Journal of Information Systems Engineering and Management
2025, 10(37s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Implementation of Artificial Vision Systems for The Manufacture of Polypropylene Sacks in the Company of Packaging

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ARTICLE INFO

Received: 29 Dec 2024

Revised: 12 Feb 2025

Accepted: 27 Feb 2025

ABSTRACT

The manufacturing industry in Colombia encounters considerable challenges that hinder its competitiveness and growth in an increasingly globalized market. Key obstacles include the urgent need to modernize production processes, enhance product quality, and minimize costs stemming from operational inefficiencies. Embracing innovative technologies, such as automation and real-time monitoring, has emerged as a pivotal strategy to address these issues and bolster the sector's performance and resilience. This article describes the implementation of artificial vision systems and sensors at Packaging Company, commercially known as Grupo Excala, whose main activity is the manufacturing of polypropylene sacks. The work presents three main systems: Cartonplast Counter: This system uses a distance sensor to count Cartonplast sheets, adapting to variations in thickness and color. Additionally, a pneumatic mechanism was integrated to enhance counting precision. Fabric Width Measuring System: Using an artificial vision camera and an RPM sensor, this system measures the fabric width in circular looms in real time. The data collected is stored in a database for subsequent analysis. Red Tape Detection System: Color sensors automatically identify, and separate defective sacks marked with red tape, ensuring that these do not reach the final product. Key Benefits Achieved: Increased Precision: Improved accuracy in sheet counting and fabric width measurement. Enhanced Product Quality: Effective elimination of non-conforming products. Process Optimization: Real-time data availability to support decision-making. Together, these technological solutions have significantly contributed to the efficiency and quality of production processes at Grupo Excala. The implementation of artificial vision systems and sensors in the manufacture of polypropylene bags has made it possible to automate critical tasks such as sheet counting, fabric width measurement and defect detection. These innovations have significantly reduced operating times in the company, improving productivity and optimizing processes

Keywords: Machine vision, defect detection, sensors, process optimization, quality control

INTRODUCTION

The manufacturing industry in Colombia faces significant challenges that limit its competitiveness and growth in a globalized environment. Among the main challenges are the need to modernize production processes, improve product quality and reduce costs associated with operational inefficiency. The adoption of new technologies, such as automation and real-time monitoring, has become a key strategy to confront these problems and strengthen the sector. In the Colombian context, factors such as the lack of access to advanced technology, dependence on manual processes and limitations in industrial infrastructure make the implementation of innovative solutions difficult. Furthermore, the pressure to meet international quality standards and the growing demand for customized products have increased the need to optimize production processes and ensure greater precision in operations. This project is part of the search for technological solutions that respond to these challenges, focusing on the design and implementation of an artificial vision system and industrial sensors in a production line for polypropylene bags. The

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company was facing critical issues related to accuracy in manual product counting, late defect detection, and integrating efficient processes to improve productivity.

Through the automation of inspection and counting tasks, this project not only seeks to increase the quality and efficiency of processes but also contribute to the development of technological capabilities in the Colombian manufacturing sector. This article details the results obtained through the implementation of three specific systems: a Cartonplast counter, a fabric width meter based on artificial vision and a defect detection system using color sensors, designed to respond to the needs of the plant and align with the challenges of the Colombian industrial environment. The manufacturing industry, in its continuous effort to improve operational efficiency and ensure high-quality products, has adopted automation and real-time monitoring as essential tools to achieve these goals. In this context, this project addresses the design and implementation of an artificial vision and industrial sensors system focused on the detection and automated counting of products in a production line of polypropylene bags.

The company faced challenges related to the inaccuracy and low efficiency of manual counting, as well as late detection of product defects. To overcome these limitations, advanced technological solutions were developed that allow automating and optimizing inspection and counting tasks, thus achieving a significant increase in the quality and productivity of the processes.

METHODS

Automatic visual inspection and computer vision are key technologies in the modernization of industrial processes, particularly in tasks that require precision, consistency and efficiency. These areas have seen significant advances in recent decades, driven by developments in hardware, image processing algorithms and artificial intelligence techniques [1]. Below is an analysis of the main aspects and advances in this field. Automatic visual inspection refers to the use of technological systems to perform inspection tasks that were traditionally done manually. These systems use cameras, sensors and algorithms to detect defects, measure dimensions, classify products and ensure quality on production lines. Computer vision, as a discipline, focuses on the automatic interpretation of digital images to extract relevant information, [2], [3]. Common AVI applications are detailed in Table 1.

Table 1. Common AVI applications

COMMON APPLICATIONS	DESCRIPTION
Quality control:	Identification of defects in manufactured products, such as cracks, deformations or assembly failures.
Real-time monitoring:	Monitoring of industrial processes to detect irregularities or variations.
Sorting and counting:	Automation of product classification tasks according to specific criteria and unit counting.
Dimensional measurement:	Accurate evaluation of dimensions and tolerances in industrial parts.

The development of automatic visual inspection has been marked by progress in the following aspects: Cameras and Sensors Advances in high-resolution cameras, infrared and wide-spectrum sensors have improved the ability to capture fine details and features invisible to the human eye. Image processing: Advanced digital processing tools, such as filtering, segmentation, and feature extraction, allow one to identify patterns, edges, and textures in industrial images. deep learning: The integration of convolutional neural networks (CNN) has transformed computer vision [4]. These architectures are particularly effective for complex tasks such as image classification and anomaly detection. Automation and integration; Modern systems are easily integrated into production lines using IoT technologies, making it easy to collect and analyze data in real time.With the development of this work, some Benefits of Automated Visual Inspection have been identified, detailed in Table 2.

Table 2 Benefits of Automated Visual Inspection

Benefits of Automatic Visual Inspection	
Consistency:	Automation eliminates the variability inherent in manual inspection, providing consistent results
Speed:	Automated systems can process large volumes of products in less time.
Cost reduction:	Although the initial investment may be high, the long-term savings in labor and error reduction offset the expense.

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Quality improvement:	Defects can be detected and corrected before the products reach the customer.

Although the development of AVI presents interesting benefits, it also faces important challenges, among which are highlighted in Table 3.
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Table 3. Challenges of Automated Visual Inspection

Variability in products:	Differences in color, texture or shape can complicate the design of robust systems.
Adverse industrial environments	Conditions such as dust, vibration, and light fluctuations affect the performance of cameras and sensors.
Initial costs	Acquiring advanced hardware and developing custom software requires significant investments
Lack of experts	The integration of these technologies requires specialized knowledge in computer vision and data analysis.

The work carried out allowed us to identify studies with great impact in the area, such as [1], this study shows how convolutional neural networks (CNN) significantly improve the accuracy in identifying defects in production lines, a second work [3] analyzes the impact of real-time processing on quality control, highlighting the importance of integration with IoT systems, and Machine Vision Applications in Quality Control, [2] reviews success stories in the application of computer vision in sectors such as automotive, pharmaceutical and textile [5].
The work carried out allowed us to identify studies with great impact in the area, such as [4], this study shows how convolutional neural networks (CNN) significantly improve the accuracy of identifying defects in production lines, a second work [6], analyzes the impact of real-time processing on quality control, highlighting the importance of integration with IoT systems and Machine Vision Applications in Quality Control. In [7] provides a comprehensive review of convolutional neural network architectures applied in automated optical inspection systems, highlighting improvements in the accuracy and efficiency of surface defect detection in manufacturing. A detailed analysis of recent advances in computer vision, including deep learning techniques and their application in industry to improve inspection and quality control processes, is provided in [8]. This work presents a computer vision-based automated optical inspection solution that addresses common challenges in industrial environments, such as scalability and tolerance to variations in multiple product lines. In [9] The implementation of deep learning models for visual inspection on textile assembly lines is explored, highlighting improvements in the accuracy and efficiency of defect detection.
These references provide an up-to-date view of trends and advances in the application of computer vision and automatic visual inspection in various industrial sectors. The future of this technology is oriented towards Greater use of artificial intelligence: More autonomous systems that not only detect defects but also classify them and suggest solutions such as the capabilities of 3D Vision in Expanding three-dimensional analysis capabilities to inspect complex objects. The implementation of automatic visual inspection and computer vision are presented as essential solutions for companies seeking to increase their competitiveness in a globalized market, improving precision, speed and quality in their production processes.

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RESULTS

Based on the needs identified in the company, extensive research was carried out to determine the most appropriate methodologies for monitoring and automating processes in the plant. As a result, it was decided to develop an internal system capable of adapting to the particularities of the existing facilities.
In the case of the Cartonplast counter, a simple solution was designed that provides the operator with greater mobility and reduces visual fatigue associated with manually counting the sheets in the summer. The main challenge during development was the selection of an effective method to address the thickness and color variations that the sheets present. To overcome this difficulty, a monitoring system based on a distance sensor was implemented. Figure 1 illustrates the process for counting cartonplast sheets.

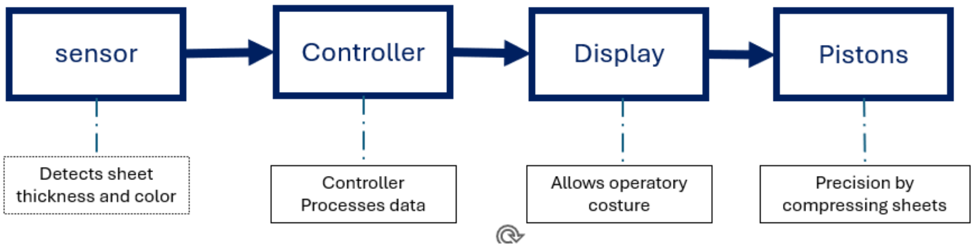

Figure 1. Description of the counting process.

The selected sensor, the "Banner Engineering LM150KIQP" model, stood out among various options on the market due to its ability to operate with different colors, its measurement range of 50 to 150 mm and its operation with a voltage of 10 to 30V. These features facilitated its integration into a mobile and compact system.
The implementation of the sensor required the use of the R45C-2K-MQ system as a signal encoder and a USL-050-B05 HDMI display with integrated operating system for programming. This set made it possible to register the references of the sheets, so that the operator only had to specify the type of sheet to process.
Additionally, the Cartonplast counter incorporates a stopper system designed to reduce the space between the sheets and improve counting accuracy. This mechanism was implemented using pneumatic pistons, guaranteeing greater efficiency and reliability in the process. Figure 2 illustrates the process.

Figure 2 Sheet counter process graph

3.1 Fabric Width Meter

The fabric width measurement project arose with the objective of monitoring circular looms in real time, key parts in the production of polypropylene (PP) bags. Controlling variations in fabric width is essential, as these can lead to non-conforming products for customers and significant material losses. To design an efficient system, different technologies were investigated, including laser sensors, ultrasound, and commercial devices. However, given the possibility of scaling the project to different types of machinery, it was decided to develop an internal solution customized to the needs of the plant.
Initial development included a Basler ACA2500-14UC machine vision camera, connected to a Raspberry Pi 4. This microcomputer was chosen for its portability, low power consumption, and its ability to integrate with a variety of sensors, thanks to its ARM architecture (Advanced RISC Machine). The system was programmed in Python, taking advantage of its extensive repertoire of libraries. OpenCV was used for computer vision tasks, pandas for data processing and analysis, tkinter to execute multiple functions simultaneously, and Google for the connection with BigQuery.
After various tests and adjustments, a robust module was developed, suitable for industrial environments, and easy to install on the company's different loom models. This module uses a Logitech camera, an RPM sensor, and a Raspberry Pi 4 as a processing unit. It works by capturing a photograph of the roller loom, measuring the actual width of the fabric using machine vision, and recording the RPM of the loom during the measurement, see Figure 3.

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Loom with fabric width measuring device	Fabric width measuring device

Figure 3. Loom – Fabric width measurement

3.2. Red Ribbon Detection

The collected data is stored in BigQuery for further analysis. In addition, Looker Studio is used as a visualization platform, allowing the daily performance of the looms to be evaluated. The dashboard includes a quality IQ process, which facilitates the monitoring of key indicators such as the number of warp and weft breaks, offering a comprehensive overview of equipment performance. The increase in production has prompted the company to implement monitoring mechanisms to identify non-conforming products efficiently. During the weaving and gusseting processes, any fabric that does not meet quality standards is marked with a red ribbon, making it easier to identify and remove in later stages. Previously, these defective bags were removed manually by operators during the finishing process, but there was a risk that some would go undetected and reach customers.

One of the systems developed to address this problem focuses on ensuring the effective identification and removal of bags marked with red tape. The main challenge lies in the wide variety of references handled by the company, which vary in color and size, complicating automated detection. To overcome this challenge, a system based on color sensors from the SICK brand, model DE-79183, was implemented. These industrial photoelectric sensors are designed to detect objects in various environments with high precision. The system is managed by an IO-Link Master model ICE3-8IOL-G65L-V1D, a device specialized in the integration and control of multiple sensors, allowing efficient data collection and management.

The connection between the sensors and the IO-Link Master is carried out using the Siemens S7-1200 PLC, configured and programmed with the TIA Portal software. This system allows, when a red tape is detected, a light alarm is activated that notifies the operator of the presence of a defective bag. This solution ensures the efficient disposal of non-conforming products, minimizing the risk of errors and significantly improving process quality.

3.3 Optimization of Processes in the Cartonplast Plant

At the Cartonplast plant, an artificial vision system was implemented to optimize sheet counting. Previously, this process depended entirely on operators, who would take a stack of sheets, count it manually and, if it contained 50 units, transfer it to the packaging table. This procedure took approximately 60 seconds. With the new automated counting system, the operator places a stack of 25 sheets on the system's sensor, then another similar stack to reach the 50 units required for packaging. Although the process involves two trips, it is completed in just 30 seconds, reducing the time needed by 50%. This represents a significant improvement in operational efficiency, allowing for greater productivity in the plant.

3.4 Detection of Red Ribbons on PP Bags

In the finishing section of the PP Sacks plant, an artificial vision system was implemented focused on the detection of red ribbons on the forming machines. This system is installed on three machines and has demonstrated a 100% detection rate of red ribbons passing through them. When red tape is detected, the system activates a light beacon that notifies the operator to remove the defective bag. The red ribbons correspond to products that do not meet quality standards and are classified under the group “Product with Various Defects (Special Agreement with Customers)”. This group includes defects such as offsets, wrinkles, mistakes, printing defects and red ribbons.

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The impact of the system has been notable. Comparing the first four months of 2024 with the last four available months, defects in this category were reduced by 23%, going from 11,054 to 2,570 defective bags. This achievement reinforces the effectiveness of the system in guaranteeing the quality of the final product and minimizing customer complaints. Previously, fabric width measurements were performed manually at a frequency of once every 60 minutes. With the implementation of an artificial vision system on the looms, automatic measurements are now made every five minutes. This advance allows deviations in width to be quickly detected, facilitating the timely identification of failures in both the machine and the raw material. The impact of the system has been notable. Comparing the first four months of 2024 with the last four available months, defects in this category were reduced by 23%, going from 11,054 to 2,570 defective bags. This achievement reinforces the effectiveness of the system in guaranteeing the quality of the final product and minimizing customer complaints.

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Figure 4. System Dashboard

DISCUSSION

The implementation of artificial vision systems and sensors in the manufacture of polypropylene bags has made it possible to automate critical tasks such as sheet counting, fabric width measurement and defect detection. These innovations have significantly reduced operating times in the company, improving productivity and optimizing processes. The designed systems ensure accurate and timely detection of non-conforming products, such as bags marked with red tape, reducing the risk of errors and ensuring that final products meet quality standards.

The integration of platforms such as BigQuery and Looker Studio allows data to be stored, analyzed and visualized in real time, providing essential tools for constant monitoring and rapid resolution of operational problems. Automation in the detection of red ribbons and the measurement of fabric width has reduced the incidence of defects by 23% in PP bags and minimized material waste, contributing to the sustainability of the processes.

The systems developed are robust, modular and capable of adapting to various machines and industrial environments typical of packaging companies, positioning the company as a benchmark in the adoption of advanced technologies within the manufacturing sector. These technological solutions not only strengthen the company's position in a globalized market but also establish a replicable model for other organizations seeking to increase efficiency, reduce costs and guarantee high quality products.In conclusion, the implementation of artificial vision systems and industrial sensors has significantly transformed production processes at Grupo Excala, demonstrating that the integration of advanced technologies is a key strategy to face the current challenges of the manufacturing industry.

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