Rotational & Controlled Mechanism and transmission system for camera scanner

1st Carlos D. López-Montero
Engineering and Science department
Tecnológico de Monterrey
Monterrey, México
A01024473@tec.mx

Abstract—**Among the services offered by Multitaskr, they perform 3D manual scanning of rooms using a camera. To improve their processes, a novel approach to automate this task by developing a mobile and foldable platform is shown through this paper. The approach is composed of a mobile platform that incorporates a robotic system that aims to improve efficiency and flexibility via the incorporation of a system of two degrees of freedom, allowing precise modification of the camera's Yaw and Pitch positions within a range of 360 degrees and -45 to 45 degrees respectively with an error less than 0.1 degree. The system offers mobility and adaptability to various room sizes and configurations thanks to its adaptable tripod where the platform is mounted. Experimental results demonstrate the effectiveness of the automated positioning of the camera. This approach enhances productivity and reduces manual effort on the process while still requiring human interaction to promote an ethical automation solution.**

Keywords—3D scanning, Automation, Robotic System, Mobile Platform, Camera positioning, 2 Degrees of Freedom, Process optimization.

I. INTRODUCTION

The automation of manual tasks in the context of tedious processes has gained significant attention due to its potential to improve efficiency and productivity while freeing resources for more important tasks. In this article, we present a novel approach to automate the manual scanning of rooms using a camera, with the aim of enhancing the processes offered by Multitaskr. The proposed approach revolves around the development of a mobile and foldable platform that incorporates a robotic system, enabling precise modification of the camera's Yaw and Pitch positions within a wide range of motion.

Manual scanning of rooms using a camera is a labor-intensive and time-consuming process. By introducing automation, we seek to streamline this task and achieve higher levels of efficiency and flexibility. The mobile platform, which serves as the foundation of our approach, offers enhanced mobility and adaptability to accommodate various room sizes and configurations. This adaptability is facilitated by the integration of a tripod mechanism that can have its height adjusted according to the specific requirements of the room being scanned; as well as having the ability via software to constrain the range of motion of the system to only scan areas of interest in a room.

The robotic system embedded within the platform introduces two degrees of freedom, allowing precise control over the camera's Yaw and Pitch positions. With a range of 360 degrees for Yaw and -45 to 45 degrees for Pitch, the system provides a comprehensive scope for capturing accurate and detailed room scans when paired with a camera designed for such tasks. The incorporation of this robotic system eliminates the need for manual intervention (to hold and move the camera) and enhances the overall efficiency and accuracy of the scanning process.

Through experimental evaluations, we demonstrate the effectiveness of our automated positioning system for the camera. The results showcase the system's capability to accurately modify the camera's position based on the desired Yaw and Pitch angles, enabling comprehensive room scanning without human intervention. This automated approach not only enhances productivity but also reduces manual effort, improving the overall efficiency of room scanning tasks. It is important to note that while our approach focuses on automation, it still requires human interaction to ensure ethical considerations are upheld. By involving humans in the process of commanding the system, we aim to create an ethical automation solution that balances efficiency gains with the preservation of human involvement and decision-making. This collaborative approach promotes a responsible and sustainable automation framework within the context of room scanning.

The rest of this article is organized as follows: Section II provides a review of the necessary concepts and research related to the components/technologies used for the solution design. Section III presents the detailed design and architecture of our proposed mobile and foldable platform, along with the integration of the robotic system. Section IV describes the experimental setup and methodology employed to evaluate the performance of our approach. In Section V, we present the results obtained from the experiments, highlighting the effectiveness and accuracy of our automated camera positioning system. Finally, Section VI concludes the article by summarizing the key findings and discussing future directions for research and development in the field of automated room scanning.

II. THEORIC FRAMEWORK

A. Electronics Division

A PCB, or Printed Circuit Board, is an electronic assembly that uses copper conductors to create electrical connections between components [1]. A PCB is generally based on a Schematic Diagram, which shows a component-level view and connections between them. [2]

Continuing with the key concepts a stepper motor is an electric brushless motor whose main feature is moving its shaft by a fixed number of degrees depending on the frequency of the electrical current pulses fed through its coils; all this is managed by a stepper motor controller, whose job is to take direction and step signal from the microcontroller and "translate" them into the adequate current and voltage waveforms for the motor [3][4].

Next is the microcontroller, which is a compact integrated circuit comprised of processor, memory and I/O peripherals on a single chip that's designed to act as an embedded circuit to control features on a system without the need for complex OS or PCs [5].

A voltage regulator, or more specifically, a Switching Voltage Regulator ensures a steady constant voltage supply by switching on and off a Flywheel Circuit (comprised of an inductor, capacitor, and diode) that can either be used to raise the voltage (in a boost configuration) or lower it (in a Buck configuration) [6].

A magnetic based encoder detects rotational position changes by measuring fluctuations of a magnetic field (generally provided by a radially magnetized magnet) via Hall elements phased 90° from each other and trigonometry theorems and Lissajous curves [7].

Finally, the following formulas were used to calculate power consumption and discharge times to validate the selection of the chosen power supply.

$$Voltage(V) * Current\ (A) * 0.15 = Watts\ with\ losses(W)\ [8] \ldots \text{(eq. 1)}$$

$$\frac{Capacity\ (Ah) * Voltage(V) * 0.9}{Watts\ (W)} = Discharge\ Time\ (Hrs)\ [9] \ldots \text{(eq. 2)}$$

DOE is a systematic and statistical method that's used to determine the relationship between factors/specifications and their effect on a process/product; it helps to structure/standardize testing while optimizing to obtain the desired results in as little as possible iterations [10]. This methodology was chosen mainly to reduce prototyping and reducing costs; however, a complete DOE couldn't be done as time constrains made it difficult to test multiple iterations of the PCB.

B. *Mechanics Division*

A slip ring is an electromechanical device that allows the transmission of power and electrical signals from a stationary to a rotating structure. [11]

A gear ratio is the ratio of the angular speed and torque of an input gear to the angular speed and torque of the output gear. A gear ratio may be calculated using the following formula. [12]

$$Gear\ ratio = \frac{No.of\ teeths\ on\ gear}{No\ of\ teeths\ on\ pinion} \ldots \text{(eq. 3)}$$

C. *Control and Programming Division*

For communication between the mobile application and the microcontroller, a WLAN network, or wireless local area network, was required. WLAN networks exchange information locally with all connected devices [13]. The network can transfer signals without any internet service or router since the selected microcontroller will generate it (Access point).

The stepper speed is controlled in the application using the metric of revolutions per minute, or RPM, so a conversion must be made. To perform this conversion, the following formulas were used:

$$\frac{Steps\ per\ second}{Steps\ per\ revolution} 60 = RPM \ldots \text{(eq. 4)}$$

III. DEVELOPMENT

A. *Electronics Division*

The main goals in this division were the design and manufacturing of the PCB to facilitate the integrations of the various electrical components and power supply (with the necessary regulatory and protective components). First, the necessary components needed to be identified to estimate the needed power supply and voltage regulators.

The selected motor and controllers are shown below. As additional information, it was decided to operate both the controllers and motor at 24V to maximize the torque available from the motors.

Component name	**Photo**	**Technical specifications**
Creality 42-20 Nema17 Motor		1.8-degree pitch angle Nominal Voltage of 3.9V Rated current 1A per phase (2A total) Nominal torque of 0.4 N*m
TB660		Motor voltage: 9V – 42V Logic voltage: 3.3V – 24V Amperage per phase: up to 3.5A Resolution: 1/2, 1/4, 1/8, 1/16 and 1/32 Protection against high temperature, thermal shutdown, short circuit, interference, polarity reversal and optocoupled control inputs

Table 1. Selected Motion Components.

After selecting the motion components, a few sensors were considered to provide feedback loops, enabling closed-loop control for the microcontroller, and having a method to define the home positions in the Yaw and Pitch axis, respectively. The sensor chosen for the Yaw axis is an AS5600 magnetic encoder and for the Pitch axis a simple Limit Switch is used to stablish a home position.

Component name	**Photo**	**Technical specifications**
AS5600		Input voltage: 3.3V – 5V Resolution: 4096 steps/0.1°
Limit Switch		None

Table 2. Feedback Sensors to be used.

Next, a microcontroller was selected; the main specifications that were followed for this was that said microcontroller required to natively have Wi-Fi and/or Bluetooth connectivity to stablish communication with a device and allow the system to be controlled remotely. Additionally, the microcontroller must have the necessary pins to communicate with the encoder, limit switch, and command the motor controllers; as an added value, It was also desired that the microcontroller could run a web server to simplify the control of the mechanism. As a result, the following microcontroller was chosen.

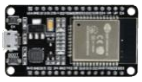
Component name	Photo	Technical specifications
ESP32 devkit V1		7 - 12V/GPIO @ 3.3V 25 GPIO pins of which 15 can be used as ADC, 25 as PWM, 2 DAC channels Wi-Fi 802.11 b/g/n/e/i Bluetooth 4.2 BR/EDR and BLE

Table 3. Selected Microcontroller

Finally, to end the electronic components selection phase the chosen battery and voltage regulators are shown. Run times and power consumption were calculated using equations 1 and 2 previously shown on the theorical framework section of this document.

Component	Voltage in Volts	Current in Amps	Watts
Motors (Controller Voltage)	24 (14.8V step-up)	7.45	110.4
Microcontroller	5 (14.8V step-down)	0.14	2.12
		Total Consumption	112.52
		Consumption with 50% margin (W)	168.78

Table 4. Calculated consumption of the electronical components

Configuration	Voltage (V)	Current (A) Nominal Peak	Capacity (Ah)	Discharge @ 114.59W (Hrs)	Discharge @ 171.88W (Hrs)
4S5P	14.8	11/22	11	1.27	0.85

Table 5. Technical Specifications of the chosen battery

Component name	Photo	Technical specifications
Elevador de Voltaje Boost 400W 15A		Input voltage: 8.5V – 50V Output voltage: 10V – 60V Output amperage: 15A maximum, 12A recommended Maximum output power: 400W Conversion efficiency: 96% Overcurrent protection, Output current regulation
LM2596 Regulador Step Down 25W 3A		Input voltage: 4V – 35V Output voltage: 10V – 60V Output amperage: 3A maximum, 2.5A recommended Maximum output power: 25W Conversion efficiency: 92% Overcurrent protection Output current regulation

Table 6. Voltage regulators for step up/down of voltage

After identifying the electrical components needed, a Schematic Diagram was generated on Eagle (A CAD software for electronic design) to visualize the necessary connections between all the components, as well as providing a template to generate the design of the PCB. As general guidelines, the Schematic was designed to provide easy connections from the microcontroller board to the sensors and motor controllers; also, the board has a power distribution section that allows to add fuses to critical components as the battery, voltage regulators and motor controllers.

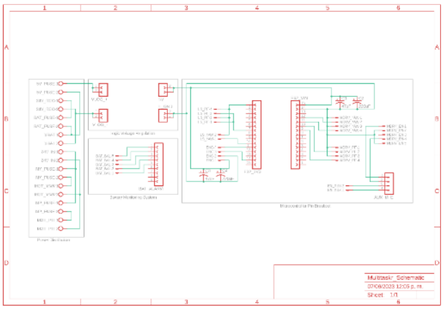


Figure 1. Daughterboard Schematics

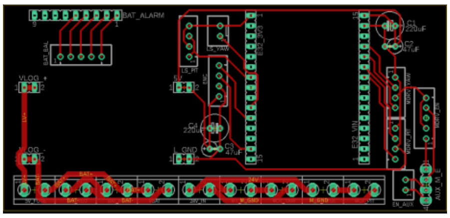


Figure 2. PCB Design

Finally, before conducting the tests; a prototype version of the PCB was manufactured using a Stripboard board and pieces of solid wiring. While the traces couldn´t be replicated, the functionality remains the same as the connections follow the ones stablished by the PCB design file.

Figure 3. Prototype PCB Top View

Figure 4. Prototype PCB Bottom View

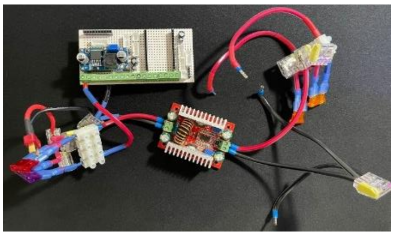


Figure 5. Prototype PCB with external Power Distribution circuit

GitHub link where relevant documents and further explanation can be found on this link: https://github.com/DanielMont15/Multitaskr-T1-Elec_Div

B. *Mechanics Division*

Throughout the project, the team used Solidworks as the main CAD software to model the system prior to manufacturing. By doing so, great time and money got to

be saved by realizing most of the prototyping and modifications first in a virtual space rather than reality. In the following paragraphs, the design process followed for obtaining the functional prototype presented is going to be elaborated upon.
The design process for the various mechanisms followed to ensure the righteous fulfillment of all the client's requirements got separated into the next steps:

(1) Brainstorming/ Mechanism proposal
(2) Selection of Actuators
(3) ActuatorValidation
(4) Design of the Mechanism
(5) Tripod Design
(6) Detailing and CAD assembly

1) Brainstorming/Mechanism proposal:

This was the very first step followed successfully identifying the project's variables. In this phase, the team reunited and discussed different mechanism ideas for the main problem presented, which was the controlled movement of a 4kg heavy box-like item around two degrees of freedom (pitch and yaw). Different ideas got discussed, but among them one stood out to all the team members. That idea was mounting an arm like structure to a disk. Such disk had to be able to turn 360° round by using an electric actuator. On top of the arm-like structure, a second actuator was going to be mounted. On the axis of such actuator, the camera was going to be mounted, and by controlling both actuators, we could eventually control both DOF we were requested. Such depiction stuck throughout the project, suffering some modifications but remaining mostly like the first idea.

2) Selection of Actuators:

Once the idea got green lighted via team consensus, the team worked on selecting the appropriate actuator to do the work. Since precise position control was required, the team decided on using stepper motors. After careful consideration, the Nema 17 were chosen for the task, but the torque provided was not enough for moving the heavy weights required, therefore, we settled on attaching a 10:1 planetary gearbox to the motor. Such gearbox was designed by PiotrChr and posted on the Thingiverse repertoire.[14] We 3D printed the gearbox using ASA, a plastic with favorable mechanical properties for such application.
Additionally, we decided to add a lazy Susan bearing to the main motor to lower the workload on the motor's shaft.

3) Actuator Validation.

To validate the selection of the actuator, gearbox and lazy Susan bearing, a test prototype was built, to which we loaded over 5 kg of weight. Such tests proved successful, therefore, with the information gathered, we proceeded to work on a final design of the mechanism that would provide the two degrees of freedom required.

4) Design of the Mechanism

Most of the parts for the mechanism were designed to be 3D printed as this provided great flexibility with the design and lowered complexity to the manufacturing. The most important elements of the design are the arm with the motor mount, the disk to which the arm is attached, the lazy Susan bearing, a slip ring (an electromechanical device that allow the connection of a set of fixed wire to wires that rotate around an axle without tangling), both motors and two halves of a cylindrical box structure to house all the electronics in the system. Also, the battery used for the project got modeled and inserted into the assembly and the motor drivers to validate the housing size was right for the system.

Also, the design team decided on adding 24 slotted windows for air circulation in the system. This was done since the heat generated by the motor drivers and the motors was high enough to present a risk of plastic meltdown if not enough air could circulate through the system.
Finally, fixing holes were added to the lower half of the housing to allow tripod fixation to the system.
The design team worked to great lanes to ensure the manufacturing and assembly of the system was as easy as possible as well as offering modularity as any change that may be implemented in the future can be done so without having to remanufacture the entire system.

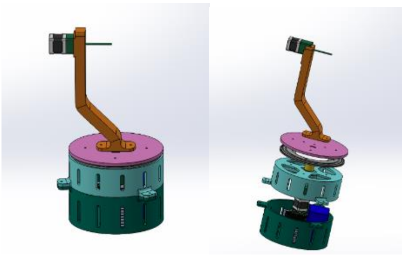


Figure 6 CAD image of the mechanism

5) Tripod Design

For designing the tripod, the team took inspiration in many commercially available tripods and worked on designing a version as cheap to manufacture as possible without compromising the structural integrity of the system. To do so, a total of 3 different diameters of PVC pipes were considered. Additionally, a set of 8 different 3D printable pieces were designed to work as links for the system as well as for a spring-loaded mechanism to ensure the system's height may be changed to the required in every case. For miscellaneous purposes, 5/16' screws and nuts were used all around the design.
One important part of this tripod's design was to ensure the client was offered some flexibility to the height to which the system was required to be and easy to handle. Therefore, the system may collapse for ease of transportation.

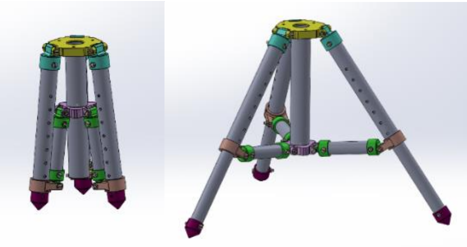


Figure 7 CAD image of the tripod

Then, a new CAD assembly was done that joined both the mechanism and the tripod. The integration of both worked smoothly. Additionally, a detailing process was done to each of the pieces designed to ensure all tolerances were right, as well as a verification to the correctness of all the geometrical mates that held the components together.
A final check to the system's height and diameter was done to ensure the design fulfilled the requirements provided by the client, which were able to hold the scanning device to an adjustable height between 90 cm to 105 cm.

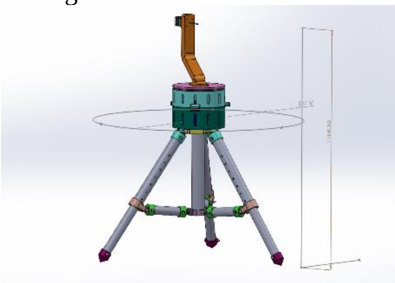


Figure 8 CAD assembly image

C. *Manufacturing of the mechanism*

To carry out the manufacturing of the system, 3D printing was selected since it was the manufacturing process that best suited the needs of the design, it was thought to use other types of manufacturing.
Some of the materials and manufacturing processes that were thought to be used were:

- MDF - laser cut.
- Metal - Machining

But these were discarded because the materials were more expensive, the manufacturing process was more complicated and time-consuming, or it simply limited the final design too much.
It was also decided to use 3D printing since if any part was damaged or damaged for any reason, replacing it was the easiest thing to do, this was also designed so that Multitaskr would have the possibility of manufacturing its own parts for any inconvenience.
For the 3D printing material, PLA and ASA were obtained. The PLA for the entire exterior part of the system, such as the casing and the tripod supports and the ASA for the manufacture of the gear boxes, it was decided to use this material since its mechanical properties are more resistant compared to PLA. For the manufacture of the tripod, it was decided to use PVC pipes as support, since these are resistant and cheap compared to any other material, likewise these were perfectly adjusted with the pieces that were manufactured in 3D.

D. *Control and codes*

Control and Code

For the development of the proposal, the needs of the training partner were analyzed. These needs consisted of a mobile application that allows control of the motors and changes their speeds (RPMs), all with the requirement of maintaining a maximum angular error of +-1°.

The team brainstormed how the app would communicate with their system and the programming language that would enable them to meet the expectations. Various communication methods were considered, given that it had to be wireless, including connection via Bluetooth, Wi-Fi, or WLAN (Wireless Local Area Network). Investigations were conducted on the development of applications using these connections, and the limitations associated with them were explored. Ultimately, it was determined that the WLAN connection would be used for three reasons:

- The WLAN connection allows the system to be controlled wirelessly without the need for internet service.
- As a web page is generated, it eliminates the need for storage space on the user's device.
- Any device with the capability to connect to a Wi-Fi network and a browser can control the system.

The ESP32, selected microcontroller, can be program in C++ or micro-Python and after investigating the available libraries and considering the project's requirements, micro-Python was selected as the programming language.

The control diagram was created before the program's development and served as the foundation for the code.

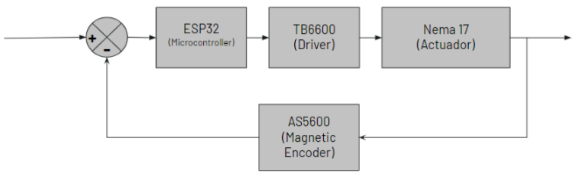


Figure 9 Control diagram

As evident, the system is designed to function as a closed loop, aiming to enhance angular precision through feedback from the magnetic encoder.

1) *Microcontroller Code:*

As mentioned earlier, the chosen programming language for the microcontroller was micro-Python due to its flexibility and extensive library catalog. The code was programmed to create an Access point and wait for a user to establish a connection. Once connected, the code generates a web page and waits for user input by pressing any button to execute the corresponding action.

The code consists of three functions, which are called based on the activated button. These functions are:

- Home: This function is triggered when the "zero" button is selected and is responsible for resetting the motors to their initial position while executing the sequence for the limit switch calibration.
- Activate_motor: This function is the main function as it sends instructions to the motors, including the direction of rotation and the desired angle of movement. It also includes instructions to modify the motors' speed.
- Web_page: This function retrieves the angles at which the motors are positioned and generates a web page displaying these values. It is crucial for the company to precisely observe the rotational position of the actuators.

Finally, all these functions are called within an infinite loop that continuously reads the URL of the web page and parses it to obtain user instructions.

2) Web app

Using the libraries available in Micro Python, the team was able to create a WLAN connection with the user. Additionally, by incorporating HTML code, the microcontroller could generate web pages that allow users to send signals to the microcontroller. The team focused on developing a user-friendly web page equipped with buttons for selecting the desired angle of movement, direction, speed, returning the motors to the starting position, and stopping their movement. After going through several design iterations and conducting rigorous functionality tests, the team achieved the following outcome:

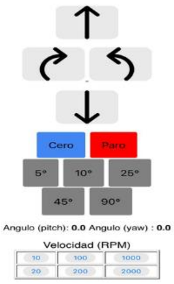


Figure 10 Final design of the web app

The web application features a range of buttons that modify the URL of the page, enabling the microcontroller code to receive and respond to the corresponding signals. Taking inspiration from 3D printer interfaces, the buttons are categorized into arrows, functions, angles, and speeds.

- Arrows: These buttons enable the user to send signals for motor movement at a specified number of degrees and a predetermined speed. The up and down arrows control the pitch, while the curved arrows control the yaw direction.
- Functions: The "zero" button returns both motors to the initial position, while the "stop" button halts their movement.
- Angles: These buttons restrict the number of degrees the motors should rotate.
- Speeds: In response to the training partner's request, buttons were added to modify the motor speeds, measured in revolutions per minute (RPM).

It's worth noting that the web page refreshes whenever any button is pressed. This functionality allows the immediate display of motor angles as soon as any movement is initiated.

GitHub link where the codes used in the prototype are found: https://github.com/EduardoMJ20/Multitaskr_eq1

IV. TESTS

A. Electronics Division

The chosen methodology for testing the electronic division work was DOE, or Design of Experiments.

Although a complete DOE couldn't be performed, the methodology was still used to determine the best manufacturing method that aligned with the team objectives and resources, while still maintaining a proper specification to be used on the prototype. As a result, the following factorial 3 by 2 factorial design was used (and marked on italics the manufacturing method that was selected).

Experiment	Factor 1: Component Connection Method	Factor 2: Soldering Technique	Factor 3: Manufacturing Complexity
1	Solder Bridging	Hand Soldering	Medium Complexity
2	Solder Bridging	Soldering Oven	High Complexity
3	*Wire Connections*	*Hand Soldering*	*Low Complexity*

Table 7. Factorial Design for PCB Manufacturing

Additionally, the response variable to be tested using the proposed factorial design was Electrical Conductivity. Previous experiences with this type of PCB had shown instabilities when used as intended. Therefore, the objective was to assess and optimize the electrical conductivity of the PCB through the chosen factorial design.

An overall measurement of 33 points was conducted on the PCB, primarily to avoid repetition of components that were daisy chained. The measurements were made by taking readings at the first and last point of each trace to obtain the average resistance.

Point	Resistance in Ohms	Point	Resistance in Ohms	Point	Resistance in Ohms
1	1.2	12	1	23	0
2	0.7	13	0	24	1.2
3	1.8	14	0	25	0.5
4	2.2	15	0	26	0.1
5	0.9	16	0	27	1.5
6	1.5	17	1	28	2.6
7	0.7	18	0	29	3
8	0	19	1	30	1

9	0	20	3	31	1.5
10	0	21	2	32	1
11	0.9	22	1	33	0.7

Table 8. Resistance measurements taken on PCB

Although measurements were taken, it is important to note that a Design of Experiments (DOE) or ANOVA analysis cannot be performed due to the lack of additional data for comparison and establishing optimal implementation of the PCB. However, it is worth mentioning that all connections passed the continuity test. While some measurements showed values in the range of 2-3 Ohms, the average resistance was reported to be 0.9 Ohms. The connections with higher resistance were predominantly found on the power distribution side of the PCB, resulting in higher power consumption than necessary. Nevertheless, these resistance levels remained within the nominal and peak amperage capacity of the 11 and 22 Amps provided by the battery.

Max Resistance	Min Resistance	Average	Variance
3	0	0.9696	0.7512

Table 9. Statistical report for the test of Continuity on the PCB

B. *Mechanical Division*

For the validation of the expectations to be met different tests were made in the system, one of them was with the tripod, once this part of the system was assembled it was decided to begin with different types of test for know if it would resist the expected weight, each piece in 3D was checked looking for some damage and analyze the movement of the pieces searching for some trouble in there. Fortunately, the tripod can support the established weight by Multitaskr without problems, also this means it can resist the weight of all the coupled systems. In the image above is the tripod and how it is assembled.

Figure 11 Assembled tripod.

Another test carried out with the tripod, was with the implementation of the second part of the system where could verify that the tripod was strong enough to support the entire implemented system. In the next images it is possible to appreciate the complete system at the minimum height and at the maximum height.

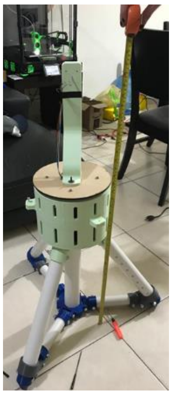


Figure 12 System at minimum height

Figure 13 System at maximum height

V. Final Test

For the final tests of the system, it was decided to simulate the weight that the system will carry. It was used a cardboard box, for simulate the space where the entire part of the camera will be placed. The application was used to send the signal to the system and thus make the movements. In the image the user is controlling the system via the web app, the system does everything that the user sends through the application.

All the weight in the system is dispersed in the wooden plate and the lazy Susan, making the system move without any problem, the gearboxes work perfectly when the signal is sent of movement, simulating a real environment that Multitaskr could face.

Figure 14 Final tests with the app web and simulating the weight.

VI. Results

As noted in Test Section – Electronics Division of the document, the Design of Experiments (DOE) could not be completed, and the measurements from the third experiment serve as the only reference point for performance evaluation. Based on these results, the following conclusions were drawn:

1) The obtained results did not meet the expectations initially set, considering that the preferred method of PCB manufacturing was industrial etching. However, since the PCB was manufactured using wire connections on a stripboard, the results were deemed acceptable. The main resistance was found in the power distribution circuit, and the continuity and resistance measurements indicated satisfactory signal integrity for the desired functional level of the prototype.

2) It was also concluded that although the final appearance and build quality of the PCB were below industrial standards, it successfully achieved the objective of simplifying the connections to the ESP board and other project components. Furthermore, the current design allows for easy component replacement.

3) Upon comparing the obtained results with the initially declared objectives in the electrical section, it was concluded that all the objectives were fulfilled, albeit not up to the planned standard. It was identified that better time management and improved communication with Multitaskr could have reduced the development time, enabling the proper manufacturing of the PCB.

4) Finally, it was concluded that the recommended approach for the electronics section of the project is to outsource the PCB manufacturing to a service like JLCPCB. The current design, which involves breaking out a few pins of the ESP32 microcontroller and providing voltage to the components, is deemed suitable. No modifications to the proposed PCB design are anticipated as its performance thus far meets the project's requirements.

Furthermore, upon analyzing the overall performance of the prototype and reviewing the test results from other areas, it was concluded that the prototype met the expected requirements. Although several obstacles were encountered during the testing phase (such as gearbox failure and some wiring mix-ups, among other minor details), the state and behavior of the prototype fulfilled the requirements set by both Multitaskr and the team. These requirements included a 2 degrees of freedom (2DOF) range of movement, comprising a full 360-degree movement on the yaw axis and a -45 to 45-degree movement on the pitch axis. The prototype also featured wireless control capabilities and the ability to withstand a payload of more than 4kg.

Additionally, the prototype offered additional benefits such as ease of manufacture for potential future mechanisms and the ability to address component failures easily. The current control implementation, utilizing a web application, proved to be user-friendly and provided a convenient pathway for adding or refining functions as needed.

While the overall performance of the prototype met the project's requirements, it was identified that an area of opportunity arose during the Bill of Materials (BOM) creation and material cost calculation. This process served as a constructive learning experience in managing, designing, and implementing an engineering project where only a few key requirements were provided, and the remaining aspects of the project required the expertise of the engineers involved.

Figure 15 Final prototype functioning.

VII. CONCLUSIONS

In conclusion, this article presented a novel approach to automate the manual scanning of rooms using a camera, with the goal of enhancing the processes offered by Multitaskr. The development of a mobile and foldable platform, equipped with a robotic system offering two degrees of freedom, enables precise modification of the camera's Yaw and Pitch positions. The experimental results obtained through extensive testing and evaluation provide valuable insights into the performance and capabilities of the automated camera positioning system.

The obtained results demonstrate that the automated camera positioning system effectively achieves the desired range of motion, allowing the camera to rotate 360 degrees on the yaw axis and tilt between -45 to 45 degrees on the pitch axis. The system successfully addresses the initial problem of room scanning automation by providing accurate and detailed movement of the camera without the need for manual intervention. The precise control over the camera's orientation enables the production of comprehensive 3D models of scanned rooms, enhancing the efficiency and reliability of data collection; thus, benefiting both Multitaskr and its clients.

Furthermore, the experimental results highlight the adaptability and flexibility of the mobile platform. The system demonstrates its capability to scan rooms of varying sizes and configurations, offering seamless integration with different environments. The stability and adjustability provided by the integrated tripod mechanism contribute to the platform's versatility and make it suitable for a wide range of room scanning applications while also providing an easy way of interchanging the equipment used for the scanning, providing further flexibility and future proofing the robotic system if modifications stay within the limits of weight for the payload.

While the automated camera positioning system enhances productivity by reducing manual effort, this study recognizes the importance of human interaction to ensure ethical considerations are met. By involving humans in the process, the proposed solution promotes a responsible and sustainable automation approach that combines efficiency gains with the preservation of human involvement and decision-making.

The presented prototype successfully addresses the client's requirements and exceeds initial expectations in terms of reliability, precision, and flexibility. The mechanical design of the system ensures rigidity and durability, providing a long-lasting solution for room scanning tasks. The user-friendly application for precise control adds convenience and accessibility without the need for specialized software installation. Finally, the electronics design allows for easy repairs/components replacement, going as far as providing flexibility to extend the operation time, having a path to operate via a wall/plug-in external power supply or even providing power to the camera system.

The lessons learned during the development of the project, including perseverance and economic considerations, contribute to the continuous improvement of the system. Future work can focus on optimizing the materials used, such as replacing plastic with more resistant alternatives like metal for the gearbox. Additionally, further refinements in design and assembly processes can enhance ease of manufacturing and reduce costs.

Overall, the experimental results confirm the system's capability to accurately modify the camera's position, enabling comprehensive room scanning without human intervention. The automated camera positioning system offers a reliable and efficient solution for room scanning tasks, while respecting ethical considerations and promoting a responsible approach to automation.

VIII. Appendix I: Identified improvement areas

After finishing our final presentation, it was identified that, with help of our teacher and Multitaskr, one key area of improvement on the performance of the device would be to modify the case in order to fit a different gearbox for the NEMA17 motor in order to alleviate the malfunctions our current gearbox had with the screw transmission system and it becoming loose when performing an specific series of movements.

It wasn’t brought to attention at the presentation, but one key factor that didn’t allowed the team to perform said modifications was the additional expensed this would’ve implied as 2Kgs of additional filament would’ve been needed, as well as different bearings and screws for the system. After analyzing the benefits of making said modifications and the additional costs (that would’ve brought the BOM to approximately 8,000-9,000 MXN) and the given economical aid by Multitaskr it was determined that the better course of action was to alleviate the problems with the transmission system.

References

[1] Z. Peterson, 2021, “What is a PCB?,” Altium, https://resources.altium.com/p/what-is-a-pcb.

[2] M. Yongendrappa, 2021, “What’s the meaning of a Schematic Diagram”, Sierra Circuits, https://www.protoexpress.com/blog/whats-the-meaning-of-schematic-diagram/#:~:text=A%20schematic%20diagram%20is%20a,components%20on%20a%20schematic%20diagram.

[3] “The Complete Guide to Stepper Motors,” RS, https://au.rs-online.com/web/generalDisplay.html?id=ideas-and-advice%2Fstepper-motors-guide.

[4] T. Agarwal, 2020, “Stepper Motor Driver : Working Principle, types and its applications,” ElProCus, https://www.elprocus.com/what-is-a-stepper-motor-driver-types-and-its-applications/.

[5] B. Lutkevich, 2019, “What is a microcontroller and how does it work?,” IoT Agenda, https://www.techtarget.com/iotagenda/definition/microcontroller.

[6] E. Coates, 2020, “Buck-Boost Converters”, Learnabout Electronics, https://learnabout-electronics.org/PSU/psu33.php

[7] “#05 principle and advantages of magnetic encoder”, Asahi Kasei Microdevices, https://www.akm.com/us/en/products/rotation-angle-sensor/tutorial/magnetic-encoder/#:~:text=The%20magnetic%20encoder%20detects%20rotational,magnet%20and%20a%20magnetic%20sensor.

[8] W. Lee, 2017, “Current Draw with Stepped Down Voltage”, ElectricalEngineering StackExchange, https://electronics.stackexchange.com/questions/337204/current-draw-with-stepped-down-voltage

[9] 2023, “How to Calculate Battery Run Time,” China-DNK Power, https://www.dnkpower.com/how-to-calculate-battery-run-time/

[10] K. M. Bower, “What is Design Of Experiments (DOE)?”, ASQ, https://asq.org/quality-resources/design-of-experiments

[11] BGB. 2023. “What is a slip ring” BGB. https://www.bgbinnovation.com/knowledge/news-and-articles/what-is-a-slip-ring

[12] Science Direct. 2023, “Gear Ratio”. ScienceDirect. https://www.sciencedirect.com/topics/engineering/gear-ratio

[13] Alestra. 2023, “Redes WLAN: características, tipos, ejemplos y diferencias”. Alestra. https://www.alestra.mx/blog/la-importancia-de-las-conexiones-wlan-en-las-empresas

[14] PiotrChr. 2022. Nema17 2-stage planetary gearbox 10:1. https://www.thingiverse.com/thing:5388912