Design and Simulation for Washing Machine by Arduino with Proteus Software

Receive: 28 February 2025; Revised; 9 June 2025; Accepted: 10 June 2025

Research Article

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Abstract— **Embedded systems have become a cornerstone of modern electronic design, offering efficient and cost-effective solutions for a wide range of applications. However, the advent of microcontrollers, particularly platforms like Arduino, has revolutionized embedded system development. This paper focused on the use of embedded systems based on Arduino controllers designed specifically for the automatic cleaning of parts within a juice filling machine. This machine is part of a factory presented at the Center of Research and development in the mechanical technical branch depending on orange juice. The designed system is simulated by the Proteus simulator and the results show the designed system works with high efficiency, improved reliability, and low costs, and the designer can supervise all system operations and identify any faults that may occur during the operational phases.**

Key Words- Filling Juice Machine, ARDUINO Board, Servo Motor, Proteus Simulator.

II. INTRODUCTION

An embedded system represents a practical computerized system designed to manage diverse functions. The definition of embedded systems is constantly changing due to the swift evolution of technology, resulting in a widely fluctuating interpretation of its scope and capabilities. Progressing technology leads to reduced manufacturing costs and facilitates the integration of diverse hardware and software components into embedded systems [1]. Typically, systems comprise inputs, outputs, and a compact processing unit. In the beverage filling and packaging industry, an array of controllers is utilized to execute the beverage filling and packaging procedures [2]. This paper focuses on employing an Arduino to effectively control and manage the washing unit as an integral part of the juice machine system. Furthermore, the system's control operations are executed through relays. Employing the Arduino Due microcontroller and its development environment, the system was meticulously designed. The programming of the Arduino system was carried out using the C programming language. Arduino efficiently processes sensor data, forwarding it to other system components. The primary considerations in designing the system were its user-friendly nature and cost-effectiveness in manufacturing[3]. The entire design process was divided into four distinct sections: design model, architecture model, implementation, and testing. The practical application of system design theory was pivotal in shaping the project's practical aspect. This theory extensively elucidates the utilization of the Arduino microcontroller in embedded systems. The practical segment of the project delineates into two facets: Hardware and Software. It elaborates on the manufacturing intricacies of the washing machine system. To facilitate easy replication for individuals without practical experience, a Proteus simulation was employed to create a comprehensive wiring diagram. Embedded system architecture serves as a broad conceptualization of the system. It does not delve into granular implementation details like software source code or hardware circuit design. Instead, it presents the hardware and software components as integral parts of interacting elements. These elements represent both hardware and software, focusing primarily on behavioral aspects and inter-relationships. A structure, within this context, serves as a specific representation of the architecture of embedded system as shown in “Fig. 1”

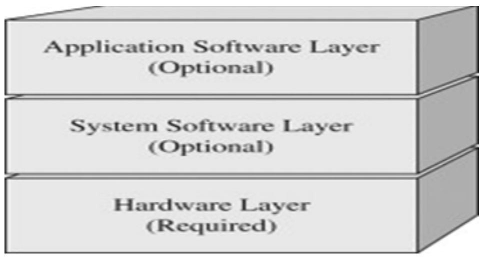

Fig. 1. Overview of Embedded Systes Architecture [4].

III. STRUCTURE OF WASHING PART IN FILLING JUICE MACHINE

The washing part is constructed from many parts, like sensors, relays, servo motor, bottle conveyor, turntable and star wheel. In this paper we will explain the benefits of each part in washing part and how it works, the “Fig. 2” shows how to connect all parts with an Arduino board.

A. Sensors

It is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. These sensors make the system more efficient and reliable. The output is generally a signal that is converted to a human-readable display at the sensor location or transmitted electronically over a network for reading or further processing. In our project we will use many types of sensors, like:

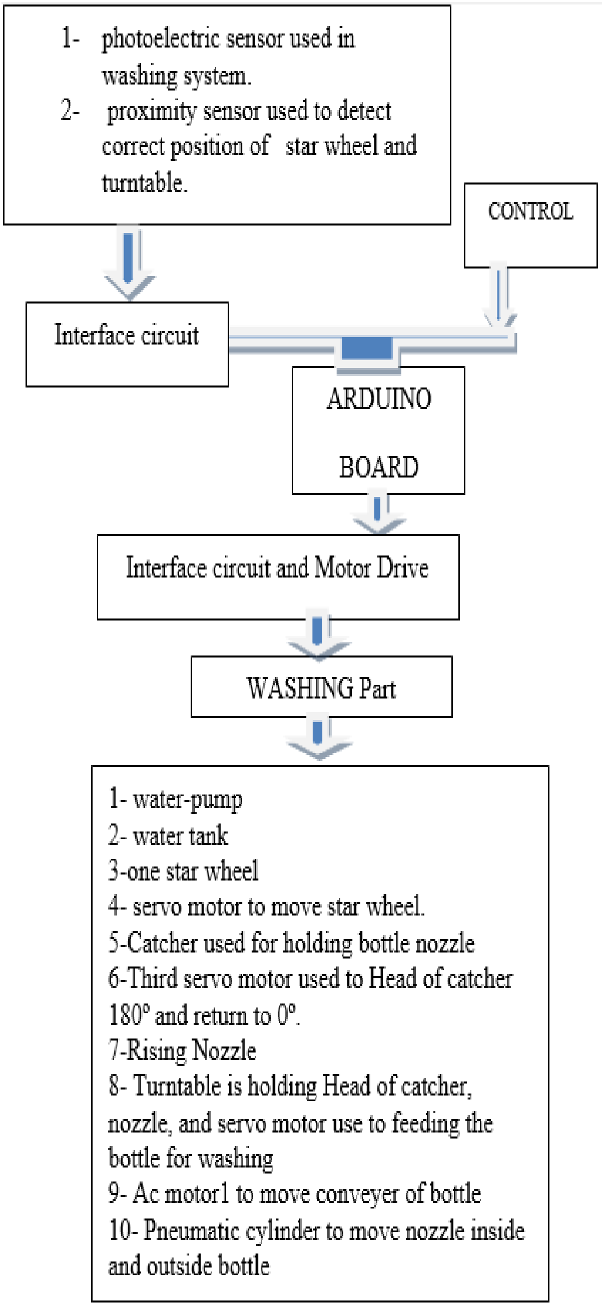

Fig. 2. shows process steps of washing unit.

a) Inductive proximity sensor:

Inductive proximity sensors are electronic devices that can detect metal objects without physical contact. The sensor generates an electro-magnetic field that is disturbed by when a metal target enters within its range. The sensor detects the presence of the metal object and electronically switches its output circuit [4]. Inductive proximity sensors are very useful in industrial control applications where contaminants such as dirt, oil, and water would cause problems for other sensing technologies, as shown in “Fig. 3”.

b) Optical Sensors:

A photoelectric sensor is a device used to detect the absence or presence of an object using an infrared transmitter and photoelectric receiver. They are largely used in industrial manufacturing [7].

c) Through-beam Sensor:

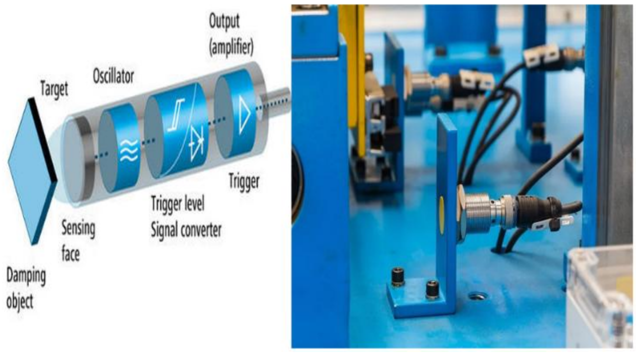

Fig. 3. Component and position of Inductive proximity sensor [5, 6]

The Emitter and Receiver are installed opposite each other to enable the light from the Emitter to enter the Receiver. When a sensing object passing between the Emitter and Receiver interrupts the emitted light, it reduces the amount of light that enters the Receiver [8]. This reduction in light intensity is used to detect an object as shown in “Fig. 4”.

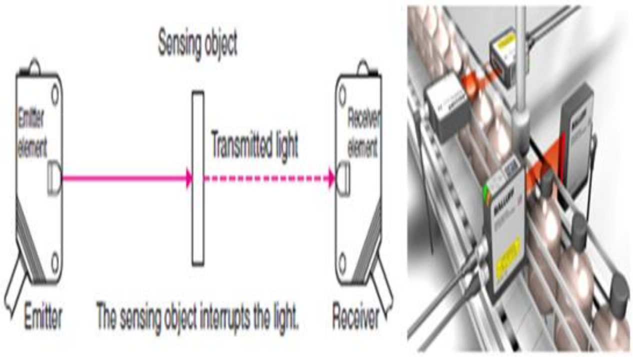

Fig. 4. explain basic work of Through-beam Sensor [9].

d) Relay:

Relay is an electromechanical switch which uses electromagnetism from small current or voltage to switch higher current or voltage for different appliances [10]. When a relay is in Normally Open (NO) contact, there is an open circuit until the relay is energized. If a relay is in Normally Close (NC) contact, there is a closed circuit until the relay is energized. As shown in “fig 5”.

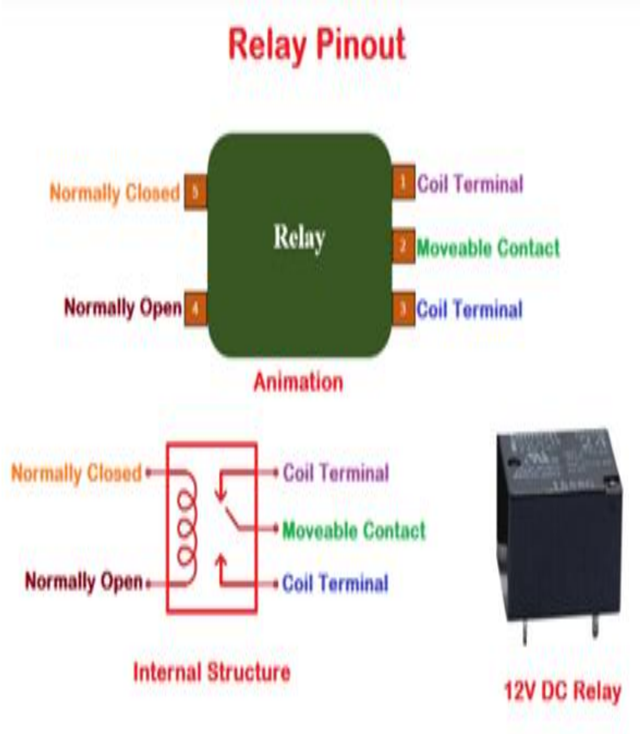

Fig. 5. Explain the Relay diagram [11].

e) Liquid level switch:

Liquid level sensor determines the amount of liquid in the water tank.

B. Pneumatic system:

A pneumatic cylinder uses air as its power source and converts it to a possible movement such as linear and rotary movement [12]. The pneumatic system is used in the washing system to move the nozzle inside or outside the bottle during washing, and it is used in the filler system to pull juice from the tank into a piston, then pump juice into the bottle and used to motion the nozzle into the bottle for filling bottles with juice, finally it is used in capper system to motion steeper down on hole of the bottle for close bottle with cap.

C. Electro valve:

A valve is a device that controls the flow of liquid. It can be opened and closed to control the flow of fluid. Valves can be hydraulic or electrical. In a hydraulic valve, the valve opens or closes depending on the liquid or air pressure [13]. In electrical valves, an electric signal is used to open or close the valve. In this paper we will use an electro valve, where it opens when the nozzle inside the bottle and closes when the nozzle is outside the bottle.

D. Turntable:

It is a disc consisting of bottle clips (head) and it's rotated on the shaft by a servo motor. The function of the bottle clip is to lock the bottleneck, where each bottle clip is equipped with a servo motor, photo sensor and pneumatic cylinder which holds spray on the nozzle as shown in "fig 6".

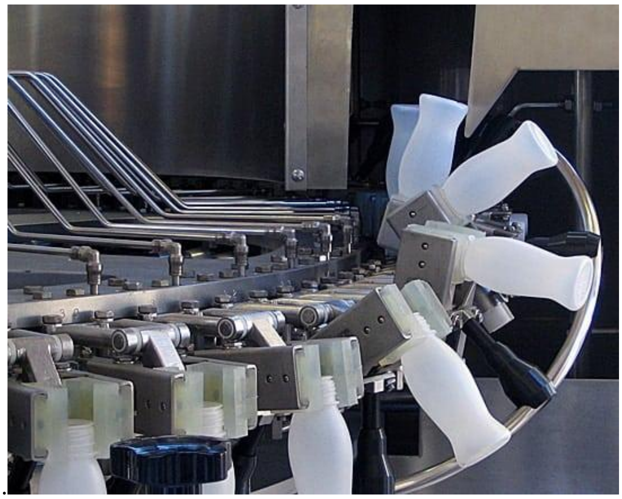

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Fig. 6. head of Turntable [14].

E. Star wheel

It is a disc with specific spaces. Each space must be wide enough to fit the diameter of the bottle. When the star wheel rotates, the bottle enters a specific space in the star wheel. Then it is transmitted by using position control for the star wheel. The star wheel needs a device to rotate it at the suitable speed and angle, so that the bottle will be in its right position. The star wheel is fixed on a shaft and rotated by a servo motor, the bottle which entered it will be replaced by another one repeatedly throughout the production run by the star wheel as shows in "fig 7".

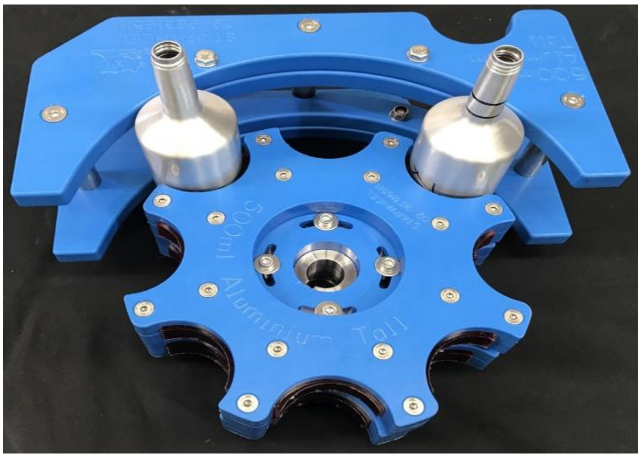

Fig. 7. holes of star wheel [15].

F. Conveyor:

The conveyer system contains two conveyors, the first for bottles and the second for caps. Each conveyor consists of AC Motor which is used to move the belt by rollers. The speed of the conveyor is controlled through a control board. After the start time and adjustment of the star wheel and turntable, the control board gives a control signal to the conveyor to carry the bottle along the production line, starting from the washing system, filling system until the capping system.

G. G. Servo Motor:

A servo motor is one of the widely used variable speed drives in industrial production and process automation and building technology worldwide [16]. While servo motors don't belong to a distinct motor classification, they are purposefully crafted for motion control applications demanding precise positioning, rapid reversals, and outstanding performance. Their utilization spans various domains, including robotics, radar systems, automated manufacturing, machine tools, computers, CNC machines, and tracking systems. A servo motor is a linear or rotary actuator that provides fast precision position control for closed-loop position control applications as shown in "fig 8.a and fig 8.b". Unlike large industrial motors, servo motors are not used for continuous energy conversion. Servo motors have a high-speed response due to low inertia and are designed with a small diameter and long rotor length. Servo motors work on a servo mechanism that uses position feedback to control the speed and final position of the motor. Internally, a servo motor combines a motor, feedback circuit, controller, and other electronic circuit [17].

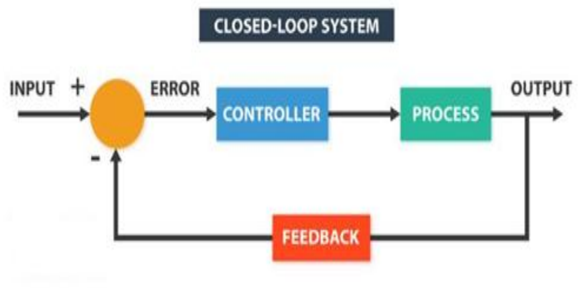

Fig. 8. a: explain close loop system [18].

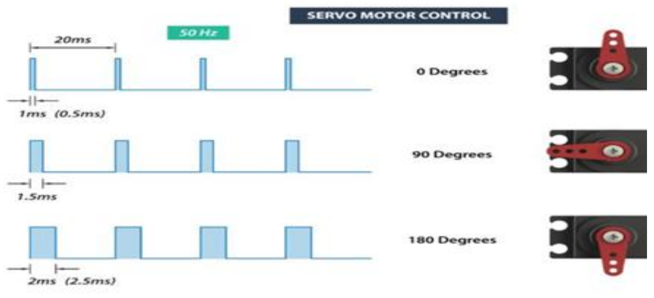

Fig. 8. b:explain Input pulse of servo motor [18].

a) Types of Servo Motors:

Basically, servo motors are classified into AC and DC servo motors depending upon the nature of supply used for its operation. Brushed permanent magnet DC servo motors are used for simple applications owing to their cost, efficiency, and simplicity [19].

b) Rotary encoder:

A rotary encoder, also called a shaft encoder, is an electro-mechanical device that converts the angular position or motion of a shaft or axle to analog or digital output signals [20]. There are two main types of rotary encoder are absolute and incremental. The output of an absolute encoder indicates the current shaft position, making it an angle transducer [21]. The output of an incremental encoder provides information about the motion of the shaft, which typically is processed elsewhere into information such as position, speed, and distance. Rotary encoders are used in a wide range of applications that require monitoring or control, or both, of mechanical systems, including industrial controls, robotics, photographic lenses, computer input devices [22].

IV. ARDUINO

Arduino stands as an open-source platform used to create computers capable of sensing and controlling aspects of the physical world beyond the capabilities of standard desktop computers. The Arduino development board embodies the principles of wiring, a corresponding physical computing platform rooted in the processing multimedia programming environment [23]. "Fig 9". illustrates the fundamental model of an Arduino system.

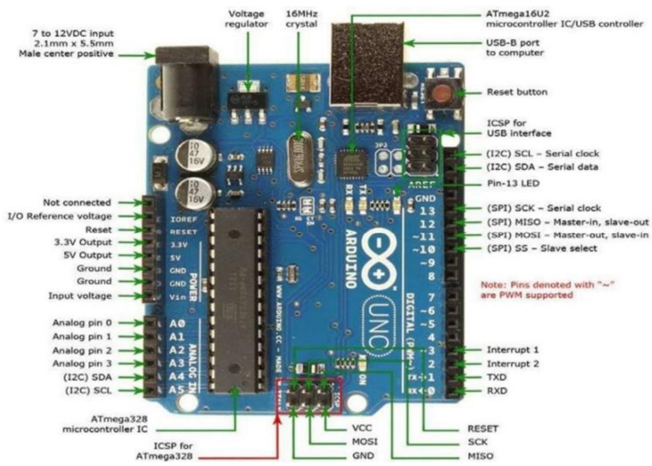

Fig. 9. Arduino Uno microcontroller [24].

A. Arduino IDE:

The Arduino IDE serves as a programming environment enabling users to create various programs and upload them into the Arduino microcontroller [25]. This IDE incorporates a built-in code parser to scrutinize user-written code before transmitting it to the Arduino. Upon program testing, it can be uploaded to the Arduino via a USB cable, the specifications of which may vary across different models [26].

V. FLOW CHART OF WASHING SYSTEM.

The Flow Chart shown in "Fig 10" illustrates the actions to be taken by the system. The flow chart below shows the steps done in detail during the washing machine where explained all the steps from the start of work of the washing until completed the all steps of the washing part.

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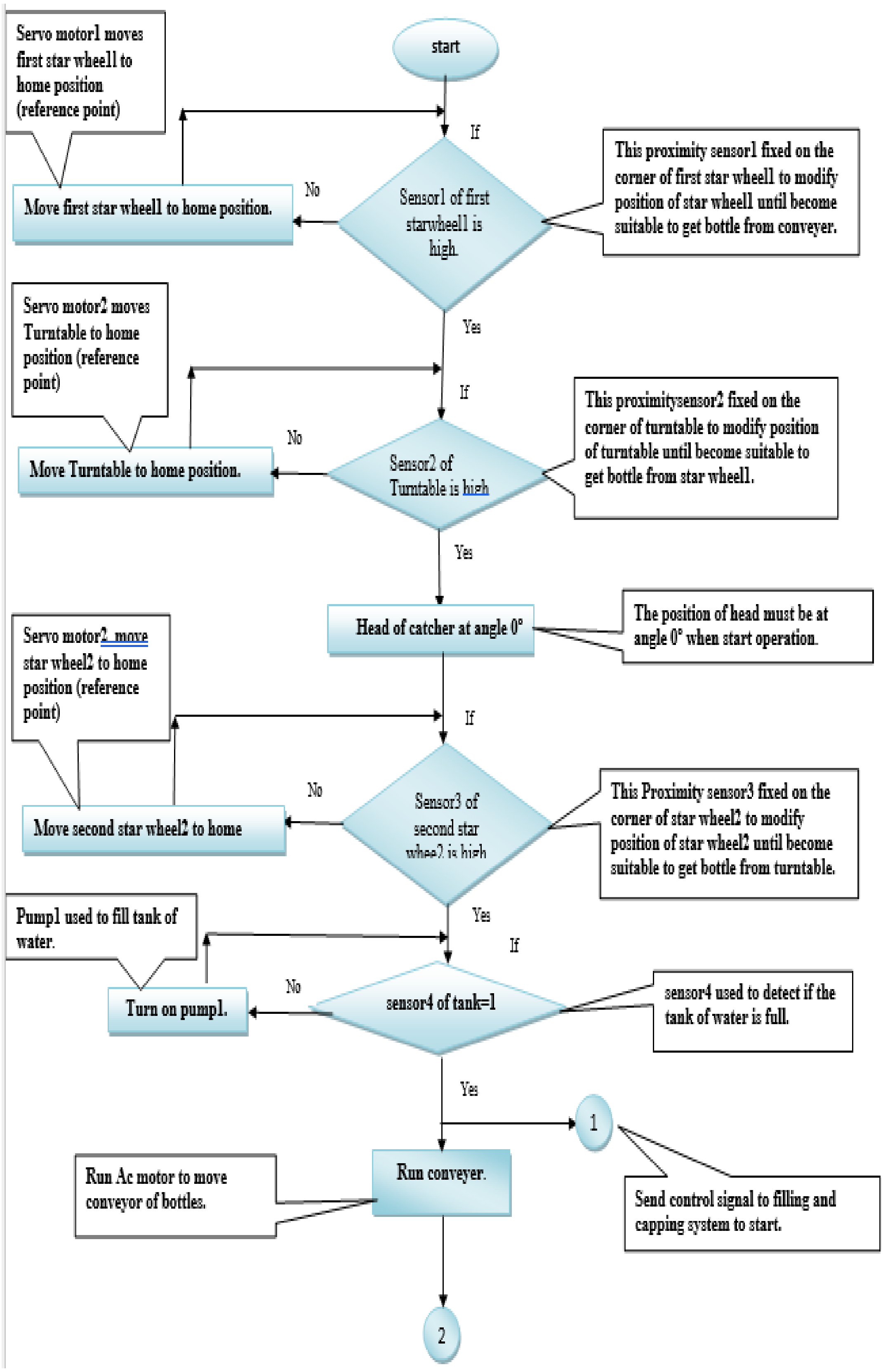
Servo motor1 moves first star wheel1 to home position (reference point)
start
If
This proximity sensor1 fixed on the corner of first star wheel1 to modify position of star wheel1 until become suitable to get bottle from conveyer.
No
Move first star wheel1 to home position.
Sensor1 of first starwheel1 is high.
Yes
Servo motor2 moves Turntable to home position (reference point)
If
This proximitysensor2 fixed on the corner of turntable to modify position of turntable until become suitable to get bottle from star wheel1.
No
Move Turntable to home position.
Sensor2 of Turntable is high
Yes
Head of catcher at angle 0°
The position of head must be at angle 0° when start operation.
Servo motor2 move star wheel2 to home position (reference point)
If
No
Move second star wheel2 to home
Sensor3 of second star whee2 is high
This Proximity sensor3 fixed on the corner of star wheel2 to modify position of star wheel2 until become suitable to get bottle from turntable.
Yes
Pump1 used to fill tank of water.
If
No
Turn on pump1.
sensor4 of tank=1
sensor4 used to detect if the tank of water is full.
Yes
1
Run conveyer.
Run Ac motor to move conveyor of bottles.
Send control signal to filling and capping system to start.
2

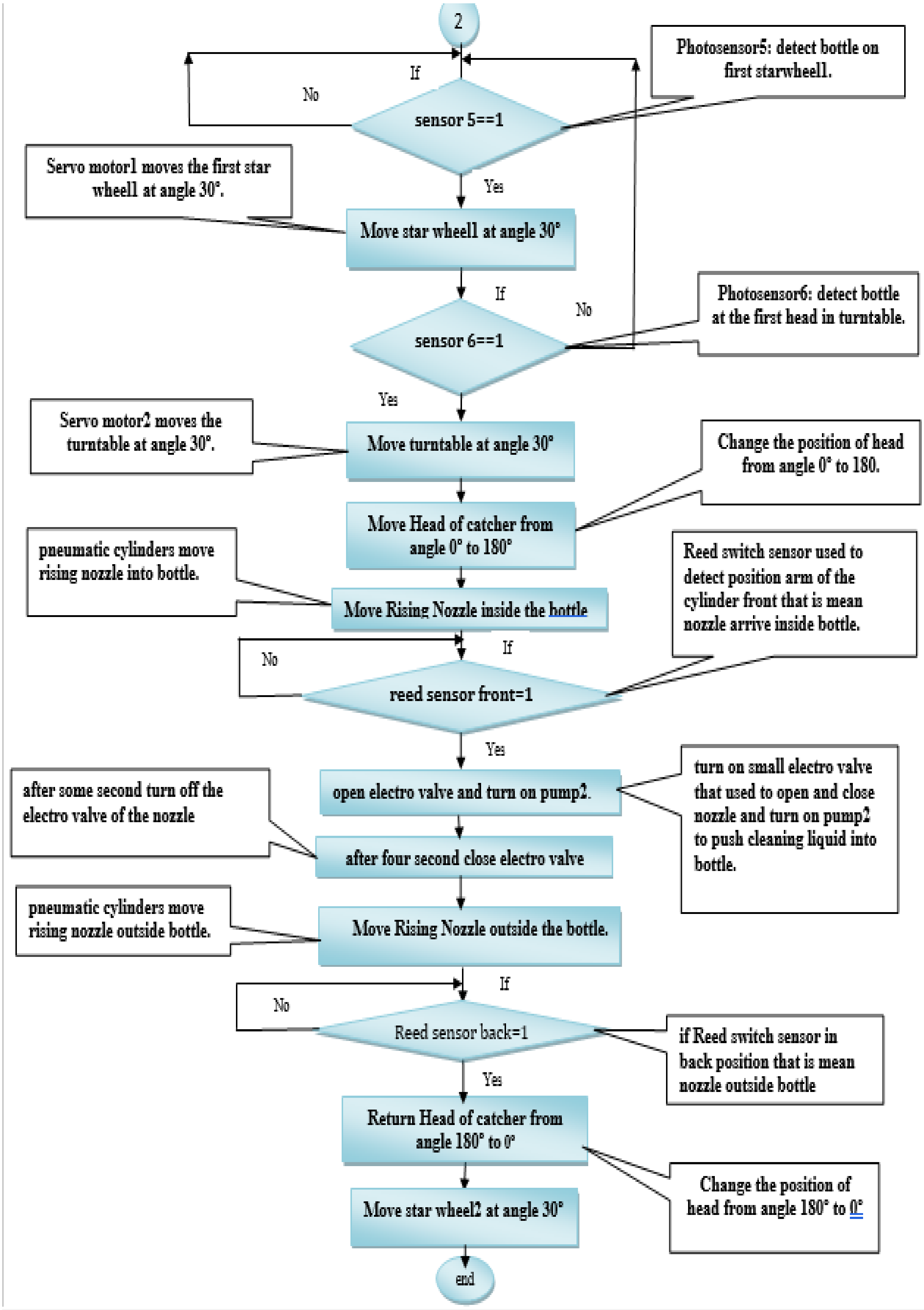

Fig. 10. shows flow chart of washing machine.

VI. Hardware Implementation

There are several testing tools that uses to analyze and emulate the system behavior before design and implementation, the hardware emulation is done via emulator tool proteus as shown in figure (12).

a) Proteus software: Proteus (Processes and Transactions Editable by Users) is simulation software designed for various microcontrollers-based designs, enabling the simulation of the entire design before its implementation. The Proteus package consists of two main components, Isis and Ares. In this simulation, Proteus ISIS Circuit Simulation will be used as software which utilizes drawing schematics and simulating circuits in real-time [27].

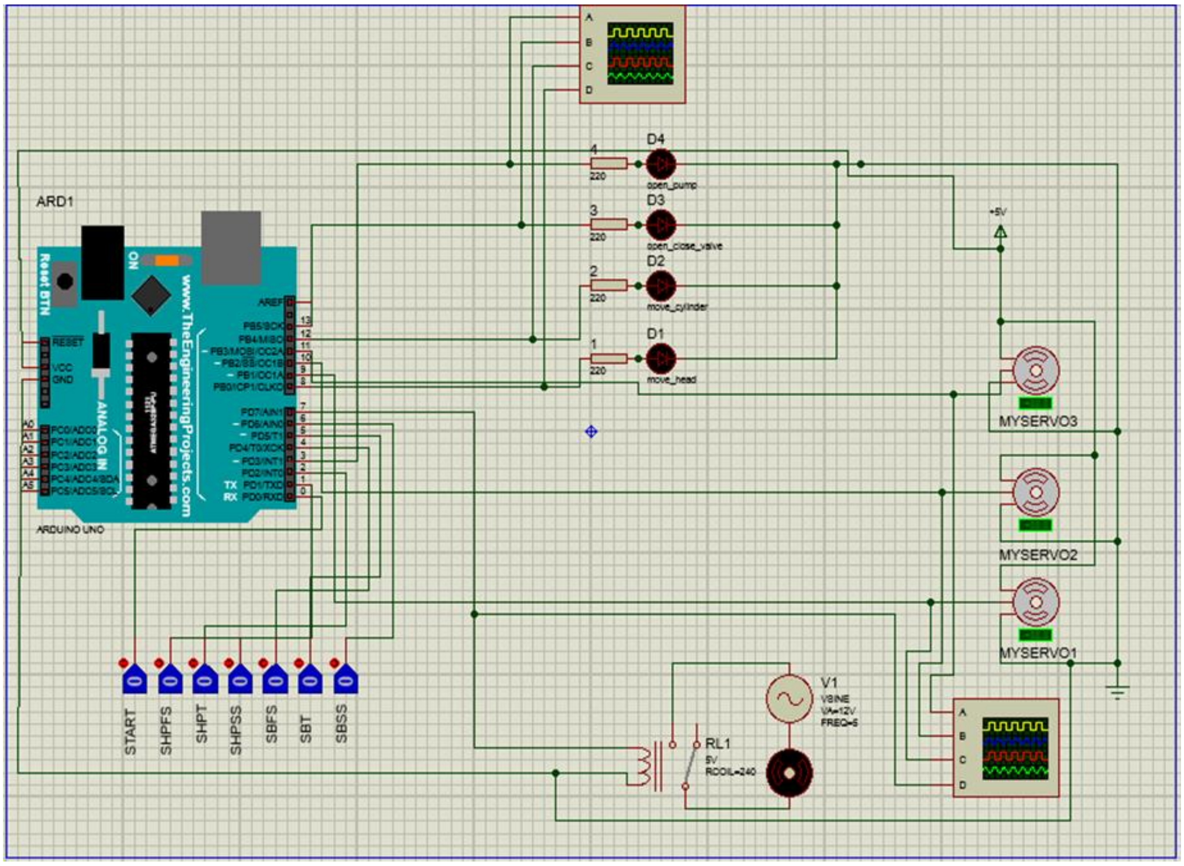

Fig. 11. Explain interface of different components with Arduino Board.

VII. RESULT

This section displays the simulation results derived from the Proteus ISIS environment, which confirm the functionality and timing of the proposed control system for the automated bottle washing unit. The simulation was created to evaluate the coordinated functionality of the sensors, actuators, and the Arduino Due controller according to the flowchart logic illustrated in Fig. 10. The primary performance metrics assessed were the accurate sequential functioning of the actuators and the suitable response of the controller to sensor inputs and outputs as shown in table 1.1. Figure 12 illustrates the logic analyzer virtual instrument in Proteus, displaying a specific sequence of HIGH signals on the designated digital output pins (D2, D3, D4).

This verifies that the code effectively executes the homing routine, positioning all-star wheels and the turntable to a defined reference point (0°). This is an essential initial step to guarantee the synchronization of all mechanical components prior to the commencement of the conveyor. A definitive screenshot illustrating the concurrent activation of the three digital pins to HIGH (5V).

Figure 13 illustrates the transition of the Arduino output pin connected to the AC motor relay (Pin D5) from a LOW (0V) to a HIGH (5V) state. The HIGH signal would activate the relay, completing the circuit to power the AC motor and initiate the conveyor belt. The simulation verifies that the control logic accurately commences the material handling process solely after the machine is appropriately initialised, thereby averting possible collisions or jams. A screenshot highlighting the status of Pin D5 and the virtual relay component indicating activation.

Figure 14 demonstrates how the photosensor activates, causing its output pin linked to an Arduino analogue input to alter its state. The Arduino code accurately reacts to this sensor input. The servo motor governing the initial star wheel receives a new pulse width, instructing it to rotate to a -60° position to engage the bottle. This illustrates the essential closed-loop feedback for automation: a sensor input directly activates a specific actuator response.

TABLE I. SUMMARIZING THE SIMULATION OUTCOMES.

Simulation Phase	**Trigger**	**Arduino Output**	**Result**	**Validation Outcome**
Initialization	Power On	Home Servos (D2, D3, D4 → HIGH)	All servos moved to 0°	PASS - System synchronized.
Conveyor Start	Homing Complete	Start AC Motor (D5 → HIGH)	Conveyor belt moved	PASS - Process started correctly.
Bottle Handling	Photosensor triggered	Rotate Star Wheel	Star wheel moved	PASS - Sensor feedback loop works.
Washing Cycle	Bottle in position	Activate Cylinder, Valve, Pump (D6,D7,D8 → HIGH)	Nozzle moved in, fluid dispensed, nozzle retracted	PASS - Core washing sequence is correct and safe.

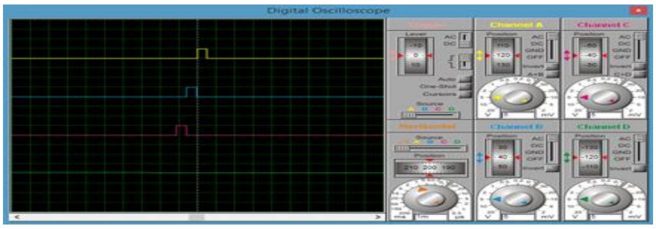

Fig. 12. Syatem Initialization and Homing Sequence

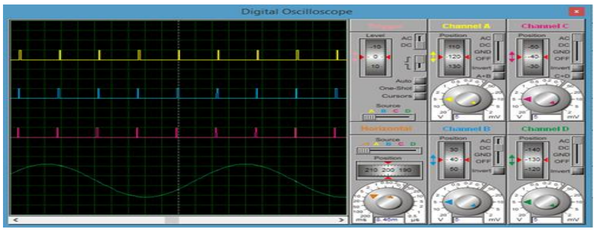

Fig. 13. Conveyor System Activation

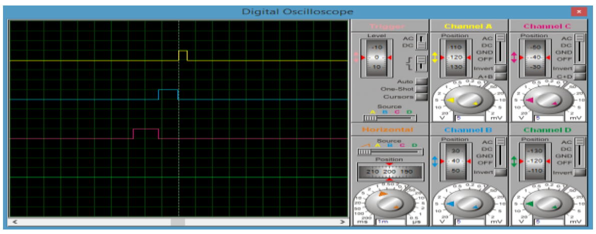

Fig. 14. Bottle Detection and Servo Positioning

In figures 15 and 16, as the bottle advances into the washing station, a series of outputs is activated. This encompasses: the extension of a pneumatic cylinder (Pin D6 → HIGH), the activation of an electro-valve (Pin D7 → HIGH), and the initiation of a pump (Pin D8 → HIGH). Subsequent to a predetermined delay, these outputs become inactive (LOW). The timing diagram of these signals represents the paramount outcome. The control system effectively performs the core washing function as demonstrated in Figure 15. The nozzle enters the bottle prior to the valve's activation.The valve activates and the pump operates for a specific duration to release cleaning fluid. The valve closes, and the pump ceases operation prior to the retraction of the nozzle. This sequence is essential to avert spills and guarantees effective washing. The simulation confirms that the timing delays programmed in the Arduino sketch are functionally accurate. A clear screenshot of the Proteus logic analyser displays the timed sequence of these four control signals returning to a low state, as illustrated in Figure 16.

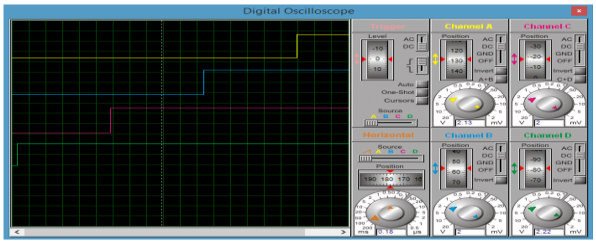

Fig. 15. Washing Cycle Execution

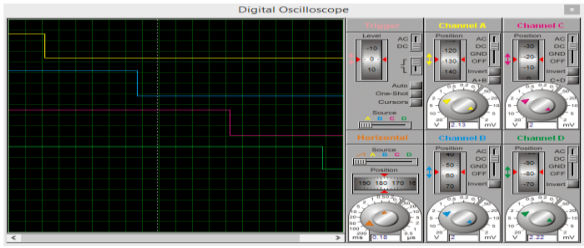

Fig. 16. Return control signal to low.

VIII. CONCLUSION

The control system designed based on Arduino to control of steps of washing unit in juice factory. Arduino microcontrollers are constantly evolving development platform.Troubleshooting and maintenance of the control system are very easy because it can changed, added, removed any component via the software in the design time and uploading that software again into it, Arduino has ability to control on multiple motor controller on one chip. The designed system is low power consumption, more reliability while reducing cost and works very easy with Protes software. The designer can supervise the whole operations of the system and detect any faults that occurs during the operation steps. The Proteus simulation effectively confirmed the design and control logic of the Arduino-based washing unit. The findings indicate that the software accurately interprets sensor data and produces the requisite output signals to control the actuators in the correct sequence and timing. All essential operational phases from initialisation and bottle handling to the exact washing cycle were performed as intended. The simulation validates the system's functional accuracy before physical implementation, thus mitigating development risk, expense, and duration. This demonstrates the effectiveness of utilising the Arduino platform in conjunction with Proteus simulation for the design and validation of cost-effective industrial automation solutions.

CONTRUBITION OF THE AUTHORS

The contributions of the authors to the article are equal stated in this section.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

STATEMENT OF RESEARCH AND PUBLICATION ETHICS

Rresearch and publication ethics were observed in the study.

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