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STUDY ON THE OPTIMIZATION OF THORACOLUMBAR BRACE-TYPE ORTHOSES

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ABSTRACT: This study examines the optimization of thoracolumbar braces for postural correction. It proposes an innovative, customizable spinal brace based on anthropometric measurements, constructed from hybrid composite materials (natural and synthetic fibers) to combine rigidity, flexibility, and sustainability. Selected materials include bamboo, flax, hemp, and cotton fibers integrated into epoxy matrices or elastic textiles. Finite element analysis (FEA) simulations assessed the mechanical behavior of components, identifying hemp fiber-reinforced composite as the most effective due to minimal deformation ($\delta=0.0073$ mm) and high strength. The study emphasizes the importance of comfort, adaptability, and reduced ecological impact in brace design.

KEY WORDS: spine, orthosis, hybrid composite, static simulation, 3D modeling.

1. Introduction

Conditions of the thoracolumbar spine, such as scoliosis, kyphosis, spondylosis or herniated discs, significantly affect patients' quality of life, limiting mobility and causing chronic pain. With the increasing incidence of these conditions, especially in the young and adult population, the need for effective postural support and correction solutions is becoming increasingly apparent.

Thoracolumbar braces are a commonly used conservative method in the management of these conditions, stabilizing the spine, correcting the spinal alignment and reducing the pain. However, many existing designs have limitations in terms of comfort, adaptability to individual anatomy and biomechanical efficiency.

In this context, the current study aims to develop an innovative concept of thoracolumbar brace, which efficiently combines the necessary stiffness to support the spine with the flexibility and comfort essential for prolonged use. To achieve this objective, a selection of hybrid composite materials will be carried out, followed by numerical simulations to evaluate the mechanical behavior of different material configurations.

Suggested concept

The suggested concept in the following pages is a thoracolumbar brace-type orthosis for postural correction, with a unique design made of sustainable materials. I developed this product based on a problem encountered by more than 80% of the population, namely incorrect posture in both orthostatic and seated positions.

The orthopedic device aims to be customizable, based on anthropometric measurements specific to each individual. In addition to a person's general measurements such as height, body mass, back length and width, shoulder length, waist and bust circumference, I have also taken measurements based on the anatomy of the back bones.

Taking into account the atypical shape of the restrictive component on the back of the brace, its justification is the anatomy of the scapulae. They produce a set of complex motions, illustrated in *Figure 2*. The movement of interest, in this case, is that of retraction, as this is when the scapulae measures the smallest distance between them. Based on the chosen reference, I measured the distances h, i and j, shown in *Figure 2*.

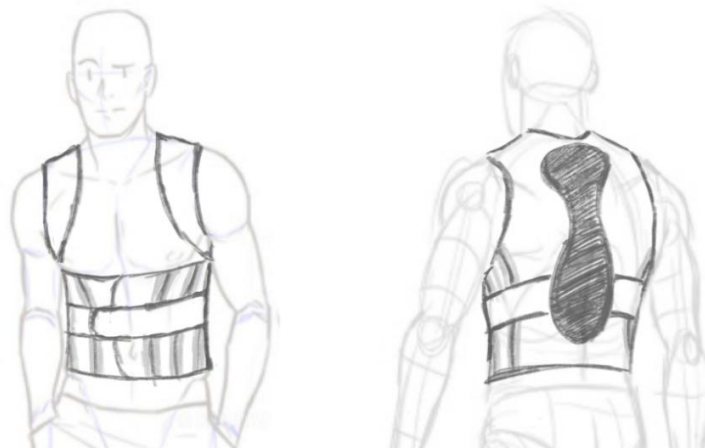


Figure 1 Sketch of the initial concept

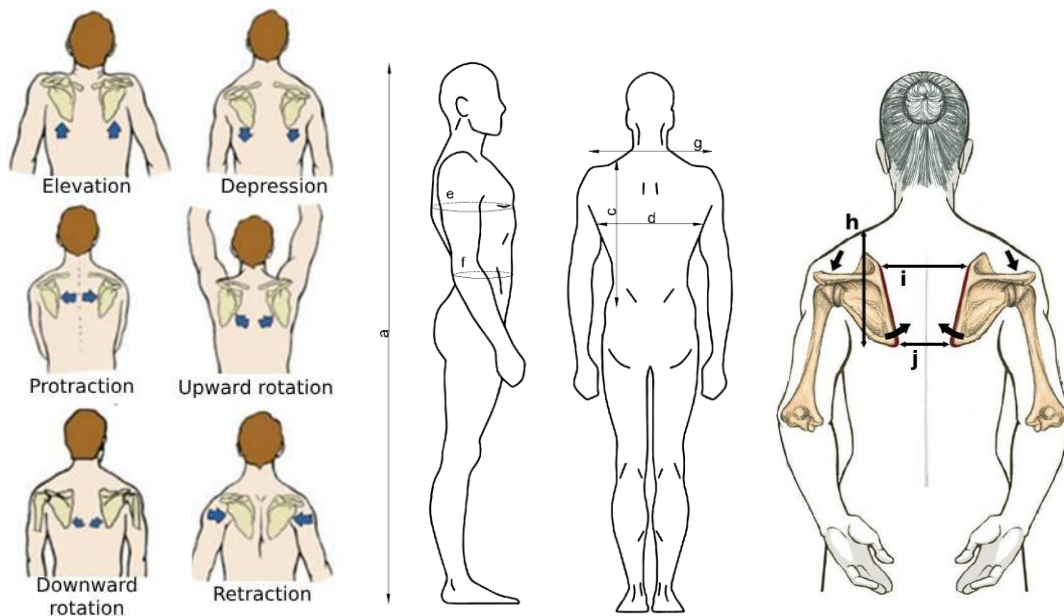


Figure 2 Scapular movements and anthropometric measurement notations [1],[2],[3]

Table 1 Anthropometric measurements used for this study

Notation	Anthropometric characteristic	Dimension
a	Height	1800 (mm)
b	Body mass	80 (kg)
c	Back length	480 (mm)
d	Back width	360 (mm)
e	Bust circumference	1000 (mm)
f	Waist circumference	780 (mm)
g	Shoulder length	500 (mm)
h	The distance from the point where the back length is measured to the point where the scapulae measures the smallest difference	150 (mm)
i	Distance between the superior angles of the scapulae	70 (mm)
j	The shortest distance measured between the scapulae	20 (mm)

The design of the orthosis was done using Autodesk Fusion 360 software, based on a 3D chest reference downloaded from the grabcad.com website, with the anthropometric characteristics from Table 1.



Figure 3 The orthosis rendering on the reference model

The thoracolumbar orthosis for postural correction consists of the following elements:

- The orthosis' base, made of fabric;
- Ergonomically shaped spinal stabilisation component;
- Six support rods;
- Support-type compartments;
- Protective pad inside the fabric;
- Metal fasteners on two sides, located on the front of the orthosis

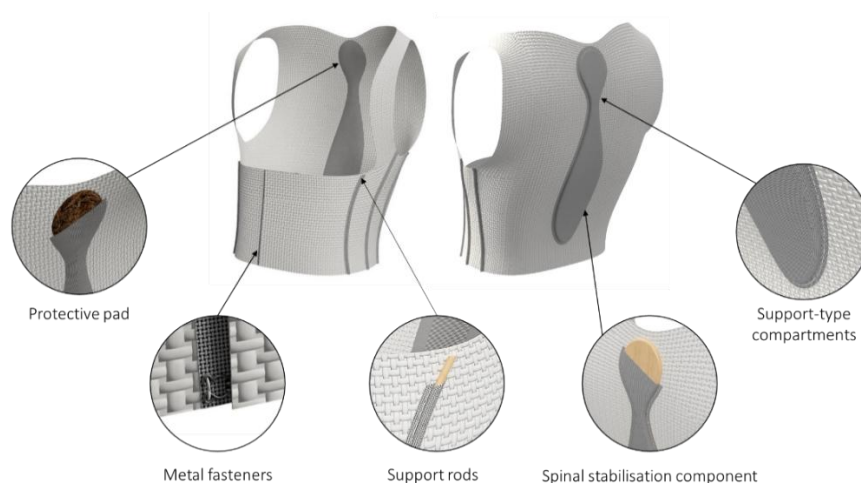


Figure 4 Detailing of component parts

Materials suggested for use

Synthetic fibers have a major environmental impact through high greenhouse gas emissions during chemical synthesis, intensive consumption of non-renewable resources and subsequent fragmentation into microplastics, affecting the biogeochemical cycles and ecosystems' health. Natural fibers are preferred due to their renewable sourcing, low carbon footprint and ability to fully biodegrade, offering a sustainable alternative to synthetics in modern composite applications.

The choice to use hybrid materials was motivated by the desire to combine the complementary advantages of natural fibers and synthetic matrices, thus obtaining composites with superior mechanical performance, light weight and reduced environmental impact. [4]

Thus, as natural fibers I chose:

- Bamboo fibers
- Flax fibers
- Hemp fibers
- Cotton fibers
- Coconut fibers

Bamboo fibers have attracted particular attention because of their low density, high stiffness, high strength and abundant availability. These fibers were extracted by chemical treatments with sodium hydroxide (NaOH) followed by mechanical processing. Alkaline treatment with NaOH significantly improved the mechanical and structural properties of the fibers, increasing cellulose content and reducing impurities. [4]

Flax fibers are among the most widely used natural fibers in composites because of their good mechanical properties, low weight and biodegradability. Flax fibres are mainly composed of cellulose (up to 75%), hemicellulose, lignin, pectin and waxes. The internal structure gives the fiber high tensile strength, mainly due to cellulose microfibrils oriented parallel to the fiber axis. [5]

Hemp fibers are valued for their outstanding mechanical properties, particularly their tensile strength and high modulus of elasticity. With its low density, hemp gives textiles excellent air permeability, which is essential for use in hot climates. Hemp is also naturally more resistant to the growth of pathogenic micro-organisms, thus helping to maintain the freshness and hygiene of the fabric. Traditionally, hemp has traditionally been exploited in the textile industry with low environmental impact. [6]

Cotton fibers offer multiple advantages, including low density, good thermal conductivity, high flexibility, resilience, elasticity and regenerative capacity, and its crystalline and fibrillar structure gives it high mechanical strength. . [7]

Coconut fiber comes from waste, which means no new trees are planted to meet the quantities needed for production. It is completely biodegradable and will be used as a lining material. [8]

In order to obtain hybrid composites reinforced with the natural fibers mentioned above, we chose the following synthetic materials:

- Rigid matrices: epoxy resin.
- Elastic matrices: polyester, nylon, elastane.

Epoxy resin matrix is commonly used in combination with natural fibers because of its excellent mechanical properties, strong adhesion to fibers and chemical and thermal stability. This combination produces durable, lightweight and environmentally friendly composites suitable for various industrial applications.

The process of synthesizing natural fiber-reinforced epoxy composites involves selecting fibers (such as flax, hemp or bamboo), treating them to improve adhesion to the matrix and formulating the epoxy resin with suitable curing agents. Processing techniques, such as hand lay-up, vacuum infusion and hot pressing, are essential to obtain composites with superior mechanical and thermal properties. Fiber-matrix compatibility, fiber orientation and interfacial adhesion significantly influence the mechanical performance of composites, such as tensile strength and thermal stability. [9]

Thus, as hybrid materials, we will have:

- Rigid composite materials reinforced with:
 - Bamboo fibers (40%) in epoxy resin matrix (60%) (BFRC)
 - Hemp fiber (40%) in epoxy resin matrix (60%) (HRFC)
 - Flax fiber (40%) in epoxy resin matrix (60%) (FFRC)
- Flexible:
 - Cotton-polyester textile with elastane (50/40/10) (C/P/E)
 - Flax-nylon textile with elastane (50/40/10) (F/N/E)
 - Hemp-polyester fabric with elastane (50/40/10) (H/P/E)

Table 2 Mechanical and physical properties of rigid hybrid composites [4],[5],[6],[10],[11],[12],[13]

PROPERTIES	BFRC	HRFC	FFRC
Thermal conductivity [W/(m*K)]	0.13	0.2	125
Specific Heat [J/(g°C)]	1.6	1.4	1.3
Thermal Expansion Coefficient [$\mu\text{m}/(\text{m}^\circ\text{C})$]	15	40	30
Young's Modulus [GPa]	13	10.5	25
Poisson's ratio	0.3	0.35	0.35
Shear modulus [MPa]	1750	3500	6000
Density [g/cm ³]	1.25	1.4	1.3
Damping coefficient	0.04	0.04	0.35
Yield strength [MPa]	100	50	75
Tensile strength [MPa]	105	725	225

Finite element analysis

Finite element analysis (FEA) methods play an essential role in the testing and optimization of a thoracolumbar orthosis, allowing the evaluation of its structural behavior prior to actual production. These analyses provide a detailed insight into the stress distribution, material strength and overall performance of the brace, thereby reducing the time and costs associated with physical prototyping.

In this study, three finite element analyses (FEA) will be performed in Autodesk Fusion 360 software, corresponding to the three materials in **Table 2**, proposed for the restrictive component of the thoracolumbar brace. In each analysis a spinal flexion moment load will be simulated in order to evaluate the behavior and compare the performance of the materials.

We applied a constraint on the inner surface of the component, as it has to be fixed to the curvature of the spine.

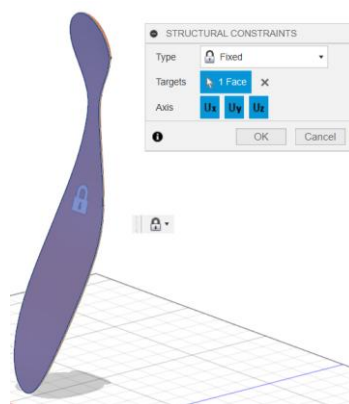


Figure 5 Application of the constraint

To find the total force exerted by the patient's body on the component, I calculated the total weight, considering the body mass from **Table 1**.

$$G = m * g = 80kg * 9.81 \frac{m}{s^2} = 784,8 N. \sim 785 N. \quad (1)$$

where, G-total weight, m-body mass and g-gravitational acceleration.

Thus, the value of 785 N is the vertical force exerted by the body (longitudinal axis) and will help in reproducing static loads.

According to the scientific article „Inhibition of forward propulsion as a gait initiation strategy in stroke patients,, by Yiou, E., & Do, M. C. (2011), a spinal flexion moment in the sagittal plane is estimated to be 40 Nm.[14]

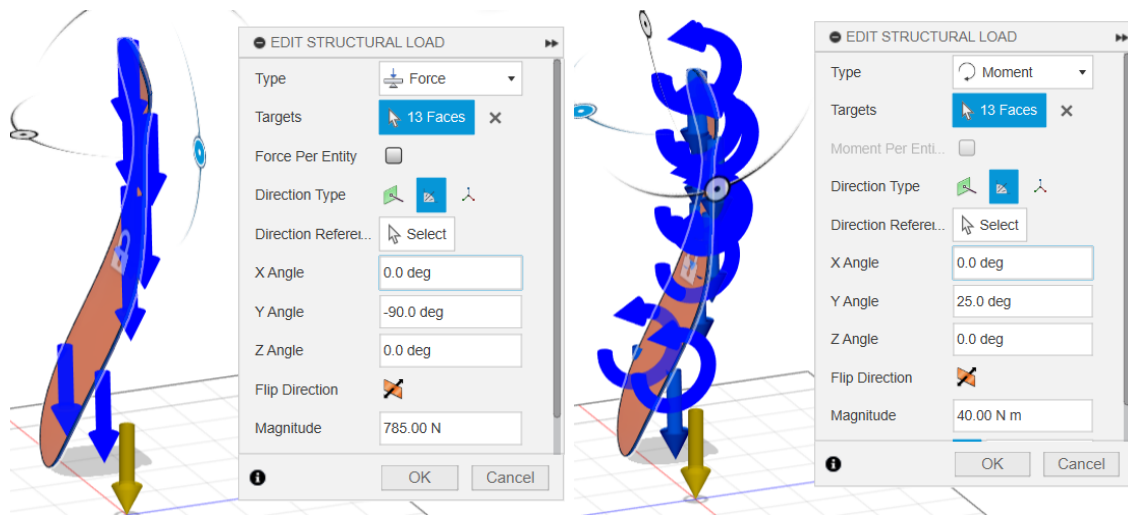


Figure 6 Application of the structural loads

Figure 7 shows the Von Mises stress legend for the three cases, where identical values resulted from the static simulation. This does not mean that the materials have the same behavior, but that the component geometry and load distribution determine this stress which indicates the possibility of material failure. Since the maximum stress value ($\sigma = 0.568$ MPa) is, on average, 99.18% lower than the corresponding yield strength values of the three materials denotes that the structure is under-stressed.

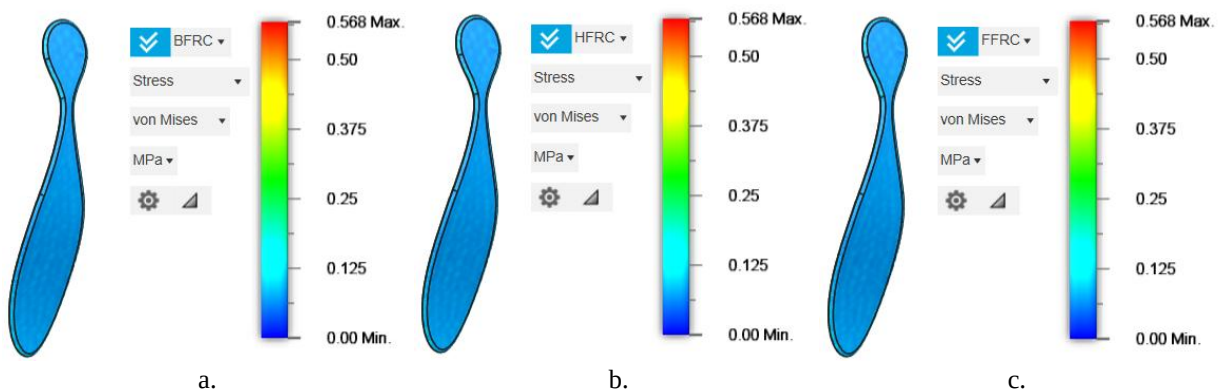


Figure 7 Von Misses (a-BFRC, b-HFRC, c-FFRC)

Figure 8 shows the deformable behavior of each material differing significantly. The material with the highest displacement value ($\delta=0.1773$ mm) is the rigid composite reinforced with bamboo fibers, however, it does not represent a severe structural deformation and falls within a range considered functionally safe. However, considering the comparison between the 3 cases, the ideal composite is the one reinforced with hemp fibers, having the lowest recorded value, i.e. $\delta=0.0073$ mm.

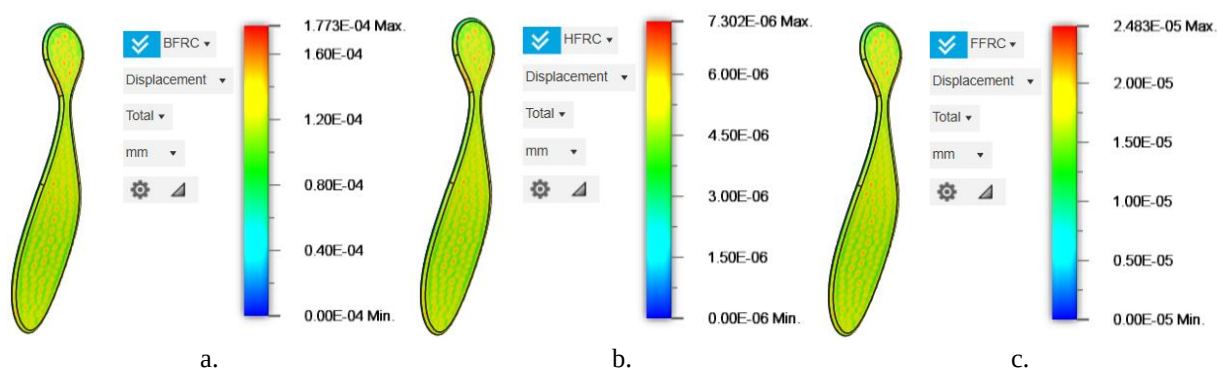


Figure 8 Displacement of the material (a-BFRC, b-HFRC, c-FFRC)

Conclusions

This study presents an innovative approach to the design of thoracolumbar orthoses, combining biomechanical principles with sustainable materials. Through comparative analysis of three types of hybrid composites (reinforced with bamboo, flax and hemp fibers), it was demonstrated that the hemp fiber-based material offers the best structural performance, recording the lowest deformation ($\delta=0.0073$ mm) under mechanical stress. This superior strength, together with the environmentally friendly properties of natural fibers, makes this composite an optimal choice for durable medical applications.

The orthosis design was optimized for comfort and customization, taking into account precise anthropometric measurements and the biomechanics of scapular movements. Finite-element simulations confirmed that the structure can efficiently support physiological loads while maintaining integrity under mechanical stress. In addition, the use of biodegradable materials reduces environmental impact, aligning the medical solution with the principles of circular economy.

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MECHANICAL OPTIMIZATION OF A COLLABORATIVE ROBOT ARM END-EFFECTOR USING GENERATIVE DESIGN

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***ABSTRACT:** This paper presents the process of mechanical adaptation and design optimization of an end-effector intended for a collaborative robotic arm, using advanced generative design techniques. Starting from the 3D model developed in the undergraduate thesis, weaknesses of the initial design were identified and corrected, and modifications were made to facilitate a more efficient and simplified assembly. The optimization aimed to improve functionality and reduce weight without compromising structural integrity. For this purpose, the Generative Design module in CREO Parametric 11 was used, enabling the development of an optimized geometry tailored to the application's requirements*

***KEYWORDS:** collaborative robot, generative design, end-effector*

1. Introduction

To further expand upon the significance of generative design in modern engineering practice, it is essential to consider its growing role in industrial innovation. Unlike classical CAD methodologies, generative design enables the exploration of a multitude of configurations through automated iterations, thereby pushing the boundaries of traditional engineering design. This paradigm shift is particularly beneficial in applications where weight reduction and structural efficiency are crucial, such as in aerospace, automotive, and robotics sectors.

Moreover, the integration of generative design tools into platforms like Creo Parametric 11 facilitates not only the generation of topology-optimized components but also their direct translation into manufacturable solutions. This seamless transition from conceptualization to fabrication significantly reduces the product development cycle. It allows engineers and designers to validate multiple high-performance configurations under simulated operational conditions, leading to more resilient and cost-effective products.

In educational settings, familiarizing students with such technologies can foster innovative thinking and prepare them for the complexities of Industry 4.0. The continuous evolution of these tools highlights the importance of integrating digital competencies into engineering curricula to support the development of next-generation industrial systems.

This study addresses the process of mechanical adaptation and design optimization of an end-effector intended for a collaborative robotic arm, with the objective of enhancing functional performance and reducing the overall weight of the component. The main goal was to transform a previously developed 3D model into a version compatible with the UFactory Lite 6 collaborative robot. To achieve this, the Generative Design module in Creo Parametric 11 was utilized, which enabled the automatic generation of an optimized geometry, tailored to structural and manufacturing requirements, ultimately contributing to a weight reduction of approximately 50% without compromising structural integrity.

2. Modification and Improvement of the Initial 3D Model

This study aims to perform the mechanical adaptation and design optimization of an end-effector intended for a collaborative robotic arm, employing advanced computer-aided design (CAD) tools.

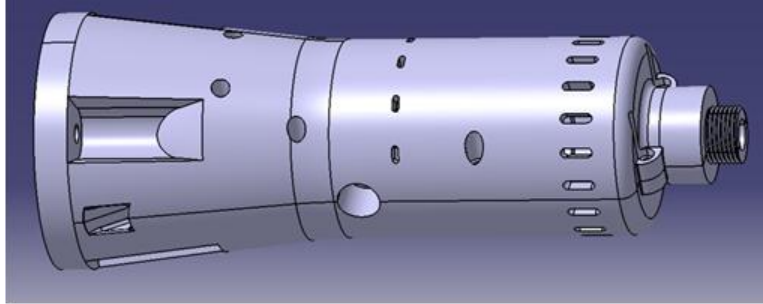


Fig. 1 Model 3D

The project commenced with an existing 3D model (fig. 1), which was adapted to be compatible with the flange of the UFactory Lite 6 collaborative robot. The number of screw holes was reduced from four to two, and the geometry was enlarged to improve mounting compatibility with the robot flange (fig. 2).

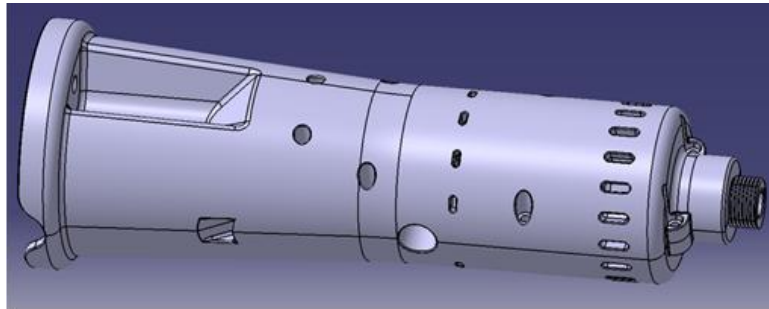


Fig. 2 Refined 3D model

Subsequently, the internal geometry was optimized by removing minor elements that did not significantly affect structural integrity (fig. 3, red zones). Critical zones identified during assembly were reinforced (fig. 3, orange zones), and the cable routing channels were resized to allow for a faster and more efficient assembly process (fig. 3, yellow zones).



Fig. 3 Internal modifications

3. CREO Parametric 11 with Generative Design

Creo 11 Generative Design is an advanced feature integrated within the PTC Creo CAD environment that leverages artificial intelligence and topological optimization algorithms to automatically generate optimized, ready-to-manufacture geometries based on a set of user-defined requirements and constraints. This technology enables rapid exploration of innovative design solutions, reducing development time and enhancing product performance. Manufacturing methods can also be specified, allowing the software to generate designs that

adhere to production constraints, ensuring that proposed geometries meet both functional and manufacturing feasibility criteria [1].

The generative design process in Creo 11 involves the following steps:

Defining design objectives such as mass reduction, increased stiffness, or optimization for specific manufacturing processes (e.g., 3D printing, milling) [2].

The specification of geometric constraints involves the precise definition of design domains, including preservation zones (e.g., functional interfaces such as mounting surfaces), exclusion regions where material generation is prohibited, and starting geometry such as minimum feature size. These parameters delineate the feasible design space and ensure compliance with functional, spatial, and manufacturability requirements during the generative optimization process. (fig. 4).



Fig. 4 Generative Design geometry interface

Applying loading conditions by introducing forces and moments expected during operation [2]. The physics toolbar (fig. 5) within the Creo 11 Generative Design environment serves as a fundamental component for setting up simulation-ready models by enabling users to define and assign critical boundary condition such as load cases, geometric constraints, external loads, contact interactions, and mass properties. These predefined physical parameters play a crucial role in accurately replicating real-world operating conditions, thereby ensuring that the generative algorithm produces structurally viable, performance-optimized, and manufacturable design alternatives that comply with both functional and mechanical requirements [4].

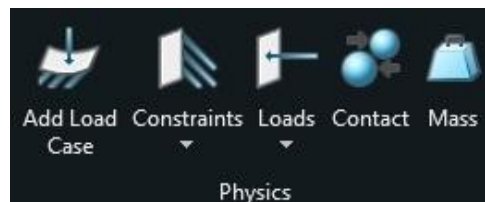


Fig. 5 Generative Design physics toolbar

In the generative design workflow of Creo 11, the accurate definition of boundary conditions is essential to ensuring the validity of structural optimization. The platform provides a comprehensive set of tools for applying geometrical constraints and load cases that reflect real-world operational requirements. These are broadly categorized into constraints and external load conditions (fig. 6).



Fig. 6 Generative Design constraints and loads toolbar

Selecting appropriate materials and manufacturing processes compatible with the generated design.

Leveraging artificial intelligence and cloud-based computing, the system autonomously generates multiple design alternatives, enabling the selection of the optimal configuration based on a comprehensive evaluation of performance, cost efficiency, and manufacturability [2].

4. External Design Optimization Using CREO Parametric 11

The Generative Design module within Creo Parametric 11 was employed to conduct a topological optimization of the external geometry, with the goal of reducing the total mass of the assembly while preserving structural integrity. During this phase, contact zones subject to mechanical stresses during operation were identified, primarily corresponding to the bearing support surfaces (fig. 7).

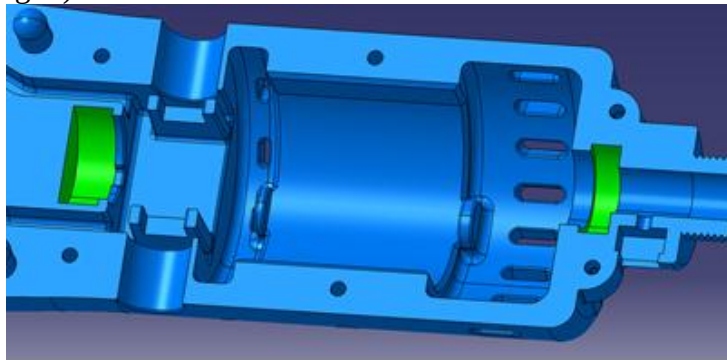


Fig. 7 Contact zones

The structured workflow followed included the following stages:

Initially, the maximum allowable design volume was defined by constructing the baseline geometry that delimits the total permissible design space (fig. 8, transparent region). This foundational geometry serves as the computational boundary for subsequent topological exploration. Subsequently, design space segmentation was performed by explicitly defining two critical categories. Preserved regions, representing functionally essential features such as mounting interfaces, contact surfaces, or load-bearing areas that must remain unaltered throughout the optimization process (fig. 8, highlighted in blue). Excluded regions, representing volumetric zones where material is prohibited due to assembly clearances, motion pathways, or predefined operational constraints (fig. 8, highlighted in red).

Once the geometric domains were established, constraints were applied to preserved geometry. These included both constraints, such as fixed support or restricted degrees of freedom, and external loads representative of real-world operational conditions (e.g., forces, moments, bearing, or pressure distributions). The precise application of these constraints and forces was critical to ensure that the optimization process would yield geometries that satisfy the structural, functional, and manufacturability requirements (fig. 8).

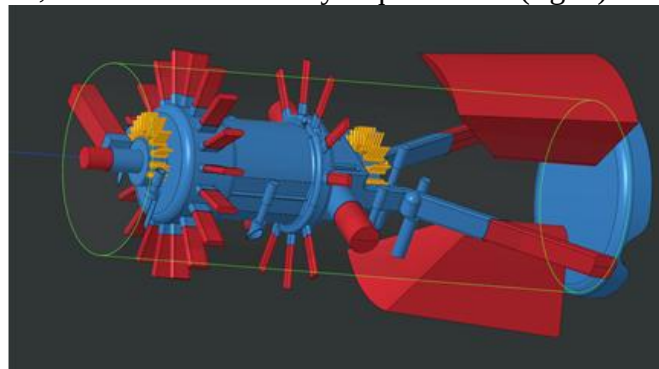


Fig. 8 Generative Design

The generative design setup included the definition of specific optimization criteria to guide the algorithm toward feasible and high-performance solutions. These criteria encompassed a targeted mass reduction objective, the selection of an additive manufacturing method (filament fabrication for 3D printing), and the imposition of geometric constraints such as minimum feature size and symmetry conditions. Planar and axial symmetry were applied to promote structural balance and reduce computational complexity [3]. Collectively, these parameters ensured that the resulting geometry would not only meet mechanical performance requirements but also remain compatible with the intended manufacturing process and design (fig. 9).

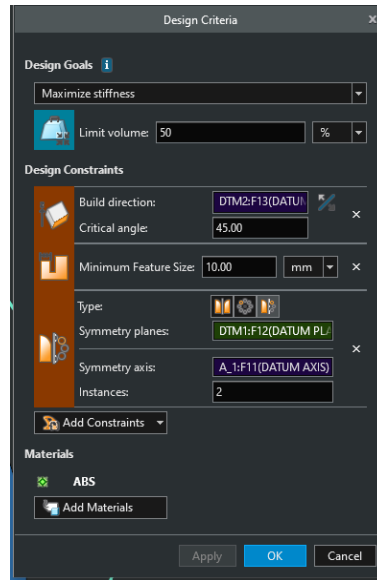


Fig. 9 Design criteria

5. Final Optimization and Conclusions

Through the successive implementation of multiple, strategically selected optimization techniques, a significant reduction (approximately 50%) in the component's overall mass was successfully achieved. This mass reduction was achieved without any degradation in structural integrity or mechanical functionality, therefore validating the effectiveness, robustness, and engineering reliability of the adopted generative design methodology. The results emphasize the potential of this approach to deliver lightweight solutions that meet stringent performance criteria (fig. 10).

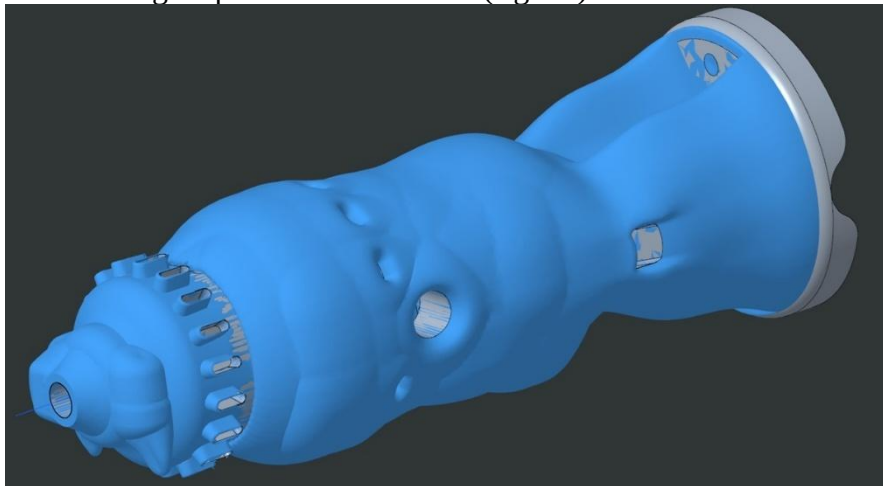


Fig. 10 Final optimization

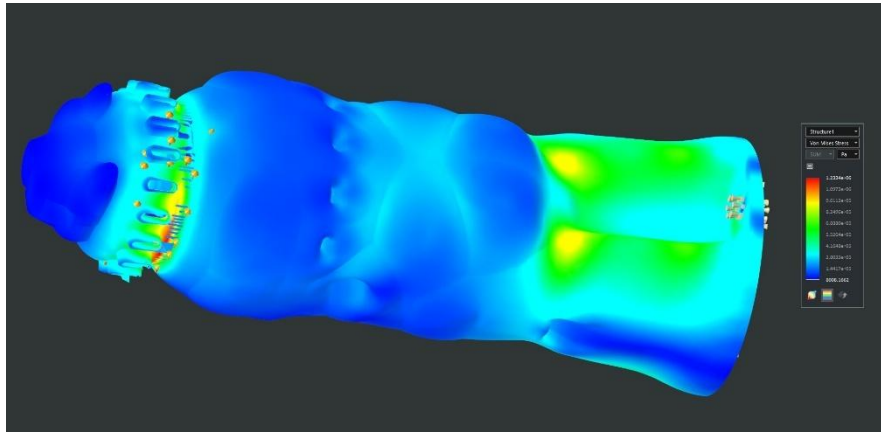


Fig. 11 Final results

Image 11 shows a finite element analysis (FEA) of an end-effector for a collaborative robotic arm, highlighting stress distribution underload. Red areas indicate high-stress zones, especially around the mounting points. Blue regions show minimal stress. The analysis helps optimize the design for strength and operational safety.

In conclusion, the implementation of generative design within this project has demonstrated not only significant weight reduction but also a notable enhancement in structural performance and manufacturability. The optimization process has yielded a design that balances innovation with practicality, adhering to both technical constraints and production needs.

This experience highlights the transformative potential of AI-driven design tools in mechanical engineering. By leveraging these advanced capabilities, engineers can make more informed decisions early in the development cycle, reducing time-to-market and increasing product reliability.

Furthermore, the insights gained from the use of Creo Parametric 11 serve as a strong foundation for future projects that require complex geometry manipulation and performance-driven optimization. These methodologies are poised to become a standard in the development of lightweight, efficient, and highly functional components across various industries.

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DEVELOPMENT OF AN AUTONOMOUS GROUND VEHICLE FOR TACTICAL OPERATIONS AND LOGISTIC SUPPORT

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SUMMARY: In today's world, conflicts can arise quickly due to rising tensions between countries. These types of conflicts can negatively impact the economy, strain relationships, and potentially lead to military confrontations. With the increasing significance of artificial intelligence, there have been significant advancements in military techniques. This project showcases the innovation of unmanned robots that can save lives and greatly assist troops involved in tactical manoeuvres. Providing logistical support to armies in the field can reduce downtime and improve supply efficiency. This innovative project aims to utilize 3D printing and wireless control to transform communication between the battlefield and main headquarters, ensuring a seamless connection that enhances operational effectiveness.

KEY WORDS: *innovation, robot, unmanned, tactical, 3D printing.*

1. Introduction

Remote-controlled robots offer a variety of activities that can enhance human interaction with products and facilitate interpersonal connections. In the defence industry, this capability has become critical, leading to the development of remotely controlled vehicles aimed at minimizing human casualties and enhancing tactical effectiveness. This paper discusses the creation of a remote-controlled robot specifically designed to provide logistical support for tactical operations.

The main component of these robots is the microcontroller, which is an electronic device intended to manage processes or interactions with the external environment. It acts as the core element of the hardware system. In addition, a wireless transmission module is utilized to allow user access. Commands are transmitted through a dedicated IP address, enabling vehicle manipulation within optimal parameters. For mobility, the robot is equipped with DC motors, which are commonly used in industrial, military, and automation applications.

These motors are preferred for their ease of use and specific advantages, including high power output, quiet operation, reliability, and low maintenance costs. Therefore, two differentially controlled DC motors are employed for manoeuvring the robot. For remote control, mobile devices such as personal digital assistants or smartphones can connect to the wireless network of the development module using a user-defined IP address.

The vehicle's body is constructed using additive manufacturing processes, which were selected for their cost-effectiveness in development and prototyping. Consequently, the design of the F1 robot incorporates various technologies, including embedded systems, wireless remote communication, lightweight materials, and 3D printing.

2. State of the arts

Microcontrollers are used for the automated control of equipment. For short-range remote communication, low-power solutions such as Wi-Fi or Bluetooth provide an optimal method for sending and receiving control and command signals. HTML software development for user interaction is a solution that requires minimal computing resources, making it possible to implement directly on the embedded module. Web page access can be provided via a WLAN network at an IP address set in the embedded module's programming code.

A microcontroller is an on-chip computer designed and optimized to perform control functions for specific electronic devices. These components easily integrate into projects, as they do not impose limitations regarding memory and interfacing capabilities. They are ideal for applications where space, resource consumption, and unit cost are critical factors. The three main roles that define microcontrollers are: receiving input signals through sensors, user interaction elements, wireless components, or Bluetooth modules; storing and processing actions and instructions; and applying the processed data to other activities—outputs.

The software component of microcontrollers involves writing code in the Python programming language, utilizing the Raspberry Pi development environment along with its available libraries. This code is structured around built-in libraries that offer core functionalities.

The Raspberry Pi Zero 2 W development board presents a versatile platform for projects in computer science and electronics. Its compact and lightweight design makes it one of the most space-efficient models in the Raspberry Pi lineup. Equipped with a 1 GHz quad-core ARM Cortex-A53 processor, it offers good performance for various applications. It includes built-in support for dual-band Wi-Fi 802.11 b/g/n/ac and Bluetooth 5.0, enabling wireless connections without the need for additional adapters. It also retains compatibility with the GPIO ports of other Raspberry Pi models, allowing connection to a variety of components and peripherals.

In the specialized literature, programmable embedded components and low-energy remote communication are often mentioned in the development of robotic platforms. For example, in [1], a solution is presented for building a robot controlled at short distances via voice commands. Communication is provided through Bluetooth, and DC motors are used. A. M. Abdulazeez in [2] emphasizes the use of robots in various environments, integrating several sensors and a camera for environmental awareness.

The use of mobile devices for control is also discussed. In [3], the RoboCar robot is presented, which includes a temperature sensor that communicates the measured temperature via Wi-Fi. Motor control is performed using an L298N H-bridge. When controlling robots, it is important to consider their mobility components, such as a chassis with a steering wheel, a four-wheel chassis with two steering wheels, tracks, etc. Thus, in [4], a control solution is presented for long robots with five axles, designed to avoid obstacles and move through narrow spaces.

3. Autonomous vehicles development

The development of autonomous vehicles involves integrating commercially available hardware components along with parts produced through mechanical processing and 3D printing. The control and command of the vehicle are managed using code sequences written in the Python programming language.

To connect the hardware components to the user, a mobile phone with any operating system that has web browsing capabilities is utilized.

3.1 Hardware Component Development

The hardware design of the autonomous vehicle centers around a platform fitted with four pairs of tracks. Directional control is managed through differential motor operation. Figure 1 provides a schematic representation of the complete hardware setup used in the vehicle's development.

To secure the perimeter and facilitate safe entry into conflict zones, an aerial monitoring system has been implemented using a DJI Tello drone. This drone serves as an aerial surveillance tool over the supply zone and is also employed to identify potential threats that could jeopardize the vehicle's security.

To ensure the efficient delivery of supplies and military equipment required by a unit, the vehicle is equipped with four pairs of tracks, allowing it to navigate difficult terrain conditions with ease. The autonomy of the robot in such environments is crucial for successfully completing its missions.

Consequently, solar panels have been installed to enhance its operational autonomy and provide energy support for the entire vehicle and its connected hardware components. Given that unfavorable conditions and the timing of vehicle intervention can vary, an optical system

has been prioritized. Therefore, a day and night vision optical system has been implemented to effectively meet any operational requirements.

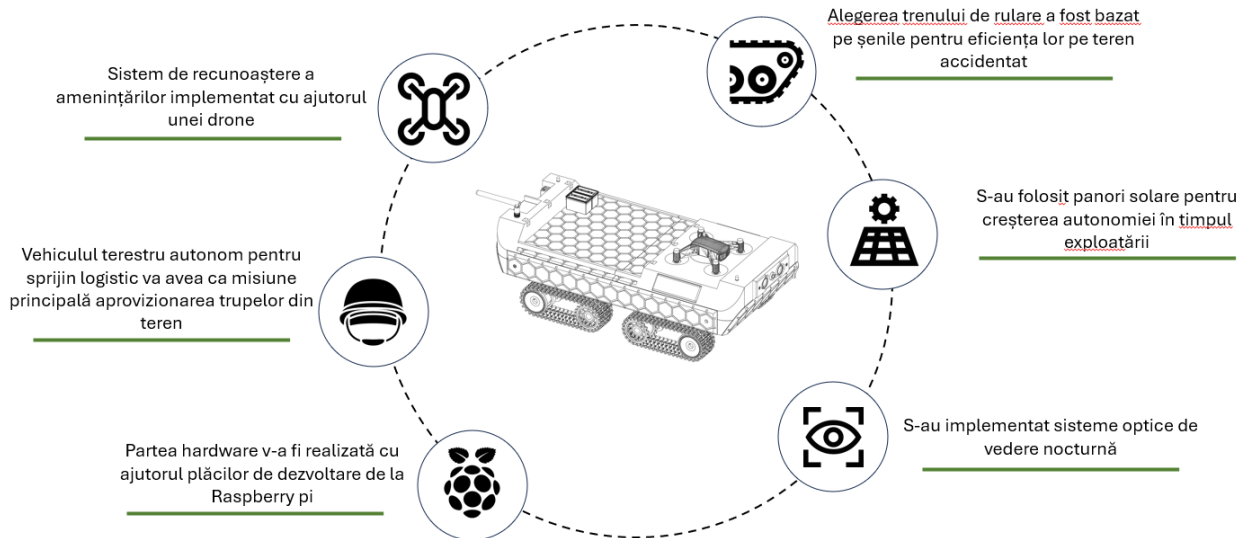


Fig. 1 Hardware Technologies Used

In terms of the overall dimensions of the autonomous vehicle, the goal was to create a 1:7 scale model based on existing vehicles developed by companies in the defense industry. The final dimensions are listed in Table 1.

Table 1. Overall Dimensions of the Autonomous Vehicle

Component	Length [mm]	Width [mm]	Height [mm]
Chassis	500	250	185

3.2 Software Component Development

The software component of the autonomous vehicle is integrated and preloaded into the memory of the Pi Zero 2W module. This software establishes the connection between the user commands and the vehicle's surveillance, monitoring, and control systems.

The surveillance function, performed using a drone, will operate in a rectangular pattern around the vehicle, providing real-time data captured by its onboard camera. The control interface will seamlessly integrate all functionalities, ensuring a user-friendly and efficient interaction between the user and the vehicle.

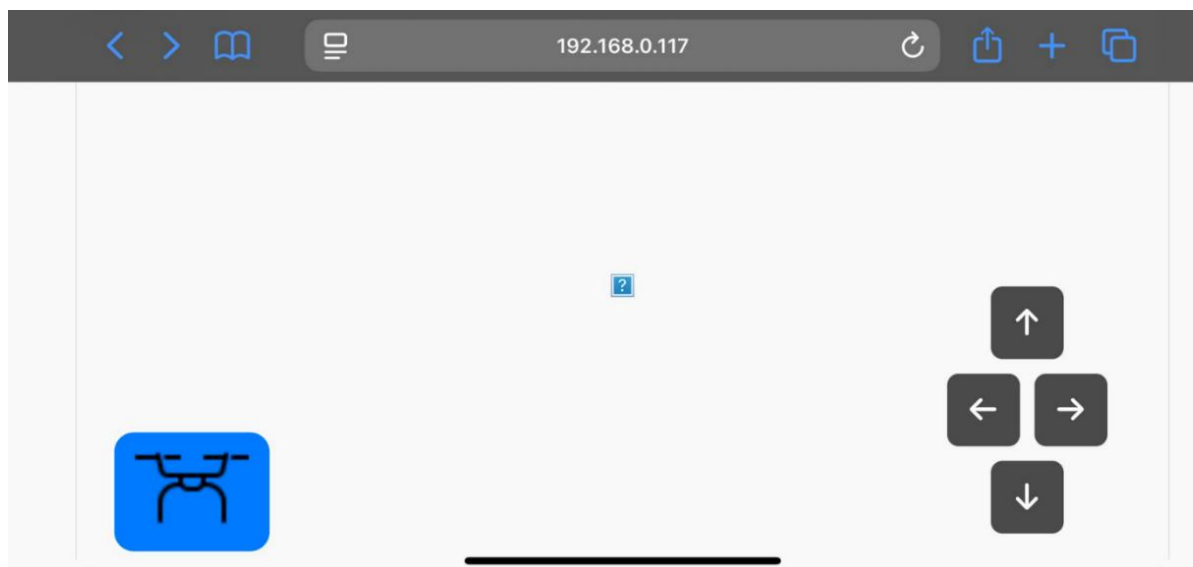


Fig. 5 Control and Command Interface

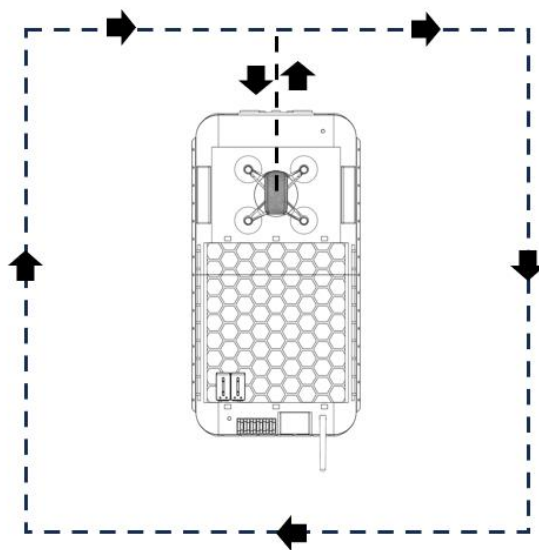


Fig 6. Drone Layout

Figure 7 presents the defined stages that the vehicle must follow to meet the user's requirements in a real-world scenario. The steps that lead to the vehicle successfully completing its route under normal operating conditions are triggered by specific **triggers**, which activate the commands necessary to execute the vehicle's full operational path.

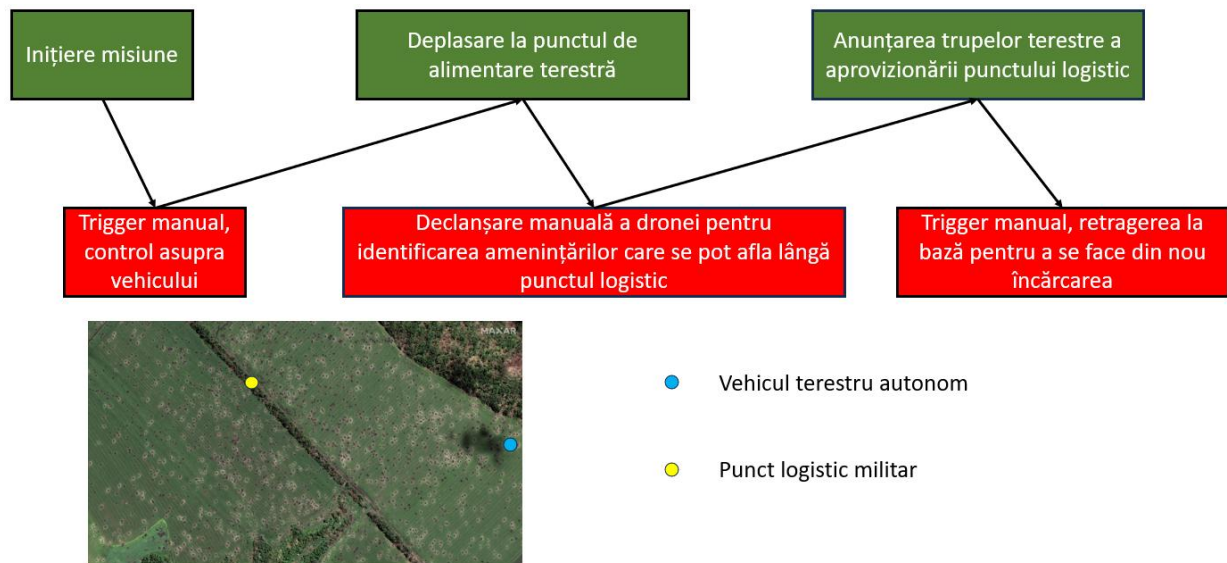


Fig. 7 Command Flow and Triggers for Vehicle Operation in a Real-World Scenario

4. Conclusion

With the recent advancements in artificial intelligence, future projects focused on autonomous vehicles will garner greater attention across various sectors, including industrial, military, medical, and manufacturing industries.

The goal of this project was to develop a 1:7 scale solution for military logistics support. Central to this project was a collection of hardware components powered by microcontrollers developed by Raspberry Pi.

On the software side, the programming languages Python and HTML were utilized. To construct the vehicle's frame, lightweight structural elements were chosen to ensure smooth and unobstructed movement.

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DEVELOPMENT OF A FUNCTIONAL PROTOTYPE FOR SENSOR-BASED VR GLOVES – APPLIED STUDY

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***ABSTRACT:** This paper presents the development of a low-cost smart glove prototype for Virtual Reality interaction. The glove uses four flexible sensors and an IMU (gyroscope and accelerometer) connected to a Raspberry Pi Pico. Sensor data is transmitted via serial interface and visualized in real time using a Python-based application. The visualization tool renders a simplified 3D hand model, showing both finger bending and overall hand orientation. The Madgwick filter is used to fuse inertial data for stable orientation tracking. The modular architecture allows future upgrades such as thumb sensing, haptic feedback, or wireless communication. The prototype is suitable for educational and experimental purposes in VR. It demonstrates the feasibility of accessible wearable solutions for intuitive human-computer interaction.*

***KEYWORDS:** VR, flexible sensors, human-machine interface, 3D visualization, Madgwick, Raspberry Pi Pico, Python, virtual reality.*

1. Introduction

Natural interaction between humans and the virtual environment is a rapidly expanding field, with applications in education, medicine, industry, and entertainment. Wearable technologies, especially smart gloves, allow for the intuitive and precise capture of movements and gestures. However, commercially available solutions are often expensive and inaccessible for academic research or educational institutions.

This paper presents an affordable, hand-built solution using low-cost materials and components, yet offering essential functionalities for interacting with VR environments: detecting the degree of finger bending and determining the hand's orientation in space. [10]

2. State of the Art

In recent years, research on gesture-based human-machine interfaces has experienced rapid development, particularly due to the growing interest in virtual and augmented reality. There are advanced commercial VR gloves on the market, such as Manus VR, SenseGlove, or HaptX, which offer extensive functionalities but are generally financially inaccessible for the educational sector. In the specialized literature, prototype solutions can also be found, using flexible sensors or computer vision technologies. However, many of these do not provide full support for real-time 3D representation of hand movement and require complex equipment. [1], [4] .

Recent studies have emphasized the growing importance of wearable technologies in Virtual and Augmented Reality applications. Flexible sensors have shown high potential for accurately detecting finger motion, enabling more natural and intuitive interaction in digital environments [1]. Research published in *Sensors* presents advanced sensor fusion techniques, such as quaternion-based orientation filters, which improve stability and accuracy in real-time tracking [12]. Furthermore, gesture-based interfaces have been successfully applied in robotics and teleoperation scenarios, as demonstrated in *Electronics*, showcasing their broader utility

beyond VR entertainment [1]. Several low-cost prototypes have also been developed for educational purposes, leveraging platforms like the Raspberry Pi Pico and open-source software [13,14]. These hybrid approaches, combining affordable hardware with efficient processing algorithms, contribute significantly to making immersive technologies more accessible in academic and experimental contexts.



Fig. 1. Various Models Available on the Market

This paper positions itself as a practical alternative with educational potential, emphasizing ease of integration and low cost, while also providing useful visualization and analysis functionalities.

3. Hardware system architecture

The prototype consists of the following components:

- 4 flexible sensors mounted on a fabric glove, for the index, middle, ring, and pinky fingers
- MPU6050 IMU module (gyroscope + accelerometer)
- Raspberry Pi Pico as the data acquisition and processing unit [6]
- Portable Li-Po battery
- USB serial connection for communication with a computer

CONNECTION DIAGRAM

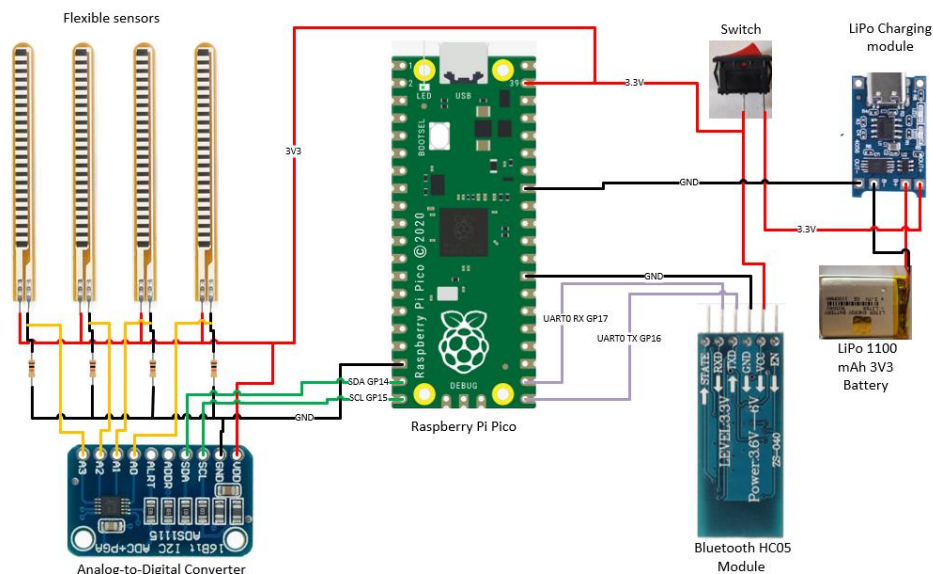


Fig. 2. Connection Diagram

4. 3D visualization system

The file `visualize_glove.py` represents the core of the software application, being responsible for interpreting the data received from the glove and graphically displaying the finger movements and hand orientation. This application is written in Python and uses libraries such as `matplotlib`, `serial`, `numpy`, and `scipy` for 3D visualization and sensor data processing.

Main functionalities:

- Automatic calibration of the flex sensors
- Conversion of flexible sensor values into bending angles (in degrees)
- 3D representation of a palm with 4 fingers
- Use of the Madgwick filter for sensor fusion between the gyroscope and accelerometer
- Real-time representation of hand orientation in space

The calibration stage is essential for the system's accuracy. Upon initialization, the glove collects a set of values from each flexible sensor while in a resting state. These values are averaged to establish a zero-reference point for each finger.

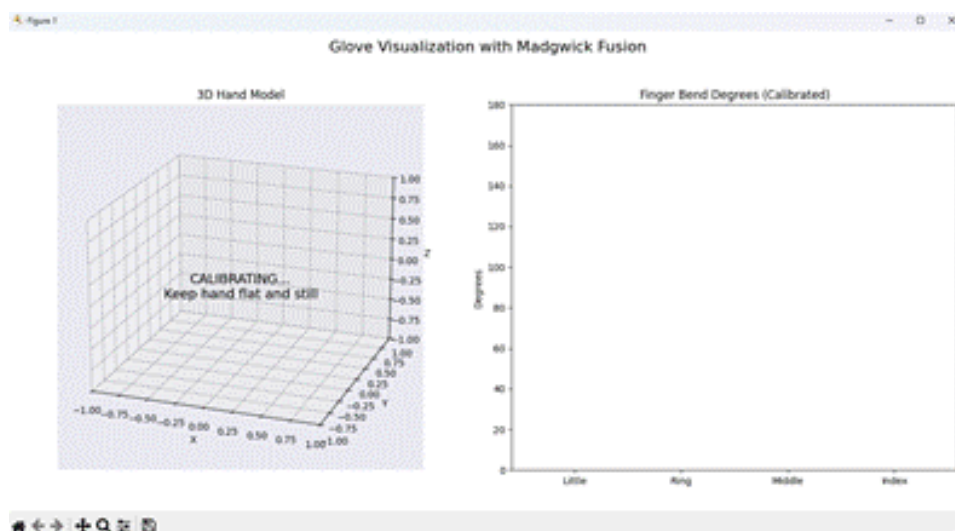


Fig. 3. Calibration Stage

if `is_calibrating`:

`calibration_values += raw_flex_values`

if `time.time() - calibration_start_time > CALIBRATION_DURATION_S`:

`calibration_values /= CALIBRATION_DURATION_S * TARGET_LOOP_HZ`

`is_calibrating = False`

else:

`bend_degrees = (raw_flex_values - calibration_values) * scale_factor`

This code highlights the simple calibration method by averaging the raw values and applying a scaling constant to obtain the corresponding bending angles. These steps are necessary because flexible sensors have slightly different characteristics and do not start from the same zero point.

For hand orientation, a Madgwick filter is used, implemented in a separate class, which processes data from the MPU6050 module. The filter combines data from the accelerometer (which measures the direction of gravity) and the gyroscope (which measures rotations) to estimate the orientation in space in the form of a quaternion. The quaternions are then converted into a rotation matrix, which is applied to the palm in the graphical model.

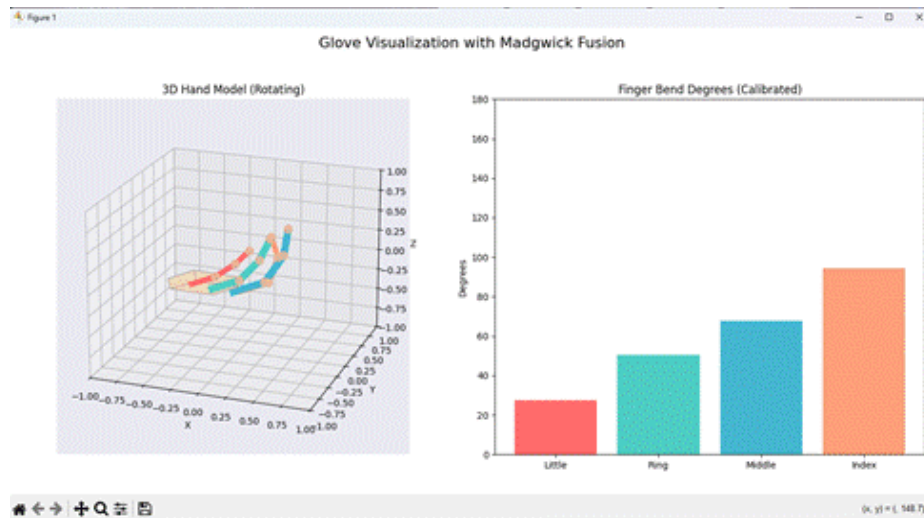


Fig. 4. Graphic Visualization

The visualization is done using matplotlib and Axes3D [5]. The palm model is represented by a simplified cube, while the fingers are drawn as 3D segments that tilt according to the angles calculated for each. The orientation of the entire hand is updated in real time, using the rotation derived from the Madgwick filter.

The code is modularly structured, allowing for the addition of new sensors or extension to a full hand model. The application is also useful for functional testing, individual sensor calibration, and real-time behavior validation.

This tool enables visual analysis of finger positions and movement dynamics, making it extremely useful in the calibration, testing, and further development of the system. Combined with sensor fusion algorithms and interactive graphical representation, it creates an ideal platform for prototyping in the field of virtual reality.

4. Data acquisition and processing methodology

Upon system initialization, the flexible sensors are calibrated by recording an average of the values read in the first few seconds. This reference value is then used to calculate the bending percentage of each finger, expressed in angles. Thus, the raw sensor values are converted into flexion degrees, which are visually reflected in the 3D model.

The hand orientation data is provided by the MPU6050 IMU module, which includes a three-axis accelerometer and a gyroscope. To achieve accurate and stable real-time hand orientation, this data is processed using the Madgwick filter. [9]

The Madgwick filter is a sensor fusion algorithm that combines information from the gyroscope (which provides angular velocity) and the accelerometer (which provides the gravitational vector) to estimate the orientation of an object in space in the form of a quaternion. The advantage of this filter over others (such as Kalman) lies in its computational efficiency and stability in noisy environments. The algorithm uses a gradient descent technique to correct the gyroscope's cumulative drift, continuously recalibrating with the measured acceleration. [3]

The relevant code is implemented in the MadgwickAHRS class, which maintains an internal orientation state in the form of a quaternion $[w, x, y, z]$. The main function `update_imu(gyro, accel, dt)` is called periodically to update the orientation.

```
q_dot_omega = 0.5 * self._quat_multiply(q, [0.0, gx, gy, gz])
# Accelerometer is used for corection
gradient = J.T @ objective_f
q_dot = q_dot_omega - self.beta * gradient
self.q = self.q + q_dot * dt
self.q /= np.linalg.norm(self.q)
```

This orientation estimate is then passed to the rendering function, which applies the resulting rotation to the 3D model of the palm and fingers. The visualization is done using the Matplotlib library, with Axes3D for spatial modeling. Each finger is composed of joint segments that tilt according to the calculated angle. The palm is represented as a simplified cube, and the entire hand is rotated based on the orientation calculated by the Madgwick filter.

By combining these technologies, the system provides a real-time representation of the user's hand, useful for calibration, analysis, and later integration into VR applications.

5. Discussions and Perspectives

The proposed solution demonstrates the feasibility of creating an accessible, portable, and functional VR system, with concrete possibilities for expansion and adaptation for more complex scenarios. With its modular architecture, the prototype allows for future improvements without the need to reconstruct the entire hardware or software assembly.

Proposed development directions include:

- Adding a fifth sensor for the thumb, enabling the detection of full hand movements and the recognition of more complex gestures. Integrating this would require minimal adaptations to the data structure and graphical rendering. [2]
- Integration with Unity applications or other VR environments to allow avatar or object control in a 3D virtual environment. This would involve transmitting sensor values via a compatible protocol (e.g., WebSocket or OSC) and developing an interpretation module in the graphic engine.
- Adding haptic feedback through small vibration actuators mounted on the fingers or palm, providing the user with tactile responses to interactions. This would simulate touching or resisting virtual objects, enhancing the realism of the experience.
- Wireless connection via Bluetooth, eliminating the USB cable and giving the user more freedom of movement. This modification would involve replacing serial communication with a Bluetooth Low Energy (BLE) connection, using modules compatible with Raspberry Pi Pico (e.g., HC-05 or Pico W).
- Gesture recognition algorithms, which can be implemented based on time-series data of bending angles and hand orientation. This would make the system smarter, automatically recognizing gestures like “ok,” “close the hand,” or “open palm.” [1]

These directions provide vast potential for development, transforming the current prototype into a complex human-computer interaction system. Additionally, the open-source architecture allows for collaborative expansion of the project by educational communities or researchers interested in natural interfaces and virtual reality.

6. Conclusions

The created prototype provides a solid foundation for further development in the field of natural interaction with virtual environments. The developed code ensures intuitive visualization, and the system's architecture is modular and easily extendable. The applied study contributes to the development of low-cost solutions for education and research, being easy to reproduce and adapt in educational or experimental contexts.

Another strength of the system is its flexibility in expanding functionalities, both on the hardware side (by adding sensors or feedback modules) and on the software side (by integrating with graphic engines, VR environments, or artificial intelligence algorithms). Additionally, choosing a platform like the Raspberry Pi Pico ensures an optimal balance between performance, cost, and ease of programming.

In conclusion, the paper demonstrates that emerging technologies such as flexible sensors and IMU data fusion can be successfully used in an educational setting to create intuitive and accessible interfaces. The result is a valuable tool for applied research and for developing skills in virtual reality, electronics, and interactive programming.

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THE INFLUENCE OF MATERIAL TYPE ON THE FUNCTIONALITY OF FINRAY GRIPPERS 3D PRINTED BY MATERIAL EXTRUSION

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***ABSTRACT** - This study investigates the influence of material type on the functionality of soft robotic grippers with fin-ray design, manufactured using 3D printing process. Three thermoplastic filaments, PLA, PETG, and PP, were used to produce identical soft fingers. Each material was evaluated based on printability, dimensional accuracy, joint clearance, and mechanical behavior during gripping. Rib angles were measured to quantify the degree of finger flexibility and object conformity. PLA showed the lowest rib angles, smooth motion, and excellent surface quality, confirming its suitability for integrated, articulated designs. PETG demonstrated higher stiffness and non-uniform deformation due to stringing and tight tolerances, requiring design calibration. PP, while flexible, presented poor adhesion, warping, and fused joints, resulting in non-functional fingers.*

KEY WORDS: Finray gripper, PLA, PP, PETG, fit, Material Extrusion process

1. Introduction

Robotic end-effectors are the interface between a robot and the objects it manipulates; therefore, their design should be closely aligned with object geometries and task-specific requirements [1]. These devices can be classified by actuation type (pneumatic, electric), functionality (e.g., mechanical, magnetic, vacuum, welding, painting), or adaptability (standard vs. adaptive) [2], and as more and complex applications are nowadays automatized, the end-effectors are expected to provide precision, modularity, and improved material performance [3].

In this context, soft robotic grippers represent a solution to these demands, enabling safe and effective manipulation of fragile or irregularly shaped items. Made from compliant materials, these grippers conform to object surfaces and offer the adaptability not provide by grippers with rigid designs. Their use is particularly valuable in fields such as food handling, medical robotics, and flexible manufacturing, where gentle and reliable object interaction is essential [4–6].

Among soft gripper designs, the fin-ray gripper design is known for its biomimetic architecture, inspired by the mechanics of fish fins [7]. They have a triangular profile reinforced with transverse ribs, and their structure deforms predictably under load, thus allowing the gripper to conform to a variety of shapes while distributing contact forces uniformly [8]. While most existing implementations focus on two-finger designs with parallel actuation, there are also configurations with three fingers that are gaining interest as these can grasp an object from multiple directions, forming a central, radial grip better suited to automation tasks with random object positioning

While previous studies have investigated fin-ray gripper design and general material behavior [9-10], there is limited data comparing how common MEX-printable materials influence the conformability of grippers to spherical shapes. Furthermore, most comparative studies focus on load capacity or grasping force rather than geometric adaptation, which is critical for object fit and handling in real-world scenarios. This study explores a three-finger fin-ray soft gripper fabricated via Material Extrusion (MEX) 3D printing, using three different thermoplastic materials: polylactic acid (PLA), PETG, and polypropylene (PP). The goal is to evaluate and compare each material's ability to conform to a spherical object, using a tennis ball as a benchmark. All tests are conducted using the same actuation system, and gripper

performance is assessed by measuring key angles that reflect the degree of finger deformation and surface adaptation during gripping.

Through controlled experimental testing, this research aims to identify how material properties influence soft gripper performance. The findings contribute to optimizing material selection for soft robotic applications, with broader implications for the design and durability of 3D-printed end-effectors.

2. Material and Method

2.1. Design of the fin-ray finger and the gripper

The gripper fingers are based on the finray effect, Festo patent [11], which mimics the structural behavior of fish fins in order to enhance adaptability and stability when interacting with objects of various shapes. This design was created using Fusion 360 and includes three fingers positioned at 120° even intervals, each finger being connected to the central body of the gripper using dovetail guides (Fig. 1).

A 5V DC motor coupled with a 127:1 gear reduction system constitutes the actuation of the gripper, a worm gear mechanism being responsible for the opening and closing motion of the fingers. All the structural components, including the housing and worm wheel, are fabricated with MEX process. These two elements are printed simultaneously, and the assembly is designed to be removable. Gear alignment is ensured using octagonal-profile pins, which facilitate smooth sliding and minimize friction, these being designed to be directly 3D-printed as an assembly.

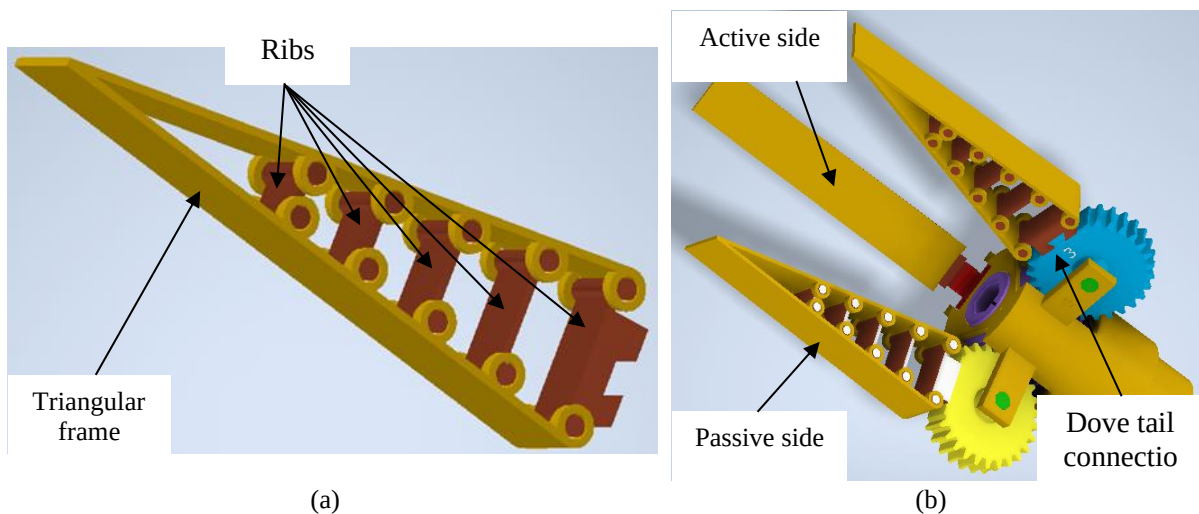


Fig. 1. Design of the soft gripper: (a) finger, (b) three fingers configuration

The rib shape plays an essential role in how the fingers perform. Thin, inclined, and flexible ribs allow better distribution of the contact force and increase the contact area, which makes them more suitable for handling fragile objects. During deformation, passive jamming takes place, being caused by friction between the ribs, which increases the stiffness of the finger and makes it transition from a stress-free to a locked state. However, too much flexibility also means a lower capacity to support heavier loads, so a balance between flexibility and strength is needed.

Among the most important design parameters of the finger are: the number of ribs, their thickness and orientation, and also the angle and thickness of the active and passive walls/sides.

If the number of ribs is increased, the contact pressure becomes higher, but this can also reduce the fingertip's travel distance. Therefore, the rib configuration must be optimized depending on the specific task the gripper is designed for. In this research, the task for the gripper is to manipulate spherical objects – a tennis ball with 60 mm diameter, and weighting 55 g.

2.2. 3D printed fin-ray fingers

Three fingers were manufactured on Ultimaker S5 3D printer from PLA, PETG and PP filaments from Ultimaker using process parameters suitable for each material, set in Ultimaker Cura V5.10.0 slicer. The fingers were then mounted onto an ABS-printed assembly, which houses the gear system and actuation mechanism.

2.2.1. 3D-printed finger from PLA

PLA is widely recognized for its ease of use in MEX 3D printing, making it well-suited for prototypes and detailed components. In the conducted tests, the PLA finger demonstrated high dimensional accuracy and smooth surface finish, with no visible defects such as under- or over-extrusion or delamination (Fig. 2). The assembly, printed as a single part, remained fully functional after support removal, with proper clearances allowing smooth movement between the internal elements. These results confirm the suitability of the selected process parameters for this geometry, material, and 3D printer.

The following main process parameters were used:

- Extrusion temperature: 215 °C
- Bed temperature: 60 °C
- Layer thickness: 0.15 mm
- Infill density: 100%
- Infill pattern: zig-zag



Fig. 2. Finger 3D-printed in PLA with support structure

2.2.2. 3D-printed finger from PETG

PETG material provides a balanced combination between stiffness and flexibility, while providing superior chemical and mechanical resistance. As the 3D printing process was conducted at a high extrusion temperature, the interlayer adhesion was increased, as well as the

risk stringing (thin filament strands forming between internal features, see Figure 3). As a general observation, the stringing can interfere with the mobility of moving parts, especially in tightly constrained geometries such as gripper assemblies.



Fig. 3. Finger 3D-printed in PETG with support structure

The final printed finger was nearly functional, as tight tolerances and PETG characteristics led to limited mobility, in some areas, the moving elements being partially fused and requiring mechanical separation.

Thus, a proper setting in 3D CAD of the assembly clearances is required when 3D printing with this material.

The following main process parameters were used:

- Extrusion temperature: 245 °C
- Platform temperature: 85 °C
- Layer thickness: 0.2 mm
- Infill density: 100%
- Infill pattern: zig-zag

2.2.3. 3D-printed finger from PP

PP is a material recommended for applications requiring flexibility and chemical resistance, but in the case of MEX process it presents several significant challenges. In the tests carried out, manufacturing proved difficult, with very poor adhesion of the thin finger to the print bed (Fig.4) which required Raft adherence setting in Cura. Still, despite the high temperatures for extrusion and printing bed, and preliminary treatments for adhesion, the results were unsatisfactory in terms of geometric stability of the print.

The printed PP fingers had a major issue, i.e. the lack of clearance between the moving components. The parts were effectively fused together, most likely due to PP's low dimensional rigidity and specific flow behavior during deposition. Under the current design and print conditions, PP was not a suitable material for FinRay-type grippers that rely on precise clearances and free movement between integrated elements.

The following main process parameters were used:

- Extrusion temperature: 215 °C
- Platform temperature: 85 °C
- Layer thickness: 0.2 mm

- Infill density: 100%
- Infill pattern: zig-zag



Fig. 4. Finger 3D-printed in PP with support structure and Raft support

3. Results

Table 1 presents a comparison of the three materials used, based on several key criteria relevant to the analyzed application.

Table 1. Comparison between analyzed materials

Characteristic/Material	PLA	PETG	PP
Printability	Very easy	Average (requires calibration)	Difficult (poor adhesion, warping)
Adherence to 3D printers' bed	Very good	Very strong	Very weak (requires special solutions)
Tolerances / clearances	Gaps kept with little residue	Reduced play / parts may stick together	Non-existent clearances – welded parts
Mechanical resistance	Good, but fragile	Very good, impact resistant	Flexible, but with good durability
Resistance to temperature	Reduced ($\sim 60^{\circ}\text{C}$)	Medium ($\sim 70\text{--}80^{\circ}\text{C}$)	Good ($\sim 100^{\circ}\text{C}$)
Postprocessing	Light (sanding, painting)	Medium (stringing possible)	Difficult to process
Observations	Good for beginners & prototyping	Good balance between durability and lightness	Requires adapted design, difficult in mobile assemblies

Figures 5–7 show the gripper during the manipulation of a tennis ball, highlighting the deformation of the fingers made from different materials. The front-facing images were analyzed using ImageJ software to measure the rib angles, which serve as indicators of the

gripper's conformity to the spherical surface. Each figure corresponds to a different material used for the fingers (PLA, PETG, and PP), illustrating variations in flexibility and contact behavior during gripping.

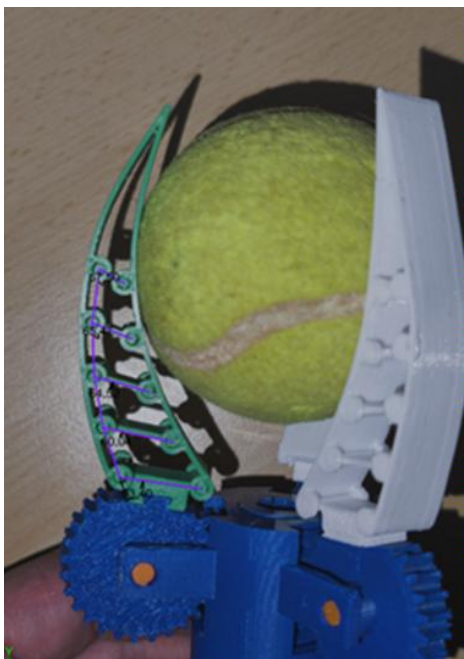


Fig. 5. PLA finray finger with rib angles measurements

PLA

- **Measured Angles (°):** 67.5, 65.47, 64.52, 60.0, 63.4 (Fig.5)

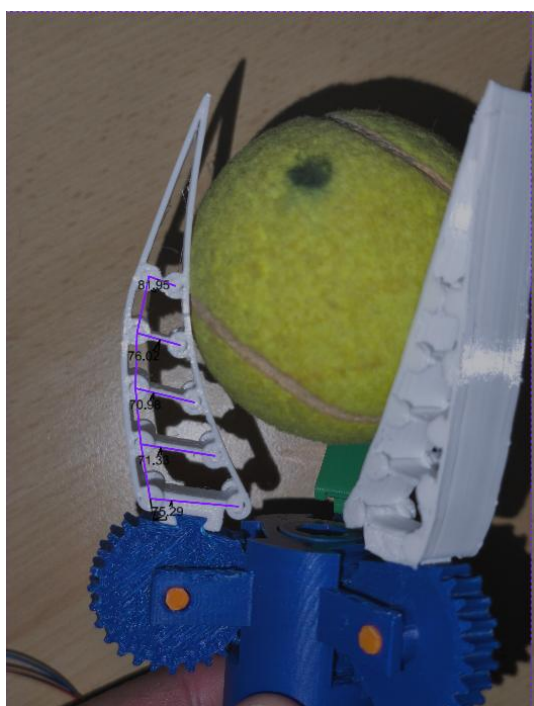


Fig. 6. PETG finray finger with rib angles measurements



Fig. 7. PP finray finger with rib angles measurements

The measured rib angles indicated that lower values are associated with increased finger flexibility, allowing better conformity to the spherical surface of the tennis ball. Among the tested materials, PLA demonstrated the most favorable balance between flexibility and structural integrity. No visible deformation was observed in the PLA fingers, and the functional clearances between articulated joints were preserved, confirming high dimensional accuracy. Overall, PLA exhibited the best performance in terms of adaptability and mechanical functionality for the given gripper design.

PETG

- **Measured Angles (°):** 81.95, 76.02, 70.98, 71.38, 75.29 (Fig. 6)

The rib angle values for PETG were consistently higher than those recorded for PLA, indicating reduced flexibility, particularly near the fingertip. The observed variation between measurements suggests non-uniform deformation, likely caused by partial sticking at the joints due to insufficient clearance or residual stringing. While finger articulation was functional, it was not optimal; this highlights the need for adjustments to CAD model tolerances to minimize friction and improve joint movement. Overall, PETG is a viable material for functional gripper applications, provided that print settings and design parameters are carefully calibrated.

PP

- **Measured Angles (°):** 92.55, 88.33, 87.09, 81.5, 82.38 (Fig. 7)

The rib angles measured for PP finger were significantly higher, indicating limited finger closure and reduced adaptability to the object's surface. This behavior is attributed to fused joints, a common issue when printing PP without optimized process conditions. The resulting finger exhibited minimal mobility, and the gripping contact was uneven, likely due to internal stress and warping. Under the current design and printing parameters, PP is not suitable for articulated structures, unless substantial modifications are made to both the geometry and process settings.

Table 2 is a summary of the measured angles for each finger/material.

An independent samples t-test revealed a statistically significant difference between the mean rib angles of PLA and PETG ($t = -4.68$, $p = 0.0016 < 0.05$). The lower average angles observed in PLA indicate greater flexibility and improved adaptation to the shape of the gripped object compared to PETG, under the tested conditions.

Table 2. Ribs' angles for fingers from different materials

Material	Angle 1 (°)	Angle 2 (°)	Angle 3 (°)	Angle 4 (°)	Angle 5 (°)
PLA	67.5	65.47	64.52	60	63.4
PETG	81.95	76.02	70.98	71.38	75.29
PP	92.55	88.33	87.09	81.5	82.38

4. Conclusions

The study evaluated the influence of material type on the functionality of Fin Ray-type grippers fabricated using MEX. PLA, PETG, and PP, three common thermoplastic filaments, were analyzed in terms of printability, dimensional accuracy, deformation behavior, and suitability for articulated finger designs.

PLA showed the best overall performance, combining excellent dimensional accuracy with sufficient flexibility for adaptive gripping. The finger printed in PLA maintained

functional clearances, showed no defects, and achieved the lowest rib angles, which correspond to better conformity to the spherical object.

PETG exhibited greater stiffness and less uniform deformation. While functional, the printed part showed signs of partial fusion at the joints due to stringing and tighter tolerances. As a result, PETG requires precise CAD adjustments and printing calibration to be suitable for articulated structures like Fin Ray grippers.

PP proved to be the least suitable material for the tested application. Despite its flexibility, the finger printed from polypropylene exhibited poor layer adhesion, warping, and fused joints, which rendered the mechanism non-functional. Major design and process adaptations would be required to successfully use PP in articulated components.

For concluding, PLA and ABS are the most appropriate choices for finray design grippers produced by material extrusion, especially in applications requiring precision and reliable motion. The selection of the printing material should always be aligned with the functional requirements of the end-use part, including expected deformation, tolerances, and mechanical demands.

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THE EFFECT OF PROCESS PARAMETERS ON THE CONDUCTIVITY OF 3D PRINTS MADE FROM COMMERCIAL POLYLACTIC ACID-BASED FILAMENT
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This paper presents an investigation on the effect of several 3D printing process parameters (temperature, deposition speed, layer thickness) on the electrical conductivity of conductive filaments based on PLA (polylactic acid). The goal is to optimize the process settings that can enable the cost-effective manufacturing of embedded electronics, sensors, and other personalized functional components with complex geometries, using commercial conductive PLA with carbon-based additives (Protopasta) on low-cost 3D printers. The main findings showed that increasing the extrusion temperature led to better conductivity, but induced variations in the measured values. Printing speed also had a significant effect on conductivity, while for layer thickness, the experimental data showed an inverse correlation with the electrical resistance.

KEYWORDS: 3D Printing, PLA, Additive Manufacturing, process parameters, conductivity

1. Introduction

Additive manufacturing (AM), especially Material Extrusion (MEX), has gained a lot of attention in the past few years for enabling the fabrication of functional parts with integrated electrical features [1-2]. Commercially available conductive filaments, such as ProtoPasta conductive PLA (polylactic acid), provide a relatively inexpensive option to integrate electrical interfaces into 3D-printed parts with the use of low-cost or desktop 3D printers. These thermoplastics materials are modified so that to include carbon fillers, usually carbon black or carbon fibers, forming percolation networks which are necessary for electrical conduction within the thermoplastic matrix [3].

Despite the potential this class of material has for 3D-printed electronics, smart sensors, and smart structures [4-5], the material's electrical resistance exceeds greatly that of conventional metals, and varies highly with process parameters. Several studies have established that the nozzle temperature, print speed, and layer height have a direct impact on the mesostructure of printed components and influence filler distribution, interlayer adhesion, and voids, also known as cellular structure, which define electrical resistance. As example, Beniak et al. [6] investigated how process parameters like nozzle temperature, layer height, and infill pattern impacted the electrical and mechanical properties of ProtoPasta conductive PLA, emphasizing the crucial impact temperature has on resistance. Similarly, Gao et al. [7] demonstrated a parabolic dependence of resistivity on nozzle temperature, and noted an effect of print speed. Stano et al. [8] confirmed the critical role of both nozzle temperature and layer height on resistivity. Glogowsky et al. [9] investigated filaments based on conductive elastomers and noted increased conductivity at lower print speeds and moderate temperatures, attributing this to improve interlayer adhesion and reduced porosity.

The current study focuses on a specific filament, PLA-based, Protopasta [10], analyzing how printing parameters influence the electrical properties of manufactured parts. The main objective was to identify optimal processing parameters that can provide good and predictable conductivity. In order achieve this, an experimental model was developed using test specimens with varying conductive path lengths, all printed from ProtoPasta filament. The study

systematically varied extrusion temperature, deposition speed and layer thickness, while keeping the other variables constant. Electrical resistivity was measured using the two-point probe method with a multimeter to obtain accurate and reproducible data.

This work aims to contribute to a deeper understanding of the process-property relationships for conductive PLA and offer valuable insights for optimizing additive manufacturing workflows in applications such as printed circuits, flexible electronics, and rapid prototyping of smart components.

2. Material and methods

The material used for manufacturing all the samples in this research was Protopasta conductive with 1.75 mm diameter filament [10] on white standard PLA sublayer. Comgrow T300 3D printer was used in manufacturing.

Several types of samples were designed using Siemens NX software, each with geometries customized to the specific process parameters being analyzed. Figures 1–2 show the drawings of these samples.

The specimen used for temperature testing consisted of a PLA+ base for stability, with five parallel conductive tracks printed from ProtoPasta Conductive PLA filament. Each track was 2 mm wide, 1.2 mm high, and varied in length from 20 mm to 100 mm. This design allowed for the evaluation of how both the printing temperature and conductor length affected electrical resistivity.

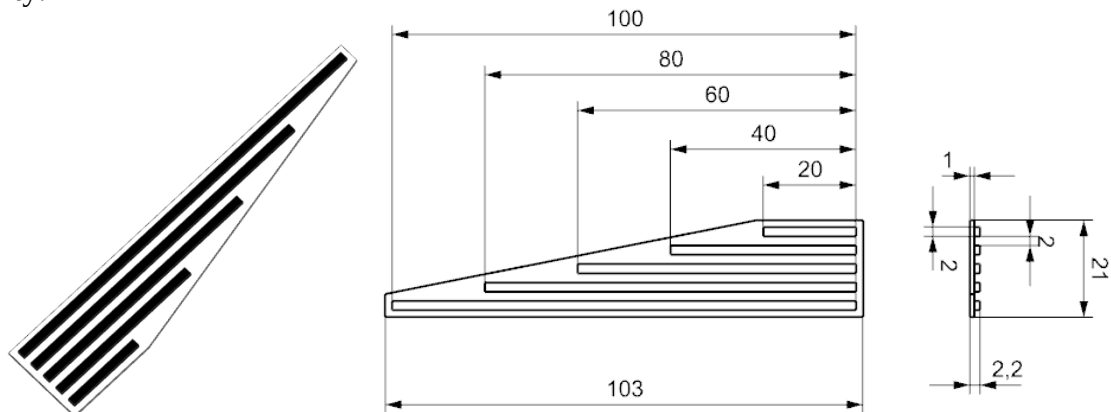


Fig. 1. Temperature specimen, isometric view and dimensions

To evaluate the impact of print speed on conductivity, specimens (Fig. 2) with conductive traces (100 mm long) were printed at four speeds: 40, 60, 80, and 100 mm/s.

Table 1 presents the process parameters used for manufacturing.

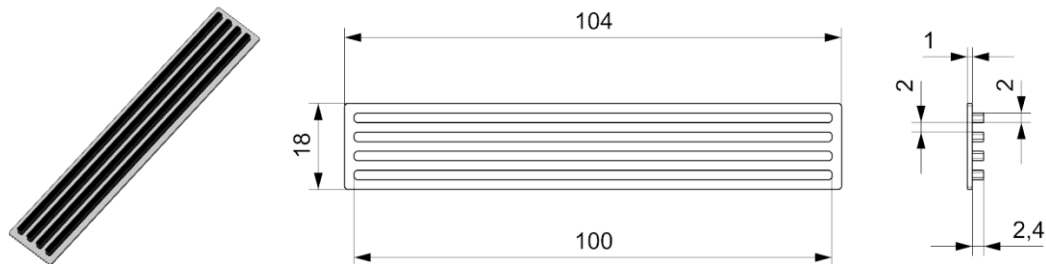


Fig. 2. Printing speed and layer thickness specimen, isometric view and dimensions

Fixed process parameters	Variable process parameters
--------------------------	-----------------------------

Platform temperature: 60 °C	Extrusion temperature: 210 °C, 230 °C
Infill density: 100%	Deposition speed: 40 mm/s, 60 mm/s, 80 mm/s, 100 mm/s
Infill pattern: N/A	Layer thickness: 0.15 mm, 0.2 mm, 0.3 mm, 0.4 mm
Line width: 0.4 mm	Wall thickness: same as Layer thickness

Table 1. Process parameters for the 3D-printed samples

All specimens were measured with CEM DT-9560 multimeter (accuracy $\pm 0.8\% + 1$ digit), as presented in Figure 3.



Fig.3. Samples conductivity measurement process

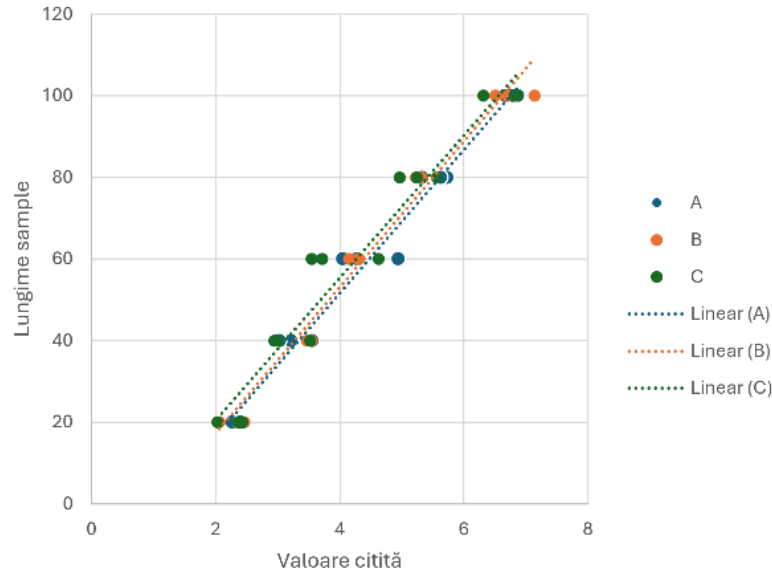
3. Results

3.1. Temperature influence on the conductivity

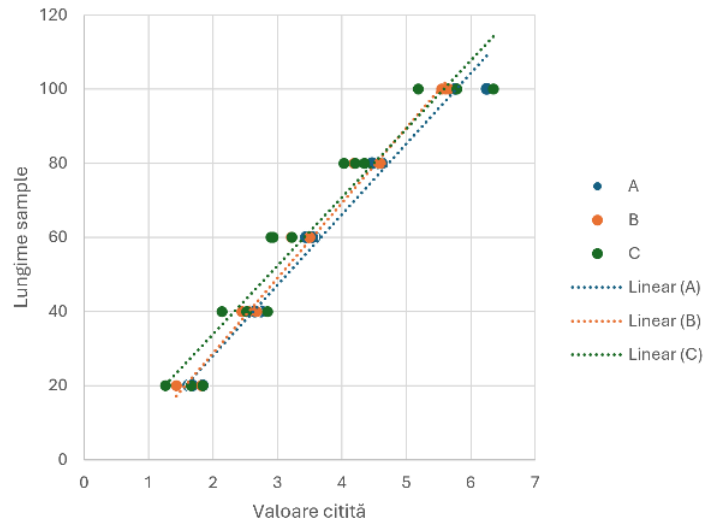
During temperature testing, the resistance of the conductive PLA specimens was measured at two extruder temperatures: 210 °C and 230 °C. At 210 °C, the resistance values increased linearly with the length of the conductive path, showing a consistent and predictable trend across all samples, as shown in Fig. 4a. When the extruder temperature was increased to 230 °C, the measured resistance values were lower for all path lengths, indicating improved conductivity at the higher temperature (Fig. 4b).

However, this improved performance came with increased variability in the results, and the linearity between resistance and length became less evident. This suggests that while higher temperatures can enhance the conductive filament's flow and interlayer bonding, thus contributing to lower resistivity, they may also introduce process instabilities, such as thermal degradation or uneven filler distribution.

Overall, increasing the print temperature led to better conductivity, but at the expense of measurement consistency and reliability.



(a)



(b)

Fig. 4. Graphs showing linear increase in resistivity: 210 °C specimen (a), 230 °C specimen (b)

3.2. Deposition speed influence on the conductivity

The first experimental setup for deposition speed evaluation involved measuring resistance at the ends of short conductive traces. However, this approach yielded highly inconsistent results due to two main factors: (1) 3D printer's extruder could not consistently maintain the target speed over short distances, especially at the start and end of traces where acceleration and deceleration effects dominated; (2) corners and endpoints showed material buildup (or "over-extrusion"), distorting the cross-sectional geometry of the conductive paths and introducing measurement artifacts. To address these issues, the sample was redesigned (Fig.5) to include extended trace lengths for ensuring that the 3D printer can achieve and maintain the target speed. Additionally, dual measurement inserts were positioned at the 100 mm mark of each trace, allowing measurements to be taken in regions of stable extrusion, free from acceleration, deceleration, or corner-related over-extrusion.



Fig. 5. Specimen redesigned for the deposition speed testing

After implementing the optimized specimen, resistance measurements showed significantly reduced variability (Fig. 6). Statistical analysis revealed that 80 mm/s provided the lowest variance between replicates, indicating an optimal balance between extrusion stability and speed. Higher speeds (100 mm/s) introduced some turbulences in material flow, while lower speeds (40–60 mm/s) localized the overheating, both contributing to variations in the resistivity.

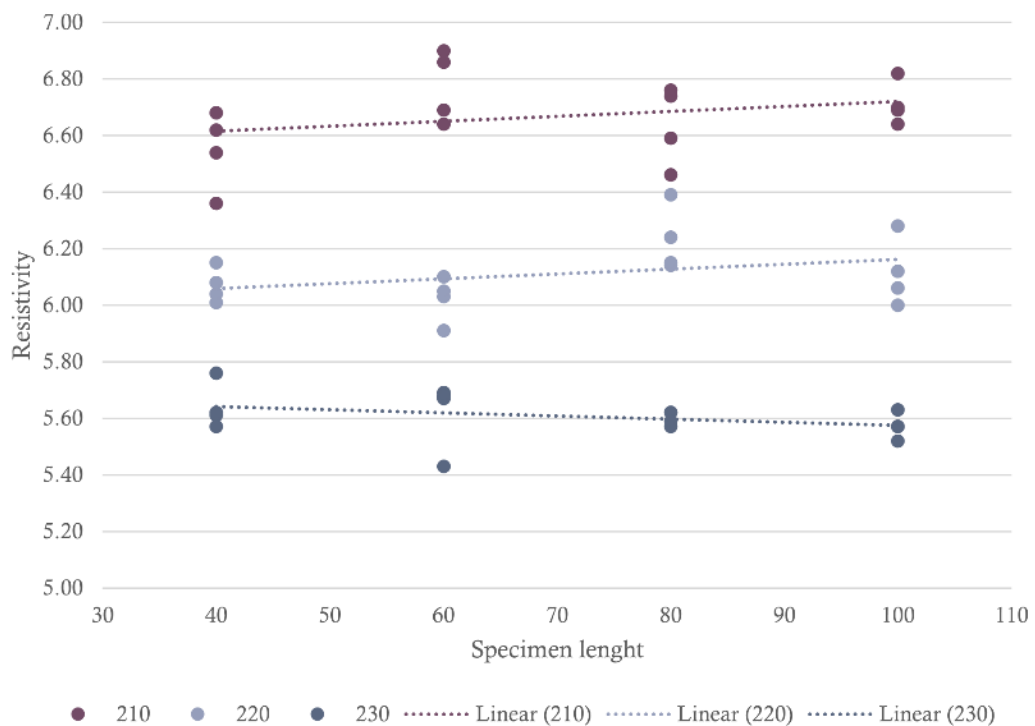


Fig. 6. Measurement results for printer speed influence

3.3. Effect of layer thickness on the electrical resistance

Specimens were 3D printed at 230 °C and 80 mm/s speed, with layer heights varying from 0.15 mm to 0.40 mm.

The findings revealed a strong inverse correlation between layer height and electrical resistance: at a layer height of 0.15 mm, the average resistance was approximately 5.55 kΩ,

while at 0.40 mm, the average resistance dropped to about 4.90 k Ω (Fig.7). This represents a decrease in resistance of roughly 12% across the tested range.

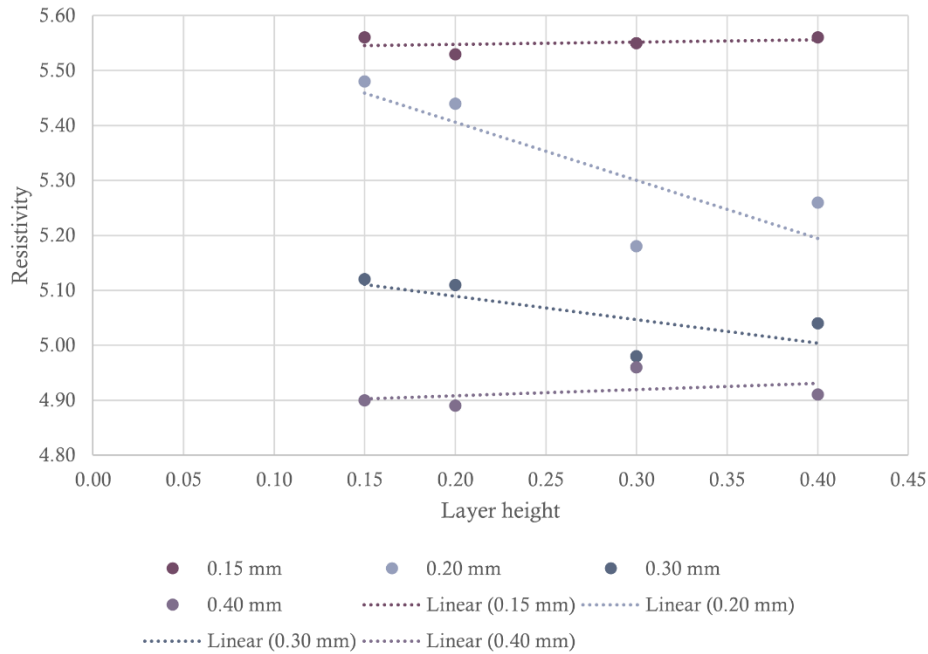


Fig. 7. Layer height conductivity results

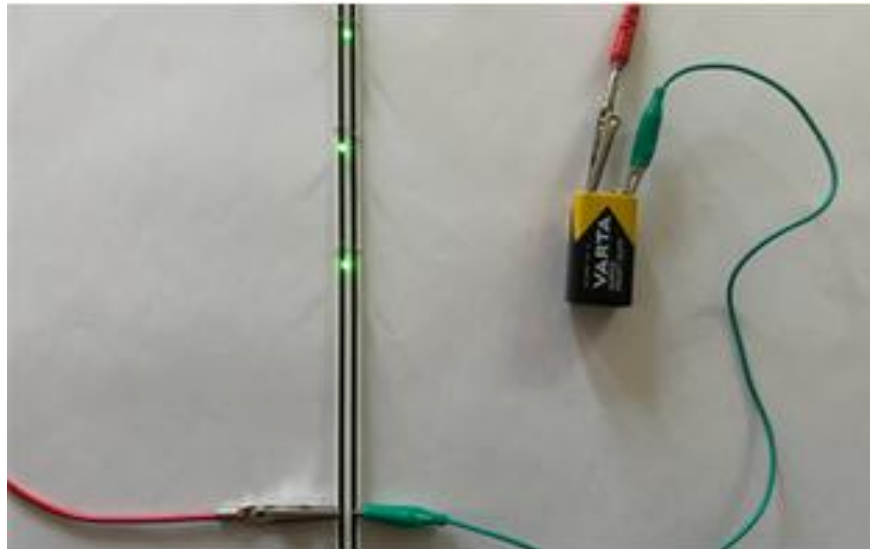
Resistance consistently decreased as the layer height increased. This negative correlation suggests that thicker layers improve conductivity, likely due to two main factors. Firstly, thicker layers result in fewer inter-layer interfaces for a given print height. Each interface acts as a potential discontinuity in the conductive carbon particle network, so reducing the number of interfaces lowers the overall resistance. Secondly, thicker layers may enable better alignment of the carbon particles within each extruded path, thus enhancing the formation of continuous conductive pathways.

4. Case study

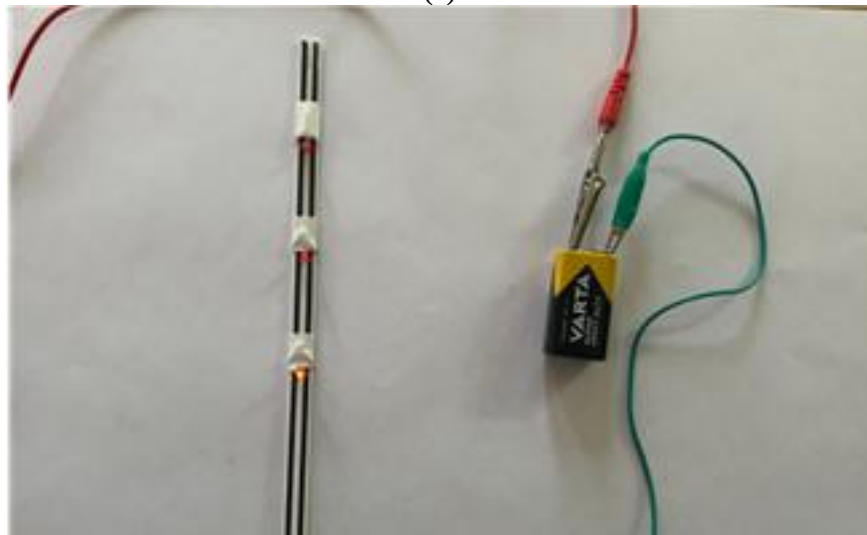
To confirm the practical implications of the study's findings, a real-world validation test was conducted using two 250 mm-long conductive traces (Fig.8). One trace was printed using found optimal settings, 230 °C extruder temperature, 80 mm/s speed, and 0.4 mm layer height, while the other used suboptimal settings of 210 °C, 100 mm/s, and 0.15 mm layer height.

Five LEDs were placed at 50 mm intervals along each trace and powered by a 9V battery. The results were: on the optimally printed trace, all LEDs illuminated uniformly at full brightness, confirming low resistivity and consistent conductivity.

In comparison, the suboptimal trace showed progressive dimming, with the farthest LED at 250 mm nearly extinguished. This visible "voltage drop" effect corresponds directly with the higher resistivity measured under the suboptimal conditions.



(a)



(b)

Fig. 8. LEDs on optimal settings (a) and suboptimal (b)

5. Conclusions and further work

This paper set out to systematically investigate how key printing parameters-extruder temperature, print speed, and layer height-influence the electrical conductivity of 3D-printed parts made with ProtoPasta Conductive PLA filament. The purpose was to identify optimal processing conditions that yield both high and predictable conductivity, thus enabling more reliable applications for 3D-printed electronics and functional prototypes.

In summary, the study demonstrates that optimal conductivity and measurement stability for conductive PLA are achieved at a print temperature of 210 °C, print speed of 80 mm/s, and a relatively large layer height (0.3–0.4 mm).

Future work will include a detailed analysis of the mechanical properties of conductive PLA. Tensile, flexural, and impact resistance tests will be conducted to evaluate how printing parameters, such as temperature and layer height, affect the material's mechanical strength. This research will aim to investigate potential trade-offs between conductivity and structural integrity, particularly for load-bearing components in printed electronics.

In addition, functional prototypes—such as strain sensors, flexible circuits, and IoT devices—will be designed and tested to validate the material’s performance in real-world scenarios. Collaborations with industry partners are planned to explore the integration of conductive PLA into wearable technology, smart packaging, and industrial monitoring systems, further assessing its potential for practical applications.

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OPTIMIZATION OF THE MANUFACTURING PROCESS OF A FINGER ORTHOSIS USING PARAMETRIC DESIGN

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***ABSTRACT:** The study presents the design process of a finger orthosis using parametric design in Grasshopper, thereby optimizing the customization of the device. The stages of modeling, simulation, and additive manufacturing are addressed, highlighting the advantages of 3D printing for the production of medical devices. A MATLAB program analyzes the efficiency of mass production using this method, demonstrating a significant reduction in manufacturing time compared to traditional techniques.*

***KEYWORDS:** parametric design, 3D printing, optimization of production process*

1. Introduction

Over the past decade, the customization of orthopedic devices has been substantially advanced by the development of additive manufacturing technologies, particularly through the widespread use of 3D printing technologies. Various rapid prototyping techniques have demonstrated significant efficacy in the medical field, especially in the fabrication of patient-specific orthoses, where anatomical precision and adaptability are paramount. The typical workflow for orthosis production generally includes three key stages: 3D anatomical scanning, data processing and modeling in CAD environments, and physical fabrication through 3D printing [1].

Conventional devices are often bulky and uncomfortable. Thus, 3D printed orthoses represent an innovative alternative, offering a customized fit to the patient's anatomy. This modern approach not only optimizes patient recovery but also reduces material consumption and production time, making 3D printed orthoses a sustainable and efficient solution in the medical field.

While 3D printed orthoses have been extensively utilized in the field of orthopedics, applications specifically targeting finger orthoses remain relatively underexplored in the scientific literature. Consequently, the present research aims to develop a customized finger orthosis, with particular emphasis on ergonomic design, as well as the reduction of both design and production time.

Finger orthoses are frequently employed in the treatment of various injuries or conditions, such as sprains and dislocations, in which joints are displaced from their normal position and require immobilization to ensure proper alignment during the healing process.

These finger orthoses can vary in type depending on the affected finger. In order to provide enhanced medical stability and to promote an extended recovery period for the injured area, the orthosis is designed to encompass both the affected finger and the adjacent finger on its right side.

Although 3D printing technology is well established, the initial two stages of the manufacturing process still present challenges related to scanning accuracy and the complexity of modeling software. Consequently, there is an increasing need for integrated, accessible, and efficient solutions that enable rapid and precise customization of medical devices. In this context, the present study proposes a comprehensive approach based on 3D scanning,

parametric modeling, and FDM printing, with a particular focus on optimizing execution time and the ergonomic performance of the orthosis.

2. Scanning

In the 3D scanning process for the fabrication of a finger orthosis, proper hand positioning is essential to ensure both the accuracy of the digital model and the final functionality of the device. Considering the application of the manufacturing process to an orthosis for the digitus medius (the injured finger), it is important for the patient to keep the two adjacent fingers in contact during scanning, as this position clearly indicates to the designer the specific area requiring immobilization.

To obtain the data required for orthosis fabrication, the affected area of the patient is scanned using an EinStar device, which employs structured light technology. Prior to scanning, it is essential to ensure uniform lighting and an appropriate environment to optimize the capture of anatomical details.

The first step in the scanning process involves connecting the device to a power source and synchronizing it with the EXStar Shining 3D software. A new project is then initiated using the object scanning mode, with a scan resolution of 2 mm and texture mapping disabled, suitable for medium and large-sized objects. Subsequently, a critical step is the calibration of the EinStar scanner (Fig. 1) to ensure optimal performance during the scanning procedure.

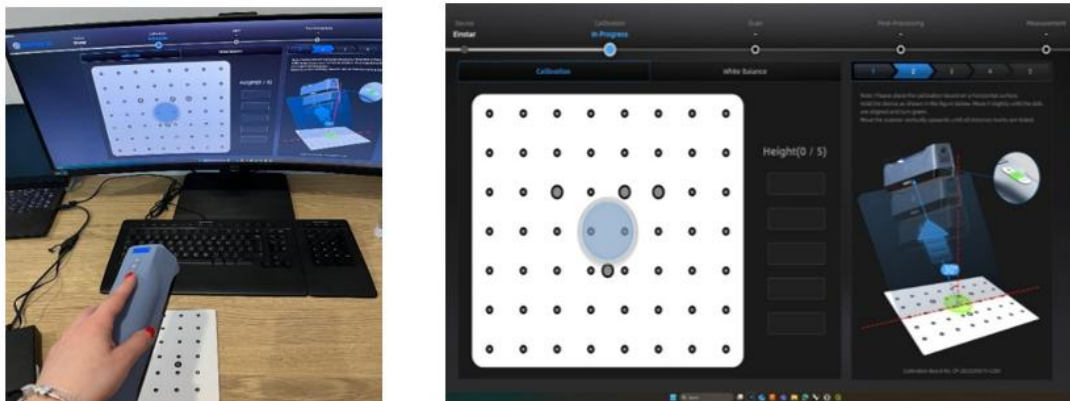


Fig. 1. Calibration of the EinStar Scanner

During the scanning process, the device must be moved uniformly around the affected area of the patient to capture all angles and anatomical details. The scanner provides real-time feedback, allowing for position adjustments and the avoidance of missing regions.

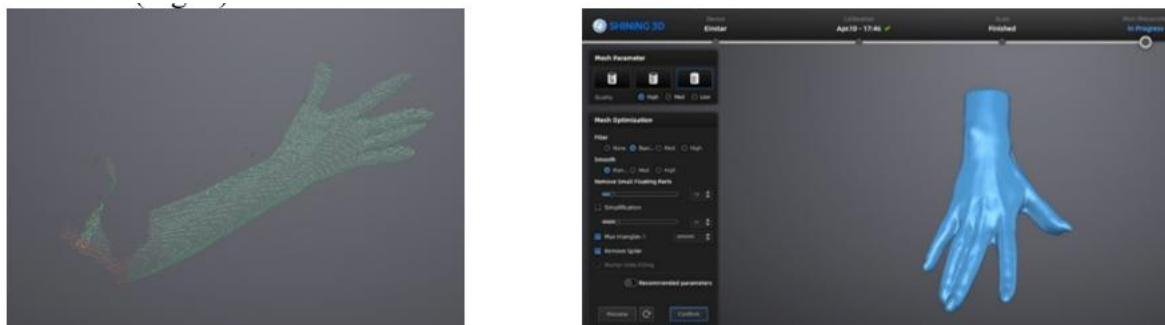


Fig. 2. Point cloud and mesh processing following scanning

An initial scan was performed. However, due to the absence of a flat support surface, the equipment positioning lacked stability, resulting in capture errors. To address these shortcomings and obtain a more accurate model, a second scan was conducted under improved conditions (Fig. 2).

To obtain a clean mesh, a post-processing step is performed on the model to remove isolated points and imperfections, as well as to reduce artifacts and missing data from the scanning process. As a result, the mesh model is exported in STL format.

By following these steps, the scanning and processing procedure in EXStar Shining 3D ensures the generation of an accurate 3D model, ready for use in the design of customized orthoses.

3. Design

The design process of a 3D printed orthosis is a important step in the development of a functional device tailored to the specific needs of the patient. To create the 3D model of the orthosis, the Rhinoceros application, along with its plugin Grasshopper, is used, allowing for a generative and algorithmic approach to design, as well as the creation of complex structures and the optimization of shape through variable parameters. This tool is particularly useful for generating organic and adaptable models, where advanced customization of the orthosis is required based on the patient's anatomical data.

Following the previous scan, the STL file is imported as a mesh into the Rhinoceros application. The geometry is then processed in Grasshopper, where a connection is established between the mesh and various parametric components, enabling more efficient analysis and processing of the model. The operational flow of Grasshopper software for orthosis design involves manually inputting initial data as input information, and, after running the script, obtaining the necessary output related to the orthosis (Fig. 3).

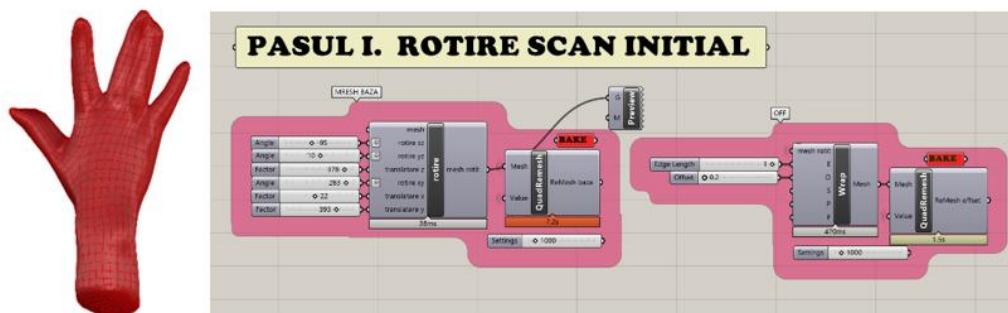


Fig. 3. Hand scan positioning

After importing the hand scan, where the affected fingers are positioned adjacent to each other, the model is oriented vertically with the back of the palm in the XY plane. The scan is then converted into a quad topology, which allows for easier editing and results in a cleaner topology. Subsequently, the model is offset by a value of 0.2 mm to prevent direct contact with the skin and to ensure the development of a functional and comfortable orthosis (Fig. 4).

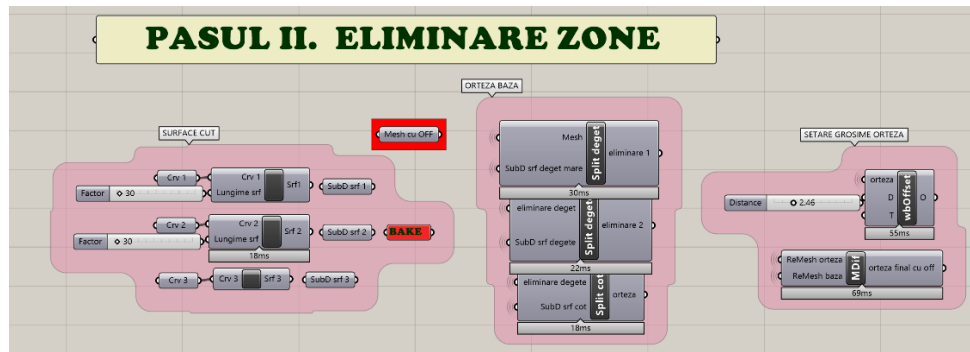


Fig. 4. Finger Removal Flow in Grasshopperde

Initially, the functional fingers are isolated in order to focus on the affected one. During this removal process, care is taken to avoid the finger joints in order to prevent the occurrence of skin occlusion.

To enable 3D printing, the orthosis is horizontally sectioned at the base, creating a flat surface for contact with the printer bed, thereby optimizing adhesion and the quality of the initial layers. The orthosis is compartmentalized in the area of the affected finger into three rectangular sections to reduce the risk of bacterial proliferation and to ensure adequate airflow.

Following the analysis of successive iterations of the 3D CAD concept, it was decided to shorten the orthosis at the fingertip area to allow its use by individuals with manicured nails. This modification does not affect the functionality or efficiency of the orthosis.

The orthosis features a buckle attachment in the palm area, positioned to provide additional functional comfort, as well as a fixed claw attached dorsally. The two components are connected by an adjustable TPU strap, positioned beneath the thumb, which stabilizes and secures the orthosis onto the hand (Fig. 5). The buckle is designed with fastening teeth positioned at a 45-degree angle to facilitate 3D printing and is used for mounting the TPU strap. Additionally, the strap includes attachment holes used to connect it to the claw.

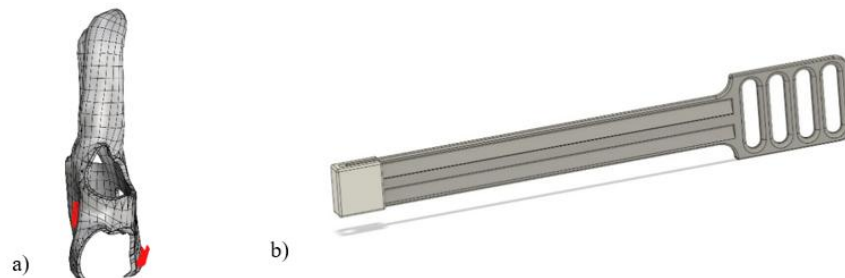


Fig. 5. Elements that stabilize and fix the orthosis on the hand

a) Claw and buckle positioning, b) TPU strap and buckle

To remove potential sharp edges or uneven areas resulting from the modeling process, which could cause discomfort to the patient, the model is converted into a SubD topology, thereby achieving a smooth and filleted surface (Fig. 6).



Fig. 6. Front-back finger orthosis

4. Printing

3D printing of an orthosis is an advanced technological process that involves the use of 3D printers. In this context, the 3D printers used are of the FDM (Fused Deposition Modeling) type, which operate by melting a plastic filament and depositing it in successive layers to create the desired structure.

The printing of orthoses requires a material that provides both mechanical strength and biocompatibility. One of the most suitable materials approved for this process is BASF Ultrafuse PLA Tough, a corn-derived filament that combines the advantages of polylactic acid (PLA) with enhanced flexibility and strength.

This material is chosen due to its skin safety, as it does not cause irritation and ensures increased comfort for patients. Made from renewable resources such as corn starch, it is free from toxic substances and does not cause allergies or skin irritations. This characteristic makes it ideal for prolonged skin contact, a fundamental criterion in the design and manufacture of medical orthoses.

Unlike other filaments, this material exhibits reduced shrinkage during cooling, which minimizes the risk of deformation and allows for the creation of precise, patient-specific orthoses.

To create the elastic printing strap, an elastic material is required. Therefore, thermoplastic polyurethane (TPU) was used, a polymeric material of the thermoplastic elastomer type, known for its exceptional combination of flexibility, mechanical strength, and dimensional stability.

The hardness of the TPU used falls within the range of 85A–95A on the Shore scale, providing a soft texture yet sufficiently robust to ensure secure fixation of the orthosis without compromising patient comfort. Additionally, the high elongation at break (up to 600%) allows the material to withstand significant deformations without cracking, a critical feature for components subjected to constant movement or uneven pressures.

The printer used for the manufacturing process is of the Sovol type (Fig. 7), with a printing volume of 350×350×345 mm³.

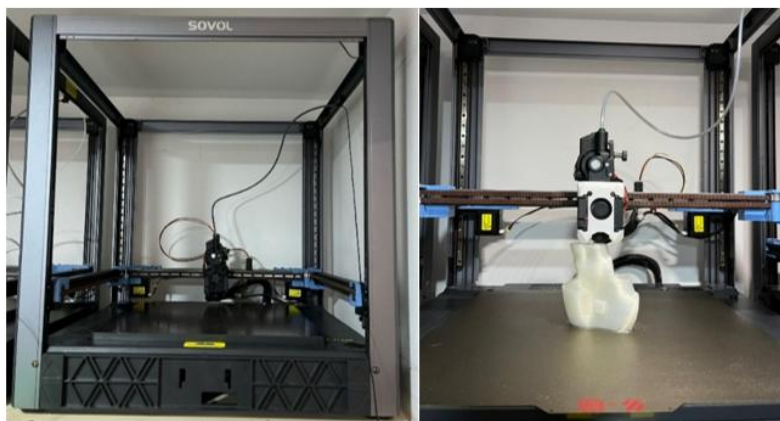


Fig. 7. Sovol 3D printer

After creating the 3D model, the file is exported in STL format and imported into the OrcaSlicer application to configure the printing data. In this software, necessary printing parameters such as material, layer thickness, and the number of walls are entered.

Considering that the orthosis has a thickness of 2 mm, the model is printed with 5 walls using a standard 0.4 mm nozzle, without infill. Another necessary function for printing is the addition of a brim layer with 20 mm inner-outer walls to ensure better adhesion to the print bed. Regarding the TPU fastening strap, it has a thickness of 1.6 mm and is set to 3 walls of 0.4 mm with an Arachne-type infill, which allows for continuous wall thickness variation, ensuring good adhesion and improved surface quality without compromising the strength of the internal structure.

Thus, after importing the STL model into the OrcaSlicer application, the data were centralized in Table 1.

Table 1. Printing characteristics in OrcaSlicer

Material	Printing characteristics	
	Finger orthosis	Strap fastening
Time	109 min	8 min
Weight	39.42 g	2.51 g

After applying the necessary configuration to the 3D printing data using the OrcaSlicer application, the finger orthosis for fixing the middle and ring fingers was obtained (Fig. 8).



Fig. 8. 3D printed finger orthosis

5. Optimization

This chapter analyzes the optimization of the orthosis design process, with a focus on comparing the efficiency between traditional methods of orthosis fabrication and the modern approach based on 3D modeling and printing.

To highlight the advantages of the new method, a series of MATLAB codes were developed to assess the costs and time required for each stage of the design process. The results generated are presented in the form of comparative graphs, providing a clear perspective on how the use of digital technologies can significantly reduce the resources involved in creating a customized finger orthosis.

A comparative analysis is then conducted on the mass production time of the finger orthosis for a sample of 100 units. The analysis aims to compare the manufacturing time of the orthosis produced traditionally with that produced using additive printing. Thus, to determine the production times, the input data from Tables 2 and 3 are used.

Table 2. Parameters for the production of orthoses using additive printing

3D printing parameters	Valuea (units)
Printing time	2 hours
Post-processing time	0.2 hours
Number of printers	6

Table 3. Parameters for traditional orthosis production

Traditional Production Parameters	Valoarea (buc)
Modeling time	1 hour
Manufacturing time	2 hours
Post-processing time	0.5 hours

Following the comparative analysis between 3D printing and traditional manufacturing methods for producing finger orthoses, the results highlight a significant advantage of additive technology in terms of production time. For a batch of 100 orthoses, 3D printing with the assistance of 6 printers running in parallel required approximately 37.4 hours, whereas traditional manufacturing of the same number of pieces took a total of approximately 350 hours.

This result demonstrates an over 8-fold increase in time efficiency in favor of 3D printing. Moreover, the additive method provides greater flexibility in adapting the shape and size of the orthosis, without the need for molds or special tools.

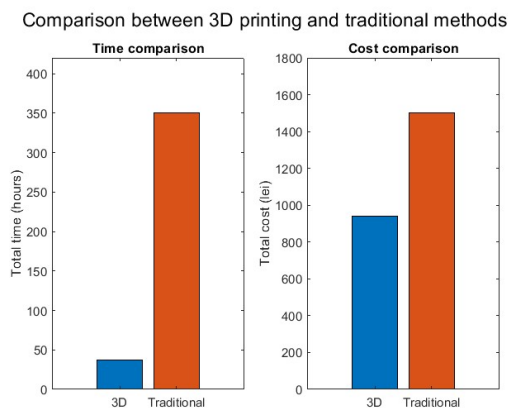


Fig. 9 Time-cost analysis

Based on the obtained results regarding production times, a cost analysis was also performed using a MATLAB code to automatically calculate the relevant values and generate comparative graphs. The analysis utilized the input data from Tables 4 and 5.

Table 4. Costs for producing finger braces using additive manufacturing

3D printing costs	Valuea (lei/unit)
Printing cost	6.6 lei
Energy cost	1 lei
Post-processing cost	1 lei
Depreciation cost	0.8 lei

Table 5. Costs for traditional brace production

Costs for traditional orthosis production	Valuea (lei/unit)
Material cost	7 lei
Labor cost	5 lei
Tool cost	3 lei

From a financial perspective, the additive method is more advantageous: the total cost for producing the 100 orthoses is lower compared to the traditional method, due to the elimination of expenses such as labor costs and special tools. Thus, the total cost is determined to be 940 lei for the additive method and 1500 lei for the traditional method.

Next, the MATLAB code was tested for different quantities of orthoses to analyze the behavior of total time and total cost as a function of production volume. This testing aimed to highlight which of the two methods – 3D printing or traditional manufacturing – scales more efficiently as the number of units increases. The analysis focused on identifying a potential inflection point, that is, the quantitative threshold beyond which 3D printing becomes more advantageous than the traditional method in terms of overall efficiency.

The scalability of the two methods reveals significant differences. 3D printing maintains almost constant time for small batches due to parallel printing, but increases in steps for large volumes because of the limitation on the number of printers. The traditional method increases linearly, being predictable but without the advantage of parallelism. In terms of costs, both methods increase linearly with volume, but 3D printing is more efficient for small batches or when traditional labor is expensive. However, the traditional method can become more cost-effective at large volumes if production is optimized and unit costs decrease (Fig.10).

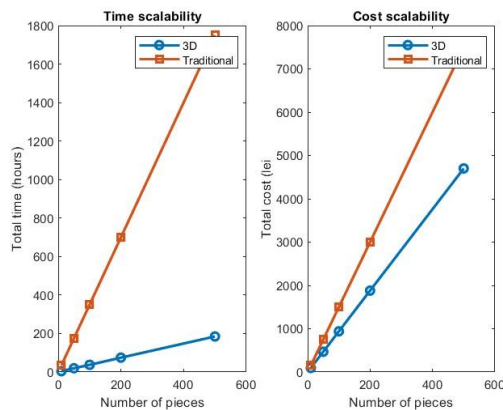


Fig. 10. Scalability of manufacturing methods

Thus, the developed MATLAB codes allowed for a clear comparison of the time and costs involved in traditional methods versus modern ones, demonstrating increased efficiency in favor of the 3D solution. It can be observed that, based on the obtained graphs, the optimization of the process not only significantly reduces the necessary resources but also

contributes to the creation of customized medical devices, more precisely adapted to the individual needs of patients. These results confirm the potential for widespread adoption of this technology in modern orthotics.

6. Conclusions and Further Research

The analysis of the proposed workflow for the design and manufacturing of a finger orthosis using parametric modeling and additive manufacturing leads to the following essential conclusions and observations:

(i) Errors arising from involuntary hand or finger movements during scanning highlight the need for a stabilization solution. A possible future improvement could involve using a transparent surface (e.g., glass) on which the hand is fixed while two scanning heads—upper and lower—perform the complete acquisition, reducing the risk of generating a defective mesh.

(ii) Parametric modeling in Grasshopper offers high flexibility in generating the orthosis geometry, enabling rapid customization based on the anatomical and functional data of the patient, as well as adapting the design to specific biomechanical requirements.

(iii) The MATLAB code applied in the optimization process demonstrated a significant reduction in manufacturing time compared to traditional methods, confirming the efficiency of the proposed method for mass production of customized orthotic devices.

These conclusions highlight the high potential of the proposed method and suggest future research directions focusing on automating data processing steps and developing integrated, accessible solutions for the increasingly diverse needs in the field of personalized medical rehabilitation.

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MAHR-CONTOUR AND ROUGHNESS

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***ABSTRACT:** The Mahr contour measuring systems are cutting-edge instruments designed to ensure high-precision contour measurements in industrial applications. They are widely used in sectors like mechanical engineering, automotive, and medical technology—for instance, measuring threads, shafts, prosthetics, and implants. Their key advantages include nanometre-level precision, high measuring speed, intuitive software, and versatile application across both standardized and custom parts. Finally, Mahr plays a key role in metrology standardization by collaborating with organizations like ISO and VDI, reinforcing its global relevance and trustworthiness.*

KEYWORDS: Mahr-contour

1. Introduction

In today's industrial context, ensuring the quality of mechanical parts is essential to maintaining the competitiveness and reliability of products. Accurate contour measurement is a fundamental component in this process and Mahr-contour gauges are some of the most advanced instruments available on the market. These devices combine cutting-edge technology with ease of use, offering efficient solutions for various industrial applications.

2. State of the art

Mahr is constantly investing in research to improve the performance of its contour measuring equipment. The MarSurf CD series contour gauges, including the CD 120 (see Fig.1), represent an important step in this direction, offering a Z-axis resolution of up to 0.04 μm , essential for high-precision measurements.



Fig. 1. MarSurf CD120

3. Technical description

Mahr contour gauges, such as the MarSurf CD models, are contour measuring devices that use a tactile probe system to analyse the profiles of parts. They are equipped with a 350 mm long probe arm, allowing the measurement of parts of various sizes. A remarkable feature of these devices is the quick-change system of the probe tips, which does not require recalibration, thanks to an innovative magnetic holder.

The MarSurf CD features an X-axis with a measuring range of up to 140 mm and a travel speed of up to 200 mm/s, ensuring fast and precise measurements. The Z-axis can also be adjusted manually, making it easy to adapt to different workpiece heights. The probe force system is automatic, guaranteeing the correct application of the measuring force, regardless of the type of tip used.

The integrated MarWin software enables easy creation of measurement programs and evaluation of contours, including determination of radii, arc lengths and angles. The patented "Tangential Elements" function supports operator-independent evaluation of tangential transitions between radii and straight lines [1].

4. Industrial applications

Mahr contour gauges are used in a variety of industries, including mechanical engineering, the automotive industry and medical technology. In mechanical engineering, they are used to measure parts such as bearings, threaded bolts and shafts. In the automotive industry, they are essential for checking components of steering, braking and transmission systems. In the medical field, Mahr contour gauges are used to measure hip and knee prostheses as well as dental implants.

A specific example is the MarSurf CD 140 AF, which offers a wide range of contour measurement functions, allowing users to easily measure both standardized parts and individual parts. The flexible workpiece holder makes handling particularly easy, and the intelligent probe system and magnetic probe tip holder ensure that probe tips can be changed easily and without tools at any time, without recalibration [2].

Automotive industry:

In the automotive sector, the MarSurf CD 120 is used to inspect critical components such as braking systems, steering or engine elements. The high positioning speed (up to 200 mm/s on the X-axis) allows for rapid inspection of complex parts, essential in mass production.

Typical applications:

- Camshaft and crankshaft inspection – measuring radius, profile shape and angles, where even the smallest deviations can affect engine performance.
- Braking and steering systems – to ensure symmetry and controlled wear of components such as brake discs or joints.
- Bearings, gears and transmission parts – require detailed contour analysis to avoid vibrations and extend service life.

Why Mahr contour meters are useful:

- They measure complex contours of machined parts with submicron precision.
- Automated systems with MarWin can be integrated directly into the production line for real-time control.
- The CD 140 and CD 280 models enable fast and reliable measurements without interrupting production.

Medical Technology:

Equipment accuracy is vital for measuring orthopaedic implants (hip, knee) and dental components. The contour graph can detect the smallest surface deviations, guaranteeing the quality and biocompatibility of medical products.

Typical applications:

- Orthopaedic implants (knee, hip): anatomical shape, uniformity of curvature and roughness are checked for optimal bone integration.
- Dental implants: thread contour, base shape and contact areas must meet strict precision standards.
- Surgical instruments: dimensional accuracy is crucial for proper function and sterilization.

Benefits of Mahr contourographs:

- The CD 280 model allows simultaneous measurement of contour and roughness, which reduces inspection time.
- Very high resolution helps to identify the smallest deformations or deviations that can affect functionality.
- Non-destructive measurements and adaptability to parts personalized for each patient (e.g. one-of-a-kind implants) [3].

Aerospace and Precision Engineering:

In the aerospace industry, where tolerances are extremely tight, the CD 120 is used for detailed analysis of turbine blades, shafts, and other critical components. Its ability to identify fine imperfections helps prevent failures under extreme conditions.

Typical Applications:

- Turbine and compressor blades – any profile variation can lead to efficiency losses or catastrophic failures.
- Precision connectors, valves and critical engine components – require extremely stable contour measurements.
- Load-bearing structures and anchorages – must meet tight tolerances for mechanical strength and minimal resonance [4].

5. Advantages

Mahr contour meters offer numerous advantages, including:

- High precision: Resolution of up to 6 nm ensures extremely precise measurements.
- High measuring speed: Travel speeds of up to 200 mm/s enable fast measurements, saving time in production processes.
- Ease of use: The quick-change probe tip system and the intuitive MarWin software make it easy to operate the device.
- Versatility: The ability to measure both standardized and individual parts makes these devices suitable for various industrial applications.
- The CD 140 and especially the CD 280 are compatible with robotic arms, which allows integration into automated test lines.
- Intelligent algorithms can identify wear patterns, vibrations or structural deviations in early stages.
- The ability to work in controlled environments (clean rooms, anti-vibration) is a major advantage in this field [5].

6. Limitations

However, there are some limitations to consider:

- Cost: The initial investment in a Mahr contour plotter can be considerable, which can be a barrier for small businesses.

- Need for staff training: To use these instruments effectively, operators must be well trained, which can involve additional costs.
- Dependence on environmental conditions: To ensure the accuracy of measurements, it is important that the device is used in controlled environmental conditions, without vibrations or temperature fluctuations [6].

7. Integration into quality control systems

Mahr contouring machines do not operate in isolation but are often integrated into automated production chains and quality control systems. In this sense, they become an essential link in the concept of Industry 4.0, where connectivity and real-time data analysis play a decisive role.

Mahr systems allow integration with analysis and reporting software, such as MarWin, which can transmit data to central servers, quality control stations or even ERP systems. This connectivity allows for complete traceability of parts, but also for rapid intervention in processes in the event of a defect or deviation from the required tolerances being detected.

Furthermore, some models can be configured to operate automatically, without human intervention, through robotic arms that position the part and trigger the measurement. Thus, the contour graph becomes not just a laboratory instrument, but an active component in the production process [1].

8. Comparison with other measurement technologies

It is important to note that tactile (probe) contouring technology offers superior accuracy compared to optical contour measurement methods, especially for metal, hard or complexly finished parts. However, in recent years, optical profile measurement systems have also emerged, such as interferometers or laser triangulation systems.

Table 1 Comparative

Feature	Mahr contour graph (Tactil)	Optical systems
Accuracy	Very high (mm)	High (microns)
Measurement time	Medium	Very fast
Contact with part	Yes	No
Vibration sensibility	High	Medium
Cost	High	Very high

This comparison highlights why, despite the development of optical technologies, the tactile contour plotter remains a preferred choice for high-precision dimensional inspection (Table 1).

9. Research and Development

Mahr constantly invests in research, with a focus on automation, miniaturization and artificial intelligence applied to metrology. New generations of contour scanners, such as the MarSurf CD 280, include machine learning functions for recognizing error patterns and optimizing measurement processes.

An emerging area is the development of multifunctional probes, capable of measuring contour and roughness simultaneously. This integration significantly reduces inspection time and operation complexity. Automatic correction algorithms, guided by artificial intelligence, can also adapt measurement parameters according to the actual behaviour of the part.

10. Mahr' contributions to the standardization of metrology

As one of the world's leading metrology companies, Mahr has played an active role in setting international standards for contour measurement. The company collaborates with organizations such as ISO and VDI to define technical norms, including methods for evaluating profiles and tolerances.

This involvement in defining the rules of the game gives Mahr contour meters a guarantee of compatibility and international recognition, which is essential for companies that export products or collaborate in global production chains [7].

11. Future perspectives

Future developments in the field of contour measurement will focus on:

- Miniaturization of equipment, to allow the inspection of increasingly smaller parts, especially in the medical and micro-mechanics fields.
- Complete automation of measurements, with the possibility for the system to decide the evaluation parameters autonomously.
- Integration of augmented reality in the process of analyzing and interpreting measurement data.
- Use of intelligent sensors connected to the cloud, for real-time evaluation of deviations and maintaining quality without stopping production [8].

Quick conclusions

- MarSurf PCV (see Fig.2): Good for basic applications, but technologically outdated.



Fig. 2. MarSurf PCV [9]



Fig. 3. MarSurf CD 120 [10]

- MarSurf CD 120 (see Fig.3): Ideal for standard industrial environments; very accurate, but without roughness measurement.
- MarSurf CD 140 (see Fig.4): Offers more flexibility, automation and accuracy, suitable for critical applications (auto, aero).



Fig. 4. MarSurf CD 140 [11]



Fig. 5. MarSurf CD 280 [12]

- MarSurf CD 280 (see Fig.5): The most advanced version – with AI, combined contour + roughness measurement, high speed and full integration into smart production lines.

12. Conclusions

The Mahr contour gauge is not just a measuring device, but a symbol of engineering precision. By combining state-of-the-art touch technology with advanced software and extensive connectivity, these devices help improve industrial processes and ensure product quality. In a constantly evolving technological landscape, Mahr remains a benchmark in dimensional metrology, providing not only instruments but also a vision for the future of industrial measurement.

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ROBOTIC INTEGRATION FOR LASER ENGRAVING

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SUMMARY: The project focuses on integrating a laser engraving system on a robot, optimized for industrial applications. The laser used is blue, focusable, with TTL control and active cooling via fan and heatsink. A more efficient cooling enclosure was identified as necessary for system stability. The design process included CAD modelling, evolving from the initial concept to the final version. The engraving system was tested using previous examples for calibration and validation. Conveyor integration allows for automatic feeding of parts. The control panel ensures essential connections for flow management. The engraving was adapted for optimal positioning relative to the robot base. Several future optimization paths were explored. The documentation includes technical resources and relevant collaborations.

KEYWORDS: robot, laser engraving, CAD modelling

1. Introduction

This project presents the development and integration of a robotic system designed for laser engraving, targeting high-precision industrial applications. By implementing [1] a TTL-controlled laser and an automated conveyor system [5], the process aims to achieve full automation, reduce human error, and improve operational efficiency. The workflow included 3D modelling, electronic system integration, [8] command programming, and practical testing under real conditions.

2. State of the art

The project has reached a functional prototype stage, where the laser engraving module is successfully integrated with the robotic arm and the conveyor system. The laser operates within controlled parameters (TTL modulation, 12V DC input [5], and active cooling), and the positioning relative to the robot base has been calibrated for optimal engraving accuracy. A custom control panel has been developed [9] for managing conveyor movement and synchronization with the engraving process. Initial tests have confirmed the system's reliability, and engraving results are consistent. Work is ongoing to further optimize cooling efficiency and automate additional workflow elements.

3. Laser module

The laser module, type FB-03 2500 (Fig. 1) is a core component of the robotic engraving system, providing the precision and consistency required for high-quality surface marking. It operates with a bright blue beam and supports TTL modulation [5], allowing real-time control via digital signals. Designed for versatility, the laser is focusable and equipped with an active cooling system, ensuring stable performance during continuous operation. Its robust construction, using aluminium and glass materials [5], makes it suitable for demanding industrial applications.



Fig. 1. Laser FB-03 2500

Tabel 1. Technical specifications

FB-03 2500	Technical specifications
Light	Blue
Focusable	Yes
Input Voltage	DC 12V
Frequency Range	0-20 KHz

To demonstrate the capabilities of the robotic laser engraving system, a series of themed engravings were created for the Easter holiday (Fig. 2). The process involved preparing custom designs, calibrating the laser focus, and synchronizing the engraving with the conveyor-fed positioning system. The results showcased precise and consistent markings on various materials, highlighting both the artistic and technical potential of the setup. This use case confirmed the system's suitability for seasonal and promotional production runs.

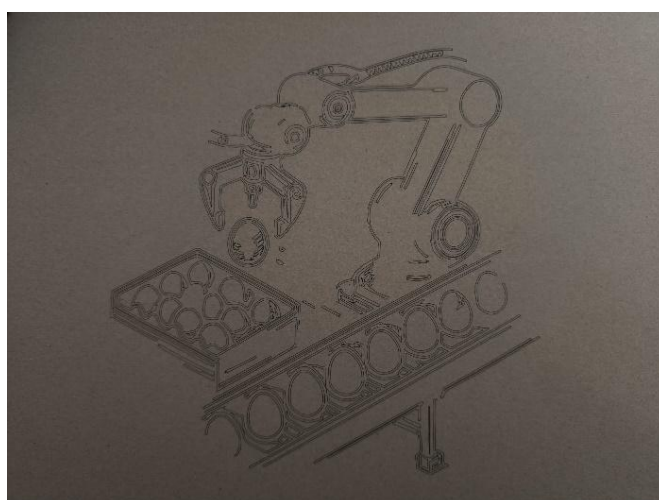


Fig. 2. Easter engraving

During prolonged use, the laser module generates significant heat, which can affect both performance and safety. While the built-in cooling system provides basic thermal regulation, it was determined that a dedicated casing is

necessary to enhance airflow and protect the laser from external factors such as dust or accidental contact. The custom-designed casing ensures more efficient heat dissipation and structural stability, allowing the system to operate continuously in an industrial environment without overheating or malfunctioning.

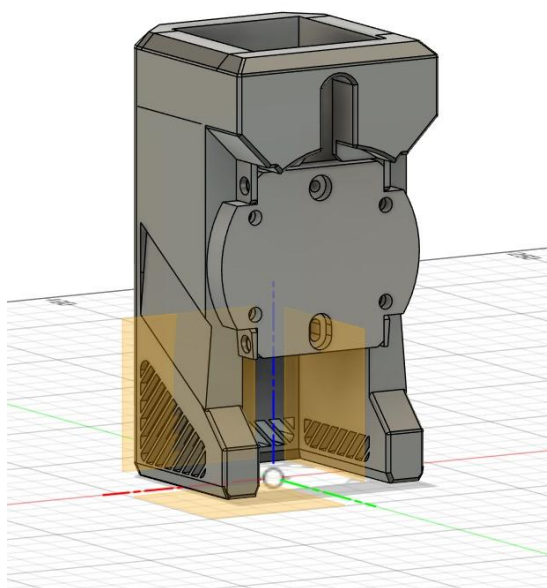


Fig. 3. The custom-design in Autodesk Fusion 360

The laser casing was custom designed (Fig. 3) and 3D (Fig. 4) printed [4] to ensure both functionality and adaptability. The design prioritizes ventilation, with integrated openings for airflow and space for the existing fan and heatsink. It also features mounting points for secure attachment to the robotic arm or frame. The material chosen for printing provides thermal resistance and structural durability, making it suitable for repeated use. The casing not only protects the laser but also improves the overall aesthetic and safety of the system [7].



Fig. 4. The custom-design printed 3D

Fig. 4 is presenting the custom-design printed 3D and Fig. 5 the engraving procedure.



Fig. 5. The engraving procedure

4. Conveyor integration

The conveyor (Fig. 6) plays a vital role in automating the engraving workflow by continuously feeding parts into the robot's working area. It ensures precise positioning and consistent spacing between engraved items, allowing for uninterrupted production cycles. A custom control panel was developed to manage conveyor movement [5], [9] and synchronize it with the robot and laser system. The integration improves efficiency, reduces manual handling, and supports scalability for larger production runs. This modular setup also allows for future upgrades [10] such as speed control, sensors, or object detection.



Fig. 6. Power Belt Conveyor

In our setup, the engraving area was carefully positioned relative to the robot's base to ensure optimal reach, stability, and precision (Fig. 7). After several trials, we selected a configuration where the engraved object is aligned slightly offset to the front-right of the robot, allowing the laser head to maintain a consistent focal distance during operation. This placement minimizes arm overextension and improves repeatability. The positioning can be clearly seen in the final photos of the project, where both the conveyor and the engraved pieces are arranged within the robot's ideal working envelope [6].

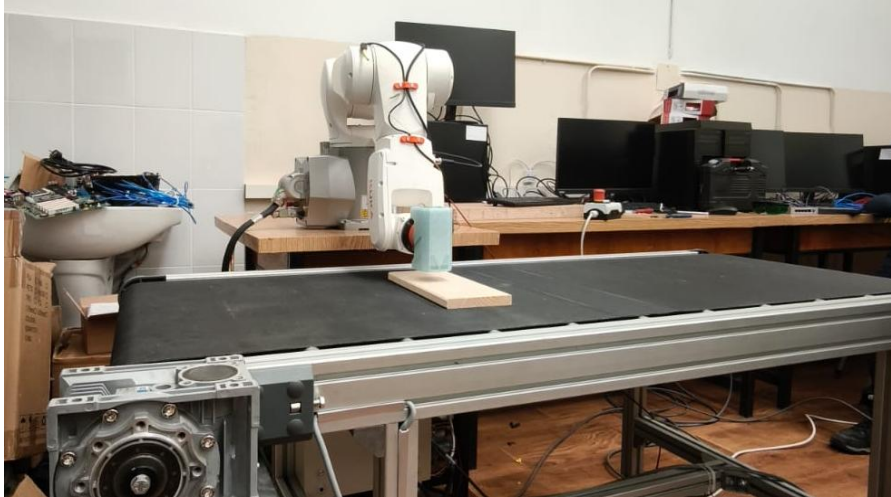


Fig. 7. Engraving positioning and alignment

The engraving process (Fig. 8) is fully coordinated between the robot controller and the conveyor through I/O signals [1], [3], [9]. Once the object is in position on the conveyor, the robot sends a signal to stop the conveyor and begin the engraving sequence. This ensures precise alignment and timing. The laser performs the engraving while the object remains stationary. After the process is complete, another I/O signal is sent from the robot to restart the conveyor and move the engraved piece out of the work area, making room for the next item. The image of the I/O connections (Fig.9) illustrates this control flow and highlights the synchronization between hardware components [7].



Fig. 8. Robotic engraving sequence

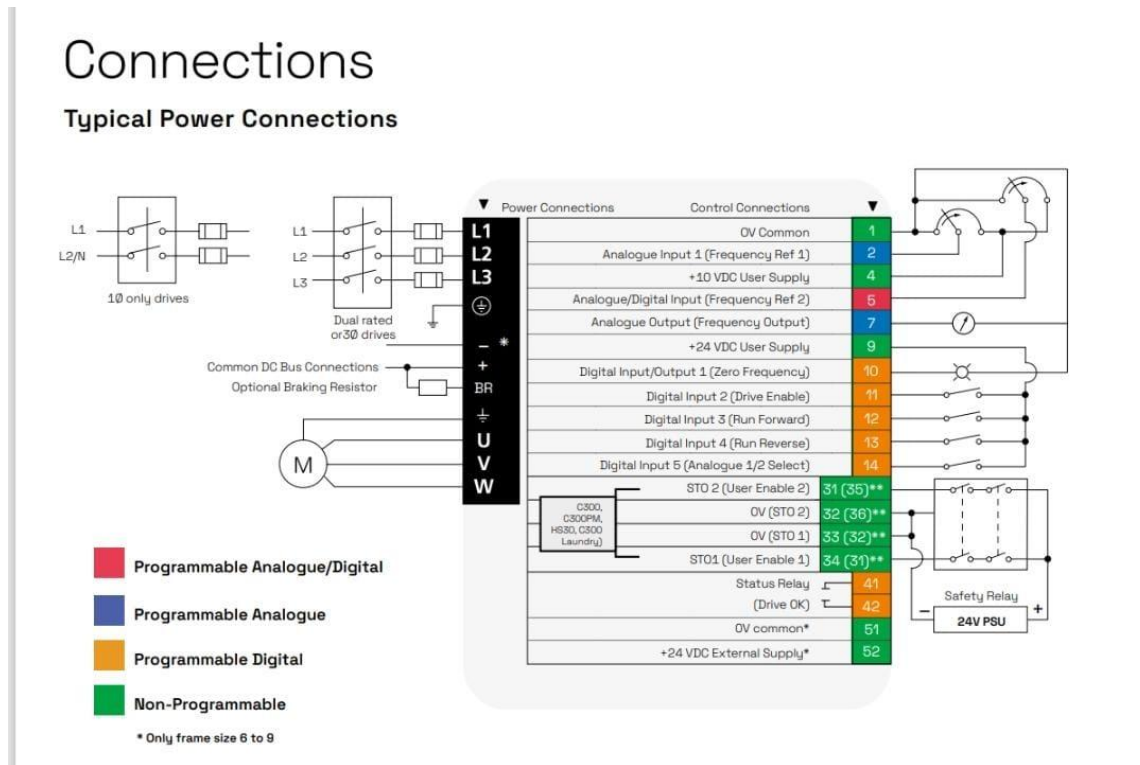


Fig. 9. Power connections

5. Future Development Plans

To further enhance the system's capabilities, several improvements are planned. These include implementing sensors to detect the presence and position of objects on the conveyor [9], allowing for more dynamic control. Additional I/O integration will enable greater autonomy and reduce reliance on manual input. We also plan to optimize the laser's cooling system by refining the casing design and exploring temperature monitoring solutions. Long-term goals include developing a user-friendly interface for parameter adjustment and expanding the system to support batch engraving with different designs. These upgrades aim to increase reliability, flexibility, and scalability for industrial applications.

Looking ahead, one of the key upgrades involves integrating a quality control camera to inspect each engraved item in real time. The camera will evaluate the engraving accuracy and overall quality, using image processing algorithms to detect errors or misalignments. Based on the camera's decision, a second robotic arm could be introduced to sort, reject, or reposition items accordingly. This closed-loop system would significantly improve product consistency, reduce waste, and enable fully autonomous operation. The combination of vision-based inspection and dual-robot collaboration aligns with Industry 4.0 standards [10] and prepares the system for more complex workflows.

An important step in improving system precision is the implementation of real-time frame generation for objects on the conveyor. By using either sensors or a vision system, the controller can dynamically create a reference frame for each incoming item, capturing both its position and orientation. This allows the robot to adjust its engraving or manipulation path accordingly, ensuring accuracy even if the object is slightly rotated or shifted. The frame data can be transmitted to the robot via I/O or communication protocols (such as Ethernet or OPC-

UA), allowing the robot to align its toolpath in real time. This approach enhances adaptability and is a key enabler for handling variable part placement in industrial workflows.

To achieve full autonomy and high-speed precision, we aim to implement real-time frame tracking (Fig.10) using a vision camera [6]. Instead of working with static object positions, the camera will continuously monitor objects as they move on the conveyor, generating live coordinate frames. These frames will include the object's exact position, orientation, and movement vector, which can be transmitted to the robot controller. By combining this data with frame transformation logic, the robot can dynamically adjust its toolpath and engrave or manipulate objects in motion — a technique known as vision-based frame tracking. This upgrade opens the door to advanced applications such as engraving on-the-fly, sorting in motion, and eliminating the need to stop the conveyor entirely.

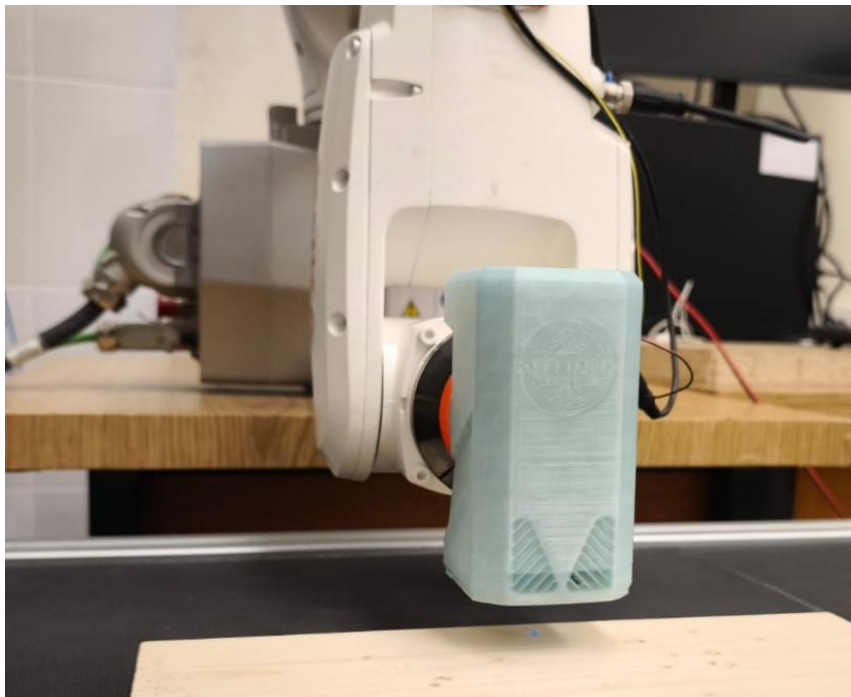


Fig. 10. Real-time object alignment for frame tracking

6. Conclusions

The development of this robotic laser engraving system marks a significant milestone in the transition from manual, repetitive tasks to intelligent and automated workflows. This project has successfully brought together mechanical design, electrical integration, software control, and real-world testing, with each step reflecting a hands-on understanding of how complex systems must interact to perform efficiently. From the selection and implementation of a TTL-controlled laser [5] to the custom-designed casing, and from the integration of a conveyor system to the programming of I/O-based synchronization, every detail was considered to ensure a robust and reliable platform.

What sets this project apart is not only the technical execution, but the clear vision for future evolution. The initial scope — engraving a fixed object placed by a conveyor — has now expanded into a modular, scalable, and intelligent system. We are no longer working with static assumptions; instead, we are building a framework that supports adaptability. Real-time frame generation [6] and the idea of dynamic alignment [10] allow the robot to interact with moving objects, increasing throughput without sacrificing accuracy.

Further, the planned integration of a quality control camera introduces decision-making into the loop. With this enhancement, the system gains the ability to *see*, *analyse*, and *act* — detecting engraving quality, identifying positioning errors, and communicating decisions to a second robotic unit for sorting, repositioning, or rejection. This dual-robot setup, guided by vision [10], reflects a manufacturing philosophy centered on flexibility, responsiveness, and autonomy.

But the innovation does not stop at hardware. The project introduces concepts aligned with Industry 4.0 — frame tracking, live feedback, sensor fusion, and potential cloud-based analytics in future iterations [6], [10]. These technologies, once considered cutting-edge, are now being prototyped in this platform, opening the door for continuous learning, adaptive routines, and smarter production.

In essence, this is not just a laser engraving machine. It is a living, evolving system — a learning environment, a proof-of-concept, and a vision of what modern, intelligent manufacturing can look like. It is the result of collaboration, creativity, and a willingness to experiment beyond traditional limits. The project will continue to grow, both in complexity and capability, and the groundwork laid here proves that scalable, intelligent robotic solutions are not only possible — they are already taking shape.

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DESIGNING A MODULAR DIY SMART IRRIGATION SYSTEM USING A LOCAL RASPBERRY PI-BASED LINUX SERVER

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***ABSTRACT:** This project explores a practical and low-cost way to automate garden or crop irrigation using off-the-shelf hardware and open-source software. It is part of a broader effort to build smarter homes and farms. At the heart of the system is a Raspberry Pi 5 acting as a local server, connected to ESP32 modules and various smart devices (relays, actuators, and sensors). The system can monitor environmental conditions and control water flow automatically. Visual programming tools (Blockly and Java) simplify customization and expansion. The solution is easy to adapt, extend, and integrate into other smart home systems.*

***Keywords:** Smart Automation, Raspberry Pi 5, DIY Systems, Visual Programming, ESP32 Modules*

1. Introduction

As digital technologies become more integrated into everyday life, smart home systems are gaining popularity in both urban and rural environments. Automating functions such as lighting, heating, security, or irrigation helps save resources and increase comfort and energy efficiency.

This project focuses on building an automated irrigation system that can be embedded into a larger local smart home infrastructure. Using a Raspberry Pi 5 and ESP32 microcontrollers, the goal is to create a flexible and self-sufficient system that can control water distribution based on real-time data like soil moisture, temperature, and time schedules.

The work stems from the need to rebuild a previously fragmented home automation setup. Past attempts, especially with electrical and thermal systems, highlighted the need for a better, more scalable and integrated architecture. This redesign started from real user needs and aimed to build a robust foundation for smart control and monitoring.

Project objectives for the low-cost way to automate garden or crop irrigation [1, 2] using off-the-shelf hardware and open-source software

- create a fully automated electronic irrigation system.
- use a local Linux-based server (Raspberry Pi 5).
- integrate ESP32 modules for controlling pumps and valves.
- design logic flows with visual programming (Blockly + Java).
- enable control and monitoring via web interface or mobile app.
- test the system in a real-life environment.
- allow for future expansion with other sensors or external services.

2. Current state of development for various automation systems used in strict household applications irrigation purposes

The present work focuses exclusively on the irrigation component of a broader centralized smart automation system. This system emerged from the need to address limitations in existing smart home solutions available on the Romanian market, particularly those dedicated to heating and electrical installations (see figure 1), which often lack reliability and scalability.

Many current smart home implementations suffer from design flaws, limited modularity, and poor adaptability to future upgrades or integrations. Below is an example of an early automation setup with critical limitations in extensibility and smart functionality management:

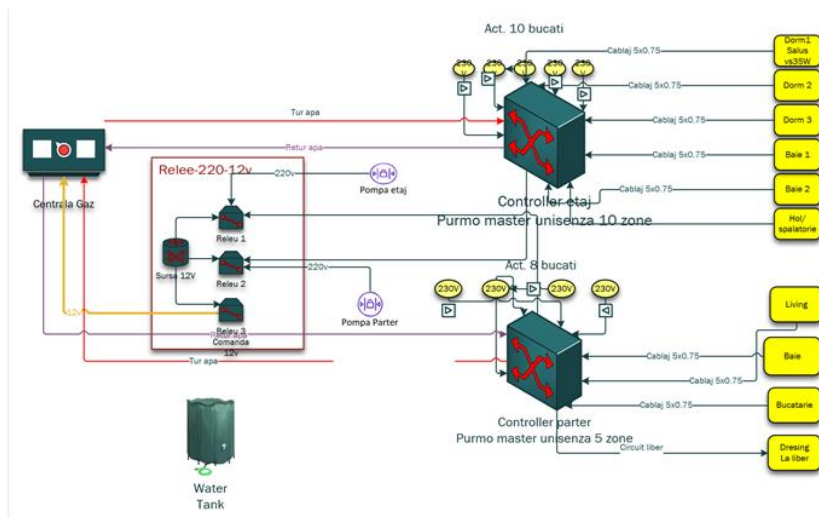


Fig. 1. Legacy smart home automation model with scalability and integration issues. Basic gas heating controller

Over time, and with approximately 4–5 months of dedicated work by an experienced integrator, such a limited system can be transformed into a more complex and robust IoT-based automation framework. This modern version allows centralized control over multiple independent smart home subsystems, using advanced sensors and visual programming tools like Blockly and Java.

The extended model supports features such as remote monitoring and control via smartphone, real-time status visualization of each smart function, and reliable interaction with multiple IoT components. This architecture forms the foundation for the future expansion of intelligent automation systems in both residential and semi-agricultural environments.

3. System implementation. Components and architecture of the DIY smart irrigation solution

To build a modular and scalable smart irrigation system, we focused on designing an integrated control solution based on open-source tools and accessible hardware. The system relies on the following key components:

- a Raspberry Pi 5, serving as a local Linux-based server.
- an ESP32 development board for connecting sensors and actuators.
- shelly smart relays and manual relays for device switching.
- specific actuators and irrigation sensors.

- a visual programming interface based on Blockly and Java for automation logic.

Visual Programming (Blockly):

Blockly, developed by Google, is a visual programming library that allows users to design control logic using graphical blocks instead of text code. It lowers the entry barrier to automation by removing syntax complexity. (<https://developers.google.com/blockly>)

It allows users to apply programming principles without having to worry about syntax or the intimidation of a blinking cursor on the command line. All code is free and open source. (<https://blocklycodelabs.dev/>)

Security and architecture highlights:

- The developed solution runs entirely locally, without relying on any external cloud infrastructure.
- The server is secured via a VPN, and access can be made remotely by authorized users to view or update real-time configurations.
- Because it avoids cloud dependencies, the system is immune to common remote hacking risks, while ensuring high stability on a local Linux environment.

This approach represents a shift from closed ecosystems. Unlike commercial solutions—where a single smart irrigation valve may cost over RON 1300 and require proprietary accessories—the DIY model remains open, flexible, and vendor-independent. Users are not locked into a single ecosystem and can extend the system using compatible devices from other manufacturers.

Software Stack:

- The software application is built in Java and runs on the Linux-based Raspberry PI server.
- It uses ioBroker, an open-source home automation platform developed in Germany, licensed for free household use.

Although alternative platforms like Home Assistant exist, ioBroker was selected due to its superior flexibility in visual programming and seamless integration with a wide range of hardware modules.

Installing the ESP32 Board and Shelly relay modules:

To enable communication between the ESP32 development board, Shelly smart relays, and the Linux-based server (Raspberry Pi 5), the system uses the MQTT protocol — a lightweight and widely adopted standard in IoT ecosystems.

About MQTT:

MQTT (Message Queuing Telemetry Transport) is a simple and efficient messaging protocol ideal for resource-constrained devices. It follows a publish/subscribe (pub/sub) model, enabling seamless communication between smart devices and the central server through an MQTT broker [3], making it an ideal solution for the purpose of the presented automation application.

The broker acts as a hub that:

- Receives messages published by devices (e.g., sensors or relays).
- Filters them based on predefined topics.
- Distributes them to the appropriate subscribers (e.g., control logic in the server).

This mechanism ensures low-latency, scalable, and secure data transmission — essential for responsive smart home or smart irrigation systems.

Integration steps required to make strictly programming connections between the smart devices used:

1. Installing the MQTT Broker adapter:

- In the ioBroker system (running on the Raspberry Pi), navigate to the Adapters section.
- Search for "**MQTT Broker/Client**".

- Install the adapter by adding a new instance.
- 2. **Configuring the Broker:**
 - After installation, open the Instances tab to view running services.
 - By default, the MQTT broker uses **port 1883**.
 - For simplicity in local testing and home use, no username or password is initially required (though these can be added for production environments).
- 3. **Connecting the device:**
 - Once the broker is active, the **ESP32 board and Shelly devices** can publish and subscribe to relevant MQTT topics.
 - This setup enables real-time data flow and control between the sensors, actuators, and automation logic.

Some reasons why it is necessary to resort to the MQTT technical solution (see figure 2), are the following:

- **Lightweight** – Ideal for low-bandwidth or unstable networks.
- **Scalable** – Supports many connected devices.
- **Reliable** – Ensures data is routed correctly to all relevant components.
- **Open and Flexible** – Easily integrates with various platforms and devices.

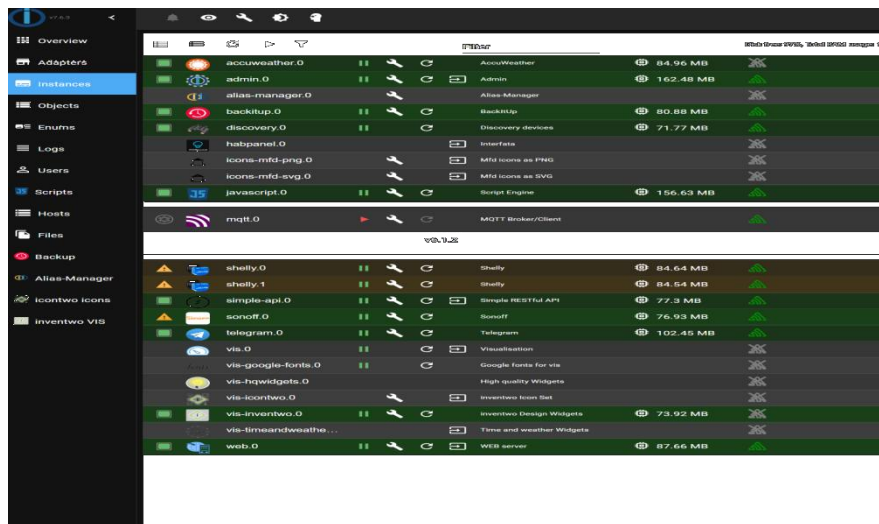


Fig. 2. View from Instances

Setup and Integration for WiFi Shelly Relay:

To integrate the Shelly WiFi smart relay into the system, follow these steps:

1. **Initial Setup via Smartphone:**
 - ✓ Power the Shelly device with a 220V source.
 - ✓ On your smartphone, search for a WiFi network named something like shelly-xxxxxx.
 - ✓ Connect to this network, then open a browser and go to <http://192.168.33.1>.
2. **Network Configuration:**
 - ✓ Access the settings interface.
 - ✓ Navigate to the WiFi settings section and connect the device to your main home network (either using DHCP or a predefined static IP).
 - ✓ Restart the Shelly device once connected.
3. **Firmware & Security Settings:**
 - ✓ Perform a firmware update and enable automatic updates.
 - ✓ Disable Access Point (AP) mode and Bluetooth, as they are not needed in this context.
 - ✓ This configuration ensures lower vulnerability and simplified networking.

The integration of the Linux server with ioBroker (Shelly adapter) is done as follows:

1. **On the Raspberry Pi server running ioBroker:**
 - Go to the **Adapters** section.
 - Search for "**Shelly Adapter**" and install it (see figure 3).

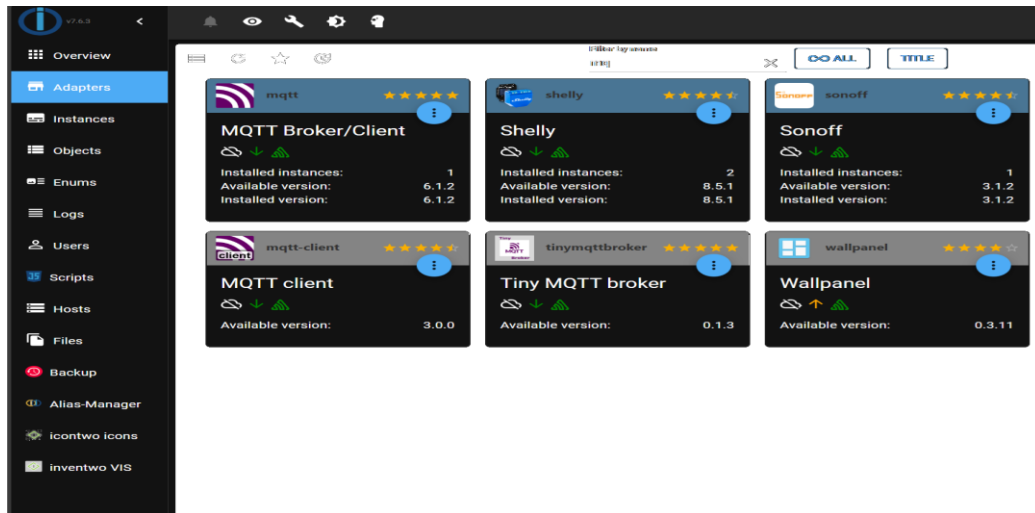


Fig. 3. View from Adapters section

2. Device Registration:

- After installation, the Shelly device should appear in the **Objects** panel within ioBroker.

3. MQTT Configuration (on the Shelly interface):

- Go back to the Shelly's web interface.
- In the **MQTT Settings** section:
 - Enter the **IP address of your Raspberry Pi server**.
 - Set the **port** (commonly 1883 or 1882, depending on your MQTT adapter).
 - Use the **username/password** created during the Linux setup for secure access.
 - Optionally, set a custom **MQTT prefix** (e.g., Releu-Lumini-Exterior1) for easier device identification (see figure 4).

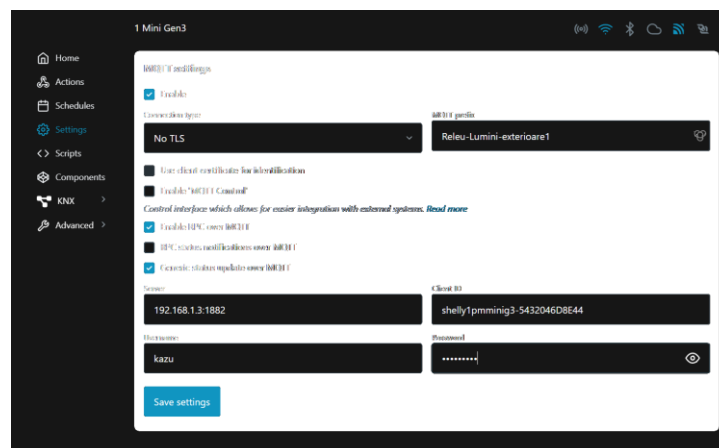


Fig. 4. View from setting up a custom MQTT prefix

4. Final Step:

- Restart the Shelly device.
- In ioBroker, under **Objects**, you should now see the Shelly device available for control and logic integration.

ESP32 configuration and GPIO Logic for smart irrigationv – necessary steps:

1. Flashing Firmware on ESP32

To configure the ESP32 controller, we used the open-source firmware **ESPEasy** (available at: <https://github.com/letscontrolit/ESPEasy>).

Configuration steps:

- Download the firmware version compatible with the specific ESP32 board (in this case, ESP32-32D).
- Connect the ESP32 to a PC via USB.
- Install necessary **serial drivers** and use a flashing tool to upload the firmware.

- After flashing, the device boots into access point mode and creates a WiFi network named ESPEASY.
- Connect to this network and access 192.168.4.1 in your browser.
- Join the ESP32 to your main WiFi network (using static IP if possible) and reboot the board.

2. Device pinout and sensor mapping

The ESP32 board allows flexible use of GPIO pins. For this new – original irrigation system, we used the following configuration from table 1.

Table 1. Configuration used

Function	GPIO Pin	Device Type
Soil Moisture Sensor	GPIO35	Analog Capacitive Sensor
Water Valve Actuator	GPIO23	Digital Output (Relay)
Water Pump	GPIO22	Digital Output (Relay)
Soil Temperature Sensor	GPIO32	Waterproof DS18B20 (1-Wire)

Each component is defined in the ESPEasy interface under the "Devices" tab, and each sensor/relay can be tested individually after setup.

3. Automation Rules Written in ESPEasy

The automation logic is written using ESPEasy's internal **rule scripting system**, which enables the board to autonomously decide when to activate irrigation based on sensor data.

Rule Code Sample:

```

On Umiditate#Sol Do
  If [Umiditate#Sol]<30
    gpio,23,0 // Open valve
  ElseIf [Umiditate#Sol]>80
    gpio,23,1 // Close valve
    gpio,22,1 // Turn off pump
  EndIf
EndOn
On Vana#State Do
  If [Vana#State]=0
    TimerSet,1,5
  EndIf
EndOn
On Rules#Timer=1 Do
  gpio,22,0 // Start pump after delay
EndOn

```

This rule system creates a lightweight, local decision-making loop, where no central server processing is needed — only MQTT communication for logging and optional override control.

Thus, we created the final solution in the form of a functional prototype, which is operational and can be used on the land of any household, with safe and controllable irrigation as the operating parameters are accessed through the IoT solution and smartphone.

The system provides an intuitive and secure interface for monitoring and controlling irrigation through the ioBroker platform [4, 5, 6]. This interface can be accessed from:

- **Laptop/Desktop** via local network
- **Smartphone** via local WiFi or remote **VPN connection**
- ☒ **Features Available in the Interface:**
- Real-time **soil moisture and temperature readings**
- Status of the **water pump** and **valve actuators**
- Control of **smart lighting** or additional devices (if integrated)
- Custom **dashboards** built with Blockly or VIS (Visualisation add-ons)
- **Manual override** or **automated logic review** via Blockly scripts
- ☒ **Security and Access:**
- No cloud dependency; all control and logic run locally
- Remote access is secured via **VPN**, eliminating external exposure
- Visual feedback helps validate real-time states of sensors and outputs

This ensures data privacy, low-latency control, and full user ownership over automation processes.

4. Implementation of the original technical solution. The way it works this original DIY system

To implement a fully automated [1-6] and modular DIY smart irrigation system (see figure 5), the following components were used:

- **Raspberry Pi 5** microserver running a local Linux-based automation environment
- **ESP32 modules**, configured for both sensor readings and actuator control
- **Shelly 1 Mini Gen3** smart relays for controlling AC/DC loads
- **Soil moisture and temperature sensors**, plus actuators for water flow control
- **Visual programming environment** (Blockly + Java) running on **ioBroker**

This original modular DIY smart irrigation system (see table 2) operates completely **locally**, without relying on cloud servers, ensuring **privacy**, **stability**, and **custom control**. Remote access is secured through a **VPN** connection.

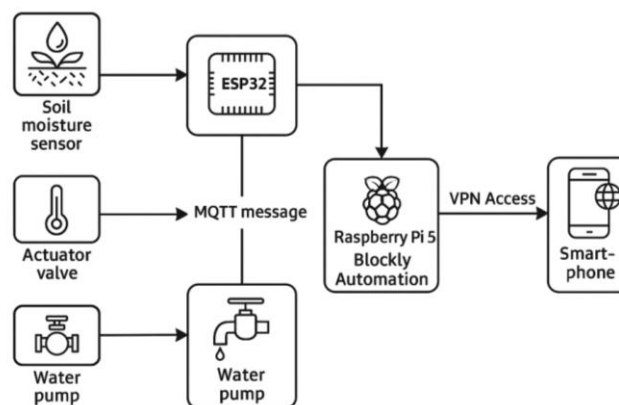


Fig. 5. View of the original solution of a modular, DIY, implemented smart irrigation system

Table 2. Hardware configuration in use

Function	GPIO Pin	Device Type
Soil Moisture Sensor	GPIO35	Analog Capacitive Sensor
Water Valve Actuator	GPIO23	Digital Output (Relay)

Water Pump	GPIO22	Digital Output (Relay)
Soil Temperature Sensor	GPIO32	DS18B20 Waterproof (1-Wire)

5. Conclusions

This completed project demonstrates a scalable, cost-effective model for automating irrigation in household or small-scale agricultural environments. This original modular DIY smart irrigation system was based on:

- **Open-source components;**
- **Visual programming tools;**
- **Local logic execution.**

Based on Raspberry Pi 5 and ESP32, this original technical solution provides precise water flow control, based on rules that can be easily accessed and at any time for necessary changes made with remote wireless commands, while remaining compatible with other smart systems, such as lighting or mobile applications. Most importantly, it can operate fully offline, ensuring **security**, **autonomy**, and **customizability**.

In the future, this prototype can be enhanced with **machine learning-based automation** or **weather-driven predictive irrigation** via meteorological data integration.

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REMOTELY CONTROLLED MOBILE SYSTEM FOR DATA ACQUISITION AND TRANSMISSION

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ABSTRACT: Data acquisition is a branch of engineering that deals with collecting information from a number of numerical and/or analog sources, converting this data into a digital form, storing and transmitting the data from a computer.

Data transmission is the transfer of data on a point-to-point or point-to-multipoint communication channel. Examples of such channels are copper wires, optical fibers, wireless communication channels, storage media, and computer buses. The data is represented as an electromagnetic signal, such as an electrical voltage signal, radio waves, microwaves, or infrared.

KEYWORDS: Remote control, Raspberry Pi, data acquisition, environmental monitoring, real-time transmission, sensors, automation, web interface.

1. Introduction

The project entitled “Remotely Controlled Mobile System for Data Acquisition and Transmission” aims to combine hardware [1, 2, 3, 4, 5] and software in order to create a data acquisition and monitoring system.

This mobile system monitors and counts the information received from several sensors (temperature and humidity, alcohol, carbon monoxide, methane gas) [6, 7, 8, 9, 10, 14 - 20] and from a video camera.



Fig. 1. Raspberry PI

I decided to use the Raspberry Pi 3B+ [11] module for data processing and for the ease with which it connects to Wi-Fi, so that it can be radio-remotely controlled. Reading the sensors and uploading the data is done using the Raspberian software [12, 13]. The acquired data can be viewed in real time using a web page that I created. Due to the

architecture of the system, it can be controlled remotely to acquire information and read parameters from different places.

2. Components used

The remote-controlled robot includes a number of hardware components, so the following were used:

- Raspberry Pi
- Camera Module V2 for Raspberry Pi



Fig. 2. Camera Module V2 for Raspberry Pi

- Accelerometer and Gyroscope Module MPU6500 GY

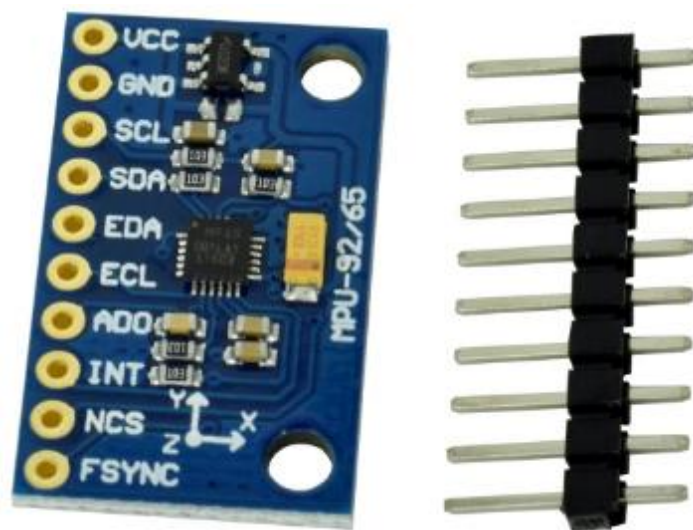


Fig. 3. Accelerometer and Gyroscope Module MPU6500 GY

- Temperature and Humidity Sensor DHT22/AM2302B [6, 7, 8, 9]

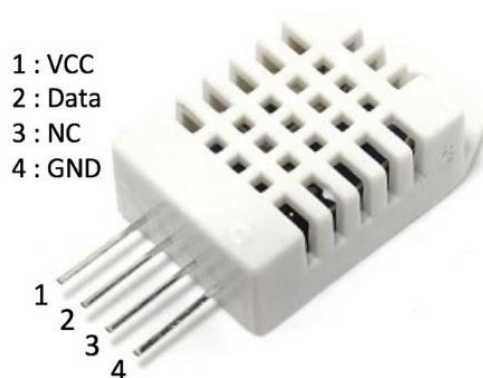


Fig. 4. Temperature and Humidity Sensor DHT22/AM2302B

- Infrared Obstacle Sensor Module



Fig. 5. Infrared Obstacle Sensor Module

- Gaseous Alcohol Sensor Module MQ-3

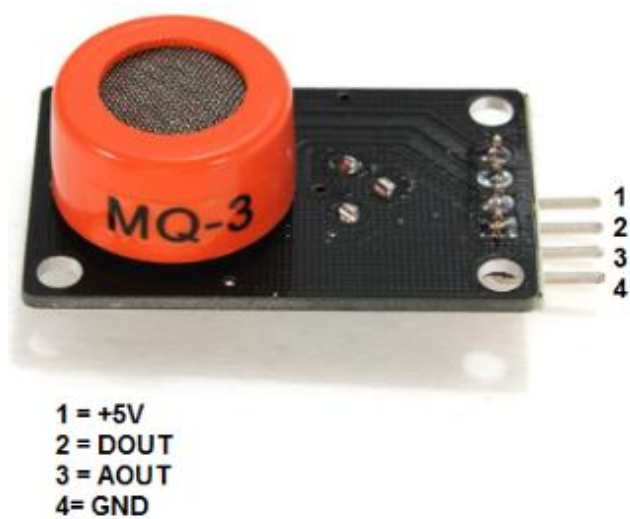


Fig. 6. Gaseous Alcohol Sensor Module MQ-3

- Gaseous Carbon Monoxide Sensor Module MQ-7



Fig. 7. Gaseous Carbon Monoxide Sensor Module MQ-7

- Analog-to-Digital Converter (ADC) Module ADS1015 GY [21]

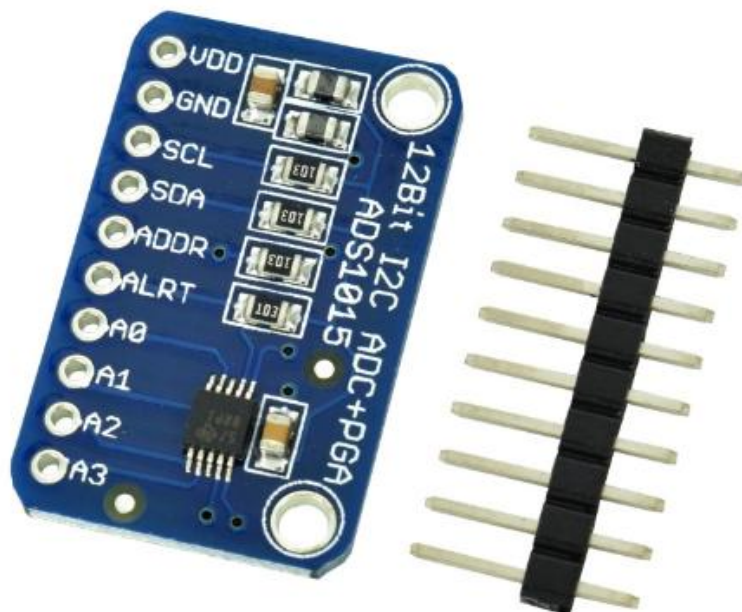


Fig. 8. Analog-to-Digital Converter (ADC) Module ADS1015 GY

- 5V Voltage Stabilizer LM7805 (TME) [22,23]



Fig. 9. 5V Voltage Stabilizer LM7805 (TME)

3. Functionality implementation

Block system Diagram:

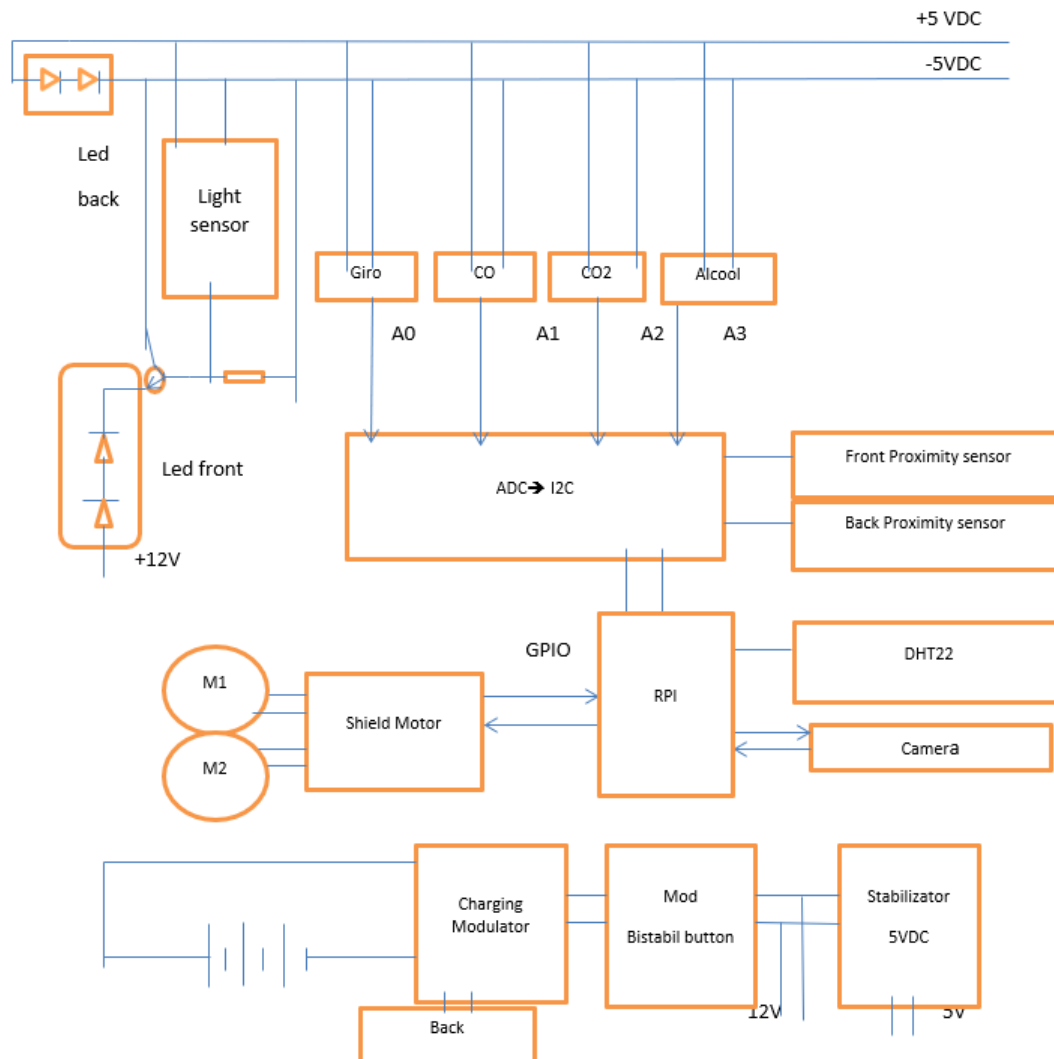


Fig. 10. Block system diagram

In the block diagram, we can see the presence of the Raspberry PI Computer where the front proximity sensors and the rear proximity sensors are connected, the DHT22 temperature and humidity sensor, the V2 video camera and the motor driver on GPIO.

Connected to the Raspberry PI is an analog-to-digital converter that converts the voltage level from the Alcohol, carbon monoxide, methane gas, gyroscope and accelerometer sensors. The connection of the analog-to-digital converter to the Raspberry PI is made on the I2C interface.

Also, powered at 5 V are the light sensors and the front and rear LEDs.

4. Functionality Description:

The acquired data can be viewed in real time using a web page that we created. Due to the system architecture, it can be controlled remotely to acquire information and read parameters from different locations.

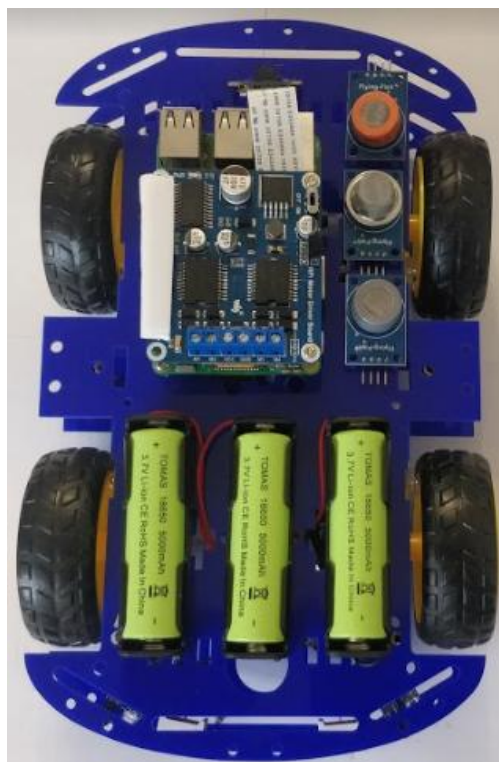


Fig. 11. Overview

The website has both the role of controlling robots remotely and the role of acquiring real-time data from several sensors: temperature and humidity, carbon monoxide, methane gas and alcohol. The website also monitors data received from a Web camera located on the robot where real-time data on the environment can be viewed.

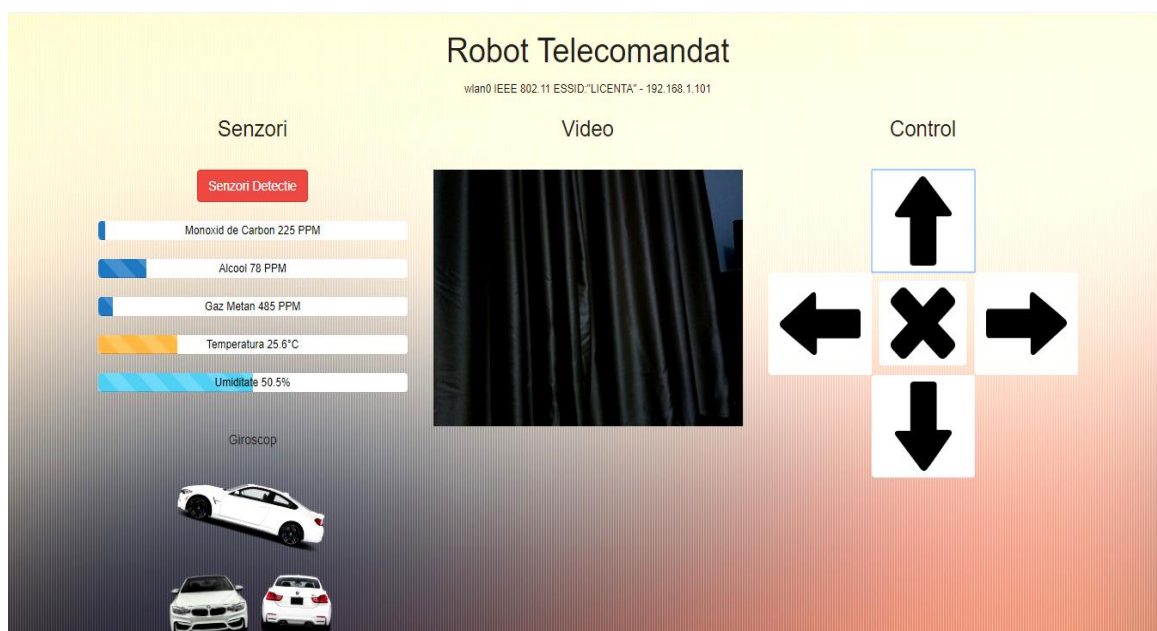


Fig. 12. Control Page

As a structure, I used a plexiglass chassis and four wheels, whose control system is very similar to that of a tank.

For my remote-controlled car-type robot to turn left, then it is necessary that the simultaneous operation of the motors on the right side be done forward, and the simultaneous operation of the motors on the left side be done backward.

The same operating principle is also in the case of a right turn, only in this case, the simultaneous operation of the motors on the right side must be done backward, and the simultaneous operation of the motors on the left side be done forward. We can say that the remote-controlled robot is also an autonomous robot because we have integrated proximity sensors in order to avoid the risk of an accident and damage to parts of the chassis structure.

Because the sensors are not of the best quality, they do not work at optimal capacity, so the automation process is not completely finished.

The remote-controlled robot's capability is also given by a sensor module that includes an accelerometer and a gyroscope, to provide information about the inclination of the terrain on which the car is located or moving.

We can thus obtain very useful information about the environment because we have a good perspective on it.

5. Conclusions

Through this project, I managed to create a mobile system for measuring and displaying environmental parameters as well as a visualization system for the surrounding space.

The system [1-9, 11-13, 21-28] I designed has the following advantages:

- permanent monitoring and visualization of the environment.
- increased accessibility due to the mobile system capable of reaching hostile environments.
- data acquisition processing.
- the multitude of available sensors from which we can have an overall perspective on the parameters of the environment.

Starting from the idea of combining a data acquisition system with a mobile system, I constantly tried to improve it.

An example would be the inclusion of the environmental visualization system, which is done with the help of a video camera.

In terms of further development, the system I created can be constantly improved by adding more efficient components or by integrating new integrated systems on the current platform.

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Access Control System Using an Electromechanically Actuated Smart LOCK

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***ABSTRACT:** This scientific project presents the design, development and implementation of an electromechanically actuated smart lock for access control applications. The system is based on a planar R-RRT mechanism that converts servo motor rotation into linear motion of the locking bolt. An ESP8266 microcontroller manages wireless communication, real-time monitoring and alarm activation via a magnetic reed sensor. The structural and kinematic analyses confirm the reliability and single-degree-of-freedom operation of the mechanism. Due to the door's inclusion in the building's emergency evacuation plan, a fail-safe configuration was adopted, allowing automatic unlocking during power failure. The resulting prototype demonstrates the feasibility of combining embedded systems, IoT technologies, and mechanical linkages into a compact and scalable smart access solution.*

KEYWORDS: access security, wireless control, smart lock, electromechanical actuation, crank-slider mechanism

1. Introduction

In the current context of increasing digitalization and automation within residential and industrial environments, access security through intelligent systems has emerged as a key research direction with significant practical applicability. Traditional access control systems, based on mechanical locks or localized electrical solutions, are gradually being replaced by modern mechatronic devices that integrate mechanical, electronic, and wireless communication functions. These systems enable remote control and real-time monitoring of secured spaces [4].

This paper presents the design and implementation of such a system: an electromechanically actuated smart lock, controlled by an ESP8266 microcontroller and based on a planar R-RRT mechanism. This mechanism converts the rotational motion of a servomotor into the linear displacement of a locking bolt, thus enabling automated locking and unlocking of a door without manual intervention.

In engineering, a mechanism is defined as a combination of rigid elements connected through kinematic pairs, allowing for the transmission and transformation of motion to achieve a specific functional objective. Mechanisms are analysed both structurally and kinematically to ensure functional performance, reliability, and control over motion [1]. The R-RRT mechanism used in this project features a single degree of freedom and belongs to the class of planar kinematic chains with lower pairs, providing a simple and robust solution for transmitting the locking command.

The electronic component manages the motor control, monitors a Reed sensor, stores access events, and triggers both audible and visual alarms, functionality that is fully integrated into a web interface accessible over a local network [3], [4].

A critical design consideration for such a system is the choice of safety logic in the event of a power failure. According to specialized literature, two main behaviors are distinguished [2]:

- Fail-safe – the door automatically unlocks if the power supply is interrupted. This configuration is recommended in scenarios where life safety is the top priority;

- Fail-secure – the door remains locked in the absence of power, making it more suitable for situations where the protection of assets or high-security areas is required.

In this case, the usage context is clearly defined: the targeted door is included in the building's emergency evacuation plan. Therefore, a fail-safe configuration has been chosen, ensuring automatic unlocking in emergency situations such as fires or power outages [2].

As an illustrative scenario, consider a restricted-access area—such as a company yard, warehouse, laboratory, or residential building—where entry is permitted only to authorized individuals. The dispatcher, located remotely and without direct visibility of the door, manages access as follows: the authorized person contacts the dispatcher by phone to request entry; the dispatcher verifies the caller's identity (phone number and purpose)- this represents Authorization Level 1. If the information is validated, the dispatcher sends the command to actuate the locking bolt via the web interface- Authorization Level 2. Optionally, an IP camera can be integrated for additional visual verification.

2. Current Development Stage

Modern access control systems increasingly rely on automation and interconnectivity. The transition from mechanical locks to smart solutions is driven by the growing demand for operational efficiency, remote control, and seamless integration into smart building infrastructures. In this context, the proposed project leverages a planar R-RRT kinematic mechanism to actuate a locking bolt, combined with a control architecture centered on an ESP8266 microcontroller [1], [4].

At its current stage of development, the system is fully functional and includes the following components:

- Bolt actuation via an MG996R servomotor, controlled by the ESP8266.
- A Reed sensor for door position detection.
- Audible and visual alerts are triggered in case of unauthorized access.
- A web interface for command execution and event logging within a local network [3].
- Wireless remote control, eliminating the need for signal cables.

A critical feature of the system architecture is its behavior under power loss. Since the application targets a door included in an emergency evacuation plan, a fail-safe configuration was rightly adopted. According to technical standards and recommendations in the literature [2], this solution ensures that the door automatically unlocks in the event of a power outage, enabling unobstructed evacuation.

To validate the system's functionality in practice, a physical prototype will be constructed alongside theoretical modeling and analysis. This prototype will feature a miniature door fitted with the complete mechanism: the servomotor, bolt system, sensors, ESP8266 control board, and user interface (see Table 1). The mock-up will facilitate testing under controlled conditions and serve as a demonstrative model to showcase the system's operation.

3. Electronic Component

In Table 1, different electronic components are presented, like ESP8266 (NodeMCU), MG996R Servomotor, Reed Sensor, Buzzer, RGB LED, External 5V Power and Red Button Module and their function is described.

Table 1. Electronic Components Used

Component	Function	ESP8266 Pin
-----------	----------	-------------

ESP8266 (NodeMCU)	Main control unit and Wi-Fi communication	–
MG996R Servomotor	Actuates the locking mechanism	D5 (GPIO14)
Reed Sensor	Detects whether the door is open or closed	D1 (GPIO5)
Buzzer	Emits warning sounds	D4 (GPIO2)
RGB LED	Indicates system status (green/red/blue)	D6 / D7 / D8
External 5V Power	Supplies power to the servomotor	GND and External 5V
Red Button Module	Triggers emergency access override	D3 (GPIO0)

4. Device Programming

The programming was carried out in the Arduino IDE environment, using the C++ programming language [5]. The device connects to a local Wi-Fi network and hosts a web server that integrates essential functions such as access control, system monitoring, and security event logging. Several key libraries were employed to implement these functionalities: ESP8266WiFi – for wireless communication [3], Servo.h – to control the MG996R servomotor, SPIFFS – a file system for storing log files and configuration data [8], NTP (Network Time Protocol) – for synchronizing accurate date and time stamps for logged events [6].

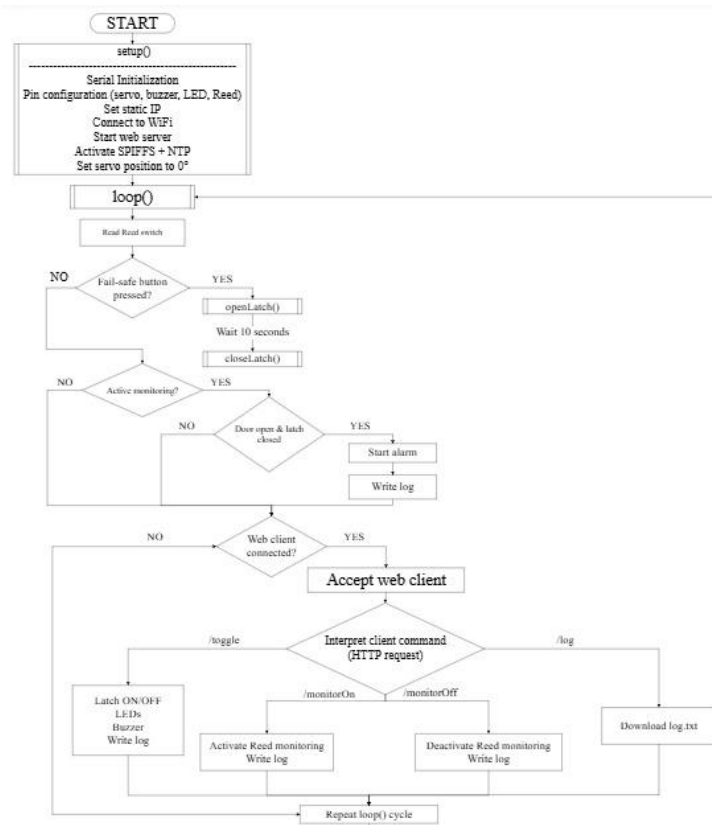


Fig. 1. System Logic Diagram

A critical feature of the system is the detection of unauthorized door openings. If the door is opened while the locking bolt is still engaged, the system immediately activates both audible and visual alarms, and the event is stored in a log file named log.txt [8]. For dynamic

display and interaction via the web interface, the front-end was developed using HTML and styled with Bootstrap 4 [7], providing a responsive and user-friendly experience.

Moreover, the system implements a fail-safe mechanism at the software level: in the event of a power outage, the servomotor is programmed to automatically move to the unlock position. This functionality is critical in emergency scenarios, ensuring that the door does not obstruct evacuation routes.

5. Mechanical Component

The mechanism used in this project is a planar linkage composed of three moving elements and one fixed element, arranged in an R-RRT configuration (Rotation–Rotation–Rotation–Translation). This type of mechanism was selected for its ability to convert the rotational motion of a servomotor into a useful linear displacement required to actuate a locking bolt. As a result, the door can be locked or unlocked in a compact, efficient, and fully automated manner [1].

All mechanical elements were measured using a caliper, in order to determine their dimensions and the relative positions of the fixed kinematic pairs (see Figures 2–5 for measurement details).

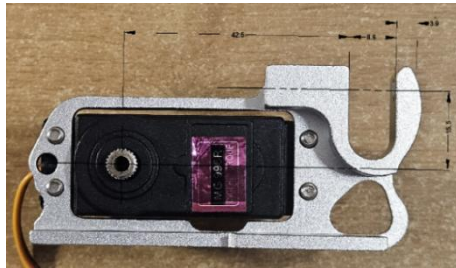


Fig. 2. Measurement of the fixed element



Fig. 3. Measurement of the piston

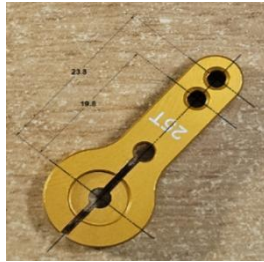


Fig. 4. Measurement of the crank

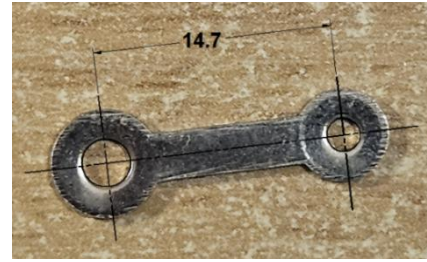


Fig. 5. Measurement of the connecting rod

5.1. Structural Analysis

The structural analysis is carried out following the methodology taught in the Mechanisms course [1]. To determine the degree of mobility of the mechanism, Gruebler's equation for planar mechanisms with lower pairs is applied:

$$M = 3 \times m - 2 \times i - s \quad (1)$$

where: $m = 3$; $i = 4$; $s = 0$.

$$M = 3 \times 3 - 2 \times 4 - 0 = 9 - 8$$

$$M = 1$$

Thus, the mechanism has a single degree of freedom, making it fully kinematically determined and driven by a single servomotor, which rotates the crank. This structure is ideal for ON/OFF applications (open/closed), requiring a simplified control strategy while ensuring kinematic stability [1].

Determining the number of independent loops (N) in a kinematic chain is also important, as it defines the number of independent vector equations that can be formulated for the system [1].

$$N = i + s - m \quad (2)$$

$$N = 4 - 3 \rightarrow N = 1$$

Table 2. Kinematic Pairs

Kinematic Pair	Type of Motion	Notation	Connection Between Links	Pair Class
A ₀	Rotation	A ₀ (0,1) - R	Base 0 and Crank 1	V
A	Rotation	A(1,2) - R	Crank 1 and Connecting Rod 2	V
B	Rotation	B(2,3) - R	Connecting Rod 2 and Piston 3	V
B ₀	Translation	B ₀ (3,0) - T	Piston 3 and Base 0	V

Table 3. Kinematic Links

Link Number	Associated Kinematic Pairs	Link Name	Representation
0	A ₀ , B ₀	binary	A ₀ —B ₀
1	A ₀ , A	binary	A ₀ —A
2	A, B	binary	A—B
3	B, B ₀	binary	B—B ₀ (T)

Thus, the structural diagram and connection diagram are constructed (see Fig. 8), both forming a quadrilateral configuration. The structural scheme is then divided into the following structural groups: the active modular group, consisting of the kinematic pair A₀ and kinematic link 1 (refer to tables 2 and 3), a 2RRT-type dyad, classified as a Class II, Order 2 group [1] (see Figures 6 and 7).

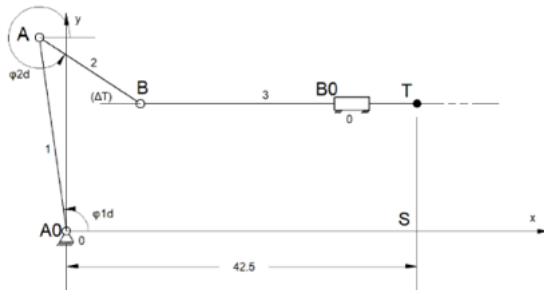


Fig. 6. Kinematic diagram of the mechanism

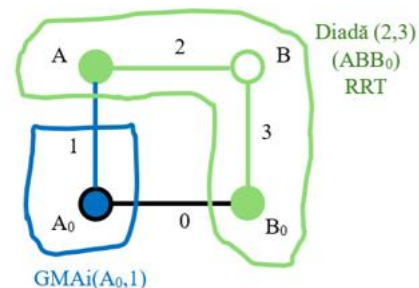


Fig. 7. Structural group decomposition

5.2. Kinematic Calculation for Determining the Crank Angle

Using the theoretical principles taught in the course, the mechanism is analyzed kinematically (see Figures 9–12) through the contour method developed by Professor Pelecudi. An inverse kinematics approach is applied to determine the crank's angular position corresponding to a given end-effector (piston) position. The crank features two threaded holes, located at 23.8 mm and 19.8 mm from the axis of the fixed pair, allowing two configurations to be considered.

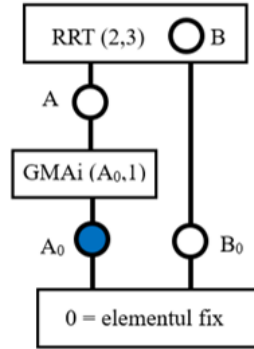


Fig. 8. Connection diagram

$$EF(0) - GMAI(A_0, 1) - RRT(2, 3) ABB_0 \quad (3)$$

In both cases, the piston stroke is identical and equals $55 \text{ mm} - 42.5 \text{ mm} = 12.5 \text{ mm}$. Therefore, two variants are analyzed: Variant 1: crank length of 23.8 mm, Variant 2: crank length of 19.8 mm.

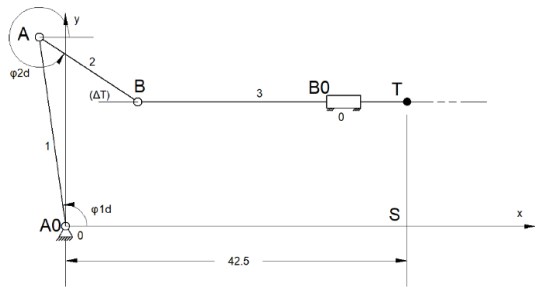


Fig. 9. Variant 1- Open Position

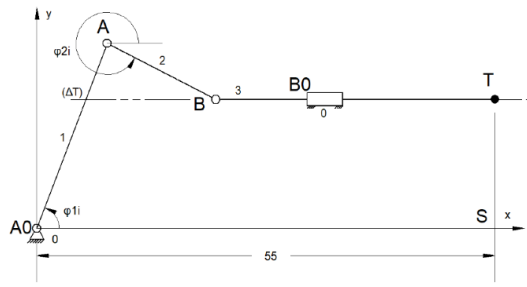


Fig. 10. Variant 1- Closed Position

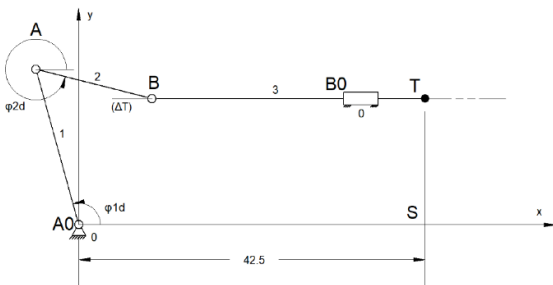


Fig. 11. Variant 2 - Open Position

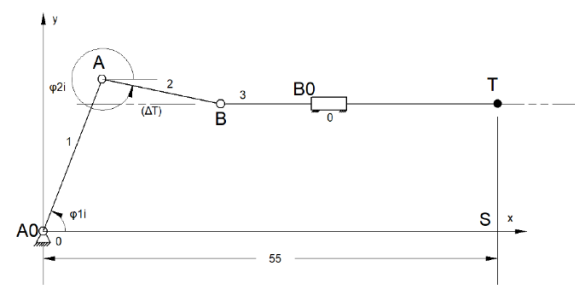


Fig. 12. Variant 2 - Closed Position

The vector equation is expressed as:

$$\overrightarrow{A_0A} + \overrightarrow{AB} + \overrightarrow{BT} + \overrightarrow{TS} + \overrightarrow{SA_0} = \vec{0} \quad (4)$$

The projection equations on the Ox and Oy axes are:

$$l_1 \cdot \cos\varphi_1 + l_2 \cdot \cos\varphi_2 + l_3 - s = 0$$

$$l_1 \cdot \sin\varphi_1 + l_2 \cdot \sin\varphi_2 - e = 0 \quad (5)$$

The nonlinear system of two equations is solved using Mathcad, provided by the Department of Mechanism and Robotics Theory, yielding the following solutions:

$$\text{variant 1: } \varphi_{1d} = 97,934^\circ; \varphi_{1i} = 69,223^\circ; \Delta\varphi_1 = 28,711^\circ$$

$$\text{variant 2: } \varphi_{1d} = 105,391^\circ; \varphi_{1i} = 68,97^\circ; \Delta\varphi_1 = 36,421^\circ$$

$$l_1 := 23.8 \quad l_2 := 14.7 \quad l_3 := 33.5 \quad s_d := 42.5 \quad s_i := 55 \quad e := 15.5$$

$$\phi_{1d} := \frac{\pi}{2} \quad \phi_{2d} := 0$$

Given

$$l_1 \cdot \cos(\phi_{1d}) + l_2 \cdot \cos(\phi_{2d}) + l_3 = s_d$$

$$l_1 \cdot \sin(\phi_{1d}) + l_2 \cdot \sin(\phi_{2d}) = e$$

$$\begin{pmatrix} \phi_{1d} \\ \phi_{2d} \end{pmatrix} := \text{Find}(\phi_{1d}, \phi_{2d})$$

$$\phi_{1deg} := \phi_{1d} \cdot \frac{180}{\pi}$$

$$\phi_{1deg} = 97.934$$

$$\phi_{2deg} := \phi_{2d} \cdot \frac{180}{\pi}$$

$$\phi_{2deg} = -33.307$$

$$\phi_{1i} := \frac{\pi}{3} \quad \phi_{2i} := 0$$

Given

$$l_1 \cdot \cos(\phi_{1i}) + l_2 \cdot \cos(\phi_{2i}) + l_3 = s_i$$

$$l_1 \cdot \sin(\phi_{1i}) + l_2 \cdot \sin(\phi_{2i}) = e$$

$$\begin{pmatrix} \phi_{1i} \\ \phi_{2i} \end{pmatrix} := \text{Find}(\phi_{1i}, \phi_{2i})$$

$$\phi_{1deg} := \phi_{1i} \cdot \frac{180}{\pi}$$

$$\phi_{1deg} = 69.223$$

$$\phi_{2deg} := \phi_{2i} \cdot \frac{180}{\pi}$$

$$\phi_{2deg} = -27.344$$

$$\Delta\phi_1 := (\phi_{1d} - \phi_{1i}) \cdot \frac{180}{\pi}$$

$$\Delta\phi_1 = 28.711$$

Fig. 13. Calculation for Variant 1- Open Position

Fig. 14. Calculation for Variant 1- Closed Position

$$l_1 := 19.8 \quad l_2 := 14.7 \quad l_3 := 33.5 \quad s_d := 42.5 \quad s_i := 55 \quad e := 15.5$$

$$\phi_{1d} := \frac{\pi}{2} \quad \phi_{2d} := 0$$

Given

$$l_1 \cdot \cos(\phi_{1d}) + l_2 \cdot \cos(\phi_{2d}) + l_3 = s_d$$

$$l_1 \cdot \sin(\phi_{1d}) + l_2 \cdot \sin(\phi_{2d}) = e$$

$$\begin{pmatrix} \phi_{1d} \\ \phi_{2d} \end{pmatrix} := \text{Find}(\phi_{1d}, \phi_{2d})$$

$$\phi_{1deg} := \phi_{1d} \cdot \frac{180}{\pi}$$

$$\phi_{1deg} = 105.391$$

$$\phi_{2deg} := \phi_{2d} \cdot \frac{180}{\pi}$$

$$\phi_{2deg} = -14.135$$

$$\phi_{1i} := \frac{\pi}{3} \quad \phi_{2i} := 0$$

Given

$$l_1 \cdot \cos(\phi_{1i}) + l_2 \cdot \cos(\phi_{2i}) + l_3 = s_i$$

$$l_1 \cdot \sin(\phi_{1i}) + l_2 \cdot \sin(\phi_{2i}) = e$$

$$\begin{pmatrix} \phi_{1i} \\ \phi_{2i} \end{pmatrix} := \text{Find}(\phi_{1i}, \phi_{2i})$$

$$\phi_{1deg} := \phi_{1i} \cdot \frac{180}{\pi}$$

$$\phi_{1deg} = 68.97$$

$$\phi_{2deg} := \phi_{2i} \cdot \frac{180}{\pi}$$

$$\phi_{2deg} = -11.701$$

$$\Delta\phi_1 := (\phi_{1d} - \phi_{1i}) \cdot \frac{180}{\pi}$$

$$\Delta\phi_1 = 36.421$$

Fig. 15. Calculation for Variant 2- Open Position

Fig. 16. Calculation for Variant 2- Closed Position

The calculated angular values can be rounded to the nearest integers. In Variant 1, the crank stroke is shorter, which results in a reduced actuation time for the locking bolt. However, upon analyzing the values of the angle φ_2 , it is observed that this configuration produces a smaller pressure angle in the B0 joint, which is advantageous as it reduces the risk of mechanism jamming (see Figures 13–16).

The servomotor shaft is split with 25 grooves, which limits the ability to precisely align the crank to a specific angle. As a result, the angular resolution is restricted to $360^\circ / 25 = 14.4^\circ$. To compensate for this limitation, the following steps are followed:

- The crank is mounted on the shaft in a position as close as possible to the desired "open" position.
- The rotation angle of the servomotor is programmed according to the kinematic calculations.

- The servomotor is activated to close the locking bolt.
- The functionality is tested, and the rotation angle is adjusted if necessary.

6. Conclusion

The presented project demonstrates the feasibility of developing an access control system based on an electromechanical mechanism actuated by a servomotor and managed by an ESP8266 microcontroller. By integrating the hardware components with dedicated control logic, a fully functional device was developed—capable of remote operation, real-time monitoring, and alert generation in the event of a security breach [3], [4].

A key factor in selecting the system configuration was its behavior under fault conditions. Since the controlled door is part of the building's evacuation plan, a fail-safe configuration was appropriately chosen to ensure automatic unlocking in the event of a power outage. This design decision aligns with safety standards and emergency evacuation regulations [2].

From a mechanical standpoint, two crank length variants were analyzed: 23.8 mm and 19.8 mm. Although both configurations met the required locking bolt stroke, the shorter crank (19.8 mm) was selected due to its lower pressure angle at the piston joint. This characteristic contributes to more reliable operation, reduced risk of jamming, and less strain on the servomotor, ultimately enhancing the system's durability [1].

To validate the design in practice, a functional prototype was built to simulate the behavior of the system on a real door. The setup incorporates all critical components: servomotor, R-RRT mechanism, Reed magnetic sensor, RGB LED, buzzer, web-based control interface, and an alarm module, confirming the system's proper functionality under simulated conditions.

- This work provides a practical example of integrating knowledge from mechanisms, electronics, and embedded systems programming into a solution with real-world applicability. Several potential directions for future development include:
- Adding an authentication layer within the web interface.
- Integrating a power backup module (battery).
- Implementing an IPTV camera for enhanced user identification.
- Replacing the servomotor with a more robust actuation mechanism, suitable for industrial environments.

Thanks to its demonstrated functionality, modular design, and scalability, the implemented system serves as a viable platform for further research and applications in automated access control, smart mechanisms, and modern security devices.

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8. Notations

The following symbols are used throughout this paper:

RRT = Rotation–Rotation–Translation (mechanism configuration).

M = Degree of mobility.

m = Number of moving kinematic links.

i = Total number of lower pairs (kinematic joints).

s = Total number of higher pairs.

$l_1=A_0A$ = Crank length.

$l_2=AB$ = Connecting rod length.

$l_3=BT$ = Piston stroke.

e=TS (Distance between the translational axis and the fixed rotational joint).

**DESIGN OF A MECHANISM INTENDED FOR HANDWRITING REPRODUCTION
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ABSTRACT: The paper presents the design, fabrication, and testing of a mechanism intended for handwriting reproduction, using the BambuLab P1S 3D printer and the CATIA CAD software. The proposed mechanism consists of five main components: the support pillar, joint, rocker arm, writing arm, and the clamps for securing the writing instrument. The tolerances between the articulated parts were tested to ensure smooth movement of the mechanism. Physical testing validated its functionality, and the results suggest potential applications in fields such as education and writing process automation. Future development includes the integration of an automated control system for tracing predefined texts.

KEYWORDS: mechanism, writing, modelling, printing, tolerances

1. Introduction

Handwriting remains one of the most expressive and personal forms of human communication. Over time, various devices have been developed to mechanically reproduce this type of movement, from historical automata to modern printers and robotic arms. The purpose of this paper is to design and build a demonstrative, simplified mechanism capable of reproducing the writing trajectory of a hand-held instrument, using accessible technologies such as 3D printing and CAD modeling.

The project is focused on creating a functional concept that illustrates the basic principles of motion transmission through articulated mechanical links. Although it is not a high-precision system, the mechanism aims to show that simple constructions can effectively mimic human gestures such as handwriting. The final model is intended to be scalable and can serve as a foundation for further developments or integrations in automated systems.

2. Current state

In recent years, the field of robotics and automation of fine human hand movements has advanced significantly, particularly regarding the reproduction of handwriting motions. Various technological approaches have been proposed to create mechanisms capable of imitating the complex actions of writing, ranging from educational applications to industrial automation. Many of these solutions employ principles of precision robotics, mechatronics, and artificial intelligence with the goal of providing accurate and rapid reproduction of handwritten text [1], [2].

2.1 Robotic mechanisms for handwriting

One of the most well-known examples of mechanisms that imitate handwriting is the WABOT-2 robot, developed in the 1980s by researchers at Wako University in Japan.

It was equipped with a robotic hand capable of writing with speed and precision, and studies from that time demonstrated its ability to reproduce cursive characters (Fig.1). However, the technology was limited by the weight and complexity of the mechanism.

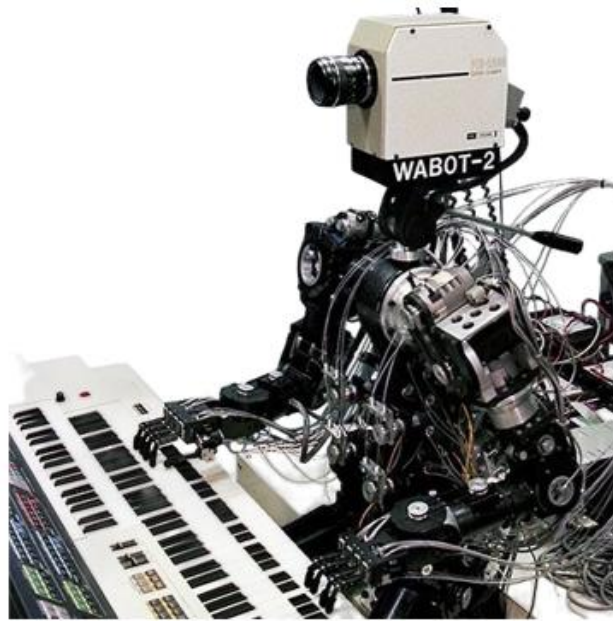


Fig. 1. WABOT 2 Robot singing at the piano [3]

2.2 3D Printers and Prototypes of Writing Mechanisms

With advancements in 3D printing technologies, more researchers and engineers have begun developing prototypes of writing mechanisms by incorporating printed mechanical components. 3D printing allows greater design freedom and optimization of parts to achieve specific functionality, and the created components can be easily customized according to the mechanism's requirements. In this context, solutions developed using 3D printers can be extremely useful for handwriting mechanism prototypes, enabling the creation of fast and precise functional prototypes [4], [5].

3. Design Process

The design process began with a manual sketch, where the main components and their interactions were defined. Basic concepts from mechanism theory were applied, such as rotational joints, fixed constraints, and motion control through linkages. Initially, the use of counterweights was also considered to balance the writing arm, but this idea was later discarded in favor of a simpler and lighter structure. Thus, the elements of the mechanism, as highlighted in the kinematic diagram, are: central pillar (1), coupling with two degrees of rotation (2), rocker arm (3), counterweight (4), writing arm (5), and the clamps for holding the writing instrument (Fig. 2).

This early stage helped clarify the overall movement and ensure the mechanism could work as intended. Once the concept was validated on paper, the next step was 3D modeling using CATIA. Each component was designed with its specific mechanical role in mind and adjusted for 3D printing constraints. Tolerances were introduced between moving parts to allow easy assembly and free, yet controlled movement.

The transition from sketch to digital model was essential for understanding how the parts interact and for preventing common assembly issues later in the process.

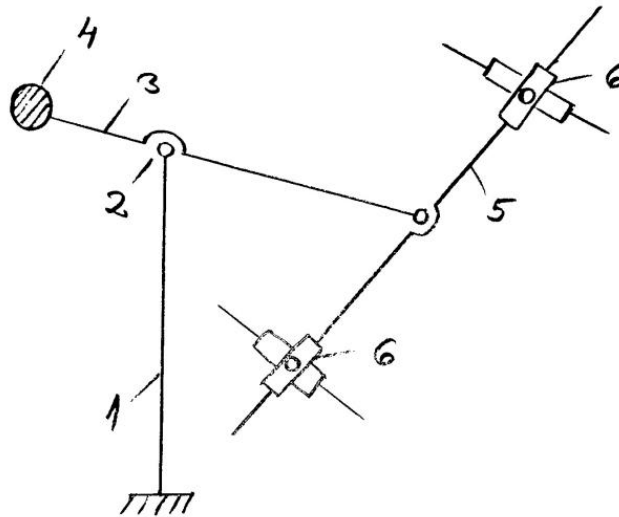


Fig. 2. Kinematic scheme of the mechanism

4. Mechanism description

The mechanism intended for handwriting reproduction is composed of a set of interconnected parts, each with a clearly defined functional role. It enables the simulation of a writing hand's motion through articulated components that generate planar trajectories. The 3D model created in CATIA is shown in the figure below:

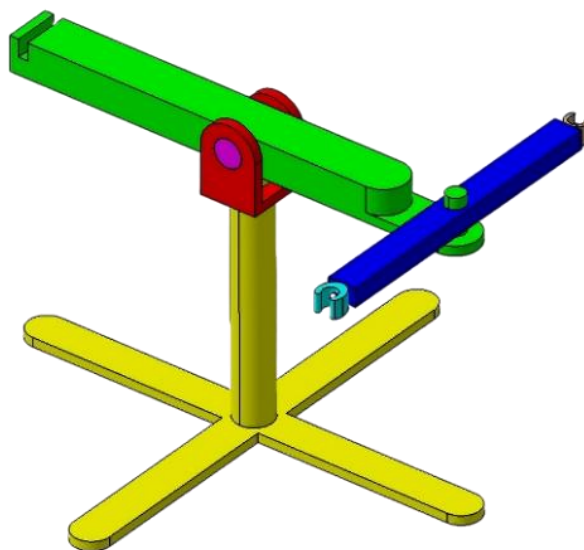


Fig. 3. Isometric view of the mechanism

4.1 The components of the mechanism

As was mentioned before, the mechanism was designed in CatiaV5R21 and these are the main components of the mechanism:

1) Central pillar (yellow)

This component serves to support the entire structure. It is mounted vertically and fixed onto a cross-shaped base, which provides stability to the mechanism during operation. It is

designed with four equal extensions positioned orthogonally to prevent tipping during dynamic movements. Functionally, the pillar acts as the structural “spine” of the assembly (Fig. 4).

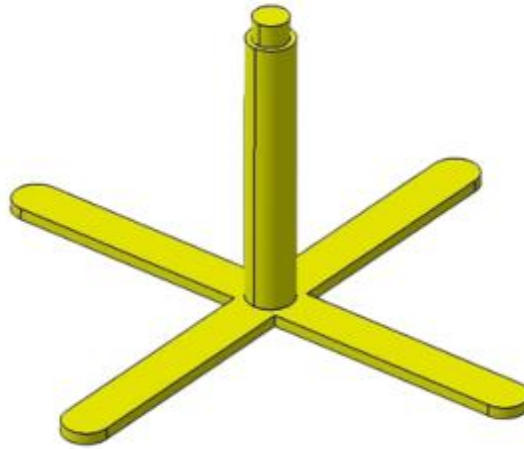


Fig. 4. Central pillar

2) Rotary joint

This part connects the vertical pillar to the green rocker arm (Fig. 5). It is a crucial component because it contains the rotating hole that allows the rocker arm to move. It essentially functions as a fixed bearing for the rocker arm's rotational shaft. As a machine element, it is a rotary joint with a limited angle of approximately 40 degrees.

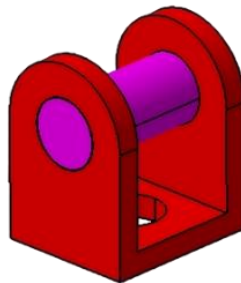


Fig. 5. Rotary joint

3) Rocker arm

It is a lever arm that rotates around the red axis. At one end, it is connected to the writing arm, and at the other end, manual force can be applied (by pressing or pulling with a counterweight). Its mechanical function is to transmit and transform linear or oscillatory motion into writing movement (Fig. 6).



Fig. 6. Rocker arm

4) Writing arm

It is a lever articulated to the rocker arm through a pivot joint (Fig. 7). It moves along a combined trajectory (oscillatory and translational), causing the tip of the writing instrument to follow a path. The length of the arm influences the amplification of the movement and the writing radius.

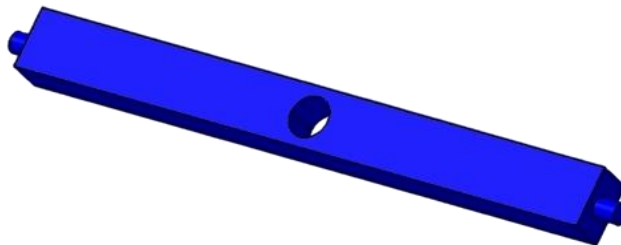


Fig. 7. Writing arm

5) Clamps for securing the writing instrument

The clamp is positioned at the end of the writing arm and serves to hold the pen, pencil, or stylus (Fig. 8). Its design is circular with a flexible opening to allow easy insertion of the instrument, while ensuring stability during movement. Several prototypes of the clamps were tested before selecting the final design.

5. CAD modelling and 3D design

The mechanism was physically produced using 3D printing technology, employing the BambuLab P1S printer with PLA filament. The printing parameters were optimized to ensure high-quality parts that allow efficient assembly and smooth movement of the mechanism. The parts were printed with a layer height of 0.4 mm, and an infill of 15%, except for the rocker arm which used 10%, balancing strength and ease of handling [6], [7].



Fig. 8. Highlights of the clamp design

An important aspect of this work was testing the tolerances between components, especially for the articulated parts. Tolerance tests were conducted to determine the optimal joint clearances to achieve smooth movements without jamming or excessive mechanical play. The tolerances varied between 0.1 mm and 0.5 mm depending on the functional characteristics of each joint [8].

From the tests performed, the observations indicate that a tolerance of 0.3 mm is most suitable for free movements with minimal play, while a tolerance of approximately 0.25 mm is best for slightly dampened movements.

6. Assembly and physical testing

After producing the parts through 3D printing, the assembly process was carried out manually, with the parts designed as “push-fit” joints to facilitate easy mounting and dismounting. Once assembled, the mechanism was tested to verify if it could reproduce the specific motions of handwriting. The results were positive, showing continuous and stable movement, with the joints performing according to the previously tested tolerance specifications.



Fig. 9. 3D printed tolerance test

It is important to emphasize that the realized mechanism is only a functional prototype, intended to demonstrate the concept of reproducing handwriting motion. Therefore, the current mechanism could not perfectly replicate the user's motions and primarily reproduces shapes and figures of low to medium complexity. Additionally, there is the possibility to insert multiple mechanisms in parallel, allowing several instances to write simultaneously and enabling the

writing process to be repeated multiple times in a continuous cycle [9]. This would increase efficiency and allow the mechanism to be used in educational or industrial contexts where automatic repetition of writing tasks is required.

7. Possible improvements

The mechanism developed in this work represents a simplified version, designed to demonstrate the basic principle of handwriting reproduction through a mechanical system. Although the primary goal was to create a functional concept, there are several possibilities for improvement, both mechanically and functionally.

One of the first directions for development is automation. Currently, the movement is manually generated, but by integrating servo motors controlled via microcontrollers (such as Arduino), it could evolve into a fully automated version capable of repeatedly writing the same characters or reproducing digitized text [10], [11]. Such an extension could transform the mechanism into an educational tool or a demonstrative device for museums or exhibitions.

Another interesting aspect is the possibility of mechanism replication. In other words, if multiple identical units are connected to the same motion source, they could write the same content simultaneously. This could be useful in areas such as signature duplication or simultaneous personalization of multiple products (e.g., for advertising purposes) [12]. From a construction standpoint, future prototypes could use more durable materials or manufacturing methods with higher precision. For example, technologies like SLA (stereolithography) or SLS (selective laser sintering) would allow the production of components with much finer clearances and tolerances, thereby increasing the reliability of the entire assembly [13], [14].



Fig. 10. Physical mechanism assembly

Furthermore, the tolerance test results obtained in this version are valuable for the further calibration of articulated parts. Identifying the optimal clearances for free or controlled movement provides a solid foundation for the next steps in the mechanism's development [15].

8 Conclusions

This paper presented a method to develop a functional device capable of reproducing handwriting using available 3D printing technology and CAD software. Tolerance testing and

subsequent adjustments led to increasingly smooth and precise movement, yielding encouraging results.

It should also be noted that multiple writing heads can be added simultaneously, allowing writing on the desired surface multiple times while the mechanism is mounted only once, without manual handling.

For future implementation, the system could be enhanced by integrating it with an automated control system, such as one based on a microcontroller, to enable tracking of predefined texts. Moreover, this solution is versatile, as it could also serve practical purposes in medical and psychological research for analyzing fine hand movements.

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THE ANALYSIS OF A RACE CAR SUSPENSION MECHANISM

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ABSTRACT: The suspension system represents a series of linkages, shock absorbers and other components that have two main roles: attaching the wheel to the chassis of the car and to assure that the car behaves well during different manoeuvres. By altering the different angles of a suspension assembly, the response of the car can vary drastically, and needs to be designed according to the dimensions and scope of the car and properties of the tires. The main objective of the paper is the design and analysis of a high-performance suspension mechanism capable of ensuring optimal tire contact with the ground, increased stability, superior handling, and adjustability according to competition requirements.

KEYWORDS: mechanisms, suspension, automotive, formula student, kinematic analysis.

1. Introduction

Formula Student is an international competition dedicated to university students, aiming to develop and manufacture a race car within a one-year timeframe. Participation offers numerous benefits, such as the improvement of engineering skills and teamwork. The project analysed focuses on the development of the suspension system for a single-seater race car.

Camber is the angle between the vertical axis of the wheel and the vertical axis of the vehicle when viewed from the front. Negative camber (wheel top tilted inward) enhances lateral grip during cornering by maximizing tire contact during body roll. However, too much negative camber reduces braking efficiency and causes uneven tire wear.

Toe describes the angle at which the front of the wheels points inward (toe-in) or outward (toe-out) when viewed from above. Toe-in improves straight-line stability, especially at high speeds. Toe-out enhances corner entry response, making the car more agile. Race cars typically use small toe-out values for better responsiveness.

Scrub radius is the lateral distance on the ground between the point where the steering axis intersects the ground and the centre of the tire contact patch. A smaller or slightly negative scrub radius is favoured in racing for minimizing torque steer, braking instability, and steering kickback, especially in high-load conditions.

Mechanical trail is the longitudinal distance between the point where the steering axis intersects the ground and the tire contact patch centre. A larger mechanical trail enhances steering stability and self-centring but may increase steering effort. An optimal value provides responsive yet stable steering feel.

Caster is the angle between the steering axis and the vertical axis of the wheel when viewed from the side. Positive caster causes the contact patch to trail behind the steering axis, contributing to self-centring and improving high-speed stability. It also generates camber gain during steering, increasing grip in corners. Excessive caster can increase steering effort, especially in manual systems.

King Pin Inclination (KPI), also known as steering axis inclination, is the inward tilt of the steering axis when viewed from the front. A higher KPI reduces the scrub radius and helps lift the vehicle slightly during steering, contributing to a self-centring effect. However,

too much KPI can reduce feedback and increase suspension friction. Combined with caster, it determines steering feel and return characteristics [1].

2. State of the art

The suspension system plays a critical role in the dynamic performance and safety of a race car. In the early design phase, two major types of front suspension systems were evaluated: **McPherson strut** and **Double Wishbone**.

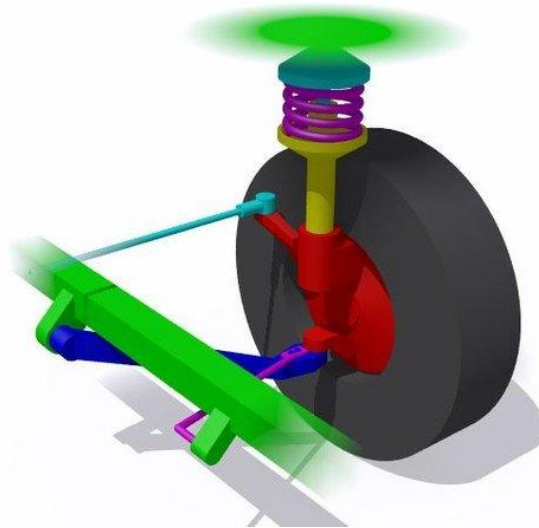


Fig. 1. McPherson suspension [2]

McPherson Suspension is a widely used independent suspension system, especially in commercial vehicles due to its simplicity, compact design, and cost-effectiveness. It consists of a single control arm and a strut assembly that integrates the shock absorber and coil spring. Although easy to design and manufacture, the McPherson system has limitations in performance applications. Its major drawbacks are:

- Limited control over camber angle during suspension travel.
- Increased lateral load on the strut, potentially reducing durability.
- Less flexibility in fine-tuning geometry for racing needs [3].

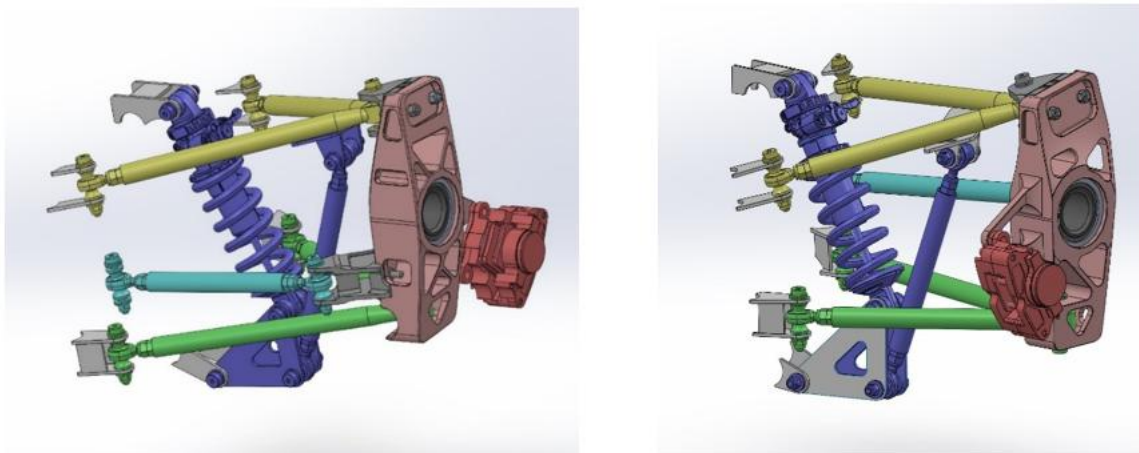


Fig. 2. Double wishbone suspension front (left) and rear (right)

Double Wishbone Suspension also known as an A-arm suspension, this system uses two control arms (upper and lower) to connect the wheel hub to the chassis. It offers significantly better control of wheel alignment parameters during suspension movement. The main advantages include:

- Precise adjustment of camber, caster, and toe angles.
- Enhanced handling and stability during high-speed cornering.
- Greater adaptability to different track conditions and driver preferences.

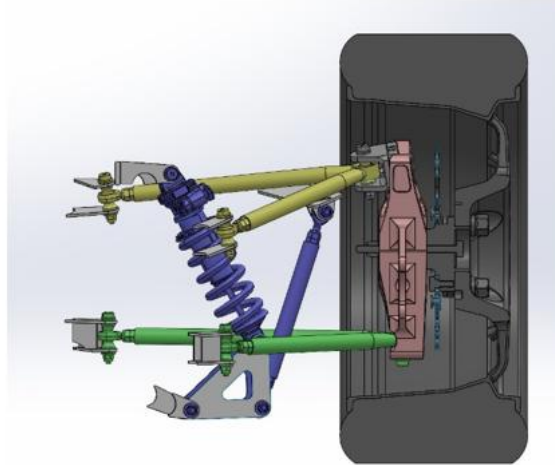


Fig. 3. Front view of rear suspension

Given the demanding performance requirements of Formula Student competitions - where cornering stability, tire grip, and geometry optimization are critical, the **Double Wishbone configuration** was selected. It allows for:

- Consistent tire contact with the road surface throughout the wheel travel.
- A lower centre of gravity by placing components more compactly within the chassis.
- More predictable and responsive handling, which is essential for competitive racing.

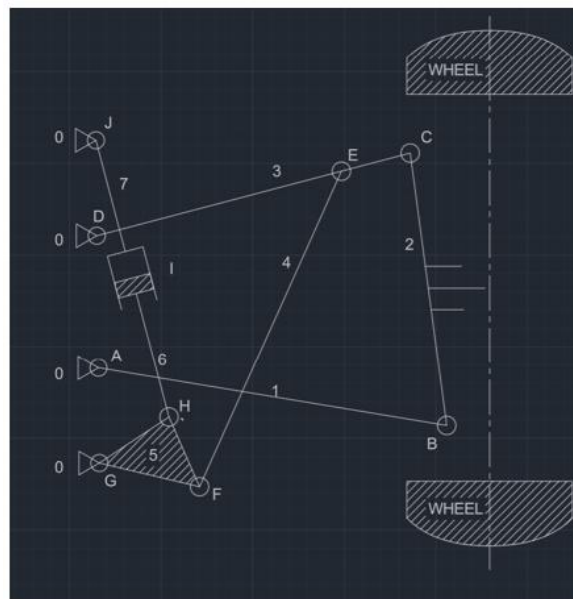


Fig. 4. Kinematic diagram

In addition to the choice of suspension type, the damping mechanism selected was a **Pull Rod system**, featuring a rocker arm and linkage connected to the upper control arm. This layout provides advantages in packaging, weight distribution, and suspension tuning.

3. Structural analysis

During and after the development of the suspension system, we have used two methodologies for analysing the kinematic behaviour of its components during its designed motion range.

3.1. Hand Calculations and In-House Software

For understanding the behaviour of the mechanism, a kinematic analysis was performed using a free body diagram representing the Front View of the suspension on one wheel, containing both the wishbones and the Pull-Rod damper actuation mechanism [3]. To allow the simplification of the mechanism to two dimensions, the toe angle variation was considered zero (approximated from 0.204 degrees), and the toe link was removed.

The chassis mounting points were considered fixed and the A couple was considered the motor. The mechanism is comprised of 7 elements and 10 inferior kinematic couples (of which 9 rotational and one translational). For the number of loops, we have used Eq. (1) and has resulted a number of 3 loops. After applying Eq. (2) a number of one motor coupling was calculated.

Mobility is calculated with the formula:

$$M = 3 \times m + 2 \times c_i + c_s \quad (1)$$

Number of closed loops is calculated with the formula:

$$N = c_i + c_s - m + 1 \quad (2)$$

In the equation above c_i is the lower pairs, c_s the number of higher pairs, N the number of closed loops, M the number of motor pairs and m the number of mobile elements.

To create structural diagram, the type of elements and the couples connected to them were analysed in Table 1.

Table 1 Kinematic elements

Element No.	Kinematic couples	Type
0	A, D, G, J	Chassis
1	A, B	Rocker
2	B, C	Con Rod
3	E, C, D	Rocker
4	E, F	Con Rod
5	F, G, H	Rocker
6	H, I	Con Rod
7	I, J	Rocker

The structural diagram (fig. 5) allowed the identification of three dyads (D1 – RRR (B, C, D), D2 – RRR (E, F, G), D3 – RTR (H, I, J)) [4].

The three dyads from the Structural diagram represent the key mechanisms of the suspension assembly. D1 is comprised of the lower wishbone, the upright and the upper wishbone. D2 represents the half of the actuation system connected to the wheel – pull rod and rocker, and D3 is made up from the rocker and the damper assembly.

Table 2 Dyads

Dyad Number	Type	Pairs
D1	RRR	B, C, D
D2	RRR	E, F, G
D3	RTR	H, I, J

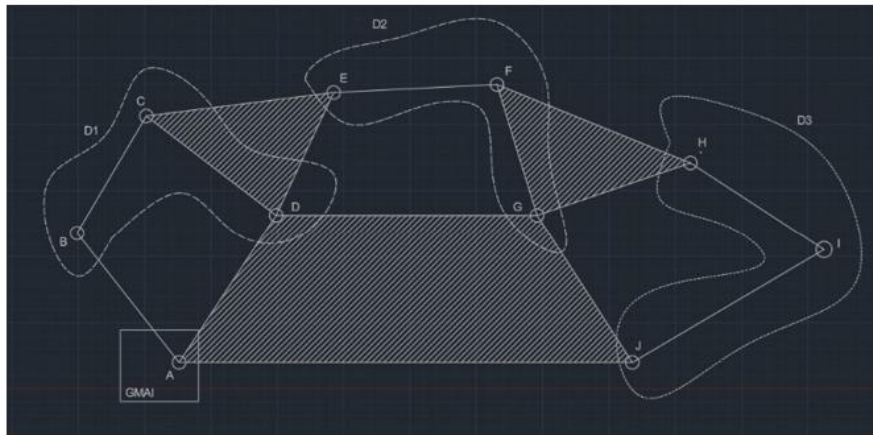


Fig. 5. Structural diagram

The connection diagram is presented in fig. 6:

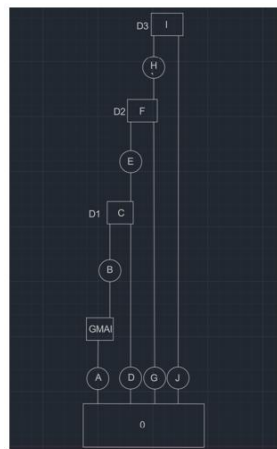


Fig. 6. Connection diagram

To calculate variation of the chamber angle during travel, a MATLAB program was developed, that provides visual representation of the kinematic behaviour of D1, displaying the initial and final position of the members and a plot of the camber angle values along the travel distance. The program can be found in GitHub repository [4].

In Fig. 7 is presented the suspension travel prompt and in Fig. 8 the numerical output.

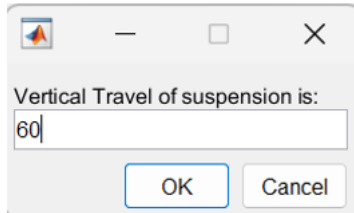


Fig. 7. Suspension travel prompt

```
Camber gain during travel: -3.0023 [deg]
lower angle gain during travel: 10.5031 [deg]
upper angle gain during travel: 11.5772 [deg]
```

Fig. 8. Numerical output

In Fig. 10 is presented the position of suspension arms and chamber variation during travel.

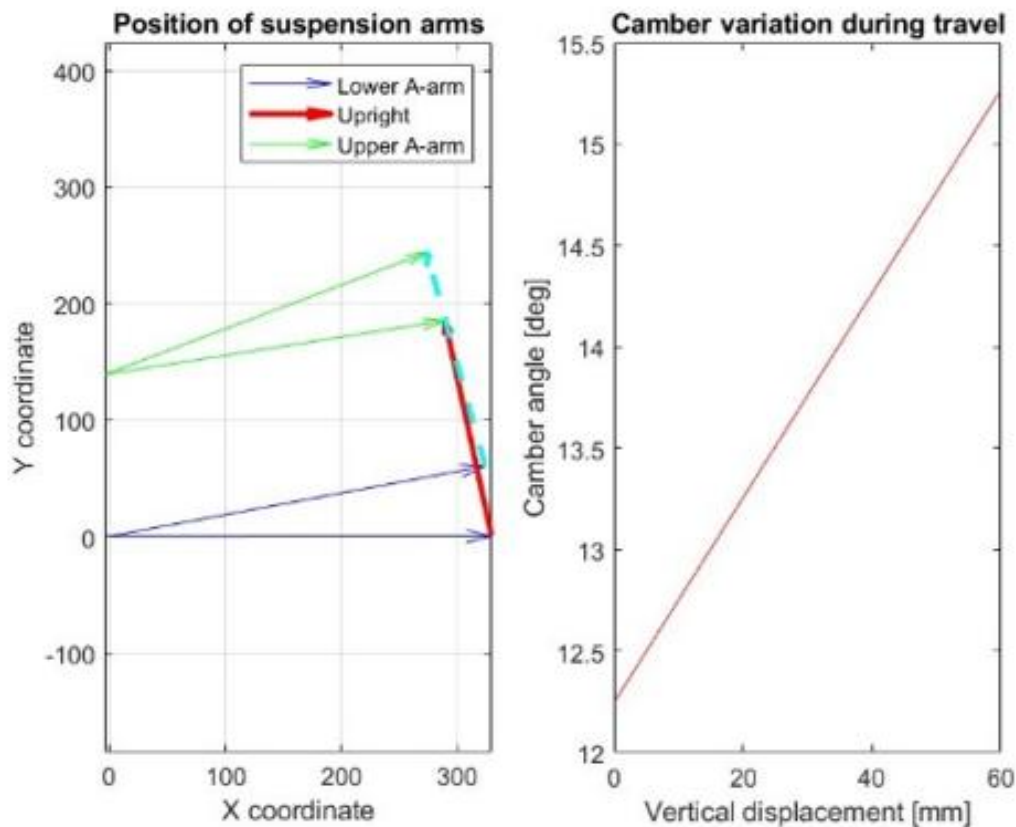


Fig. 9. Resulting graph

3.2. COTS kinematic analysis software

In order to furthermore observe the kinematic behavior in more complex real-life conditions, we gained access to a 2-week free trial version of a well-known software tool named Optimum kinematics. In this tool we can upload our suspension and select what type of motion we want to simulate (heave, roll, pitch). After a simulation is run, we can extract all the data we need in order to evaluate the suspension.

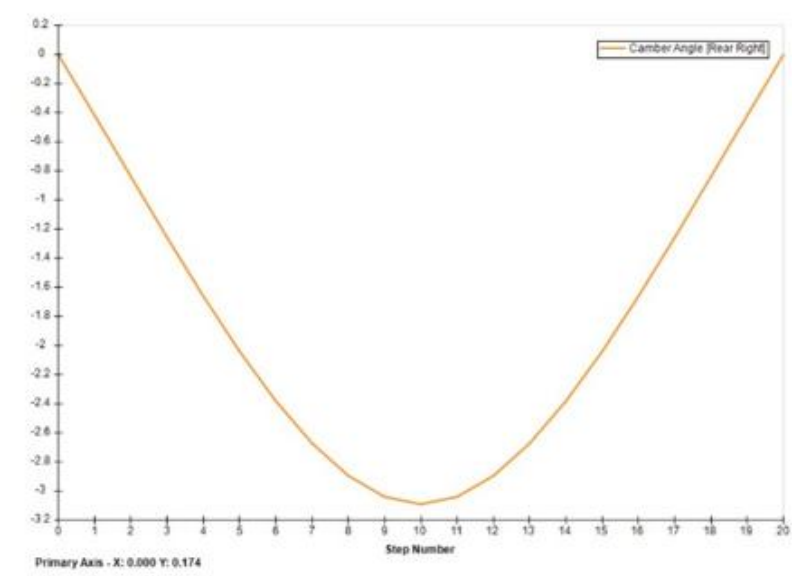


Fig. 10. Chamber gain

Using the graph from Fig. 13 we managed to:

- Ensure that the negative camber increases during a corner, to assure that the tire works at optimal slip angles.
- Keep the change of the toe as small as possible during the full range of motion to increase the predictability and stability of the car.

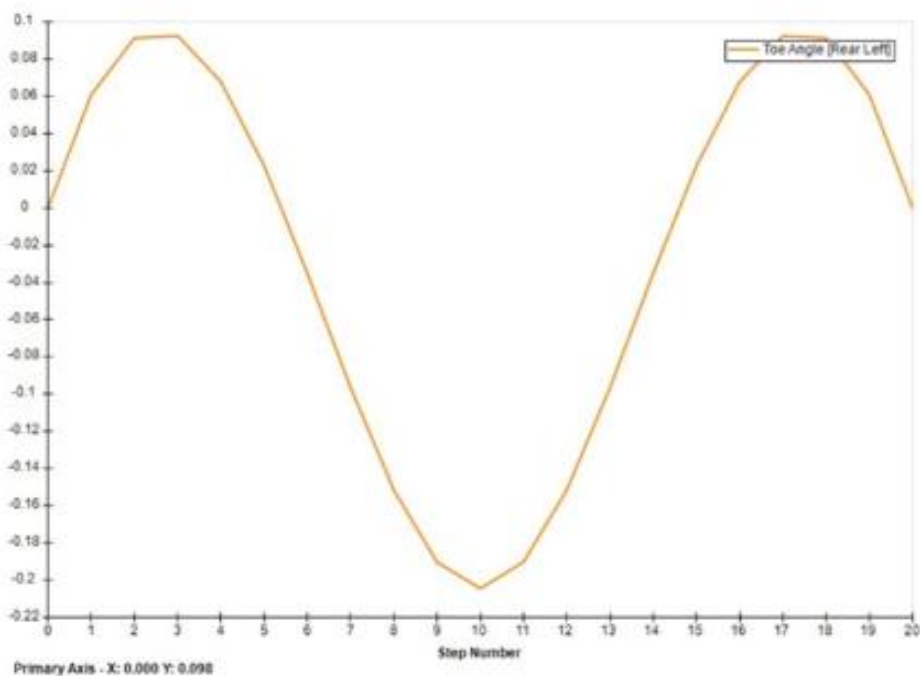


Fig. 11. Toe gain

In Fig. 12 are presented the values from the graphs obtained for Toe Angle and Chamber Angle.

	Toe Angle [Rear Left] (deg)	Camber Angle [Rear Left] (deg)
Start Value	0.000	0.000
End Value	0.000	0.000
Max Absolute Value	0.204	3.090
Variance Value	0.011	1.059
Std Deviation Value	0.103	1.029
Step [0]	0.000	0.000
Step [1]	0.061	-0.416
Step [2]	0.091	-0.838
Step [3]	0.092	-1.256
Step [4]	0.068	-1.660
Step [5]	0.023	-2.040
Step [6]	-0.035	-2.381
Step [7]	-0.096	-2.671
Step [8]	-0.151	-2.895
Step [9]	-0.190	-3.039
Step [10]	-0.204	-3.090
Step [11]	-0.190	-3.039
Step [12]	-0.151	-2.895
Step [13]	-0.096	-2.671
Step [14]	-0.035	-2.381
Step [15]	0.023	-2.040
Step [16]	0.068	-1.660
Step [17]	0.092	-1.256
Step [18]	0.091	-0.838
Step [19]	0.061	-0.416
Step [20]	0.000	0.000

Fig. 12. Value from the graphs

4. Conclusion

For race cars, the suspension needs to be designed to allow the car to be driven at the limit of tire grip and allow adjustability for different track conditions. While the car is being driven, it experiences lots of different accelerations and forces, those that are in the horizontal plane come from the tires. For this reason, the specific tire that the car is using needs to be the point around the whole suspension is being designed. This being why we have set specific goals for all the important angles mentioned above. By performing this mechanism analysis, we have gained a clearer understanding of the behavior of the system that we have designed, allowing us to create better iterations that are being closer to target values.

Thanks to the two methods of testing the suspensions behaviour during the design process, we were able to ensure that we respected the parameters we set at the beginning of the design process, solving issues that the previous iteration of the suspension had.

By using the methods presented above, the speed with which we have optimized the geometry of the mechanism, especially for the variation of the toe angle, increased dramatically. It has also offered us a method to verify that the data that we extracted from one piece of software is accurate and thus ensures that the real-world implementation of the computer model will behave as planned.

For the design of future versions for the suspension mechanism of such vehicles, this study can serve as a guideline to better visualize, understand and optimize suspension kinematics

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- [5]. Fig. 1 By User Casito on en.wikipedia - Created by Casito. He releases the drawing to GDFL. POV-Ray source is available upon request, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=173790>

Special Thanks to: UPB Drive Formula Student Team

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ROBOTIC ARM ORTHOSIS

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Summary: Technological advancements in recent decades have enabled the rapid development of robotic orthoses, applied in fields such as medical rehabilitation, assistive devices, and neuromuscular therapy. This research focuses on designing a robotic orthosis for individuals with Parkinson's disease, aiming to compensate for tremor and improve motor function. The approach involves computer-aided design (CAD), additive manufacturing (3D printing), and experimental testing to develop a customizable, responsive device that adapts to patient-specific needs and provides real-time movement correction.

KEY WORDS: *robotic arm, 3D printing, 3D design.*

1. Introduction

In recent decades, technological progress has enabled the development of smart orthoses dedicated to individuals with Parkinson's disease, aiming to reduce pathological tremor and improve fine motor functions. These integrated devices combine inertial sensors, real-time control algorithms, and precision actuators to stabilize affected joints and restore controlled movements.

This research focuses on the design and development of a smart orthosis, optimized both mechanically (through a lightweight structure produced by 3D printing) and functionally (by integrating an active tremor compensation system). The development process includes computer simulations, rapid prototyping, and experimental testing in controlled conditions to precisely calibrate the system's response to the patient's movements.

By analyzing the prototype's performance, the research aims to identify the most effective solutions for tremor attenuation, maximizing user comfort and minimizing energy consumption. The results contribute to the advancement of assistive technologies and to increasing the autonomy of individuals affected by Parkinson's disease.

2. Current state of the art

The evolution of smart orthoses for patients with Parkinson's disease has seen significant advances over the past two decades, driven by progress in biomechanics, robotics, biomedical sensors, and advanced control algorithms. Initially, orthoses were simple passive devices designed solely to stabilize joints, but today, active solutions are being developed that can detect pathological tremor and apply compensatory forces in real time.

Notable examples include the GyroGlove [1], a smart glove equipped with miniature gyroscopes that generate mechanical resistance to stabilize hand movements affected by tremor. Another example is Liftware Steady [2], a smart utensil developed by Verily (part of Alphabet/Google), which reduces tremor during eating through micro actuators and adaptive control systems. Experimental devices, such as orthoses based on soft exoskeletons (soft exosuits) developed in research laboratories like the Harvard Wyss Institute, utilize flexible materials and embedded sensors to provide support and stabilization without compromising patient comfort.

In parallel, the use of technologies such as 3D printing allows for customization of devices based on the patient's morphology, reducing both costs and production time. The integration of artificial intelligence (AI) and deep neural networks enables algorithms to learn from each patient's movement patterns, automatically optimizing the orthosis's response.

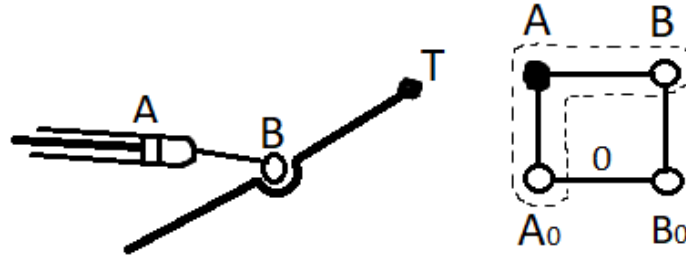


Fig. 1. Structural diagram of the mechanism

As research progresses, smart orthoses are becoming more compact, energy-efficient, and capable of wireless connectivity for remote monitoring, paving the way for integrated solutions in neurological rehabilitation and real-time personalized intervention.

3. The steps used

The design and development of the robotic orthosis involved a series of specific steps and techniques, as detailed below.

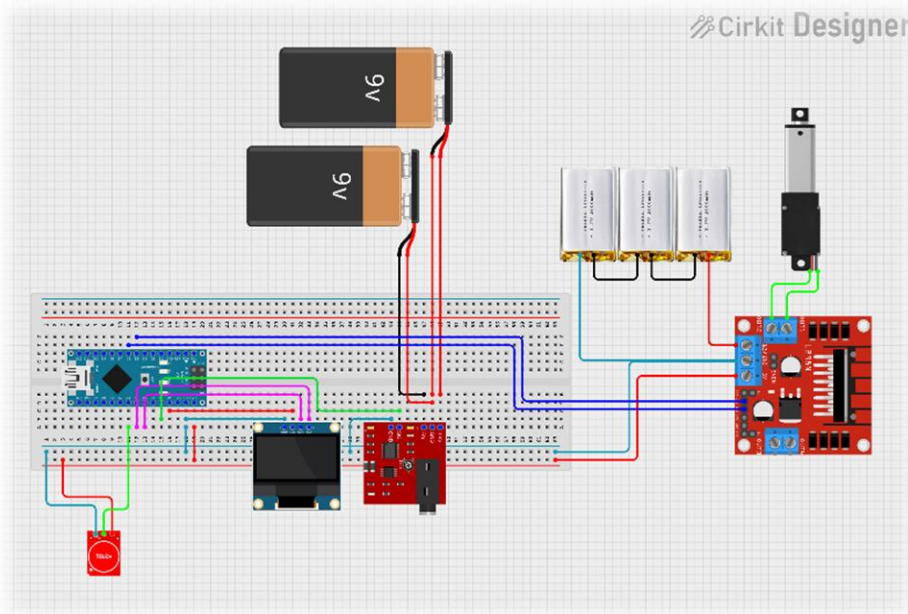


Fig. 2. Circuit of the arm part

Step 1: Preliminary research was conducted to identify various models of robotic rehabilitation that could be reliable for the intended purpose.

Step 2: Identification and acquisition of the necessary hardware components:

- EMG sensor module
- Arduino Nano R3
- Dupont wires

- Breadboard
- OLED 0.96" Display
- Motor Driver L298N
- Two 9V batteries

Step 3: Based on the mechanism structure (see fig.1), detailed virtual models of the orthosis and the display casing were created using Blender software, considering the dimensions of the hardware components to ensure seamless integration into the final model. The design process included multiple iterations to achieve the final shape.

Step 4: Using the Arduino IDE software, the orthosis and the OLED display were programmed.

```
// Monitorizare prag
if (voltage > thresholdVoltage) {
  belowTriggerTime = 0;
  if (!aboveActive) {
    if (aboveTriggerTime == 0) aboveTriggerTime = now;
    if (now - aboveTriggerTime >= confirmDuration) {
      aboveActive = true;
      belowActive = false;
      startFadeIn(fadeAbove);
      stopPinImmediately(fadeBelow.pin);
    }
  }
}

else {
  aboveTriggerTime = 0;
  if (!belowActive) {
    if (belowTriggerTime == 0) belowTriggerTime = now;
    if (now - belowTriggerTime >= confirmDuration) {
      belowActive = true;
      aboveActive = false;
      startFadeIn(fadeBelow);
      stopPinImmediately(fadeAbove.pin);
    }
  }
}
```

Fig. 3. Motor activation

Step 5: The circuit shown in (fig. 2), along with the code, was used to create smooth motion of the electric motor. The values read from the sensor were mapped and converted into a range from 0 to 1023, which adjusts the motor's position accordingly (fig. 3).

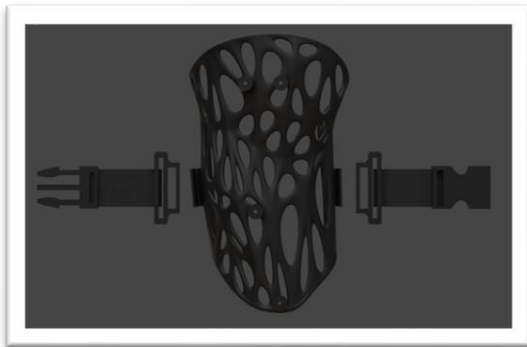


Fig. 4. Rigid mounting module for the arm



Fig. 5. Rigid mounting module for the forearm

Step 6: The values read from the sensors were assigned, if the value exceeds the set threshold, the motor either extends or retracts.

Step 7: After completing the design phase, a physical prototype was produced using modern manufacturing techniques, such as 3D printing (using black PLA).

Step 8: The resulting prototype was subjected to tests to evaluate the functionality of the arm. This integrated approach, combining computer-aided design with additive manufacturing techniques, enabled the rapid creation of an orthosis.

4. Results

The following components were designed and developed as part of the robotic orthosis: rigid mounting module for the arm (fig. 4), rigid mounting module for the forearm (fig. 5), skeleton ensuring correct relative motion of the two modules (fig. 6).



Fig. 6. Skeleton Ensuring Correct Relative Motion of the Two Modules Fig. 7. Prototype or robotic orthosis

After 3D printing and assembly, the result is presented in Fig. 7 where the robotic orthosis can be seen.

The utility of the arm was demonstrated through the tests conducted and it can be used in the future in various contexts, such as educational purposes, technological activities, etc.

5. Conclusions

This analysis highlights the feasibility of using modern technologies, including 3D printing, in the production of smart orthoses for individuals with Parkinson's disease.

This orthosis can be manufactured in customized sizes, adapted to the individual patient's morphology, and can be equipped with various types of sensors and actuators, depending on specific clinical requirements.

Additionally, it is compatible with the integration of advanced control systems, allowing for real-time tremor compensation with increased precision, including fine control of movements or adaptive adjustments, with extremely short reaction times.

6. References

[1] <https://gyrogear.co/>

[2] <https://www.michaeljfox.org/news/apply-free-liftware-stabilizing-spoon?>

ANALYSIS OF ANIMAL LOCOMOTION: BETWEEN FUNCTIONALITY, STRUCTURE AND AESTHETICS

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ABSTRACT: The problem analyzed in this paper, namely the structural analysis and modelling of a mechanism with rods, analysis of animal locomotion: between functionality, structure, and aesthetics, presents a wide range of studies, from the most basic ones, such as structural, kinematic, and kinetostatic analysis, to geometric-kinematic analysis and sizing of rod mechanisms. Additionally, rod mechanisms are found in the mechanisms used for moving windows in the side doors of vehicles, in mechanically operated windshield wiper mechanisms, in crane mechanisms for various lifting or lowering tasks, in industrial robot mechanisms for object manipulation etc., thus having a wide range of applications.

KEYWORDS: mechanism, connecting rod, crank, rocker.

1. Introduction

The linkage mechanism studied in this paper is a mechanism designed to transform rotational motion (generated by the crank) into translational motion (of the slider within the frame). Due to its simple operating principle, it has a wide range of technical applications and belongs to the category of mechanisms with the most diverse areas of use. The objective pursued in this work is to perform the structural analysis of the selected linkage mechanism and to physically build the mechanism. This objective will be achieved by designing the kinematic diagram of the planar mechanism, identifying its kinematic elements and pairs, and developing both the structural and connection diagrams of the mechanism. Therefore, these goals will be gradually pursued and accomplished throughout the paper.

2. Current stage

At the current stage of research, linkage mechanisms are being studied in a wide variety of contexts, ranging from basic structural and kinematic analyses to applications in vehicle mechanisms, windshield wipers, cranes, industrial robots, and more. They are valued for their simplicity and have a broad range of applications, including in vehicles, industrial equipment, and robotics. This paper begins by presenting the mechanism and the objectives of the study. It then proceeds with the structural analysis of the mechanism, introducing its kinematic diagram and detailing its components and kinematic pairs. The number of independent loops and the degree of mobility are calculated in order to gain a deeper understanding of the mechanism.

3. Structural analysis

The linkage mechanism selected for this study belongs to the category of planar mechanisms and consists of kinematic elements connected through kinematic pairs. To begin the structural analysis of this planar mechanism (see Fig. 1), it is first necessary to present its kinematic diagram (Fig. 2) [1].

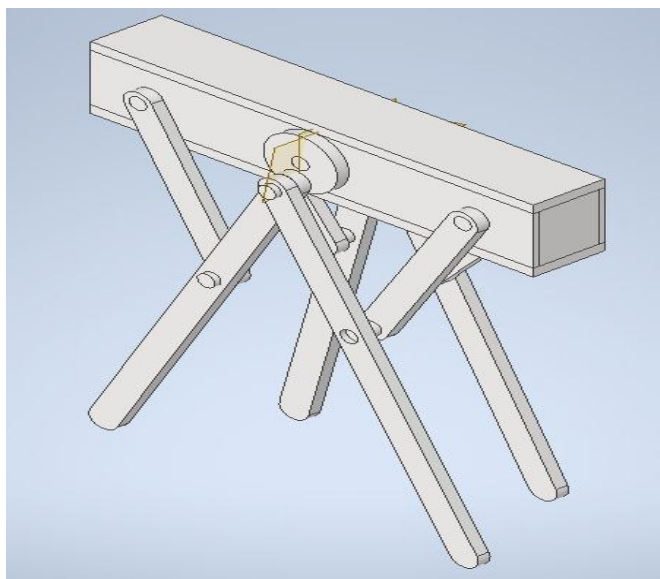


Fig. 1. The 3D mechanism

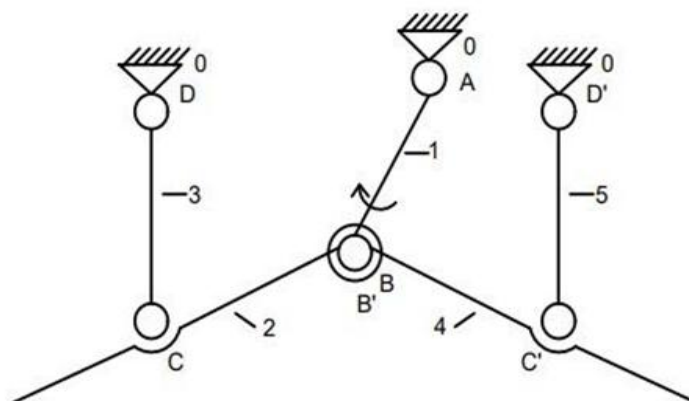


Fig. 2. The kinematic diagram of the mechanism

0 - fixed element, 1 - crank, 2 and 4 - connecting rod, 3 and 5 – rocker

The number of independent loops is:

$$\begin{aligned} N &= i + s - m \\ N &= 7 + 0 - 5 \\ N &= 2 \end{aligned} \quad (1)$$

The mechanism is composed of:

- five moving kinematic elements ($m = 5$) and three fixed kinematic elements, labeled with the number 0;
- seven lower kinematic pairs (revolute joints), labeled with letters (A, B, B', C, C', D, D') – $i = 7$, $s = 0$.

The degree of mobility of the mechanism:

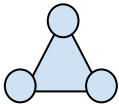
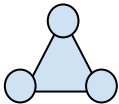
$$\begin{aligned} M &= 3 \times m - 2 \times i - s \\ M &= 3 \times 5 - 2 \times 7 - 0 \\ M &= 1 \end{aligned} \quad (2)$$

$$n = m - 1 \quad (3)$$

Tabel 1. Kinematic Pairs

Kinematic couple	Movement made	Notation	The linkage between kinematic elements	Couple's class
A	rotation	A(0,1)	fixed element 0 and crank 1	V
B	rotation	B(1,2)	crank 1 and connecting rod 2	V
B'	rotation	B'(2,4)	connecting rod 2 and connecting rod 4	V
C	rotation	C(2,3)	connecting rod 2 and rocker 3	V
D	rotation	D(0,3)	fixed element 0 and rocker 3	V
C'	rotation	C'(4,5)	connecting rod 4 and rocker 5	V
D'	rotation	D'(0,5)	fixed element 0 and rocker 5	V

Tabel 2. Elements

The number of kinematic elements	The couplings belonging to the kinematic element	The name of the element	Representation
0	A, D, D'	ternary	
1	A, B	binary	
2	B, B', C	ternary	
3	C, D	binary	
4	B', C'	binary	
5	C', D'	binary	

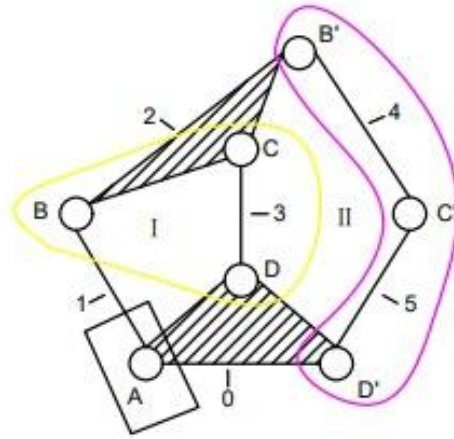


Fig 3. Structural diagram

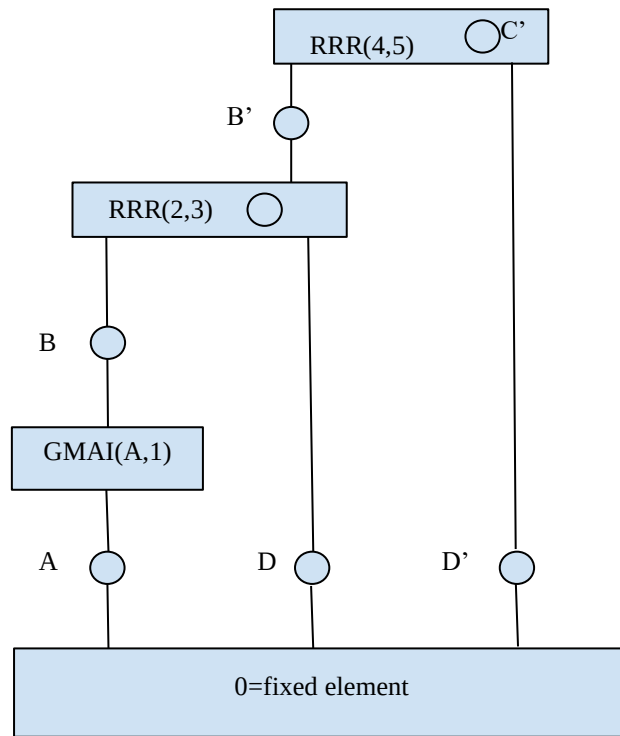


Fig 4. Connection diagram

4. Assembly of the mechanism

Materials used: Parts made through 3D printing from PLA, soldering gun, cutter, plastic gearmotor, batteries, battery holder, male-to-male wires, on/off switch, nails, lighter, soldering hammer [5].

The construction of the Locobot prototype began with dimensioning the main body, designed to support the plastic gearmotor. The body measured 15 x 2 cm, with a thickness of 0.2 cm. Subsequently, the body structure was assembled, and four lateral supports were added, serving as axles for attaching the leg supports (see Fig. 5) [2].



Fig. 5. Components

On one side of the body, a sidewall was mounted, on which the differential was fixed. This element is essential for generating step-like motion. The legs were mounted on the differential's axle and connected to the main leg supports that perform the actual movement [3].

For optimal operation, the differential was positioned at two distinct angles: 0° and 180° . After completing these steps for both sides of the Locobot, the connection between the motor, switch, and battery holder was made, allowing electrical power and automated motion control. The final configuration of the assembled mechanism is shown in Fig. 6.

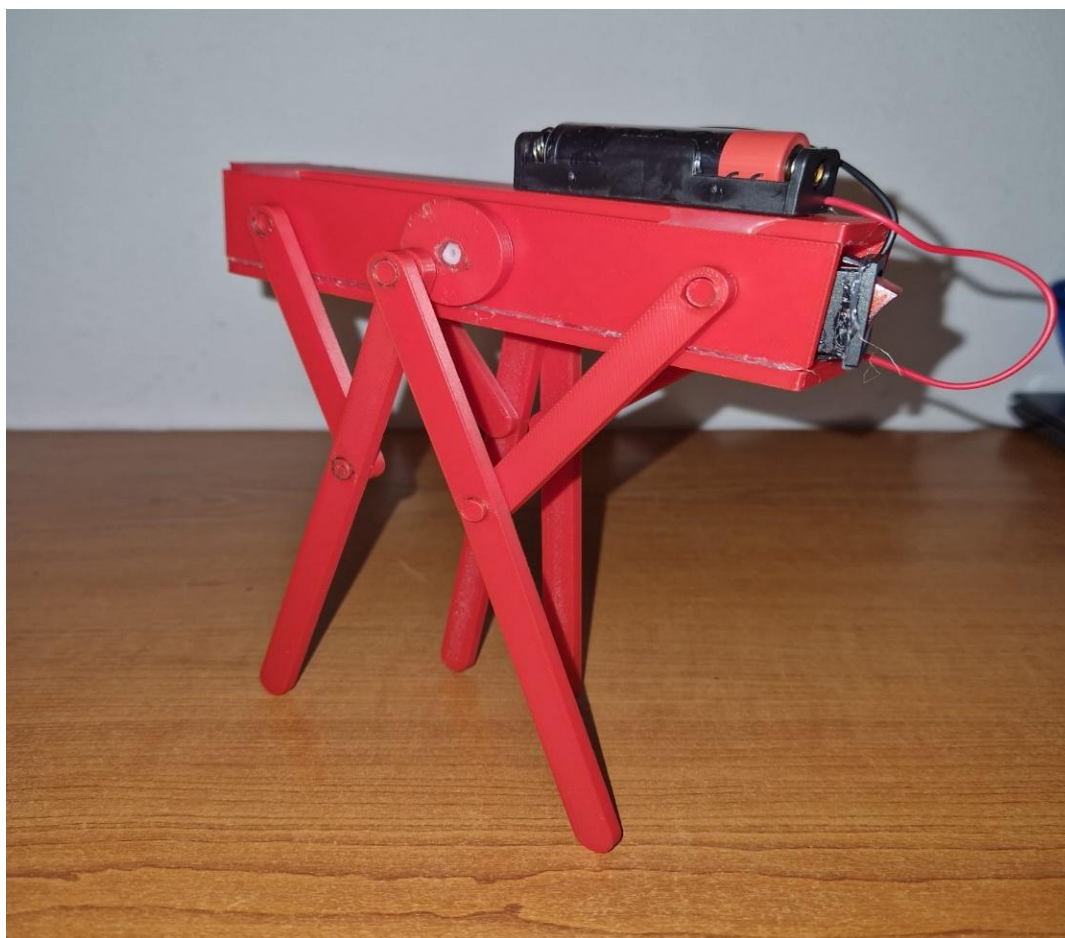


Fig 6. Final mechanism

5. Conclusions

In conclusion, the paper thoroughly addressed the bar mechanism, highlighting its importance and applicability in various technical fields. Through the structural analysis and modeling of this mechanism, new perspectives were opened for understanding its operation and optimizing its use in different practical applications.

Additionally, the paper emphasized the diversity of bar mechanisms' uses, from simple applications in automobiles to advanced uses in industrial robots. Thus, the paper contributes to the knowledge and development of this type of mechanism, opening new directions for research and innovation in the field of mechanical engineering.

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7. Notations

The following notations are used throughout the paper:

GMAI = active modular group;
RRR = rotation-rotation-rotation;
 i = the number of lower couplings;
 s = the number of upper couplings;
 M = the degree of mobility of the mechanism;
 m = the number of mobile cinematic elements;
 n = the total number of elements.

MANAGEMENT OF COMMUNICATION BETWEEN THE DESIGN DEPARTMENT AND THE PRODUCTION DEPARTMENT

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ABSTRACT: Managing communication between the design and manufacturing departments is critical to ensuring effective collaboration and project success. This involves harmonizing the designers' creative vision, focused on innovation and technical detail, with the pragmatic goals of manufacturing, which prioritize feasibility and efficiency. A critical factor in this relationship is the clarity of the information conveyed, as differences in technical language or ambiguities can lead to errors and delays. Also, the lack of clear communication channels or well-defined processes can lead to conflicts and wasted time. In this context, collaboration can be improved by creating a common framework of understanding, using digital tools to monitor projects and organizing regular meetings between teams. By establishing common goals and maintaining transparent communication, the two departments can work synergistically, reducing risk and ensuring the delivery of a quality end product.

KEYWORDS: communication, improvement, departments.

1. Introduction

Effective communication between design and production is essential to the success of any organization that produces semi-finished products or services for customers. This communication ensures that products are made according to customer specifications, meeting quality standards and delivery deadlines.

1.1. The Importance of Effective Communication Within the Company:

- **Error Reduction:** Clear communication helps prevent misunderstandings that can lead to production errors.
- **Efficiency Improvement:** Accurate and timely information can speed up production processes and reduce delays.
- **Innovation and Feedback:** Collaboration between the two departments can generate new ideas and innovative solutions.

2. Communication Channels

2.1. Regular Meetings

Regular meetings between the design and production teams are crucial to maintaining smooth communication. These can be organized:

- **Weekly or monthly** depending on the scope of the project: to discuss progress, challenges encountered and future plans.
- **Kick-off meetings:** at the beginning of each project, to set clear objectives and align stakeholder expectations.
- **Evaluation meetings:** at the end of a project, to analyze lessons learned and propose improvements for future collaborations.

2.2. Digital platforms

Using effective digital platforms (Microsoft Teams, Outlook) can improve communication and collaboration. These platforms allow:

- **Instant messaging:** facilitating rapid communication and clarification of concerns in real time. For each ongoing project, a representative from each department is designated to respond to all concerns that arise along the way.
- **Document sharing:** teams can upload and access relevant documentation, ensuring that both departments have access to the latest information. Teams will work in SharePoint so that all information is updated on time, thus eliminating mistakes such as missing documentation.

- Project management: using tools such as Jira and Bitbucket to track the progress of tasks and assign responsibilities. On these platforms, tasks will be assigned to people and the hours worked for each project will be recorded.

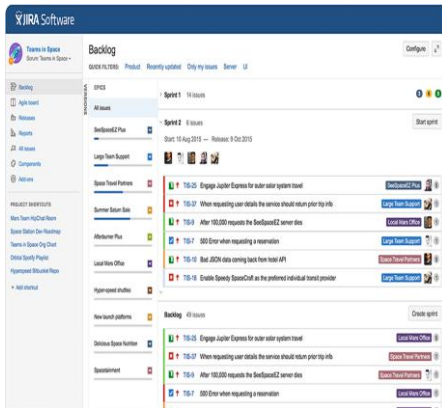


Figure 1. Ex. JIRA interface.

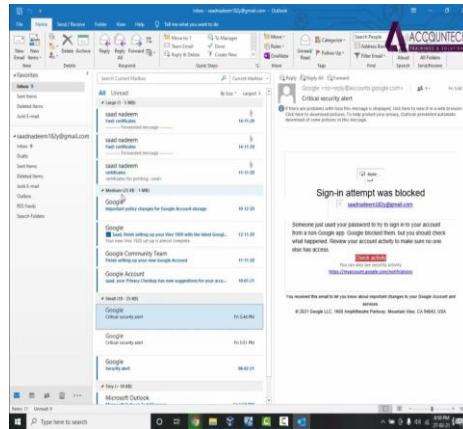


Figure 2. Ex. Microsoft Outlook interface

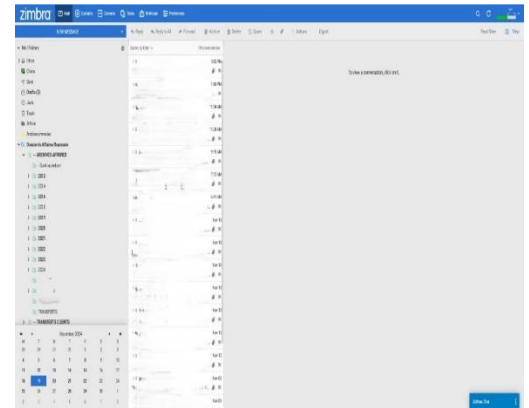


Figure 3. Ex. Zimbra interface

2.3. Clear Documentation

Well-structured documentation is essential to avoid confusion and ensure transparency. This should include:

- Technical specifications: precise details about the materials, dimensions and tolerances of product parts.
- Procedure manuals: standard steps for production processes, including clear instructions for operating equipment.
- Progress reports: updates on the status of the project and any changes or adjustments needed.
- Quality plans

3. The communication process

3.1. Defining responsibilities

Clarifying roles is essential to avoid overlaps and confusion. This can include:

- Dedicated working groups: forming mixed teams from both departments to deal with specific projects.
- Clearly defining points of contact: establishing liaisons to facilitate communication between departments.

3.2. Continuous Feedback

Feedback is a key element in the communication process. It is important to establish:

- Formal feedback mechanisms: scheduled feedback sessions, in which teams can discuss problems encountered and proposed solutions.
- Performance evaluation systems: periodic evaluations of collaboration between departments to identify areas for improvement.

Checklist for reducing interdepartmental communication errors

1. Clear and Complete Documentation

- Clear and complete technical specifications: Ensure that all part specifications (dimensions, tolerances, materials) are documented and referenced to applicable standards.
- Updated technical drawings: Verify that all drawings and sketches are in their final version, signed and approved by the design department.
- Detailed data sheets: Provide data sheets with information about each part, specifying process requirements and casting parameters (temperature, casting speed, cooling time, etc.).

2. Review and Validation Procedures

- ☐ Design Review Meetings: Set up regular meetings between design and manufacturing to discuss details and answer questions before production begins.
- ☐ Feasibility Check: Ensure that manufacturing reviews drawings and specifications to identify potential production issues and discuss them with designers.
- ☐ Simulations and Prototypes: Consider conducting simulations or prototypes before final production to detect problems and optimize the casting process.

3. Production Process:

- ☐ Is the production plan detailed and includes all necessary operations?
- ☐ Are the necessary resources (materials, equipment, personnel) allocated?
- Measuring Instruments:
 - ☐ Are the measuring instruments calibrated and in accordance with specifications?
 - ☐ Are regular checks of the instruments performed?
- Quality Control:
 - ☐ Is there a detailed quality control plan?
 - ☐ Are inspections performed at all stages of the production process?
- Feedback:
 - ☐ Is there a closed feedback system to identify and resolve problems?
 - ☐ Are the root causes of errors analyzed?

4. Effective Change Communication

- Clear change management procedures: Implement a change tracking system for design documentation, with automatic notifications to the production department.
- Rapid feedback on changes: Encourage the production department to provide prompt feedback on changes that may affect manufacturing capacity or product quality.
- Controlled document versions: Use a document management system (DMS) that ensures access to only the current version of drawings and specifications.

5. Training and Instruction

- Train employees in reading and interpreting technical drawings: Ensure that all production operators understand the symbols and specifications on technical drawings.
- Quality standards training: Provide training sessions on quality requirements and applicable standards for castings.
- Communication process simulation: Organize communication sessions between design and production to test and improve collaboration.

6. Feedback and Continuous Improvement

- ☐ Monitoring communication errors: Record and analyze communication errors that occur and document their causes to take preventive measures.
- ☐ Regular feedback meetings: Organize weekly or monthly meetings between design and production to discuss recent errors and proposed solutions.
- ☐ Review communication processes: Conduct a periodic analysis of the communication process and adjust collaboration procedures based on feedback received from teams.

Table 1. Checklist for reducing interdepartmental communication errors.

Nr.crt.	Obiectiv	Subpoints	DA/NU
1	Clear and Complete Documentation	Clear and complete technical specifications:	
		Up-to-date technical drawings	
		Detailed technical data sheets	
2	Review and Validation Procedures	Project review meetings	
		Feasibility check	
		Simulations and prototypes	
3	Production Process	Production planning	
		Measuring instruments	
		Quality control	
4	Effective Communication of Changes	Clear change management procedures	
		Quick feedback on changes	
		Document version control	
5	Training and Instrution	Training employees in reading and interpreting technical drawings	
		Training on quality standards	
		Simulating communication processes	
6	Feedback and Continuous Improvement	Monitoring communication errors	
		Regular feedback meetings	
		Reviewing communication processes	

Additional Notes:

- Supporting technology: Consider implementing collaborative software that integrates design and production data, with real-time access for both departments.
- Clear responsibilities: Each department should have clear roles and responsibilities in the project approval and communication process.
- Standardization: Standardizing documents and communication processes will reduce ambiguity and improve coherence between teams.

3.3. Problem Management

An effective problem management system is essential to respond quickly to uncertainties. This system should include:

1. Escalation processes: establishing a protocol to raise issues that cannot be resolved at team level.
2. Problem databases: keeping a record of problems encountered and solutions implemented to avoid their recurrence.

Creating a database based on feedback received

Feedback is essential in an organization, especially in a casting company, as it supports efficiency, quality and continuous development of processes.

To measure the frequency of feedback in a casting company, it is necessary to establish a structured system that records each instance of feedback between the design and production departments.

3.3.1. Create a Feedback Recording System

- **Project Management Platform:** Use a software platform (such as Trello, Asana, Jira) that allows feedback to be recorded and tracked in a structured manner. Each feedback session should be documented as a separate entry (e.g., as a task or comment) and include details about the topic, the people involved, and the follow-up actions.
- **Standardized Feedback Forms:** Develop a standardized feedback form that employees can fill out. The form can include fields for date and time, details about the subject of the feedback, and the departments involved. These forms can be submitted either manually or electronically and recorded in a centralized database.

3.3.2. Specific Metrics for Measuring Feedback Frequency

- **Number of Feedbacks per Project/Product:** Record the total number of feedbacks provided for each project or product and analyze their frequency. For example, you can track how many feedback sessions were required from project initiation to completion of the piece.
- **Feedback per Week/Month:** Monitor the total number of feedbacks between the two departments over a fixed time frame, usually weekly or monthly. This metric provides a picture of the consistency of feedback over time.
- **Feedback Typology:** Divide the feedback into categories (for example: bug fixes, design improvements, production issues, etc.) and analyze the frequency of each category. This can help you understand what type of issues occur most often and require attention.

3.3.3. Qualitative and Quantitative Analysis

- **Quantitative Feedback Analysis:** Establish a numerical ratio between the number of feedbacks and the total number of projects completed in a period. This will show an average of the frequency of feedback, reflecting the need for communication between teams.
- **Feedback Response Time Analysis:** Measure the average time between when feedback is issued and when it is dealt with. A high frequency of feedback, but with quick responses, can indicate healthy and active communication.

3.3.4. Periodic Meetings and Reports

- **Weekly/Monthly Feedback Reports:** Prepare periodic reports that summarize the frequency of feedback between the two departments. These reports can include graphs and trends to see how the frequency varies over time.
- **Feedback Review Meetings:** Hold regular meetings to discuss the main feedback topics between design and production. During these meetings, you can analyze both the quantity and quality of feedback and identify ways to optimize communication

3.3.5. Feedback Scoring and Evaluation System

- **Communication Index:** Develop an index that measures the level of communication between departments, based on the number of feedbacks and the timeliness of responses. This can be a weighted average of the frequency, response time, and complexity of feedback.
- **Feedback Effectiveness Score:** This score can be a combination of the frequency of feedback and the number of corrective actions taken. The score could help evaluate the effectiveness of feedback, showing how useful it was in preventing production errors.

3.3.6. Digital Tools for Automation of Measurement

- **Data Analytics Software:** If there is a centralized feedback database, you can use data analytics tools (e.g. Power BI, Tableau) to visualize and analyze feedback frequency, type, and impact.
- **Alert and Notification Automation:** Use an automated notification system to alert managers if feedback frequency exceeds a pre-set threshold. This way, they can quickly intervene to resolve communication issues in a timely manner.

4. Communication Challenges

4.1. Communication Barriers

Communication barriers can arise for a variety of reasons, including:

- **Terminology Differences:** The technical jargon used by the design team may be unclear to the production team. It is important to develop a common language.
- **Organizational Culture:** Cultural differences between the two departments can lead to misunderstandings. Fostering a collaborative culture is essential.

4.2. Project Changes

Frequent changes to design or specifications can create confusion. This can be managed by:

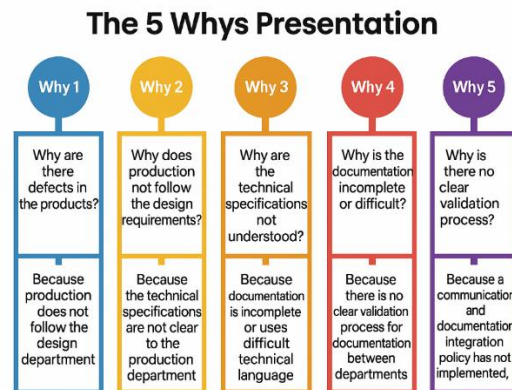
- **Change management systems:** implementing a clear protocol for managing project changes so that all team members are informed.
- **Rapid change communication:** ensuring that all changes are communicated immediately and properly documented.

4.3. Resistance to change

Adopting new communication methods or technologies can be met with resistance from staff. It is important to:

- **Provide training and support:** organize training sessions to help employees become familiar with the new processes.

- Promote the benefits: clearly communicate the advantages of the new methods to gain team support.



Img. 4 5Way diagram presentation

Possible solutions:

- Implementing regular clarification meetings between design and production.
- Creating a standardized format for technical documentation, validated by both parties.
- Using common software for project tracking and specification review.
- Organizing trainings for communication and the use of technical terminology.

5. Conclusions

Effective communication between design and production not only improves product quality, but also optimizes internal processes. Investing in communication strategies, appropriate technologies, and staff training will lead to better collaboration and, ultimately, to the success of the organization.

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COMPARATIVE ANALYSIS OF THE TABLET PRODUCT FROM THE PERSPECTIVE OF CONSUMER PROTECTION

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SUMMARY: Tablets are classified as products intended for long-term use, which requires compliance with a strict legal framework concerning consumer protection. In this context, both European and national regulations mandate that manufacturers implement preventive measures aimed at reducing health risks for users. Proper labeling, usage interval recommendations, and the integration of functional features are required. Furthermore, current standards promote the optimization of ergonomic and technical characteristics of tablets to ensure that daily, long-term use does not negatively impact consumers quality of life. This study highlights the importance of adhering to legal requirements regarding consumer protection in the case of tablets, which are considered long-use products.

KEYWORDS: analysis, tablets, legislation, advertising.

1. Introduction

The present study aims to highlight the importance of complying with consumer protection requirements in the field of tablet commercialization, as these products fall into the category of devices intended for long-term use. In today's digital age, tablets have become indispensable tools in both professional and personal contexts, combining the portability of smartphones with the functionality of laptops. This versatility has led to a rapid diversification of models available on the market, ranging from premium products with advanced technical specifications to affordable options for everyday use. This paper sets out the following main objectives: to analyze the European and national legislative framework in the field of consumer protection, with reference to the relevant framework law namely Law No. 296/2004 on the Consumer Code as well as applicable European regulations such as Directive (EU) 2023/988 on general product safety. Special attention will be given to the liability of manufacturers for product safety, in accordance with the applicable legislation, as well as to obligations related to the provision of legal and commercial warranties. The analysis will cover aspects such as proper labeling, compliant advertising, safety in use, and access to essential consumer information. Through this study, the goal is to identify both good practices and shortcomings observed in the tablet commercialization process, in order to formulate conclusions and recommendations aimed at improving consumer protection.

2. Current state

In recent years, tablets have become essential devices in everyday life, being used in a wide variety of contexts such as education, remote work, entertainment, communication, and internet browsing. According to data provided by Statista and Eurostat [1], between 2020 and 2024, tablet usage increased by over 35% in Europe, driven by high demand during the pandemic and the shift toward hybrid work and learning models.

Particularly among minors and students, the tablet has established itself as a central tool for digital education. At the same time, an increasing number of adult consumers are starting to prefer tablets over laptops for daily activities due to their enhanced portability and ease of use. This trend has led to increased responsibilities for manufacturers, who are required to ensure not only technological performance but also safety and transparency in use.

3. Illustrative analysis of several popular models

Within this research, five popular tablet models from various manufacturers were selected to provide an overview of how technical specifications, market positioning, and information provided to consumers align with consumer protection requirements. The selection of these models does not aim for an exhaustive or detailed comparative evaluation but serves an illustrative role in supporting the general analysis.

Table 1. Comparison between tablet models

Nr.Crt.	Photo with model	Manufacturer	Model	Screen	Processor
1.		Apple	iPad Air 11" (M2)	11", LCD	Apple M2
2.		Samsung	Galaxy Tab S9 11"	11", AMOLED	Snapdragon 8 Gen 2
3.		Lenovo	Tab P11 Pro Gen 2	11.2", OLED	MediaTek Kompanio 1300T
4.		Huawei	MatePad Pro 11	11", OLED	Snapdragon 870
5.		Honor	Pad V8 Pro	12.1", LCD	MediaTek Dimensity 8100

An essential factor influencing both the user experience and the level of protection they receive is the device's operating system and its associated software update policies. These two elements not only affect the long-term performance of tablets but also play a critical role in ensuring the user's digital security and compliance with legal standards regarding consumer protection. A transparent, regularly updated, and well-documented operating system enables users to make informed decisions, protect their personal data, and benefit from a durable and safe product. Additionally, clear software update policies can extend the device's lifespan, reducing risks associated with the prolonged use of an insecure or outdated system.

Table 2. Comparative table of operating systems and support period for updates

Nr.Crt.	Manufacturer	Model	Operating System	Update Support
1.	Apple	iPad Air 11" (M2)	iPadOS	5-6 ani
2.	Samsung	Galaxy Tab S9	Android 13	4 ani
3.	Lenovo	Tab P11 Pro Gen 2	Android 12	2-3 ani
4.	Huawei	MatePad Pro 11	HarmonyOS 3.0	3 ani
5.	Honor	Pad V8 Pro	Android 12	2-3 ani

4. Accompanying documents and legal regulations

According to the provisions of Law No. 449/2003 regarding the sale of products and associated warranties, this chapter will analyze the documents that must accompany the Apple iPad Air product to ensure an adequate level of consumer protection. Law 449/2003 transposes into national legislation the European directives on consumer protection and guarantees the consumer's right to compliant, safe products accompanied by essential information.

Considering that Apple is a market leader in tablets, recognized for compliance with European and international standards, this analysis aims to highlight how the manufacturer meets legal obligations related to: the warranty certificate, the declaration of conformity, user manuals, purchase invoices, as well as the network of authorized service centers.

The warranty certificate for the iPad Air is an essential document that provides the consumer with assurances regarding repair or replacement of the product in case it presents manufacturing defects. It is available both on Apple's official website and in the product package. Apple offers a limited one-year warranty, which can be extended by purchasing the AppleCare+ plan. This additional plan provides coverage for hardware defects and technical support for a longer period. The warranty applies to manufacturing defects but does not cover accidental damage or normal wear and tear. If the user encounters a problem with the device, they must contact Apple Support to request repair or replacement of the product in accordance

with the warranty terms. Apple does not limit the consumer's right to the two-year legal warranty. In Europe, when a customer reports a defect after the first year expires, Apple may direct them to the authorized seller (e.g., eMAG, Altex, etc.), who is obligated to provide repair or replacement according to the legal warranty. On European websites (including apple.com), Apple clearly states that legal rights are not affected by the commercial warranty offered by Apple.

Apple provides a declaration of conformity confirming that the iPad Air complies with European safety and health regulations, as well as consumer protection requirements. Apple Inc., as the manufacturer, declares under its sole responsibility that the iPad Air product complies with the essential requirements set forth in the following European normative acts:

- Directive 2014/53/EU on radio equipment, which regulates electromagnetic safety and the use of radio frequencies;
- Directive 2015/863/EU (RoHS), which restricts the use of certain hazardous substances in electronic products;
- Directive 988/2023 on general product safety, which ensures that the product does not pose risks to consumer health.
- Directive 884/2024/EU-WEEE on the recycling of electronic products.

To demonstrate compliance, Apple applied the assessment procedure outlined in Annex III of Directive 2014/53/EU, involving the notified body Element Materials Technology Portland – Evergreen Inc., number 0981, for the evaluation of the essential requirements in the following articles: 3.1(a) concerning user health and safety protection, 3.1(b) regarding electromagnetic compatibility (EMC), and 3.2 related to the efficient use of the radio spectrum. All conformity certification tests were conducted in specialized and accredited laboratories with full traceability, particularly at Element Materials Technology – Portland – Evergreen Inc., a notified body recognized at the European level, which validated the fulfillment of the mentioned requirements. [2]

The applicable standards are listed in the table below:

Table 3. Applicable standards for iPad Air

Safety and health	Electromagnetic compatibility	Spectral Efficiency, Use of Radio Frequencies	Hazardous substances and traceability	Energy efficiency
EN IEC 62368-1:2020	EN 301 489	EN 300 328	EN IEC 63000:2018	EN 50564:2011
EN 50566:2017	EN 55032:2015	EN 301 893		IEC 62301:2011
	EN 55035:2017	EN 300 440		Regulation (EC) No 1275/2008
		EN 300 330		
		EN 303 687		

The declaration of conformity is available online on Apple's website, and by providing it, Apple assures consumers that the product complies with legal requirements and international standards, thus contributing to the protection of users' health and safety. The user manual is another crucial document accompanying the iPad Air, helping users operate the device correctly, minimizing risks of improper use, and protecting their long-term health. The user manual is available both in physical format within the device package and online on Apple's official website.

These instructions provide detailed information on how to set up and use the device correctly. Among the important aspects included in the user guide are:

- Initial device setup, which includes connecting to the internet, creating an Apple account, and configuring applications;
- Recommendations for prolonged use, such as taking breaks to prevent eye strain and other issues related to long-term screen use. These recommendations are extremely important given that extended device use can lead to health problems such as eye fatigue and back pain;
- Device care, instructions on how to clean the screen and protect the iPad from potential external damage;
- Personal data protection, including recommendations to enable security options such as Face ID, Touch ID, and data encryption to safeguard the user's personal information.

These instructions are essential for ensuring that the user has a safe usage experience and avoids risks associated with improper use of the product. The invoice is another essential document in the purchase process of an Apple product, as it serves as proof of purchase and is necessary to benefit from the warranty. In the case of the iPad Air, the invoice contains detailed information such as:

- Product details, including the full model of the tablet, serial number, and product description;
- Purchase date, which is important for determining the warranty validity period;
- Amount paid, reflecting the purchase price of the product, which is necessary for return or replacement requests. [3]

It is essential for the consumer to keep the invoice to prove the purchase and to be able to request assistance in case of a defect. The invoice is issued either by Apple or by the company's authorized distributors and must be kept throughout the warranty validity period.

Table 4. Comparative Table: Documents and compliance

Nr.Crt.	Manufacturer	Model	Warranty certificate	Declaration of conformity	User manual	CE Marking
1.	Apple	iPad Air 11" (M2)	Yes/ 12 months	Yes (online)	Yes	Yes
2.	Samsung	Galaxy Tab S9	Yes/ 24 months	Not publicly accessible	Yes	Yes
3.	Lenovo	Tab P11 Pro Gen 2	Yes/ 24 months	Not publicly accessible	Yes (PDF)	Yes
4.	Huawei	MatePad Pro 11	Da/ 24 months	Not publicly accessible	Yes (digital)	Yes
5.	Honor	Pad V8 Pro	Da/ 24 months	Not publicly accessible	Yes (digital)	Yes

The warranty certificate provided by Apple partially complies with legal provisions. The following elements are respected:

Product identification (model, serial number);
Warranty duration;

- Rights granted under the warranty, without affecting the consumer's legal rights;
- Repair or replacement at no cost during the warranty period;
- Information about the warranty provider (Apple Distribution International Ltd.);

However, the certificate does not meet the essential requirements of Law 449/2003 because: It is not provided on a durable medium (it is not included in the box, not printed or delivered separately in digital form, but only available within the device settings);

- It does not mention the average product usage duration in Romania, only in other countries;
- It does not specify the maximum repair time;

- It does not clearly contain instructions on how to exercise the warranty or the specific address of the service center;

These shortcomings arise because Apple applies a standard global warranty format without adaptations to national legislations, such as Romania's Law 449/2003.

5. The Meaning of the CE mark and its role

The CE mark, emblematic of a product's compliance with European Union standards, represents a fundamental guarantee for consumer safety and protection. [4] In the case of electronic products such as the iPad Air, the CE marking certifies that the device meets the essential requirements stipulated by European legislation, ensuring that the product is not only safe to use but also protects both the user's health and the environment. It serves as indisputable evidence of adherence to a set of rigorous regulations covering safety, public health, environmental protection, and transparency of consumer information.

The symbol provides strong assurance that the product has undergone strict safety testing according to the standards set by EU law. Therefore, consumers can trust that the product has been tested and evaluated against the highest safety standards, with no risks associated with improper use. When a consumer sees the CE mark on an iPad Air, they can be confident that the product complies with legal requirements and offers adequate protection against potential risks arising from its use.

The CE mark is not limited to user safety but also encompasses environmental protection aspects. In this regard, Apple is obliged to comply with European regulations regarding the use of hazardous substances and the recycling of electronic products. According to Directive 2011/65/EU (RoHS), the iPad Air is designed to be free from toxic substances such as lead, mercury, or cadmium, which could harm users' health or the environment. Furthermore, Apple adheres to regulations concerning the management of waste electrical and electronic equipment (WEEE), actively contributing to reducing the ecological impact of its products. The CE mark is applied on the original packaging of the tablet. Consumers can observe it at the time of purchase and when examining the product, ensuring that it complies with European regulations before being opened.

Some products imported from China may bear labels like "Made in China" or "Exported from China" and may feature a graphical symbol similar to CE, which has no connection to European regulations. It is important for consumers to be aware that the CE mark should not be confused with other symbols. A product bearing the CE mark means it has been tested and certified in accordance with European regulations. However, a product marked only with "Made in China" and other export symbols does not guarantee compliance with the same safety or consumer protection standards as a product marked with CE.

6. Advertising and compliance with ethical standards in product promotion

Companies, in their effort to position their products as revolutionary, often resort to strong visual messages and impactful concepts. Apple, one of the largest manufacturers of electronic equipment, is recognized not only for the quality of its products but also for its visionary advertising campaigns. However, even a brand with a solid reputation can face criticism when the message conveyed exceeds the limits accepted by legal and moral norms. A relevant example in this regard is the recent advertisement for the new iPad Pro, in which Apple

used a giant hydraulic press to destroy a series of objects emblematic of human creativity, a piano, a typewriter, an analog camera, and other cultural symbols. The purpose of the visual was to suggest that the new iPad Pro can replace all these creative tools, reinforcing the idea of complete digitalization and technological efficiency. However, this type of product presentation generated a negative public reaction, being interpreted as a form of symbolic aggression against cultural heritage and traditional artistic expression. In this context, the question arises about the compliance of such an advertising message with the applicable legislation. Romania's Law no. 158/2008 on advertising provides that any form of promotion must be clear, not misleading to the consumer, and must not contradict public morals or cultural values. Apple's advertisement could be analyzed under several articles of this law:

Firstly, according to Article 5, advertising must not create confusion or unrealistic expectations. The way the advertisement was constructed may suggest that the iPad Pro can completely substitute all traditional creative tools, which is obviously an exaggeration. This overstatement can negatively influence consumers' decisions by inducing the perception that the product is a universal replacement, when in reality it is only an advanced digital tool.

Secondly, Article 6 prohibits any message that is contrary to public morals or that may harm cultural values. In this case, the destruction of objects with high symbolic value, in a violent and insensitive context, can be perceived as a lack of respect for cultural heritage and for traditional artistic and intellectual activities. Furthermore, Article 7 requires that advertising should not imply that technology can completely eliminate essential components of human life. Apple seems to convey the message that a single device, the iPad Pro, can replace any form of artistic expression, which can be interpreted as a reductionist and commercial view of creativity. Finally, Article 10 states that advertising must not create unjustified fear, confusion, or unrest. In this case, the aggressive visual approach, where elements of human creativity are crushed and eliminated, may generate unease among those who appreciate art, tradition, and culture, conveying the idea that these are outdated and irrelevant.

Within a regulated market where consumer protection is a fundamental principle, it is essential that advertising messages be crafted not only with commercial intent but also with social responsibility and respect for the audience to which they are addressed.

7. Conclusions

Following the analysis of Apple's warranty policy and consumer experiences, it is observed that although Apple enjoys strong brand recognition due to the quality of its products, there are certain non-compliances related to respecting consumer rights regarding warranty and repair processes. European Union and national legislation provide a solid foundation for protecting users of electronic devices, ensuring transparency in information, the possibility of repair and product returns, and the right to warranty. At the same time, these regulations also address aspects of cybersecurity and personal data protection, which are essential in the context of digital interconnectivity. It is important for users to be aware of these rights and to understand the risks associated with excessive or improper use of tablets. Proper information and effective application of legislation contribute to shaping a responsible consumer, capable of making informed decisions and protecting their health and economic interests. In conclusion, for technological progress to truly support society, it must be accompanied by clear legal measures, digital education, and active collaboration between manufacturers, authorities, and consumers.

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MEDICAL DEVICE FOR MONITORING LOAD DISTRIBUTION ON A FOOT UNDER ORTHOPEDIC TREATMENT

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ABSTRACT: This paper presents the design and development of a load monitoring and warning system for an orthopedic foot using the HX711 sensor, an Arduino microcontroller, and a mobile application created in MIT App Inventor. The system allows real-time monitoring of weight and emits an acoustic signal when the measured weight exceeds predefined values set through the app (10 kg, 20 kg, 30 kg, 40 kg, 50 kg). The HX711 load cell sensor is mounted in a custom 3D-printed TPU90 holder, which ensures durability and precise measurements. The proposed architecture integrates Bluetooth communication between the Arduino and the app for data transmission. The mobile application is intuitive and enables the user to select the weight threshold for which a warning is desired. The project was tested and calibrated to ensure accuracy and stability in measurements.

KEYWORDS: operated leg, progressive loading, Arduino, orthopedic treatment

1. Introduction

Monitoring the progressive loading of an operated leg in real time is an essential aspect in orthopedic medical applications, where precision and rapid response are crucial for preventing injuries and optimizing recovery.

Progressive weight-bearing of the operated leg is an essential process in postoperative recovery, especially after orthopedic interventions (fractures, prostheses, ligament reconstructions, etc.). This involves gradually resuming weight-bearing on the affected leg, as directed by the doctor or physiotherapist, to avoid complications and promote proper healing. Loading is done **under medical supervision. Pain is an important indicator** – any excessive pain indicates overuse. **Physical therapy** is essential to strengthen the muscles, restore mobility and correct gait. However, both the doctor and the patient can be assisted in this process of progressive loading by a device for monitoring the load on the foot. The role of the device is to signal the patient when the load established by the doctor for the current stage of healing is exceeded.

Our project proposes a system for monitoring the load on the operated foot using a special heel pad equipped with a weight measurement sensor, an HX711 weight reading module and an Arduino Uno development board, connected via Bluetooth to a mobile application developed in MIT App Inventor (which can run on any mobile device operating system – iOS, Android, etc.). The novelty lies in the integration of the weight cell into a 3D printed heel pad, ensuring both user comfort and precise monitoring of weight distribution.

2. Current status

Currently, there are devices for monitoring the progressive loading of a lower limb, used especially in postoperative recovery or sports rehabilitation. These help the patient and the therapist to **accurately measure how much weight is applied to the operated leg**, preventing

overuse and optimizing the recovery process. One can discuss **pressure-sensing insoles**. **These** **are** inserted into the shoe and measure the pressure and weight distribution on the sole in real time (for example **Moticon Science** , **Tekscan F-Scan** , **Loadsol**) .

Clinics or rehabilitation centers use so-called force plates to evaluate the forces exerted during walking or exercise (**Kistler** , **AMTI** , **Bertec**) .

However, these devices are very expensive (from a few hundred euros to a few thousand euros, depending on the sensors used, software applications, etc.). This major disadvantage means that such a system cannot be used at home by a patient, but only in a hospital or a specialized clinic, with relatively high costs and a series of time constraints.

In this regard, I have designed a cheap and easy-to-use device, which will not exceed 50 Euros.

3. Design and construction of the device

The proposed system consists of a customized insole on the patient's foot, which contains a weight sensor. This sends signals to an Arduino Uno development board that analyzes the data in real time and generates a sound or message on the mobile application if the patient exceeds the load set for the respective treatment phase. A block diagram of the proposed system/device is presented in Figure 1.

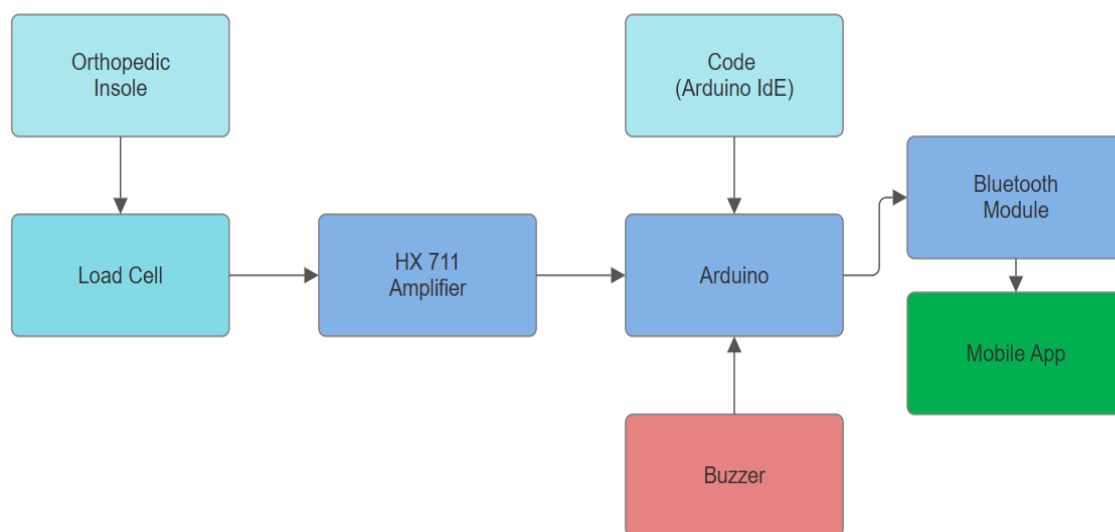


Fig.1. Block diagram of the proposed system

The insole was designed in Autodesk Fusion 360, on a Bambu printer Lab P1S made of flexible TPU90 material. This is specially designed for the dimensions of the weight sensor and positioned to a certain extent so as not to inconvenience the user. Figure 2 shows a screenshot of the invoice processed in the Bambu Studio software application of the printer used.

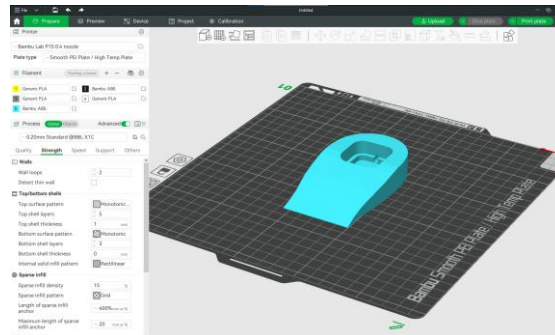


Fig.2. Screenshot of the slip in the Bambu Studio software application

The heel has a special hole to guide the wires outside the shoe or prosthesis and a gap inside it to allow the sensor to be pressed without penetrating the material (see figure 3). It has a high degree of flexibility due to the material used.



Fig.3. Physical form of the coupon

The heel cup has been designed with an inner layer of hard PLA+ filament to ensure uniform pressure distribution on the weight sensor. This structure optimizes measurement accuracy and increases the reliability of the collected data.

In this project, we used an Arduino Uno development board, which communicates via a Bluetooth HC-05 module with a mobile application developed in MIT App Inventor. The Bluetooth HC-05 module is a very popular module used in electronics and automation projects to enable wireless serial communication (UART) between microcontrollers (in this case Arduino) and other devices (the mobile phone via the application developed in MIT App Inventor). An HX711 module was also used to transmit signals regarding the pressing task, by mobile application. The HX711 module is an ADC (Analog- to -Digital Converter) with integrated signal amplifier, specifically used to read load cells (load cells) – that is, to measure weight or force (in this case weight).

The connection diagram of the sensor, the Bluetooth module and the HX711 reading module is shown in Figure 4.

The purpose of this connection is to allow detailed and real-time monitoring of the information transmitted by the weight sensor (load cell) integrated into a 3D printed TPU90 (Thermoplastic Polyurethane) insole. Polyurethane with Shore hardness 90A), on a Bambu printer Lab P1S combo. 3D printing with TPU 90 filament has several specific advantages, due to its elastic properties and excellent strength. TPU 90 offers a balanced elasticity: it is soft enough to absorb shock, but firm enough to provide plantar support. It is not as soft as EVA foam, but it is more durable and does not easily collapse over time. The material absorbs the impact with each step, reducing pressure on the joints (ankles, knees, hips). TPU is hydrophobic – it does not absorb water or sweat, which reduces the risk of bacteria and odor development.

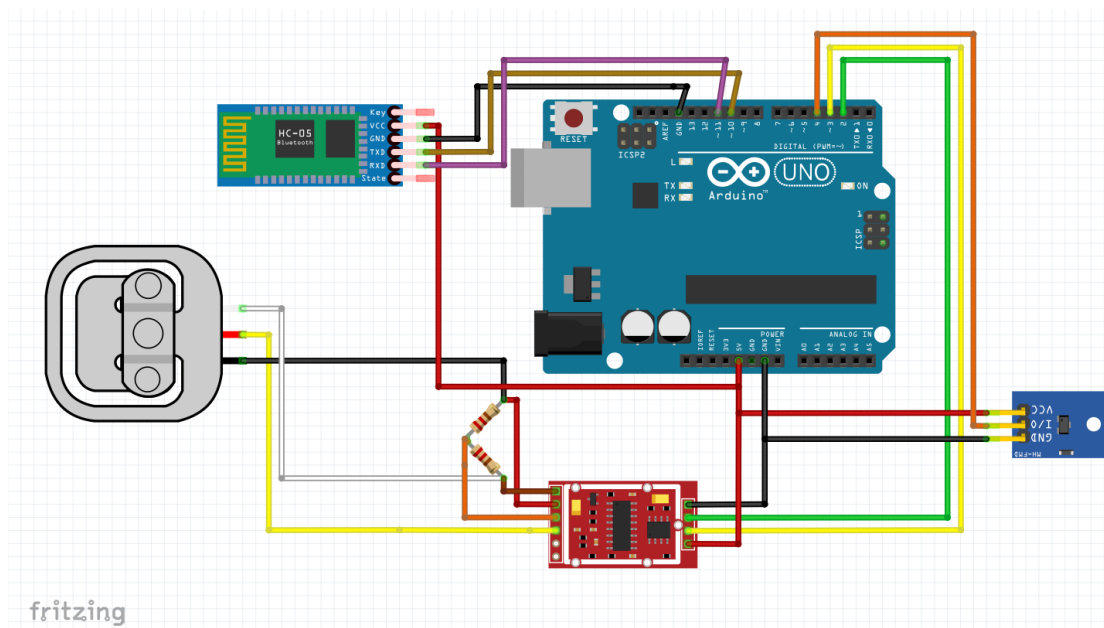


Fig.4. Project diagram made in the Fritzing platform

The code of the entire project made in Arduino IDE that communicates with the monitoring application is partially presented below:

```

1 #include <SoftwareSerial.h>
2 #include "HX711.h"
3
4 #define DOUT 2 // Data Pin HX711
5 #define CLK 3 // Clock Pin HX711
6 #define BUZZER_PIN 4
7
8 HX711 scale;
9 SoftwareSerial BTSerial(10, 11); // RX, TX pentru HC-05
10 float threshold = 0.0;
11
12 void setup() {
13   Serial.begin(9600);
14   BTSerial.begin(9600);
15   scale.begin(DOUT, CLK);
16   pinMode(BUZZER_PIN, OUTPUT);
17   Serial.println("Sistem de Monitorizare Greutate - Initializare completa");
18 }
19
20 void loop() {
21   if (BTSerial.available()) {
22     String data = BTSerial.readStringUntil("\n");
23     data.trim();
24     threshold = data.toFloat();
25     Serial.print("Prag de greutate setat: ");
26     Serial.println(threshold);
27   }
28
29   if (scale.is_ready()) {
30     float weight = scale.get_units();
31     Serial.print("Greutate masurata: ");
32     Serial.println(weight);
33
34     if (weight >= threshold && threshold > 0) {
35       digitalWrite(BUZZER_PIN, HIGH);
36       delay(500);
37       digitalWrite(BUZZER_PIN, LOW);
38       delay(500);
39     } else {
40       digitalWrite(BUZZER_PIN, LOW);
41     }
42   } else {
43     Serial.println("Eroare de conectare la senzor!");
44     delay(100);
45   }
46 }

```

Fig.5. Code made in Arduino IDE

The application is structured in a simple and intuitive way, consisting of five buttons and a real-time weight indicator. Each button allows the selection of a weight threshold (10 kg, 20 kg, 30 kg, 40 kg, 50 kg), at which the buzzer will be triggered to alert the user when this value is exceeded. The graphical interface of the application is presented in figure 6.

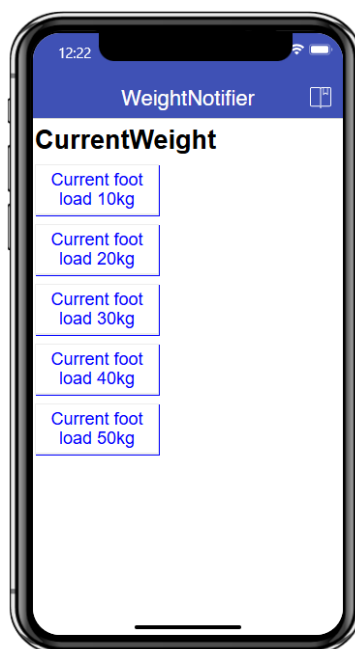


Fig.6. WeightNotifier (application made in Mit App Inventor)

The weight indicator displays the values measured by the sensor in the heel in real time, thus allowing constant and precise monitoring of the pressure exerted.

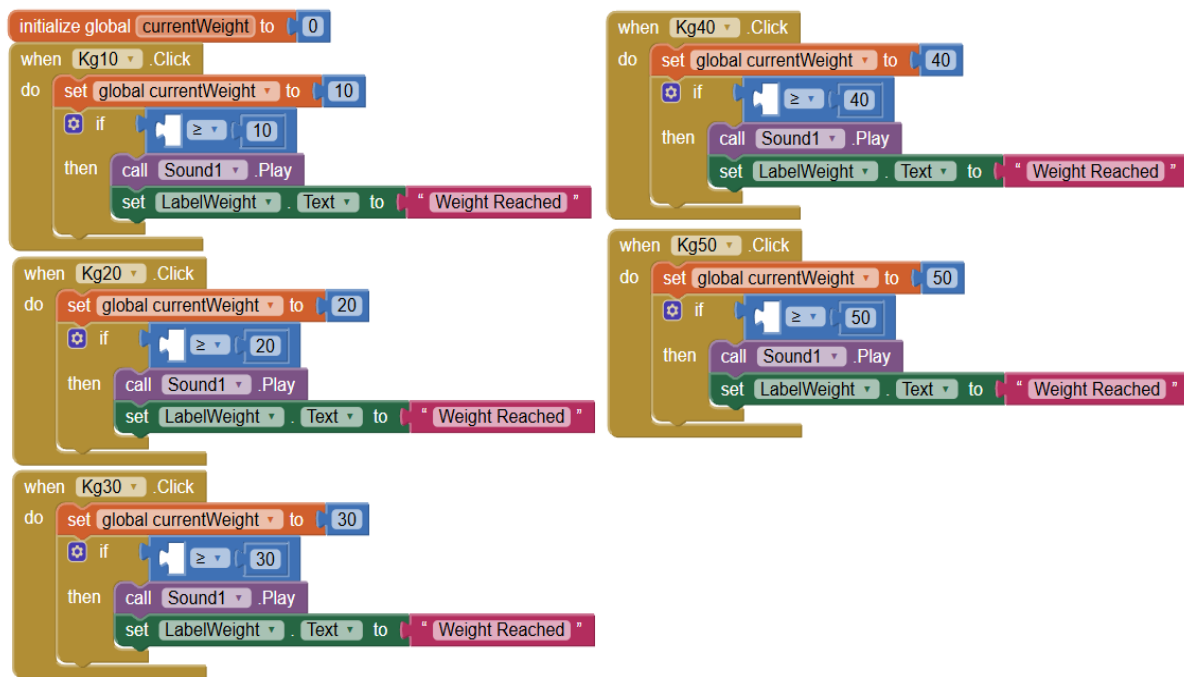


Fig.7. Block diagram made in MIT App Inventor

The block diagram illustrates the operation of the application, allowing the interpretation of the values transmitted by the HX711 amplifier. This ensures correct communication between the sensor, the Bluetooth module and the mobile application, triggering the audible alarm when the selected weight threshold is exceeded.

4. Conclusion

The project demonstrates the efficiency of an intelligent system for monitoring and warning the weight distribution on the heel, using a gravity sensor (load cell) together with its HX711 amplifier, an Arduino microcontroller and a mobile application developed in MIT App Inventor.

The proposed solution makes a significant contribution to the field of orthopedic medical devices, providing an accurate and accessible method to assess in real time the pressure exerted on the patient's foot. The integration of a buzzer for audible alerts and an intuitive mobile interface allows both the patient and the medical staff to be quickly informed when the applied weight exceeds the set critical values.

The heel cup, manufactured by 3D printing from TPU90 and reinforced with a layer of PLA+ for uniform pressure distribution, ensures durability and increased comfort. The project can be expanded in the future by implementing additional functionalities, such as data storage in the cloud for detailed analysis and integration with IoT platforms for remote monitoring. Thus, the proposed solution represents an important step towards smarter and more efficient orthopedic devices.

The work makes the following original contributions:

- **Integrating a weight sensor into a 3D printed heel cup made of TPU90** – a flexible and durable material, optimal for orthopedic applications.
- **Development of an intuitive mobile application in MIT App Inventor** , which allows setting weight thresholds and live monitoring; this mobile application can be compiled for any type of operating system currently existing on mobile devices (iOS , Android, etc.);
- **Buzzer sound alert system** when the selected weight is exceeded, providing real-time feedback for users.
- **Wireless communication via Bluetooth (HC-05)** , eliminating the need for a wired connection and facilitating use in various environments.
- **Optimization of the heel pad design** to allow for uniform pressure distribution on the sensor, increasing measurement accuracy.

Future research in the field will aim to integrate the monitoring system into a smart prosthesis, designed to allow the attachment of sensors without compromising the user's comfort.

This would facilitate detailed analysis of weight distribution across the entire foot structure, not just at the sole (using multiple sensors). It is expected to develop algorithms to detect imbalances and gait abnormalities, providing useful feedback for posture correction and optimizing recovery. Integration with IoT technologies would allow real-time monitoring and remote data access, contributing to accurate diagnosis and efficient recovery.

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SELF-ASSESSMENT OF ORGANIZATIONAL PERFORMANCE USING THE EFQM MODEL 2025

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ABSTRACT: This paper proposes the study of the organizational performance self-assessment model using the EFQM Excellence Model, version 2025. For a detailed understanding of the implementation strategy of the excellence model, the history of the most recent changes made to the model in the last 15 years was followed. The field in which the research on the application of the model was conducted is the automotive industry, and the organizational context is the development of semiconductors and components.

KEYWORDS: EFQM, model, sustainability, resilience, improvement

1. Introduction

The EFQM Model is an internationally recognized management framework designed to help organizations navigate change and enhance performance. It promotes the adoption of best practices, enabling organizations to assess their strengths, identify areas for improvement, and align their actions with environmental, social, and economic goals. The model's clearly defined mission is to empower organizations to create lasting impact, contribute to a more sustainable future, and generate meaningful value for all stakeholders.

2. Current State

The EFQM Model (European Foundation for Quality Management) has undergone significant transformation since its launch in 1991 to the present day, reflecting the needs of modern organizations to adapt to an increasingly complex and dynamic environment. The evolution of this model can be coherently traced through its key development stages, which include conceptual, structural, and methodological changes.

The EFQM Model was initially introduced in 1991 as an excellence framework intended for evaluating organizational performance in the context of awarding the European Quality Award. In this early phase, the emphasis was placed on improving the quality and efficiency of internal processes.

In 1999, the publication of the eight fundamental concepts of excellence took place, which became the foundation of the EFQM philosophy. At the same time, the RADAR tool was introduced, designed to assess an organization's ability to effectively implement strategies and processes.

The concept of Public Responsibility was renamed Corporate Social Responsibility in 2003, marking a transition towards a more modern view of the role of organizations in society. Additionally, the model was adjusted to adapt to different economic sectors through customized versions.

The 2010 edition of the EFQM model was marked by conceptual simplification and a clearer alignment between the excellence concepts and the assessment criteria. The term "Processes, Products & Services" was introduced to replace the former "Processes," and the criteria weightings were established: most at 10%, while key results and customer-related results received 15%.

In 2013, the EFQM Model became more flexible and focused on organizational agility. A notable change was the shift in language: the emphasis moved from “evidence” to the “ability to demonstrate” results. Additionally, the excellence concepts became actionable, reflecting organizations’ need to concretely implement theoretical principles.

The EFQM 2020 Model represented a paradigm shift. The focus moved from mere operational excellence to value creation through a clear organizational purpose. The model integrates concepts of digital transformation, innovation, and stakeholder engagement. The criteria are aligned with the organization’s strategy and the ecosystem in which it operates. Additionally, the RADAR tool was redesigned to holistically assess strategic planning, execution, and outcomes.

The EFQM 2025 Model marks the maturation of the strategic approach through the explicit integration of the UN Sustainable Development Goals, Artificial Intelligence, and predictive analytics. Performance assessment extends beyond financial aspects, including indicators of social impact, environmental responsibility, and governance (ESG). RADAR becomes a forward-looking tool that helps organizations anticipate and proactively respond to changes. Additionally, the model promotes ethical leadership, organizational resilience, and smart resource allocation.

This paper aims to apply the latest version of the EFQM model, starting from an organizational context firmly rooted both in the present and with clear development prospects for the future: the development of semiconductors and microcontrollers for the automotive industry.

3. Organizational Self-Assessment

The EFQM self-assessment is carried out in four main stages: (1) **Planning and team formation**, where the areas to be assessed are selected and participants are trained; (2) **Organizational self-assessment**, in which relevant stakeholders respond to the EFQM sub-criteria, describing activities, processes, and results in relation to the model; (3) **Assessment by assessors**, who analyze the inputs using the RADAR logic and provide structured feedback including strengths, areas for improvement, comments, and scores visualized through spider charts; and (4) **Periodic reassessment**, through which the organization monitors its progress and repeats the process to support continuous improvement and strategic transformation.

3.1 Planning and team formation

Planning and team formation represent the initial stage in the EFQM self-assessment process, aimed at preparing the organization for a rigorous and coherent analysis. In this phase, the objectives of the assessment are established (e.g., continuous improvement, strategic alignment, or preparation for external recognition), the scope is defined (entire organization, division, project), and the self-assessment team is formed. This team consists of representatives from various functional areas and hierarchical levels who possess a thorough understanding of the processes being assessed.

The planning and formation of the EFQM self-assessment team began with establishing the overall objective of the process: to analyze the degree of implementation and integration of the principles of excellence at all organizational levels, as well as to evaluate the maturity of the organizational culture and existing management systems. To this end, a mixed self-assessment team was formed, consisting of four key stakeholders strategically selected to provide a comprehensive and balanced perspective on the organization’s operations.

The team included a representative from **top management** – the Organization’s General Director; two representatives from **middle management** – the General Manager of QMS (Quality Management System) and the General Manager of EHS (Environment, Health, and Safety); as well as a representative from **lower management** – the Project Manager. This structure was chosen to reflect how EFQM principles are understood, applied, and supported from the strategic to the operational level. Thus, the assessment targeted not only the performance of

systems but also the organizational culture, alignment of values, employee engagement, and management effectiveness across all activity areas.

3.2 Organizational self-assessment

In this stage, each stakeholder participating in the self-assessment will describe, from their own perspective, how each criterion and implicitly each sub-criterion is implemented at the organizational level, providing scores according to the scale presented in Figure 2.

	E	D	C	B	A
Description (Enablers & Results)	Inability to achieve	Limited ability to achieve	Ability to achieve	Comprehensive ability to achieve	Outstanding ability to achieve
% Score	0	25	50	75	100

Fig. 2. Scores from E to A

In the present paper, Criterion 1 – Purpose, Vision & Strategy will be developed from the perspective of each stakeholder for each sub-criterion as follows.

Table 1. Sub-criterion 1.1.

Organization's General Director	General Manager of QMS
1.1 Define Purpose & Vision Evidence (Please enter notes and evidence to support your scoring) At GXT Semiconductors Romania, our Purpose is aligned with the global direction of the group: "Secure Connections for a Smarter World." Locally, we have adapted this mission to better reflect our specific impact on the automotive industry and the semiconductor ecosystem in Central Europe: "Driving intelligent mobility and secure innovation in automotive semiconductor technologies." This was not merely a translation but the result of a collaborative process carried out in 2022 through internal workshops (Purpose & Vision Alignment Workshops – see the document 'GXT Romania Purpose Vision Outcomes 2022'), which involved over 100 key employees and members of the local board. Our Vision for 2030 is clearly defined: to become one of the most respected competence centers in Europe for semiconductor solutions in the automotive sector, in both embedded software and secure hardware design and validation. The Purpose and Vision are systematically communicated through onboarding sessions, quarterly townhalls, and our internal knowledge-sharing platform ('GXT Connect Romania'). Our leadership is regularly trained to embody these values through the internal coaching program 'Leading with Purpose', and recognition campaigns such as "Purpose Champions" reward employees who bring our values to life in real projects.	1.1 Define Purpose & Vision Evidence (Please enter notes and evidence to support your scoring) As a manager responsible for compliance with critical international standards, my visibility into the Purpose and Vision is present, but mostly indirect. I find them reflected in the way quality, safety, and cybersecurity policies are structured. Our Purpose, "Secure Connections for a Smarter World," is aligned with the group's strategic direction, but at the local level it is primarily manifested through indirect initiatives—such as the full adoption of ISO 26262 functional safety requirements across all embedded software projects, or the integration of cybersecurity resilience practices in line with ISO 21434. In shaping the Vision, I occasionally contribute through feedback during strategic workshops and internal audit activities, but I was not directly involved in its initial definition. I believe more active involvement of operational structures in adjusting the vision across technical verticals would enhance alignment and ownership. My direct stakeholders (the safety and security teams) perceive the Vision through the lens of audit objectives and system requirements, rather than as an inspirational guidepost. I believe there is room for improvement here, particularly in terms of cross-functional internal communication.
General Manager of EHS	Project Manager
1.1 Define Purpose & Vision Evidence (Please enter notes and evidence to support your scoring) From the EHS perspective, the organization's purpose and vision are interpreted and translated into operational actions through the principles of "Safe by Culture, Green by Design," integrated into the EHS Policy revised in January 2024, available in document EHS-POL-01. Although the overall purpose is defined at the global level and communicated by general management ("Secure Connections for a Smarter World"), in Romania its translation into actions related to sustainability, occupational health, and environmental responsibility has been achieved through a series of consultations within the EHS Governance Council, involving union representatives and production team leaders. The EHS vision is articulated through a set of long-term strategic objectives, such as: Zero major incidents by 2030 Reducing CO₂ emissions by 40% by 2027 (compared to 2020) Water neutrality in processed water consumption by 2032 These objectives are aligned with global initiatives (e.g., Science Based Targets, SDG 3, SDG 6, SDG 13), but are perceived more as a formal commitment rather than an integral part of the strategic culture. Clearer inclusion of these goals in the strategy documents could strengthen their connection with the overall direction.	1.1 Define Purpose & Vision Evidence (Please enter notes and evidence to support your scoring) As a software project manager, I relate to the organization's Purpose as a constant reference point: "creating a safer, connected, and sustainable future through responsible technological innovation." This is also reflected in the software domain, where we develop critical modules for automotive safety, such as stacks for ADAS and BMS systems. At the project level, the vision translates into delivering embedded solutions with high levels of quality and compliance (ASPICE CL2-3, ISO 26262 ASIL B/D). This vision inspires our technical teams to take ownership not only of the code but also of the value brought to the ecosystem. In 2023, I participated in a series of workshops facilitated by the strategy department, where I, along with other PMs, contributed to defining the direction for the "Digital Integration Strategy 2025." During these sessions, we analyzed and adapted the organizational vision from a software scalability and cross-platform interoperability perspective. Together with stakeholders from the technical and product areas, in 2024, we defined a "Tech Vision Companion Document" for the ADAS direction, which translates the global vision into a context specific to our software projects.

Tabelul 2. Subcriteriul 1.2.

Organization's General Director	General Manager of QMS
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1.2 Understands its Ecosystem, its Own Capabilities & Major Challenges E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) Understanding our ecosystem is essential for the competitiveness of GXT Romania. We participate annually in the global Strategic Foresight Planning process (as outlined in the document 'GXT Global Foresight Report 2024'), but we have also developed our own local trend assessment ('GXT Romania Market & Ecosystem Analysis 2023'), focused on key automotive megatrends: electrification, autonomy, functional safety, and cybersecurity. In Romania, we contribute to the ecosystem through two major pillars: the development of secure embedded software and collaboration in the co-development of IP blocks for automotive microcontrollers. For example, our team has been involved in designing hardware security modules for microcontrollers in the M47V2 family (see 'M47V2 Secure IP Co-Development Report Romania 2023'). However, we face challenges in rapidly anticipating regulatory changes at the European level and in attracting high-end talent for emerging requirements in AI on Chip and Secure Embedded Systems. To enhance this capability, in 2025 we will initiate partnerships with technical universities in the region and develop our own Technology Trend Monitoring Program.	1.2 Understands its Ecosystem, its Own Capabilities & Major Challenges E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) As the Compliance and Quality Manager, I am deeply connected with the ecosystem in which we operate. I directly participate in strategic risk assessments, including scenarios involving supply chain disruptions, legislative changes, or evolving OEM requirements. Our ecosystem is defined by three main pillars: international regulations (UN SDGs, EU Fit for 55), specific automotive customer requirements, and emerging technologies influencing our processes—AI, cybersecurity, and electrification. I have full access to internal capability assessments such as ASPICE and CMMI, which provide a clear picture of our process maturity. These are reported quarterly in the "Process Maturity Consolidated Report" and are based on effective audits. Additionally, I collaborate with R&D and production teams to anticipate and mitigate strategic risks, such as the lack of functional safety competencies or the incompatibility of software processes with German OEM requirements.
General Manager of EHS	Project Manager
1.2 Understands its Ecosystem, its Own Capabilities & Major Challenges E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) The EHS department conducts an annual external and internal context analysis as part of the strategic planning process in accordance with ISO 14001 and ISO 45001 (document: EHS-RMP-ENV-SAF-Context Analysis, v4/2024). Among the identified and monitored megatrends are: - Increasing requirements for reducing carbon footprint in the supply chain (Scope 3) - Intensification of social and environmental audits from OEM customers - Digitalization of EHS systems through IoT, AI for predictive detection, real-time compliance tracking - Pressure for circularity (material recovery, zero waste, green packaging) Internal capabilities are periodically evaluated through the EHS Maturity Model Assessment and include: - Implementation of an automated near-miss tracking system (in Power BI) - ISO 14001 and ISO 45001 certification maintained without major nonconformities - Infrastructure for gas detection, safe evacuation, and controlled ventilation (upgraded in 2023) Persistent challenges: - Budget constraints for expanding green infrastructure - Need for a unified integrated EHS risk analysis system (project planned for 2026)	1.2 Understands its Ecosystem, its Own Capabilities & Major Challenges E D C B A ☐ ☐ ☒ ☐ ☐ Evidence (Please enter notes and evidence to support your scoring) Our ecosystem is complex: it involves demanding OEMs, multiple standards (ASPICE, ISO 26262, UNECE R155/156), international development teams, and a rapidly accelerating market. As a software PM, I need to understand these dimensions, manage them within projects, and anticipate barriers. For example, one major challenge is the shift from monolithic to modular architectures (AUTOSAR Adaptive), which we address through training sessions and gradual refactoring. Another ecosystem trend is the integration of cybersecurity by design, which influences milestone planning and deliverables. We maintain a skills matrix correlated annually with the technology roadmap. In 2024, we reviewed HiL/SiL testing capabilities and adapted the automated testing strategy to support projects with critical latency requirements. On the prediction side, we follow market reports (Gartner, McKinsey) as well as internal input from the "Engineering Foresight Review" — a GXT initiative analyzing technological impacts on software development. These influenced the inclusion of ML inference modules in our ADAS roadmap for 2026.

Tabelul 3. Subcriteriul 1.3.

Organization's General Director	General Manager of QMS
1.3 Identifies & Understands the Needs of Key Stakeholders E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) GXT Romania treats stakeholder management as an integral part of strategic planning. We have a clear segmentation structure ('Stakeholder Mapping and Prioritization Matrix Romania 2023'), where we distinguish between: - OEM/Tier 1 customers, - Strategic IP and EDA tool suppliers, - Local and educational authorities, - Employees and emerging technology leaders. Through annual surveys (Voice of Customer Survey 2023, Voice of Employee Survey 2023) and regular Stakeholder Forums, we continuously capture needs and expectations. For example, following feedback from a strategic OEM customer, we accelerated the development of an integrated hardware-software solution for secure OTA updates, a project initiated in Romania in collaboration with the global center. A deep understanding of stakeholder strategies helped us reposition part of our R&D portfolio by prioritizing local Functional Safety IP validation. However, anticipating major disruptive shifts, such as the native integration of AI into embedded automotive modules, is still in the process of maturing.	1.3 Identifies & Understands the Needs of Key Stakeholders E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) In the quality and compliance area, my main stakeholders are OEMs, audit bodies, key customers, as well as my colleagues from R&D, testing, and production. Through the complaint management system and internal audits (e.g., "Lessons Learned Database," IATF and ASPICE audits), we frequently understand the explicit and implicit needs of our customers. Additionally, we adjust our procedures based on changes in standards (e.g., the transition from ASPICE 3.0 to 4.0 or the new TISAX assessment annexes). I have directly contributed to defining the strategic quality priorities for 2025, including the cross-site requirements of European OEMs. From my perspective, there is a solid understanding of both internal and external stakeholders in our area, but we still have opportunities to strengthen structured feedback mechanisms with the software teams, where cybersecurity requirements are often interpreted differently between teams.
General Manager of EHS	Project Manager
1.3 Identifies & Understands the Needs of Key Stakeholders E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) The needs of EHS stakeholders are analyzed based on the annually updated EHS Interest and Influence Matrix (doc: EHS-SH-Map-2024.xlsx), with input from: - OEM customers (requirements on sustainability, net-zero targets, social due diligence) - Chemical suppliers (REACH compliance) - Employees (safety, ergonomics, psychosocial protection) - Authorities (compliance with reporting requirements, labor inspections by ITM, environmental inspections by ANPM) Communication channels include: - Green Pulse Survey (feedback on sustainability perception) - Annual EHS questionnaire (employee satisfaction related to occupational health & safety and ecological impact) - Dialogue sessions with employee representatives (monthly occupational health & safety committee) Recent example: Following feedback on increased thermal discomfort in the testing area, we correlated the "heat stress hours" indicator with the occupational health & safety satisfaction score and initiated a pilot project for controlled ventilation using CO₂ and temperature sensors.	1.3 Identifies & Understands the Needs of Key Stakeholders E D C B A ☐ ☐ ☐ ☒ ☐ Evidence (Please enter notes and evidence to support your scoring) The direct stakeholders in software projects are multiple: OEMs, hardware teams, QA, safety, security, and product management. For each, we manage expectations through refinement sessions, requirements management (DOORS, Jama), and incremental demos. Starting in 2023, we introduced a technical stakeholder map in strategic projects, based on which we calibrate priorities according to each entity's impact on the software deliverable. Stakeholder needs are increasingly influenced by digitalization: OEMs require full traceability, shorter time-to-market, and compatibility with proprietary middleware. We respond with DevOps practices (CI/CD with Jenkins, code quality gates with SonarQube) and a continuous delivery system on virtual platforms (SiL environments). Additionally, in 2024, we started correlating internal stakeholder needs (e.g., the testing team) with project management practices: we modified the daily review process to integrate QA feedback into the sprint backlog. This resulted in a 14% reduction in rework tasks over the last two quarters.

Tabelul 2. Subcriteriul 1.4.

Organization's General Director	General Manager of QMS
1.4 Develops & Adapts Strategy E D C B A Evidence (Please enter notes and evidence to support your scoring) GXT Romania's strategy is aligned with the global vision, yet adapted to the specifics of the regional ecosystem. In 2022, we defined a three-year strategy ('Romania Strategic Initiatives Plan 2022–2025'), built on three main pillars: - Expanding software capabilities for Cybersecurity and AI on Chip, - Contributing to the co-development of secure hardware IP blocks, - Enhancing local capabilities in validation and testing for automotive microcontrollers. Although we translated these directions into concrete initiatives (e.g., the development of Secure Boot Modules in Romania), rapid adaptation to external changes—such as the acceleration of carbon neutrality requirements—still requires improvement. Our plan for 2025 is to integrate quarterly Strategic Adjustment Sprints to enable faster and more responsive adaptability, especially in the face of emerging technological risks.	1.4 Develops & Adapts Strategy E D C B A Evidence (Please enter notes and evidence to support your scoring) My contribution to strategy development is rather one of translation: I transform group- or customer-level requirements into local policies, processes, and KPIs. For example, I was involved in defining the ASPICE maturity improvement strategy, which was integrated into the local digitalization strategy. At the same time, I contributed to aligning the functional requirements from ISO 26262 and integrating them into the embedded development roadmap, in collaboration with the technical teams and the safety manager. The strategy is well documented, but it is sometimes perceived as “top-down.” I believe we can move towards a more collaborative approach in defining actions, especially in the area of technical processes and organizational resilience. Reference document: “Local Quality & Compliance Strategy 2025 – Annex to Operational Plan.”
General Manager of EHS	Project Manager
1.4 Develops & Adapts Strategy E D C B A Evidence (Please enter notes and evidence to support your scoring) The EHS Strategy 2023–2026 is defined in document EHS-STRAT-2023.2, aligned with GXT's global strategy and compliant with SDG, CSR, and ISO requirements. The strategic priorities include: - “Work Safe First” – achieving zero LTIR (Lost Time Incident Rate) by 2027 - “Decarbonize Operations” – reducing energy consumption per wafer by 20% by 2025 - “Resilient Supply Chain” – developing an ESG supplier matrix The strategy was developed with participation from key internal stakeholders (production, maintenance, HR) and integrated into departmental OKRs. However, the strategy's adaptability is limited due to: - Delays in receiving information about legislative changes (e.g., EU Taxonomy) - Lack of integrated prediction tools reduces the ability to quickly adapt to emerging risks (e.g., extreme weather conditions, increased heat stress)	1.4 Develops & Adapts Strategy E D C B A Evidence (Please enter notes and evidence to support your scoring) Although I am not directly responsible for defining the organizational strategy, I actively participate in translating it into operational plans and project roadmaps. In software, the strategy focuses on scalability, quality, agility, and standardization. Together with the CTO and engineering leads, I contributed in 2023 to defining a technological transformation initiative—“Unified Platform Evolution”—which envisions a gradual migration to a common software platform across multiple products. The strategy is reviewed and adapted quarterly during the Engineering Strategy Sync sessions, where we analyze progress, team capabilities, and market requirement evolution. Resources are allocated based on objectives set during Program Increment Planning, with adjustments made according to capacity and risk. For example, in Q1 2024, we reconfigured the ADAS project team to respond to a major change in the scope defined by the OEM. We involve stakeholders from QA, cybersecurity, and Safety in the review process—especially for ASIL D projects—to ensure strategic coherence and compliance.

Tabelul 2. Subcriteriul 1.5.

Organization's General Director

1.5 Designs & Implements a Performance Management & Governance System

E

D

C

B

A

Evidence (Please enter notes and evidence to support your scoring)

Performance management at GXT Romania is based on a local Balanced Scorecard ('GXT Romania Balanced Scorecard 2024'), focused on four pillars: Financial, Innovation, Customers, and Employees.

In addition, we track separate KPIs for software development and hardware R&D activities.

Performance is monitored monthly, and the results are discussed during local Management Review meetings and integrated into the global reporting system ('Romania Monthly Performance Review Reports').

Governance includes dedicated committees for:

Innovation and Research (for co-developed hardware-software projects),

Compliance & Sustainability,

Cybersecurity Governance Committee.

While the governance structure is solid, we acknowledge that greater involvement of external stakeholders (e.g., representatives from academia or OEM clients) in the innovation committees could enhance the strategic relevance of decisions and the organization's transparency.

General Manager of QMS

1.5 Designs & Implements a Performance Management & Governance System

E

D

C

B

A

Evidence (Please enter notes and evidence to support your scoring)

I am directly responsible for the implementation and maintenance of the governance system in the quality and compliance area. At GXT, we have a clear framework based on ISO 9001 and IATF 16949, with extensions for ASPICE and CMMI in the software domain.

The performance management system includes KPIs monitored monthly, internal and external audits, reporting to the group, and a system of management reviews at the level of each function.

Additionally, I have defined and maintain escalation mechanisms and nonconformity management processes, as well as maturity dashboards that support operational decisions ("Process Conformity Scorecard").

I consider the system to be functioning well, with a high degree of transparency and accountability, but full integration of governance in cross-functional projects remains an important objective for 2025.

General Manager of EHS

1.5 Designs & Implements a Performance Management & Governance System

E

D

C

B

A

Evidence (Please enter notes and evidence to support your scoring)

The EHS department uses an integrated management system validated by ISO 14001 and ISO 45001 certifications, which includes:

- EHS Dashboard with monthly indicators (LTIR, number of incidents, water consumption, energy consumption, waste recovery rate)

- Standardized risk assessment processes (EHS-HIRA-Tool v2.3)

- Monthly performance reviews within the EHS Performance Review Board

The governance structure consists of:

- EHS Lead Team (cross-functional, including production, maintenance, HR)

- Reports to the General Director and to the global GXT group (QBR – EHS chapter)

- Involvement of employee representatives and occupational health physician

The level of accountability and transparency is well defined, but the recognition system (e.g., for teams with zero incidents) could be improved to support a culture of proactive engagement.

Project Manager

1.5 Designs & Implements a Performance Management & Governance System

E

D

C

B

A

Evidence (Please enter notes and evidence to support your scoring)

In software projects, governance is implemented through a control system based on:

- milestone-based delivery,

- QA gates,

- daily/weekly reporting, and

- monthly performance reviews (Project Health Dashboard).

KPIs are clearly defined: burn-down rate, story throughput, code coverage, defect density, traceability coverage (per ISO 26262), audit readiness (ASPICE), and stakeholder satisfaction scores (e.g., post-sprint reviews). I personally contributed to developing a local Integrated Engineering KPI Dashboard that tracks all these metrics for each team.

The system is fully integrated with Jira, GitLab, and Jenkins, providing real-time visibility into progress and blockers. Starting in 2024, we added indicators for developer well-being and cognitive load index, reflecting the cultural maturity of our governance system.

Key documents include:

- "Software Project Governance Framework" (updated semi-annually)

- "KPI and Risk Heatmap" — reviewed monthly by the Engineering Quality Review Board

The visual representation of the average scores assigned by stakeholders is shown in Figure 3.

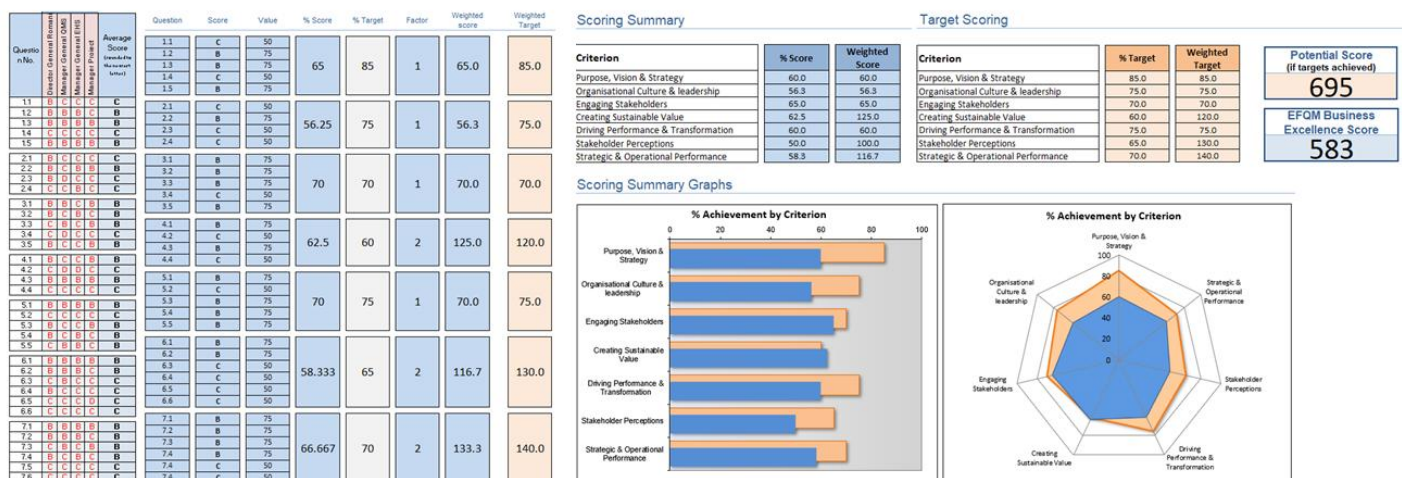


Fig. 3. Consolidated Results of the Self-Assessment

3.3. Assessment by assessors

In this stage, each assessor analyzes the stakeholders' responses and completes the evaluation matrix, based on the RADAR logic, providing feedback, strengths, opportunities for improvement, and additional comments. In this paper, the emphasis was placed on highlighting objective evidence.

Elements	Attributes	Inability to achieve 0%	Limited ability to achieve 25%					Ability to achieve 50%					Comprehensive ability to achieve 75%					Outstanding ability to achieve 100%					
Approach	Sound: The approaches have a clear rationale, aim to fulfil and respond to Key Stakeholder needs, are described appropriately and are designed to be fit for the future.	Not much happening at all; perhaps some good ideas but they have not progressed much beyond wishful thinking.	Islands of successful implementation but not structured.					Some relevant approaches have been developed but they are not fully mature or don't fully cover the subject.					Have been in place for a minimum of 12 months.					Some examples of approaches being refined based on assessment and learning.					
Approach	Aligned: The approaches support organisation's Purpose, Vision & Strategy and are integrated with other relevant approaches.	Not much happening at all; perhaps some good ideas but they have not progressed much beyond wishful thinking.	Islands of successful implementation but not structured.					Some relevant approaches have been developed but they are not fully mature or don't fully cover the subject.					Have been in place for a minimum of 12 months.					Some examples of approaches being refined based on assessment and learning.					
Deployment	Implemented: The approaches are consistently deployed in relevant areas in a timely manner.	Not much happening at all; perhaps some good ideas but they have not progressed much beyond wishful thinking.	Islands of successful implementation but not structured.					Some relevant approaches have been developed but they are not fully mature or don't fully cover the subject.					Have been in place for a minimum of 12 months.					Some examples of approaches being refined based on assessment and learning.					
Deployment	Flexible: The deployment of approaches allows flexibility and adaptation.	Not much happening at all; perhaps some good ideas but they have not progressed much beyond wishful thinking.	Islands of successful implementation but not structured.					Some relevant approaches have been developed but they are not fully mature or don't fully cover the subject.					Have been in place for a minimum of 12 months.					Some examples of approaches being refined based on assessment and learning.					
Assessment & Refinement	Evaluated & Understood: Internal and external insights and feedback on the effectiveness & efficiency of the approaches and their deployment are collected, understood and shared.	Not much happening at all; perhaps some good ideas but they have not progressed much beyond wishful thinking.	Islands of successful implementation but not structured.					Some relevant approaches have been developed but they are not fully mature or don't fully cover the subject.					Have been in place for a minimum of 12 months.					Some examples of approaches being refined based on assessment and learning.					
Assessment & Refinement	Learn & Improve: Findings from insights and feedback are used to inspire creativity and generate improved and innovative approaches and deployment.	Not much happening at all; perhaps some good ideas but they have not progressed much beyond wishful thinking.	Islands of successful implementation but not structured.					Some relevant approaches have been developed but they are not fully mature or don't fully cover the subject.					Have been in place for a minimum of 12 months.					Some examples of approaches being refined based on assessment and learning.					
OVERALL TOTAL (not higher than the score for 'Sound')		67.2	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100

Fig. 4. Evaluation matrix

Strengths

- ✓ **Strategic clarity:** The Purpose is solidly formulated and differentiated from the global level, indicating strategic maturity and a well-defined local identity.
- ✓ **Broad participation and collaboration:** Involvement of over 100 people in defining the Vision-Purpose direction demonstrates a valuable participatory approach.
- ✓ **Integration into systems and policies:** Reflection in policies such as EHS-POL-01 and within quality programs like ISO 26262/21434 indicates good formal embedding.
- ✓ **Coaching and recognition activities** ("Leading with Purpose," "Purpose Champions") demonstrate commitment to inspirational behaviors.

Opportunities for Improvement

- **Consistency in perception:** The Quality Manager and the EHS Manager perceive the Vision more as a formal constraint or operational framework rather than an inspirational guide or strategic catalyst.
- **Cross-functional integration:** Communication and application of the strategic direction at the non-managerial team level and execution lines could be strengthened.
- **Systematization in evaluation:** Clear references are lacking regarding how the degree of ownership of the purpose and vision is periodically assessed and adjusted.
- **Continuous feedback:** Workshops and consultations have been conducted occasionally; developing a routine of cyclical feedback would strengthen the learning dynamics.

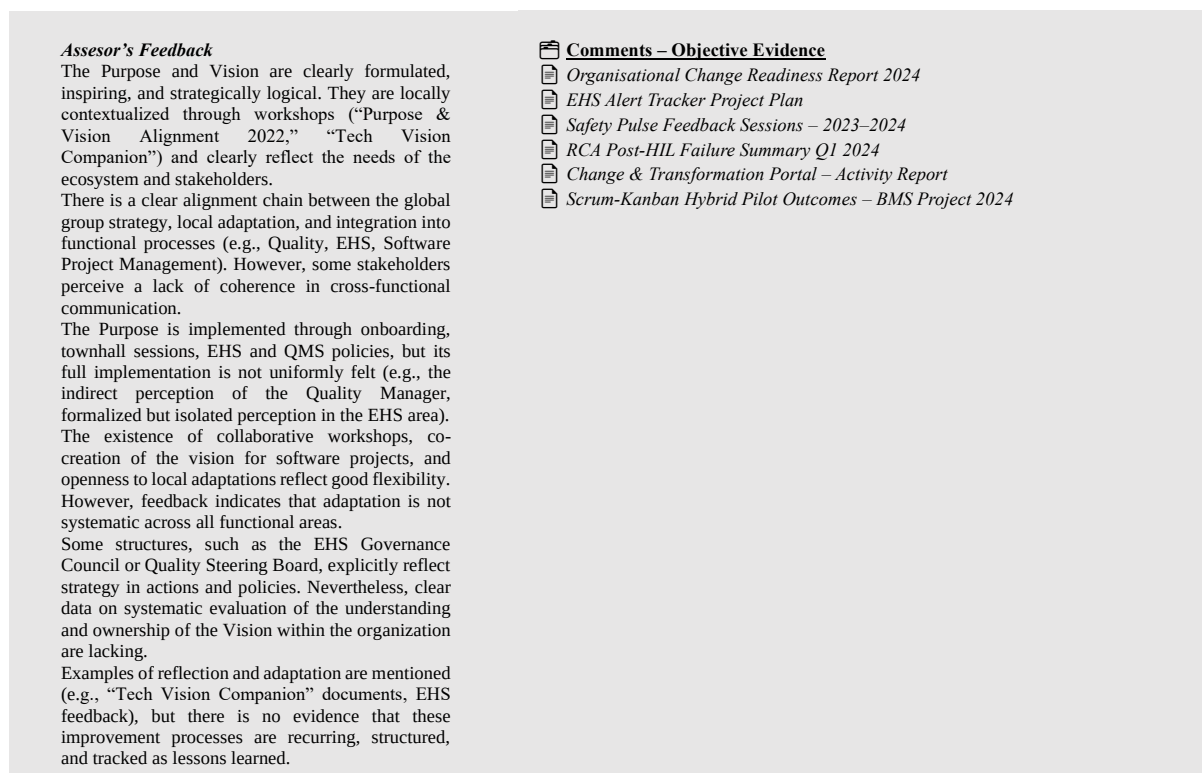


Fig. 5. Feedback, Strengths, Opportunities for improvement and Comments

Assessors will repeat the process for each sub-criterion, obtaining a specific score for each criterion.

No.	Question	Score	%
1.1	Define Purpose & Vision	67.2	69
1.2	Identify & Understand Stakeholders Needs	68.8	
1.3	Understand the Ecosystem, own Capabilities & Major Challenges	70.0	
1.4	Develop Strategy	68.0	
1.5	Design & Implement a Governance & Performance Management System	70.8	

Fig. 6. Score Obtained for Criterion 1

3.4. Periodic reassessment

Within the organization, it was decided that periodic reassessments will be conducted every two years, in accordance with the recommendations made by the EFQM assessor team following the initial evaluation. They suggested that a 24-month interval is appropriate to allow for the effective implementation of improvement actions, as well as to observe their effects at both strategic and operational levels.

The decision to conduct reassessments at this interval was also supported by the management team, which aimed to use the EFQM model as a continuous tool for organizational diagnosis and development, rather than as a one-time initiative. Thus, the reassessment process is planned as an integral part of the management cycle, aligned with the annual review of strategy and overall performance. The reassessment not only validates the progress made but also allows for the adaptation of action directions according to new challenges and opportunities, supporting the organization's sustainable strategic transformation.

4. Conclusion

The EFQM model represents an integrated strategic framework that helps organizations assess their performance, align their activities with long-term objectives, and respond to the challenges of a rapidly changing world. Through its systemic structure and RADAR logic, the model offers a balance between analyzing processes and results, supporting a culture of learning, innovation, and continuous improvement, with a strong focus on creating value for all stakeholders.

The EFQM 2025 version consolidates this approach, positioning the model as a true tool for strategic transformation and sustainability. Emphasis is placed on adaptability, resilience, and transformational leadership, integrating ESG principles deeply into organizational decisions and processes. Thus, excellence becomes inseparable from responsibility towards society and the environment.

By promoting systems thinking, partnership ecosystems, and co-created value, EFQM 2025 provides a practical guide for organizations that aim not only to perform but also to remain relevant, agile, and sustainable in a complex and unpredictable context. Thus, the model becomes more than just an assessment tool, it is a platform for transformation and a framework for modern organizational leadership.

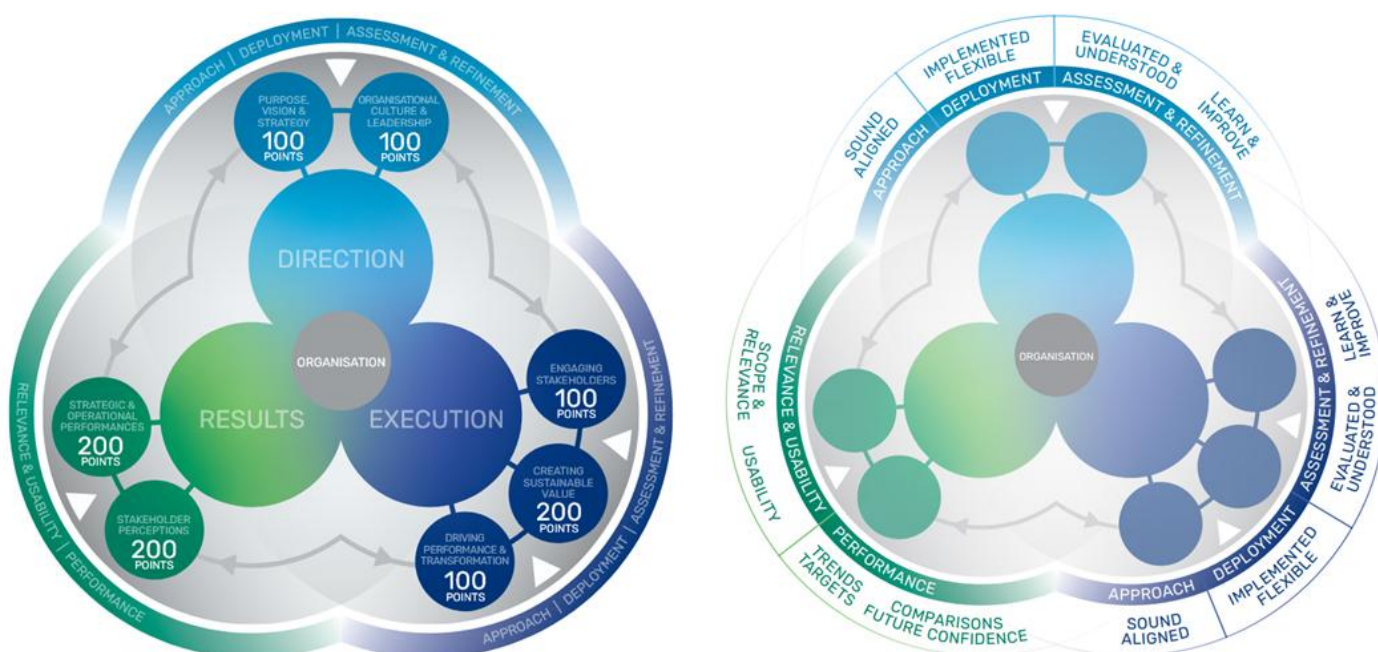


Fig. 7. The EFQM Model 2025

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COMPARATIVE ANALYSIS OF MOTOR THIRD PARTY LIABILITY INSURANCE FROM THE PERSPECTIVE OF CONSUMER PROTECTION

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Abstract: The paper highlights the importance of consumer protection in the field of motor third-party liability insurance, both in traditional and digital purchases. It has been demonstrated that digitization, although it brings speed and autonomy, cannot completely replace the role of human advice. Triangulation analysis (survey, contracts, advertising) shows that the lack of personalized information makes consumers vulnerable. The implementation of a "Human Checkpoint" in the online process is proposed to increase the level of customer education and understanding. The main conclusion is that a sustainable future for RCA effectively combines technology with human support.

Keywords: RCA, digitization, counseling, information, protection.

Cuvinte cheie: RCA, digitalizare, consiliere, informare, protecție.

1. Introduction

Motor third-party liability insurance (MTPL) is a key element of consumer protection in the automotive sector, being mandatory for all owners of registered vehicles. At the same time, MTPL serves to guarantee compensation for persons injured in road accidents.

The purchase of insurance is undergoing a major transformation, with the shift from direct interaction with agents and brokers to online purchasing using digital platforms and mobile applications. This transition brings advantages, but also challenges, especially in terms of providing accurate information to consumers and the risk of unfair commercial practices. [1]

In this paper, we aim to analyze the role of human interaction in the RCA purchase process and the impact of digitization on consumer protection, addressing issues such as understanding contractual terms, satisfaction levels, the importance of advice, and the specific risks of online purchasing. The research is based on an online questionnaire distributed to people in order to identify their perceptions and experiences in the RCA purchase process. It also examines how current legislation (Government Ordinance No. 21/1992, Law No. 132/2017, Law No. 158/2008) protects consumers and proposes solutions for improving commercial practices. [2]; [3]

2. Current study

Consumer protection in Romania is ensured by the state through guaranteed access to products and services, accurate information, the defense of legitimate rights, and consumer involvement in decision-making. The law applies to both new and used or reconditioned products. The main rights of consumers include protection against risks and complete information. Access to a variety of products and services, the right to compensation, and the possibility of organizing into associations to defend their interests.

RCA regulations (Law 132/2017)[4];[5] establish the conditions of policies, the rights and obligations of the parties, as well as the obligation to clearly inform consumers. Government Ordinance 21/1992 requires that information be accessible in Romanian, and Law 158/2008 prohibits misleading advertising.

The digitization of the RCA policy purchase process has also brought new challenges for consumer protection. The issuance of contracts in electronic format, the lack of direct human advice, and possible difficulties in understanding the contractual conditions can generate risks

. However, ongoing adaptation of the rules is necessary to address the challenges posed by emerging technologies.

Currently, motor third-party liability insurance is regulated by clear rules that establish the rights and obligations of the parties, ensuring transparency of information provided to consumers and protecting them against unfair practices. However, with the shift to online purchasing, new challenges arise regarding the effective enforcement of these rules and maintaining an adequate level of consumer information and protection.

3. Case study

In recent years, digitization has significantly transformed the way MTPL policies are offered and sold. Insurance companies have introduced online platforms, mobile apps, and electronic signature options,

aiming to reduce processing time, increase customer autonomy, and optimize costs. However, this rapid transition also comes with risks: the lack of personalized advice can lead to a superficial understanding of contracts, and digital platforms do not always clearly highlight exclusions or risks. Thus, consumers who are less familiar with financial terms may become vulnerable, which highlights the importance of combining digitization with educational support and advice.

The research is quantitative in nature and aims to analyze consumer behaviors and perceptions in the purchase of MTPL policies. A structured online questionnaire was used to collect data, which looked at aspects such as satisfaction levels. The level of information and perception of risks associated with purchasing methods. The questionnaire, consisting of 13 closed and open questions, was distributed online to a sample of at least 20 people, aged between 18 and 60, from urban and rural areas, selected from among vehicle owners who had purchased RCA in the last 2 years. The research tests the following hypotheses: consumers are more satisfied and better informed when purchasing RCA through human interaction, and the perceived risk is higher for online purchases. This methodology provides a solid framework for achieving the study's objectives and assessing the impact of digitization on consumer protection.

4. Questionnaire results

The survey involved 50 respondents, distributed almost equally by gender and place of residence, but predominantly young people between the ages of 18 and 25. The majority (83.3%) had purchased an RCA policy in the last two years, confirming the relevance of the group analyzed. Interestingly, 76.5% preferred human interaction when purchasing, while only 23.5% opted for the online environment, showing that, although digitization is advancing, brokers and agents remain essential.

The main reason for choosing the method was speed (35.3%), followed by human advice and advantageous price (29.4% each). In terms of information, almost 90% said they received clear information, but only 64.7% fully understood the contractual terms. Satisfaction was higher among those who used advisors, confirming the hypothesis that human interaction positively influences the perception of the service.

In terms of risks, more than half of respondents perceive online purchases as riskier, citing issues such as data security, incomplete information, or difficulties in obtaining compensation. Finally, participants suggested useful improvements: payment in installments, price transparency, complete digitization, efficient assistance, and clear guidelines on the terms and risks of motor vehicle liability insurance.

5. Tables and figures

Presentation of the RCA market and the offers analyzed: This subchapter compares the five main insurance companies offering RCA services: Allianz-Țiriac, Groupama, Omniasig, Asirom, and Generali. The analysis includes the estimated annual price, bonus-malus class, company seniority, human component, assistance in case of damage, contract clarity, type of advertising, and applicable framework law. The resulting table highlights the differences in terms of agent professionalism, application accessibility, and level of contractual transparency.

Table 1: Comparison of insurance companies

Criterion	Allianz-Țiriac	Groupama	Omniasig	Asirom	Generali
Estimated price/year (class B8)	510 RON	495 RON	505 RON	490 RON	520 RON
Bonus-malus class	B8	B7	B8	B6	B8
Company age	30+years	20+ years	25+ years	30+years	190+ years global, 20+ Romania
Human component	Efficient advisors, quick response	Direct relationship, friendly agents	Professional call center, but sometimes busy	Friendly staff, but variable	Trained staff, digitalized support
Claims assistance	Mobile app, fast	App + direct centers	Call center + claims centers	24/7 telephone assistance	App + online platform

MTPL contract – clarity	Transparent, complete	Clear, explanatory	detailed but formal terms	Sometimes ambiguous	Well-structured contract
Advertising	Focus on quality and responsibility	Emphasis on reliability and safety	Convincing, with discounts	Emotional, long-standing loyalty	Premium, stability, and tradition
Framework law	OG 21/1992 + Law 132/2017	OG 21/1992 + Law 132/2017	OG 21/1992 + Law 132/2017	OG 21/1992 + Law 132/2017	OG 21/1992 + Law 132/2017

For a concrete analysis, we selected two RCA policies issued by Grawe and Allianz-Țiriac, corresponding to two different consumers. The analysis takes into account the bonus-malus class, the total premium paid, the type of purchase, the existence of direct settlement, access to the mobile application, after-sales support, and the degree

The image shows a complex insurance policy form from Grawe Romania. It includes sections for:

- 1. CARTE INTERNAȚIONALĂ DE ASIGURARE PENTRU AUTOMOBILĂ**: International Motor Insurance Card.
- 2. EMISĂ SUB AUTOTESTAT**: Issued under the authority of the Romanian Automobile Insurance Company.
- 3. VALABILITATE - VALID**: Validity section with dates from 08.12.2023 to 07.12.2024.
- 4. VALABILITATE TESTIFICATĂ**: Testified validity section.
- 5. DATE PERSONALE**: Personal data of the policyholder.
- 6. DATE VEICUL**: Vehicle details including make (VW), model (GOLF), and registration (B23FXT).
- 7. DATE ASIGURARE**: Insurance details including the broker (INTER BROKER S.R.L.) and the policy number (RO/26/J26/JA 093796117).
- 8. DATE DE CONTACT**: Contact information for the insurer and broker.
- 9. DATE DE PLATĂ**: Payment details.
- 10. DATE DE RĂSPUNDERE**: Liability details.
- 11. DATE DE ANULARE**: Cancellation details.
- 12. DATE DE REVENIRE**: Return details.
- 13. DATE DE REVENIRE**: Return details.
- 14. DATE DE REVENIRE**: Return details.
- 15. DATE DE REVENIRE**: Return details.
- 16. DATE DE REVENIRE**: Return details.
- 17. DATE DE REVENIRE**: Return details.
- 18. DATE DE REVENIRE**: Return details.
- 19. DATE DE REVENIRE**: Return details.
- 20. DATE DE REVENIRE**: Return details.

of transparency. (see Table 2)

Fig. 1: Grawe company RCA policy

Contract de asigurare de răspundere civilă auto RCA, seria RO/07/R7/YD Nr. 123462438, emisa de Allianz-Tiriac. Documentul conține informații detaliate despre asigurător, asigurat, vehicul și condițiile contractului.

Fig. 2: Allianz-Tiriac motor vehicle liability insurance policy

Table2 : Comparison of two real RCA policies		
Criteria	Allianz-Tiriac	Grawe
Bonus-Malus Class	M1 (malus)	B8 (bonus)
Total premium (RON)	1635	1057,97
Direct debit	Included	Not included
Vehicle power (kW)	51	103
Cylinder capacity (cc)	1422	1968
Purchase	Broker (OVb)	Broker (Inter Broker)
Digital platform	Allianz app	Basic website
Helpline 5	From	From
Access to tariff simulation	Yes (Allianz platform)	Limited (via broker)
Information transparency	Partially	Low

Advertising and emotional influence in RCA



Fig. 3: RCA advertisement that violates the principles of information



Figură 4: Reclamă RCA corectă

In a competitive market such as RCA insurance, advertising plays a key role in influencing consumer decisions. While brokers offer personalized advice and decision-making support, digital advertising focuses on speed and price, risking transmitting incomplete information and exploiting emotional impulses. The study of advertisements shows clear contrasts: aggressive advertisements, such as "RCA 100% Ieftin", put pressure on consumers and can be misleading, while balanced campaigns, such as that of UNSAR - ASF, promote responsibility and safety, respecting the legislation. Ultimately, a balance between information, clear contracts and fair advertising is essential to protect consumers.

Table3 : Triangulation analysis

Evaluated criterion	Consumer survey	RCA contracts (Allianz / Grawe)	RCA ads & websites
Level of information	88% said they were informed (mainly through brokers)	Allianz - partial information / Grawe - technically ambiguous	Focus on price, not clarity or education
Clarity of clauses	Only 64.7% fully understood them	Allianz - clearer terms / Grawe - difficult to interpret	No clear explanations or guidelines
Access to human counseling	76.5% had human interaction	Both clients were guided by brokers	Fast sales-oriented interfaces without consultants
Perceived risks	52.9% consider online shopping more risky	Allianz offers direct settlement, Grawe does not	Risks are minimized or absent from communication
Accessibility & ease of use	Online platforms considered less intuitive	Allianz - mobile app / Grawe - simple interface	Focus on autonomy, not ease of understanding

1. Comparative analysis through triangulation

Triangulation analysis compares consumer perceptions, the actual content of MTPL contracts, and the messages conveyed through advertising, highlighting any discrepancies between expectations and reality. This approach allows for a deeper understanding of how marketing, actual experience, and contractual obligations influence consumer decision-making in the MTPL market.

The triangulation analysis (see Table 3) carried out in this paper compares consumer perceptions, the content of RCA contracts, and the messages conveyed through advertising, highlighting the discrepancies between the expectations created by marketing and the reality of the contracts. The results show that, although digitization brings advantages such as speed and autonomy of decision-making, consumers are better

informed, more satisfied, and perceive less risk when they receive human advice. Advertisements tend to oversimplify, and

Contracts are difficult to understand without personalized explanations, which means that brokers' support remains essential.

The paper proposes an innovative solution—the introduction of a "Human Checkpoint" in the digital RCA process, whereby consumers receive clear explanations from a certified advisor before signing the policy. This measure would increase the actual level of information and reduce disputes, ensuring a balance between the advantages of digitization and consumer protection. In conclusion, the study emphasizes that technological progress should not eliminate the human component, but rather integrate it intelligently, making it more accessible and efficient.

2. Conclusions

In conclusion, the research emphasizes that consumer protection in the MTPL field cannot be guaranteed solely through legal regulations or rapid digitization, but through a smart balance between technology and the human factor. The ideal future of the RCA market is a "digital-human" one, where technological innovation becomes a tool for information, education, and advice, rather than a mere means of accelerated sales. Only in this way will consumers be able to make free, fair, and well-informed choices, benefiting from transparency, personalized support, and a higher level of protection. In essence, real progress in this sector means not only faster and more accessible policies, but also more informed, confident, and better-protected consumers in the face of market risks and pitfalls.

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CASE STUDY ON CUSTOMER ORIENTATION IN THE TELECOMMUNICATION SECTOR

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***ABSTRACT:** This paper aims to identify and analyze the main customer orientation strategies employed by leading companies, with a focus on a comparative study between the Apple and Samsung brands. It highlights the tactics and strategies these companies use to create customer value, build loyalty, and differentiate their products in a competitive market. Key concepts such as personalized customer experience, innovation driven by consumer needs, and the importance of feedback in the continuous improvement process are also addressed. The paper emphasizes the central role of the customer in modern marketing and product development strategies.*

KEYWORDS: ISO 9001, leadership, customer profile.

1. Introduction

In the current context of a globalized market and increasingly fierce competition among brands, customer orientation has become a key element in the successful strategy of organizations. Companies can no longer overlook the voice of consumers, and continuous adaptation to their needs, desires, and expectations has become a decisive differentiating factor. Customer orientation strategies involve an integrated approach aimed not only at attracting but also at retaining customers by offering consistent and personalized experience.

This paper analyzes various strategies applied by renowned companies, with a focus on two emblematic and representative brands in the technology industry: Apple and Samsung. The study aims to highlight how these companies manage to anticipate and effectively respond to market demands by leveraging customer feedback and building lasting relationships with their clients. Understanding these strategies provides a valuable framework for developing effective practices in any field that places the customer at the core of its activity.

2. Current status

Introductory concepts

ISO 9001:2015: This international standard is based on the quality management principles outlined in ISO 9000. These descriptions include a statement of each principle, a justification of why the principle is important for the organization, examples of benefits associated with the principle, and typical actions that can improve organizational performance when the principle is applied. The quality management principles are:

- customer focus;
- leadership;
- engagement of people;
- process approach;
- improvement;
- evidence-based decision making;

- relationship management with interested parties. [1]

Customer focus

Top management must demonstrate leadership and commitment with respect to customer focus by ensuring that:

- a) customer requirements, as well as applicable legal and regulatory requirements, are determined, understood, and consistently met;
- b) risks and opportunities that can affect the conformity of products and services and the ability to enhance customer satisfaction are identified and addressed;
- c) customer satisfaction enhancement remains a focus.

Table 1.1 below summarizes relevant information regarding the most well-known and best-selling mobile phone brands, highlighting their popularity among consumers.

Table 1.1. Information Regarding the Most Well-Known and Best-Selling Mobile Phone Brands

Brand	Year of foundation	Country of origin	Customer orientation
Apple	1976	SUA	It focuses on premium user experience, an integrated ecosystem (iOS, Mac, etc.), high-quality support, and strong customer loyalty. Emphasis on simplicity and privacy.
Samsung	1938	South Korea	Offers a wide range of products for different budgets. Constantly innovates (e.g., foldable phones).
Xiaomi	2010	China	Focused on value for money, it has an active online community, and listens to user feedback.
Huawei	1987	China	Emphasis on technological innovation and high-performance cameras.

Considering the four brands analyzed in the previous table, a decision has been made to detail the market strategies of the two most popular brands – Samsung and Apple – due to their significant impact on the mobile phone industry.

The relevant standards for customer orientation, continuous improvement, and leadership will be analyzed for both companies, Apple and Samsung.

Apple

Founded in 1976 by Steve Jobs, Steve Wozniak, and Ronald Wayne, Apple is a symbol of innovation and premium quality. Through an integrated ecosystem, its products – iPhone, iPad, MacBook – offer a seamless experience, appreciated for their elegant design, intuitive interface, and dedicated user support.

Samsung

Founded in 1938, Samsung has become a global technology giant, offering a diverse range of products from smartphones to home appliances. It is renowned for innovations such

as AMOLED displays and foldable devices, targeting various market segments through aggressive marketing strategies. The name Samsung comes from the Korean language and means “three stars” (sam = three, sung = stars).

Both brands have succeeded in building loyal customer bases and have profoundly influenced the technology industry through customer satisfaction-oriented strategies and continuous innovation.

Competition between brands

According to Counterpoint’s Global Monthly Handset Model Sales (Sell-Through) Tracker, December 2024 (Fig. 1.2), a comparison of sales between the two brands, Apple and Samsung, was conducted over the years 2023–2024.

Apple holds the leading position in the study based on the top 10 smartphone products. In 2023, Apple featured seven products in the top sales, but in 2024, the number of top-selling products decreased to six.

Apple, the producer of the famous iPhone, was the only major mobile phone manufacturer to register an increase in units sold in 2023, according to an IDC study. The American company’s sales grew by 3.7% last year, reaching 234.6 million units. Samsung sold 226.6 million units, reflecting a 13.6% decline in shipments.

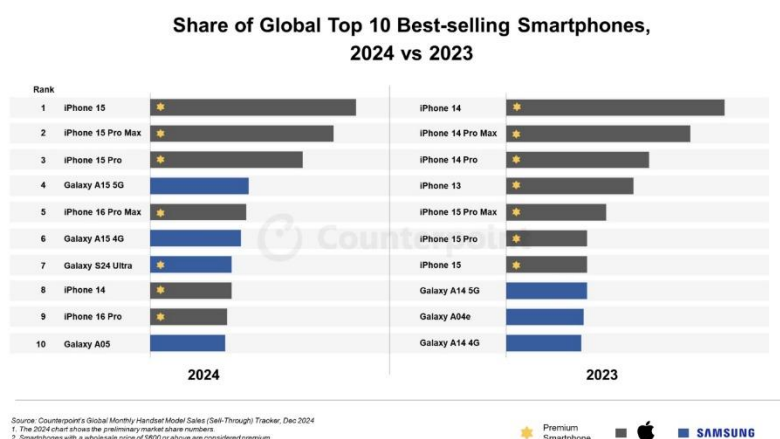


Fig. 1.2. Source Counterpoint’s Global Monthly Handset Model Sales (Sell-Through) Tracker [3]

Customer Orientation

Apple

According to the standard, within the approach to customer satisfaction and requirements, Apple personally manages customer facilities by introducing a technical and public relations department.

Apple cultivates a very loyal customer base due to consistent quality, unique design, and a premium experience offered. Apple focuses on creating an integrated ecosystem that enhances the value delivered to customers and maintains their trust in the long term. Customer trust is a central pillar of its strategy. Apple invests in continuous training and recognizes the individual contributions of its employees.

Process performance and customer satisfaction are continuously improved, and customer feedback is used to identify and resolve issues. At the core of a proper customer orientation lies leadership, a concept supported by CEO Tim

Cook, as reflected in statements such as: "We do what is right, even when it's not easy." and "We believe that how we behave is as important to Apple's success as making the best products in the world. Our Compliance and Business Conduct policies form the foundation of how we operate and put our values into practice every day."

According to IDC studies, Apple held a market share of 20.1% in 2023 regarding shipments, while Samsung reached 19.4%, and Xiaomi 12.5%. Oppo had an 8.8% market share, and Transsion held 8.1%. Transsion, through its brands Tecno, Infinix, and Itel, recorded a growth of 30.8% last year.

In the Chinese market, Apple offers customers a limited-time discount on some of the latest iPhone models.

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The company led by Jobs was built on the principle of innovation. One of the pieces of advice given by the Apple executive to a human resources portal highlighted that a leader must always come up with new ideas and fresh initiatives to improve the organizational mission: "Regardless of the industry you operate in, constant innovation aligned with your mission will keep you one step ahead of other players." [4]

Samsung

Samsung also strives to meet and exceed customer expectations through cutting-edge technological products. The company is known for its rapid adaptability to market demands and constant innovation, with highly customizable and accessible products. For example, the diversity of Galaxy phone models caters to a wide range of preferences and budgets.

Samsung considers ethical management not just a tool to respond to rapid changes in the global business environment but also a driver for building trust among its various stakeholders: customers, shareholders, employees, business partners, and local communities. In line with its goal of becoming one of the world's most ethical companies, Samsung continues to train its employees and operate monitoring systems, applying a fair and transparent corporate governance system.

Samsung's five business principles are:

- We respect laws and ethical standards
- We maintain a clean organizational culture
- We respect our customers, shareholders, and employees

Samsung states: "We turn customer satisfaction into our absolute priority. We provide products and services that meet customer needs and expectations. We maintain a sincere and friendly relationship with our customers and humbly accept suggestions and complaints. We also respect and honor information. Our leadership style is oriented towards the value offered to shareholders.

We provide shareholders with long-term benefits through reasonable investments and improved operational efficiency. We create stable benefits through solid management activities and increase the company's market value. We also respect the rights, reasonable requests, and ideas of shareholders.

We strive to improve the 'quality of life' of our employees.

We offer all employees equal opportunities and treat them fairly, in accordance with their abilities and performance. We encourage employees' continuous self-development and

support necessary improvements to fulfill tasks. At the same time, we create a work environment that can function autonomously and creatively."

- We care about the environment, safety, and health
- We are a socially responsible corporate citizen

Samsung keeps its customers close by offering promotions, vouchers, and discount codes for the newest phone models launched on the market.

Its two main objectives are to create products and services that provide maximum customer satisfaction and to maintain the number one position in its field of activity.

3. Data Collection – The Questionnaire

Between April 23–30, 2025, a case study has been conducted composed of 13 questions over 7 days. The questionnaire was sent to approximately 100 people, and we received 52 responses. The following figures present the obtained statistics and their interpretation. Analyzing data from the first three questionnaire questions (Fig. 1.4), it can be observed that the majority of respondents (aged 18–25) belong to the younger segment of the population, indicating a high interest in the topic, likely due to their familiarity with technology and high usage of mobile phones. Age groups 26–45 and 46–60 were less represented, suggesting either a lower willingness to participate or less exposure to the questionnaire distribution channel. [5]

From a gender perspective, 74.4% of respondents were female, while only 25.5% were male. This imbalance might reflect either greater openness among women to participate in surveys or initial distribution of the questionnaire predominantly within female social circles.

Regarding the area of origin, 80.4% of participants were from urban areas, while only 19.6% were from rural areas. This result suggests a concentration of responses in urban zones, where internet access and mobile device availability are easier, and exposure to such initiatives is higher.

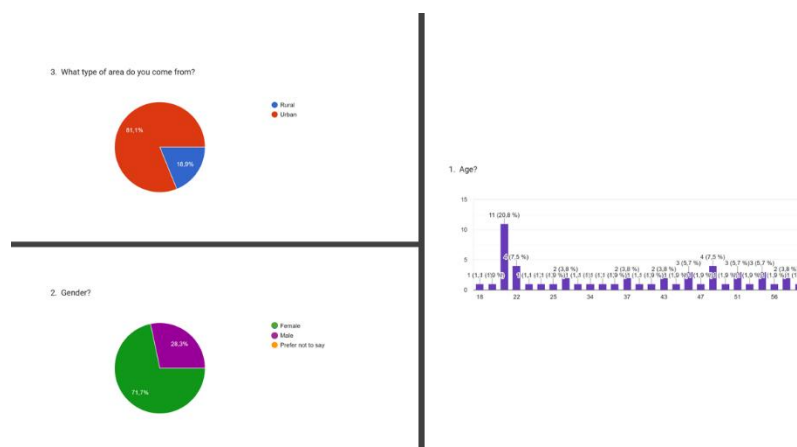


Fig. 1.4. The results of the first three questions of the study

The majority of respondents use Apple (41.2%) and Samsung (39.2%) phones, while other brands, such as Xiaomi (7.7%), have a lower presence (Fig. 1.5). This indicates a clear preference for premium brands.

Regarding usage duration, 76.5% of participants have been using products from their current brand for over 3 years, which reflects a high level of loyalty and satisfaction. The brand quality ratings are generally very high: most respondents gave the maximum score (5) for aspects such as understanding user needs, customer communication, responsiveness to

requests, product customization, and support service. This demonstrates a positive perception and a satisfying user experience.

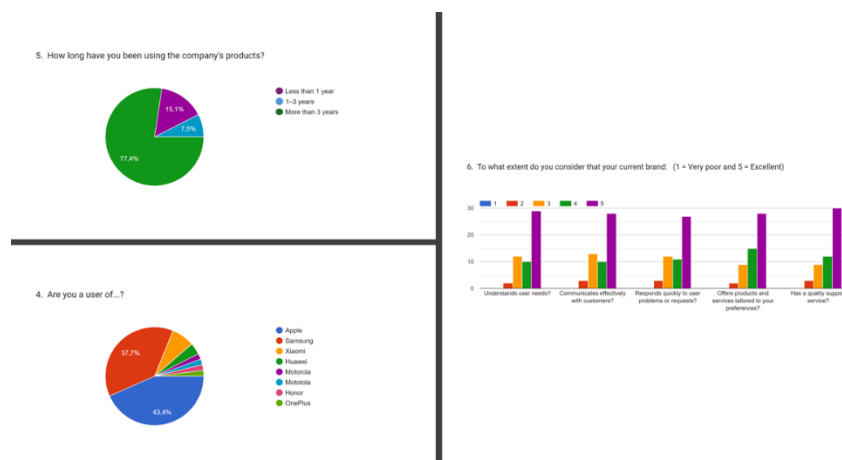


Fig. 1.5. Findings from questions 4, 5, and 6 of the study

To the question regarding the willingness to recommend their current brand (question 7), 42 respondents gave the highest score (5), reflecting a high level of satisfaction and trust in the brand used. Only a few gave lower scores, suggesting an overall positive perception.

Regarding the intention to change brands within the next year (question 8), 80.8% responded negatively, and 15.4% were unsure, indicating strong brand loyalty and a low degree of indecision. Only 3.8% expressed a clear intention to switch.

In question 9, the reasons mentioned by those willing to switch brands include battery life, promotional gifts, or market offers available at the time of purchase. These responses indicate that switching would be driven more by opportunistic factors than by major dissatisfaction.



Fig. 1.6. Findings from questions 7, 8, and 9 of the study

Only 25.5% of respondents noticed differences in how Apple, Samsung, or other brands relate to their customers, while 70.6% did not observe any differences (fig. 1.7). Those who answered affirmatively mentioned aspects such as Apple's superior product quality, differences in communication strategies, Samsung's better customer relationship, as well as Apple's limitations in terms of personalization and app usage.

11. If your answer to the previous question was "Yes," what differences have you noticed?

Superior quality, ease of use
Each of the two has different communication and promotion strategies
Battery health, image quality
I haven't noticed much of a difference

10. Have you noticed any differences in how Apple, Samsung, or other brands relate to their customers?

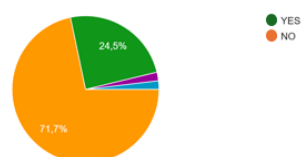
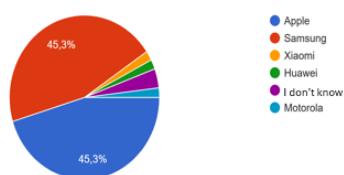


Fig. 1.7. Results of questions 10 and 11 from the survey

To the question regarding the brand with the best customer relationship, Samsung was chosen by 46.2% of respondents, closely followed by Apple with 44.2%, indicating that both brands are perceived positively in terms of their relationship with users. Other brands (Xiaomi, Huawei, Motorola) were mentioned by a very small percentage, highlighting their lower presence in consumers' overall perception (fig. 1.8).

Regarding the confidence to purchase other products from the same brand based on a positive experience, the majority of respondents (86.5%) stated that it significantly or very significantly influences their purchasing decision, which emphasizes the importance of a good experience in ensuring customer loyalty.

12. Which brand do you consider to have the best customer relationship?



13. To what extent does your positive experience with the brand give you confidence to purchase other products from the brand?

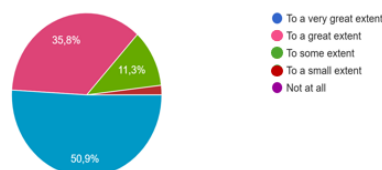


Fig. 1.8. Results of questions 12 and 13 from the survey

4. Conclusions

Analyzing the results, it can be observed that the brands in the study are largely aligned with the core principles of ISO 9001:2015, especially regarding customer focus, customer satisfaction, and continuous improvement.

In terms of overall customer satisfaction, the survey responses indicate a high level of contentment. To the question "Would you recommend your current brand to a friend?" (question 7), most respondents gave scores of 5 (excellent) and 4, indicating a high level of loyalty and trust.

The survey results show that users are generally satisfied with how brands understand their needs. For example, in response to the question "To what extent does your current brand understand user needs?" (question 6), most respondents rated it with 5 (excellent) and 4, suggesting that the brands are largely successful in meeting their users' expectations.

The survey highlights that users pay close attention to technical aspects such as battery life, camera quality, and the freedom to customize devices. For example, in response to the question "What would make you switch to another brand?" (question 9), some respondents mentioned "battery life" and "Apple's limitations in customization."

These findings suggest that although users are generally satisfied, there are opportunities for improvement that could further enhance the customer experience.

5. Bibliography

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