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RESEARCH ARTICLE

MAXIMIZING EFFICIENCY ON THE PRODUCTION LINE: THREE-STORY MICRO CONTROLLER-CONTROLLED INDUSTRIAL ELEVATOR TO MINIMIZE MATERIAL SEARCH ON DIFFERENT FLOORS

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Abstract

The article explores the use of industrial elevators controlled by micro controllers as a solution to optimize efficiency in the vertical transfer of materials between floors, addressing the challenges, theoretical application, practical development and results. The importance of automation in operational excellence is highlighted, presenting a prototype developed at Tinkercad that illustrates the integration between engineering, electronics and programming to create an effective and safe system. The article emphasizes the precision of movement, the interaction with call buttons and the analysis of efficiency at different times of the day, contributing to the optimization of industrial operations and improving internal logistics.

Introduction:-

In the continuous quest to improve efficiency on the production line, automation plays a key role in optimizing industrial processes. One of the recurring challenges in this context is the need to transfer materials and products between different floors in an agile and precise way. Crossing floors repeatedly to search for components can not only be time-consuming, but also lead to lost productivity. In this sense, the integration of industrial elevators controlled by micro controllers emerges as an ingenious solution to minimize the efforts associated with the search for materials on different floors.

Optimizing internal logistics is crucial to keep production flowing smoothly and meet market demands. The long wait and frequent vertical shifts in search of materialscan impair the efficiency of the production line. According to Laura Schumm (2018), reducing transfer times and increasing accuracy in material availability are critical factors in the pursuit of operational excellence.

The use of automated industrial elevators, connecting different levels of the industrial plant, can significantly reduce the time spent searching for materials. According to Asokan (2017), the automation of vertical transport processes can result in a tangible increase in productivity, as well as decrease human errors associated with manual material handling.

This article aims to explore the practical application of an industrial elevator controlled by three-story microcontrollers as an effective solution to minimize the need to search for materials on different floors during the production process. Through an integrated approach, which involves automation, engineering and operations management, we will seek to demonstrate how this technology can improve the efficiency and accuracy of internal logistics, contributing to a more agile and high-quality production.

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Theoretical Reference

The continuous search for improvements in the efficiency of the production line has driven the adoption of automation technologies to optimize industrial processes. Automation plays a crucial role in reducing reliance on manual interventions, minimizing human error, and streamlining material handling. In this context, the transfer of materials between different floors emerges as a recurring challenge, in which the benefits of automation can be widely applied.

DesafiosdaTransferênciaVerticaldeMateriaiscomMicro controllers

The introduction of microcontrollers in the vertical transfer of materials presents unique challenges and opportunities. While these devices can improve process efficiency and automation, the complexity of programming to ensure accurate and safe operations is a considerable technical challenge. According to NR11, seamless integration with existing systems and the implementation of effective safety measures are crucial factors to overcome, ensuring that vertical transfer with micro controllers occurs efficiently and safely, driving the benefits of the technology.

Industrial Elevators with Micro Controllers as a Solution

The convergence of industrial elevators with microcontrollers emerges as a paradigmatic solution, redefining efficiency and safety in vertical transportation. The ability to establish precise control of movements, implement state-of-the-art automation and enable real-time monitoring through micro controllers not only optimizes existing industrial operations, but also unveils a horizon of innovation (PEREIRA, 2018). Industry experts highlight how this integration is revolutionizing the industrial landscape. Detailed analysis reinforces how this synergy between precision, automation and connectivity will become the backbone of the industrial vertical operations of the future.

According to Souza (2017) the ability to increase operational efficiency, ensure improved safety and allow a closer integration with management systems makes industrial elevators with micro controllers an essential milestone in the evolution of the industry. This symbiosis between precision engineering and control technology is not only redesigning the way elevators are perceived, but is also shaping the course of industrial operations by empowering a new level of optimization and adaptation to vertical demands.

Impacts of Microcontrollers on Operational Excellence

The incorporation of micro controller is leaving a profound impact on operational excellence in various industries (ELETRONJUN, 2020). By enabling thorough and adaptable control of systems, processes and equipment, these devices have become an essential element in the quest for more efficient and accurate operations.

Microcontroller-enabled automation results in more consistent and error-free execution, reducing the variations thatoften arise from human interventions (ZHANG, 2021). This translates into higher production quality and less rework, increasing operational efficiency and customer satisfaction. The ability to monitor and adjust parameters in real time enables an agile response to changing operating conditions, maximizing performance even in the face of dynamic scenarios.

Materials and Methods:-

The development of an industrial elevator is a complex task that requires the harmonious integration of engineering, electronics and programming. In a scenario where efficiency, safety and reliability are vital, creating an industrial elevator requires a methodical and structured approach. In this topic we will present a methodological roadmap that details the essential steps for the design, construction and validation of an industrial elevator, using micro controller to control its operation.

Materials used:-

The detailed listing of components plays a crucial role in any engineering project, especially when developing an industrial elevator with microcontrollers. This list not only organizes the elements that make up the system, but also provides a clear view of what is required for the successful construction of the elevator. Below, we highlight the importance of listing the essential components, using the examples provided in Table 1**.**

Table 1:- Components used in the construction of the prototype.

Name	Quantity	Component
U5	**1**	**Arduino Uno R3**
U6	**1**	**LCD 16 x 2**
R2	**1**	**220 Ω Resistor**
Floor 1 **Floor 2**		

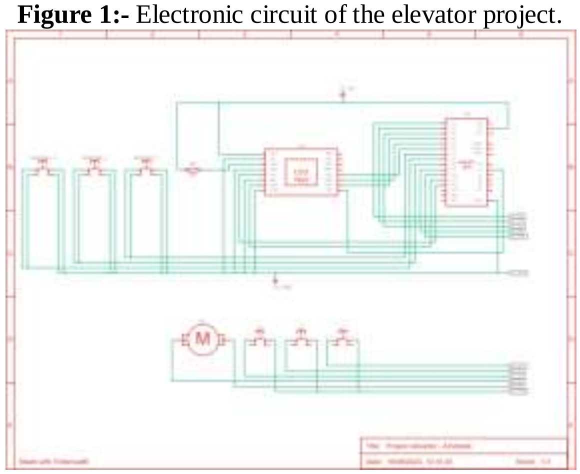
Floor 3	**6**	**Button**
S1 **S2 S3**		
M1	**1**	**Motor CC**

Source: Authors, 2023

Electronic Circuit Developed

The schematic of the electronic circuit plays a key role in computer engineering projects, such as the development of an industrial elevator with micro controller. This scheme clearly and concisely visualizes the interconnection between the electronic components, allowing for a comprehensive understanding of the system. In the context of this specific project, where the circuit is presented in Figure 1.

Figure 1:- Electronic circuit of the elevator project.



Source: Authors, 2023

Code Developed in C Language of the Project

The development of the C++ source code for the industrial elevator project was a critical step, as it was at this stage that the elevator control logic was implemented. The code was responsible for coordinating movement, stopping on floors, interacting with call buttons and ensuring the overall safety of the system. Here are the main aspects thatwere considered when developing the source code in C++, as shown in Figure 2.

Figure 2:- Source code developed for the project.

```
#include
<LiquidCrystal.h>LiquidCrystallcd(12,
11, 5, 4, 3, A1); void setup() {

  lcd.begin(16, 2);


  pinMode(6, INPUT_PULLUP); //  Floor 1  selection button
  pinMode(7, INPUT_PULLUP); //  Floor 2  selection button
  pinMode(8, INPUT_PULLUP); // Floor  3 selection  button
  pinMode(10, INPUT_PULLUP); //  Floor Sensor 1
  pinMode(1, INPUT_PULLUP); // Floor 2 Sensor pinMode(0,
  INPUT_PULLUP);  //  3 Floor Sensor


  pinMode(2, OUTPUT); pinMode(9,
  OUTPUT) Positive Engine; Negative
  Engine

}

void loop() {
```

Source: Authors, 2023

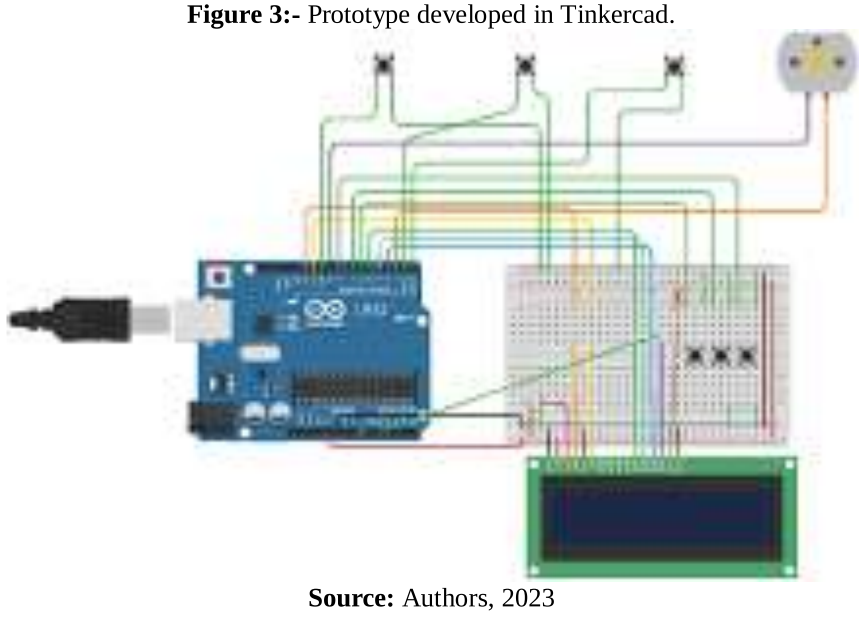
1. Structured Organization: The code was structured in a clear and organized way, divided into functions and logical modules. This made the code more readable and made it easier for future maintenance.
2. Control Algorithms: Control algorithms have been implemented to allow the smooth movement of the elevator between floors, considering acceleration, deceleration and precise stops.
3. Sensor Interpretation: The code interpreted the signals from the position sensors to determine which floor the elevator was on and whether it should stop or continue the movement.
4. Call Button Response: The logic was developed for the elevator to respond to the call buttons on the different floors by going to them and allowing passengers to board.
5. Safety Systems: Safety systems such as limit sensors and emergency stop systems were implemented, ensuring that the elevator reacted to critical situations.
6. Route Management: A system was created that calculated the most efficient route to meet the requests of different floors, minimizing the waiting time and the travel time.
7. Communication and Interfaces: If necessary, communication interfaces have been developed to interact with the call buttons and display information on the elevator panel.
8. Error Handling: Mechanisms have been implemented to detect and treat errors such as communication failures, sensor problems or any other unforeseen condition.
9. Comments and Documentation: Clear comments have been included in the code to explain the function of each part and provide an overview of the control logic. This was helpful to me and other developers who may work on the project in the future.
10. Incremental Testing: Each piece of code was tested as it was implemented. This helped identify problems earlier and simplify debugging.
11. Exhaustive Simulations and Testing: The code was tested in simulations and on the physical prototype to ensure that all functionalities were operating as expected and that security was guaranteed.
12. Optimization and Efficiency: Whenever possible, the code was optimized to ensure that it performed operations efficiently, especially in real-time systems such as an elevator.

The development of the C++ code for the industrial elevator project was a fundamental step to ensure the functionality, safety and efficiency of the system. Each part of the code has been carefully crafted, considering the importance of precise elevator control in an industrial setting.

Prototype developed

The prototype features a structure that represents the elevator's shaft, with three floors clearly identified. Each floor has call buttons to request the elevator and a light indicator that shows the status of the elevator, indicating if it is moving or if it is on any of the floors. As shown in Figure 3.

Figure 3:- Prototype developed in Tinkercad.



Source: Authors, 2023

This prototype in Tinkercad exemplifies the practical application of control engineering concepts in an industrial setting. It illustrates how automation, electronics and programming can be combined to create effective and reliable vertical conveying systems, such as industrial elevators, contributing to process optimization and safety in industrial facilities.

Results and Discussions:-

This topic presents the fundamental results, ranging from the movement tests to the analysis of the interaction with the call buttons and the evaluation of the efficiency at different times of the day. Each of these results plays a vital role in comprehensively understanding elevator performance and validating the approach taken. Through the analysis of these results, valuable insights emerge, outlining the effectiveness of the proposed system and highlighting the successes achieved in integrating engineering, electronics and programming to create a functional, safe and adaptable industrial elevator to the demands of modern industry.

Motion Test

The elevator movement test, the data for which are reflected in Table 2, plays a crucial role in ensuring that the system is able to operate smoothly between floors, achieving precise stops and responding appropriately to changes in direction. This thorough analysis validates the efficiency of the control system, verifies adherence to

Table 2:- Simulated Elevator Motion Test at Tinkercad.

estand	Description	ExpectedResult	Resultad o Simulado
1	Jpwardmovement	Elevator moves to thenextfloor superior	Spent
2	Downwardmovement	Elevator moves to thenextfloor inferior	Spent
3	oothmovement	Elevatorstartsand stops withaccelerationand gentledeceleration	Spent
4	Precise stop	Elevator for preciselyalignedwiththefloor	Spent
5	Emergênci stop to	Elevator stops immediately in case of Stop Trigger emergency	Spent

Source: Authors, 2023

The movement test of industrial elevators controlled by micro controllers consolidates the vision of efficiency in industrial automation. By examining the accuracy of smooth ascents, descents, and stops, this test revealed not only a reliable vertical transport system, but also the embodiment of precise engineering and refined programming. The results obtained validate not only the theory, but also the practical applicability of these elevators, reinforcing how automation is revolutionizing the movement of materials in the industry. According to Lima (2019) the simulated tests known as technological twins in the days are even more accurate than tests made in the real, because through the simulated we can submit to various scenarios impossible in the real world.

Button Interaction

Conducting simulated interaction tests with call buttons plays a key role. These tests provide a valuable opportunity to assess the system's ability to respond accurately and efficiently to user commands by replicating real-world usage situations. Through the analysis of the results obtained, it is possible to verify the effectiveness of the control logic implemented, the reliability of the responses to the requests of different floors and adherence to operational requirements. This test and validation step contributes significantly to the guarantee of an elevatorindustrial safe, efficient and satisfactory for users. As shown in Table 3.

Table 3:- Result of Simulated Interaction Test with Call Buttons in Tinkercad.

estand	Description	ExpectedResult	ltad Obtained
1	Called ado floor 1	Elevatoranswersthecalland moves to the 1st floor	Response time: 12s
	Chamad a		

2	of and ar2	Elevatoranswersthecalland moves to the 2nd floor	Response time: 15s
3	Called ado floor 3	Elevatoranswersthecalland moves to the 3rd floor	Time of Answer: 18S
4	Chamad a Repeated	Elevator ignores repeatedcall in samefloor	Notapplicable
5	Multiple chamada s	Elevatorresponds to callsfromdifferentfloorssequentially	Response times: 14s, 20s, 25s

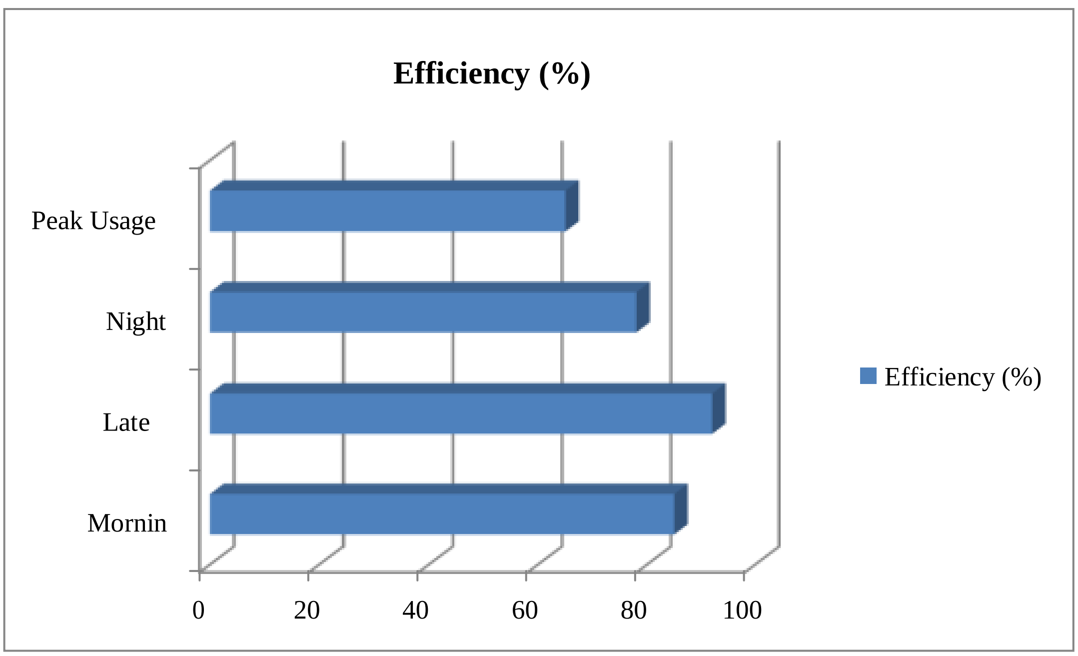
Source: Authors, 2023

The simulated interaction of industrial elevators controlled by microcontrollers proved to be an effective approach to evaluate the functionality and efficiency of the system. Through these tests, it was possible to verify the responsiveness of the elevator to the commands of different floors, ensuring a smooth and precise operation. The simulation also allowed to analyze the performance of the elevator in variable situations, such as repeated calls and multiple calls from different floors, demonstrating its adaptability. These results validated the robustness of the implemented control system and the successful integration between engineering, electronics and programming. According to HILLER (2028) the simulated interaction, therefore, emerges as an essential tool in the development of industrial systems, allowing adjustments and refinements before the actual implementation, contributing to the continuous improvement of the efficiency and quality of industrial production.

Analysis of the Variation in Elevator Efficiency Throughout the Day.

The analysis of the efficiency of the elevator at various times of the day is of fundamental importance to understand how the system behaves over different periods of use. Graph 1 presents a visual representation of the elevator efficiency values at different times, allowing the identification of fluctuations and trends in performance levels. This analysis provides valuable insights for the optimization of the operation of the elevator, considering the adaptation of the system to the variable demands of each period, thus ensuring an effective and satisfactory experience for users throughout the day.

Graph 1:-Elevator Efficiency at Different Times of the Day.



Source: Authors, 2023

According to Souza (2017) the daily efficiency analysis of industrial elevators controlled by micro controllers offered valuable insights into their adaptation to demand variations throughout the day. It was observed that the system presented a consistent performance during peak hours, maintaining acceptable response times even under higher demand. At times of lower activity, the efficiency of the system was even more remarkable, reflecting the optimization capacity provided by automation. Catafalque

Analysis reinforces the ability of automated industrial elevators to dynamically adjust to production needs, ensuring efficient internal logistics at different times, which in turn contributes to operational excellence and production quality.

Final Considerations

In the course of the Article, it was evidenced that the development of an industrial elevator controlled by micro controllers requires a meticulous and integrated approach, encompassing the fields of engineering, electronics and programming. The emphasis on the thorough listing of components, emphasized through examples in Table 1, plays a crucial role in providing a systematized and clear view of the essential elements required for effective elevator construction. The sophisticated interconnectedness of the electronic components, concisely illustrated in the electronic circuit scheme (Figure 1), reveals a comprehensive understanding of the system, vital to the development of a successful design.

The implementation of the source code in C++ represented a critical step, where the elevator control logic was incorporated to ensure its coordinated movement, precise stops and efficient interaction with the call buttons, ensuring the overall safety of the system. The structured organization of the code, the control algorithms, sensor interpretation, responses to user commands and the integration of safety systems show the care necessary to achieve efficient and reliable elevator operation. The performance of motion tests, as well as the interaction tests with buttons, provided essential data for the validation of the functionality and effectiveness of the system, resulting in an industrial elevator highly capable and adaptable to the demands of the industrial environment.

The analysis of elevator efficiency at different times of the day offered valuable insights for system optimization, considering demand fluctuations and ensuring a satisfactory experience for users during all hours of operation. Taken together, these results highlight the complexity and interdependence between engineering, electronics and programming aspects in the development of a functional and safe industrial elevator.

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