AN-NAJAH NATIONAL UNIVERSITY
Faculty of Engineering & Information Technology
Department of Computer Engineering

GRADUATION PROJECT II

GloviX

PREPARED BY:
Masa Anani
Maha Samara

SUPERVISED BY:
Dr. Anas Toma

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Disclaimer

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Abstract

Maintaining proper hand hygiene and frequent glove replacement is essential in medical and hygiene-sensitive environments to reduce the risk of infection and cross-contamination. However, the traditional process of hand sanitization and glove wearing can be time-consuming, inconvenient, and often requires direct human assistance, especially in high-pressure environments such as hospitals and laboratories.

This project presents **GloviX**, an automated, contactless system designed to perform hand sanitization, drying, and medical glove wearing in a single integrated workflow. The system consists of two enclosed units: a sanitization unit and a glove dispensing unit. **GloviX** utilizes an Arduino-based control system, ultrasonic sensors for hand detection, motors and actuators for mechanical movement, and airflow mechanisms for glove preparation and inflation.

The developed prototype successfully demonstrates the feasibility of automating the glove-wearing process while reducing human contact and encouraging faster glove replacement. Although no quantitative measurements or clinical validation were conducted, practical testing confirmed that the system performs its intended functions effectively. **GloviX** highlights the potential of combining embedded systems, mechanical design, and automation to improve hygiene practices in medical, industrial, and laboratory environments.

Chapter 1

Introduction

1.1 General Background

Healthcare-associated infections (HAIs) represent a major global challenge to patient safety and public health. According to the World Health Organization (WHO), approximately one in ten patients worldwide acquires at least one infection during the course of receiving healthcare services. These infections lead to prolonged hospital stays, increased medical costs, and higher morbidity and mortality rates. In Europe alone, HAIs are responsible for millions of additional hospital days every year, placing a significant burden on healthcare systems.

Hand hygiene and the proper use of medical gloves are considered fundamental measures in preventing the transmission of infectious diseases. Medical gloves act as a protective barrier between healthcare workers and patients, reducing the risk of cross-contamination. Organizations such as the Centers for Disease Control and Prevention (CDC) and WHO emphasize that gloves must be worn correctly and replaced frequently, especially between patients and different medical procedures.

Despite their importance, studies show that glove usage in clinical environments is often inconsistent. Healthcare workers frequently fail to change gloves at appropriate times, and contaminated gloves are sometimes used across multiple tasks. Research has demonstrated that gloves can easily become contaminated during use and may transfer microorganisms to surfaces, medical equipment, or other patients if not replaced properly. In addition, traditional glove boxes and manual glove-wearing methods may themselves contribute to contamination, as multiple users touch the same box opening or glove edges.

Another critical issue is the time and effort required to wear medical gloves. In high-pressure environments such as operating rooms, emergency departments, and intensive care units, healthcare workers must act quickly. Manual glove-wearing can be time-consuming, uncomfortable, and sometimes difficult, especially when gloves stick together or tear during use. In some surgical settings, doctors even require assistance from another person to wear sterile gloves, increasing dependency and human contact.

To address these challenges, modern healthcare systems are increasingly adopting automated and touchless solutions that enhance hygiene while improving efficiency. Automated disinfection systems and contactless technologies have proven effective in reducing contamination risks and encouraging compliance with hygiene protocols. In this context, the GloviX system is proposed as an innovative hardware solution that combines automatic hand disinfection, drying, and glove wearing in a single integrated process. By minimizing human contact and reducing the time required to wear gloves, GloviX aims to improve infection control practices across various environments.

1.2 Project Objectives

The primary objectives of the **GloviX** graduation project are as follows:

- To design and implement an automated system that integrates hand disinfection, hand drying, and medical glove wearing in a sequential manner.
- To reduce the time and effort required to wear medical gloves by enabling users to wear gloves within seconds without manual assistance.
- To minimize contamination risks by eliminating direct contact with glove surfaces and glove dispensing mechanisms.
- To encourage frequent glove replacement by simplifying and accelerating the glove-wearing process.
- To provide a notification mechanism that alerts users when disinfectant liquid or medical gloves are running low, ensuring timely refilling and uninterrupted operation.
- To utilize an Arduino-based control system to manage sensors, actuators, airflow, and suction mechanisms efficiently.
- To reduce glove damage and material waste caused by improper manual glove-wearing techniques.

1.3 Project Significance

The **GloviX** system provides significant value in improving hygiene, efficiency, and safety in environments that require frequent glove usage. By automating both hand disinfection and glove wearing, the system directly addresses common causes of contamination and non-compliance with infection prevention guidelines.

In medical environments such as hospitals, clinics, laboratories, and operating rooms, GloviX can reduce staff workload and eliminate the need for additional personnel to assist in glove wearing. This is particularly important in sterile environments where minimizing human interaction is essential. The contactless operation further reduces the risk of cross-contamination between users.

Beyond healthcare applications, GloviX can be effectively utilized in pharmacies, beauty centers, food processing facilities, factories, research laboratories, and restaurants where protective gloves are required. By saving time, reducing glove waste, and improving hygiene compliance, the system contributes to safer working conditions and higher operational efficiency.

Overall, GloviX represents a practical and innovative solution that aligns with international infection control guidelines and addresses real-world challenges associated with manual glove usage.

1.4 Organization of the Report

This report is structured into six chapters as follows:

- **Chapter One** introduces the project, including background, objectives, significance, and report structure.
- **Chapter Two** provides a theoretical background and reviews previous studies related to hand hygiene, glove usage, and automated systems.
- **Chapter Three** presents the complete methodology, including system overview and architecture, main control unit, power supply and wiring, hand detection monitoring, user interface and alert systems, 3D-printed components, and detailed descriptions of both the hand sanitization box and glove dispensing box with their respective mechanical and electronic subsystems.
- **Chapter Four** presents the results obtained from implementation and testing of the GloviX system, demonstrating successful system operation, functional verification, and practical observations from prototype testing.
- **Chapter Five** evaluates the extent to which project objectives were achieved, discusses the actual contribution of the GloviX system, and analyzes its strengths, limitations, and challenges encountered during development.
- **Chapter Six** summarizes the general conclusions, provides recommendations for system improvement, outlines opportunities for future expansion and scaling, and identifies open work that remains beyond the project scope.

Chapter 2

Theoretical Background and Related Work

2.1 Theoretical Background

The effectiveness of hand hygiene and proper glove usage in preventing healthcare-associated infections (HAIs) has been extensively studied. Hand hygiene is recognized as the most critical measure for preventing pathogen transmission in clinical settings. According to the World Health Organization (WHO), consistent hand hygiene can reduce HAIs by up to 40% World Health Organization (2009).

Medical gloves provide a physical barrier that protects both healthcare workers and patients. However, improper glove use, including prolonged wear and failure to change gloves between tasks, can lead to cross-contamination Centers for Disease Control and Prevention (CDC) (2020). Theoretical models of infection control suggest that minimizing direct contact and automating hygiene-related procedures reduces the transmission pathways for bacteria and viruses Kampbell and Davis (2018).

Automation in glove dispensing and hand sanitization can also enhance compliance with hygiene protocols. Several studies indicate that touchless glove boxes and automated hand disinfecting systems significantly reduce microbial contamination compared to traditional manual methods Igor (2019). Additionally, implementing alert mechanisms for low disinfectant or glove levels ensures uninterrupted operation, which is crucial in high-demand environments like operating rooms and intensive care units.

2.2 Related Work

Several prior works have attempted to automate aspects of hand hygiene and glove management:

- **Automated Hand Sanitizers:** Devices that dispense a measured dose of alcohol-based sanitizer when hands are detected by infrared or ultrasonic sensors. These devices have been proven to increase hand hygiene compliance in hospitals Gould et al. (2017).

- **Touchless Glove Dispensers:** Systems such as IGIN's automated glove dispensers use a mechanical or pneumatic mechanism to allow users to wear gloves without direct contact, thereby reducing contamination risks IGIN Technologies (2020).
- **Integrated Sterile Systems:** Some studies combine hand sanitizing and glove wearing into a single device for operating rooms, showing a reduction in time and higher compliance Roberts (2016).
- **Low-Level Notifications:** Research emphasizes that providing alerts when consumables (e.g., gloves or sanitizer) are low enhances reliability and continuous availability of hygiene systems Smith (2018).

While these systems address specific problems, they often focus on either disinfection or glove dispensing, but rarely integrate both functions in one compact system. Many lack real-time notifications or fail to ensure fast and effortless glove wearing.

2.3 Relevance to GloviX

The **GloviX** project draws directly from the theoretical background and related work discussed above. By integrating automated hand disinfection, drying, and glove wearing, GloviX addresses limitations found in existing systems:

- **Integration of Processes:** Unlike previous devices that focus only on one aspect, GloviX provides a full workflow from hand disinfection to glove wearing.
- **Touchless Operation:** Reduces cross-contamination risks associated with manual glove handling.
- **Speed and Efficiency:** Optimized for fast operation, essential in medical and high-pressure environments.
- **Notification System:** Ensures timely refill of sanitizer or gloves, improving reliability and operational continuity.
- **Practical Applicability:** Designed for use in hospitals, clinics, laboratories, and other environments requiring hygiene compliance, extending its relevance beyond traditional healthcare settings.

Overall,**GloviX** builds upon the theoretical insights and lessons learned from previous research to provide a comprehensive, automated, and practical solution for improving hygiene and glove management in critical environments.

Chapter 3

Methodology

This chapter presents the complete methodology followed in designing and implementing the proposed automated hand sanitization and glove dispensing system. The methodology covers the system architecture, hardware components, control mechanisms, sensing units, actuation systems, and the overall operational workflow. Special attention is given to the integration between mechanical, electronic, and embedded control elements to ensure reliability, safety, and usability.

3.1 System Overview and Architecture

The proposed system consists of two physically separated yet electronically integrated wooden enclosures:

- A **Hand Sanitization Box**
- A **Gloving Box**

Both enclosures are fully sealed to ensure controlled internal operation. Each box includes a circular hand inlet designed for user interaction, while the top surfaces are covered with transparent glass panels supported by wooden frames, allowing visual inspection without compromising isolation.

The entire system is centrally controlled using an **Arduino Mega 2560**, which manages sensing, actuation, user interaction, and alert mechanisms.

Figure 3.1: Overall system architecture of the proposed solution

3.2 Main Control Unit

The **Arduino Mega 2560** is selected as the main controller due to its large number of digital and analog input/output pins, which allows seamless integration of multiple sensors, motors, actuators, and display units.

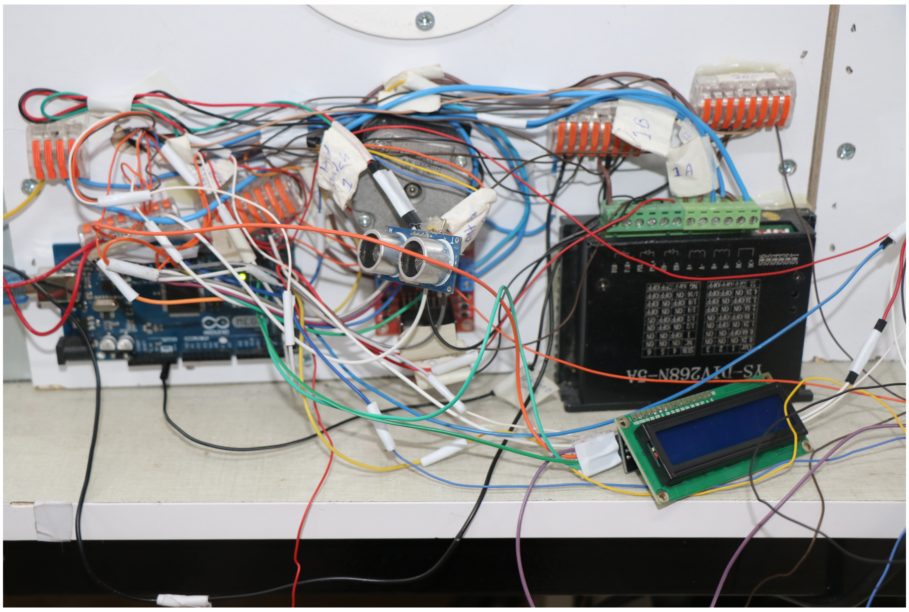
The controller performs the following main functions:

- Monitoring hand detection sensors
- Controlling motors, valves, and actuators
- Managing glove counting and alcohol level tracking
- Triggering alerts and notifications
- Displaying system messages on the LCD screen

The system firmware is developed using the **Arduino IDE**, enabling modular and structured control logic.

(a) Arduino Mega 2560

(b) Arduino IDE



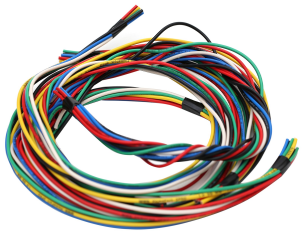
(c) Overall Hardware Wiring and Component Integration

Figure 3.2: Main Control Unit and System Wiring

3.3 Power Supply and Wiring

The system is powered by a dedicated power supply unit providing stable voltage to all components. Various wiring types and connectors are used to ensure secure and reliable electrical connections.

(a) Power Supply



(b) Wires

(c) Connectors

Figure 3.3: Power Supply and Wiring Components.

3.4 Hand Detection and Usage Monitoring

Ultrasonic sensors are used to detect hand insertion in both the sanitization box and the glove dispensing box. Although the same sensing technology is applied, each unit serves a different purpose within the system.

In the sanitization box, the ultrasonic sensor detects the user's hand and triggers the sanitization sequence, including alcohol spraying and hand drying.

In the glove box, the ultrasonic sensor performs dual functionality by detecting hand insertion and counting each glove dispensing operation. The usage counter helps estimate glove packet depletion and supports refill monitoring.

(a) Ultrasonic in box1

(b) Ultrasonic Sensor

(c) Ultrasonic in box2

Figure 3.4: Hand Detection and Usage Monitoring.

3.5 User Interface and Alert System

An LCD display with I2C interface is used to present system messages, including:

- Welcome messages
- User instructions

- Alert notifications

A buzzer is integrated to provide audible alerts in cases such as alcohol depletion or glove unavailability.

(a) LCD with I2C module

(b) LCD and Buzzer in the System

(c) Buzzer

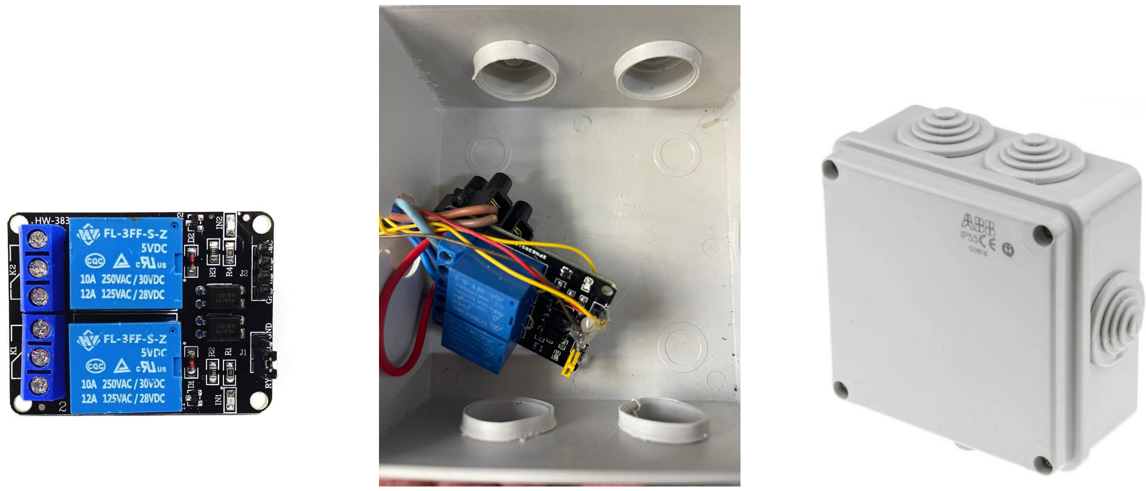
Figure 3.5: User Interface and Alert System.

3.5.1 Relay-Based Actuator Control

A two-channel relay module is used to control high-power electrical devices through the Arduino controller. The relay enables safe isolation between the low-voltage control signals of the Arduino and the high-voltage AC-powered devices.

In the sanitization box, one relay channel is used to control the hand drying unit, which operates on mains electricity. In the glove dispensing box, the second relay channel controls the vacuum unit responsible for air suction and glove inflation.

This configuration allows the system to safely manage electrical actuators in both boxes while maintaining reliable and synchronized operation.



(a) Relay Module 2-Channel

(b) Wired relay module enclosed inside the electrical box

(c) Electrical box

Figure 3.6: Relay-Based Actuator Control.

3.6 3D Printed Components

Due to limited availability of specialized mechanical parts, several components were custom designed and manufactured using 3D printing.

3.7 Hand Sanitization Box

The hand sanitization box is responsible for detecting hand insertion, spraying alcohol, and drying the hand automatically.

Figure 3.7: Hand Sanitization Box

3.7.1 Alcohol Dispensing Mechanism

Alcohol dispensing is achieved using a spray bottle equipped with a custom-designed **3D-printed alcohol press mechanism**. This mechanism is driven by a servo motor that applies controlled pressure to release a predefined amount of alcohol.

- Servo motor controlled via PWM
- Custom 3D-printed press component

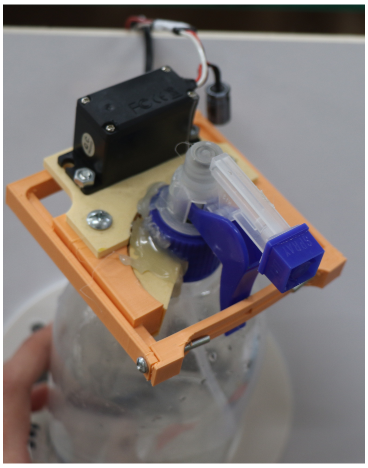


Figure 3.8: Alcohol Dispensing Mechanism

3.7.2 Alcohol Level Monitoring

XKC-Y25-V liquid level sensor is installed to monitor the availability of alcohol inside the container. The sensor operates in digital mode:

- LOW signal: alcohol available
- HIGH signal: alcohol depleted

When alcohol is depleted, the system triggers an alert using the buzzer and displays a warning message on the LCD screen.

Figure 3.9: Liquid Level Sensors

3.7.3 Hand Drying System

After alcohol spraying, a drying phase is activated using an **electric air dryer** controlled via a relay module. This ensures safe electrical isolation while providing sufficient airflow for hand drying.

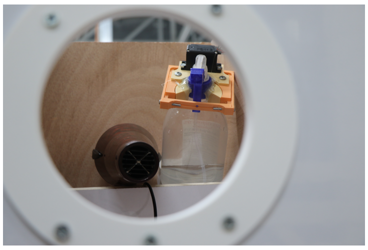


Figure 3.10: Hand Drying System

3.8 Gloving Box

The gloving box automates glove retrieval, inflation, and user access while ensuring hygiene and inventory tracking.

Figure 3.11: Gloving Box

3.8.1 Glove Refill Access Port

To facilitate easy maintenance and refilling, the glove box is equipped with a dedicated side access port. This port allows glove packets to be inserted or replaced without the need to disassemble the system or interfere with its internal mechanisms.

The access opening is designed to be tightly sealed during normal operation to preserve internal air pressure conditions and prevent contamination. A secure locking mechanism ensures that the port remains closed while the system is active, maintaining both safety and operational reliability.

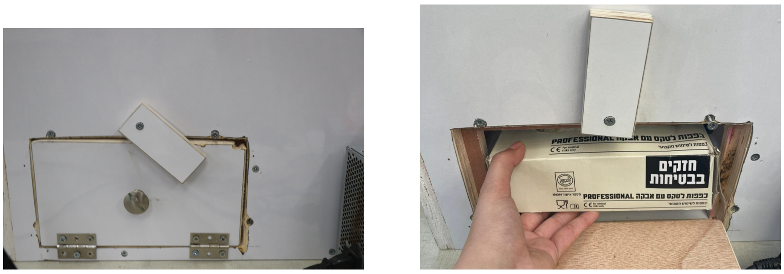


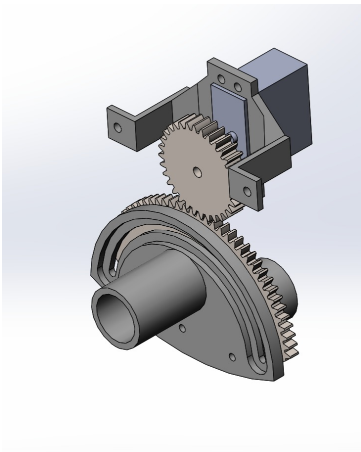
Figure 3.12: Side access port used for inserting and refilling glove packets while maintaining an airtight enclosure.

3.8.2 Vacuum and Airflow Control

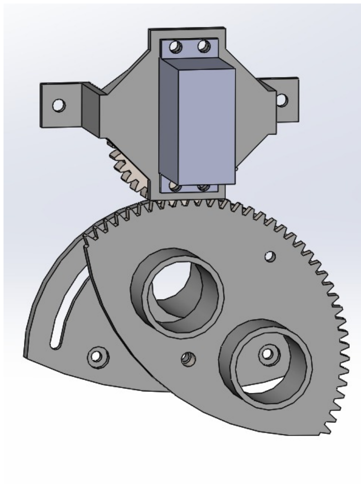
A single vacuum pump is used for two operational modes:

1. Glove suction and handling
2. Air evacuation to inflate the gloves

Mode selection is controlled using servo-operated valves, enabling airflow direction switching based on system state.

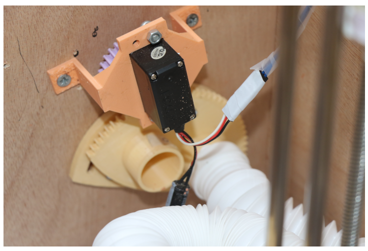


(a) servo-operated valves design 1



(b) servo-operated valves design 2

(c) Vacuum pump air intake port.



(d) servo-operated valves in the system

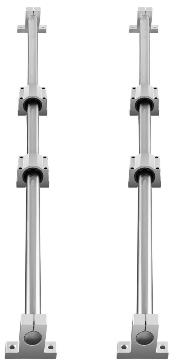
Figure 3.13: Vacuum and Airflow Control

3.8.3 Mechanical Glove Handling and Shutter Mechanisms

This subsection describes the mechanical systems responsible for glove retrieval, positioning, and preparation within the glove box. The design integrates linear and horizontal motion mechanisms, controlled suction, and positional sensing to ensure reliable and safe glove dispensing.

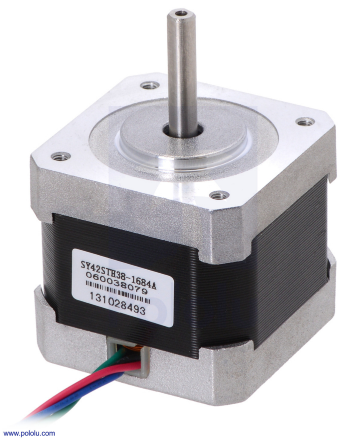
3.8.3.1 Overall Mechanical Structure

The glove box incorporates a dedicated mechanical structure that supports all moving components, including motors, transmission elements, and suction interfaces. The structure was designed to maintain alignment and stability during operation, while also allowing easy integration with electronic control components. NEMA 17 stepper motors are used to drive both vertical and horizontal motion mechanisms, which are detailed in the following subsections.



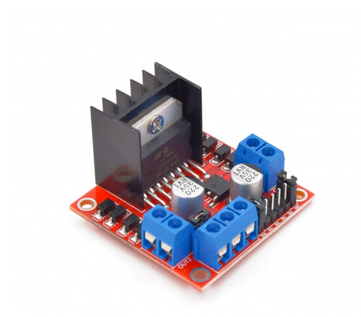
(a) smooth rods lead and linear bearing

(b) Coupler and power screw



(c) Stepper motor

(d) 5A Motor driver



(e) H -bridge circuit

Figure 3.14: Figure 3.14: Overall Mechanical and Drive Components of the Glove Box.

3.8.3.2 Vertical Glove Pickup Mechanism

The vertical glove pickup mechanism is responsible for lifting and releasing a single glove from the glove packet. This motion is driven by a NEMA 17 stepper motor, controlled via a 5A-rated motor driver, which converts rotational motion into precise vertical displacement. A shaft coupler and a threaded steel rod transmit motion smoothly, ensuring controlled glove pickup. The vertical position is continuously monitored using reference sensors to prevent overtravel and mechanical stress.

Figure 3.15: Vertical glove pickup mechanism including the stepper motor, linear motion assembly, shaft coupler, and threaded rod.

3.8.3.3 Suction Interface for Glove Handling

To enable reliable glove extraction, a suction interface is integrated into the pickup mechanism. This interface contains multiple small openings designed to apply vacuum pressure evenly, allowing the system to grip a single glove without causing damage.

The suction component was fabricated using 3D printing to achieve the required geometry and precision.

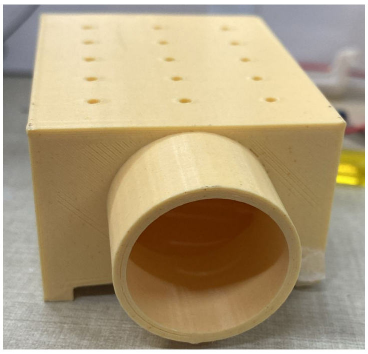


Figure 3.16: 3D-printed suction interface with multiple openings for controlled glove pickup.

3.8.3.4 Shutter Movement System

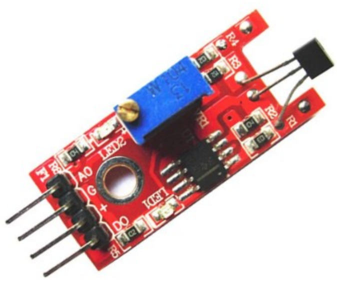
The shutter movement system controls the horizontal transfer of the glove and assists in positioning it correctly before user interaction. This mechanism operates using a separate stepper motor, controlled through an H-bridge circuit to enable forward and backward motion.

Mechanical travel limits are defined to ensure consistent positioning and to protect the system from mechanical collision.

3.8.3.5 Position Sensing and Motion Limits

Accurate position detection is achieved using a combination of Hall effect sensors and limit switches. These sensors define upper and lower reference points for vertical movement, as well as forward and backward boundaries for the shutter system.

This sensing strategy ensures safe operation, repeatability, and protection against mechanical overload.



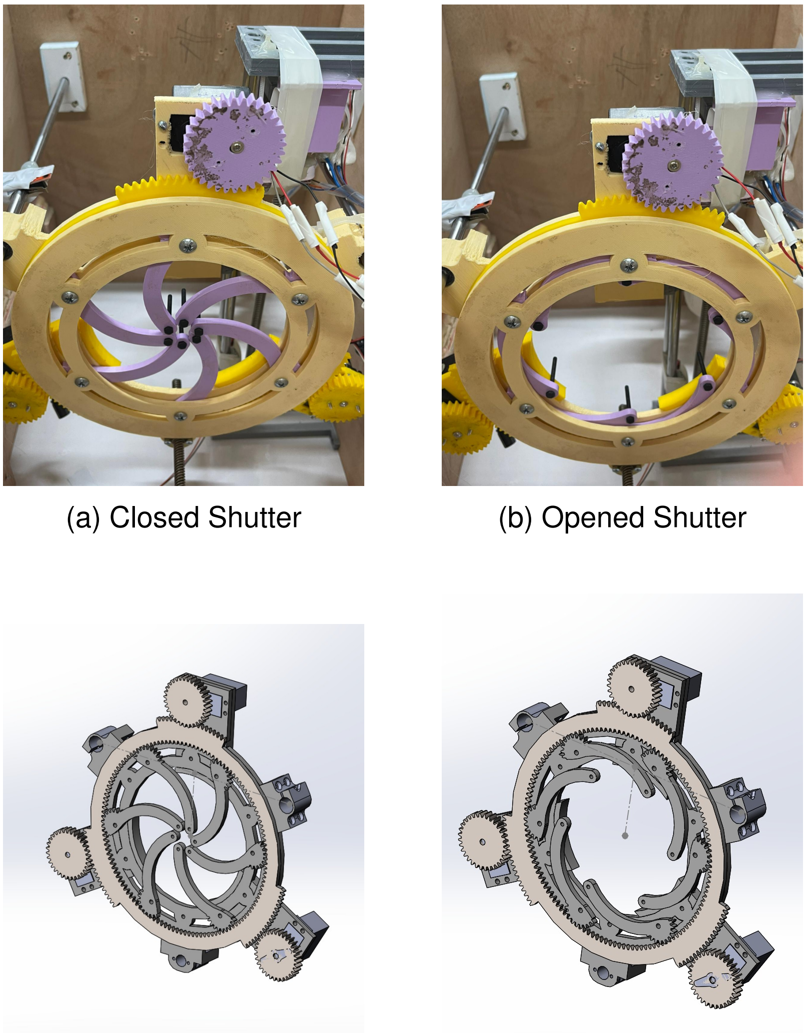
(a) Hall effect sensor

(b) limit switch

Figure 3.17: Hall effect sensor and limit switches used for position reference and motion safety.

3.8.4 Glove Release Mechanism

Three servo motors are used to actuate a custom 3D-printed glove gripping and release mechanism, providing accurate and repeatable control during glove placement and inflation.



(a) Closed Shutter (b) Opened Shutter

(c) Closed Shutter design (d) Opened Shutter design

Figure 3.18: Glove Release Mechanism.

3.8.5 Glove Inflation and User Interaction

After glove positioning:

- The box air is evacuated
- Gloves are inflated
- The user inserts their hand and wears the glove

3.9 Operational Workflow

The complete operational sequence of the system includes:

1. Hand detection
2. Sanitization and drying
3. Glove preparation and inflation

4. User glove wearing
5. Inventory monitoring and alerts

(a) Alcohol Empty Warning.

(b) Gloves Empty Warning.

Figure 3.19: Inventory monitoring and alerts.

(a) Welcoming message on LCD

(b) User inserts hand into the box

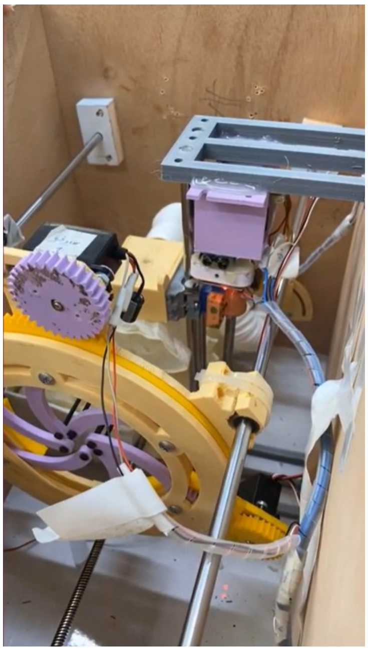
(c) Sanitization in progress

(d) ”Turn your hand” message

(e) User rotates hand inside the box

(f) Drying process starts

Figure 3.20: Operational Workflow in box 1.



(a) Pick the glove from the packet

(b) The shutter is moving to open and take the glove

(c) The shutter places the glove for inflation

(d) Inflating the glove

(e) User inserts hand for wearing

(f) Gloved hand ready for use

Figure 3.21: Operational Workflow in box 2.

Chapter 4

Results and Analysis

This chapter presents the results obtained from the implementation and testing of the GloviX system. The evaluation is based on practical observations during prototype operation rather than quantitative measurements, as the primary objective was to validate the functionality and feasibility of the proposed system.

4.1 System Operation Results

During testing, the GloviX system successfully performed the complete operational sequence, which includes hand detection, alcohol spraying, hand drying, glove preparation, and glove wearing. The system was able to detect the presence of the user's hand using ultrasonic sensors and automatically initiate the corresponding processes without direct human intervention.

The sanitization box effectively sprayed alcohol onto the user's hand, followed by a drying process, ensuring readiness before glove wearing. Subsequently, the glove dispensing box prepared and delivered a glove, allowing the user to wear it smoothly by inserting their hand into the glove opening.

4.2 Functional Verification

The system demonstrated the following verified functionalities:

- Automatic detection of hand insertion.
- Contactless alcohol spraying and drying.
- Automatic preparation and inflation of gloves.
- Successful wearing of gloves without direct hand contact.
- Notification alerts when alcohol or glove supplies were depleted.

Although no precise timing, sterilization level measurements, or statistical testing were conducted, the observed behavior confirms that the system achieves its intended functional goals.

4.3 Observations and Analysis

Based on practical usage by the project team, the GloviX system reduced manual effort and eliminated direct contact during glove wearing. Minor operational errors were occasionally observed, mainly due to mechanical alignment or hardware limitations; however, these issues did not prevent the system from completing its main tasks.

Overall, the results indicate that the GloviX prototype is functional and capable of providing an automated, hygienic glove-wearing solution suitable for medical and industrial environments.

Chapter 5

Discussion

This chapter discusses the extent to which the project objectives were achieved, the actual contribution of the GloviX system, and its strengths and limitations.

5.1 Goal Achievement

The primary objectives of the GloviX project were to enhance hygiene, reduce infection risks, and improve efficiency during glove wearing. Based on system testing and observations, these goals were successfully achieved. The system enables rapid, contactless hand sanitization and glove wearing, which helps encourage frequent glove replacement and reduces dependence on human assistance.

5.2 Actual Contribution

The main contribution of GloviX lies in integrating multiple processes into a single automated system. Unlike traditional methods, the system combines hand sanitization, drying, glove preparation, and supply monitoring into one workflow. This integration improves usability and offers a practical solution that can be applied in various environments such as hospitals, clinics, laboratories, pharmacies, and other hygiene-sensitive workplaces.

5.3 Strengths and Limitations

5.3.1 Strengths

The GloviX system offers several advantages:

- Fully automated and contactless operation.
- Integration of sanitization and glove wearing in one system.
- Supply monitoring with alert notifications.
- Applicability across multiple medical and industrial fields.

5.3.2 Limitations and Challenges

Despite its strengths, the project faced several limitations and challenges. The overall system cost was relatively high due to the large number of hardware components, including motors, sensors, and power supplies. In addition, several mechanical parts required for the system were not commercially available, which necessitated the use of custom 3D-printed components.

While 3D printing enabled rapid prototyping and design flexibility, it also introduced concerns regarding material durability, as some parts may be subject to wear or mechanical failure over time. Utilizing stronger industrial-grade materials could improve reliability but would significantly increase the overall project cost.

Moreover, various hardware-related challenges were encountered during development, such as component malfunction, overheating, and unexpected system behavior. Since the project was developed by computer engineering students, the team had limited prior experience in advanced mechanical design and fabrication. Consequently, technical consultation was sought during the development process.

These challenges, while imposing limitations, provided valuable hands-on experience and highlighted important areas for future improvement and system optimization.

Chapter 6

Conclusions and Recommendations

This chapter summarizes the overall conclusions of the GloviX project, presents recommendations for system improvement, explores opportunities for future expansion, and identifies open work that was not completed within the scope of this project.

6.1 General Conclusions

The GloviX project successfully demonstrated the feasibility of an automated, contactless system for hand sanitization and glove wearing. The developed prototype integrates multiple processes—including hand detection, alcohol spraying, drying, glove preparation, and glove wearing—into a single workflow controlled by a microcontroller-based system.

Although the project was implemented as a prototype, practical testing confirmed that the system performs its intended functions effectively. GloviX addresses key challenges related to hygiene, infection prevention, and operational efficiency, particularly in environments where frequent glove replacement is required. The system highlights the potential of automation in reducing human intervention and encouraging safer practices in medical and industrial settings.

6.2 Recommendations for System Improvement

Several improvements can be considered to enhance the performance, usability, and reliability of the GloviX system. One important recommendation is the use of stronger and more durable materials for mechanical components instead of standard 3D-printed plastics. This would improve long-term reliability but may require higher manufacturing costs.

Noise reduction is another critical area for improvement. The air suction unit, as well as the drying mechanism, produces noticeable noise despite attempts to reduce it. Future designs could utilize quieter industrial suction systems, acoustic insulation, or alternative airflow mechanisms to minimize user discomfort.

Additionally, the overall system enclosure can be improved in terms of aesthetics, portability, and organization. A more compact and lightweight design with better cable management would make the system more suitable for real-world deployment, especially in clinical environments.

6.3 Opportunities for Future Expansion

The GloviX system offers several opportunities for future expansion. One possible enhancement is supporting different glove sizes based on hand dimensions, allowing the system to adapt to multiple users more effectively. Another potential improvement is adding dual-hand operation, enabling simultaneous preparation for both hands.

Furthermore, the concept can be expanded into a comprehensive personal protective equipment (PPE) preparation system. This could include automated handling of gloves, gowns, shoe covers, and head covers, forming a complete preparation station for medical staff prior to surgical procedures.

With further development, the system could be adapted for use in high-demand environments such as operating rooms, isolation units, and laboratories, where fast and standardized preparation is essential.

6.4 Open Work

Several aspects remain as open work and were not addressed within the scope of this project due to time, resource, and access limitations. The system was not tested in real hospital or clinical environments, and no large-scale user testing was conducted. Additionally, no quantitative measurements were performed to evaluate sanitization effectiveness, time efficiency, or long-term reliability.

Another important limitation is the dependency on the physical organization of glove packaging. The system requires well-aligned and consistent glove bundles to function correctly, which depends largely on glove manufacturing and packaging standards. As a result, not all commercially available glove packs are compatible with the current design.

These open challenges provide valuable directions for future research and development and highlight areas where collaboration with medical institutions and manufacturers would be beneficial.

References

Centers for Disease Control and Prevention (CDC). (2020). *Gloves and hand hygiene*. https://www.cdc.gov/handhygiene/

Gould, D., et al. (2017). Impact of automated hand sanitizers on compliance rates in hospitals. *Infection Control & Hospital Epidemiology*, *38*, 123–130.

IGIN Technologies. (2020). *Automatic touchless glove dispensers* (Product White Paper). IGIN Technologies.

Igor, I. (2019). Automated glove dispensing systems for clinical hygiene. *International Journal of Healthcare Technology*, *15*, 120–128.

Kampbell, J., & Davis, L. (2018). Infection control models in healthcare settings. *Journal of Hospital Infection*, *99*, 23–30.

Roberts, K. (2016). Integrated sterile systems in operating rooms. *Journal of Surgical Innovation*, *23*, 45–52.

Smith, L. (2018). Notification systems for medical consumables. *Healthcare Technology Letters*, *5*, 89–94.

World Health Organization. (2009). *Who guidelines on hand hygiene in health care*. WHO Press.