Development of Automatic Cloth Folding System by Using Arduino Uno Microcontroller and Servo Gears

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Abstract – *The manual folding processes in various industries are prone to inefficiencies, errors, and delays due to their repetitive and labor-intensive nature. Maintaining consistency in folding techniques is also challenging, resulting in disorganized clothing and potential quality issues. Moreover, the high volumes of laundry in busy households or commercial sectors contribute to inefficient folding process. Therefore, this project proposed an automated cloth-folding system. By using this system, the problems related to garments folding can be solved quickly and neatly. The designed system utilized a combination of ultrasonic sensors, gear servo motors, a power supply, an Arduino Uno microcontroller, and a flat board made of plastic with hinges or folding lines that create specific folding templates. The automated cloth-folding system successfully addresses the inefficiencies and challenges associated with manual folding processes, offering a promising avenue for improving speed and consistency in garment folding, particularly for standard-sized items.*

Keywords*: Arduino Uno Microcontroller, Garment folding, Servo gears*

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I. Introduction

Domestic chores are time-consuming and unfinished work. One of the common chores which usually needs more attention is cloth folding process. Cloth folding work is not only applicable in domestic houses but also on a big scale in fabric industries. Manual folding processes often involve repetitive and labor-intensive work, leading to potential errors, inconsistencies, and delays in production. Besides, maintaining consistency in folding techniques is challenging, leading to wrinkled or disorganized clothing. Moreover, the high volumes of laundry in busy households or commercial sectors contribute to inefficient folding process.

S. Gunputh [1] and M. S. Ahsan [2] describes an electromechanical device that can fold various types of clothes through the Android app command. The whole software system was implemented on the Arduino platform. The designed system proved that the folding time by machine is reduced by 3 seconds if compared to manually done by human. In [3], semi-automatic folder machine specifically used for t-shirt by using PID controller id designed. The PID controls the movement of the DC motor that operates the folding board. V. Petrík [4] implemented an automated system of single-arm robotic garment folding. Their investigation was based on the static equilibrium of forces, and they modelled the clothing as an elastic shell using a two-13-dimensional geometry.

Y. Li [5] designed a two-arm Baxter robot that can manipulate deformable objects with accuracy and efficiency by following optimized trajectories. The model has a quick and reliable algorithm that can automatically identify crucial places on clothing, such as the corner of the waist, the collar, and the sleeve ends. The work is the improvement of the previous work in [6] – [8]. J. Stria [9] contributed to the garment detection and manipulation such as sorting, folding, etc. using a dual-arm robot as part of the Clo Pema (Clothes Perception and Manipulation) project. To find garment landmark spots, the figure is fitted into a segmented garment contour. It demonstrates method to automatically derive folded variations of the unfolded model. The model's success in the 15 entire folding process, which applies to many different clothing categories (towels, trousers, shirts, etc.), and which was experimentally tested using a two-armed robot, serves as evidence of its universality and applicability. Their work is an expansion and improvement on priceless polygonal model works because it also deals with polygonal models.

MATLAB and C++ were used to implement the algorithms.

Meanwhile, K. I. [10] proposed a system that can fold garments using small mobile robots and a standard table. Despite having little workspace, they were nonetheless able to put their method into practice. While an external camera is positioned above the mobile robots to collect RGB image files for the PC, the markers on the robots are used to get coordinates and adjust the clothing. Inspired by robot vacuums, [11] developed a folding system by using mobile robots. The cloth is lying horizontally on the table. The mobile robot does the folding task with a sequence for each type of cloth based on image detection. This research occupied a large space for its folding operation. Another research involved robot for folding operation is presented by [12]. Different from the previous research, this work used dual-arm robot instead of mobile robot for folding process. Cloth manipulation is virtually learned by using physics manipulator to reduce the burden on manipulation experiment. A method using Bayesian optimization is proposed to obtain folding manipulation efficiently using the simulator. The effectiveness of the proposed method is verified by experiments using an actual robot.

A system that is capable of fully autonomously transform a clothing item from a random crumpled configuration into a folded state is presented in [13]. Its algorithm includes a novel fold detection and grasp generation strategy to compute valid grasp poses on the cloth which accounts for deformability. A stock PR2 robot whose two arms alternatingly perform grasps on a T-shirt equipped with fiducial markers is used in this research. [14] implement a single-arm robot to consider 2 forms of manipulation: flattening a crumpled towel and folding a flat one. The robot identified the corners of a garment using computer vision. N. Silitonga [15] designed an automatic cloth folding tool using ultrasonic sensors and an Arduino Uno microcontroller. Irawan, Yuda., Wahyuni, Refni., & Fonda, Hendry. Y. Irawan [16] implemented an automatic clothes-folding device using Gear Servo and Arduino Uno Microcontroller.Tthe Arduino Uno, Servo A, Servo B, Servo C, UltraSonic Sensors, Power Supply, and other parts will eventually be housed. Silitonga studied the functionality of the above-mentioned parts when they are all linked to a wooden board [15].

Based on the previous works, most of the research focused to ease the cloth folding process and reduced the time taken. Therefore, an automatic folding machine is also proposed in this article to overcome these difficulties. The research introduces a significant advancement in the field of textile handling and automation which is particularly valuable in contexts where manual folding is labor-intensive and time-consuming, such as in large-scale laundry operations or textile manufacturing. The primary contribution of the research is the potential for substantial reductions in the time required to fold cloths. Manual folding is often slow and inconsistent, so an automatic machine can streamline the process, leading to increased productivity and operational efficiency. In addition, automated folding machines can ensure a consistent quality of folds, which might be difficult to achieve manually. Consistency in folding process can enhance the presentation and organization of textiles, which is crucial in retail and distribution settings.

II. Methodology

The goal of this research is to develop the prototype of the garment folding machine. It is constructed by controlling the movements of the servo motor based on the detection of the garment on the folding board within 10 cm. The detection process is implemented by ultrasonic sensor. This sensor was chosen because the ultrasonic distance meter is a low-tech, straightforward tool for measuring distances. Using "non-contact" technology, ultrasonic sensors gauge a target object's or material's distance through the air [17]. One of a series of microcontrollers based on the Atmega328 8 is the Arduino Uno [18]. The ATmega328 microcontroller is a versatile device capable of executing program code, interfacing with digital and analogue devices, communicating with other modules, generating precise timing and PWM signals, managing memory, handling interrupts, and implementing power-saving features. This device is a development of an outdated microcontroller that has been enhanced with several capabilities necessary for the microcontroller's operation. Additionally, a USB connection was provided for microcontroller programming. Arduino Uno was ready to use once it has been configured by connecting the USB cord to a computer. The Arduino Uno contains a 16MHz ceramic resonator, six analogue inputs, 14 digital input/output pins, a USB port, an input power socket, an ICSP header, and a reset button.

The type of Arduino chosen to develop the prototype of the project depends on the complexity of the project and the required processing speed. There are several cloth folding machines which utilized an Arduino to develop the system. [2] used Arduino Uno to design the control unit for cloth folding system. The designer integrates the system with Android applications such that it is user friendly. [13] implement machine learning techniques to train the two arms of PR2 robot to perform grasps on a T-shirt equipped with fiducial markers. [14] developed an ABB robot with policy based on reinforcement learning. The action of the robot is designed by observations of the environments. The research manipulates two forms of cloth which are flattening crumpled towels and folding a flat one. Two omnidirectional robots are programmed by using Arduino in [11] to implement the cloth folding tasks. The program is written using Phyton.

In this project, the operation starts with the detection of garments. When cloth is detected, the system triggers the servo motors to execute the folding sequence, displaying the distance and the count of folded clothes on an LCD. LEDs provide visual cues, indicating the detection of clothing or its absence. The designed mechanism will ensure proper placement of the cloth on the folding board, count the number of folded clothes, and display that information on the LCD screen such that the user can monitor the folding progress and system's performance. The prototype is created as a convenient platform that efficiently folds large quantities of clothes within a short period. The automatic folder is specifically programmed to fold and stack simple clothes. The designed prototype integrates the ATMega328P Arduino Uno microcontroller with ultrasonic sensor and servo-motor gears. Fig. 1 shows the prototype of cloth folding tool developed in this research.

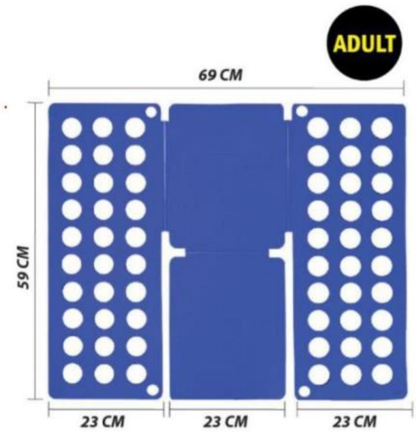


Fig1. Cloth folding tool developed in this research

A cloth-folding tool is developed to simplify the folding process of various types of garments efficiently and neatly. The measurement of this tool is 69cm x 59 cm wide area. A wooden table as shown in Figure 1 is attached at the backside of the cloth folding tool as the main structure that will eventually hold the Arduino Uno, Servo A, Servo B, Servo C, Servo D, Servo E, Servo F, Servo G, Servo H, Servo I, Servo J, Servo K and Servo L, Ultrasonic Sensors, Power Supply, LCD and more parts.

Fig 2. Wooden table attached at the backside of the cloth folding tool

An electric circuit as illustrated in the diagram in Fig. 3 is attached to the wooden table.

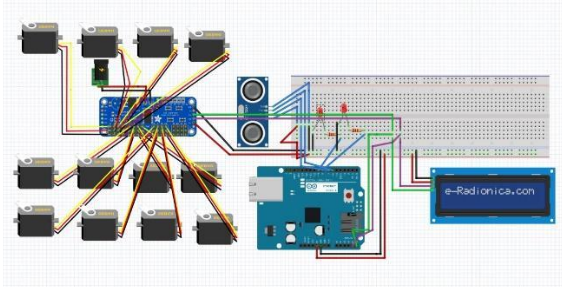


Fig 3. Electric circuit diagram

The Arduino UNO (ATMega328P) is chosen as microcontroller for the system since it is a simple, low-powered, low-cost microcontroller and widely available usage. The ATMega328P has enhanced power-saving features, allowing it to operate at lower power levels and consume less energy compared to other microcontrollers. It is mounted to a wooden board together with other electrical components as illustrated in Figure 4.

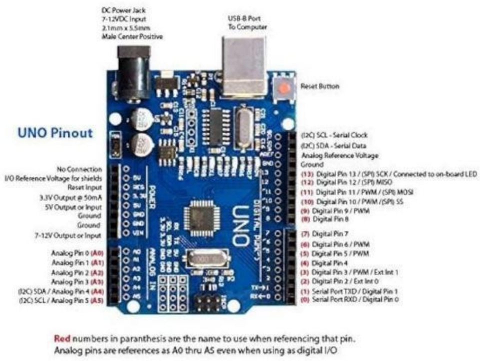


Fig 4. Arduino UNO (ATMega328P)

Arduino is programmed to control the action of servo motors that are attached to the wooden table. Twelve servo motors Tower Pro SG90 are used and placed on the hinges of the folding tool. This servo motor operates at 0.1sec/60° speed. The algorithm determines the action of the servo motor to control the movement of the folding tool in the folding process. Fig. 5 displays the servo motors used for this work.

Fig 5. Servo motors Tower Pro SG90

The 16x2 LCD (liquid crystal display) module is also attached to the system to provide information on the number of folding garments. All these electrical components are connected to the Arduino through PCA9685 C16 Channel Servo / PWM Driver - I2C interface which is a popular integrated circuit (IC) that serves as a 16-channel servo and PWM (Pulse Width Modulation) driver. The PCA9685 module is connected to the microcontroller and communicates with the microcontroller using I2C protocol by connecting the SDA (data) and SCL (clock) pins of the PCA9685 to the corresponding pins on the microcontroller. The PCA9685 has 16 output channels, labelled from 0 to 15. Each servo motor is connected to one of these channels. This component is illustrated in Fig. 6.

Fig 6. PCA9685 module

Ultrasonic Sensor (HC-SR04) is used to detect the presence of garments on the folding tool. The HC-SR04 ultrasonic sensor employs SONAR to calculate an object's distance. It provides exceptional non-contact range detection from 2 cm to 400 cm. In this research, the sensor is set to detect the garment within the distance of 10cm. Upon detection of garments, the microcontroller triggers the servo motor for folding process. The main problem in cloth folding process is difficulties to identify the corners of garment and to select appropriate gripping positions and moving trajectories. This research is trying to reduce these difficulties. The ultrasonic sensor is shown in Fig. 7.

Fig 7. Ultrasonic sensor

III. Results and Discussion

Fig. 8, 9 and 10 illustrate the full assembly of cloth folding machine with different view, top view, side view and rear view of the system.

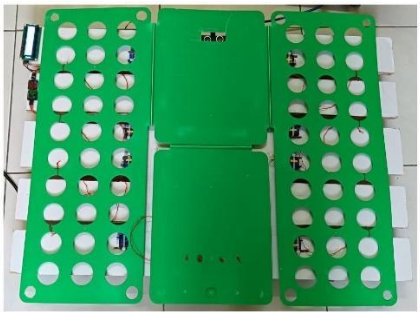


Fig 8. Top view of cloth folding machine

Fig 9. Side view of cloth folding machine

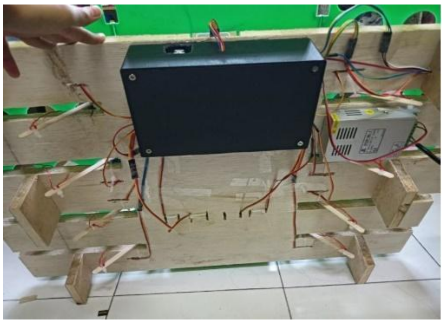


Fig 10. Back view of cloth folding machine

The servo motors are located on the wooden table such that it can pull the plastic material for folding process. This is shown in Fig. 11.

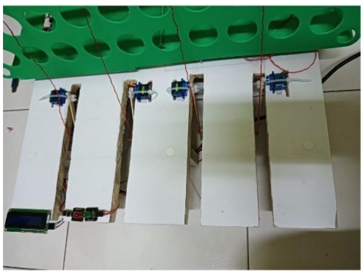


Fig 11. Location of the servo motors on the cloth folding machine

The present of garment materials is indicated by the color of LED lighting. Red color indicates that no garment is detected while the present of the garment is shown by green color. This situation is illustrated in Fig. 12 and Fig. 13.

Fig 12. LED indicates the absence of garment

Fig 13. LED indicates the present of garment

LCD displays the distance and the number of the detected garment. This is shown in Fig. 14.

Fig 14. LCD display the distance and number of detected garments

The effectiveness of the system's performance is analyzed based on the different material, thickness, and form of garments. For t-shirt, long shirt, and jacket as shown in Fig. 15, the folding process by the machine is proper. The complete folding process for each type of garment took about 6 seconds excluding the activation delay.

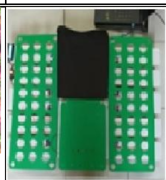
Fig 15. T-shirt, long shirt, and pants

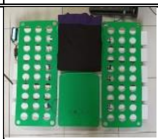
However, for thick towel and long pants as illustrated in Fig. 16, it is difficult to obtain proper folding procedure for these two types of garments. This might be happened because the towel is thick and huge while the pants are made from heavier fabrics, and it has long structure. The inability of the servo motors to adequately support the weight of these items led to suboptimal results.

Fig 16. Jacket and towel

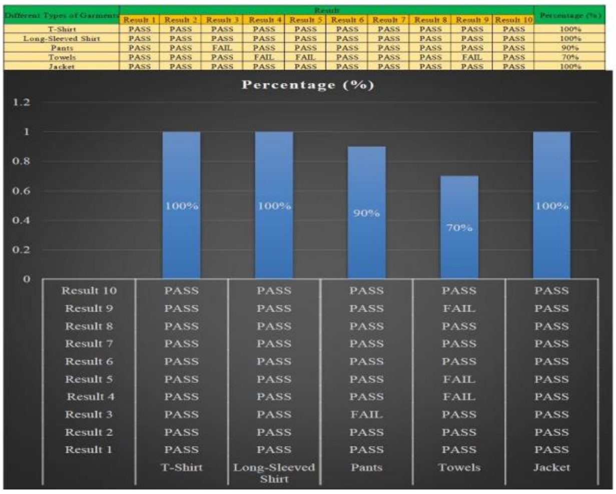
All these results are concluded in Table I based on different type and form of material. Referring to Table I, the probability for the developed prototype to successfully fold the towel and pants are 70% and 90% respectively. This depends on the position and the material of the garments on the prototype surface. For t-shirts, long sleeve shirt and jacket, the system able to fold this type of garment properly.

TABLE I
THE RESULTS OF TESTING DIFFERENT TYPES OF GARMENTS

ITEM NAME	INITIAL IMAGE	FINAL IMAGE	RESULT
T-Shirt			PASS

Long-Sleeved Shirt			PASS
Pants			PASS/FAIL
Towels			PASS /FAIL
Jacket			PASS

Graph in Fig. 17 illustrates the percentage of successful in folding process for different types of garments.



Different Types of Garments	Result										Percentage (%)
	Result 1	Result 2	Result 3	Result 4	Result 5	Result 6	Result 7	Result 8	Result 9	Result 10	
T-Shirt	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	100%
Long-Sleeved Shirt	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	100%
Pants	PASS	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	PASS	90%
Towels	PASS	PASS	PASS	FAIL	FAIL	PASS	PASS	PASS	FAIL	PASS	70%
Jacket	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	100%

Fig 17. The successful rate of folding process for different types of garments

Based on the results obtained, the prototype has some constraints. The main limitation of the developed prototype is its servo motor has certain weightage restriction. Pants and towel are heavier than shirt and jacket therefore the probability to obtain proper folding process is lowered. In addition, the system required delay for each folding process. The "delay" refers to the time interval needed for the machine to complete each folding operation. This processing time is essential as it encompasses the time required for the machine to perform all the necessary steps involved in folding the cloth. This includes tasks such as aligning the cloth, executing the folding action, and preparing for the next item.

IV. Conclusion

The main operation of garment folding process in this project is organized by the servomotor and sensor attached to the folding tool. The movement of the plastic plat is determined by the movement of servomotor to ensure the successful of the folding process. The servomotor is attached on the backside of the folding tool. Based on the obtained results, the success of garment folding process is depends on the garment’s materials, form and weightage within the limit that can be handled by the servomotor. Since the main operation of the developed prototype is determined by the servomotor, higher specification of this motor is suggested to improve the operation ability of the developed system.

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Conflict of Interest

There is no conflict of interest regarding the publication of this article. The paper is free of plagiarism.

Author Contributions

Author 1: Data collection, supervision; Author 2 : draft preparation, writing; Author 3 : draft review and editing; Author 4 : draft review and editing;

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