Enhancing E-commerce Delivery Efficiency Through Automated Sorting Systems

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Abstract: E-commerce has revolutionized shopping, providing unmatched convenience to consumers. Nevertheless, swift and efficient product delivery remains a substantial challenge, impacting both delivery times and costs. In this work, we address this issue by proposing an innovative solution: the automation of product sorting. We have developed an automated system that utilizes pneumatic actuators to replace human operators responsible for sorting items in the delivery process. Our study demonstrates substantial improvements in delivery efficiency, significantly reducing delivery times and associated costs, all while enhancing the E-commerce customer experience.

Keywords: Automated System, delivery time, Sorting Systems, Pneumatic Actuator, infrared sensor

الملخص: قامت التجارة الإلكترونية بتحول جذري في مجال التسوق، حيث قدمت للمستهلكين مستوى لا مثيل له من الراحة. ومع ذلك، لا يزال هناك تحدي كبير يتعلق بسرعة وفعالية تسليم المنتجات. من أجل مواجهة هذا التحدي البارز، قمنا بمحاولة إيجاد حلاً مبتكرًا من خلال تطوير وبرمجة نظام ذكي وآلي يستند إلى تعويض العمل البشري في عملية فرز المنتجات باستخدام تكنولوجيا حديثة ودقيقة. أظهرت النتائج المحصل عليها تقدمًا كبيرًا في تحسين كفاءة عملية التوصيل، حيث قللنا بشكل ملحوظ الوقت و التكلفة.

الكلمات المفتاحية: نظام آلي، وقت التوصيل، أنظمة الفرز، المكبس الهوائي، جهاز الاستشعار بالأشعة تحت الحمراء

1- Introduction:

The rise of E-commerce has heralded a revolution in how consumers worldwide conduct their shopping. The ability to browse a vast array of products from the comfort of our homes, compare prices with a click, and finalize purchases within minutes has fundamentally reshaped our shopping habits. This transformation has allowed E-commerce businesses to thrive and assert a new dominance in the commercial landscape [1]. However, even as consumers have been enthralled by the convenience offered by e-commerce, they have also grown increasingly demanding. One of the most pressing expectations is rapid delivery. The promise of receiving products within a record time has become a standard in the e-commerce industry. Customers, accustomed to digital speed, no longer tolerate extended delivery times.

This new reality has placed significant pressure on delivery service providers. Consumer expectations have pushed these companies to fundamentally rethink their processes to meet the growing demand for speed and efficiency. Fast delivery has become a decisive factor in customer satisfaction, and its effective management has become an ongoing quest. It is within this context that our research comes into focus [2]. We have delved into this critical issue, seeking to understand how to reconcile the need for swift deliveries with operational

efficiency in the realm of e-commerce. Our work has culminated in an innovative solution, implementing automated systems to expedite product sorting, resulting in a significant reduction in delivery times while enhancing the overall customer experience. In this context, we present our findings and the implications of our research at this conference.

2- Description of Conventional Sorting System

In a conventional delivery system, the parcel sorting process within the delivery company follows a well-established procedure. Initially, the reception of parcels is managed by the company's reception agent, where parcels from vendors are received. Once these parcels are received, and the information from both the vendors and customers is recorded, the parcels are then transported to the storage area [3]. This transfer is accomplished using an automated conveyor system, powered by a motor [4]. Alongside the conveyors, qualified operators are responsible for sorting the received items (see figure 1). This sorting can be done based on several criteria, such as destination, volume, or through color-coded or labeled systems aimed at reducing delivery time. For example, the sorting method may depend on the final destination of the parcel. Take, for instance, the case of Algeria, where sorting is carried out according to the country's four corners: the North, South, East, and West. Four operators are assigned to this task, and they classify items according to these four regions. This can result in the use of four distinct colors for packaging parcels, with each color corresponding to a specific region.

Figure 1: Conventional Sorting System

Furthermore, the sorting criteria may vary depending on the delivery company's strategy. In addition to geographic destination, sorting can be based on characteristics such as the color of items, their volume, or size. Some operators may be responsible for sorting large items, while others focus on medium or small items. Thus, the sorting process offers various criteria to adapt to the specific needs of the delivery company, ensuring optimal efficiency in parcel distribution. This level of flexibility allows for a personalized response to the requirements of each shipment, whether it involves distinguishing between destination regions or identifying categories of items using diverse criteria.

3- Description of the proposed system

In this section, we provide a comprehensive overview of the proposed system, offering insights into the modifications and enhancements that have been implemented. The following

subsections delve into key aspects of our system, each shedding light on specific alterations aimed at improving functionality and performance

3.1- Operator Hands Replacement using Pneumatic Cylinders

In the pursuit of optimizing sorting systems and reducing human intervention, pneumatic cylinders have emerged as pivotal components in the realm of automation. These precision-engineered devices harness the power of compressed air to facilitate controlled and efficient motion. In the context of sorting systems, pneumatic cylinders play a transformative role by replicating the dexterity and reliability of human hands. These cylinders are adept at delicately manipulating parcels, objects, or components, precisely positioning them for sorting or assembly. Their rapid response times and programmable controls ensure a seamless integration into automated sorting processes, enabling the elimination of manual labor and enhancing the overall efficiency of the system. As a result, pneumatic cylinders stand at the forefront of modern automation, offering a reliable and versatile solution for tasks that once relied on human touch and intervention.

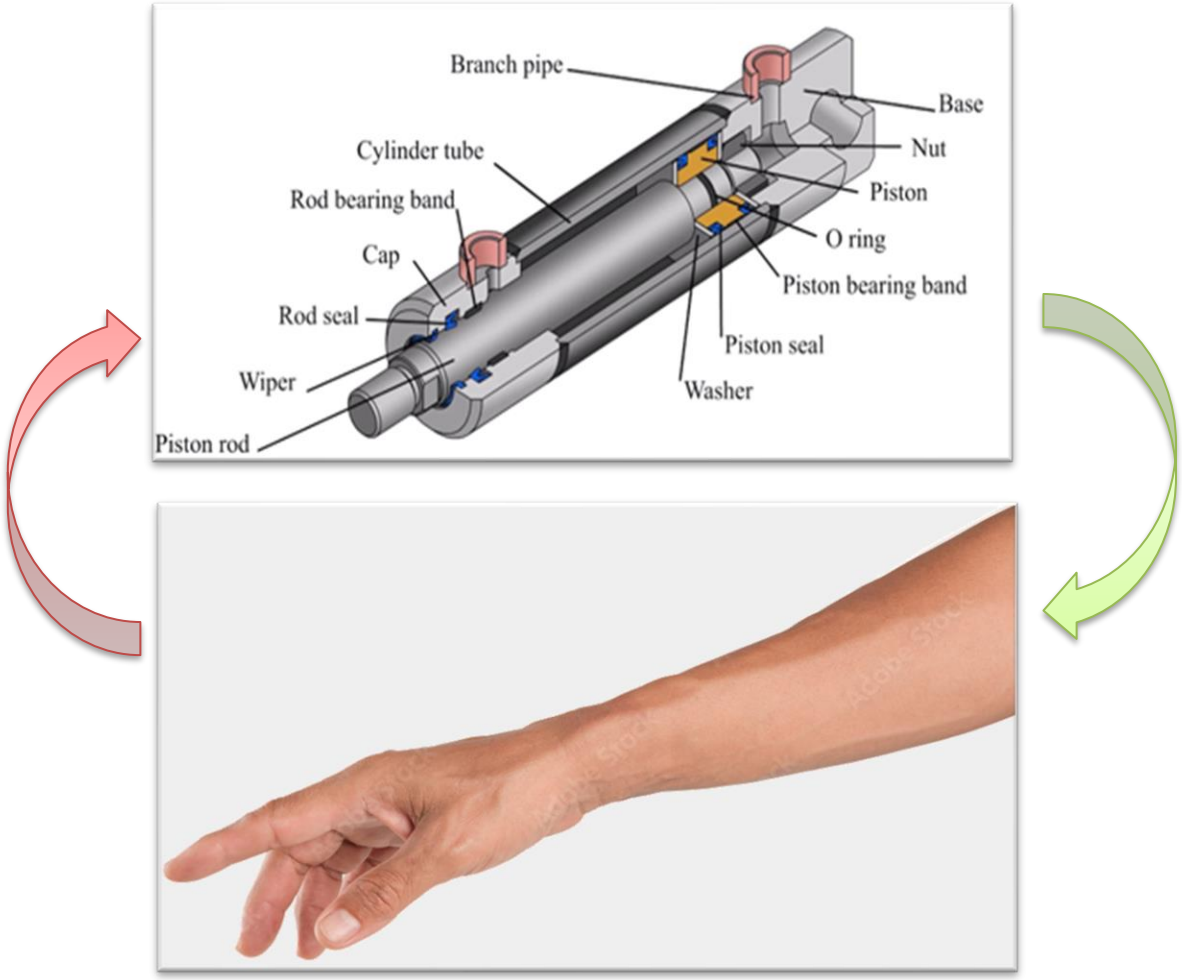

Figure 2: Operator Hands Replacement using Pneumatic Cylinders

3.2- Introduction of Infrared Barriers for Parcel Detection

Infrared (IR) barriers have emerged as a key technology for replacing traditional human visual inspection in the context of object detection and the isolation of sorted parcels. This paradigm

shift harnesses the capabilities of IR technology to streamline sorting operations, significantly improve accuracy, and reduce errors. In this conference paper, we delve into the application of IR barriers as a cutting-edge tool in the realm of parcel sorting. By exploring the principles, advantages, and real-world implementations of this technology, we aim to shed light on its role in shaping the future of automated sorting systems, offering unparalleled precision and efficiency in the industry.

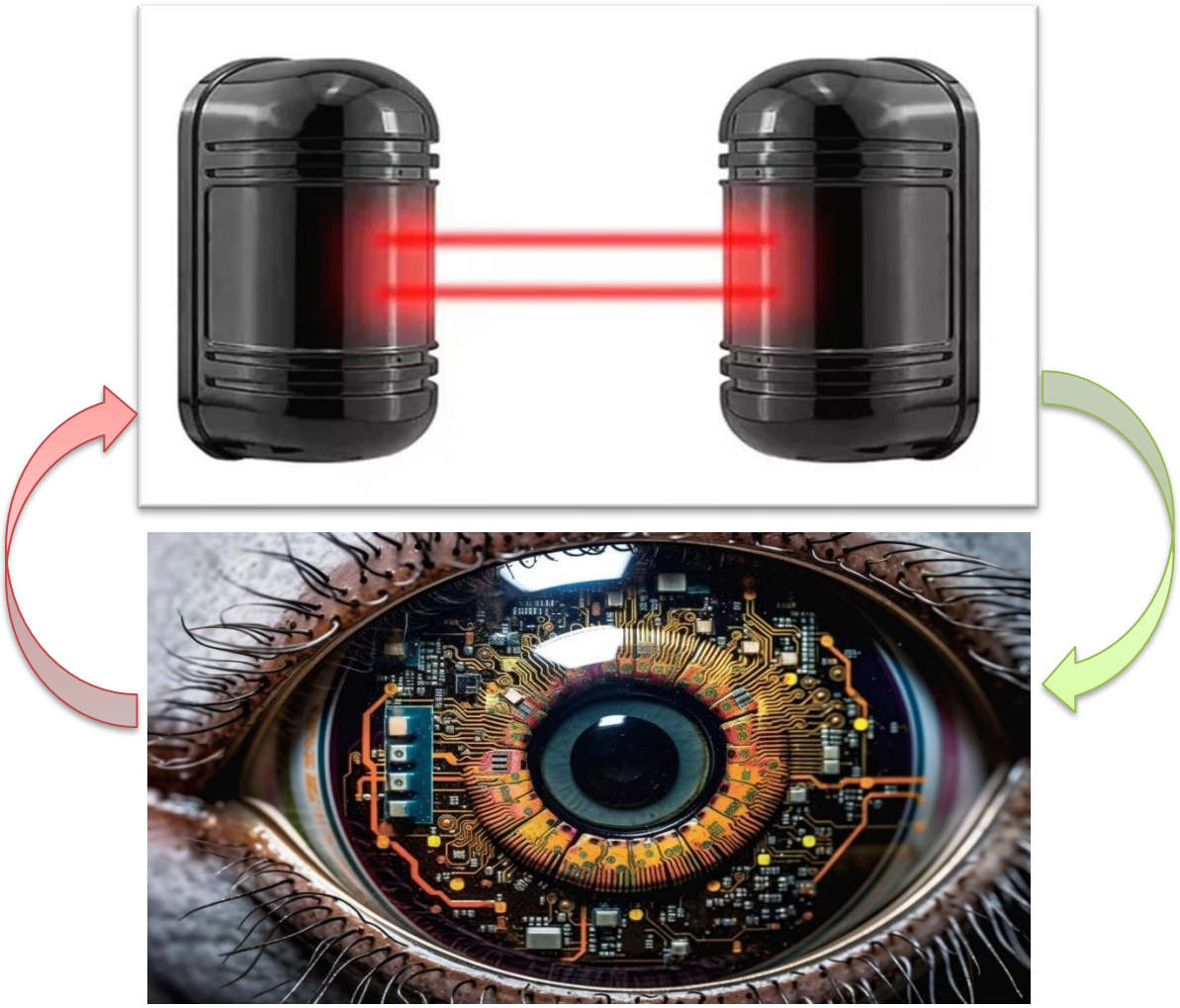

Figure 3: Operator Eyes Replacement using Infrared Barriers

3.3- Use of industrial programmable automation to replace operator brain

The industrial programmable automation system can be introduced as an innovative solution designed to replace the cognitive capabilities of an operator's brain while simultaneously orchestrating the harmonious coordination between visual perception and physical execution. This transformative technology leverages advanced algorithms, sensors, and robotic actuators to replicate and enhance the decision-making prowess of a human operator while meticulously synchronising it with the precision of mechanical actions. This paper explores the advent of such systems, their profound implications for efficiency, accuracy, and productivity in sorting processes, and the consequential shifts in the landscape of industrial operations.

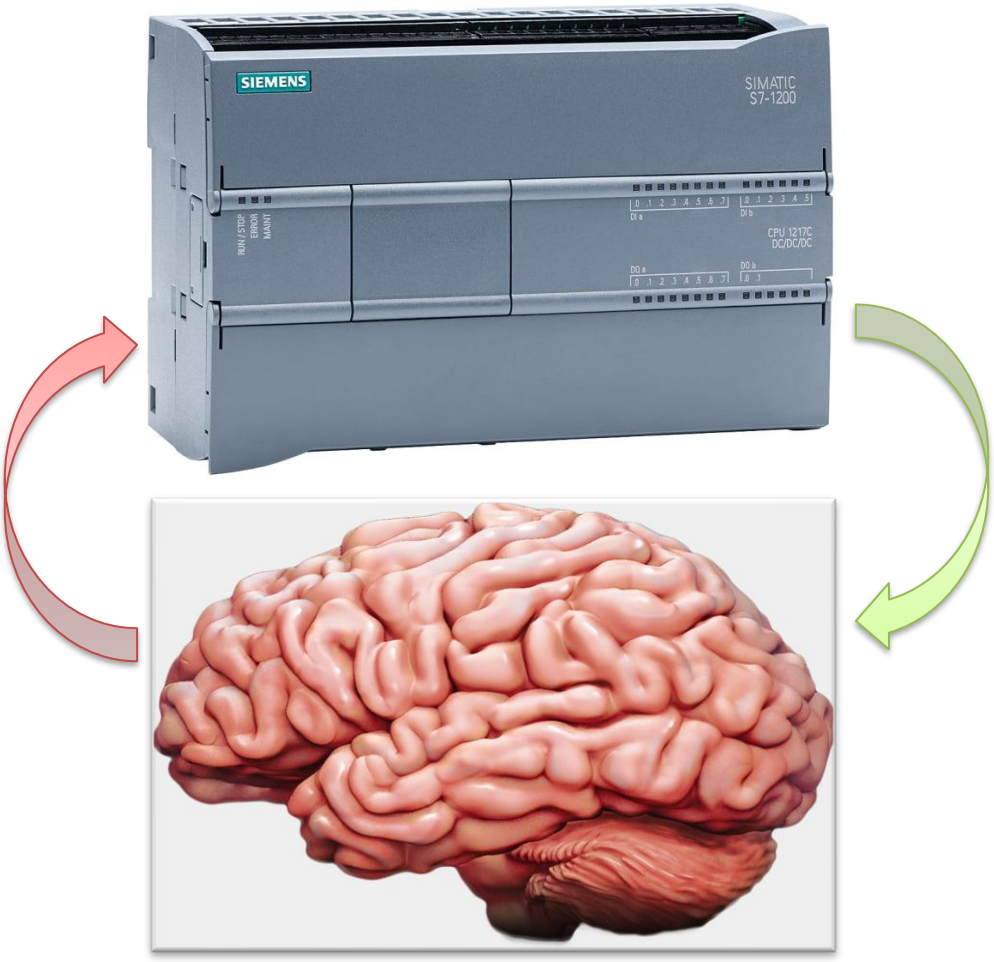

Figure 4: Use of industrial programmable automation to replace operator brain

4- Automated Sorting System: The Ultimate Solution

To enhance the efficiency of this system, it is imperative to minimize both the sorting time and the number of operators, which will lead to a reduction in delivery costs. This process improvement plays a pivotal role in fostering E-commerce development and optimizing the delivery service. To address this challenge, a commonly adopted solution in automated systems is to replace the manual intervention of operators with pneumatic cylinders that perform precise in-and-out movements to sort objects effectively. These cylinders are positioned near the conveyor (see figure 5), effectively taking over the operator's

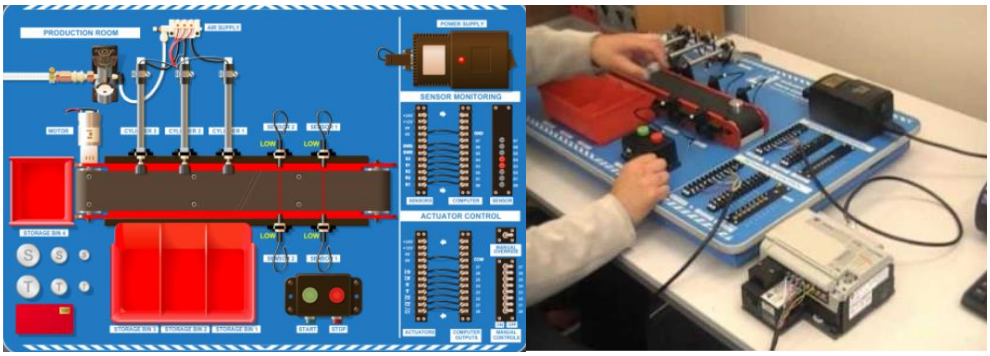

Figure 5: Automated Sorting System (the ultimate solution)

role. Additionally, the visual capability that allows operators to distinguish objects is replaced by sensors capable of performing the same task. The coordination between the cylinders and sensors is managed by a programmable logic controller (PLC), serving as the brain of the operator.

Lastly, our task involves programming this automation system to ensure its efficient operation. In our study, we tackled three distinct problems based on sorting criteria, with the primary indicator being volume. To this end, we selected three different categories of cylindrical objects for each specific problem (see figure 6). In the first problem, cylindrical objects had varying radii, while in the second problem; we considered cylindrical objects with varying heights. Finally, in the third problem, we considered cylindrical objects with variable dimensions in terms of width and height. In this paper, we focus exclusively on sorting objects based on their width.

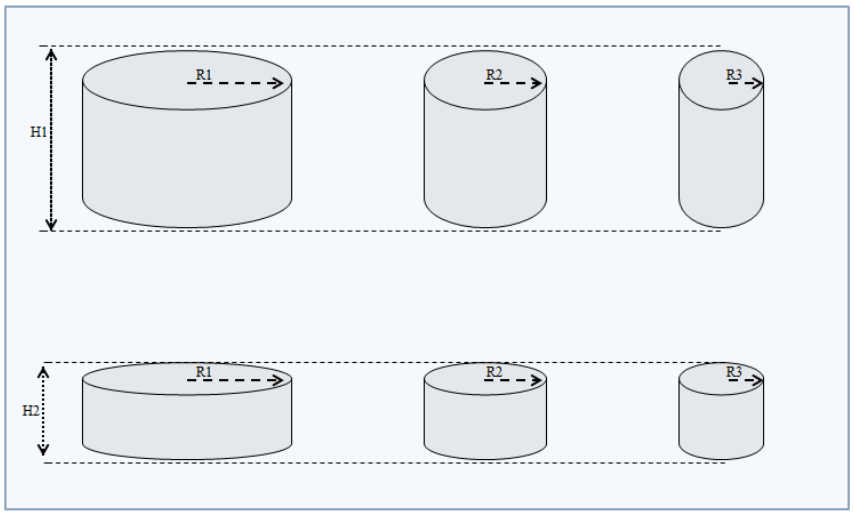

Figure 6: Cylindrical objects to be sorted

5- Description of the Proposed Automation Logic

Our focus is to sort cylindrical objects based on their diameter using pneumatic actuators to direct them to the appropriate stocking area, taking into account the constant conveyor speed and the cutoff time measured by the infrared sensor. For this purpose, we consider the following data:

- N: The Total number of objects to be sorted.
- $Speed$: The conveyor speed (constant).
- D_i: The diameter of object i, with i varies from 1 to N.
- N_v: The number of pneumatic cylinder (which is equivalent to the number of objects to be sorted).

We consider the following variables:

- T_{ci}: The cutoff time measured by the infrared sensor for object i, where i varies from 1 to N.
- V_i: Binary variable indicating the state of actuator i, where i varies from 1 to N_v. $V_i = 1$ means the actuator's rod is extended, and $V_i = 0$ means the rod is retracted.
- C: Binary variable indicating the state of the infrared sensor. $C = 0$ means the barrier is cut (object detected), and $C = 1$ means the barrier is intact (no object detected).

The logical steps are as follows:

- When an object passes in front of the infrared sensor for the first time, the sensor variable will be equal to zero (i.e $C = 0$) , The PLC initiates a counter to measure the corresponding cutoff time, T_{ci}, and stores this value in the internal memory.

- Thereafter, the PLC selects an appropriate pneumatic actuator, denoted as 'i', and sets its variable to one ($V_i = 1$) in order to extend its rod and thus store the object. The choice of the actuator can be either automatic or user-imposed.

- When an object of the same type passes in front of the infrared sensor again, the PLC measures its cutoff time T_{ci}.

- If the measured cutoff time during the subsequent passage is close to or equal to T_{ci}, the controller triggers the appropriate actuator ($V_i = 1$) to direct the object to the corresponding stockage area.

- Otherwise, another actuator is selected, and the objects are placed in their respective storage areas by setting its variable to one.

- Finally, the all the objects are successfully sorted based on its diameter.

This logic takes into account the constant conveyor speed, the cutoff time measured by the infrared sensor, and the action of pneumatic actuators to sort cylindrical objects based on their diameter.

6- Conclusion:

This study indicates the promise of automating product sorting to solve the issues of effective product delivery in the e-commerce sector. In conclusion, this study exhibits the promise of automating product sorting. Significant gains in delivery efficiency have been gained as a result of the transition from manually operated systems to those that are fully automated and make use of pneumatic actuators. Because of this, delivery times have been cut significantly, and online retailers have seen significant cost reductions. As the e-commerce sector continues its rapid pace of change, the widespread implementation of automation technologies, such as those described in this paper, maybe a critical factor in fostering more technological advances and improving customer service quality.

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