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Arduino-based Automated T-Shirt Folder with Sensor Integration and Motor Control

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ABSTRACT

Manual folding of t-shirts has long been recognized as a time-consuming task. In recent years, the rise of automation in systems and machinery has significantly contributed to increased productivity, reduced manual labor, and improved overall efficiency. With this, automated folding machines have emerged. The aim of this paper is to design and develop an Arduino-based automated T-Shirt folder that incorporates sensor integration and motor control. This study used ultrasonic sensors, servo motors, and the Arduino Uno microcontroller to fold t-shirts of various sizes. To complete the folding task successfully, the developed machine incorporates a feedback and control mechanism. The performance of developed T-Shirt folder was evaluated, assessing its folding speed. The results revealed that the machine can adeptly fold t-shirts of different sizes at an average speed of 8.16 seconds per shirt, reducing the time it takes for a human to perform the same task. This project exhibits promising potential for further refinement and potential application in the clothing industry.

Keywords : T-shirt Folding Machine; Servo Motor; LDR Sensor; Arduino

1 INTRODUCTION

THE demand for automated systems and machines has significantly risen across various industries in recent years to enhance productivity, reduce manual labor, and improve overall efficiency [1]. Among the numerous time-consuming household chores, folding clothes is a common task that many find exhausting and uninteresting after washing and drying. Properly folding garments are necessary to make them compact and easily storable [2]. This task is not limited to households but is also relevant to businesses like laundry services. Laundries often have a large volume of clothes to be folded within a fixed timeframe, and sometimes they need help to deliver the clothes to customers on time due to workload and other challenges [3]. In order to address these issues, automated folding machines have emerged.

Wankhede et. al [4] developed a t-shirt folding machine using DC motors wherein the folding process will start by pressing a button. The time spent folding the t-shirt also has been slashed to half since the machine can do the folding in almost half of the time taken by the manual way. Yet this study uses a button to activate the folding process.

Divya et al. [5] also use DC motors to fold t-shirts utilizing their rotary motions to complete the task. In their device, they incorporated sensors, specifically ultrasonic sensors, to automate it. The efficiency of the developed T-shirt folding machine is 50% greater when compared to manual-folding.

Silitonga et al. [6], in their study “Design and Simulation of Automatic Folders," goal is to design and simulate the folding tool automatic fabric using ultrasonic sensors and a microcontroller Arduino Uno. In their study, they used servo motors to fold clothes and pants.

In the study of Divya et al. and Silitonga et al, although they incorporated sensors in their devices but it is not used to automatically initiate the folding process. There is still a needs buttons to start the task.

Li et al. [7] devised a cloth folding machine capable of autonomously folding clothes when a piece of laundry is placed on the machine. The board of the machine is equipped with photo sensors that detect the presence of clothes, while a passive infrared sensor detects the movements of human hands and arms. Through testing, it was determined that the cloth folding machine successfully detects the presence of cloth and proceeds to fold them automatically. Although in this study, it has incorporated sensor to automatically fold the t-shirt without pressing any buttons yet just like in the previous three researches, their devices do not support size adjustment mechanisms for various sizes

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of t-shirt using sensor integration and motor control.

With the limitation of the previous researches, this study opts to automate the t-shirt folding without pressing buttons and make a device that supports size adjustments using sensors and motors. The primary objectives of this research are (1) to design and develop an Arduino-based automated t-shirt folder with sensor integration and motor control and (2) to test and evaluate its folding speed performance.

2 METHODOLOGY

This section consists of the overall description of the Arduino-based Automated T-Shirt Folder with Sensor Integration and Motor Control, including the development procedure.

2.1 Mechanical Drawing of the machine

Figure 1 shows the 3D design of the machine. It has a sturdy base (brown). The base measures 93 cm in length, 78 cm in width, and 10 cm in height. Inside this base, the intricate electrical wiring and electronic connections network is neatly integrated.

At the top of the machine, there are five folding boards. Folding board A, the top one, has a dimension of 20 cm x 15 cm x 1 cm. Folding board B, the middle one, measures 30 cm x 15 cm x 1 cm. On either side of the middle board are two additional folding boards. The right board, folding board D and the left board, folding board C both have dimensions of 24 cm x 60 cm x 1 cm. Furthermore, the bottom board, folding board E has a dimension of 25 cm x 69 cm x 1 cm allow. Each folding board has a 5 cm x 5cm hole where the LDR sensor is located.

A catch tray is incorporated into the design to facilitate an accessible collection of folded t-shirts. The catch tray, mounted at the top part of the device, has dimensions of 35 cm x 30 cm x 0.5 cm, providing ample space to gather the neatly folded t-shirt.

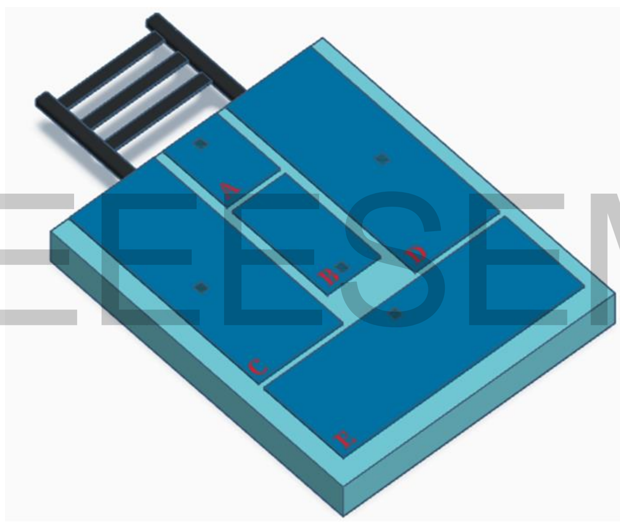

Fig. 1. 3D design of the machine

2.2 Block diagram

As shown in Fig 2., Arduino Mega 2560 serves as the machine's central control unit. The signal values generated from the light-dependent resistor (LDR) and ultrasonic sensor will be used as input and processed in the control unit. After processing, the control unit will send signals directly to the servo motor and the L298N motor driver. Then the motor driver will control the linear motors. The system is powered by two supplies, 12V 1.5A for the linear motor and 5V 1A for the sensors, Arduino Mega 2560, motor driver, and servo motor.

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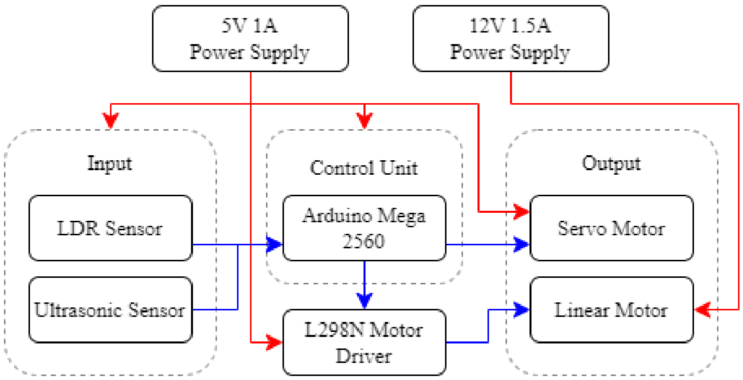

Fig. 2. Block diagram of the machine

2.3 Feedback and Control Block Diagram

In this study, a closed-loop feedback and control mechanism, as depicted in Figure 3, is implemented. The machine is specifically designed to fold small-size t-shirts with dimensions not exceeding 45 cm in length and 30 cm in width. However, when a t-shirt larger than the default size is detected, the machine utilizes a feedback and control loop to adjust itself accordingly.

The input of the machine is the t-shirt itself. Once the light-dependent resistor (LDR) is covered by the t-shirt, indicating that the light level falls below a predefined threshold value, the microcontroller sends signals to the linear motor located at the bottom of the three folding boards, folding board B, C and D. These signals prompt the motor to adjust the position of the folding boards in accordance with the size of the shirt. The adjustment process continues until the sensors reach the threshold value and achieve logical equivalence, at which point the microcontroller signals the linear motor to stop further adjustments.

Upon completion of the adjustment phase, the folding mechanism comes into play, involving the movement of the servo motors. After which, the motors initiate a reverse movement, returning the folding boards to their default position, which is configured for small-size shirts.

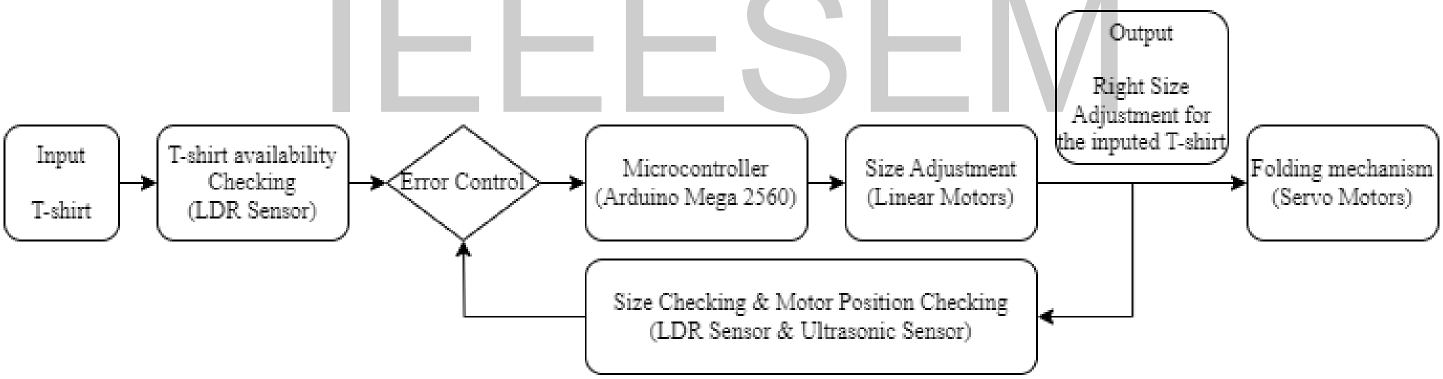

Fig. 3. Feedback and Control mechanism of the system

2.4 Schematic diagram

Figure 4 illustrates the schematic diagram of the system design. The system comprises five servos responsible for the folding mechanism, two motor drivers (L298N) utilized to control the motors, three motors dedicated to adjusting the folding boards based on the size of the t-shirt, seven LDR sensors employed to detect the presence and size of the t-shirts, and one ultrasonic sensor implemented to prevent excessive adjustment of the middle folding board location. All these components are interconnected and connected to the central control unit, which is an Arduino Mega 2560.

The motors receive a 12V power supply, which is the maximum voltage required to achieve their optimum speed while the remaining components are supplied with a 5V power source, as it is the recommended voltage for the other components used in the system.

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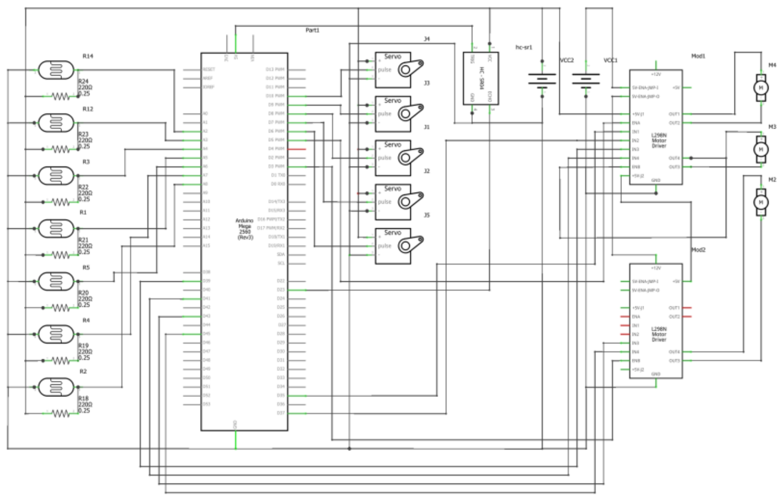

Fig. 4. Schematic Diagram of the machine

2.5 Logical application and mechanical movement of the system

Fig 5 shows the location of the LDR sensors and the ultrasonic sensor. There are seven LDR sensors, one (LDR sensor 1) at the folding board A, two (LDR sensors 2 & 3) at folding board C, the two (LDR sensors 4 & 5) at the folding board D and two (LDR sensor 6 & 7) at the folding board B. Furthermore, one ultrasonic sensor inside of the device is located in the middle.

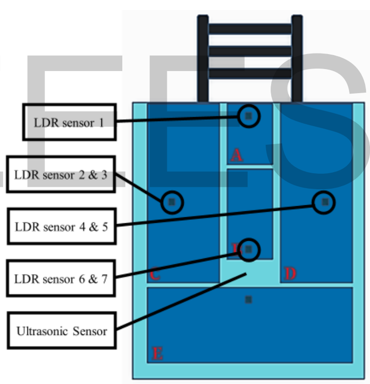

Fig. 5. Location of LDR sensors

Fig 6 shows the movement of the folding boards for size adjustment using the linear motors attached below. LDR sensor 2 & 3 is responsible for the movement of the folding board D, LDR sensor 4 & 5 for the folding board C and, LDR sensor 6 & 7, and the ultrasonic sensor for the folding board B. The movements involved are extending the folding boards, reversing, and stopping.

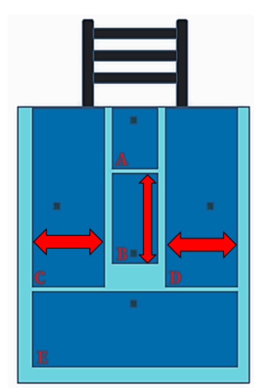

Fig. 6. Movement of the folding boards for size adjustment

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The initiation of the device is triggered by the LDR sensor 1. When a t-shirt is placed on the device, covering the LDR sensor 1 and causing its output value to drop below the threshold, the size checking process is activated by the control unit.

The evaluation of the left side of the t-shirt is performed using LDR sensors 2 and 3. If the left side of the shirt covers both sensors, indicating that it is below the threshold, the folding board C extends. Conversely, if the left side of the shirt does not cover both sensors, indicating that it is above the threshold, the folding board C moves in reverse. The extension and reversal of the folding board C continue until LDR sensor 2 is uncovered and LDR sensor 3 is covered, indicating the boundary of the left side of the t-shirt and signaling the end of the adjustment process for that side.

After completing the evaluation of the left side, the right side of the t-shirt is examined. Similar logic is applied as with the left side, but this time LDR sensors 4 and 5 are involved in the assessment.

The final evaluation is performed on the middle section of the t-shirt. LDR sensors 6 and 7 are utilized for this purpose, alongside an incorporated ultrasonic sensor within the middle folding board. The logic applied to LDR sensors 6 and 7 is similar to that used with LDR sensors 2, 3, 4, and 5. However, the ultrasonic sensor is responsible for preventing over-extension of the folding board B towards the bottom folding board. Additionally, the ultrasonic sensor contributes to the logic applied in the folding mechanism. This logical app logical application and its corresponding linear motor movement below the folding board is illustrated in Fig 7.

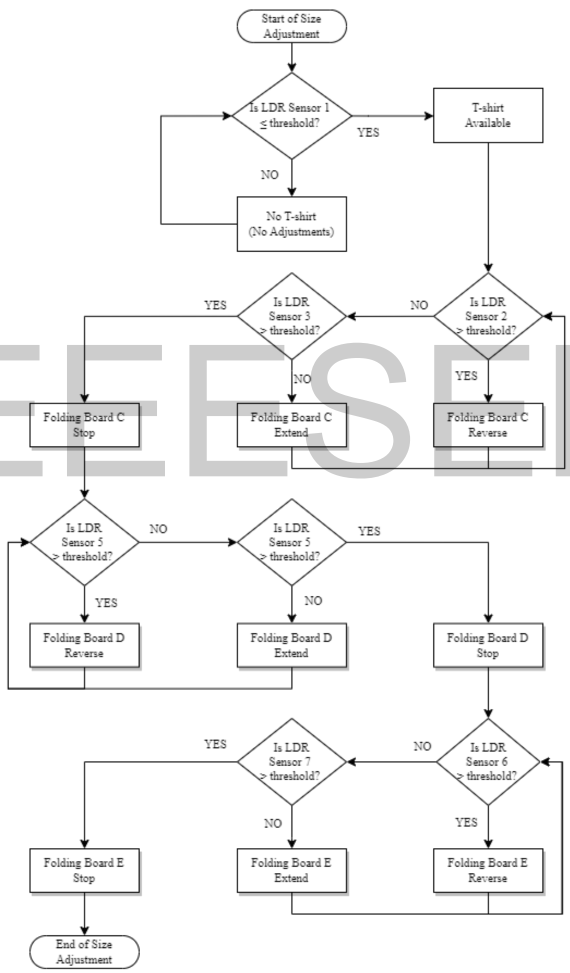

Fig. 7. Flowchart of the Logical Application and its Corresponding Linear Motor Movement below the Folding Board

2.6 Folding mechanism

Fig. 8 shows the servo motors' location responsible for the folding mechanism. Servo 1 moves the folding board A, Servo 2 moves the folding board B, Servo 3 moves the folding board C, Servo 4 moves the folding board D, and Servo 5 moves the folding board E.

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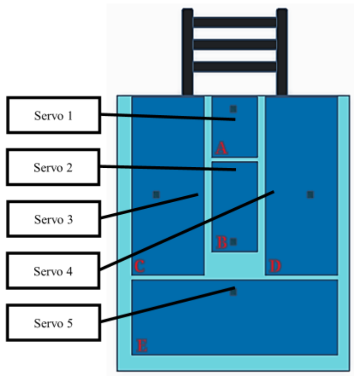

Fig. 8. Location of the Servo motors

The folding mechanism logic and servo movement sequence are presented in Fig. 9. Two cases are considered, which are determined by the output analog value of the ultrasonic sensor.

In Case 1, when the ultrasonic sensor outputs a distance below the threshold, indicating a small t-shirt size, the folding process involves four folding boards: top, right, left, and middle. The bottom folding board is excluded, as it is unnecessary and would consume unnecessary energy. The sequence of the folding mechanism begins with the right folding board, followed by the left board. Next, the right board is engaged again to fold the excess sleeve, followed by the middle board. Finally, the top folding board completes the folding process, placing the folded t-shirt into the catch tray.

In Case 2, when the ultrasonic sensor outputs a distance above the threshold, signifying a non-small t-shirt size suitable for adults and plus sizes, the t-shirt has variable dimensions, including varied length and width. The folding mechanism for not small t-shirts involves all five folding boards: top, right, left, middle, and bottom. The sequence of the folding mechanism is the same as in Case 1, but with the addition of the bottom folding board. The movement sequence begins with the bottom folding board, followed by the right board, left board, right board again, middle board, and finally, the top folding board.

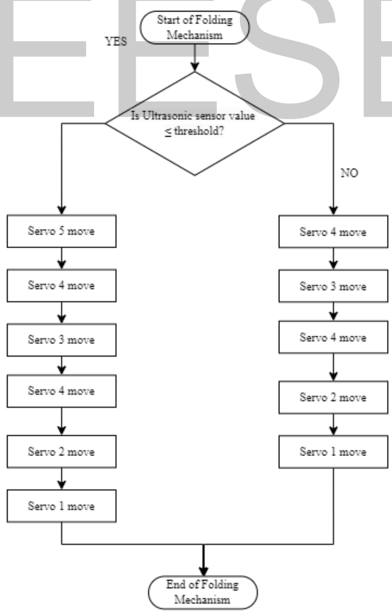

Fig. 9. Flowchart of the Logical Application of the Folding Mechanism

3 Results And Discussion

3.1 Developed Automatic T-shirt Folder

Fig 10 shows the external appearance of the developed device, wherein it has five folding boards, all made from a carton material, utilizing its characteristic of being lightweight, with holes for the LDR sensors and a metal catch tray. The device's base is made of wood, provid-

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ing a solid foundation for the entire device. With the holes made for the LDR sensors, it can correctly provide analog values for evaluating the location of the edge of the t-shirt. However, if the angle of the light source is not directed straight to the device, giving a shadow, it struggles to identify and evaluate the size of the t-shirt correctly.

Fig. 10. Developed t-shirt folder

Fig. 11 shows the inside of the device with the electronic connections of the device and the mechanical components in facilitating the movement of size adjustment.

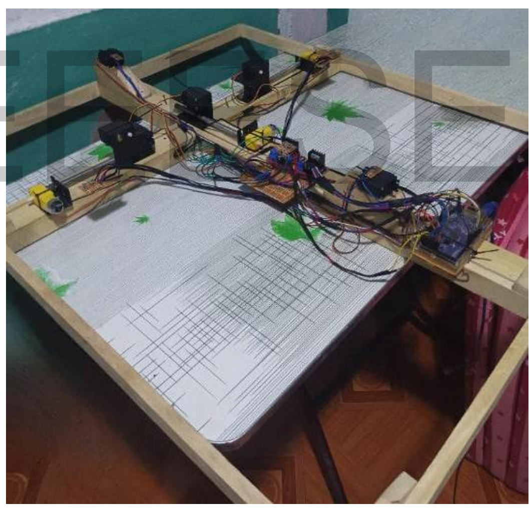

Fig. 11. Inside of the Developed t-shirt folder

3.2 Working Procedure of the Developed T-shirt Folder

The sequence of the folding mechanism of the small-size t-shirt and not small-size t-shirt are shown in Fig. 12 and Fig. 13, respectively. The small-size t-shirt has six steps, including laying down the t-shirt as the first step. For the not-small size, it has seven steps which constitute the steps in small size with an addition of the movement of the bottom folding board. In the folding mechanism, the servo motors' torque and the designed arm that pushes and pulls the folding board can handle the accumulated weight of the folding board and the t-shirt.

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Fig. 12. Folding Sequence of Small size T-shirt

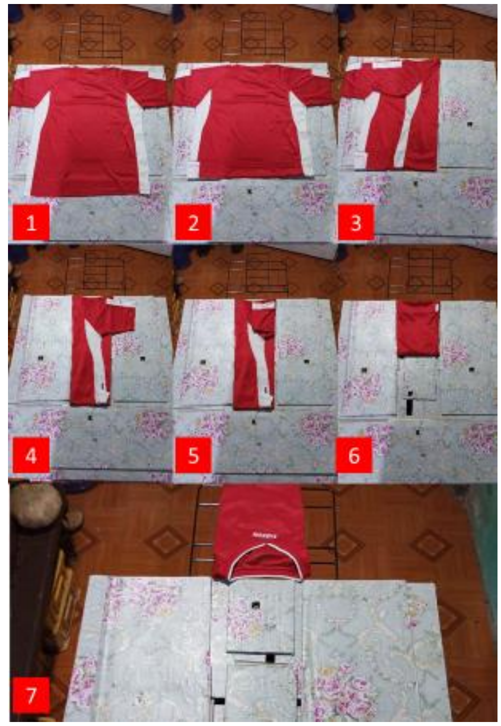

Fig. 13. Folding Sequence of Not Small size T-shirt

3.3 Performance Evaluation

Table 1 shows the time it takes to fold the t-shirts. There is a total of 12 random-size t-shirts that are for kids and adults. The attained average folding speed of the t-shirt is 8.16 secs.

Ten individuals were tasked with folding five randomly selected t-shirts from a set of samples used to test a device. Their average folding speed was calculated to be 11.56 seconds. This finding aligns with the study conducted by Ahsan et al., which reported an average human folding speed of 12 seconds [2].

Table 2 compares the human and the developed Arduino-based Automated T-Shirt Folder. Based on the results, the developed Arduino-based Automated T-Shirt Folder reduces the folding time by 3.41 secs. This distinctly shows that 30% of the t-shirt folding time is saved by utilizing the machine.

TABLE 1
SPEED OF THE FOLDING T-SHIRT USING THE DEVELOPED ARDUINO-BASED AUTOMATED T-SHIRT FOLDER

T-shirt Samples	Developed Arduino-based Automated T-Shirt Folder
Sample 1	8 secs
Sample 2	8 secs
Sample 3	7 secs
Sample 4	7 secs
Sample 5	8 secs
Sample 6	7 secs
Sample 7	9 secs
Sample 8	8 secs
Sample 9	9 secs
Sample 10	9 secs
Sample 11	10 secs
Sample 12	8 secs
Average speed	**8.16 secs**

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TABLE 2
COMPARISON BETWEEN HUMAN AND MACHINE FOLDING TIME FOR T-SHIRT

	Human	**Developed Arduino-based Automated T-Shirt Folder**
T-shirt Folding Time per shirt (Sec)	11.56 secs	8.16 secs

4 CONCLUSION & RECOMMENDATIONS

In this study, Arduino-based Automated T-Shirt Folder was designed and developed. Based on the tests, it can neatly fold different sizes of shirts with the help of sensors and motor control. The developed machine reduces the time it takes for a human fold a t-shirt. This study and the developed machine can assist and provide support to easily fulfill the needs of folding t-shirts. The findings of this research contribute significantly to both scientific knowledge and practical applications, particularly within the clothing industry and other relevant sectors that involve t-shirt folding.

For future works, the researchers recommend exploring alternative technologies for size adjustment, such as hydraulic and pneumatic linear actuators, to enhance the speed and efficiency of the adjustment process. It is also suggested to investigate the incorporation of other alternative sensors. Computer vision technology could be considered for size identification and expanding the folding capabilities so that various garments will be included aside from t-shirts. Additionally, the researchers recommend to make other basis of comparison for the device performance like people that are experts in folding t-shirts or other existing automated t-shirt folding machines. These future research directions have the potential to advance and refine the automated folding process, meeting the evolving demands of the industry.

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