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Development and Integration of an IoT-Enabled Weight Sorting System with PLC for Inventory Management

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Abstract: The convergence of automation and the Internet of Things (IoT) within industrial systems has significantly advanced with the onset of Industry 4.0. This paper presents the design, implementation, and performance evaluation of an IoT-integrated weight-based sorting system controlled by a Siemens Programmable Logic Controller (PLC). The system employs high-precision Xcluma 10 kg load cell sensors to detect the weight of objects, categorizing them accordingly. The Raspberry Pi Compute Module 4 augments the system's processing capabilities, handling data computation and wireless communication to an IoT cloud platform. Data transmission is facilitated through the Waveshare Industrial IoT Wireless Expansion Module, ensuring real-time monitoring and smart inventory management. The setup comprises essential components such as robust power supplies, Ethernet switches, actuators, and a 7-inch Wintake LCD display for local monitoring. The system's modular design and its potential for scalability demonstrate the viability of smart inventory systems in modern industrial environments.

Key words: Weight-based sorting, IoT, Siemens PLC, Load cells, Smart inventory management

1. Introduction

The fourth industrial revolution, or Industry 4.0, signifies a transformative era in manufacturing and industrial processes characterized by the convergence of digital technologies, advanced automation, and the Internet of Things (IoT) (1). Industry 4.0 (2) aims to create smart factories and intelligent manufacturing systems, driven by the need for increased efficiency, flexibility, and responsiveness in production environments. The integration of IoT and automation technologies is crucial in achieving these objectives, enhancing operational efficiency and accuracy.

Efficient material sorting(3) is vital in manufacturing and warehousing settings. Traditional sorting methods often rely on manual labor or basic automation systems, which are prone to errors and inefficiencies. Advanced sorting systems utilizing IoT and automation technologies (4) significantly enhance the speed and accuracy of material handling processes. However, there remains a substantial gap in the implementation of sophisticated sorting systems that can integrate with IoT infrastructure for real-time inventory management (5). Many existing systems are designed for specific applications and lack the flexibility to adapt to diverse industrial requirements.

Weight-based sorting (6) is essential in various industries, including manufacturing, packaging, recycling, and food processing, where differentiating products by weight is crucial. Implementing a reliable and efficient weight-based sorting system requires advanced sensing technologies and robust integration with processing and communication platforms.

This research paper aims to address these challenges by designing and implementing an IoT-integrated weight-based sorting system(7) using a Siemens Programmable Logic Controller (PLC). The primary objectives include designing and implementing a sorting system that categorizes objects based on their weight using load cells. Integrating this sorting system with an IoT infrastructure (8) enables real-time monitoring and inventory management. Key components such as the Raspberry Pi Compute Module 4, the Waveshare Industrial IoT Wireless Expansion Module, power supplies, actuators, Ethernet switches, cables, connectors, and an LCD display are seamlessly integrated. The system's performance (9) will be evaluated in terms of sorting accuracy, speed, and reliability to ensure its effectiveness and efficiency.

The significance of this study lies in its potential to revolutionize material sorting processes within the framework of Industry 4.0. By leveraging IoT (10) and advanced automation technologies (11), the proposed system offers several benefits. Automated sorting processes enhance efficiency by reducing the need for manual labor, increasing operational efficiency, and minimizing human error. IoT integration enables real-time monitoring, allowing for tracking sorted materials and providing valuable data for inventory management and decision-making (!2). The system's modular design ensures flexibility and scalability, making it easily adaptable to various industrial applications and different production volumes. The reduction in manual labor and optimization of sorting processes contribute to overall cost savings for manufacturers and warehouses, highlighting the system's cost-effectiveness.

Existing literature on material sorting and inventory management highlights several approaches and technologies (13). Traditional sorting systems often rely on mechanical methods or basic sensors to differentiate materials based on simple attributes like size or weight. While effective in certain applications, these systems lack the sophistication required for more complex sorting tasks, such as precise weight differentiation.

Recent advancements in sensor technology have introduced load cells capable of detecting a wide range of weights with high precision. These sensors, when integrated with advanced processing units and IoT platforms (14), can significantly

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enhance sorting systems. Previous studies have demonstrated the feasibility of using load cells for weight-based sorting in specific contexts, but comprehensive solutions integrating these sensors with IoT for real-time inventory management remain limited.
This research paper presents a novel approach to material sorting that combines the strengths of load cells, PLCs, and IoT technologies (15). The key contributions include a detailed design and implementation of a weight-based sorting system leveraging advanced sensing and IoT technologies. Additionally, it provides a comprehensive integration framework for seamless incorporation of various components to achieve efficient and reliable sorting and inventory management (16). The study offers an in-depth evaluation of the system's performance, providing valuable insights into the practical applications and limitations of the proposed approach.

2. Materials and Methods

2.1. Materials

At the heart of the system lies the Siemens PLC (CPU ST30DC/DC/DC), tasked with controlling the overall system architecture. The PLC interfaces with Xcluma 10 kg load cell weight sensors to detect object weights. The Raspberry Pi Compute Module 4 acts as the primary computational node, facilitating IoT integration and handling data transmission. Wireless communication to the IoT cloud platform is managed by the Waveshare Industrial IoT Wireless Expansion Module, providing robust and low-latency data transfer. The system's infrastructure is further supported by reliable power supplies, industrial-grade Ethernet switches, durable cabling, and high-quality connectors to ensure system stability. A 7-inch Wintake LCD display serves as the user interface for real-time system monitoring and control.

2.2 **Methods**

2.2.1 Component Integration

- **Load Cells and PLC Interface**: The Xcluma load cells are wired to the input terminals of the Siemens PLC, enabling precise weight measurement. The PLC processes the signals received from the load cells and prepares the data for sorting.
- **PLC and Actuators**: Once the PLC identifies the object's weight, it triggers the actuators accordingly. These actuators are responsible for physically sorting objects based on their weight thresholds.
- **PLC and Raspberry Pi Communication**: The PLC communicates with the Raspberry Pi Compute Module 4 through a dedicated protocol, enabling seamless data transfer for further processing and analysis.
- **Wireless Communication**: Data transmission from the Raspberry Pi to the cloud platform is handled wirelessly using the Waveshare IoT Wireless Expansion Module, ensuring real-time connectivity and system monitoring.
- **User Interface**: The Wintake 7-inch LCD display provides a user-friendly interface for local monitoring. The display presents real-time system status and sorting activity, enabling operators to interact with the system efficiently.

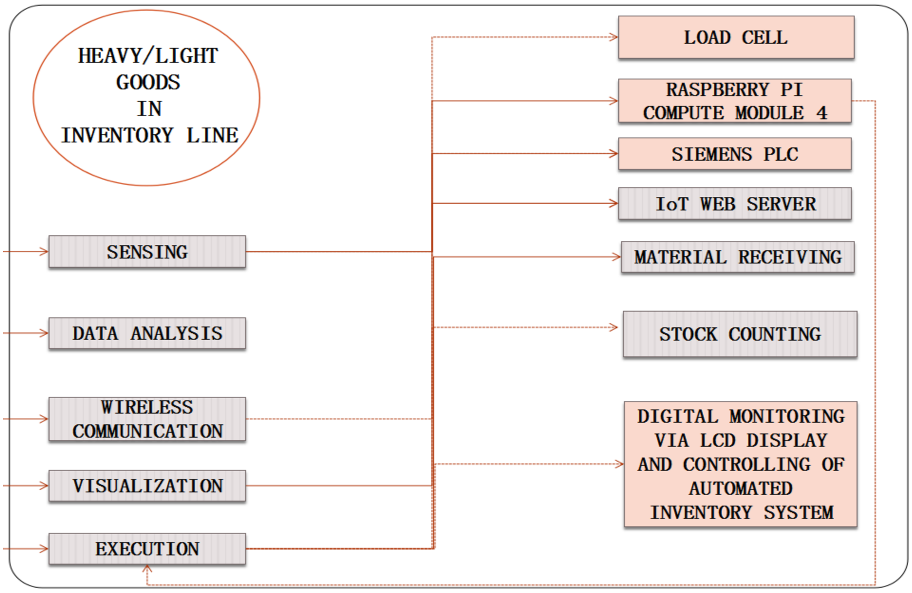

Figure 1. System architecture of the proposed weight sensor system

3. Results and Discussion

3.1 Hardware Setup

The system was assembled by connecting the Xcluma load cells to the input terminals of the Siemens PLC. The PLC's output terminals were connected to the actuators responsible for executing sorting decisions based on weight

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classifications. The Raspberry Pi Compute Module 4 was integrated with the PLC, allowing advanced data processing and wireless transmission via the Waveshare IoT Wireless Expansion Module. The system components were linked using Ethernet switches to maintain reliable communication between devices, while appropriate power supplies ensured continuous system operation. The Wintake LCD interface was configured for real-time status monitoring and system control.

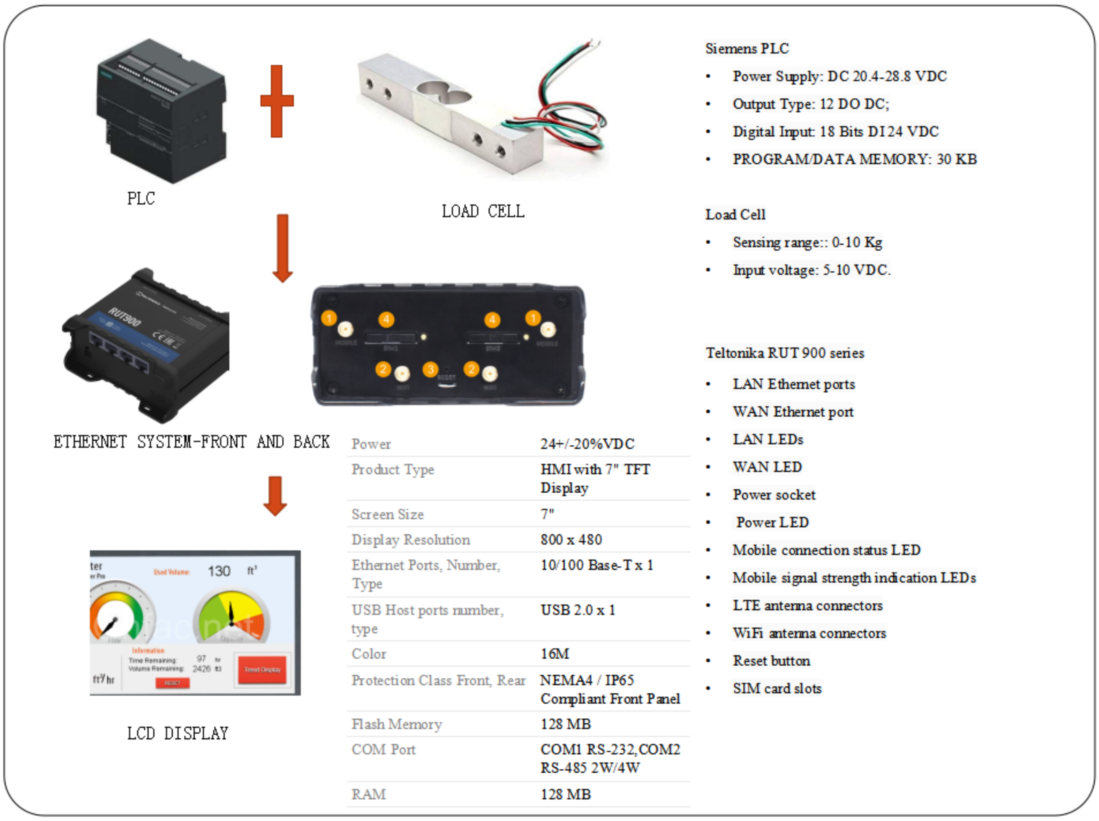

Figure 2. Features of the various components of the developed IMS

3.2 Software Installation

The Siemens PLC was programmed to process data from the load cells and control actuators based on specific weight thresholds. The Raspberry Pi was configured with the necessary software to handle data computation, enabling seamless integration with the IoT cloud platform for real-time monitoring and inventory management. Additionally, a graphical interface was developed for the LCD display, allowing for intuitive user interactions and system oversight.

3.3 Testing & Caliberation

System testing involved calibrating the load cells to ensure high accuracy in weight detection. Various test objects of differing weights were used to validate the sorting process. The system's real-time data transmission capabilities were thoroughly tested by assessing its responsiveness to dynamic changes in inventory and sorting activities. The IoT cloud platform successfully logged and processed data from the sorting operations, confirming the system's reliability and accuracy.

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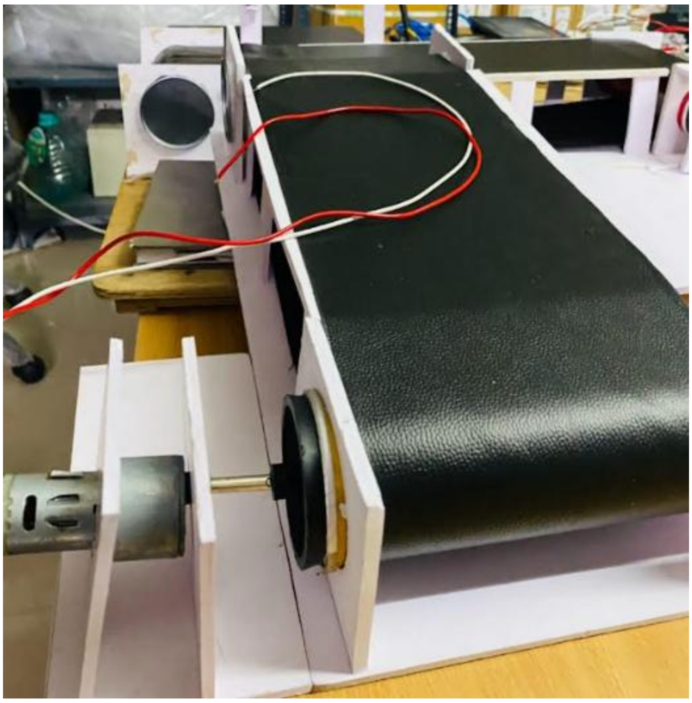

Figure 3. The developed prototype for weight based sensing system

3.4 Data Visualization and Analysis

Data from the sorting process were visualized on the Wintake LCD screen, allowing for real-time insights into the sorting mechanism. In addition to on-screen visualization, the data could be exported in Excel format for further analysis. This feature enhanced operational decision-making by providing detailed records of sorted materials, supporting advanced inventory management practices.

	A	B	C	D	E	F
1	created_at	entry_id	Less than 10 Kg	Less than 10 kg	Floor No.	longitude
2	8-Aug-24	79329	4	4	2	
3	8-Aug-24	79330	5	3	2	
4	8-Aug-24	79331	7	6	2	
5	8-Aug-24	79332	2	8	2	
6	8-Aug-24	79333	4	2	2	
7	8-Aug-24	79334	1	6	2	
8	8-Aug-24	79335	2	7	2	
9	8-Aug-24	79336	3	9	2	
10	8-Aug-24	79337	3	5	2	
11	8-Aug-24	79338	3	2	2	
12	8-Aug-24	79339	4	2	2	
13	8-Aug-24	79340	6	4	1	
14	8-Aug-24	79341	2	2	1	
15	8-Aug-24	79342	6	5	1	
16	8-Aug-24	79343	4	7	1	
17	8-Aug-24	79344	2	8	1	
18	8-Aug-24	79345	7	2	1	
19	8-Aug-24	79346	5	0	2	
20	8-Aug-24	79347	8	2	1	
21	8-Aug-24	79348	8	5	1	
22	8-Aug-24	79349	3	2	1	

Figure 4. Real time details downloaded by cloud storage system

4. Conclusion

This study introduces a highly efficient IoT-integrated weight-based sorting system designed for industrial applications within the framework of Industry 4.0. By utilizing Siemens PLCs for precise control, load cells for accurate weight detection, and the Raspberry Pi Compute Module 4 for advanced data processing, the system achieves optimal performance in real-time sorting and inventory management. Wireless communication to the IoT platform, facilitated by the Waveshare Industrial IoT Wireless Expansion Module, ensures real-time data accessibility. The modular design of the system allows for scalability and flexibility, making it suitable for a wide range of industrial environments. The results indicate that the system significantly enhances sorting efficiency, minimizes human intervention, and improves inventory accuracy, aligning with the goals of smart manufacturing.

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