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INTEGRATED CONTROL AND MONITORING SYSTEM (ICMS) USING DIGITAL ELECTRONIC BOARDS FOR OBJECT MONITORING AND DETECTION AT SHORT DISTANCES

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Abstract: This scientific paper explores the use of single-board computers in various projects, particularly focusing on the practical development of an Integrated Control and Monitoring System (ICMS) designed for short-range object monitoring and detection. The adoption of this technology fosters advancements in electronic systems, microcomputers, and microprocessors, thereby enhancing their usefulness for educational and research initiatives. By incorporating real-time monitoring and data processing, this system is crucial in areas such as surveillance security and disaster management, and it also finds applications in industrial automation, environmental monitoring, smart buildings, agriculture, energy management, healthcare, transportation, military uses, and research and education.To assess the effectiveness of the ICMS, two simulations were carried out. The first simulation concentrated on wireless data transmission, showcasing the real-time collection, processing, and transmission of sensor data through a wireless communication module, with results shown on both an LCD and a laptop screen. The second simulation examined servo motor control driven by sensor feedback, where the motor adjusted dynamically in response to object detection within a defined range. These simulations validate the practical functionality and reliability of digital electronic boards in creating real-time monitoring and automation systems. The results of this study underscore the potential of ICMS technology to enhance smart applications and automation across various industries while also paving the way for further advancements in object detection, security, and real-time monitoring solutions.

Key words: Integrated Control and Monitoring System (ICMS), Digital Electronic Board, object detection and monitoring, short distances, surveillance security, simulation

1. INTRODUCTION

The topic of this scientific paper has wide-ranging applications in digital electronics, programming, and IoT devices, which are essential fields in today's digital landscape. The growing integration of smart technologies and real-time monitoring systems has spurred advancements in object detection, automation, and control systems, enhancing efficiency across various industries. In this context, programming and algorithm development are crucial, acting as foundational elements in the effective implementation of complex systems. This paper centers on the creation of an Integrated Control and Monitoring System (ICMS), which employs a digital electronic board for short-range object monitoring and detection (hereafter referred to as ICMS).

The use of digital electronic boards in different educational and research areas has greatly propelled technological progress and innovation. These adaptable, cost-effective, and programmable boards allow for easy integration with a variety of sensors, actuators, and communication modules, making them perfect for automation, control, and real-time data analysis. This paper emphasizes the significance of digital electronic boards as a vital component in developing intelligent systems, especially in the design of ICMS for real-time object detection.

This research illustrates the effective development of the Integrated Control and Monitoring System (ICMS), showcasing how it connects digital electronic boards, sensors, and other vital digital components. The system facilitates real-time object detection and monitoring, with results displayed on a computer screen. Furthermore, the incorporation of simulator radar technology improves the accuracy of object detection and allows for real-time data analysis. The information is stored in an

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online database, which supports efficient tracking, retrieval, and analysis to enhance decision-making across various applications.

To assess the effectiveness and functionality of the proposed ICMS, two MATLAB simulations are performed. The first simulation emphasizes wireless data transmission, where sensor readings are gathered, processed by a digital electronic board, and sent via a wireless communication module to an online database. The real-time data is shown on an LCD and a laptop screen, demonstrating the system's capability to monitor object presence from a distance. The second simulation investigates servo motor control based on sensor feedback, where the motor adjusts its position dynamically in response to object detection within a defined range. This simulation underscores the automation potential of ICMS and its possible applications in robotics, industrial automation, and security systems.

By integrating real-time detection, wireless communication, and automated response mechanisms, this research contributes to the advancement of modern control and monitoring systems. The findings of this paper emphasize the significance of digital electronics and IoT technologies in shaping next-generation intelligent systems for education, research, and industry. The results of the simulations confirm the feasibility, efficiency, and accuracy of the developed ICMS, paving the way for further enhancements in automation, security, and real-time monitoring applications.

2. DIGITAL ELECTRONIC BOARD

A digital electronic board is a compact computing system that includes only the essential circuitry needed for operation, often sold without external casings or accessories to keep costs low. These boards, commonly known as single-board computers (SBCs) or development boards, are highly versatile and programmable, allowing for integration into various digital platforms to build complex systems and advance the field of digital science [1], [2], [3].

At the heart of every digital electronic board is a microprocessor, which serves as the processing unit and includes multiple General-Purpose Input/Output (GPIO) ports for connecting external devices, integrating sensors, and supporting automation applications. Different manufacturers provide a wide array of microprocessors, each tailored for specific functions, with variations in capabilities, processing power, and cost, making them suitable for a range of scientific, industrial, and experimental uses [1], [3], [4].

One of the key advantages of modern digital electronic boards is the robust global online community that supports them. Enthusiasts, engineers, and researchers actively share projects, research papers, open-source code, and troubleshooting tips, which fosters innovation and speeds up learning. The availability of open-source software and hardware designs further empowers individuals to experiment, create prototypes, and contribute to advancements in science and technology [1].

Different applications necessitate specific board configurations. For example, some boards are optimized for multimedia processing, equipped with powerful microprocessors that can handle high-resolution video and audio playback, while others are designed for low-power embedded systems used in automation and robotics. The combination of hardware flexibility and software programmability makes these boards fundamental in the development of IoT systems, robotics, home automation, surveillance, and many other technological innovations [1], [4], [5], [6].

3. DIGITAL ELECTRONIC COMPONENTS AND PARTS FOR THE PRACTICAL PART

In this section are shown all the digital electronic components and parts that were used for the practical part of ICMS for object detection at short distances (see Tab. 1) [1].

Table 1 – Used digital electronic components and parts for the practical part [1]

Ordinal number	Type of components and parts
1.	Digital Electronic Board
2.	Laptop
3.	USB-cable
4.	Breadboard
5.	Jumping wires
6.	Servo Motor
7.	Sensor for Object Detection
8.	Wireless Communication Module
9.	LCD Display
10.	Power Supply (9V battery or adapter)

4. BLOCK DIAGRAM OF THE PROPOSED SYSTEM

In this section of the scientific paper is shown a block diagram of the proposed ICMS for object monitoring and detection at short distances (see Figure. 1). In the figure is shown all connectionsof the digital components and parts, which will give in the display or screen the detected objects from the sensor with the exact angle and distance, and these results are also sent to the online database through the wireless communication module, where they can be later analyzed and stored for further analysis and examination [1], [7], [8]. The power supply is mostly used for independent work of the ICMS in different conditions and situations, but also it can be used effectively by charging from the laptop if it's connected with USB cable [1], [9]. All the other digital components and parts are connected with jumping wire through the breadboard, and this integrated system is connected to the laptop through the USB cable, which the connection is with serial communication [1], [10].

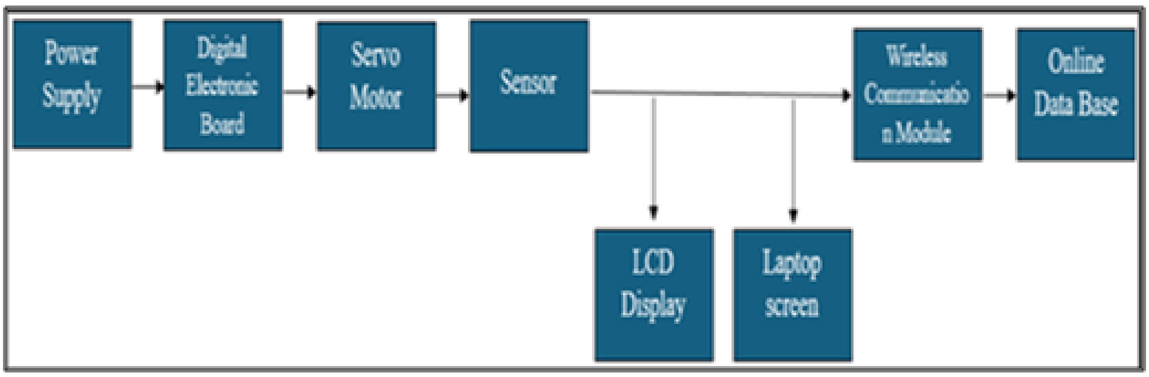

Figure 1 – Proposed Block Diagram of ICMS for object monitoring and detection at short distances

5. SIMULATION AND RESULTS

- **Simulation 1: Wireless Data Transmission for Sensor Readings**

This system simulates the collection of real-time sensor data and its transmission through a wireless communication module.The sensor data varies in a waveform, reflecting changes in distance measurements.The data sent over the network shows a similar pattern but includes minor variations caused by network noise or interference.The results illustrate how sensor readings can be transmitted wirelessly to an online database and displayed on an LCD screen or laptop.

- Objective

This simulation is designed to model how sensor data (such as distance or object detection) is transmitted through a wireless communication module to an online database while also providing real-time results on an LCD screen and a laptop.

- Methodology
  - A simulated sensor system produces dynamic readings over time.
  - The digital electronic board processes these readings.
  - A wireless module sends the data to an online database.
  - The readings are then displayed on both an LCD screen and a laptop interface.

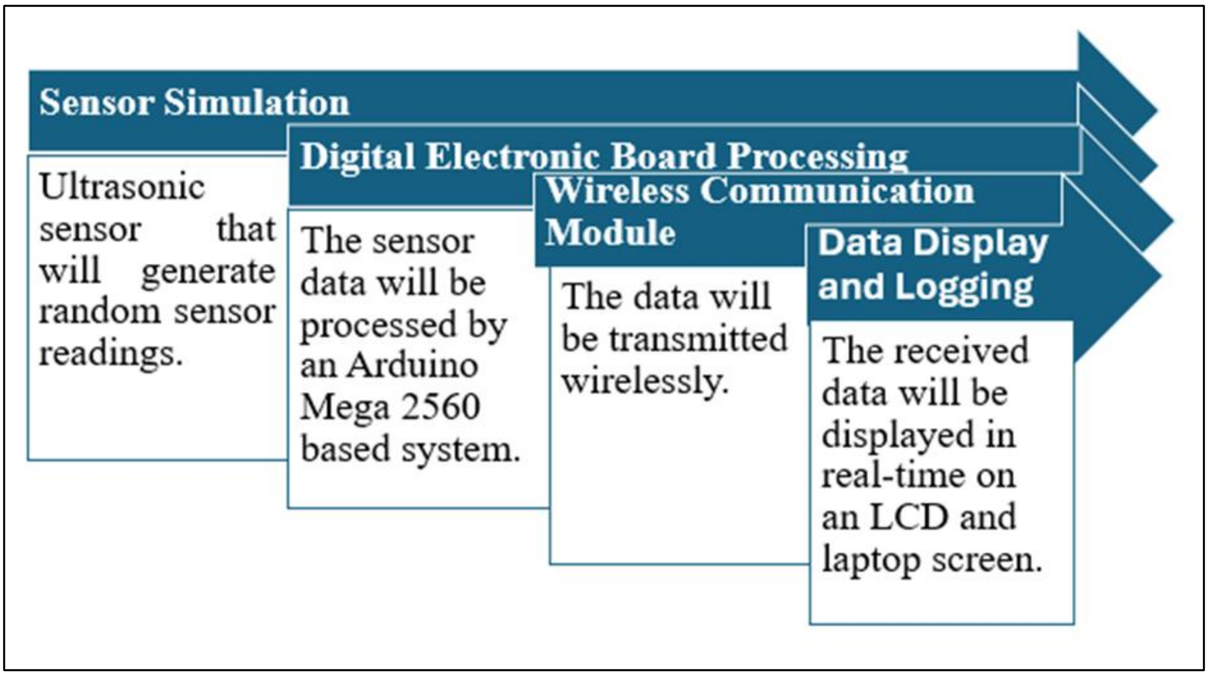

Figure 2 – Data Processing and Transmission Flow in Sensor-Based System

- Results and Discussion
  - The simulated data indicates a smooth transmission of sensor values, with only minor fluctuations caused by network latency.
  - The graphical results verify that data is accurately displayed in real-time on external devices.
  - This simulation showcases effective data logging and monitoring capabilities for remote sensor applications.

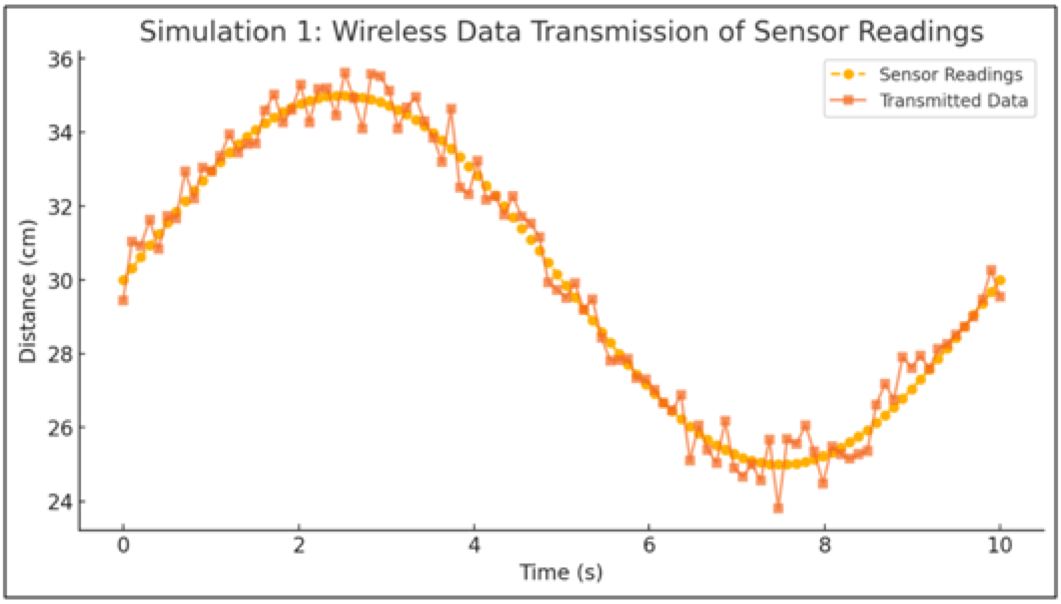

Figure 3–Wireless Data Transmission of Sensor Readings

- **Simulation 2: Servo Motor Control Based on Sensor Feedback**

The system triggers a servo motor when it detects an object within 30 cm.If the sensor identifies an object closer than 30 cm, the motor rotates to 90 degrees.When no object is present, the servo motor stays at 0 degrees.This configuration is beneficial for automated object detection and motion response systems.

- Objective

To create a servo motor control system that reacts dynamically to sensor inputs, showcasing a real-time feedback loop.

- Methodology

A sensor measures the proximity of an object and relays distance information to the digital electronic board.When an object is detected within 30 cm, the servo motor rotates to 90°.If no object is present, the servo stays at 0°.The data is transmitted and shown on an LCD screen.

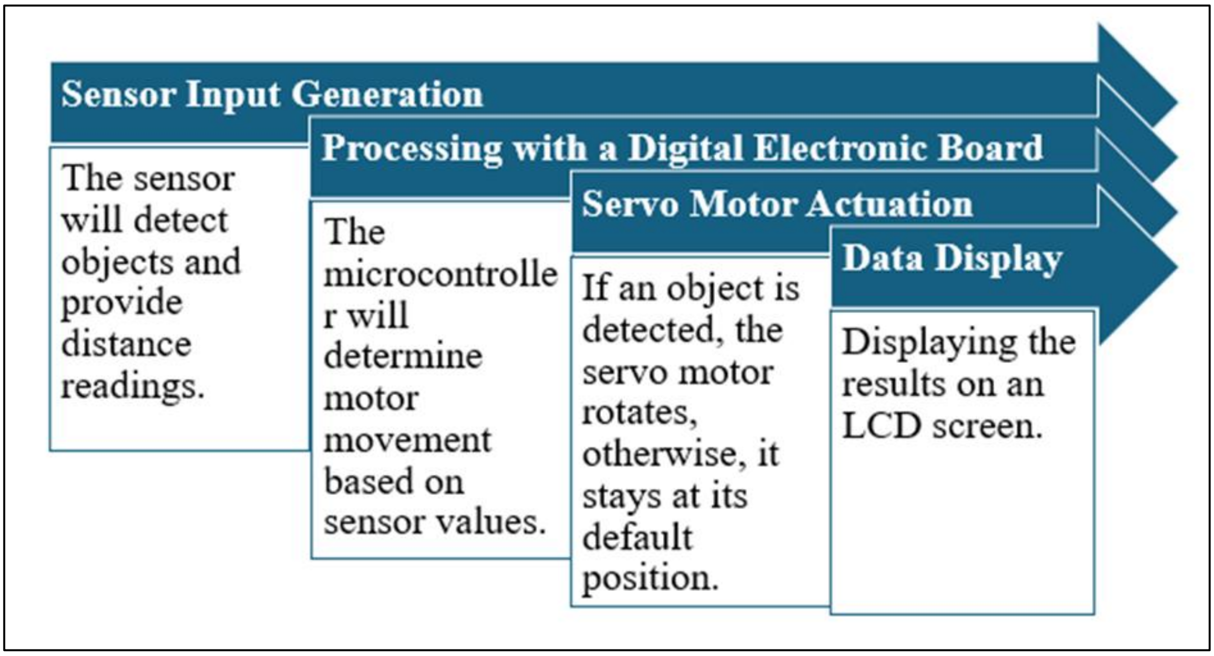

Figure 4 – Workflow of Sensor-Based Servo Motor Control

- Results and Discussion

The servo motor effectively responds to real-time sensor inputs.

The graph illustrates sharp changes when an object enters or leaves the detection area.

This demonstrates the system's capability to automate movement based on real-time data, which is beneficial for applications such as object tracking, robotics, and industrial automation.

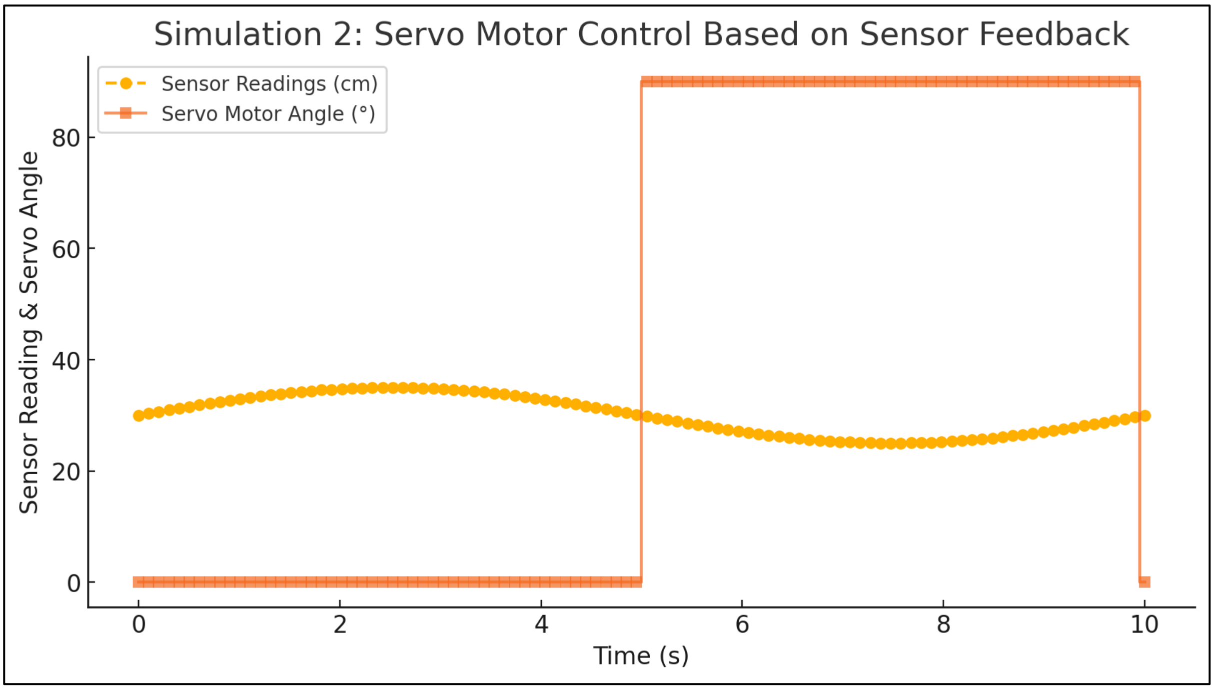

Figure 5 – Sensor-Based Servo Motor Control

6. ADDRESSING SEVERAL SIGNIFICANT SCIENTIFIC AND ENGINEERING PROBLEMS

The proposed ICMS using digital electronic board integrated with different electronic components and parts that simulate radar technology addresses several significant scientific and engineering problems [2 – 4]:

1. Real-time Object Detection and Tracking

Problem: Efficiently detecting and monitoring objects in real-time is crucial and important for applications in different fields, also for educational or research purposes. As we all know and have information on, all traditional systems can be expensive and complex to to implement [5 – 7].

Solution: The proposed ICMS uses low-cost digital electronic board, sensors, and other digital components and parts to provide a real-time, scalable, and affordable solution for object detection and monitoring at short distances. This enhances the ability to monitor and detect objects in various environmental conditions according to the performances of the sensor and the other used digital components and parts [8 – 9].

2. Data Integration and Wireless Communication

Problem: In contemporary IoT (Internet of Things) technologies, devices, gadgets, platforms, or apps, integrating digital electronic board with digital sensor data and wirelessly communicating it to a centralized online database or cloud platform for additional analysis and storage is a typical difficulty.Key concerns are ensuring data integrity, transmitting data in real time, and storing data efficiently [5 – 7].

Solution: Online databases and wireless communication modules are included in the ICMS to enable smooth data integration and transmission. This makes long-term data analysis and real-time monitoring possible, which are crucial for anomaly identification, predictive maintenance, and performance optimization [8 – 9].

3. Comparative Analysis of Detection Systems

Problem: It is essential to comprehend the benefits and drawbacks of various object detection methods (such as 180-degree vs. 360-degree) to choose the best technology or system for a given application [5 – 7].

Solution: The project offers important insights into the performance characteristics of 180-degree and 360-degree radar systems, including detection range, accuracy, and coverage, by generating and comparing them. By facilitating well-informed decision-making for certain use cases, this comparative analysis improves the technology's overall efficacy and efficiency [8 – 9].

4. Affordable and Scalable Solutions

Problem: Many of the object detection and monitoring systems currently in use are too expensive and complex for smaller businesses or applications with limited funding [5 – 6].

Solution: The system based on Arduino provides an affordable and expandable substitute. Advanced monitoring and detection technologies are now available to a wider range of applications, including small businesses, educational institutions, and hobbyists, thanks to their cost and simplicity of deployment [7 – 9].

5. Environmental and Safety Monitoring

Problem: Monitoring and tracking environmental conditions or changes and ensuring safety in various settings such as industrial, military, and urban environments is critical and complex. Traditional monitoring systems are more specialized and are not too flexible and effective [5 – 9].

Solution: The proposed ICMS can be adapted to different conditions depending on the performances of the used digital components and parts, but also it can be updated as a system from various environmental and safety monitoring and tracking applications or platforms. By continuously monitoring, detecting, or tracking objects, it can help prevent different accidents, enhance situational awareness of the environments, and improve safety in diverse environments depending on the situation and complexity of the risk [5 – 9].

7. CONCLUSION

In this paper, we discuss several accomplishments in utilizing digital development electronic boards or single-board computers for the integration of an advanced ICMS aimed at short-distance object monitoring and detection. The study showcases the versatility, features, and capabilities of these boards, emphasizing their ability to integrate smoothly with a variety of digital components, sensors, communication modules, and computing platforms. Their cost-effectiveness, user-friendliness, and sophisticated functionalities make them especially beneficial for students, researchers, and professionals engaged in scientific experiments, educational initiatives, and practical applications across various fields.

As part of this research, two MATLAB simulations were carried out to verify the functionality of digital electronic boards in sensor-based applications. The first simulation concentrated on wireless data transmission, where sensor readings were processed and sent using a communication module, with real-time data displayed on an LCD and a laptop screen. The second simulation explored servo motor control driven by sensor feedback, showcasing an automated response where the motor adjusted its position based on object detection within a specified range. These simulations validate the practical application and reliability of digital boards in creating interactive and responsive monitoring systems.

The results of this study highlight the significance of incorporating modern digital technologies into short-range object monitoring and detection systems, particularly within the context of an efficient ICMS. By harnessing the flexibility of digital electronic boards, future advancements in object detection, automation, and real-time monitoring can be further improved, leading to enhanced accuracy, scalability, and integration with advanced computational models. These innovations can facilitate the development of more efficient and intelligent control and monitoring systems, making them highly relevant in security and surveillance applications.

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