Faculty of Electrical Technology and Engineering

DEVELOPMENT OF PROGRAMMABLE AUTOMATION SYSTEM ON CLOTH-FOLDING TOOL USING ARDUINO UNO MICROCONTROLLER AND SERVO GEARS

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature :

Supervisor Name : TS. DR. SAHAZATI BINTI MOHD ROZALI

Date : 7/1/2024

Signature :

Co-Supervisor Name (if any) :

Date :

DEDICATION

To my dear mother, Rolina Binti Nordin, and my father, Mokhtar Bin Mohd Tahir,
To my sisters, my friends who have been a huge help to me, and
I sincerely appreciate and thank TS. Dr. Sahazati Binti Mohd Rozali, my supervisor, for all of your help.

ABSTRACT

This project addresses the pressing issue that the manual folding processes in various industries are prone to inefficiencies, errors, and delays due to their repetitive and labor-intensive nature. Not only that, maintaining consistency in folding techniques is challenging, resulting in disorganized clothing and potential quality issues. Moreover, the high volumes of laundry in busy households or commercial settings further compound the difficulty of folding clothes efficiently. Therefore, this project prioritizes designing and implementing an automated system for a cloth-folding tool. It is intended that using this tool would help with problems related to folding garments quickly and neatly without having to fold them by hand. The tool typically consists of a flat board made of plastic with hinges or folding lines that create specific folding templates. The system utilized a combination of ultrasonic sensors, gear servo motors, a power supply, an Arduino Uno Microcontroller to control the folding tool. The Arduino Uno is used as the controller for the automation system. In addition, the Arduino IDE is used for the programming of the system. In summary, the automated cloth-folding tool demonstrated exceptional accuracy, achieving nearly 100% success rates in folding T-shirts, long-sleeved shirts, and jackets. However, challenges were encountered with thicker and larger items such as towels and pants, where the servo motors struggled to support the weight. Despite these limitations, the overall efficiency of the system is evident, with each garment taking approximately 6-7 seconds to complete the folding process. The proposed solution 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: folding clothes, cloth-folding tool, Arduino Uno Microcontroller

ABSTRAK

Projek ini menangani isu mendesak bahawa proses lipatan manual dalam pelbagai industri terdedah kepada ketidakcekapan, ralat dan kelewatan kerana sifatnya yang berulang dan intensif buruh. Bukan itu sahaja, mengekalkan konsistensi dalam teknik lipatan adalah mencabar, mengakibatkan pakaian tidak teratur dan isu kualiti yang berpotensi. Lebih-lebih lagi, jumlah cucian yang tinggi dalam rumah tangga yang sibuk atau persekitaran komersial menambahkan lagi kesukaran untuk melipat pakaian dengan cekap. Oleh itu, projek ini mengutamakan mereka bentuk dan melaksanakan sistem automatik untuk alat lipatan kain. Ia bertujuan untuk menggunakan alat ini akan membantu masalah yang berkaitan dengan melipat pakaian dengan cepat dan kemas tanpa perlu melipatnya dengan tangan. Alat ini biasanya terdiri daripada papan rata yang diperbuat daripada plastik dengan engsel atau garisan lipatan yang mencipta templat lipatan tertentu. Sistem ini menggunakan gabungan penderia ultrasonik, motor servo gear, bekalan kuasa, Pengawal Microcontroller Arduino Uno untuk mengawal alat lipatan. Arduino Uno digunakan sebagai pengawal untuk sistem automasi. Selain itu, IDE Arduino digunakan untuk pengaturcaraan sistem. Secara ringkasnya, alat lipat kain automatik menunjukkan ketepatan yang luar biasa, mencapai hampir 100% kadar kejayaan dalam melipat baju-T, baju lengan panjang dan jaket. Walau bagaimanapun, cabaran dihadapi dengan barangan yang lebih tebal dan lebih besar seperti tuala dan seluar, di mana motor servo bergelut untuk menyokong berat. Walaupun had ini, kecekapan keseluruhan sistem adalah jelas, dengan setiap pakaian mengambil masa kira-kira 6-7 saat untuk menyelesaikan proses lipatan. Penyelesaian yang dicadangkan berjaya menangani ketidakcekapan dan cabaran yang berkaitan dengan proses lipatan manual, menawarkan jalan yang menjanjikan untuk meningkatkan kelajuan dan konsistensi dalam lipatan pakaian, terutamanya untuk item bersaiz standard.

Kata kunci: melipat pakaian, alat lipatan Kain, Microcontroller Arduino Uno

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LIST OF SYMBOLS

δ	-	Voltage angle
$\circ$	-	Degree angle

LIST OF ABBREVIATIONS

V	-	Voltage
A	-	Current
P	-	Power

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The background of the study, the research problem, the research question, the research aims, the scope, the limitations, and the significance of the study are all explained in this chapter.

1.2 Background

An automation system is a technological framework that integrates various hardware and software components to perform tasks and processes with minimal human intervention. It leverages advanced technologies such as robotics, artificial intelligence, machine learning, and sensors to automate repetitive or complex tasks, streamline workflows, increase efficiency, and reduce errors. By replacing manual labour and enabling precise and consistent operations, automation systems have the potential to revolutionize industries across sectors, ranging from manufacturing and logistics to healthcare and customer service. The automatic clothes folder is a convenient platform that efficiently folds large quantities of clothes in a short period. It is designed to assist individuals such as housewives, college students, or anyone who struggles with the task of folding clothes. Domestic chores can be time-consuming, and leaving unfinished work can be uncomfortable. The automatic folder eliminates the need to spend excessive time on folding, allowing users to engage in other activities instead. To address this, a tool was developed to assist humans in quickly and automatically folding clothes. The tool is equipped with a simulation feature that counts the number of clothes folded, displayed on an LCD screen. The automatic folder is specifically programmed to fold and stack simple clothes. In this study, the design utilizes the ATMega328P microcontroller, specifically the Arduino Uno, which integrates microcontroller-based building automation systems and various technologies and processes. By integrating the microcontroller, the control system for electrical equipment can achieve optimal performance. This research aims to design and simulate a clothes-folding system based on an ultrasonic sensor. The implementation of this tool is anticipated to simplify the clothes-folding process, reducing the time required and eliminating the need for manual folding.

1.3 Problem Statement

The problem addressed in this article is the design and simulation of automatic folders, which aims to improve the efficiency and accuracy of folding tasks in various industries. Manual folding processes often involve repetitive and labour-intensive work, leading to potential errors, inconsistencies, and delays in production. Not only that, maintaining consistency in folding techniques is challenging, leading to wrinkled or disorganized clothing. Moreover, high volumes of laundry in busy households or commercial settings exacerbate the difficulty of folding clothes efficiently. By developing an automatic folding system, the article aims to explore innovative designs and simulate their performance to enhance productivity, reduce costs, and ensure consistent quality in the folding process. The research focuses on integrating robotics, machine vision, and advanced control algorithms to achieve precise and reliable folding operations, thereby addressing the challenges associated with manual folding techniques.

1.4 Project Objective

Specifically, the objectives are as follows:

a) To design and construct a fully functional automatic folding system that can fold a piece of cloth automatically by integrating servo motors, an ultrasonic sensor, and an Arduino Uno Microcontroller.

b) To optimize the cloth detection and positioning mechanism of the system, which involves fine-tuning the ultrasonic sensor's sensitivity and programming algorithms.

c) To integrate an LCD display to provide real-time feedback and information to the user.

1.5 Scope of Project

The goal of this research is to create an intelligent semi-automation system that makes use of cutting-edge industrial components and engineering software. The prototype of the garment folding machine is constructed to accurately control the movements of the servos based on the detected presence of the garment. Moreover, to ensures accurate and reliable cloth detection within a distance of 10 cm and also includes mechanisms or guides to ensure proper placement of the cloth on the folding boards, and lastly, to count the number of clothes that have been automatically folded and display that information on the LCD screen, which helps users keep track of the folding progress and provides a convenient way to monitor the system's performance. It had to incorporate the layout of the equipment and the way the mechanisms interacted with the low-voltage control units, which were represented by the servo motors as actuators, and ultrasonic sensors as transceivers. In order to accomplish proper machine motion, the following requirements must be applied to the machinery parts:

The scope of this project is as follows:

a) An ultrasonic sensor will detect the presence of the cloth at a distance of 10 cm.

b) Arduino should be programmed with servo motors flawlessly.

c) Machine parts must interact and be connected to accomplish the initial and end positions without any jerk and material worn out.

d) The clothes must be folded neatly and nicely in a short time.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The articles related to this project were discussed in this chapter. It included projects created by institutions before this project has developed. The theory and application of the parts, tools, and programming language utilized in the prior project are covered in this chapter.

2.2 Background

This chapter explores some of the studies conducted on clothes-folding machines. The research project categorizes clothes folding into three types based on the technological level. The first type is manual folding, which is performed by hand and remains the oldest and most effective method to date. The second type is semi-automatic, where clothes are placed on a platform and the machine handles folding. This method involves humans spreading and arranging the clothes on the platform, while a motor-controlled platform performs the folding. The third type is fully automated folding, where intelligent folding machines take charge. In this case, the clothes are automatically spread, arranged, and folded by a machine. This approach often involves a two-armed robot equipped with cameras or rangefinders for image detection and dexterous grippers for manipulation. However, achieving full automation in clothes folding is still a topic of serious research, and a complete breakthrough has not yet been achieved in this area.

2.3 Journal

NO	AUTHOR	TITLE	YEAR	ABOUT
1.	Nogar Silitonga	Design and Simulation of Automatic Folders	2019	This research designed an automatic cloth folding tool using ultrasonic sensors and an Arduino Uno microcontroller. The results of this study concluded that a lot of folding clothes can fold the clothes within a short namely a short-sleeved shirt with a time of 4 seconds, ¾ sleeves with a time of 5 seconds, and shorts with a time of 3 seconds. Therefore, the tool can be used to assist the workdays, which is still done manually. [16]
2.	N. Anju Latha	Distance Sensing with Ultrasonic Sensor and Arduino	2018	The project's goal was to create and use an ultrasonic distance metre. The device described here is capable of both target detection and target distance calculation. The ultrasonic distance metre 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. The result the analogue signals that the sensor receives are converted to digital signals by the microcontroller and output in the analogue form. It is used to identify obstacles in the current work and determine their precise distance. To acquire a nearly precise distance measurement, the inbuilt analogue to digital converter is calibrated. On an LCD panel, the measured distance is also shown. It can be applied to robotics, automation, and robotic automobile backing systems, as well as to

				production lines, tanks, and sensing snow depth. This instrument will also be used in the mechanical and civil fields for small, precise measurements. [21]
3.	Kuldeep Singh Kaswan	Robot Role Of Arduino in Real World Applications	2020	Arduino is a programmable board that is open source. It is a single-board computer that is very user-friendly and powerful and has been popular in both the hobby and professional markets. It includes an Integrated Development Environment (IDE) where users may create and execute programmes for an Arduino board and a microcontroller.[20]
4.	Muhammad Apriliyant	Semi Automatic T-Shirt Folding Machine Based on PID (Proportional Integral Derivative)	2020	The ideal way to make clothing folding simpler and more time-effective is with a semi-automatic t-shirt folding machine. This device contains a servo motor that moves the folding board, making it such that the user only needs to handle the shirt once and press a button for the shirt to automatically fold and be organised neatly through the clothing stacker board. To prevent pressure from being applied upward while the pile of folded clothing is built up, the PID approach is applied to DC motors that move beneath the clothes folder.[19]

2.4 Arduino Microcontroller

(P. U. Siahaan, et al., 2018) showed a study of an easy-to-use Arduino Uno-based water turbidity meter using LDR and LED sensors. This utility was created using an ATmega328 microcontroller. One of a series of microcontrollers based on the Atmega328 is the Arduino Uno [2]. The ATmega328 microcontroller is a versatile device capable of executing program code, interfacing with digital and analog 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 [3]. 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 [4]. The most recent and final series of Arduino USB devices is Arduino Uno R3. Figure 2.1 showed an image of the Arduino Uno R3.

Figure 2.1 Arduino Uno R3.

The innovation in question was a device with a dynamic form-based Arduino Uno that has a program installed to calculate the amount of water turbidity in a glass container. A microcontroller-based program needs to be highly accurate and secure. A tool to gauge water turbidity will be developed by the author. Because Light Emitting Diode (LED) transcribed analog data, this system used an Arduino microcontroller module as a data processor and Analogue Digital Converter (ADC) as an analog-to-digital converter signal [1]. The result of this instrument was shown on an LCD and was used as a method to detect water turbidity. Once the instrument was assembled, it should assist the relevant parties in assessing the water's quality so that water productivity increases and it is safe to consume. Overall, the ATmega328 microcontroller served as a powerful and flexible platform for a wide range of embedded systems and electronic projects.

(Abu Sulayman, I. I. M., Almalki, S. H. A., Soliman, M. S., & Dwairi, M. O., 2017) designed an automated house system based on remote sensing with an Arduino Uno Kit serving as the primary controller. The PC home main server and the Arduino Uno microcontroller board ATMega328P, which introduce a variety of digital and analog inputs, serial interface, and digital and PWM outputs, are the two primary hardware components of the proposed home automation system. Through a USB cable, it is connected to and in communication with the PC. The software is free as well. Figure 2.2 depicts the proposed system's design. The Matlab-GUI platform management and Arduino uno control method are installed on a PC in a home, allowing the user to operate home appliances from a mobile device. The microcontroller board's ports are attached to a few devices and sensors. The user's mobile phone can monitor and access household appliances remotely [5].

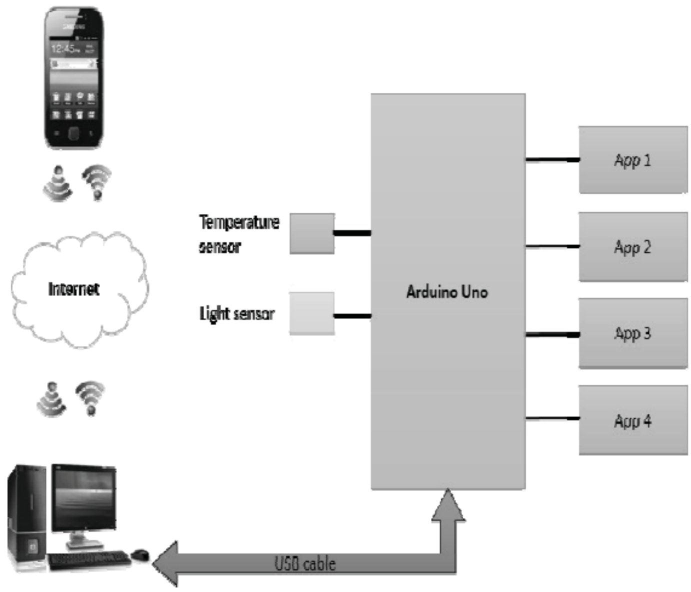


Figure 2.2 Proposed home automation system architecture.

(Gunputh, S., Murdan, A. P., & Oree, V., 2017) implemented a home automation system based on the Arduino microcontroller that is low-cost and multifunctional. The microcontroller, which controls all of the system's operations, is the brain of the smart home automation system. It analyses and interprets all sensor data before sending the relevant signals to command actuators. Several new microcontrollers, such as the Arduino, Raspberry Pi, LaunchPad, PIC, and BeagleBone, have recently entered the market. Each of them has advantages, thus choosing the right microcontroller for the system must be done while keeping a set of design requirements in mind. Cost, the amount of Input/Output (I/O) pins, sensor capability, and programming simplicity are the main considerations in this case. The Arduino Mega was chosen because it provides an easy-to-use development environment, is inexpensive, and is widely accessible. The Arduino is captivating because of its vast support community, a broad set of support libraries, and add-on boards that enhance its interface capabilities, in addition to noteworthy features like good memory size and a big number of I/O ports. The ATmega2560 AVR processor serves as the foundation for the Arduino Mega development board [6]. The main technical specifications of the Arduino Mega are summarized in Table 2.1.

Table 2.1 Technical specifications of the Arduino Mega.

Parameter	**Value**
Operating Voltage	5V
Digital I/O Pins	54
PWM Digital I/O Pins	14
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

In conclusion, the Arduino microcontroller is a versatile and popular open-source hardware platform used for building and prototyping various electronic projects. It consists of a simple microcontroller board, an integrated development environment (IDE), and a supportive community. There are advantages and disadvantages when it comes to choosing an Arduino microcontroller. In choosing the right microcontroller for my research project, I need to consider the complexity of my project. If the project is relatively simple and doesn't require a large number of I/O pins or extensive memory, the ATMega328 may be sufficient. It is cost-effective and can handle basic tasks effectively. Not only that, I need to consider the processing speed. Both microcontrollers have similar clock speeds, but if the project requires faster processing, the ATMega328 has a slight advantage with its higher maximum clock speed of 20 MHz. Yet, comparing ATMega328 with ATMega328P, ATMega328P is better because the "P" in ATMega328P stands for "picoPower," indicating that it is a low-power version of the ATMega328. The ATMega328P has enhanced power-saving features, allowing it to operate at lower power levels and consume less energy compared to the

ATMega328. The ATMega328P is the newer version and is more commonly available than the ATMega328. It has largely replaced the ATMega328 in new designs and is easier to find on the market. For my research project, I will be using the ATMega328P.

2.5 Folding System Designs

Programmable automation refers to the use of technology and computer programming to control and automate various processes and tasks. It involves the design and implementation of systems that can execute predefined instructions and commands to perform specific actions without human intervention. Some of examples are Industrial Robots and Arduino. A fully automatic folding system and a semi-automatic folding system are two different approaches to automating the process of folding objects, typically referring to folding clothes or textiles. A fully automatic folding system is designed to handle the entire folding process without requiring much human intervention. These systems typically incorporate advanced robotics and computer vision technologies to identify and manipulate the objects being folded. Semi-automatic folding systems are often used in smaller-scale environments like retail stores, hotels, or individual households. They simplify the folding process, reduce human error, and improve efficiency, while still allowing users to retain control over the folding technique.

2.5.1 Semi-Automatic Folding System

2.5.1.1 Industrial Robots

(Petrík, V., Smutný, V., Krsek, P., & Hlaváč, V., 2017) implemented an automation system of single-arm robotic garment folding. Their investigation was based on the static equilibrium of forces, and they modeled the clothing as an elastic shell using a twodimensional geometry. As a result, the work is an improved version of a previous method for one-dimensional path construction. Their design has the benefit of keeping the garment from slipping while it is being folded on a surface with little friction. The fact that material quality identification is mostly left up to the operator's physical labour is one of the drawbacks [7]. Figure 2.3 shows different folding scenarios for a square towel and the real single-arm robotic folding.

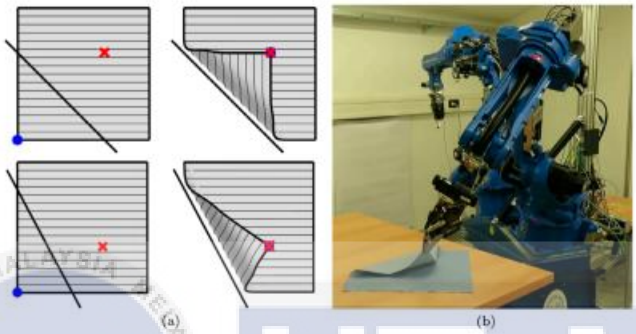


Figure 2.3 (a) Different folding scenarios for a square towel. (b) The real single-arm robotic folding.

(Li, Y., Yue, Y., Xu, D., Grinspun, E., & Allen, P. K., 2015) designed a two-arm Baxter robot that can manipulate deformable objects with accuracy and efficiency by following optimized trajectories. [8] 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. An online optimization algorithm that derives the best manipulation paths from the evolution of the mathematical model and predictive thin shell simulation. An innovative method for producing a similar manipulation result that adapts the simulation environment to the robot working environment. The trajectories can be scaled to fit similar clothes of various sizes because they are universal in nature. The essential phases of garment folding are shown in Figure 2.5, together with the entire pipeline of garment manipulation. The pipeline of garment manipulation, which includes gripping, visual identification, regrouping, unfolding, laying flat, and folding, ends with the folding of the garment. The pipeline's many steps have all been satisfactorily addressed in their earlier work [9] [10] [11], except for the folding operation at the end. Finding the best trajectories to properly fold clothing is the focus of this paper's discussion of the robotic folding task shown by the purple rectangle in Figure 2.4. By assuming that the garment is originally laid flat on the table as demonstrated in their earlier work [11]. A pre-defined folding plan is employed to generate the best folding trajectories by locating the garment's key points (see sections V-A). After many phases, we use the Baxter robot to get a desirable folding result that is consistent with the simulation.

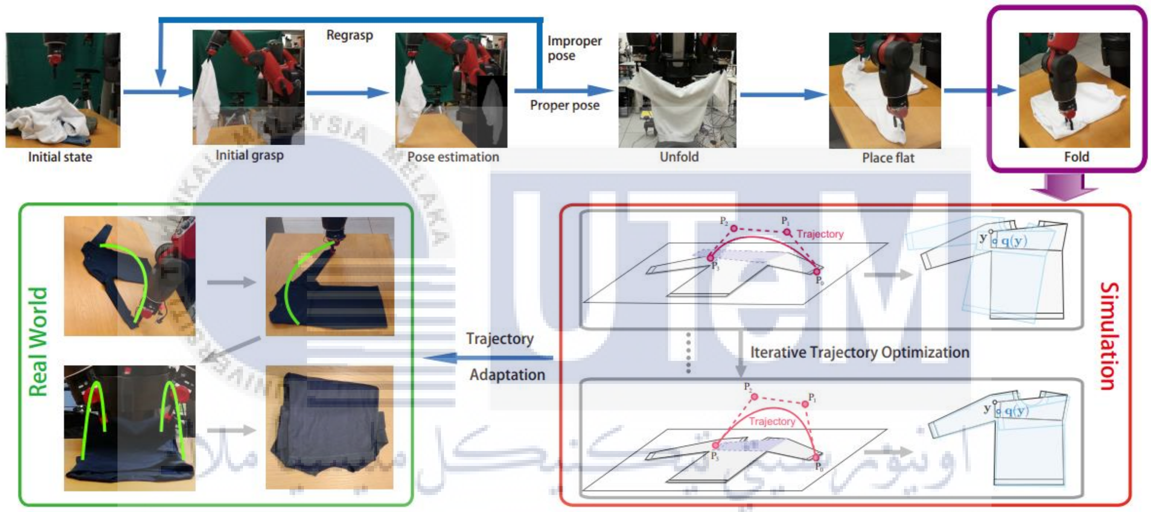


Figure 2.4 TOP ROW: Entire pipeline of dexterous manipulation of deformable objects. BOTTOM ROW: Details of the folding procedure.

(Stria, et al., 2014) contributed to the garment detection and manipulation such as sorting, folding, etc carried out in our case using a dual-arm robot as part of the CloPeMa (Clothes Perception and Manipulation) project, which is financed by the European Commission. The R750 turntable, two DX100 controllers, and two Motoman MA1400 robotic arms make up the CloPeMa testbed as shown in Figure 2.5. To find garment landmark spots, the figure is fitted into a segmented garment contour. It is demonstrated how automatically deriving folded variations of the unfolded model. The model's success in the 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. The novelty in their study since a new garment polygonal model and its manipulation planning algorithm was created. Both MATLAB and C++ were used to implement the algorithms. On a laptop with an Intel M430 2.27 GHz processor and 8 GB of memory, the performance was assessed. These findings demonstrated that CloPeMa can be accelerated by two orders of magnitude [12].

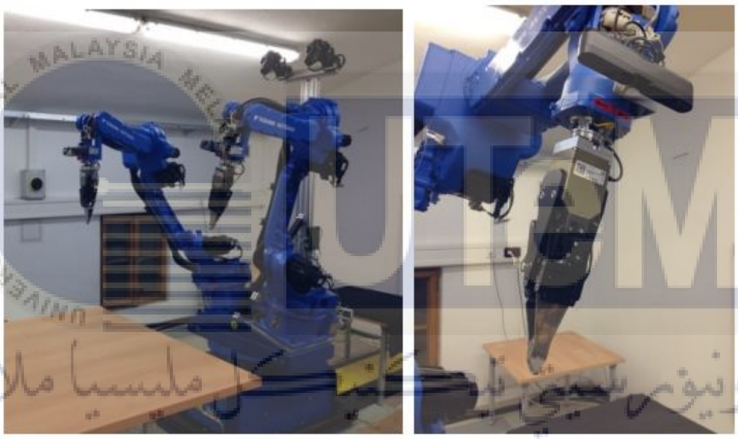


Figure 2.5 Testbed and a detail of the arm with a mounted gripper and Xtion on the wrist.

(Miller, S., van den Berg, J., Fritz, M., Darrell, T., Goldberg, K., & Abbeel, P., 2011) illustrated the effectiveness of our algorithm through the implementation of an end-to-end folding system on the Willow Garage PR2 robot. A cloth is deformable, flexible, and non-rigid in shape, which makes it highly challenging to manage, as has been said, and is noteworthy [13]. The main obstacle to the full development of the garment folding machine has been its complexity. [13] They have developed several fabric arrangements based on some presumptions that may be represented by some polygonal parameters. They put their algorithm, which generates the motion plans for carrying out a certain type of fold, to the test on a Willow Garage PR2 robot. Figure 2.6 demonstrate the PR2 robotic platform (developed by Willow Garage) performing a g-fold on a towel [13].

Figure 2.6 The PR2 robotic platform developed by Willow Garage performing a g-fold on a towel.

They gave it the name "*g-folds*," which stands for "gravity folds," and they employed four types of clothing which are short sleeve shirts, long-sleeves, trousers, and towels for their model. A polygon is used to symbolize each of these groups. An algorithm to accurately identify the corners of the piece of cloth was created in a related paper (Maitin-Shepard, Cusumano-Towner, Lei, & Abbeel, 2010). [14] Due to the durability of geometric signals in texture variation, they based their method on them. They used a towel as the basis for their studies rather than t-shirts. They concluded that their system, which they tested using Willow Garage PR2, can be used to analyze various types of clothes.

2.5.1.2 Small Mobile Robots

(Watanabe, Kawamura, Iizuka, & Suzuki, 2017) 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. [15] 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. The coordinates required to fold the clothing are traced by their system using a path-planning technique. The system's structure is depicted in Figure 2.7 while the experimental environment is shown in Figure 2.8.

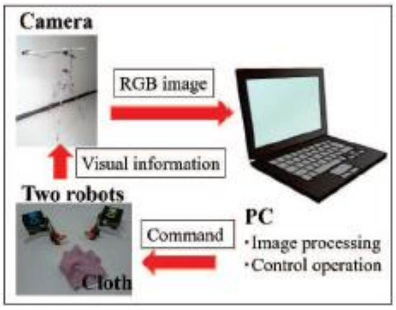


Figure 2.7 Automatic folding system.

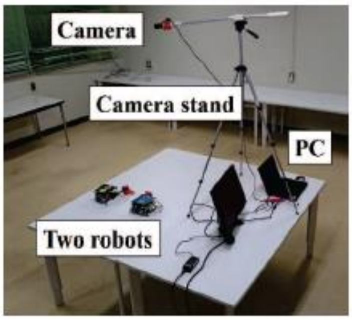


Figure 2.8 Experiment at environmental.

Figures 2.9 and 2.10 depicted the miniature mobile robots. Each robot's upper portion is equipped with two different types of markers. Image processing is used to determine the marker's centre coordinates, which are then used to determine the robot's location. An inverse trigonometric function is used to determine the robot's direction from the centres of the two markers. The finger and fixed plate make up the hand. The hand grabs the clothing while rotating its fingers to place the fixed plate between the table and the clothing. The arm raises the garments.

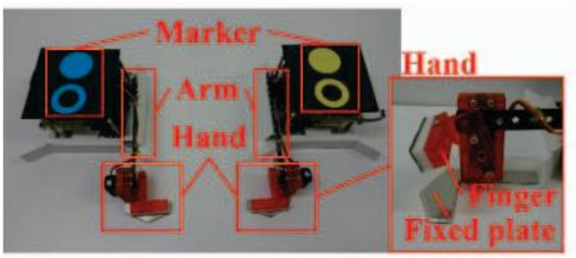


Figure 2.9 Appearance of the mobile robots.

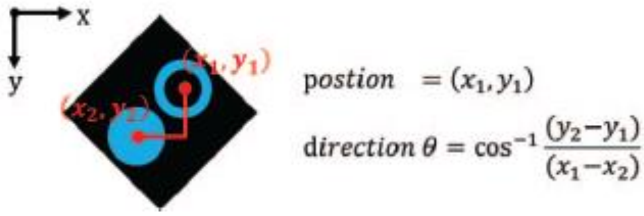


Figure 2.10 Direction and position of the mobile robots.

The mechanism for calculating the robots' trajectory is then described. Figure 2.11 depicted the creating trajectory. First, the grabbing point was chosen and a support line was created perpendicular to the table's edge there. The perpendicular line from the two-point and support lines produced the trajectory. The robots follow the trajectory as they go.

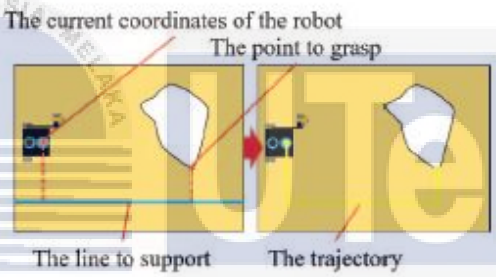


Figure 2.11 Appearance of the trajectory.

2.5.2 Semi-Automatic Folding System

2.5.2.1 Cloth-Folding Tool

(Silitonga, N., Hutapea, J. M., Dumayanti, I. S., Sianipar, A. N. N., & Sitepu, S., 2019) designed an automatic cloth folding tool using ultrasonic sensors and an Arduino Uno microcontroller. The plywood model has the following measurements 3 mm thick, 5 cm high, 70 cm long, and 50 cm wide in Figure 2.12. Push button input process system for the Arduino Uno. The servo that operates the folding board is the output. The remote controls included an ultrasonic sensor that transmits data automatically, an ATMega328P microcontroller, an Arduino Uno, an LCD6 with I2C, a buzzer, a motor servo, and three buttons. Buzzer ON indicated that the pants have been folded. If the ultrasonic sensor detects that there are clothes to be folded by the program settings, then the controller will work folding clothes in the circuit above. The data from the ultrasonic sensor is done at a distance of 6 cm. When you're done folding clothing, the alarm will notify you of your completion and convey information about how many items you've folded to the LCD as shown in Figure 2.13.

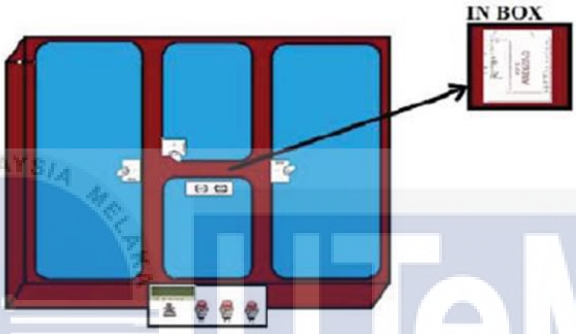


Figure 2.12 Prototype design of the folding clothes model.

Figure 2.13 Counter (results of clothes that have been folder).

Irawan, Yuda., Wahyuni, Refni., & Fonda, Hendry. (2021) implemented an automatic clothes-folding device using Gear Servo and Arduino Uno Microcontroller. The author's strategy for doing this research with wooden boards is shown in Figure 2.14. The wooden frame, shown in Figure 2.15, is where the 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 [16].

Figure 2.14 Wood frame.

Figure 2.15 Component placement.

The power supply, which powers the Arduino Uno, as well as several other components, including ultrasonic sensors and servos A, B, and C, are all attached behind this wooden axis in the manner described by Estevez [18] so that the function can be carried out as efficiently as possible. The procedure of integrating tools and programs. The procedure for coding the application and tools that will be made is shown in Figure 2.16. Not only that the servo coding is also shown in Figure 2.17.

Figure 2.16 Tools and applications.

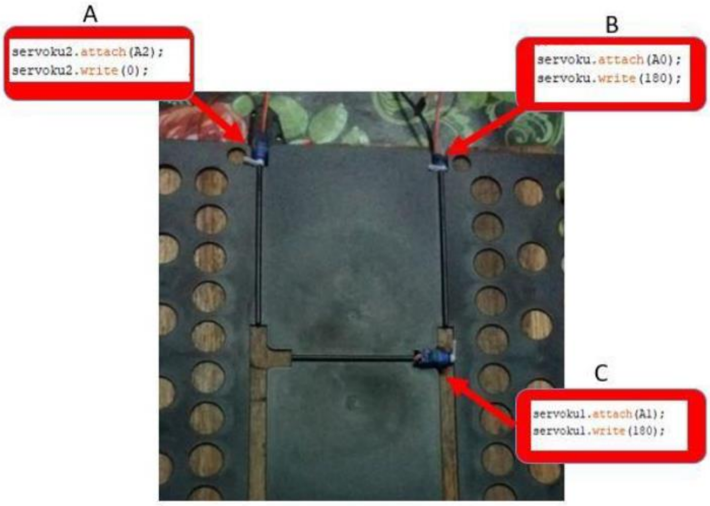


Figure 2.17 Servo coding.

In conclusion, various articles on clothing folding using various techniques have been examined. While some studies are attempting to design a fully automated folding of clothes, others have designed a semi-automatic folding. I will be a semi-automatic folding system because this project does not address the detection and dispersal of the clothes. The system used a push button for both machine start-up and shutdown. Additionally, after the clothes have been folded by the machine, you have to pick them up by hand.

2.6 Comparison

Method	Outcome	References
Folding system using robots	The implementation of an automatic folding system using robots brings numerous benefits to industries such as retail, hospitality, and laundry services. By leveraging robotic technology, this system streamlines and automates the folding process, resulting in increased efficiency and reduced labor costs. The robots, equipped with sensors and cameras, can accurately identify and locate items to be folded, while robotic arms or grippers handle the objects with precision. Folding algorithms, developed through machine learning or artificial intelligence techniques, determine the most efficient folding methods based on item properties. The robots execute the folding process with accuracy and consistency, ensuring neatly folded items. With integrated quality control mechanisms, the system ensures the final folded items meet desired standards. Overall, this automated solution revolutionizes the folding process, improving productivity, reducing manual labor, and enhancing the overall efficiency of operations.	[7], [8], [12], [13], [14], [15]
Folding system using Arduino microcontroller	An automatic folding system using an Arduino microcontroller provides a cost-effective and accessible solution for basic folding tasks. The Arduino microcontroller allows for easy prototyping and customization, enabling the system to control motors or actuators and integrate sensors for item detection. While it may have limitations in handling complex folding tasks or advanced functionalities, it streamlines the folding process, reducing manual labor and improving efficiency in small-scale operations or personal projects. Overall, the Arduino-based system offers a practical and affordable option for basic automation needs, although it may not be suitable for large-scale industrial applications requiring higher levels of complexity and precision.	[1], [5], [6], [16], [17]

2.7 Summary

In summary, based on earlier research, this project involves creating a tool for folding cloth and integrating it with an automation system. The folding system for the technique project will be semi-automatic. This is because you have to pick the clothing by hand after being folded clothing by the machine. The main instrument for folding garments is a cloth-folding tool. The system for controlling the cloth-folding tool is introduced, and it uses the Arduino UNO (ATMega328P). In order to flip each door of the cloth-folding tool, four servo motors are mounted on wooden table on each side , totalling twelve servo motors in this project. To determine how many pieces of clothing have been folded, the LCD is employed and the ultrasonic sensor will measure the appropriate height between the clothes and the clothes stacking opening doors. The microcontroller delivers control signals to the servo gears if the distance determined by the sensor shows that the cloth is within the intended range. The mechanical servo gears, which can control angles precisely, are attached to the machinery for folding cloth. Last but not least, the code for Arduino programming is written, edited, and organized using the Arduino IDE.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodologies to construct the prototype of the system is explained in this chapter. The first stage in carrying out this project was researching the basic concepts for the machine prototype. The project's performance procedure is broken down into a few stages to guarantee its success. The project's flowchart is shown in Figure 3.1.

3.2 Selecting and Evaluating Tools for a Sustainable Development

The technology and techniques that will be utilized to gather and analyze data must be carefully chosen and evaluated when developing and implementing an automation system for the folding clothes project. This entails a variety of methodological concerns, including analyzing the precision and dependability of sensors, the compatibility of various tools and software, and the project's effects on the environment. It's also critical to think about the project's social and economic ramifications, including making sure that the data is accessible to and intelligible by a variety of stakeholders and weighing the advantages and disadvantages of various tool choices.

3.3 Methodology

The project's flowchart is shown in Figure 3.1.

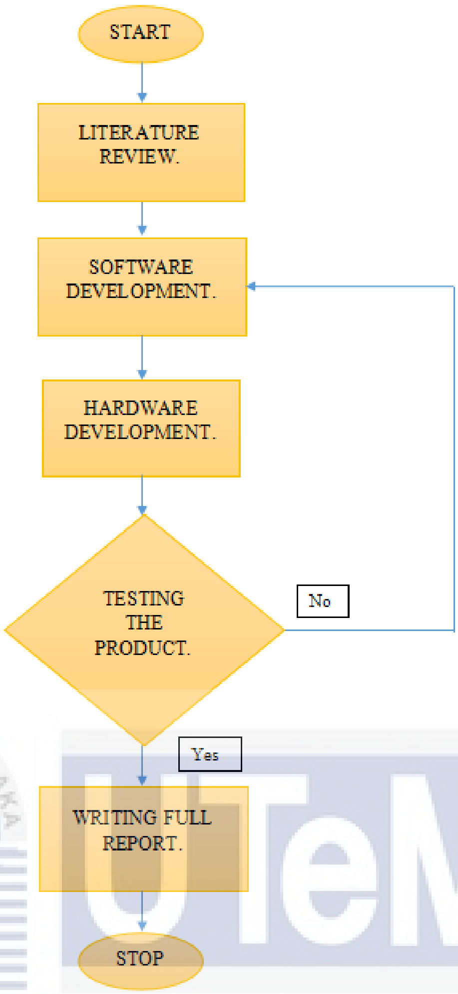


Figure 3.18 Research methodology flow chart.

Prior to the commencement of development, it is necessary to provide a clear statement outlining the objectives, significance, and purpose of the project. This initial step establishes the context and lays the groundwork for subsequent stages. Following the introduction, the project progresses to an in-depth examination of existing literature. This phase involves conducting a thorough analysis of relevant scholarly works, publications, and other pertinent resources pertaining to the project's subject matter. The primary objectives of the literature review are to identify any gaps in knowledge, evaluate the current state of the topic, and identify areas that necessitate further research. By critically reviewing and synthesizing existing literature, the project acquires valuable insights and theoretical frameworks that guide its trajectory.

Software development takes a prominent role once the literature review concludes. This phase involves the planning, creation, and implementation of software solutions tailored to meet the specific objectives and requirements of the project. The utilization of widely recognized software development methodologies like Arduino and Proteus guarantees a thorough and successful development process. Concurrently, hardware development progresses alongside the project. This stage focuses on designing and constructing physical systems, devices, or components that accompany and support the software program. Meticulous selection, prototyping, and optimization of the necessary hardware elements are undertaken to enhance their performance and ensure compatibility with the software. Effective communication and collaboration between the software and hardware teams are vital for seamless integration and optimal functionality.

After the completion of both software and hardware development, the project moves into the testing phase. Testing plays a crucial role in ensuring that the product functions properly, meets its intended purpose, and fulfills user requirements. The project team employs various testing techniques, including functional testing, performance testing, and user acceptability testing, to identify and rectify any issues or flaws. The objective of the testing phase is to verify that the software operates as expected and interfaces effectively with the hardware. However, if any faults or problems are detected during the testing process, it becomes essential to revisit the software development stage. This iterative process ensures that both the hardware and software components are improved and optimized before proceeding further.

3.4 Project Methodology

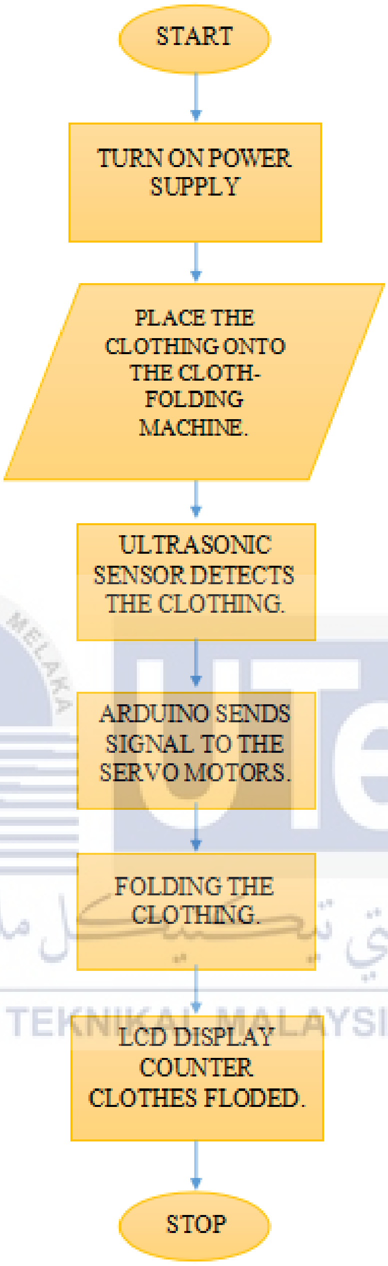


Figure 3.19 Flowchart of the operation of garment folding machine.

3.4.1 Explanation of the Project Flow

The automatic folding clothing system is designed to streamline the process of folding clothes through a combination of Arduino-controlled servo motors and an ultrasonic sensor. The system begins with the initialization, powering up the servo motors and setting up the necessary components. Upon activation, the ultrasonic sensor checks for the presence of clothing within a 10 cm range. If clothing 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. After folding, the system ensures the proper pickup of the folded cloth and prompts the placement of a new garment for the process to repeat seamlessly. This automated workflow aims to efficiently fold clothes while keeping track of the count, providing a user-friendly and efficient solution for household tasks.

3.4.2 Mechanical Design

Mechanical design is a crucial factor to take into account while creating hardware because it has an impact on how well the tools work and produce outcomes. A cloth-folding tool, as the name suggests, is a device or tool designed to aid in folding clothes efficiently and neatly. Its purpose is to simplify the process of folding various types of garments, such as shirts, pants, towels, and more. The area of this tool is 69cm x 59 cm. An example of a cloth-folding tool is in Figure 3.3

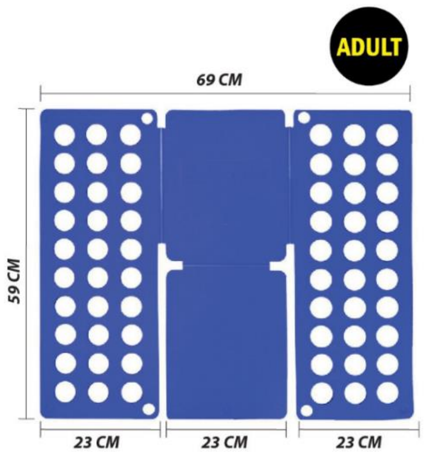


Figure 3.20 Cloth-folding tool.

Figure 3.21 Wooden table.

A wooden table will be attached at the back 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. The electrical components are mounted to the back of the wooden board in Figure 3.4.

3.4.3 Electrical Design

3.4.3.1 Circuit Diagram

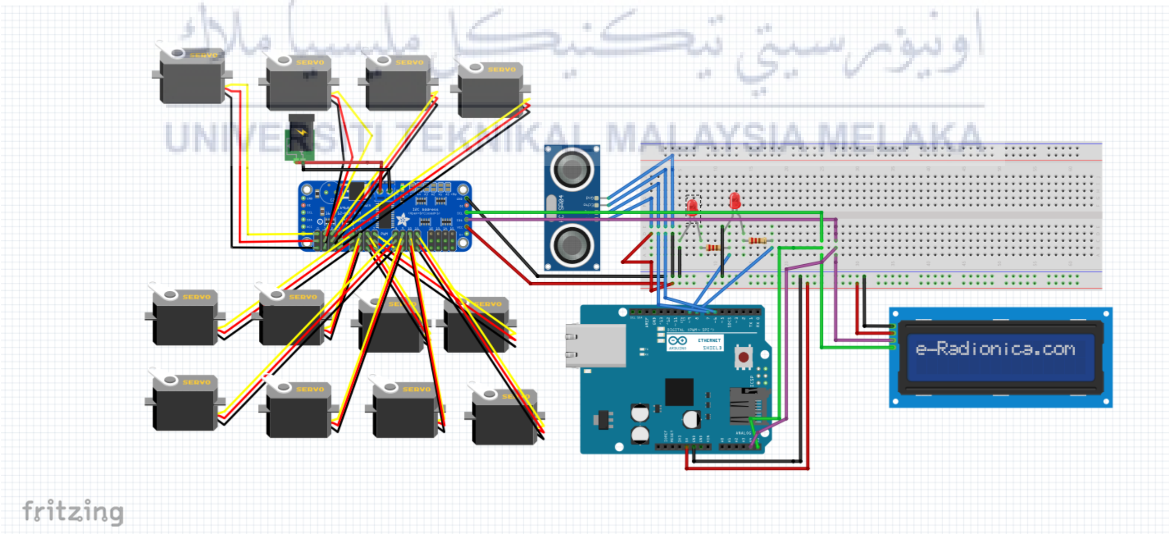


Figure 3.22 Circuit Diagram.

3.4.3.2 Arduino Uno Microcontroller

The easiest and most transparent programming environment on Arduino is its most intriguing feature. For beginners, the programming environment is simple to use, and

Arduino hardware is extendable and open source. As a result, the project's controller will be an Arduino UNO. The ATMega328P microcontroller, commonly used in many projects and autonomous systems where a simple, low-powered, low-cost microcontroller. It is widely available and relatively inexpensive, making it accessible for hobbyists, students, and small-scale projects. The ATMega328P has enhanced power-saving features, allowing it to operate at lower power levels and consume less energy compared to the ATMega328. The microcontroller will be mounted to a wooden board along with other electrical components. The specifications of the Arduino UNO are displayed in Table 3.2, and the Arduino UNO module is depicted in Figure 3.6. Since we are dealing with servo motors in our design, this microcontroller is perfect to use.

Table 3.2 The specifications of the Arduino UNO (ATMega328P).

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6 -20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5KB is used by the bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

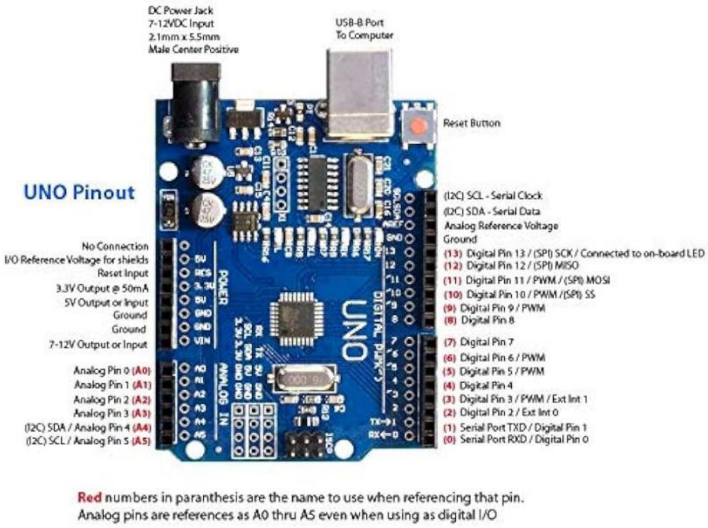


Figure 3.23 Arduino UNO.

3.4.3.3 Servo Motor

Servo motors are ideal for this project due to their ability to provide precise angular rotation and positional control. Each servo motor consists of a small DC motor, a set of gears, and a position feedback system (potentiometer). The servo motor receives control signals from the microcontroller to set the desired position.To achieve the folding motion, you can position the four servo motors strategically around the folding mechanism on each side of the folding boards. Since there will be twelve servo motors used in this project, the hinges of the cloth-folding tool are where the motors will be placed. The microcontroller serves as the brain of the system, coordinating the actions of the servo motors. You will need to program the microcontroller to execute a specific folding algorithm. The algorithm can include steps such as grasping the cloth, guiding it, and applying the necessary folding force. Each servo motor's position can be adjusted incrementally to achieve the desired folding motion. The TowerPro SG90's table of specifications is displayed in Table 3.3, and an image of the device is displayed in Figure 3.7.

Table 3.3 The specifications of the Servo Motor (TowerPro SG90).

Servo Motor	TowerPro SG90
Weight	9g
Dimension	23.2 x 12.2 x 29 mm
Stall Torque	1.8kg/cm
Gear Type	POM gear set
Operating Speed	0.1sec/60°

Operating Voltage	4.8V
Temperature Range	0 ºC – 55 ºC
Dead Band Width	10 µs
Power Supply	Through External Adapter
Servo Wire Length	25 cm
Servo Plug	JR (Fits JR and Futaba)

Figure 3.24 Servo Motor (TowerPro SG90).

3.4.3.4 LCD (liquid crystal display)

The 16x2 LCD (liquid crystal display) module is one of the most commonly used displays for Arduino projects. It has two rows of 16 characters each, allowing you to display alphanumeric information typically represented by a 5x8 pixel matrix, giving it the ability to display text, numbers, symbols, and simple graphics. These displays are usually inexpensive, easy to use, and widely supported by Arduino libraries. An LCD module is typically connected to the Arduino controller to provide a visual display of the required information. It might show crucial information about the folding process, such as how many pieces of clothing have been folded and showing the target distance of the clothing. This real-time display is used to track the progress of the folding process. The LCd Once one fabric has been folded, the counter increases. The result is we will be able to know how many garments have been folded. The 16x2 LCD's specifications are shown in Table 3.4, and its image is shown in Figure 3.8.

Table 3.4 The specifications of the Module (16x2 LCD).

Module	16x2 LCD
Display Size	16 characters x 2 rows
Character Size	Typically 5x8 pixels
Controller Chip	Commonly HD44780 or equivalent
Operating Voltage	5V
Communication Interface	Parallel or serial
Display Area	64mm x 16mm
Dimension	80mm x 36mm x 13mm

Figure 3.25 16x2 LCD.

3.4.3.5 Motor Driver

A power supply with an output of 5V and a current capacity of 5A (Amperes) is capable of providing electrical power at a constant voltage of 5 volts, with the ability to deliver up to 5 amperes of current. It would be often used to power or charge electronic devices such as microcontrollers, single-board computers (e.g., Raspberry Pi), LED strips, USB-powered devices, and other low-power electronics. The higher current rating is beneficial for devices that require more power.When choosing or using a power supply, it's important to ensure that it meets the voltage and current requirements of the device you're powering. Using a power supply with a higher voltage or current than what a device is designed for can damage the device. Conversely, using a power supply with lower current may not provide enough power for the device to operate properly. Always check the specifications of both the power supply and the device to ensure compatibility.

Table 3.5 The specifications of the Power Supply (5V 5A).

Module	16x2 LCD
Operating Voltage	5A
Output Current	5V
Power Output	25W
Shell Material	Metal case/Aluminum case
Input Voltage	100-240V AC
Frequency	50Hz - 60Hz

Figure 3.26 Power Supply (5V 5A).

3.4.3.6 Motor Driver

PCA9685 C16 Channel Servo / PWM Driver - I2C interface)is a popular integrated circuit (IC) that serves as a 16-channel servo and PWM (Pulse Width Modulation) driver. It provides a convenient and efficient way to control multiple servos or generate PWM signals for various applications. The PCA9685 chip uses the I2C (Inter-Integrated Circuit) interface, which allows for easy communication with microcontrollers or other devices. The PCA9685 module will be connected to the microcontroller. The PCA9685 communicates with the microcontroller using I2C protocol, so connect the SDA (data) and SCL (clock) pins of the PCA9685 to the corresponding pins on the microcontroller. Then, connect the VCC and GND pins of the PCA9685 to the power supply (usually 5V) and ground. Moreover, the servo motors must be connected to the PWM output pins of the PCA9685. The PCA9685 has 16 output channels, labeled from 0 to 15. Each servo motor will be connected to one of these channels. Table 3.5 details the PCA9685 table specifications. Additionally, PCA9685 is depicted in Figure 3.9.

Table 3.6 The specifications of the Motor Driver PCA9685.

Motor Driver	PCA9685 (16 Channel Servo/PWM Driver - I2C interface)
Number of Channels	16
PWM Frequency	24 Hz to 1.5 kHz
Default Frequency	200 Hz
Supply Voltage Range	2.3V to 5.5V
Operating Voltage	4.8V
Maximum Current	25 mA per channel
Dimension	62.5mm x 25.4mm x 3mm

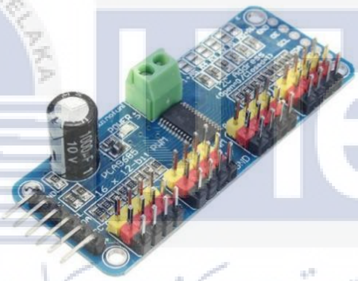


Figure 3.27 PCA9685 (16 Channel Servo / PWM Driver - I2C interface).

3.4.3.7 Ultrasonic Sensor

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 or 1 inch to 13 feet in an easy-to-use compact with high accuracy and consistent readings. The microcontroller sends a short electrical pulse to the trigger pin of the HC-SR04 sensor. This pulse triggers the sensor to emit an ultrasonic sound wave. If the emitted sound wave hits an object, it reflects towards the sensor. The HC-SR04 sensor has a built-in receiver that detects this reflected sound wave. The sensor measures the time it takes for the sound wave to travel from the sensor to the object and back. It does this by comparing the time of the emitted pulse with the time of the received pulse. Using the known speed of sound in air, which is approximately 343 meters per second at room temperature, the microcontroller calculates the distance between the sensor and the object. It uses the formula: Distance = Speed × Time / 2. If the distance measured by the sensor indicates that the cloth is within the desired range, the microcontroller sends control signals to the servo gears. The servo gears, which are mechanical devices capable of precise angular control, are connected to the cloth folding mechanism. The table specifications for the ultrasonic sensor (HC-SR04) are shown in Table 3.6. Figure 3.10 also depicts an image of an ultrasonic sensor.

Table 3.7 The specifications of the Ultrasonic Sensor (HC-SR04).

Ultrasonic Sensor	HC-SR04
Operating Voltage	5V DC
Operating Current	approximately 15 mA
Operating Frequency	40 kHz
Sensing Angle	Approximately 30 degrees
Accuracy	3 mm
Operating Temperature	-10°C and +70°C
Maximum Current	25 mA per channel
Dimensions	45 mm x 20 mm x 15 mm (L x W x H)

Figure 3.28 Ultrasonic Sensor (HC-SR04).

3.4.4 Software Design

The Arduino IDE shown in Figure 3.11 simplifies the process of uploading your compiled code to the Arduino board. It automatically handles the communication between your computer and the Arduino board, allowing you to easily transfer your code with a single click.

Figure 3.29 Arduino IDE.

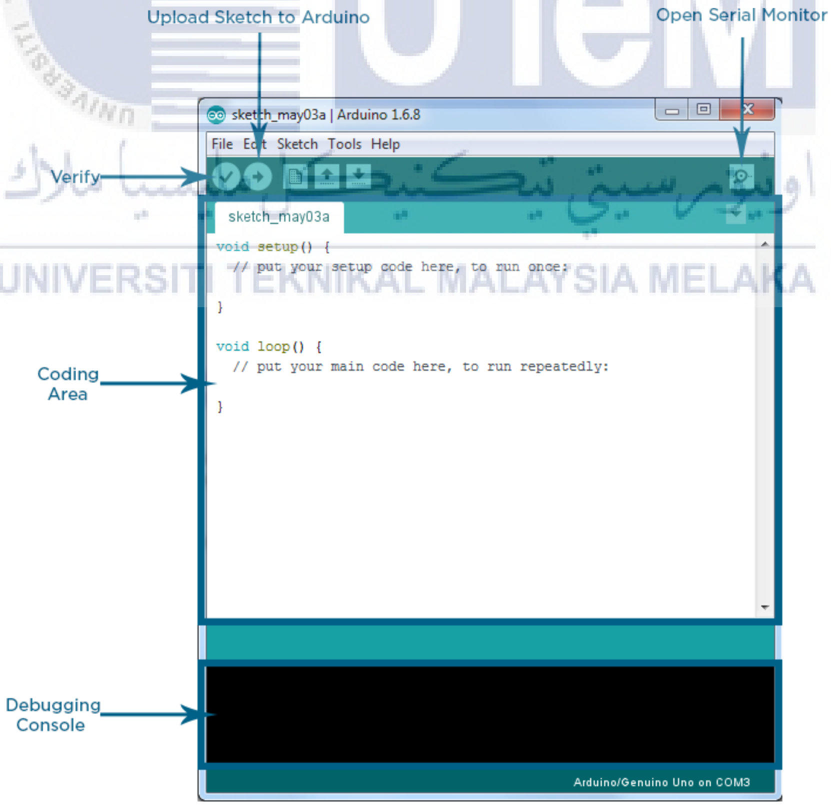


Figure 3.30 The Main Working Space for Arduino IDE.

The primary workspace for the Arduino IDE is depicted in Figure 3.12. The Arduino IDE will open a fresh file each time you begin a new project. This program, which we refer to as a sketch, will have a set of guidelines telling your board how to communicate with other connected devices. The Verify button will go line by line through your code to make sure there are no coding issues. We can start troubleshooting sketches with this button, which will be helpful. Your confirmed code will be sent to your Arduino via Upload Sketch. When the upload is finished, a success message and an upload progress metre will show up in your IDE. You may view data being sent to and from the Arduino board using the Serial Monitor button, and in some circumstances, you can even give the Arduino commands in real-time. We will explore the ins and outs of the serial monitor in later courses because it is crucial to projects. When it comes to coding, you should enter your instructions and comments here. The Arduino will grey out and generally disregard comments. The IDE will colour-code these tags as you input instructions, variables, and functions to make your sketch simple to read. You can find the line and character number that is causing your programme to malfunction using the debugging terminal. A notification indicating that the programme compilation was successful will also be output. As we learn more about Arduino IDE software, this part will be quite helpful to do the coding for the project.

3.5 Summary

This chapter presents the proposed methodology to develop a new, effective, and integrated approach to estimating large-scale machines to fold clothes with an automation system. The primary focus of the proposed methodology is on accomplishing a simple, less rigorous and effective estimation in such a way that it would not cause a significant loss of accuracy of the results. The methods also intended to use the generally available and limited data of the network and load from the power utilities. The ultimate intent of the method is not to obtain the highest accuracy, but, for efficiency and ease to use.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and analysis of the automatic garment folding system. The impact of the folding mechanism on effectiveness, product quality, and process control is summarized. The results are interpreted, their implications for the laundry sector are explored, and any potential challenges or restrictions are addressed.

In this chapter, we delve into the outcomes and in-depth analysis stemming from the development of a novel programmable automation system designed for cloth-folding tools. The exploration revolves around the integration of an Arduino Microcontroller and precision gear servo motors, aiming to shed light on the envisaged results and potential implications of this innovative approach. By focusing on the anticipated impact on efficiency, product quality, and overall process control, this section aims to encapsulate the projected findings derived from theoretical analysis and existing research. Through the lens of a theoretical framework, the results are scrutinized, their potential influence on the laundry sector is dissected, and any foreseeable challenges or limitations are addressed within the ensuing discussion. By thoroughly examining the expected outcomes and engaging in a comprehensive discourse, this chapter endeavors to offer valuable insights and practical recommendations for further research and advancements in the realm of automated cloth-folding systems.

The primary focus of this chapter revolves around the presentation and analysis of results and insights derived from the actual implementation of the programmable automation system. The subsequent discussion section provides a more nuanced interpretation and analysis of these results, delving into their significance and ramifications within the context of the laundry sector. This dialogue encompasses a range of topics, including an exploration of the system's advantages and disadvantages, potential avenues for further development, and comparisons with existing technologies. By scrutinizing the findings within the practical setting of a laundry environment, this discussion aims to contribute a nuanced understanding of the system's performance and its potential implications for the broader industry.

Moreover, the discussion section serves as a platform for a reflective assessment of the overall efficacy of the automated folding system, incorporating a motion sensor for detection. This evaluation extends to encompass insights garnered from user feedback, the user-friendliness of the system, and the feasibility of scaling up the implementation to a larger operational context. Furthermore, the discourse provides an avenue to address any challenges or impediments encountered throughout the developmental and deployment phases of the system. In doing so, potential recommendations or future directions for refinement and enhancement can be thoroughly examined.

4.2 Machine Hardware

4.2.1 Machine Full Assembly Hardware

The figures below will show us the full assembly of the clothes folding machine with the different views. In addition of its steps and each signal from the computer to the arduino.

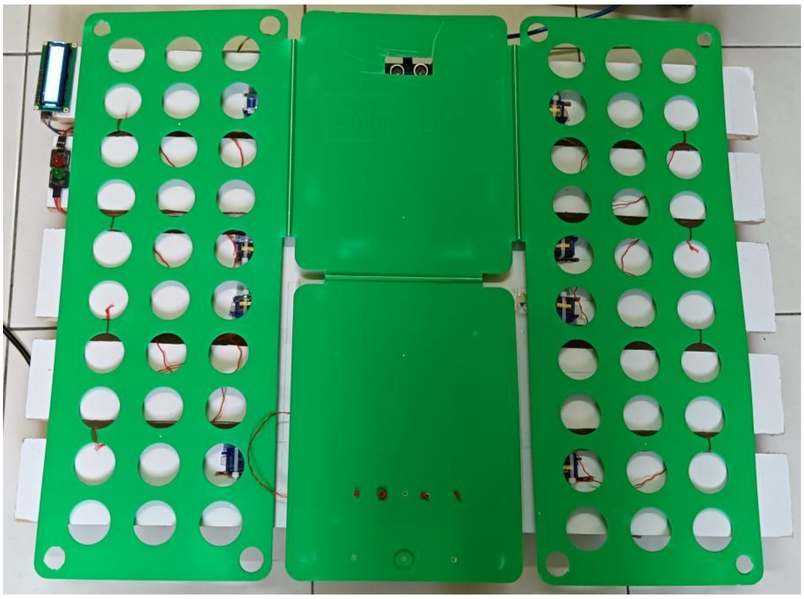


Figure 4.31 Top View of the Automatic Cloth-Folding Tool.

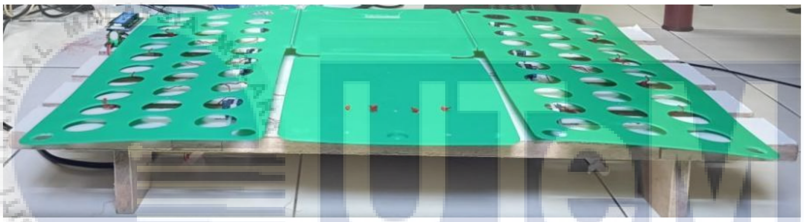


Figure 4.32 Middle View of the Automatic Cloth-Folding Tool.

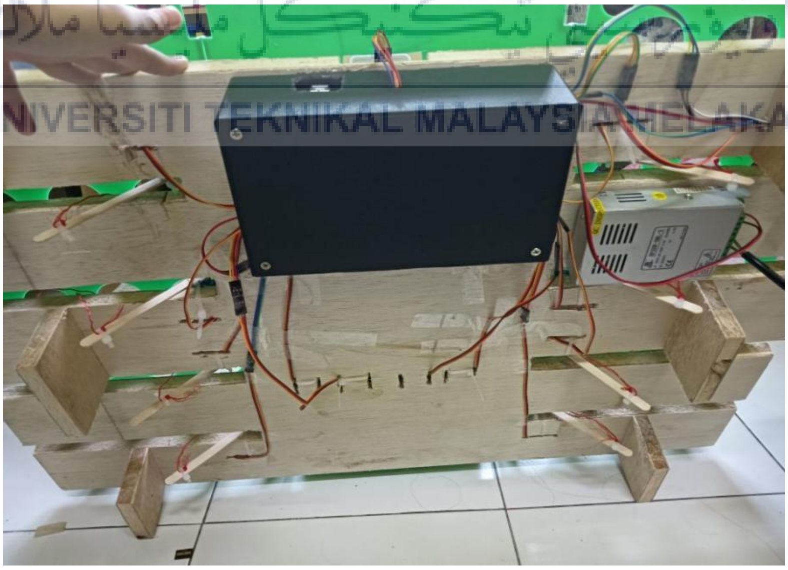


Figure 4.33 Back View of the Automatic Cloth-Folding Tool.

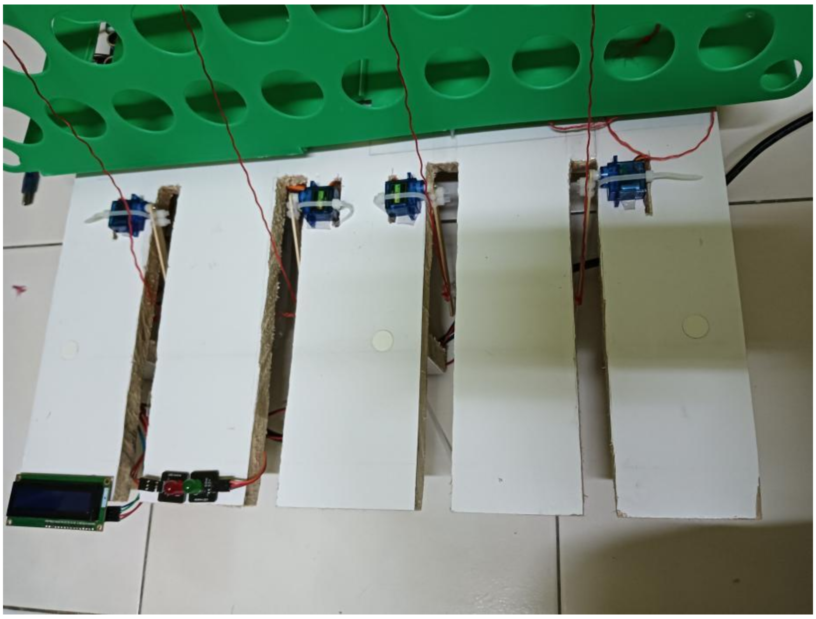


Figure 4.34 Placement of the servo motors.

Figure 4.35 LED did not detect an object.

Figure 4.36 LED detects an object.

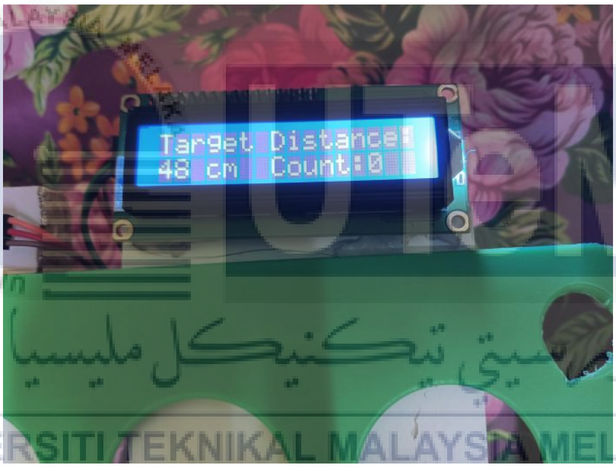
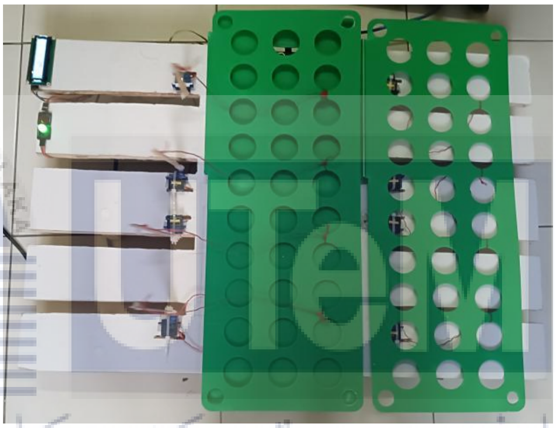


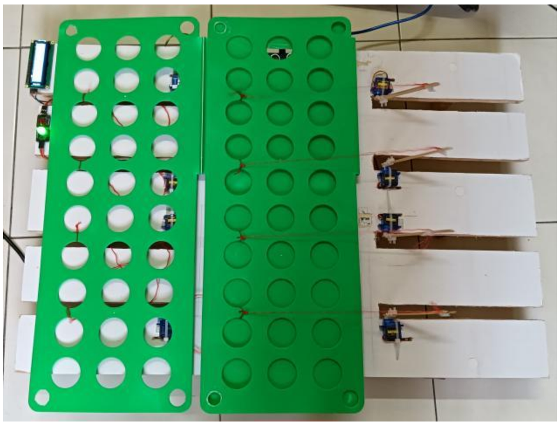
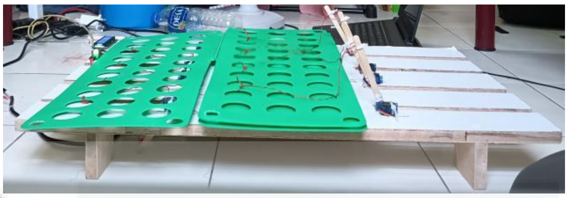
Figure 4.37 Display Target Distance and Counter.

4.2.2 Machine Steps

After uploading the proper coding to the arduino to servo motors as shown in figure 4.8. We can easily see when the servo motors are in action for the folding steps. Table 4.1 shows the servo motors flipping each sides of the folding board in action.

Table 4.8 The steps on flipping the Folding Board.

NO.	STEPS	IMAGE OF THE FOLDING MACHINE IN ACTION
1	FLIPPING THE LEFT BOARD	 TOP VIEW  MIDDLE VIEW

2	FLIPPING THE RIGHT BOARD	 TOP VIEW  MIDDLE VIEW
3	FLIPPING THE MIDDLE BOARD	 TOP VIEW  MIDDLE VIEW

4.2.3 Arduino IDE Coding

The provided Arduino code is written to run on the Arduino platform using the Arduino IDE software. The code utilizes various libraries and components to create a distance measurement system with an ultrasonic sensor, and it also controls servo motors and LEDs based on the detected distance. This Arduino code is designed for a system that uses an ultrasonic sensor to measure the distance of the clothing. If the distance is less than or equal to 10 cm, the system performs certain actions, such as counting the number of detected objects, turning on an LED, and controlling servos connected to an Adafruit PWM Servo Driver.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Adafruit_PWMServoDriver.h>

#define SERVOMIN 150  // Minimum pulse length
#define SERVOMAX 600  // Maximum pulse length

LiquidCrystal_I2C lcd(0x27, 16, 2);

#define trigPin 7
#define echoPin 6
#define ledPin 8  // LED pin when object detected
#define noObjectLedPin 9  // LED pin when no object detected

Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver();

const int activationDelay = 7500;  // 20 seconds delay (in milliseconds)
unsigned long lastActivationTime = 0;
int objectCounter = 0;

void setup() {
  pwm.begin();
  pwm.setPWMFreq(60);

  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(noObjectLedPin, OUTPUT);

```

```
  lcd.init();  // Initialize the LCD
  lcd.backlight();
  lcd.clear();
  lcd.setCursor(4, 0);
  lcd.print("Analyzing...");
  delay(2000);
  lcd.setCursor(0, 0);
  lcd.print("Target Distance:");
}

void loop() {
  long duration, distance;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance = (duration / 2.0) / 29.1;

  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
  lcd.print(distance);
  lcd.print(" cm");
  lcd.setCursor(7, 1);
  lcd.print("Count:");
  lcd.setCursor(13, 1);
  lcd.print(objectCounter);
  delay(250);

  Serial.println(distance);

  if (distance <= 10) { // Check if an object is within 10 cm
    if (millis() - lastActivationTime >= activationDelay) {
      objectCounter++;
      lcd.setCursor(7, 1);
      lcd.print("Count:");
      lcd.setCursor(13, 1);
      lcd.print(objectCounter);

      // Turn on the LED for object detected
      digitalWrite(ledPin, HIGH);
      digitalWrite(noObjectLedPin, LOW);

      // Motors on for servo 0, servo 1, servo 2 and servo 3.
      for (int i = 0; i < 4; i += 4) {
        pwm.setPWM(i, 0, SERVOMIN);
        pwm.setPWM(i + 1, 0, SERVOMAX);
        pwm.setPWM(i + 2, 0, SERVOMIN);
        pwm.setPWM(i + 3, 0, SERVOMAX);
        delay(1000);  // Delay for 1 second with all motors on
        pwm.setPWM(i, 0, SERVOMAX);
        pwm.setPWM(i + 1, 0, SERVOMIN);
        pwm.setPWM(i + 2, 0, SERVOMAX);
        pwm.setPWM(i + 3, 0, SERVOMIN);
      delay(1000);  // Delay for 2 seconds with all motors off
      }
```

```
      // Motors on for servo 4, servo 5, servo 6 and servo 7.
      for (int i = 4; i < 8; i += 4) {
        pwm.setPWM(i, 0, SERVOMAX);
        pwm.setPWM(i + 1, 0, SERVOMIN);
        pwm.setPWM(i + 2, 0, SERVOMAX);
        pwm.setPWM(i + 3, 0, SERVOMIN);
        delay(1000);  // Delay for 1 second with all motors on
        pwm.setPWM(i, 0, SERVOMIN);
        pwm.setPWM(i + 1, 0, SERVOMAX);
        pwm.setPWM(i + 2, 0, SERVOMIN);
        pwm.setPWM(i + 3, 0, SERVOMAX);

      delay(1000);  // Delay for 2 seconds with all motors off
      }
      // Motors on for servo 8, servo 9, servo 10 and servo 11.
      for (int i = 8; i < 12; i += 4) {
        pwm.setPWM(i, 0, SERVOMIN);
        pwm.setPWM(i + 1, 0, SERVOMAX);
        pwm.setPWM(i + 2, 0, SERVOMIN);
        pwm.setPWM(i + 3, 0, SERVOMAX);
        delay(1000);
        pwm.setPWM(i, 0, SERVOMAX);
        pwm.setPWM(i + 1, 0, SERVOMIN);
        pwm.setPWM(i + 2, 0, SERVOMAX);
        pwm.setPWM(i + 3, 0, SERVOMIN);
        delay(1000);
      }

      // Turn off the LED for object detected
      digitalWrite(ledPin, LOW);
      // Turn off the LED for no object detected
      digitalWrite(noObjectLedPin, LOW);

      lastActivationTime = millis();  // Reset the activation time
    }
  } else {
    // Turn on the LED for no object detected
    digitalWrite(noObjectLedPin, HIGH);
  }
}
```


Figure 4.38 Arduino IDE Coding for the project.

In Figure 4.8 shows the coding project that is used. The code establishes key constants, including SERVOMIN, SERVOMAX, and activationDelay, defining servo motor pulse lengths and activation delay intervals. Additionally, it declares variables such as lastActivationTime and objectCounter for managing activation delays and counting detected objects. Pin assignments for the ultrasonic sensor, LEDs, and servo control are specified, with ledPin and noObjectLedPin serving as indicators for object detection. The setup function initializes the PWM Servo Driver, configures pin modes, and initializes the LCD, displaying an "Analyzing..." message briefly before configuring it for the "Target Distance:" display. The loop function continuously measures distances using the ultrasonic sensor, updating the LCD with current distance and object count. If an object is within 10 cm and the activation delay has passed, the system increments the object counter, activates an LED, controls servo motors, and resets the activation time. If no object is detected, a different LED is activated. Overall, the code orchestrates an Arduino-based system for object detection and servo control with dynamic LED indications.

4.3 Results

These are the results of testing different types of garments that have conducted after developing the machine as shown in Table 4.2.

Table 4.9 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

Regarding the T-shirt, long-sleeved shirt, and jacket, the results were nearly 100% accurate; however, we were unable to make the same claim about the towels and pants. The towel that was chosen for this project is thick and somewhat huge. The pants are made of a significantly heavier fabric, and they are extremely long. The servo motors must have suffered because they were unable to support the towel's weight. Each garment took about 6 seconds to finish folding without counting the activation delay.

4.4 Analysis

4.4.1 Graph Analysis of activationDelay over Operation Time.

By incorporating an activation delay, the system avoids immediate consecutive folding actions, providing sufficient time for the user to handle the previously folded cloth, place a new garment, and prepare the system for the next cycle. This intentional pause enhances the overall user experience and allows for a smoother workflow, reducing the likelihood of errors or disruptions during the clothing folding process. If the activationDelay increase, the time for the whole operation to fold a garment increase. Table 4.3 shows the graph of activationDelay against Operation Time.

Table 4.10 The results of activationDelay against Operation Time.

Operation Time (s)	activationDelay (ms)
26	20000
23	17500
21	15000
18	12500
16	10000
13	7500
11	5000
7	2500

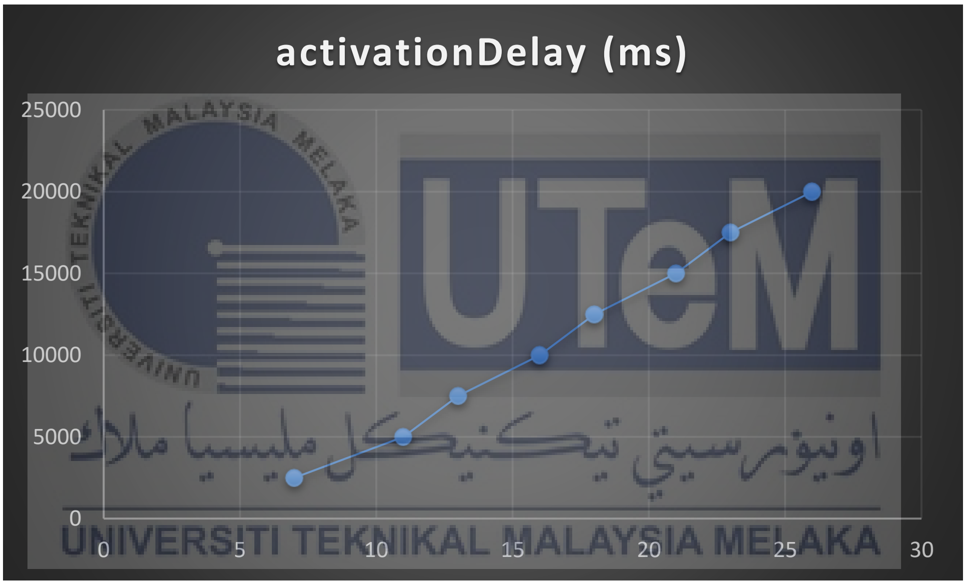


Figure 4.39 The graph of activationDelay against Operation Time.

By increasing the activationDelay, you introduce a longer waiting period between consecutive folding operations. This can have various implications:

- Increased Time Between Folding Cycles: The system will wait for a longer duration before attempting the next folding operation.

- Reduced Frequency of Folding: If the delay is too long, the system may fold garments less frequently, which could be beneficial in scenarios where a slower pace is desired.

- User Interaction Window: A longer delay provides more time for the user to interact with the folded garment, pick it up, and place a new one on the folding board before the next folding cycle begins.

It is important to balance the activationDelay based on the desired system behavior and user preferences. Too short a delay might result in rapid and continuous folding, while too long a delay might reduce the overall efficiency of the clothing folding process. Adjust the value based on practical considerations and user requirements for a satisfactory user experience.

4.4.2 Graph Analysis 2

Table 4.11 The percentage of success 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%

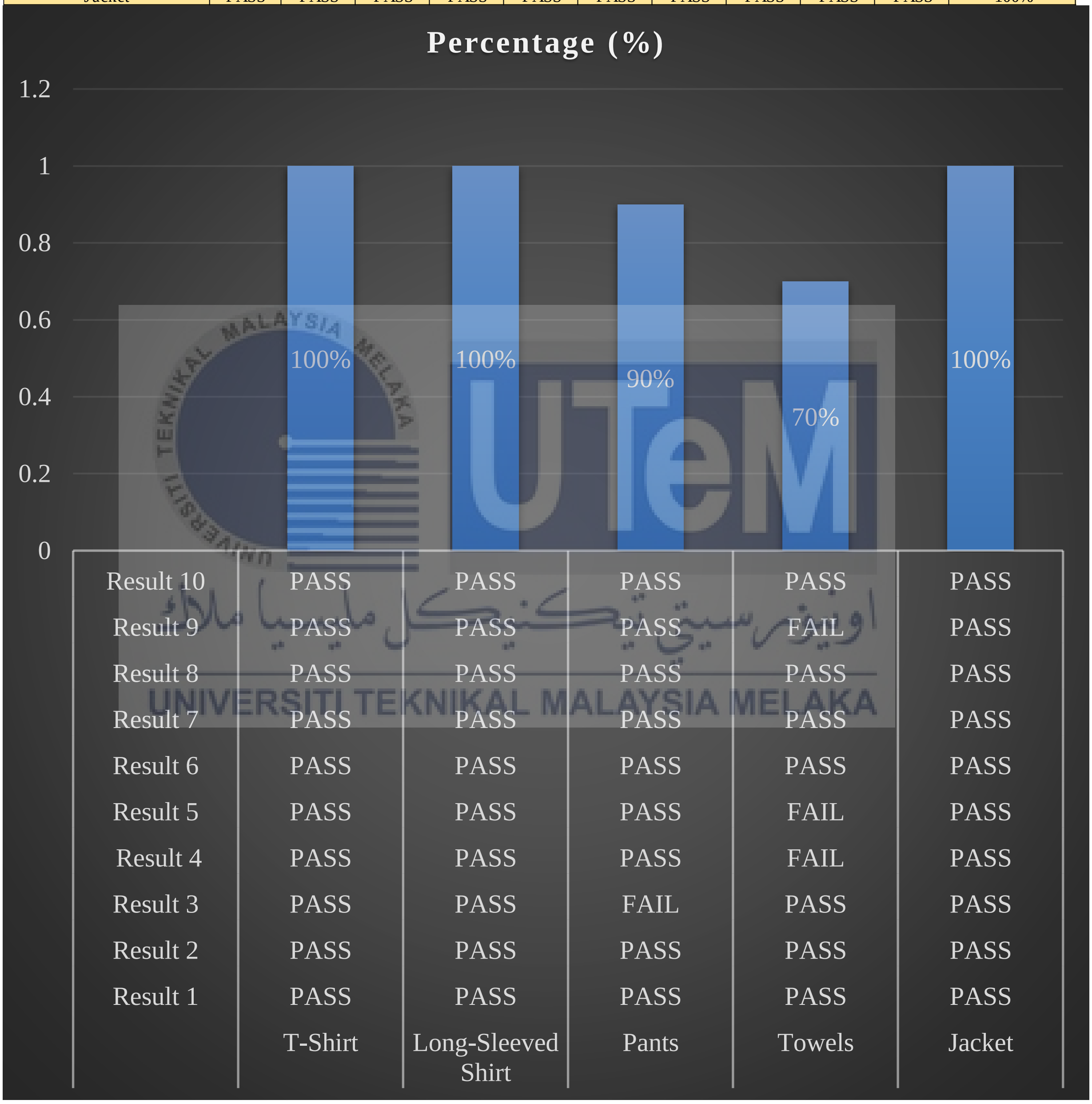


Figure 4.40 The graph of the percentage of success for different types of garments.

The failure in a folding process can be attributed to various factors, and identifying the root cause is crucial for improving the manufacturing process. Here are some common factors that can lead to failure in the folding process:

1. Material Issues
    - Material Clothes Properties: Inconsistent material properties, variations in thickness, or poor quality of the material can affect the folding process. By
    - Material Project Fracture: Brittle or fragile materials may fracture during the folding process, leading to failure.
2. Maintenance Issues
    - Lack of Maintenance: Poorly maintained machines may suffer from increased wear and tear, reducing their effectiveness.
3. Design Issues
    - Poor Design: Inadequate consideration of material properties, bend tolerances, and manufacturability in the design phase can result in folding difficulties.
4. Machine and Tooling Problems
    - Equipment Misalignment: Misalignment of the folding machine or tooling can result in inaccurate folding and uneven bends.
    - Tool Wear: Worn-out or damaged tools may not produce precise folds, leading to defects.
    - Insufficient Tonnage: If the machine lacks the required tonnage, it may struggle to fold thicker or tougher materials.
5. Overloading Servo Motors

- If the load on the servo motors exceeds their capacity, it may lead to overheating or failure. Ensure that the servo motors used are capable of handling the load associated with the folding process.

6. Communication Issues

- If there are communication issues between the Arduino and the servo motors, it may result in unexpected behaviour. Check the wiring, connections, and ensure that the Arduino code is correctly programmed to control the servo motors.

7. Physical Obstructions

- Physical obstructions in the folding area, such as debris or misplaced objects, can interfere with the folding process. Ensure that the workspace is clear of any obstacles.

8. Servo Motor Calibration:

- Improper calibration of servo motors may result in unexpected movements or misalignment during the folding process. Make sure that the servo motors are calibrated accurately and synchronized to perform the desired folding motion.

Identifying the root cause of failure in the folding process requires thorough testing and analysis of each common factor. Here's how we perform testing analysis on each of the factors mentioned:

1. Material Issues

- Conduct material testing to ensure consistent properties and quality.
- Perform tensile testing to identify variations in thickness.
- Test material fracture toughness to assess brittleness.

2. Maintenance Issues

- Implement a regular maintenance schedule for folding machines.
- Monitor wear and tear through preventive maintenance checks.
- Analyze historical maintenance records to identify patterns of failure.

3. Design Issues

- Review the design specifications for material considerations.
- Assess bend tolerances through prototyping and testing.
- Evaluate manufacturability by simulating the folding process in a virtual environment.

4. Machine and Tooling Problems

- Conduct alignment checks on the folding machine.
- Implement regular tooling inspections and replacements.
- Perform tonnage testing to ensure the machine's capacity matches material requirements.

5. Overloading Servo Motors

- Test servo motors under different load conditions.
- Monitor motor temperature during operation.
- Ensure that servo motors are within their specified capacity for the folding process.

6. Communication Issues

- Inspect wiring for loose connections or damage.
- Verify communication protocols between Arduino and servo motors.
- Test the Arduino code in a controlled environment to identify potential issues.

7. Physical Obstructions

- Conduct workspace inspections before each folding process.
- Implement sensors or cameras to detect and prevent obstructions.
- Analyze historical data for incidents related to physical obstructions.

8. Servo Motor Calibration

- Develop a calibration procedure for servo motors.
- Test servo motor movements under different conditions.
- Ensure synchronization between multiple servo motors in the system.

By systematically testing and analyzing each factor, you can identify the specific issues causing failures in the folding process. This data-driven approach allows for targeted improvements and optimizations in the manufacturing process. Regular monitoring and continuous improvement efforts will contribute to enhanced reliability and efficiency in the folding process.

4.5 Summary

This chapter presented case studies to demonstrate the proposed folding system with the appropriate use of electrical components and appliances. The case studies are based on

[16] and [17] and are most helpful for the making of this project on a similar method and electrical components based on what they used. The results produced using the suggested approach demonstrate consistency with changes in the system parameters and produce reasonably accurate findings. This study concluded that folding a lot of garments in a short time is possible. The automatic cloth-folding system demonstrated impressive accuracy, particularly with T-shirts, long-sleeved shirts, and jackets, achieving nearly 100% success. However, challenges arose when attempting to fold thicker and heavier materials such as towels and pants. The inability of the servo motors to adequately support the weight of these items led to suboptimal results.

Analysis of the failures pointed towards various contributing factors. Material issues, including inconsistent properties and variations in thickness, affected the folding process. Maintenance deficiencies, environmental factors like temperature and humidity, and design inadequacies also played a role. Machine and tooling problems, such as misalignment and worn-out tools, further contributed to the issues. Overloading of servo motors, communication issues between Arduino and servos, and physical obstructions in the workspace were identified as additional factors impacting the folding process.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis presents the approach for estimating an automated system for folding clothes utilising an Arduino microcontroller and servo gear motors is presented in this thesis. In order to attain the desired goals or outcomes and provide effective results with just reasonably correct information, the proposed technique is based on a logical and well-thought-out approach. Overall, the study described in this thesis has been successful in advancing knowledge about the significance of a practical and efficient system estimating methodology for folding clothes. The purpose of gathering information from earlier researchers is to develop a project design concept.

In conclusion, the design of the machine's structure, mechanical components, and controller are crucial in creating a machine that can operate well. The programming that has been made using Arduino codes has been proven successful as the results of is properly shown. The project successfully developed an automated folding system, by integrating servo motors, an ultrasonic sensor, and an Arduino Uno Microcontroller to simplify the clothes-folding process, reducing the time required and eliminating the need for manual folding. With proven effectiveness in comparison to manual folding method, this project aimed to revolutionize the way people approach household chores, offering a convenient and time-saving solution that enhances efficiency and contributes to a more automated and streamlined lifestyle.

The development of a programmable automation system on a cloth-folding tool using Arduino Uno Microcontroller and servo gears offers a promising solution to the challenges associated with manual clothes folding for enhancing cloth-folding processes in industries such as textile manufacturing, retail, and laundry services. The system's integration of accessible and affordable technology, coupled with its precise and customizable capabilities, provides a cost-effective and efficient tool for businesses to streamline their operations, reduce labour costs, and improve productivity. With its potential for customization and adaptation to different cloth types and folding patterns, this programmable automation system presents a compelling commercial opportunity in the market. Further research and development in this field can lead to advancements in cloth-folding automation, contributing to the growth and optimization of various industries.

It is recommended to do a full investigation of various fabric kinds, combining flexible sensors and algorithms, to ensure the success of the automated cloth-folding system and solve recognized problems. A proactive maintenance plan, improved environmental robustness, and continuing design refinement will all contribute to maximum performance and durability. Furthermore, improving servo motor capability to handle heavier textiles, guaranteeing steady communication, and maintaining an orderly workspace with safety precautions are critical for consistent and dependable folding. These suggestions are intended to help the system progress into a more dependable, adaptive, and user-friendly solution, hence enhancing its success in the automation and robotics arena.

5.2 Potential for Commercialization

The development of a programmable automation system for a cloth-folding tool using Arduino Uno Microcontroller and servo gears holds significant potential for commercialization. By integrating the Arduino Uno Microcontroller, which is widely accessible and affordable, with servo gears, the system enables precise and customizable cloth folding processes. This technology offers a valuable solution for industries involved in textile manufacturing, retail, or laundry services, as it streamlines the cloth-folding process, enhances productivity, and reduces labour costs.

The programmable automation system can be marketed as an efficient and cost-effective tool that simplifies cloth folding tasks, allowing businesses to optimize their operations and achieve higher efficiency in handling large volumes of garments or fabrics. Additionally, the system's flexibility and programmability provide opportunities for customization and adaptation to various cloth types, sizes, and folding patterns, further enhancing its appeal to potential commercial users.

Not only that, the automated cloth-folding system offers increased efficiency and productivity compared to manual folding. For commercial laundry services, this translates to faster turnaround times and increased capacity. In a residential setting, users benefit from time savings and the convenience of automating a repetitive task.

Moreover, user-friendly features. Integration of an LCD for real-time feedback and user interaction enhances the user experience. The system's simplicity and ease of use make it attractive to a wide range of consumers, including those with limited technical expertise.

Furthermore, the rapid increase of technological Innovation. The incorporation of Arduino Microcontrollers and servo gears showcases technological innovation. This not only enhances the performance of the cloth-folding system but also positions the product as a cutting-edge solution in the smart home and automation market.

The system's design also allows for potential integration with other smart home devices or home automation systems. This could open avenues for partnerships and collaborations with other technology providers, expanding its market reach.

Lastly, as consumers increasingly seek sustainable solutions, the automated cloth-folding system can contribute to reducing energy and time consumption in the laundry process. Highlighting these eco-friendly aspects in marketing can further enhance its commercial appeal.

Thus, the Programmable Automation System on Cloth-Folding Tool demonstrates strong potential for commercialization by addressing market needs, leveraging technological innovation, and offering user-friendly features. Strategic marketing, partnerships, and attention to sustainability can further enhance its position in the market.

5.3 Future Works

The development of a Programmable Automation System on Cloth-Folding Tool using an Arduino Uno Microcontroller and Servo Gears opens up several avenues for future works and improvements. Here are some potential areas for further development:

- Enhanced Sensing and Recognition

    Investigate advanced sensing technologies, such as computer vision or machine learning algorithms, to improve cloth detection and recognition capabilities. This could enable the system to identify a broader range of fabrics and clothing types accurately.

- Adaptive Folding Algorithms

    Develop adaptive folding algorithms that can adjust the folding technique based on the specific characteristics of each garment. This could involve considering factors such as fabric thickness, elasticity, and size to optimize the folding process for different types of clothing.

- Multi-Item Folding

    Expand the system's capabilities to handle multiple items simultaneously. This could involve incorporating mechanisms for sorting and folding various clothing items in a single cycle, further increasing efficiency.

- Smart Connectivity

    Integrate smart connectivity features, such as Wi-Fi or Bluetooth, to enable remote monitoring and control. Users could have the flexibility to start, stop, or check the status of the cloth-folding process using a mobile application or through smart home systems.

- Energy Efficiency

Implement energy-efficient features to reduce power consumption. This may involve optimizing the control algorithms, using energy-efficient components, or incorporating sleep modes during idle times to conserve energy.

- Fold Customization

  Provide users with customization options for folding preferences. This could include adjustable folding styles, stack sizes, or folding speed settings to cater to individual preferences or specific garment requirements.

- Material Handling Mechanisms:

  Investigate advanced material handling mechanisms to accommodate heavier fabrics or larger garments. This could involve enhancements to the servo motors, folding boards, or additional support mechanisms to ensure reliable folding for a broader range of materials.

- Collaborative Research:

  Collaborate with researchers and experts in the fields of robotics, automation, and garment manufacturing to leverage their insights and contribute to the ongoing advancements in the automation of clothing-related tasks.

In conclusion, the future of folding clothes using Arduino Microcontrollers and servo motors holds exciting possibilities for improving efficiency, adaptability, connectivity, portability, and sustainability. As technology evolves, these innovations can transform the way we approach mundane tasks, making them more convenient and enjoyable for users.

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APPENDICES

AppendixA   Arduino IDE Coding

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Adafruit_PWMServoDriver.h>

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#define SERVOMAX 600  // Maximum pulse length

LiquidCrystal_I2C lcd(0x27, 16, 2);

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#define echoPin 6
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unsigned long lastActivationTime = 0;
int objectCounter = 0;

void setup() {
  pwm.begin();
  pwm.setPWMFreq(60);

  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(noObjectLedPin, OUTPUT);

```

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  lcd.init();  // Initialize the LCD
  lcd.backlight();
  lcd.clear();
  lcd.setCursor(4, 0);
  lcd.print("Analyzing...");
  delay(2000);
  lcd.setCursor(0, 0);
  lcd.print("Target Distance:");
}

void loop() {
  long duration, distance;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance = (duration / 2.0) / 29.1;

  lcd.setCursor(0, 1);
  lcd.print("                ");
  lcd.setCursor(0, 1);
  lcd.print(distance);
  lcd.print(" cm");
  lcd.setCursor(7, 1);
  lcd.print("Count:");
  lcd.setCursor(13, 1);
  lcd.print(objectCounter);
  delay(250);

  Serial.println(distance);

  if (distance <= 10) { // Check if an object is within 10 cm
    if (millis() - lastActivationTime >= activationDelay) {
      objectCounter++;
      lcd.setCursor(7, 1);
      lcd.print("Count:");
      lcd.setCursor(13, 1);
      lcd.print(objectCounter);

      // Turn on the LED for object detected
      digitalWrite(ledPin, HIGH);
      digitalWrite(noObjectLedPin, LOW);

      // Motors on for servo 0, servo 1, servo 2 and servo 3.
      for (int i = 0; i < 4; i += 4) {
        pwm.setPWM(i, 0, SERVOMIN);
        pwm.setPWM(i + 1, 0, SERVOMAX);
        pwm.setPWM(i + 2, 0, SERVOMIN);
        pwm.setPWM(i + 3, 0, SERVOMAX);
        delay(1000);  // Delay for 1 second with all motors on
        pwm.setPWM(i, 0, SERVOMAX);
        pwm.setPWM(i + 1, 0, SERVOMIN);
        pwm.setPWM(i + 2, 0, SERVOMAX);
        pwm.setPWM(i + 3, 0, SERVOMIN);
      delay(1000);  // Delay for 2 seconds with all motors off
      }
```

```
      // Motors on for servo 4, servo 5, servo 6 and servo 7.
      for (int i = 4; i < 8; i += 4) {
        pwm.setPWM(i, 0, SERVOMAX);
        pwm.setPWM(i + 1, 0, SERVOMIN);
        pwm.setPWM(i + 2, 0, SERVOMAX);
        pwm.setPWM(i + 3, 0, SERVOMIN);
        delay(1000);  // Delay for 1 second with all motors on
        pwm.setPWM(i, 0, SERVOMIN);
        pwm.setPWM(i + 1, 0, SERVOMAX);
        pwm.setPWM(i + 2, 0, SERVOMIN);
        pwm.setPWM(i + 3, 0, SERVOMAX);

      delay(1000);  // Delay for 2 seconds with all motors off
      }
      // Motors on for servo 8, servo 9, servo 10 and servo 11.
      for (int i = 8; i < 12; i += 4) {
        pwm.setPWM(i, 0, SERVOMIN);
        pwm.setPWM(i + 1, 0, SERVOMAX);
        pwm.setPWM(i + 2, 0, SERVOMIN);
        pwm.setPWM(i + 3, 0, SERVOMAX);
        delay(1000);
        pwm.setPWM(i, 0, SERVOMAX);
        pwm.setPWM(i + 1, 0, SERVOMIN);
        pwm.setPWM(i + 2, 0, SERVOMAX);
        pwm.setPWM(i + 3, 0, SERVOMIN);
        delay(1000);
      }

      // Turn off the LED for object detected
      digitalWrite(ledPin, LOW);
      // Turn off the LED for no object detected
      digitalWrite(noObjectLedPin, LOW);

      lastActivationTime = millis();  // Reset the activation time
    }
  } else {
    // Turn on the LED for no object detected
    digitalWrite(noObjectLedPin, HIGH);
  }
}
```

Appendix B Gantt Chart for PSM2

Activity/ Task	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Project briefing, title selection, synopsis														
Identify objectives, problem statements														
Research reviews														
Model and component selection														
Methodology design simulation														
Final report, presentation preparation														