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Research on Dynamic Weighing and Sorting System Based on PLC

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Abstract: In the industrial production of instant noodles, accurately cutting fresh, non-fried noodle strands and controlling the weight of each portion are critical to ensuring product quality and cost efficiency. In response to the growing demand for automation in the instant noodle manufacturing process, this study proposes a dynamic weighing and control system based on a Programmable Logic Controller (PLC). The system utilizes the Siemens S7-1200 series PLC, specifically the CPU1217C module, as the central controller. Communication and data exchange between the PLC and various subsystems are realized through industrial Ethernet and related protocols. The proposed system is capable of precise cutting and real-time weighing of fresh noodles. Based on the measured weight, the system automatically sorts the noodles into acceptable and non-conforming batches. This approach significantly enhances the automation level of the production line, improves production efficiency, reduces operational costs, and strengthens the system's control accuracy and stability. Experimental and practical results demonstrate that the dynamic weighing and sorting control system provides an effective solution for the design and optimization of automated instant noodle production lines. Furthermore, it offers theoretical and practical support for achieving fast, accurate, and cost-effective manufacturing.

Keywords: Automation Control; Programmable Logic Controller (PLC); Dynamic Weighing; Industrial Ethernet.

1. Introduction

With the advancement of technology and the widespread adoption of industrial automation, PLC have become indispensable core components in modern industrial production. In particular, their application in the food manufacturing industry has significantly improved production efficiency, reduced labor costs, and played a crucial role in ensuring food safety and product quality. In today's fast-paced society, instant noodles-recognized as a staple of convenient food-have gained widespread popularity among consumers due to their ease of preparation and quick consumption, making them one of the most in-demand food products on the market. Consequently, how to leverage advanced automation technologies to further enhance the automation level of instant noodle production lines, optimize manufacturing processes, improve productivity, and reduce production costs has become a critical issue facing the industry. In response to these challenges, this paper proposes an automated control system for instant noodle production lines that integrates industrial Ethernet, servo control technology, PLC-based control, and dynamic weighing systems. This integrated approach aims to meet the increasing demand for automation in instant noodle manufacturing and provides a comprehensive solution for production line optimization.

In the production of instant noodles, accurate weighing of raw materials serves as the foundation for ensuring product quality, enhancing production efficiency, and controlling manufacturing costs. Traditional static weighing methods often suffer from limitations such as insufficient accuracy, cumbersome operation, and low throughput, which are increasingly inadequate in the context of modern high-efficiency production demands. With the continuous advancement of automation technologies, high-performance dynamic weighing control systems driven by PLC have emerged as an effective solution to these challenges. By enabling real-time control and precise measurement, such systems significantly improve both the accuracy and efficiency of the production process, driving a transformative shift in the manufacturing of instant noodles.

This study focuses on the design and implementation of an efficient and stable automated production line control system through the integrated application of industrial Ethernet communication technology, PLC control, servo control technology, and dynamic weighing techniques. The system is designed to optimize the production rhythm and enhance overall production line performance while ensuring high precision in manufacturing. By enabling seamless collaboration between the PLC and various subsystems and utilizing industrial Ethernet for high-speed data exchange and control signal transmission, the system achieves strong real-time responsiveness and operational stability. Moreover, the system demonstrates a high degree of flexibility, allowing it to adapt to varying production requirements and changes, thereby improving the overall efficiency and responsiveness of the production line. The objective of this research is not only to elevate the level of automation in instant noodle production but also to promote intelligent and refined process management through technological innovation. It offers a practical and viable solution to the broader goal of advancing automation in the food manufacturing industry. Through an in-depth analysis of the control system's design and application, this study provides valuable theoretical support and practical guidance for achieving high-efficiency and intelligent industrialized production of instant noodles.

2. The overall scheme design of the system

The hardware architecture of this high-efficiency, high-precision dynamic weighing control system consists of several key components, including an upper-level PC, industrial Ethernet switch, servo system, PLC system, weighing instrumentation, and a touchscreen interface. These components are integrated to function collaboratively through efficient data exchange and precise control, enabling accurate weighing and real-time data management throughout the production process.

To address the compatibility issues between serial communication and Ethernet communication, the control system incorporates a serial communication server. This device functions as a converter, transforming the serial communication signals from the weighing instruments into Ethernet-compatible signals. Through the use of the serial communication server, the weighing instruments can seamlessly exchange data with other components of the system (such as the PLC and the upper-level PC) via industrial Ethernet, thereby ensuring unified and efficient communication across the entire system.

In the data processing segment of the system, the upper-level PC plays a central role in remote monitoring and data management. It communicates with the PLC via the industrial Ethernet switch and performs advanced processing on the data retrieved from the PLC. The upper-level software supports a wide range of functions, including remote monitoring, data storage, querying, and full CRUD (Create, Read, Update, Delete) operations on production data, significantly enhancing the convenience and efficiency of data management. Production data is transmitted to the PC through industrial Ethernet and stored in an SQL Server database [4], providing robust support for subsequent data retrieval and analysis.

The touchscreen serves as the interface through which operators interact with the system. Through the touchscreen, operators can monitor production status in real time, view operational information, and adjust production parameters. The touchscreen provides an intuitive user interface, ensuring ease of operation and transparency on the production line. Through this interface, operators can access production data at any time, track production progress, and make necessary adjustments to system parameters.

All these devices are interconnected through an industrial Ethernet switch, which plays a central role in data exchange and signal transmission within the system. The Ethernet switch connects the PC, serial communication server, servo system, touchscreen, and PLC into a cohesive network, enabling data transmission between all devices via Ethernet communication. This Ethernet-based communication method enhances the system's stability, reliability, and real-time performance, ensuring rapid information transfer and efficient system operation. The hardware architecture of the weighing system is shown in Figure 1.

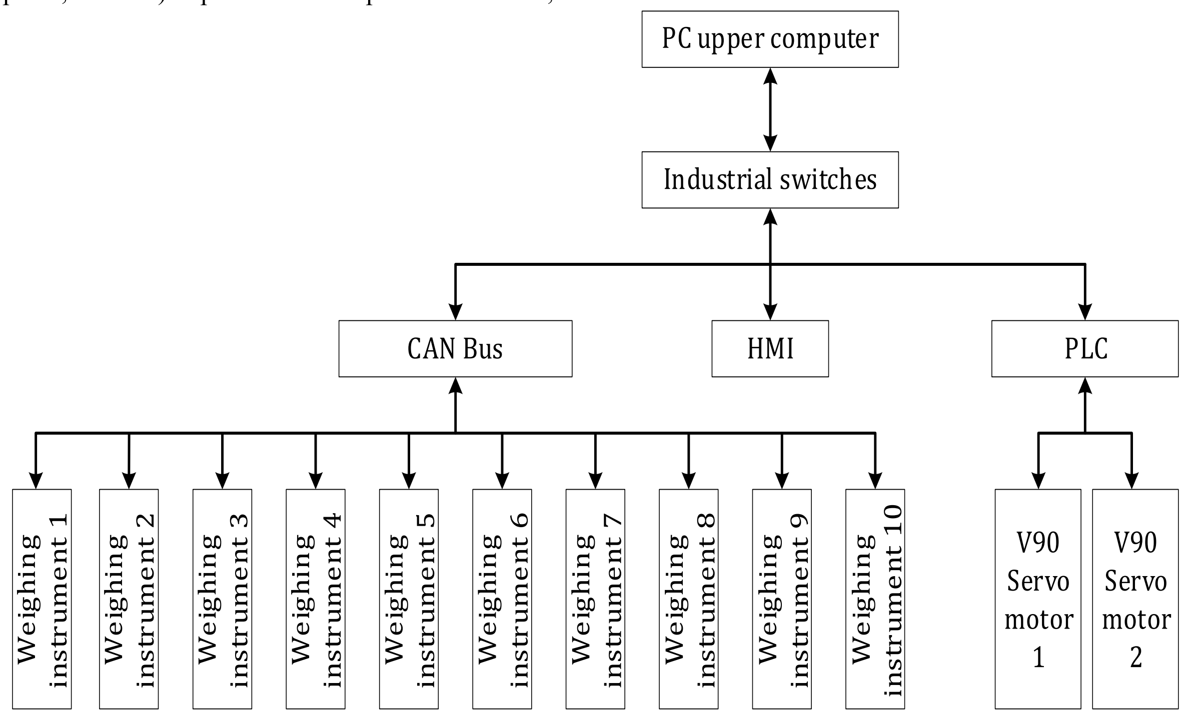

Figure 1. System hardware architecture

3. System hardware configuration

The system uses the Siemens S7-1200 series CPU 1217C DC/DC/DC model as the main controller. For weighing data collection, the Mettler-Toledo SLP331D-RTU single-point digital weighing sensor is selected based on the company's requirements. The servo system utilizes a 750W motor (model 1FL6042-2AF21-1LB1) and a driver (model 6SL3210-5FB10-8UF0) from the Siemens V90 series. The touchscreen, serving as the human-machine interface (HMI) for the production site, is the Siemens 6AV2123-2JB03-0AX0 model. The specific hardware models are summarized in Table 1.

Table 1. System hardware configurations

Serial number	Hardware	Model
1	CPU	S7-1217C DC/DC/DC
2	Servo drives	6SL3210-5FB10-8UF0
3	Servo motor	1FL6042-2AF21-1LB1
4	Touch screen	6AV2123-2JB03-0AX0
5	Load cells	SLP331D-RTU

4. Communication settings

In the communication between the PLC and the weighing instruments, multiple real-time weighing instruments are distributed at different locations, and the communication between the PLC and each weighing instrument is implemented using RS485. The wiring configuration for RS485 communication is as follows: the PLC's RDA- connects to the B terminal of the instrument, while the PLC's RDB+ connects to the A terminal of the instrument. The PLC communication settings are configured to match those of the weighing instruments, with the following parameters: baud rate of[6]115200, 8 data bits, 1 stop bit, no parity bit, and a timeout response time set to 0.1 seconds.

Communication between the PLC and the touchscreen is conducted via Ethernet. The two devices are connected through a switch, and communication settings are configured in the PLC's configuration software. The IP addresses of the PLC and the touchscreen must be in the same subnet, with the PLC's IP address set to 10.110.59.1 and the touchscreen's IP address set to 10.110.59.15. In the configuration, both the local and remote port numbers are set to 9600, the network type is selected as 0-UDP, and the server/client setting is set to 0-client. In the device properties page, the PLC node address is set to 1, and the computer node address is set to 12. After completing the settings, the configuration is downloaded to the touchscreen, and the connection method is chosen as TCP/IP network [7], with the target machine name being the touchscreen's IP address.

The PLC acts as an intermediary for data transmission and processing, handling and transmitting data from multiple instruments. Address areas should be allocated to avoid overlapping with special function areas, ensuring the customer's data length requirements are met, while also reserving address space for future processing. Data received by the PLC from the instruments and the upper-level PC needs to be transmitted to the touchscreen for display. Similarly, PLC-received settings from the touchscreen and instrument data need to be sent to the upper-level PC for display.

5. Design of high-efficiency and high-precision dynamic weighing control system

The overall layout of the designed high-efficiency, high-precision dynamic weighing control system is shown in Figure 2. This control system integrates multiple functional modules, making full use of industrial automation and modern communication technologies to ensure outstanding performance in terms of efficiency, accuracy, and intelligence. The system primarily consists of the feeding module, weighing and sorting module, shaping module, and PLC electrical control module, among others. Data exchange and coordination between the modules are facilitated through industrial Ethernet and CAN bus[8] technologies, forming a tightly coordinated, mutually supportive automated production line.

The feeding module is the first link in the system, responsible for accurately delivering raw materials to the weighing and sorting module. This module adopts advanced conveying technology to ensure smooth, uniform, and efficient material flow. Through precise control, the feeding module can automatically adjust the delivery rate according to production requirements and maintain stable operation of the production line by communicating in real-time with the PLC.The feeding module transports the noodles, which have been cut in the previous step, via a conveyor belt to directly above the feeding station. The noodles slide down at the separating plate, pass through a bending plate, and enter a channel before being directed into a distribution hopper. The distribution hopper swings alternately to the left and right within one cycle, ensuring that 10 noodle blocks enter the gaps between 10 partition plates. The automatic feeding function is completed within approximately 1.2 seconds. The specific feeding process is shown in Figure 3. The feeding module not only improves material delivery speed but also effectively prevents material wastage, ensuring refined management of the production process.

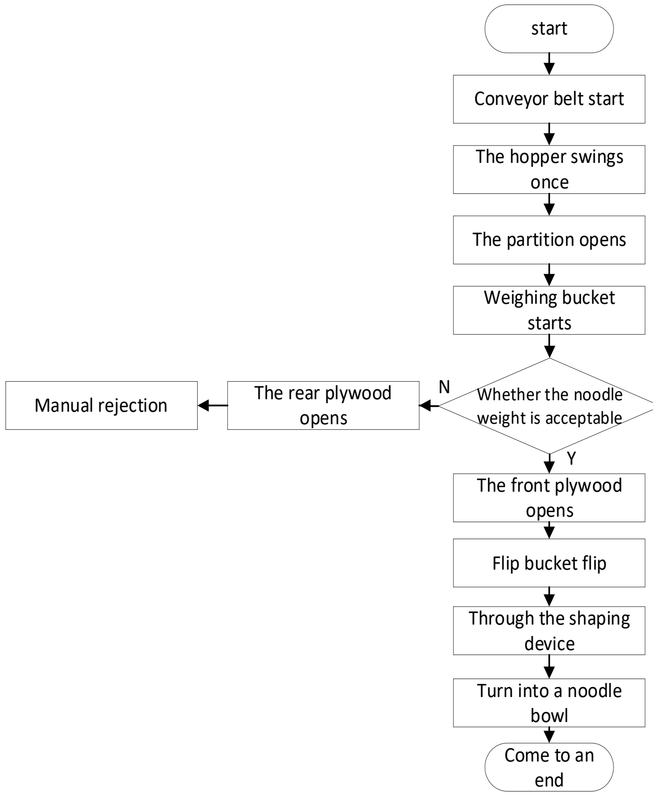

Figure 2. The overall layout of the high-efficiency and high-precision dynamic weighing control system

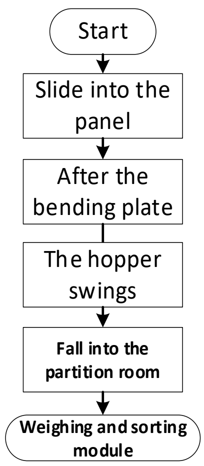

Figure 3. The overall layout of the high-efficiency and high-precision dynamic weighing control system

The weighing and sorting module is the core component of the system, responsible for dynamically weighing and sorting the raw materials entering the system. Through high-precision sensors and PLC control technology, the system can collect weighing data in real time and accurately classify and distribute the raw materials. The specific weighing process is as follows: After the noodle blocks pass through the feeding module, they fall between the partition plates. At this point, the flap transitions from a closed to an open state. The noodle blocks pass through the gaps between the partitions and are guided by the flap into the weighing hopper. This weighing and sorting module primarily performs weighing and sorting of the noodle blocks. Based on the product specifications, it removes any non-compliant products, which are then transported to the manual platform for further processing. Qualified noodle blocks are sent into the noodle bowl, where they proceed to the next stage of production.

When the noodle block's weight does not meet the required standards, the rear flap opens backward, sending the noodle block back to the previous production step for manual processing. If the noodle block meets the quality standards, the front flap opens forward, and the noodle block falls into the valve hopper. This process significantly improves product consistency and quality, while ensuring the precise mixing of materials throughout the production process. Through the weighing and sorting module, the production line can automatically adjust the material ratio and distribution, thereby improving both production efficiency and product quality. The entire process takes approximately 1.2 seconds, as shown in Figure 4.

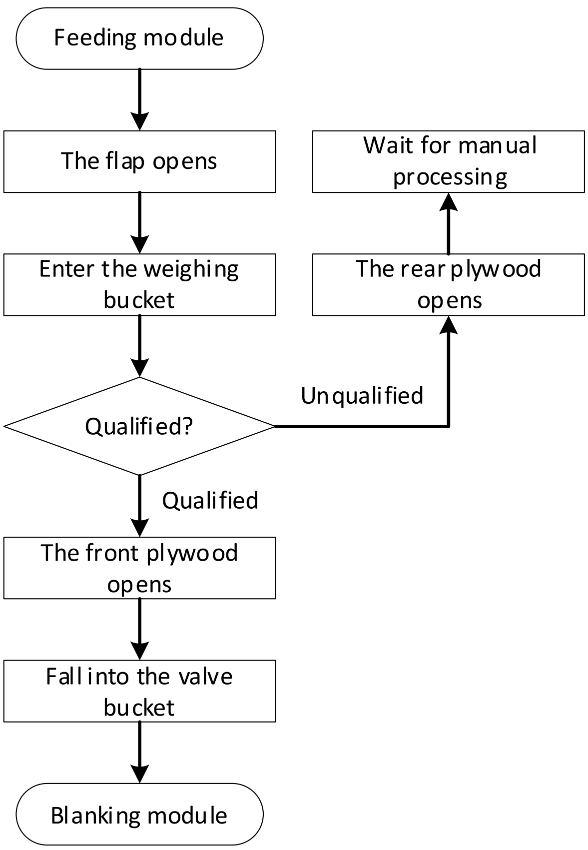

Figure 4. Weighing and sorting process

As shown in Figure 5, the flap rotates to allow the noodle block to fall. It is then guided by the shaping device and falls into the noodle bowl, where it proceeds to the next frying stage. The entire process takes approximately 1.2 seconds.

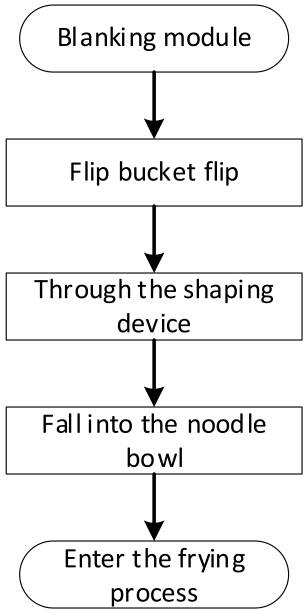

Figure 5. Blanking process

The shaping module is responsible for the initial shaping of the instant noodle raw materials to ensure they meet the processing requirements of the production line. Through high-precision mechanical control systems and PLC automatic adjustments, the shaping module can automatically adjust the shaping speed and force based on actual production needs, ensuring the consistency of the material's shape throughout the production process. The shaping module not only guarantees production stability but also offers flexibility in adjusting operating parameters according to different product requirements, thereby improving the adaptability of the production line.

The PLC electrical control module uses the Siemens S7-1200 series 1217C, which communicates via an industrial Ethernet bus to control the system. It manages communication and control for various peripherals such as the frequency converter, servo motor, sensors, solenoid valves, touchscreen, travel switches, and limit switches. The human-machine interface is constructed with a touchscreen, which provides the interactive HMI for the production management, status management, and maintenance management of the noodle weighing and sorting process.

6. Conclusion

This paper proposes a multi-weighing instrument management system based on a Programmable Logic Controller (PLC). The system is capable of achieving the following functions: unified display of data from multiple weighing instruments, processing of weighing data, querying of production records, statistical management of data by the upper-level computer, and basic product settings for the production workshop. The upper-level software and touchscreen interface of the system are designed to be simple and user-friendly, enabling management personnel and on-site workers to quickly operate the system after a brief training. Practical application results demonstrate that the system accurately monitors production status and archives historical data through the upper-level computer. In modern production, this system is crucial for enhancing management's understanding of on-site production information, reducing error rates, improving production efficiency, and enabling data traceability. Furthermore, the application of high-precision dynamic weighing technology ensures accurate material measurement, reduces errors, and enhances product quality and safety. This, in turn, optimizes production processes, improving both the efficiency and economic benefits of the enterprise.

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