Research Article

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Design of a new sorting colors system based on PLC, TIA portal, and factory I/O programs

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Abstract: In the recent industry field, automation has become the most important role in production processes to improve efficiency, increase production, and reduce workers. Sorting the products based on their color is a common task in the industries, but using manual sorting may take a longer time and human error may occur, especially if the production quantities are very large. To contribute to improving the quality and speed of production, we have proposed a new system to automatically separate products based on their color. This article presents a new system for identifying and separating industrial products based on their colors. The implemented system consists of three sensors used to detect the colors of the products, four chutes, and two conveyor belts designed to guide objects along the manufacturing path, and three push mechanisms to place objects in their designated places. The system includes an emergency interface, a reset interface, a stop interface, as well as communication using the PN (PROFINET Process Field Net) protocol, a programmable logic controller, and a 1511-1 central processing unit. This system has been precisely programmed and simulated using FACTORY I/O software and TIA PORTAL software to control and monitor the system effectively. The Supervisory Control and Data Acquisition system also includes a Human–Machine Interface user interface for maximum control. The performance of this system was tested by sorting 250 objects of different colors. These tests resulted in the successful separation of a total of 85 blue objects, 89 green objects, and 86 gray (metallic) objects within a time period of 20 min. This system shows wide applicability in various industries including diamond mining, recycling, and grain manufacturing sectors.

Keywords: color sorting, PLC, TIA portal, factory I/O, SCADA, HMI

1 Introduction

In modern industry, the importance of automation is rapidly increasing, as manual sorting processes have become less efficient and accurate. Manual color-based sorting of objects is shown to be error-prone and time-consuming, which is particularly hampering large-scale operations [1].

In modern industry, the use of automation systems is becoming increasingly popular as reliance on manual labor declines. The process of manual sorting is done by manually separating items and classifying them into different groups based on their colors, without depending on automated systems or mechanical mechanisms. Regarding automated sorting performance, its superiority is clearly demonstrated in the areas of efficiency and accuracy, as a result of the employment of advanced sensor technologies and complex programmed control systems [2,3]. Using automated systems can reduce dependence on manual systems and save production times, resulting in reduced manufacturing costs [4–6]. In the diamond and mining industry, color sorting systems are used to separate diamonds and other precious metals from unwanted materials and waste. These systems are widely used to sort other materials such as mice droppings and small stones from grains by using high-resolution sensors to enhance the quality of the product [7].

The aim of this study is to improve a new sorting objects system to sort objects according its colors. The performance of this system is simulated and programmed via the FACTORY I/O program and TIA PORTAL program, and monitored and controlled via human–machine interface (HMI) and Supervisory Control and Data Acquisition (SCADA). The system consists of a reset button and stop button to reset

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and stop the system, respectively, and an emergency button is used in case of emergency. Also, it consists of four chutes, three motor drives, two conveyor belts, three color sensors, and programmable logic controller (PLC) unit to control the system. This system can be applied effectively in many industry fields for reducing costs and enhancing the processes and the quality of the products.

TIA Portal software is an integrated development environment used to design and operate industrial automation systems. The software collects necessary processes for designing and developing control systems in one interface, which increases efficiency and reduces the time in developing industrial automation. This software plays an essential role in improving productivity and performance in industries [8,9].

FACTORY I/O is a simulation software used in the industrial field. FACTORY I/O simulates devices such as PLCs, sensors, actuators, and many other industrial devices. Using this software, engineers, programmers, and business owners can create virtual environments that represent real factories and industrial facilities, to test and develop automation solutions and check the performance of systems without the need for real equipment. This contributes to saving costs and increasing the effectiveness of development and training processes in the field of industrial automation [10–12].

SCADA is an integrated system used in industrial automation to control and monitor processes and operations in a variety of industries. SCADA collects, displays, analyzes, and controls data from widely distributed devices and equipment through a graphical user interface. The components of a SCADA system include sensors that collect data from the field, data acquisition units that transmit data to the central monitoring unit, a central processing unit (CPU) that processes and analyzes data, and an HMI that allows operators to view and monitor operations, data storage systems, and reports. SCADA is used in a variety of industries such as chemical industries, electricity production, water and wastewater treatment, oil and gas production, and general industrial automation. It can improve production efficiency, increase process safety, save time and resources, and increase quality and precise control of industrial processes [13]. SCADA systems can be integrated with other systems, such as building management systems and distributed control systems with the goal of improving the overall efficiency, reliability, and safety of operations. This integration allows operators to remotely control and monitor industrial processes, viewing real-time data and information to quickly identify and respond to problems [14–16].

An HMI is a user interface that allows a person to interact with a machine or process in industrial settings, it enables operators to monitor and control aspects of the manufacturing or production process. HMI can come in different types like text-based, graphical and web-based interfaces, and typically configurable to allow operators to customize the interface to their specific needs. Some of the advanced HMI are built to be Smart HMI, which enable to have much more advanced features like having the ability to use machine learning and AI in the interface [17,18].

Our work stands out by seamlessly integrating advanced technology into color-based object sorting, significantly improving efficiency and accuracy in industrial processes. It replaces labor-intensive manual sorting with automation, reducing errors and enhancing productivity. This represents a crucial advancement in industrial automation, building upon existing literature to practically apply cutting-edge and PLC technology to color-based sorting. Our work offers an efficient solution suitable for large-scale industrial operations, contributing novel insights to revolutionize color sorting across diverse industries.

The remainder of this study is organized as follows: Section 2 reviews related works, Section 3 describes the design and implementation of the proposed system and discusses the results and Section 4 presents the conclusions. Finally, the future works are presented in Section 5.

2 Related works

Various systems have been designed to sort objects according to its color. At the present time, there are many types of color sorting systems like chute color sorting, belt color sorting, and optical sorting systems.

Al Hinai and Farh [19] designed a color sorting system using a color sensor to process images and distinguish the colors of objects. This system is implemented using a PLC controller, a conveyor belt, and a Raspberry Pi that has a camera that acts as a color sensor to send input signals to the PLC controller. CD drives were used to move things into designated bins, and there was an HMI interface to control and monitor the system. With high success, this system has demonstrated its ability to accurately separate four objects based on its color. Although it achieved remarkable success in carrying out this task, it has some flaws in the mechanical design. These disadvantages state that there are technical challenges affecting its ability to handle heavy objects, as a result of the design of the conveyor belt.

Sazly Anuar et al. [20] had made a remarkable effort in developing a system to separate LEGO bricks based on their color. This system consists of a set of technological devices, where the Arduino is used as the main control unit, and is equipped with an advanced sensor used to

detect and determine the color of the LEGO series piece, in addition to using a servo motor for orientation and sorting purposes. The small LEGO pieces are inserted into the system manually. The function of this system is to classify LEGO bricks according to their colors. It is possible to increase the effectiveness by using a PLC, which enhances the efficiency.

Kulkarni et al. [21] designed a mechanical system for object sorting, based on the Raspberry Pi. This system includes a camera for capturing images of objects to direct objects to specified locations. OpenCV computer vision technology is also used to detect colors and shapes in objects. This system has demonstrated good performance in the automated sorting process, but there are opportunities to further improve its efficiency through remote control system integration.

Lita et al. [22] developed a sorting color system using a color sensor, servo motors, and a microcontroller to control their system. This system can be used in agricultural applications. However, the mechanical design of the system is weak.

Babu [23] developed a sorting system consisting of chutes, an Arduino Uno, a DC motor, and a color sensor. Although this system is considered cheap, it can only sort objects of three colors.

Batra et al. [24] developed a mechanical sensing sorting system using two TCS3200 RGB color sensors. The goal of this system is to classify ripe tomatoes from others based on their color. A servo motor is included for transporting tomatoes and an Arduino Uno controller to control operations. The results showed that the system achieves an accuracy rate of about 93.33%, meaning that most of the time it correctly distinguishes between ripe and overripe tomatoes. However, weaknesses in the mechanical design of the system were also discovered. These weak points represent potential wear and tear on the conveyor belt and other mechanical components due to frequent use of the system. Therefore, the design of mechanical parts has to be reviewed and improved to ensure better accuracy and higher reliability of the system over time.

Ruoyu et al. [25] developed a sorter for tomatoes, this system includes a feeder designed to transport tomatoes from one place to another using a conveyor belt. This system features advanced technology as it is equipped with a color sensor that helps in detecting and distinguishing tomato colors. To process data related to tomato colors, a chip was used and the system was programmed using the VHDL language. However, this system is small for large industrial fields.

Singh and Ali [26] built a sorting objects system according to dimensional and color of the objects. The system has sensors to measure the height and width of the objects, color sensor, an AC motor, and two conveyors. The system needs to add a PLC to improve the performance of the process.

Adamu and Shehu [27] developed a tomato sorting system to sort immature tomatoes from ripe tomatoes. They used an Arduino Uno and a color sensor. However, this system needs a PLC to improve its performance and effectiveness.

Komol and Podder [28] developed a sorting products system according its colors. This system consists of a color sensor, conveyor belt, an Arduino Uno, and an AC motor. However, this system needs to add a PLC to improve its controllability.

Shravani et al. [29] designed a sorting color system. The system includes a sensor, servo motors, and an Arduino Uno controller. However, this system is too small and it is suitable for educational purposes.

Sihombing et al. [30] developed a citrus fruits sorting system. This system used an LCD screen, color sensor, a servo motor, and an Arduino Uno. However, this system is designed for use in small-scale applications.

However, previous studies covered systems that used small controllers like an Arduino Uno or microcontrollers to sort the products and built small and weak mechanical systems. This study presents a new system built for color sorting using a PLC unit to control and an enhanced mechanical system. It has the ability to sort large amounts of objects for large-scale production applications with high efficiency. Besides, the use of advanced PLC gives this system the ability to effectively handle complex algorithms, implement safety functions, and easy expandability for the future of the system if necessary. In addition, the system can sort a relatively large number of objects within a relatively short period of time.

3 System description, design, and results

The operation flow chart of our color sorting system is shown in Figure 1. To initiate the system, the operator presses the start button and the two conveyor belts start the operation. When an object is placed on the conveyor belt, the sorting process begins. The color sensors are arranged as follows: blue, green, and gray. The sensing process is carried out sequentially in the order as mentioned in Figure 1. When a sensor senses the color of an object it is programmed to detect, then the control system activates the specific pusher and directs the object to the

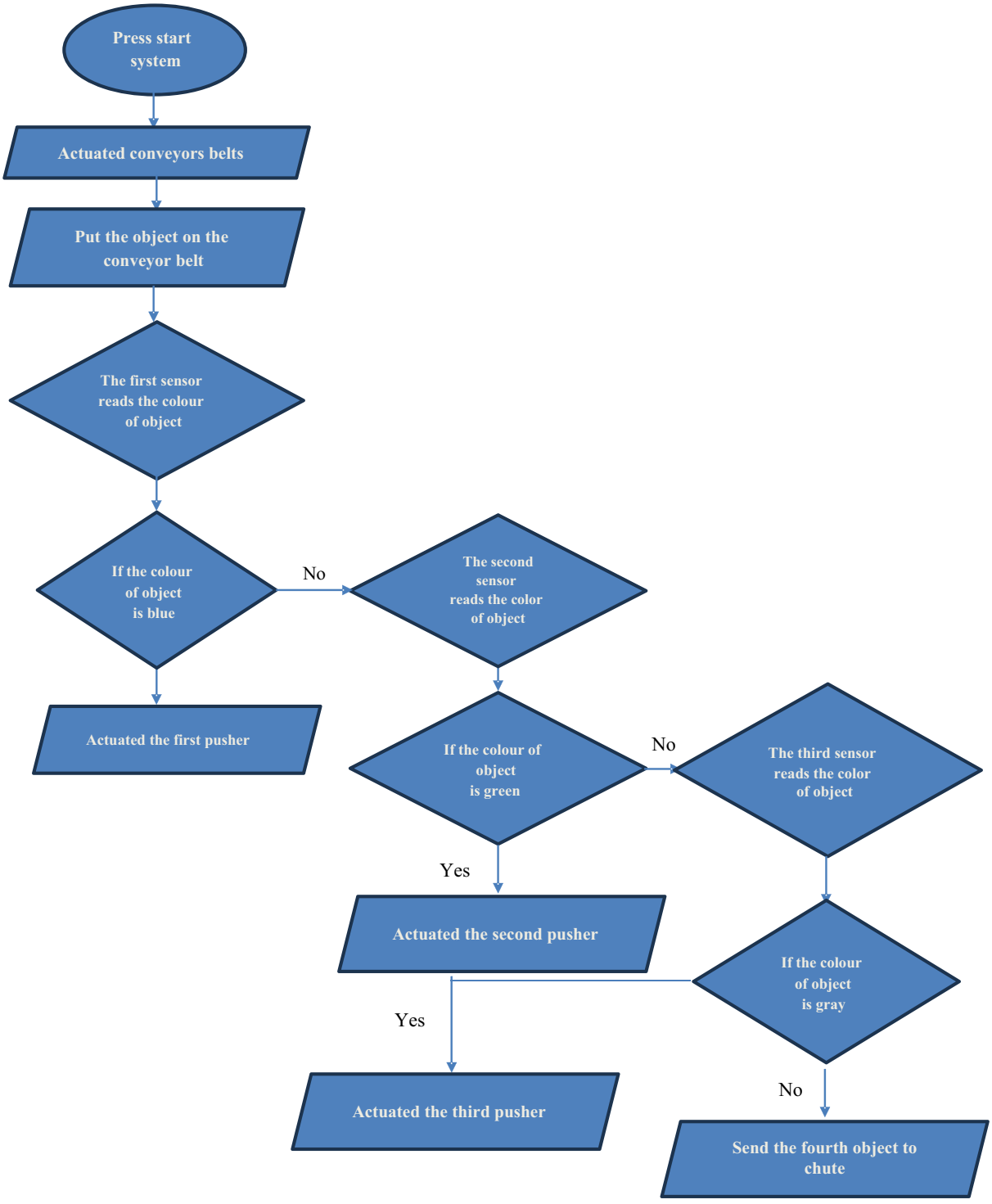

Figure 1: The flowchart of system.

specific chute. When the three sensors do not detect the color of an object, then the system directs it to a specific fourth chute that could not be sorted by color. This process repeats for each subsequent object placed on the conveyor belt.

As depicted in Figure 2, our sorting color system consists of two conveyor belts, with the first conveyor belt being 4 m in length and the second conveyor belt being 2 m in length. The system also includes four chutes for depositing sorted objects, three sensors for detecting the

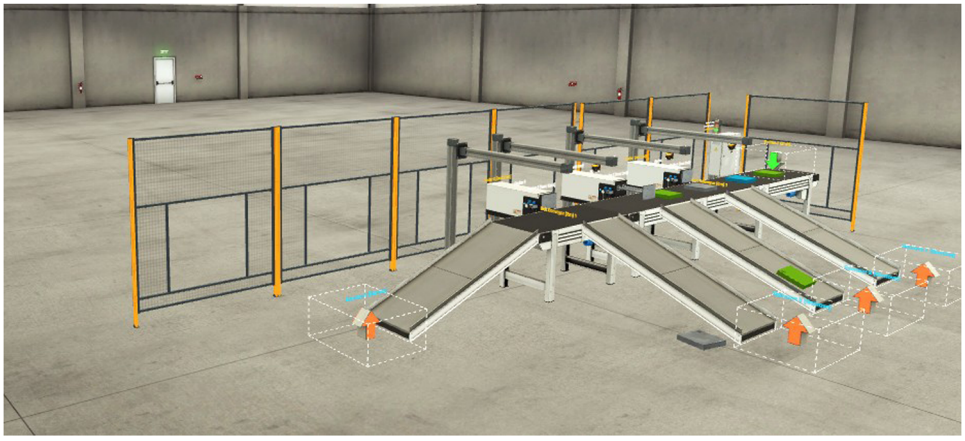

Figure 2: The proposed system's components by using FACTORY I/O program.

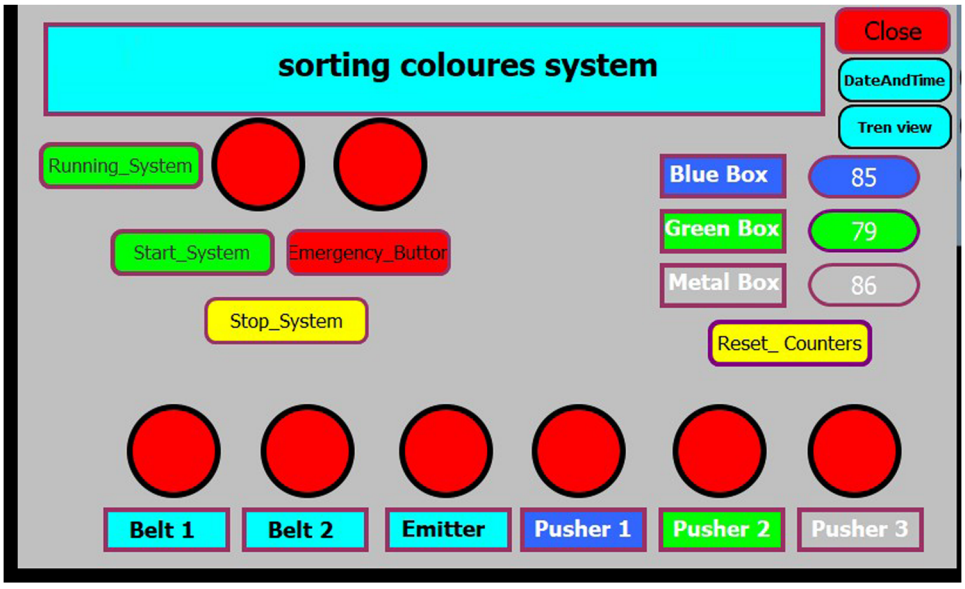

Figure 3: SCADA and HMI by using TIA PORTAL program.

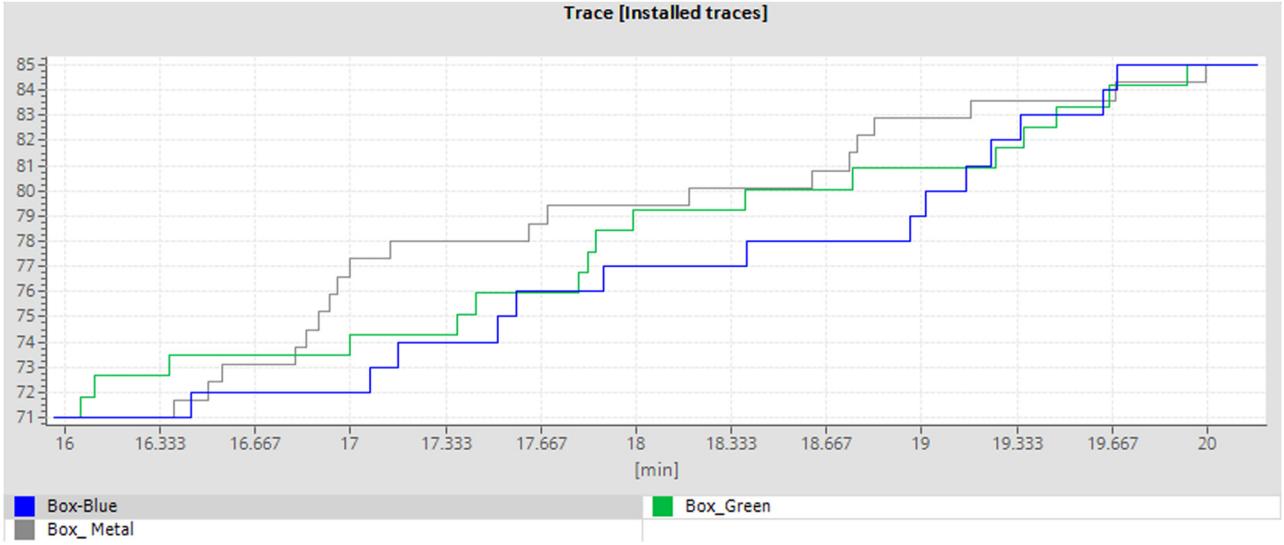

Figure 4: The results of the color sorting system after 20 min.

Table 1: System setup details

Part	Details
Conveyor belt	To achieve the transfer of the object from the starting location to the sensor (23 kg)
DC motor	To drive the conveyor belt (2.5 Amps)
Chute conveyor low	To put objects in its position (4 chute)
Color sensor	To detect objects' colors (0–10 V)
Pusher	To push objects into chutes (pneumatic)
Electric switchboard	Control panel
Stop button	To stop the system
Reset button	To reset the system
Emergency button	Used in emergency
Factory IO	Used to simulate and interact with real-life operations

chromatic properties of the objects, three pushers for directing the objects to the appropriate chutes, and three columns for mounting the sensors. The system is regulated by a CPU 1511-1 PN PLC manufactured by Siemens, and it was programmed and simulated using TIA PORTAL and FACTORY I/O software. The system can be controlled and monitored using a SCADA and HMI, as illustrated in Figure 3. The system also includes reset counters, a stop button, and an emergency button for resetting counters, stopping system operation, and addressing emergency situations, respectively. The result shows that the system has sorted 250 objects in 20 min (85 blue object, 89 green object, and 86 gray (metal) object), as shown in Figure 4.

The color sensor performance will remain accurate over the operation period with a continuous electricity supply and a suitable temperature range (0–40°C), where temperature rises beyond the specified range may reduce the accuracy and performance of the color separation process Table 1 shows the system setup details.

4 Conclusion

In this work, we propose a color sorting system, the novelty of the implemented system is its ability to sort different objects at high speed and accurately, based on colors, which can be monitored and controlled using SCADA and HMI. Also, our system distinguished by its integrated architecture which consists of two conveyor belts, four chutes, three sensors, three pushers, three columns, and a CPU 1511-1 PN PLC can be used to automatically sort objects based on their colors. The system was programmed to sort 250 objects in 20 min, including 85 blue objects, 89 green objects, and 86 gray (metal) objects. The results were reliable and trustworthy. The system demonstrates versatility for potential utilization across diverse industries, including but not limited to grain processing, diamond mining, and recycling sectors. Its versatility arises from its capacity to efficiently and accurately sort objects based on their color, a fundamental requirement in industries where color-based classification is essential for quality control and product differentiation.

In future work, we plan to improve the mechanical sorting system by adding more advanced sensors or choosing a better PLC controller. In addition, the system can be developed and adapted to sort a wider range of colors or objects, giving it the ability to modify, expand, or adopt new methods of sorting based on other criteria such as shape or size. This is in addition to directing the system toward diverse industries and applications where color classification is necessary. Ultimately, the system can be easily integrated with other automated control systems to achieve efficiency improvements and increased productivity down the production line.

Conflict of interest: Authors state no conflict of interest.

Data availability statement: Most datasets generated and analyzed in this study are in this submitted manuscript. The other datasets are available on reasonable request from the corresponding author with the attached information.

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