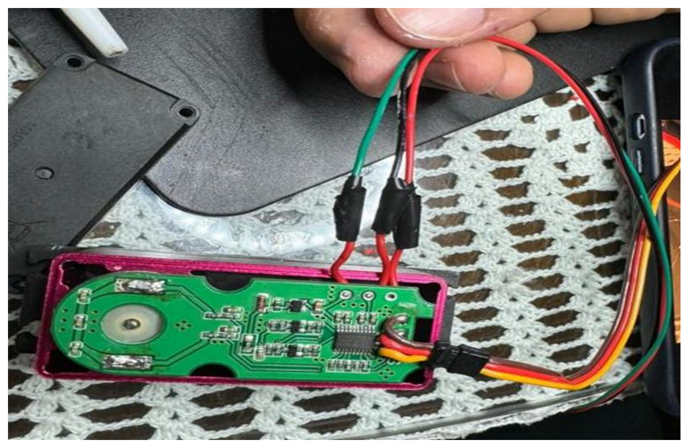

Fig. 7 Servomotor Arrangement

A Python program that combines several technologies was used:

- Speech recognition: Captures and transcribes user's voice [6].
- OpenAI API: Interprets spoken commands and generates customized responses [9].
- Serial: Links the program with the Arduino to transmit commands in real time [19].

The part of voice recognition that the audio input to be the microphone in our case we use a microphone of the shure brand with support to hold it that is banked, it should be emphasized that the microphone represents the user's voice [14].

The developed system achieved a functional integration between voice processing and robot control. Movements are natural and precise, synchronized with the user's commands [18]. In addition, real-time communication ensures an efficient and robust interactive experience [7].

The voice recognition process is through the input, it converts the audio to text so that the chatbot can interpret it and perform the programmed commands for communication in response to the robot and the programmed physical movement to be performed [15]. The processing part, also called AI processing, implies that the information from the microphone is passed to the AI to be analyzed and processed in turn [12].

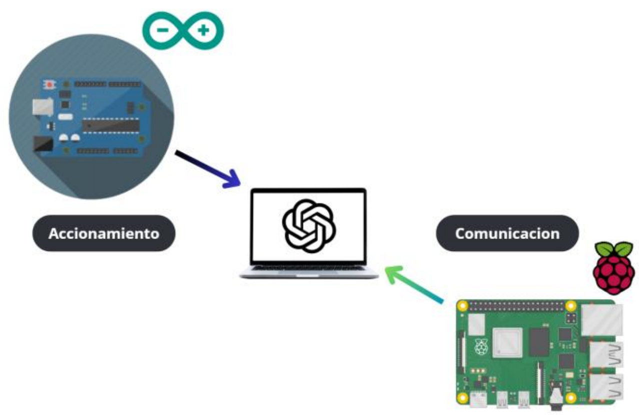

Fig. 8 Arduino and Raspberry Pi Connection

D. Gesture Recognition

The above model shown is based on coding Python code with Visual Studio Code in which the GPT creates a GPT code that is generating a code with respect to the question or interaction that is being performed with its surroundings or a particular user [11]. This system is powered by GitHub copilot tuning tools in the code developers and completing more complex functions [4]. A platform as mentioned above is the Open AI AP integrated by advanced AI capabilities in modeling applications such as intelligent chatbots, automatic content generation, and data analysis with respect to the language it interprets [15]. It should be emphasized that the project was designed for educational purposes and therefore it is important to consider the use of safe and ethical artificial intelligence to mitigate risks associated with advanced systems [18].

As a key feature of the Oak-D lite is that it is a stereo camera that can calculate the depth at which an object of interest is located, especially if it is a 3D depth allowing to visualize what is in the environment measured by a permitted distance [2], it should be emphasized that all this data analysis on the screen that is capturing the camera is in real time, performing tasks such as detection, tracking and reconstruction of the environment [8]. Among the applicable model supports such as object detection, facial recognition, motion tracking and in certain aspects such as image classification or reconstruction [3]. Being the objective of the project the part of tracking the object of the hands and detection of hand gestures [7].

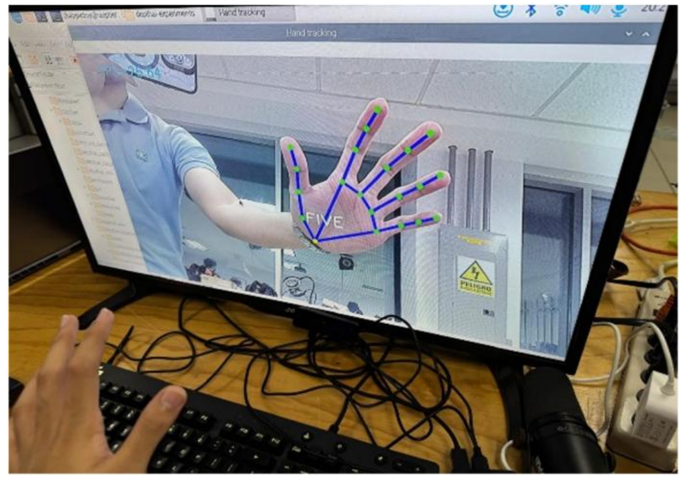

Fig. 9 Gesture Recognition with Oak-D lite

The main objective of the Oak-D camera is not only to track the object and detect it as such, but it also must be given a feedback application in the robot so that it can interact with the surrounding media [13]. The function was implemented in the neural network to detect gestures in the hands visualize the gesture and are seen on the screen as shown in the figure [6].

E. Advanced System Control

The programming that was done in Arduino is for the set part of the movements of the servomotors. As previously mentioned, the movement of the servomotors has a reference axis to put a limit on the movements of the robot, because if the servomotors move more than necessary [20], the problem of calibration is reached, the arms are recalibrated especially because only the large servomotors of 80 kg were removed the potentiometers to have the reference of limits that usually in the design of the robot are placed as a set of gears for the potentiometers to move in relation to the movement of the servomotors [17].

The most complex and interactive part of the robot is the implementation of advanced technologies, such as computer vision with the Oak-D lite camera and the integration of artificial intelligence through GPT code with the Open AI module, allowing a closer interaction with the robot, such as communication with it [2].

The importance of the diagram is for future generations that continue working on the robot model so they can have a reference of how is the schematic of connections such as the voltage supply sources that we have 12v and 24v of 20 amps for the capacity required by the servomotors [6}, the direct connection to the servomotors is made and would be completed all the connection required by the robot, adding the Oak-D camera that is directly connected to the raspberry PI [19].

Fig. 10 Complete Robot

IV. Conclusions

In summary, we can denote all the methodology involved in the development of a robot demonstrating a technical challenge with many electronic components integrated to form a feedback control system. It should be emphasized that open-source platforms allow us to better realize an idea by simplifying design tasks, knowing which controller to use and allowing advances in robotics research. The focus of the project is to perform movements and mimic human behavior and fluidity.

The development of the control and interaction system for the robot demonstrates the feasibility of integrating advanced technologies such as voice processing and microcontroller programming to create dynamic and functional solutions. The joint implementation of Python and Arduino allowed not only to control the robot's movements, but also to establish an interactive experience, where simple voice commands such as “Hello Hello” trigger precise physical responses.

As part of future work, this robot could be implemented as an educational tool to assist in teaching robotics-related subjects and to actively support students in the development of their research projects, fostering innovation and hands-on learning [21-22].

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References

[1] Jaeuk Cho, Dongwoon Choi, and Jong Hyeon Park. Sensor less Variable Admittance Control for Human–Robot Interaction of a Dual-Arm Social Robot. IEEE Access, 2023. Conference Name: IEEE Access.

[2] Dipankar Das, Md. Golam Rashed, Yoshinori Kobayashi, and Yoshinori Kuno. Supporting Human–Robot Interaction Based on the Level of Visual Focus of Attention. IEEE Transactions on Human-Machine Systems, December 2015. Number: 6 Conference Name: IEEE Transactions on Human-Machine Systems.

[3] Malcolm Doering, Dylan F. Glas, and Hiroshi Ishiguro. Modeling Interaction Structure for Robot Imitation Learning of Human Social Behavior. IEEE Transactions on Human-Machine Systems, June 2019. Number: 3 Conference Name: IEEE Transactions on Human-Machine Systems.

[4] Jiangfei Duan, Xiuhong Li, Ping Xu, Xingcheng Zhang, Shengen Yan, Yun Liang, and Dahua Lin. Proteus: Simulating the Performance of Distributed DNN Training. IEEE Transactions on Parallel and Distributed Systems, October 2024. Conference Name: IEEE Transactions on Parallel and Distributed Systems.

[5] Shanshan Jiao, Jiabao Wang, Guyu Hu, Zhisong Pan, Lin Du, and Jin Zhang. Joint Attention Mechanism for Person Re-Identification. IEEE Access, 2019. Conference Name: IEEE Access.

[6] Lihua Lei, Zhangning Xie, Huichen Zhu, Yuqing Guan, Ming Kong, Bo Zhang, and Yunxia Fu. Improved Particle Swarm Optimization Algorithm Based on a Three-Dimensional Convex Hull for Fitting a Screw Thread Central Axis. IEEE Access, 2021. Conference Name: IEEE Access.

[7] Giacomo Lunghi, Raul Marin, Mario Di Castro, Alessandro Masi, and Pedro J. Sanz. Multimodal Human-Robot Interface for Accessible Remote Robotic Interventions in Hazardous Environments. IEEE Access, 2019. Conference Name: IEEE Access.

[8] Jubayer Al Mahmud, Bandhan Chandra Das, Jungpil Shin, Khan Md. Hasib, Rifat Sadik, and M. F. Mridha. 3D Gesture Recognition and Adaptation for Human–Robot Interaction. IEEE Access, 2022. Conference Name: IEEE Access.

[9] Stanley Mugisha, Vamsi Krishna Guda, Christine Chevallereau, Damien Chablat, and Matteo Zoppi. Motion Prediction with Gaussian Processes for Safe Human–Robot Interaction in Virtual Environments. IEEE Access, 2024. Conference Name: IEEE Access.

[10] Yinghao Ning, Yifan Liu, Fengfeng Xi, Ke Huang, and Bing Li. Human-Robot Interaction Control for Robot Driven by Variable Stiffness Actuator with Force Self-Sensing. IEEE Access, 2021. Conference Name: IEEE Access.

[11] Kyeong-Beom Park, Sung Ho Choi, Jae Yeol Lee, Yalda Ghasemi, Mustafa Mohammed, and Heejin Jeong. Hands-Free Human–Robot Interaction Using Multimodal Gestures and Deep Learning in Wearable Mixed Reality. IEEE Access, 2021. Conference Name: IEEE Access.

[12] Anees Peringal, Mohamad Chehadeh, Rana Azzam, Mahmoud Hamandi, Igor Boiko, and Yahya Zweiri. Design of Dynamics Invariant LSTM for Touch Based Human–UAV Interaction Detection. IEEE Access, 2022. Conference Name: IEEE Access.

[13] Silvia Rossi, Alessia Coppola, Mariachiara Gaita, and Alessandra Rossi. Human–Robot Interaction Video Sequencing Task (HRIVST) for Robot’s Behavior Legibility. IEEE Transactions on Human-Machine Systems, December 2023. Number: 6 Conference Name: IEEE Transactions on Human-Machine Systems.

[14]Chapa Sirithunge, A. G. Buddhika P. Jayasekara, and D. P. Chandima. Proactive Robots with the Perception of Nonverbal Human Behavior: A Review. IEEE Access, 2019. Conference Name: IEEE Access.
[15]Yuchuang Tong, Haotian Liu, and Zhengtao Zhang. Advancements in Humanoid Robots: A Comprehensive Review and Future Prospects. IEEE/CAA Journal of Automatica Sinica, 2024. Publisher: IEEE/CAA Journal of Automatica Sinica.
[16]Yafeng Wang and Tiefu Zhao. A High-Efficiency Low-Wearing Hybrid Voltage Regulator for Utility Applications. IEEE Open Journal of Industry Applications, 2023. Conference Name: IEEE Open Journal of Industry Applications.
[17]Yuan Wei. A Comprehensive Approach to the Generation of Human-Like Arm Movements on Robot NAO. IEEE Access, 2020. Conference Name: IEEE Access.
[18]Ze-Feng Zhan and Han-Pang Huang. Imitation System of Humanoid Robots and Its Applications. IEEE Open Journal of Circuits and Systems, 2023. Conference Name: IEEE Open Journal of Circuits and Systems.
[19]Xue Zhao, Xiaoan Chen, Ye He, Hongli Cao, and Tianchi Chen. Varying Speed Rate Controller for Human–Robot Teleoperation Based on Muscle Electrical Signals. IEEE Access, 2019. Conference Name: IEEE Access.
[20]Petr ˇC´ıˇzek, Martin Zoula, and Jan Faigl. Design, Construction, and Rough-Terrain Locomotion Control of Novel Hexapod Walking Robot with Four Degrees of Freedom Per Leg. IEEE Access, 2021. Conference Name: IEEE Access.
[21]M. G. O. Avila, J. L. O. Avila, J. A. Salinas, L. A. A. Medina and N. A. L. Zelaya, "Design and application of a digital platform for university entrepreneurship in San Pedro Sula," 2020 IEEE World Conference on Engineering Education (EDUNINE), Bogota, Colombia, 2020, pp. 1-6, doi: 10.1109/EDUNINE48860.2020.9149504.
[22]J. R. Caballero Castellanos, M. Cardona and J. L. Ordoñez-Avila, "Chatbot for Validation of Research Topics for Engineering Students," 2023 IEEE 41st Central America and Panama Convention (CONCAPAN XLI), Tegucigalpa, Honduras, 2023, pp. 1-5, doi: 10.1109/CONCAPANXLI59599.2023.10517536.