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Application of Automation Technology in Mushroom Stem-Cutting: A Case Study from Xinshe, Taiwan

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Abstract

The Xinshe region is one of Taiwan's major mushroom production hubs, renowned for its high annual yield and exceptional quality. However, despite the growing demand in both domestic and international markets, the region faces a lack of comprehensive automated processing equipment, limiting productivity and exacerbating labor shortages. To address these challenges, this study applies advanced automation technology to develop a mushroom stem-cutting machine aimed at enhancing production efficiency, ensuring consistent product quality, and boosting market competitiveness. This paper presents the design and implementation of the mushroom stem-cutting automation system, detailing its working principles, technological advantages, and potential applications. The adoption of this technology offers a promising solution to improve operational efficiency, stabilize product quality, and mitigate labor dependency, contributing to the modernization of traditional agricultural practices.

Keywords: Automation, Mushroom, Stem-cutting, Production efficiency, Agricultural

INTRODUCTION

The shiitake mushroom (Lentinula edodes) industry plays a significant role in Taiwan's agricultural economy, with the Xinshe region recognized as one of the country's major production centers due to its high-quality yield and stable output. In recent years, the increasing demand from both domestic and international markets has placed considerable pressure on traditional cultivation and processing methods. Most notably, manual stem-cutting operations, which are labor-intensive and time-consuming, have become a critical bottleneck in the

production chain. These traditional practices not only limit scalability but also contribute to labor shortages and inconsistencies in product quality, both of which adversely affect the industry's overall competitiveness.

To address these challenges, the integration of automation into mushroom processing has emerged as a promising solution. Automation not only offers the potential to alleviate the dependence on manual labor but also enables improvements in production efficiency and product standardization. In particular, the application of machine vision and precision control technologies can greatly enhance the accuracy and reliability of tasks such as stem trimming, which is essential for meeting market standards and ensuring product uniformity.

This study proposes the development of an automatic stem-cutting system for shiitake mushrooms by combining image recognition with automated mechanical processing. The goal is to increase operational efficiency, reduce labor requirements, and ensure consistent quality across products. By targeting a specific bottleneck in mushroom post-harvest handling, this research aims to contribute to the advancement of smart agriculture practices and promote sustainable growth within Taiwan’s mushroom industry. Moreover, the proposed system has the potential to serve as a model for similar applications in other labor-intensive agricultural sectors.redundant or unnecessary data and explanation.

MATERIALS AND METHODS

The main structure of the proposed equipment is constructed using aluminum extrusion profiles, which provide high precision and adjustable mobility during the development phase. The system adopts a belt conveyor mechanism, enabling shiitake mushrooms to be inserted into designated openings and transported along the belt, where the caps and stems are separated by a fixed blade. This design not only adheres to ergonomic principles but also accommodates the high-throughput requirements of mushroom insertion and processing. The dimensions, height, and overall configuration of the system were determined through extensive discussions with mushroom growers to ensure practicality and feasibility. As a result, the design is streamlined, containing no superfluous elements, and is tailored to the actual operational needs of the industry. Through a continuous and streamlined motion, the shiitake mushrooms are securely guided by the belt and pulley system as they pass through the cutting blade, resulting in the precise separation of the stem and leaving behind an intact and high-quality mushroom cap. This automated process enables mushroom growers to operate efficiently even under high-throughput conditions, allowing ample time for mushroom placement without interrupting the workflow. Consequently, the system significantly reduces the physical strain associated with manual stem cutting and lowers the overall labor and time costs in the harvesting process.

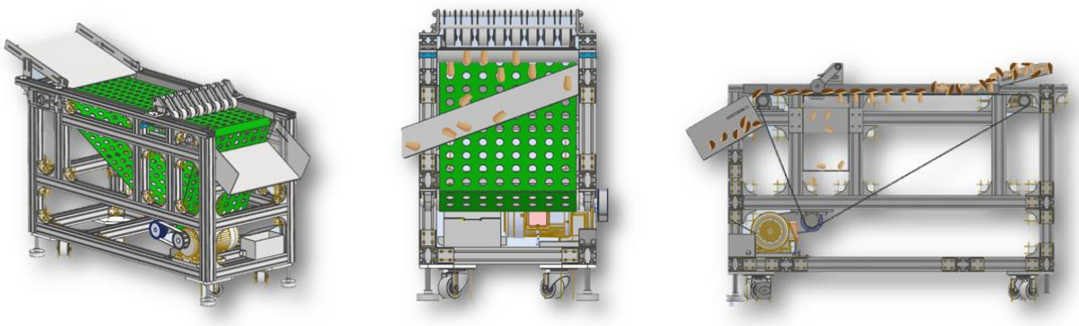

Figure 1. Mechanism Design

In response to practical needs, this study places particular emphasis on understanding and translating the real-world expectations of mushroom growers into functional system design. Rather than merely fulfilling basic requirements, the proposed system aims to deliver enhanced usability and operational efficiency. One of the primary concerns expressed by farmers is ease of operation. To address this, a user-friendly and intuitive interface has been developed, enabling even inexperienced users to operate the system with minimal training. Furthermore, all operational data are uploaded to a cloud-based platform for advanced analysis, allowing farmers to monitor and manage the production process with minimal labor input. This approach not only saves time but also significantly improves overall operational efficiency, enabling growers to focus on production optimization and business management, thereby achieving greater economic returns.

Figure 2. On-site human-machine screen and cloud network record data

This study employs a combination of image processing techniques—including mean shift clustering, color feature extraction, binarization, structural analysis, and superpixel segmentation—to extract relevant features from the stem portion of shiitake mushrooms. Subsequently, the largest inscribed circle method is applied to identify the dominant shape within the stem region and to analyze its width for subsequent classification. Three variations of the inscribed circle method were tested, with all three approaches yielding an error rate of approximately 70% across different stem size categories. Despite the presence of classification inaccuracies, feedback from mushroom growers indicated overall satisfaction with the system, citing substantial improvements in both the efficiency and accuracy of the stem-cutting process.

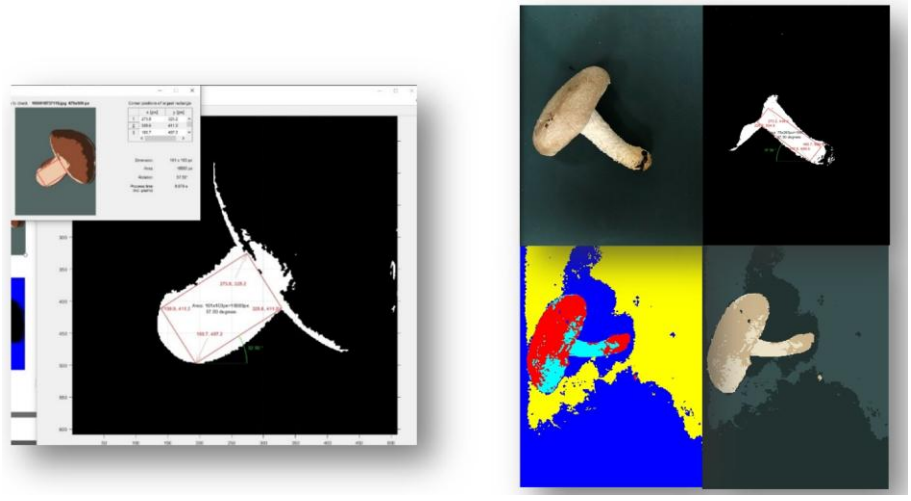

Figure 3. Fuzzy inscribed circle analysis and image processing analysis

RESULTS & DISCUSSION

This study successfully developed a semi-automated stem-cutting system for shiitake mushrooms that integrates image recognition technology to enable fast and accurate classification and removal of mushroom stems. In addition, the system uploads operational data to a cloud-based platform for real-time analysis and monitoring, contributing to the modernization and digital transformation of agriculture—an industry traditionally perceived as labor-intensive.

The anticipated benefits of the proposed system are outlined as follows:

Increased Production Efficiency through High-Precision Automated Classification:

The system significantly reduces the time and labor required for manual stem cutting by improving both the speed and accuracy of the process. It minimizes waste and mechanical damage to the mushroom stems, thereby preserving the integrity and aesthetic quality of the mushroom caps. This enhancement increases the market competitiveness and added value of the product.

Reduction in Training Costs and Labor Dependence:

In response to the aging agricultural workforce and ongoing labor shortages, the system reduces reliance on manual labor and lowers the associated costs and risks. By minimizing the need for intensive training and manual processing, it addresses workforce challenges while enhancing operational stability and sustainability.

Intelligent Data Analytics and Industrial Innovation:

The integration of automated control with cloud-based data analysis facilitates the transition toward smart agriculture. The system not only strengthens the technological capacity and core competitiveness of the mushroom industry but also fosters innovation and creates new opportunities for growth. The intelligent monitoring system collects and analyzes production data in real time, providing valuable feedback to farmers. This data-driven approach enables better decision-making, optimized production strategies, and supports long-term, sustainable industry development.

CONCLUSIONS

In addition to successfully validating the mechanical feasibility of the system, this study demonstrates the practical application of theoretical knowledge in real-world agricultural settings. The optimized shiitake mushroom stem-cutting machine has not only significantly improved production efficiency and production line monitoring capabilities but has also incorporated intelligent features, including integrated detection, monitoring, and feedback mechanisms. These advancements have led to a higher degree of automation and system responsiveness. More than a technological advancement, this work represents a tangible contribution to local agricultural development, showcasing a successful integration of modern technology with traditional farming practices. Furthermore, the study provides new opportunities for innovation across the entire agricultural value chain, serving as a catalyst for industrial upgrading and transformation. We firmly believe that this intelligent stem-cutting system will emerge as a key innovation in the field of agricultural automation, opening up new possibilities for the future of smart farming and sustainable agricultural production.

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