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# A low cost intelligent sorting mechanism using infrared and colour sensor with servo driven robotic arm

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**ABSTRACT**

In the era of industrial automation, traditional manual sorting remains a bottleneck characterized by high operational costs and reduced throughput. This research presents an integrated automated sorting system comprising a robotic arm and a conveyor belt mechanism designed to streamline object classification. The system utilizes an infrared (IR) sensor for object detection and a colour sensor for classification based on predetermined criteria. Upon detection, the robotic arm executes precise picking motions to sort objects by colour, significantly minimizing human intervention. Experimental results demonstrate the system's high reliability and efficiency. While the IR sensor consistently detected objects within a 5 cm range, the integration of a physical stopper proved essential for stabilizing object positioning. Initial inaccuracies in colour detection were resolved through iterative frequency-to-red, green, blue (RGB) mapping, eventually achieving 100% accuracy for red, green, and blue targets. Performance tuning revealed that a 1 s servo delay optimized the balance between mechanical stability and speed, yielding an average cycle time of 6.66 seconds. With a 95% overall success rate, this system offers a cost-effective automation solution tailored for small and medium-sized enterprises (SMEs) and highlights the scalability of servo-based robotic sorting in manufacturing and recycling sectors.

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## 1. INTRODUCTION

Automation has transformed many facets of human living and has become an essential part of modern life. Automation has been used to save costs, increase efficiency, and decrease manual labour in everything from industrial robots to garage door openers [1], [2]. One of the most often used robotic systems in the industrial sector is the robotic arm, sometimes referred to as the serial manipulator. A serial manipulator is made up of several links that are joined by motorized joints from a base to an end effector. Pick-and-place jobs, spot welding and arc welding [3], and painting [4] are just of the industrial uses for these robotic arms. Robotic arms are available in a variety of shapes and sizes, depending on the demands of the task [5], [6]. Both sensors and pre-programmed instruction sets are used to control them. Figure 1 shows the usage of robotic arm through various industries [7].

In industrial environments, manual object sorting presents several critical challenges, including inefficiency, high labor costs, and a high risk of human error. These repetitive tasks not only lead to fatigue and potential injury among workers but also reduce overall productivity. As a result, laborers, manufacturing firms, and logistics companies are significantly affected facing issues like increased operational costs, inconsistent output quality, and heightened safety risks in the workplace. Although automated sorting systems exist, many are either too expensive or lack flexibility, making them unsuitable for small and medium-sized enterprises (SMEs) that require cost-effective and adaptable solutions [8].

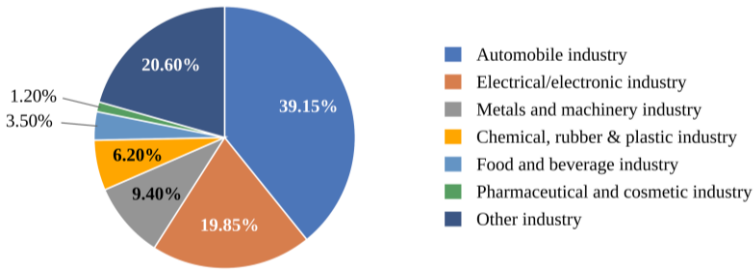



Figure 1. Robotic arm in different industries

The key aspects compared are summarized in Table 1, followed by a detailed discussion of the findings. The comparison table highlights the unique characteristics and capabilities of each system. For example, studies by [9], [10] use microcontrollers such as Arduino Uno and Arduino Nano to focus on cost-effective solutions, which makes them appropriate for smaller-scale applications. On the other hand, studies by [11], [12] place more emphasis on cutting-edge technology like computer vision and deep learning, which increase sorting accuracy but also cost more because they need more processing power. Furthermore, by incorporating machine learning for object identification with comparatively high accuracy and minimal resource needs, Rao *et al.* [13] offers a compromise. The sensors employed in these investigations also differ greatly; while studies by [11], [12] make use of more advanced RGB-D and computer vision systems, studies by [9], [10] rely on more basic camera-based systems. These variations highlight how cost, accuracy, and complexity must be balanced when creating automated object sorting systems.

Table 1. Comparative analysis of previous research

| Aspect | [9] | [11] | [13] | [10] | [12] |
|---|---|---|---|---|---|
| Sorting Basis | Shape and color | RGB-D object detection | Object identification | Color-based | Color and height |
| Sensors Used | Image processing camera | RGB-D camera | Camera and TensorFlow | Pixy2 camera | Computer vision |
| Microcontroller/ Processor | Arduino Uno | High-performance processor | Arduino Uno | Arduino Nano | High-performance processor |
| Sorting Accuracy | 85% | >90% | ~92% | 85% | 99% |
| Strengths | Cost-effective, simple implementation | Advanced deep learning capabilities | Machine learning integration | Easy integration with Arduino Nano | High precision and multi-factor sorting |
| Limitations | Limited to shape and color; moderate accuracy | Requires high computational power | Computationally intensive training phase | Restricted to color-based sorting | High cost due to advanced setup |

In the modern industrial landscape, the rise of robotic arms and conveyor systems has been a game-changer for cutting down human error and speeding up production. As noted by Szabo and Lie [14], these automated setups do more than just move objects; they drastically lower costs by taking over the repetitive, exhausting tasks that usually lead to manual mistakes. The secret to their precision lies in how well the sensors talk to each other. Research by Khanh *et al.* [15] point out that fine-tuning details—like the exact height of a color sensor or its frequency mapping—is what truly makes a system reliable in a busy warehouse setting. Perhaps most importantly, these affordable mechatronic solutions have leveled the playing field, allowing smaller businesses (SMEs) to access the kind of high-tech automation once reserved for giants [16]. As we look ahead, mastering calibration techniques remains the best way to ensure these systems stay accurate, even when lighting and environmental conditions change [17].

To address these challenges, this research proposes the development of an automated object sorting system utilizing a robotic arm and conveyor mechanism, integrated with infrared (IR) and color sensors to detect and classify objects based on predefined criteria. This work contributes to embedded automation by demonstrating a reconfigurable, sensor-driven robotic sorting system that can be extended to IoT enabled smart manufacturing environments.

## 2. RESEARCH METHOD

This section describes the design, development, and implementation of the proposed automated object sorting system, including system architecture, design rationale, theoretical formulation, and embedded system considerations.

The procedures to complete the automated item sorting system are shown in the system integration flowchart in Figure 2. First, all of the software (Arduino code) and hardware (robotic arm, conveyor belt, motors, and sensors) are ready. An Arduino Uno was chosen over more advanced processors (like FPGA or STM32) to focus on a cost-effective embedded solution. The parts are then combined to guarantee correct connections and synchronization. After preliminary system testing to confirm fundamental operation, sensors (IR and colour sensors) and motors are calibrated for precise movement and detection. System performance is then enhanced to guarantee efficiency and seamless operation. The system is now prepared for complete operation and demonstration after every component has been examined and adjusted.

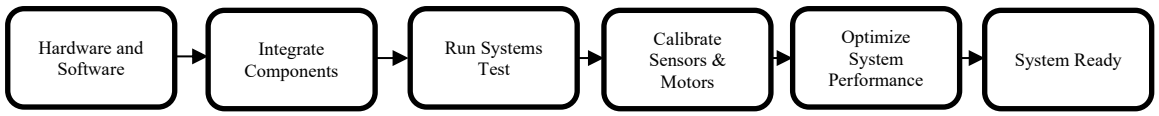



Figure 2. System integration flowchart

The automated sorting procedure is shown in the block diagram in Figure 3. When an IR sensor detects the presence of things, the conveyor belt transfers them. The conveyor halts when an object is spotted, and the robotic arm then scoops it up. If object not spotted, the belt will continue running. After determining the object's colour using a colour sensor, the robotic arm inserts it into the proper container, either a red, blue, or green container. The system ensures continuous and effective object sorting by restarting after sorting.

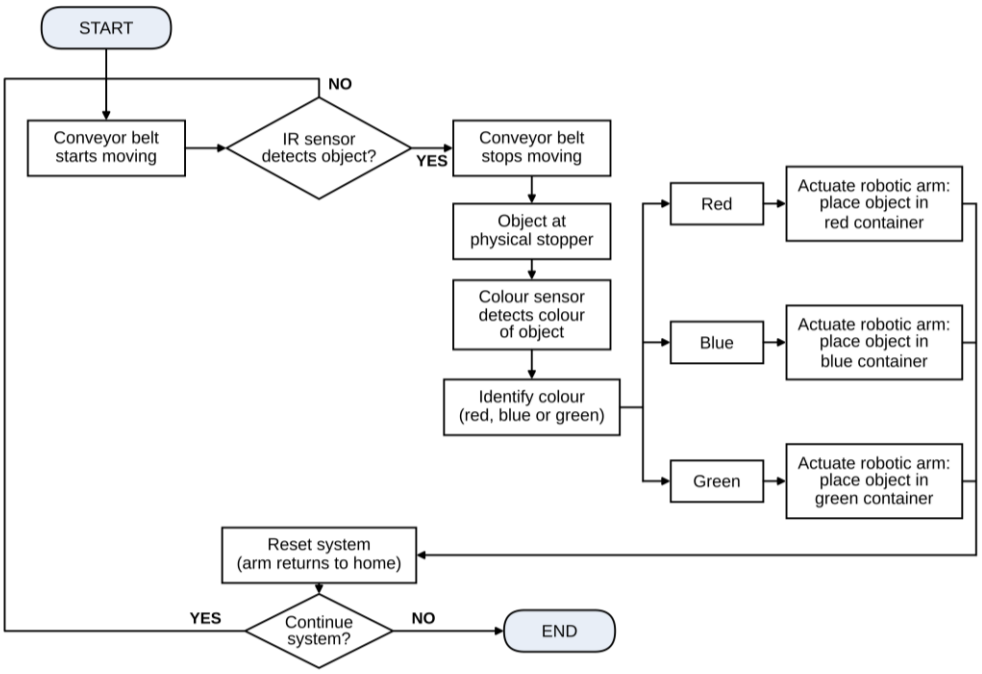



Figure 3. Block diagram

Shulhan *et al.* [18] focused on the design and optimization of robotic arm motion for automated sorting. It uses Arduino-based control systems to manipulate the robotic arm and improve the speed and efficiency of the sorting task. The study highlighted the trade-off between speed and precision, suggesting that multiple servo motors could be used for different arm segments to achieve more fluid and faster movements. Figure 4 illustrates a robotic arm with 4 degrees of freedom.

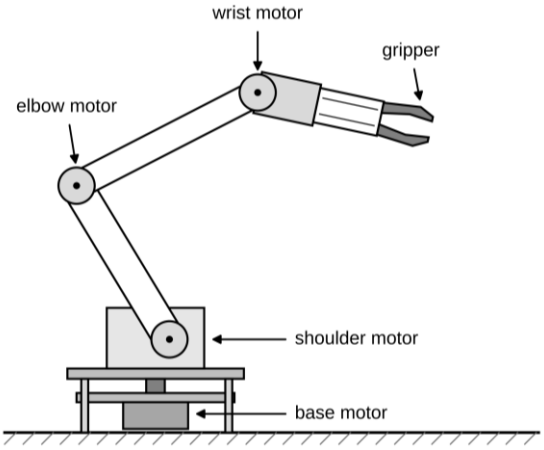



Figure 4. Illustrations of robotic arms with 4 DOF

A study by [19]–[21] investigated the integration of conveyor belts and robotic arms in a sorting system, focusing on the synchronization of the two systems to ensure smooth operation. They used a feedback loop to dynamically adjust the speed of the conveyor belt based on sensor inputs and the robotic arm's current position. This approach improved the overall efficiency of the system, reducing the time required for sorting. Based on (1), the linear speed (v) of the conveyor belt is directly proportional to both the angular velocity (ω) of the pulley and its radius (r). When the pulley rotates, points on its edge move linearly, and the distance they cover depends on the radius of the pulley and how fast it is spinning.

$$v = \omega . r \quad (1)$$

Conveyor belts are critical components in sorting systems, providing the means for objects to move from one stage of the process to another. The challenge in designing conveyor belt systems lies in achieving precise control over the movement of objects while maintaining a consistent flow [22]–[24]. A Thike *et al.* [25] examined the use of DC motors for controlling the speed and direction of conveyor belts in sorting systems. Their research demonstrated that DC motors can be precisely controlled using microcontrollers like Arduino, and they highlighted the need for synchronized control between the belt and robotic arm to prevent misalignment or delays during sorting. Small electronic devices frequently use the tiny, high-performance model 130 DC motor. It runs between 3 V and 6 V DC and can reach up to 13,000 rpm at 6 V without any load. The motor usually has an efficiency of about 70% and produces a torque of about 0.3 oz-in (0.021 Nm). It is effective for low-power applications since it has a power output of about 1.5 W and drains 0.2 A when there is no load. Its compact dimensions of 36 mm in length and 22 mm in diameter make it perfect for toys, tiny robots, and other portable electronics.

## 3. RESULTS AND DISCUSSION

In this section, it presents the outcomes of various tests conducted on the automated object sorting system, including servo motor speed tuning, colour sensor detection accuracy, IR sensor performance, and overall system behaviour. The aim of these tests is to evaluate and optimize the efficiency, accuracy, and responsiveness of the robotic arm and conveyor mechanism in sorting-coloured objects.

### 3.1. Servo motor speed testing

To evaluate the impact of servo motor delays on the speed and efficiency of the sorting process, multiple tests were conducted by adjusting the delay() function in the Arduino program. The goal was to

determine the shortest possible delay that allows complete servo motor movements without compromising performance.

With delay(1000) or 1s delay between servo movements, an average speed of 6.66 seconds over 10 attempts have been recorded. Speed has been improved, and movement were complete as well. To understand how the delay impacts servo speed, the approximate angular speed (ω) can be calculated using formula 2. Where Δθ is the total angle the servo rotates (in degrees) and Δt is the delay time (in seconds).

$$\omega = \frac{\Delta\theta}{\Delta t} \quad (2)$$

Based on Table 2, delay(1000) or 1s delay provided the best performance in terms of speed and accuracy. An attempt was made to further reduce the total cycle time by eliminating certain robotic arm movements between clamping and dropping, but this led to collisions with the conveyor, making the adjustment unfeasible.

Table 2. Experiment on cycle of servo motors

| Delay time (sec) | Average cycle time (sec) | Remarks |
|---|---|---|
| 2.0 | 15.22 | Complete movement; slowest cycle |
| 1.5 | 11.18 | Improved speed; movements still complete |
| 1.0 | 6.66 | Optimal balance between speed and accuracy |
| 0.5 | Non-conclusive | Incomplete movements; reduced precision |

### 3.2. Colour sensor testing and results

In this section, a colour sensor is employed to detect the colour of objects moving on a conveyor belt, enabling sorting into designated containers using a robotic arm. The system is configured to recognize three primary colours: red, green, and blue. The sensor determines the dominant red, green, and blue (RGB) values of each object and communicates the data to the Arduino Uno microcontroller to guide the sorting process.

#### 3.2.1. Colour sensor data collection and mapping

Initial testing involved positioning coloured objects at different distances from the sensor and observing the raw frequency data output on the Arduino Serial Monitor (baud rate: 9600). A blue object was used first to observe the variation in frequency values based on proximity. At a close distance of 3 cm, the sensor recorded a blue frequency value of 59, and at a farther distance of 10 cm, a value of 223. This behavior is illustrated in Figure 5.

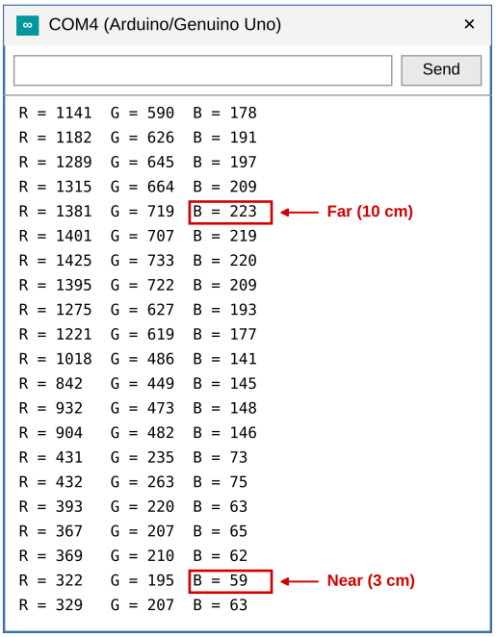



Figure 5. Raw frequency data from colour sensor when a blue object is placed at different distances

The raw frequency values are then mapped to standard RGB ranges (0 to 255) using the Arduino map() function. For example, a frequency of 59 maps to an RGB value of 255, and 223 maps to 0. This mapping allows RGB values to be used in conditional logic: if R is the highest: classify as red, if G is the highest: classify as green, if B is the highest: classify as blue. For this project, distance of 3 cm is used as minimum and 5 cm is used as maximum. Figure 6 shows the setup of the colour sensor as it detects objects of different colours, demonstrating red in Figure 6(a), blue in Figure 6(b), and green in Figure 6(c) colour detection.



(a) (b) (c)

Figure 6. Setup showing the colour sensor facing different coloured objects: (a) red colour detection, (b) blue colour detection, and (c) green colour detection

### 3.2.2. Evaluation and testing of colour detection accuracy

To assess sensor accuracy, a total of four tests were conducted using nine objects, three each of red, green, and blue. The results of each test were recorded and tabulated in Table 3. Table 3 summarizes the detection results for each test cycle. In Test 1, the system was poorly calibrated, leading to only 4 correct identifications. Subsequent tests saw improved performance through manual RGB mapping. By Test 4, all colours were correctly identified, achieving 100% accuracy.

Figure 7 illustrates the trend in accuracy improvement over four testing phases. The graph highlights the effectiveness of calibration using the map() function in the Arduino code. This stacked bar chart in Figure 8 visualizes how many objects of each colour were correctly detected in every test. It reveals the progression and challenges in calibrating for red detection, which was resolved by Test 4.

Table 3. Experiment on colour sensor detection

| Test number | Detect red | Correct red | Detect green | Correct green | Detect blue | Correct blue | Total correct | Accuracy (%) |
|---|---|---|---|---|---|---|---|---|
| Test 1 | 0 | 0 | 8 | 3 | 1 | 1 | 4/9 | 44.45 |
| Test 2 | 0 | 0 | 6 | 3 | 3 | 3 | 6/9 | 66.67 |
| Test 3 | 0 | 0 | 3 | 3 | 6 | 3 | 6/9 | 66.67 |
| Test 4 | 3 | 3 | 3 | 3 | 3 | 3 | 9/9 | 100 |

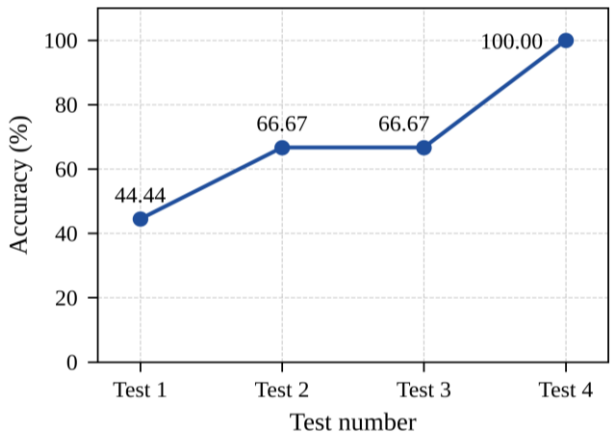



Figure 7. Accuracy progression graph for each test cycle

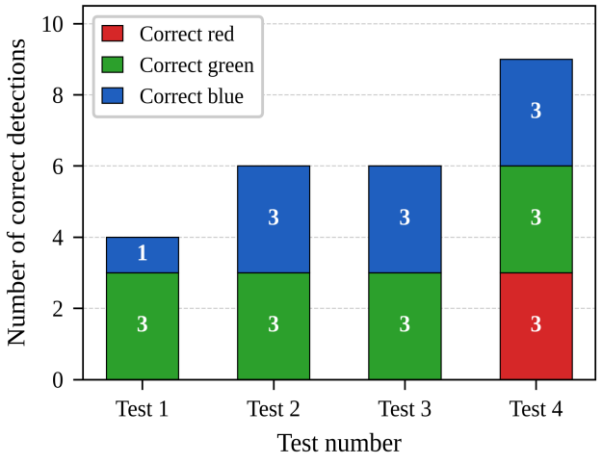



Figure 8. Stacked bar chart showing the breakdown of correct colour detection per test

### 3.3. Infrared sensor performance analysis

IR sensors play a crucial role in automation systems, especially in object detection and distance measurement applications. In this project, an IR sensor is integrated into the color-sorting robotic arm and conveyor belt system to detect the presence of an object before initiating color detection and robotic sorting.

Based on Table 4, the IR sensor used in this project is a reflective-type analog IR proximity sensor. It operates effectively within a detection range of 0.5 cm to 5.0 cm, making it suitable for short-distance object detection applications like the conveyor-based color sorting system. It functions on a supply voltage of 3.3 V to 5 V, which is fully compatible with the Arduino Uno. The sensor provides an analog output, meaning it returns a continuous range of values (typically from 0 to 1023) based on the intensity of the reflected IR radiation.

Table 4. IR sensor specifications

| Parameter | Details |
|---|---|
| Detection range | 0.5 cm–5.0 cm |
| Output type | Analog (0–1023) |
| Operating voltage | 3.3 V–5 V |
| Response time | <1 ms |
| Interface | Analog pin to Arduino |

This analog signal allows for more precise distance estimation compared to digital sensors that only provide binary (on/off) output. Furthermore, the sensor exhibits a fast response time of less than 1 millisecond, ensuring that objects are detected in real time as they move along the conveyor. The sensor connects to the Arduino through one of its analog input pins, enabling seamless data acquisition and processing within the microcontroller.

To assess the IR sensor's performance, a series of tests were conducted by placing colored objects RGB on the moving conveyor belt and observing detection responsiveness. To evaluate the effectiveness of the IR sensor in detecting objects on the moving conveyor belt, based on Table 5, three tests were conducted using coloured objects red, green, and blue placed at various points within the sensor's effective range. In all three tests, the sensor successfully detected the object when it was approximately 4.8 to 5.0 cm away, which is within the sensor’s maximum detection range of 5 cm. The sensor responded immediately upon the object entering its field of view, confirming its high responsiveness.

Table 5. IR sensor detection test results on conveyor belt

| Test no. | Object colour | Detection distance (cm) | Sensor response | Motor stop delay |
|---|---|---|---|---|
| 1 | Red | 4.8 | Immediate | ~0.5 sec delay |
| 2 | Green | 4.9 | Immediate | ~0.5 sec delay |
| 3 | Blue | 5.0 | Immediate | ~0.5 sec delay |

Despite accurate object detection, a consistent motor stopping delay was observed, causing the object to slightly overshoot the ideal position. Electrical and software configurations were verified to be correct. To address the delay between detection and motor response, a physical stopper was added to the conveyor belt at the sensor location. This ensured that once detected, the object would halt exactly in front of the IR sensor. As a result, the colour sensor could reliably scan and classify the object.

## 4. CONCLUSION

This study presented the design and implementation of a low-cost automated object sorting system using an IR sensor, colour sensor, servo-driven robotic arm, and conveyor mechanism, integrated through an embedded microcontroller platform. The system successfully demonstrated reliable object detection, classification, and sorting, achieving an overall success rate of approximately 95% under controlled conditions. The system demonstrated reliable activation through a push-button interface, while iterative testing enabled smooth and consistent robotic arm movement, with a 1 s servo delay identified as optimal for stable sorting operations. Colour classification accuracy, initially inconsistent, was significantly improved through manual frequency mapping, allowing dependable identification of blue, green, and red objects. Although the IR sensor performed well for object presence detection, conveyor stopping latency required the addition of a physical stopper to achieve precise alignment for colour reading. Overall, the prototype demonstrates successful integration of sensors, actuators, and embedded logic to achieve automated colour-based sorting. For future development, enhancements such as implementing camera-based object recognition, incorporating real-time feedback to improve sorting accuracy, optimizing conveyor speed control, adding wireless monitoring, and scaling the system for higher throughput or industrial environments would further improve performance and expand its practical applications.

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## AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

| Name of Author | C | M | So | Va | Fo | I | R | D | O | E | Vi | Su | P | Fu |
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

## CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this paper.

## DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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