Storage Locker Featuring Voice Activation for Visually Impaired

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Abstract: People who are visually impaired find it is challenging to temporarily store their precious or personal belongings to keep them safe. To improve their quality of life, visually impaired individuals need a storage locker equipped with assistive technology where they may store their valuables or personal items while they are at home or on the go. The voice-activated storage locker for the visually impaired individuals that is proposed in this study involve a voice recognition module, voice playback, a micro servo motor, and a braille keypad. With these integrated features, it will be easier for visually impaired individuals to operate the storage locker, which will boost its efficacy. A rotating mechanism would be activated by an electronic system built within the lock employing a servo motor. To make them easier for those with visual impairments to operate, standard storage locker types have been upgraded to include digital voice control. The results of a test conducted on 20 people with visual impairments showed that accurate passwords spoken by the user could lock and open the storage locker with an accuracy of up to 95%.

Keywords: Automation, Embedded system, Visually impaired person, Voice activate, Storage locker.

1. INTRODUCTION

A person with impaired vision is one whose vision is unable to function normally. Being blind or visually impaired presents several problems in society throughout one's life. They encounter a variety of challenges as they go about their regular lives. Depending on the severity of their visual impairment, a person with a visual impairment may find it difficult to do things that come naturally to a normal person. They receive less attention from society, though. A visually impaired individual typically lacks an adequate lockable cabinet or compartment system to store their personal items, whenever they are at home or on private property, a public indoor space (such as a mall, a hospital, a school, a place of worship, a train station, etc.), or a public outdoor space (such as a park, a beach, a playground, a restaurant, etc.). In fact, they require assistance from someone to store their stuff whether they are at home or away.

Most storage lockers currently on the market are primarily intended for use by people with normal vision, but they are not appropriate for use by people who are blind or visually impaired because the locker location and keyhole are difficult to see due to these individuals' limited eyesight issues. Additionally, the digital keypad used by locker systems lacks a braille pattern to allow those who are blind to input their password and verify it is accurate. Each digit on the keypad really has a braille pattern that can be read by those who are blind. To help them input their passwords correctly, they may feel the recognisable braille pattern of each digit. In addition, it was discovered that the security boxes available on the market lack playback voice features. A visually impaired user cannot be informed of the state of the boxes without the playback voice. In addition, there is no sign indicating the location of an inhabited locker or whether the door is locked or open for those who are blind. After the actions were completed, the user was not given the door lock/unlock status. In order to allow people with visual impairments easily control the storage locker even when they are elsewhere, this research proposes to create a voice recognition-based storage locker.

Literature review had been conducted on a series of storage locker available in the market nowadays. An automatic safety deposit box system [1] has been developed for the market. It offers the keyboard and the fingerprint sensor as two input options. This will increase the system's security level because each person's fingerprint is unique. However, because there is no indication that a person with vision loss can place their finger on the fingerprint capture module, this safety deposit box is not appropriate for them. A short message-based security box [2] employing an Arduino and GSM module was also developed in 2018. The advantage is that it will alert the user if the locker was being broken into. A locking system that uses a servo motor with memory and easy-to-adjust rotational angle. However, since the mobile device's GUI is difficult for visually impaired people to operate, it was not appropriate for usage by them.

There haven't been many applications lately that are specifically for visually impaired people. A Braille-

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E-ISSN: 2409-9694/22

based password entry method was created in 2017 [3]. It has a voice playback functionality and a braille label. A person who is visually impaired may easily discern the numbers thanks to braille labels, and the voice reading lets you know how the system is doing. However, it was suggested that this technology would eventually accept voice input. 2019 had seen the development of a voice-activated door interlock system [4]. It contains a voice input feature that makes it simple for someone who is blind to communicate. The MATLAB voice processing method has a drawback in that its recognition accuracy isn't as good. Theoretically, voice recognition offers customers a convenient way to access numerous applications by speaking to them directly [5, 6]. In fact, speech recognition technology can convert spoken words into printed text using machine learning and potent algorithms [7]. There are numerous voice recognition-based applications on the market right now [1-4, 8].

A voice recognition system for controlling electric household appliances [9] was established in the year 2020. A voice module called EasyVR was used. Both dependent and independent voice approaches are advantageous for this module. This design system makes extensive use of both techniques to imply in a variety of circumstances, including an independent technique for controlling household appliances by acknowledging the voices of many people and a dependent technique for controlling a safe deposit box by recognising the voices of a single person. The key drawbacks for this invention were the reduced identification accuracy and the limited simultaneous execution of 5 commands.

A voice-activated, password-protected locker [8], which is another locker device that is more comparable, was developed in 2019. The speech recognition VR2 module utilised by this system can recognise up to 15 commands. Since only 5 commands can be saved in this module, it can only be used in certain circumstances. Additionally, a voice-recognition-based remote control was also invented in 2019 [10], replacing VR2 module with the more advance VR3 module. The VR3 module has the benefit of being able to run 7 instructions simultaneously and having an integrated function that enables the execution of more than 7 commands. Consequently, it was determined that this module complies with the specifications of our suggested system.

To meet the demands of visually impaired persons, the suggested voice recognition and storage locker system should include features like a voice module (with voice recognition on more than 7 commands), voice playback speaker, servo motor, and a braille label keypad [11-13]. Using the qualities mentioned above as a foundation, a voice-activated storage locker system is created in this work to temporarily store the valuables or personal items of visually impaired users, enhancing their quality of life. The user will first be informed of the storage locker's status by a voice playback speaker when the storage locker is engaged. The user must correctly pronounce the pre-programmed password to open the locker. If necessary, they can also change the passwords. In this instance, the passwords were standardised to be 6 digits long. If the user's 6-digit password matches one of the pre-set passwords in the database, the storage locker will be unlocked. In the meantime, a voice playback speaker will notify each status, such as "password correct," "wrong password," "password change," etc., allowing users to know the status of the storage locker. The user must give the "clear" command to cause the servo rotating mechanism to lock the locker. As a result, the storage locker will return to its original position, which is locked.

The following describes how the paper is structured: The voice-activated storage locker system model is described in Section II, and the proposed voice-activated storage locker algorithm is covered in Section III. Results of several performance reviews are reported in Section IV. Section V will conclude with a few conclusions and future projections.

2. VOICE ACTIVATED STORAGE LOCKER MODEL

Figure **1** depicts the proposed voice-activated storage locker system paradigm. This calls for the usage of two input devices: a Braille label keypad device as an alternative for users to enter their password and a speech recognition module (voice to text converter) for voice input. The microcontroller analysed the voice, the speaker informed the user, and the micro-servo operated as a lock and unlock mechanism. However, the specifics of each block will be described as follows:

A. Voice Input Device

One of the input devices utilised to lock and unlock the storage locker is a voice recognition module. This

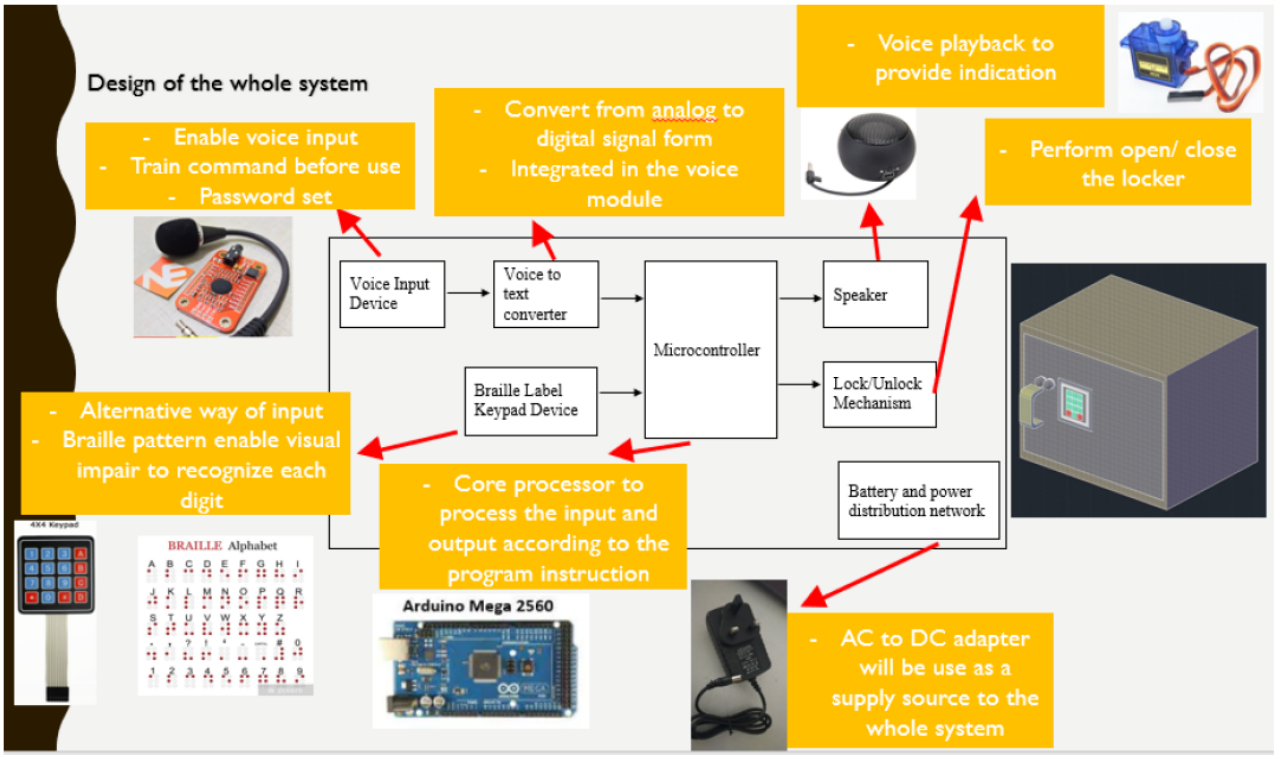


Figure 1: Voice Activated Storage Locker System Model.

module was utilised to perform the lock/unlock process as well as to store and detect a person's voice. Additionally, this module must perform voice training by picking up on a person's specific orders, and the trained commands must be saved in the database. When the user's voice matches one of the database's voice commands, the lock/unlock mechanism will be activated. A microphone, which transmits the user's spoken voice to the voice recognition module, is important part of a voice input device. There are many different types of microphones available in the market, this including condenser microphones, crystal microphones, dynamic microphones etc. The crystal microphone also has a high impedance and a poor frequency response. Dynamic microphones are directional, have a high mass, and are noise-free by nature. However, it is not appropriate for use in this project because it does not successfully reduce superfluous noise while giving louder voice input. However, this project cannot use it because of its low frequency response. The voice input's clarity might not be accurately reflected by this. A condenser microphone is found to be suitable for this project needs because of its low mass and shifting polar pattern, which enable it to better reject noises coming from the sides and back. Condenser microphone audio input rates range from 20Hz to 20kHz, and noise cancellation rates are 13dBA.

B. Voice Recognition Module

One of the input devices utilised to lock and unlock the storage locker is a voice recognition module. This module was utilised to perform the lock/unlock process as well as to store and detect a person's voice. Additionally, this module must perform voice training by picking up on a person's specific orders, and the trained commands must be saved in the database. When the user's voice matches one of the database's voice commands, the lock/unlock mechanism will be activated.

Furthermore, LD3320 module does not required any training or recording. Each character just needs to define properly in the program for identification purpose. However, this is not suitable to use in our project due to lower recognize accuracy (training not required) and supporting less commands. Oppositely, voice recognition V3 module as shown in Figure **2** features with 7 commands effective at the same time, higher recognition accuracy up to 99 percent, support both GPIO and serial port function and integrated function with support over 7 commands. Hence, this will be more compatible with our project requirement.

Figure 2: Microphone Voice Recognition V3 Module.

C. Arduino Mega Microcontroller

There are many different microcontrollers available in the market. The three most popular microcontrollers are the PIC, Raspberry PI, and Arduino MEGA. The capabilities of various microcontrollers vary and are entirely depending on the end-user application. These little microcontrollers do several tasks effectively. The cost-effectiveness of Arduino MEGA will be more than that of PIC and Raspberry PI. The Raspberry Pi runs on its own operating system and is completely self-contained. It is much suitable for usage in larger and more sophisticated programmes because it has HDMI connectors, an audio jack, a micro-SD slot, an ethernet port, and other features. But this is inappropriate for this project because installing the operating system is complicated (OS). The OS must first be downloaded and saved to your SD card before you can use it. This could be challenging for a beginner to operate, and the installation and configuration guidelines are unclear. The potential for overheating is still another negative. The powerful processor causes the Raspberry Pi board to heat up quickly. The sustainability factor is therefore not perfect.

The Arduino MEGA will be used in this project. One of the reasons for this is the inclusion of several GPIO pins. The features offered will provide solid support for this project. Additionally, when choosing this microcontroller, it is important to take into account the greater power input voltage. The microprocessor can operate with voltages between 9V and 20V. In fact, the amount of power input is crucial to this project because each component's average current and voltage requirements must be met for it to work properly. Additionally, the Arduino MEGA will act as the central processor, processing spoken voice and braille keypad input from the user before activating the locking mechanism.

D. Lock/Unlock Mechanism

For the storage locker to be locked and unlocked, the locking mechanism is a requirement. Instead of a solenoid, a micro servo motor will be used as the locking mechanism. There are several factors at influence, including accuracy, economics, voltage ratings, etc. Micro servo motors are employed to lock and unlock storage lockers quickly, precisely, and flexibly. The design of the locking structure allows for the setting of a specific value for the degree of rotation. Additionally, it is inexpensive and appropriate for usage in a variety of applications. It is also easily controllable using Arduino software because it is integrated with the Arduino library. Contrarily, solenoid has various drawbacks that make it unsuitable for application. When the input voltage is too high or too low, the solenoid will encounter issues. It will have an impact on whether the magnetic field is strengthened or weakened. In addition, it required a larger input voltage than the 6V or 12V micro servo motor. A tiny servo motor requires only 5V to function, which makes it more energy efficient than a solenoid. Another benefit of micro servo motors over solenoids is their flexible programming. For example, it can be turned on and off as needed to produce the best possible voltage distribution. As a result, the other component that it interacts with can receive a voltage that is sufficient.

A locking mechanism in the storage locker consist of a lock jamb and a servo motor-based door hinge were present Figure **3**. The lock jamb, which is made of durable metal and has a "L"-shaped design that serves as a dead bolt when the storage locker is locked, is made. In this situation, there may be a selection of locking mechanisms available for the storage locker system. An integrated locking mechanism and a modular locking mechanism are the two most common types of locking mechanisms used in a storage locker (conventional lock). For direct locking and unlocking of the storage locker's lock jamb, an integrated locking mechanism combines a lock tumbler with intermediary components. This type of locking mechanism is frequently utilized in safety boxes.

On the other hand, a modular locking mechanism differs from an integrated locking mechanism in that the lock tumbler is directly connected to the gear (with a well-set coding). Typically, a plug is found inside the cylindrical chamber of a modular locking mechanism. The tumbler can be turned if the proper key sequence was used to insert it. In practice, the two different locking mechanisms can be combined in the storage

(**a**) (**b**)

Figure 3: Locking Mechanism (**a**) Lock jamb (**b**) Servo motor-based door hinge.

locker's locking design. The conventional kind, which is a modular locking mechanism, can be conceptually developed in the suggested design system to become a digitally based locking mechanism. In this case, a servo motor was used in place of the usual locking mechanism. In a traditional lock, a key had to be inserted into the cylinder lock structure. A user needs the proper key pattern and a small bit of force to lock or open the locker.

The only requirement for a digital lock structure, such as a servo motor, is a little amount of power to turn the tumbler to lock or unlock the storage locker. The servo motor was chosen for the suggested storage locker system because it can be utilized as a locking mechanism, has an adjustable degree of rotation, and an attach and detach function (benefits for power distribution). By selecting the required degree of rotation, the operating principle is greatly simplified. The locker's degree of rotation was often set at 90 degrees, the perfect angle for locking and unlocking. Initial positions for the servo motor were 0 degrees (locking state) and 90 degrees (unlocking state) (unlock state). When the servo motor rotates 90 degrees, the tumbler will move upward (clockwise direction), releasing the locker. The tumbler will return to its starting angle of 0 degrees to lock the locker.

E. Battery and Power Distribution Network

The power supply is the main concern because it gives the entire system its voltage and current. They come in a few different varieties, including AC to DC adapters, non-rechargeable batteries, and rechargeable batteries. A good non-rechargeable battery, like those used in Automated External Defibrillators (AED), will last a long time, but once it is exhausted, it cannot be used again, which could be bad for the environment. Furthermore, when a battery is running short on power, it can be recharged. However, there are still drawbacks, such as its short recharging time, unstable voltage under low power, and propensity for downtime. Due to its constant voltage and built-in voltage regulator, the AC to DC adapter (9V/1A) that connected to an AC power socket was chosen as the project's power source. As a result, the entire system will receive a comparable distribution of voltage and current to ensure continuous power supplies without much interruption.

F. Speaker

Speaker is crucial for visually impaired. They will be given notification of the locker system's state due to the speaker's presence. Active speakers and passive speakers are the two types of speakers now available on the market.

An amplifier is not present in a passive speaker. To function properly, it relies on external amplifiers and receivers, which can be more difficult than using active speakers because there are so many additional variables that could affect its performance. Multiple connections and components, like receivers or subwoofers, are supported with this type of speaker system, which is one of the benefits of these speakers. In addition, the replacement is simpler. The disadvantage of a passive speaker is that it uses a lot more power than an active speaker. Additionally, signal loss will be happening since if one speaker isn't working properly, the performance of the entire system may suffer. For the speaker to work properly, external parts like amplifiers and receivers must be interference-free and working flawlessly.

An active speaker has a built-in power amplifier. So, it is ideal for PCs, laptops, tablets, and other devices because all you need to do to receive sound is plug it in through Bluetooth or a line-in connection. It is possible to produce a high-quality sound without using any additional amplifiers or tweeters. This active speaker's benefit is that no additional parts, such as receivers or amplifiers, are required. An amplifier's adjustability and sound quality are correctly optimized. However, the music will be much clearer because the signal goes through crossover before it gets to the amplifier. Furthermore, this kind of speaker only consumed a small amount of electricity.

The use of an active speaker is proposed. Active speakers have the benefit of not requiring additional parts like receivers or amplifiers. This is an advantage of using active speakers for our project. In fact, the entire circuit will be highly intricate and require more GPIO pins if additional components like receivers or amplifiers are necessary. However, because the receiver or amplifier consumed a lot of power, it will typically require a secondary supply voltage. Additionally, sound and amplifier adjustments are correctly tuned. Therefore, there won't be a problem with signal loss. However, the sound will be much clearer because the signal goes through crossover before it gets to the amplifier. Furthermore, this kind of speaker only required very little power which is suitable as the required voltage for the speaker to power up is 3.7V.

G. Braille Label Keypad Device

The braille keypad's main function is to make it easier for the visually impaired to enter passwords, to back up the voice recognition module in case the voice recognition part not functioning well during password speaking stage. Each digit on the keypad has raised dots that reflect a different braille pattern. There are two different types of keypads available on the market: 4X4 keypads and 4X3 keypads. The special characters and numbers in the 4X3 keypad are the same as those in the 4X4 keypad, however the HEX digits are an exception and are not suited for usage because an additional HEX key is needed to implement other functions.

On the other hand, it is frequently utilized in 4X4 keypad for any application that needs HEX digits. Additionally, special characters denoted by "*" and "#" can be found together with the numbering key from 0 to 9. With its ability to address the primary flaw of the 3X4 keypad, this will be a better choice for the proposed system. In addition, braille's raised dots make it simple for those who are blind to distinguish the numbers and alphabet on a keypad. As a result, the proposed system now includes a 4X4 keypad with braille labels.

3. VOICE ACTIVATED STORAGE LOCKER ALGORITHM

Following is a detailed discussion of the proposed voice activation algorithm for the storage locker system:

Step -1: Setting up Word-Bank Database for the Password:

The necessary commands must be trained during this phase of training for the speech recognition system to pick them up. As a result, three concepts-sampling, quantization [14], feature extraction and matching [15]-are used throughout the training phase. Therefore, a spoken time of 1500ms can be stored in each command database. To boost the recognition accuracy of the commands, each command was trained up to twice. 13 commands were pre-programmed into the voice recognition module's word bank database during this phase. The commands that are available are: (0) Zero, (1) One, (2), Two, (3), Four, (4), Five, (5), Six, (7), Seven, (8), Eight, (9) Nine, (10), Change Password, Enter, and Clear (12). Additionally, the user can only set passwords that are up to 16 digits long because that is the length of the password storage mechanism.

Step 0: Setting up Password:

This password system introduced a standard-length password of six digits. In this instance, the software has three components: the *Initial Password* set, the *New Password 1* set, and the *New Password 2* set. As a result, the user can configure the system to utilise their preferred six-digit password. P=[**x**], where **x** is an array used to store the number of digits used as passwords, is the equation used to describe the *Initial Password* set condition. The following six-digit password string would be stored in the array [**x**]:

$$P= [x0, x1, x2, x3, x4, x5] \quad (1)$$

The same principle also applies to the *New Password 1* set, abbreviated as NP1, and the *New Password 2* set, abbreviated as NP2, where the password length is set at six digits, expressed as follows:

$$NP1 = [x0, x1, x2, x3, x4, x5] \quad (2)$$

NP2= [x0, x1, x2, x3, x4, x5] (3)

Step 1: User Input:

The user can enter the initial set command to access the storage locker after the system has been activated. To verify the 6-digit password, the voice command "Enter" must be used after the password has been input. Additionally, if a user wants to change their password, they can use the "Change password" command, in which case the system will prompt them for a new password and need them to confirm it a second time. The password will successfully change whenever the provided password matches the specified password. At first, the system will continue to wait for the user to speak. The user is requiring to speak their password digit by digit at a 1.5 second distance time gap. As a result, the spoken digit will be divided into six individual blocks. Equation for the six digits index blocks written as follows:

Index [6]: [x0], [x1], [x2], [x3], [x4], [x5] (4)

Step 2: Voice Signal Matching:

Mel-frequency cepstral coefficients (MFCC) feature extraction technique [15] is used in the voice signal matching process. The powers of the spectrum of the input blocks are translated onto the Mel scale by applying the Fourier transform to a signal and using triangle or cosine overlapping windows. The discrete cosine transform of the list of Mel log powers is then calculated. As a result, the amplitudes of the final spectrum were created. The system will check the newly entered password with the user's predetermined password that is stored in the database. The original password had six digits. The microcontroller will indicate to the speaker and the return statement will be "Password correct, door open" if the user speaks up to six digits and the six digits match the predefined password recorded in the database. If so, Step 3 (Opening the storage locker lock) will be performed. Contrastingly, If the password entered does not match the predetermined password that is saved in the database, the speaker will say, "Wrong password, please input again," and the user will be taken back to Step 1. Equation for representation written as follows:

Predefined password: P = [7, 2, 4, 6, 8, 5] (5)

User input password: Index [6] = [x0, x1, x2, x3, x4, x5] (6)

(Note that although the first password is established correctly, it can be changed, if necessary, by the user.)

The password verification was done by comparing the **Predefined password** and **User input password**.

If Index [] <= 6 && P [7, 2, 4, 6, 8, 5], Password matched.

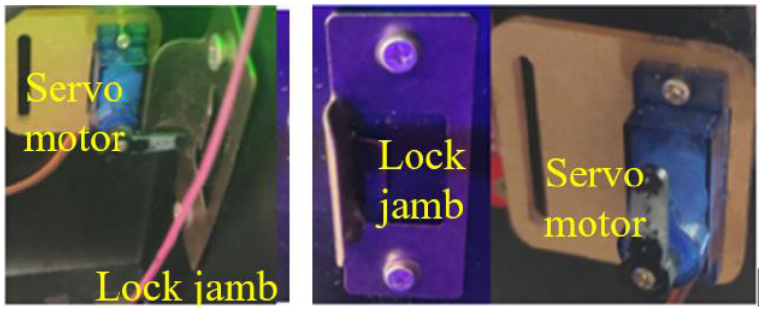
Return status: “Password correct, door open”. Proceed to **Step 3**.

If Index [6] ≠ P [7, 2, 4, 6, 8, 5], Password Wrong

Return status: “Wrong password, please enter again”. Back to **Step 1**.

Step 3: Lock Open/ Close:

The storage locker would be locked and unlocked by a servo motor. The IR sensor was initially turned off, and the servo motor was in its default setting of 0 degrees. The lock state is represented by the starting setting of the servo motor, which is 0 degrees. The servo motor will turn 90 degrees clockwise to unlock the storage locker door if the 6-digit input password is correct. In addition, the command "clear" locks the storage locker again. This indicates that the servo motor will rotate in the opposite direction, or 0 degrees, to lock the storage locker, when the user delivers the "clear" instruction. The lock/unlock structure was shown in Figure **4**.



(**a**) (**b**)

Figure 4: Lock structure (**a**) Locked state (**b**) Unlocked State.

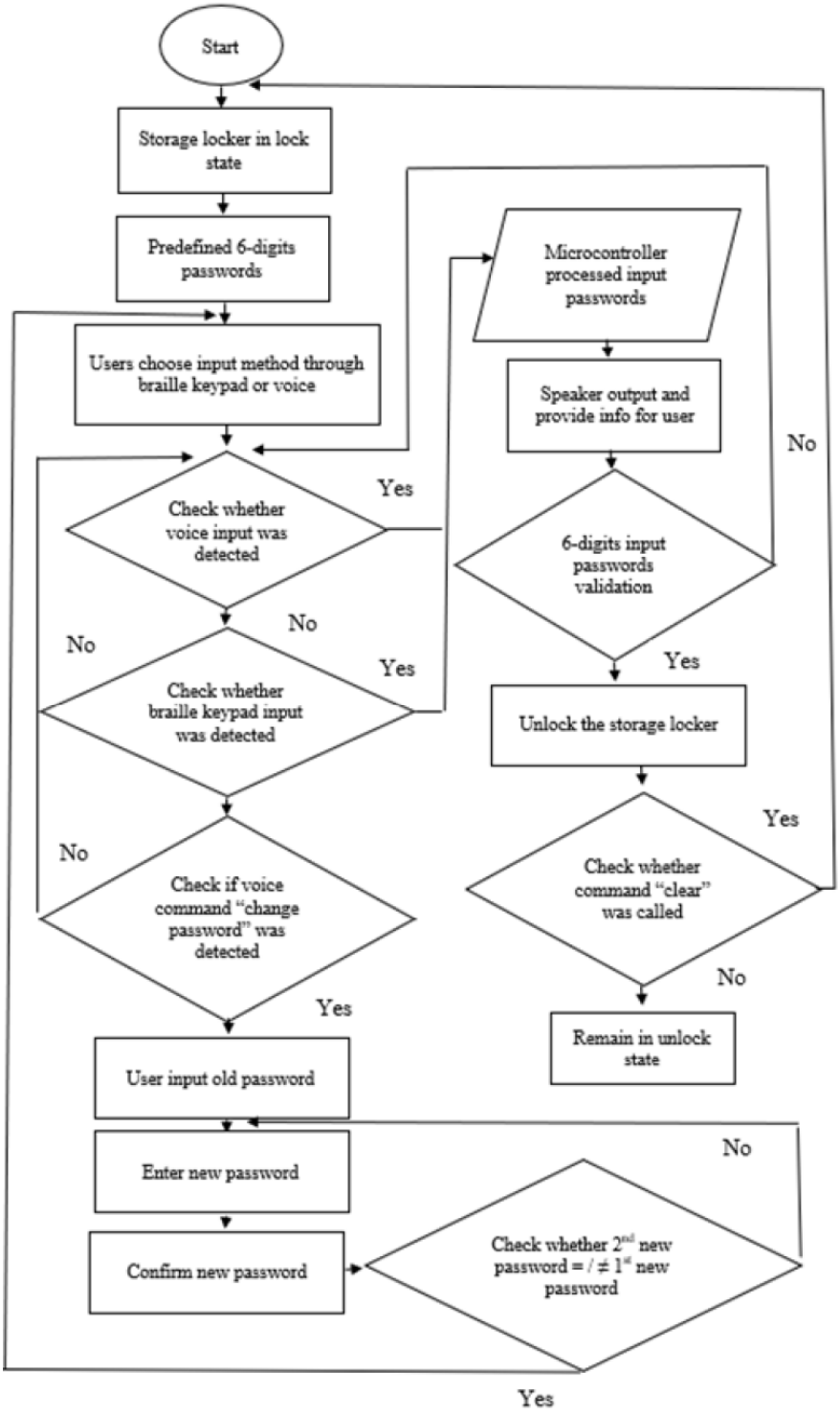


Figure 5: Flowchart for the Voice Activated Storage Locker Algorithm.

The overall flowchart for the working algorithm is shown in Figure **5**.

4. PERFORMANCE EVALUATION

This section discusses the performance reviews of the voice-activated storage locker. As depicted in Figure **6**(**a**), the voice-activated storage locker prototype is constructed. The prototype storage locker is 31.5 cm in length, 24 cm in width, and 25 cm in height. To assess the effectiveness of the voice-activated storage vault, an experimental test was conducted. Users are asked to voice activate a 6-digit password during the experiment, and the voice

(**a**) (**b**)

Figure 6: (**a**) Voice Activated Storage Locker (**b**) Visual impairment person.

activation system manages to recognise correctly spelt passwords and activate the locking/unlocking mechanism. As a result, this is taken into account successful cycle. As seen in Figure **6**(**b**), a test was performed on a person with vision impairment.

Twenty visually impaired individuals were asked to test the voice-activated storage locker's functionality. For evaluating performance, the experiment involves 1,000 random locking/unlocking cycles (each participant who is visually impaired receives 50 random locking/unlocking cycles). 25 randomly selected unlocking cycles and 25 randomly selected locking cycles were examined. 900 of the 1,000 tested instances had a positive outcome. According to the results, the storage locker can lock and unlock with up to 95% accuracy when detecting voice passwords.

To further analyse the failure in voice activation scenarios, the Confusion Matrix is used. The four potential outcomes are listed in Table **1** as follows:

Situations involving false positives (FP) and false negatives (FN) are given particular attention because they are the most frequent failures to thoroughly explore. The FP + FN failed voice password recognition cases include instances when a false positive occurred. The user-specified spoken digit will also include other digits, according to further research into these False Positive cases (FP). For instance, "4" will be added if the spoken digit is "7". The mitigation method was developed by clearly defining the UART pins for both the input voice module and the training phase, which are "Serial 1 and Serial 3," to further debug this scenario. Each voice module can now

Table 1: Confusion Matrix of Voice Activated Failure Analysis Cases

Outcomes	Meaning
True positive (950)	The predicted voice password is correct, and it is the correct user inputted password.
True negative (41)	The predicted voice password is incorrect, and it is the incorrect user inputted password.
False positive (0)	The predicted voice password is correct, and it is the incorrect user inputted password.
False negative (9)	The predicted voice password is incorrect, and it is the correct user inputted password.

recognize its own digit, which was properly programmed throughout the training procedure.

Subsequent inspection carried on the False Negative (FN) instances shows that the spoken digit by users cannot keep pace because of the user's low voice input and the speech recognition V3 module's inadequate sensitivities, but this is an infrequent situation. As a mitigation strategy to prevent such failures in the future, increase the values of the resistor/capacitor pair in the circuitry that amplifies the spoken signal would be a better choice.

Three questions about the usability of the voice-activated storage vault were posed to the visually challenged participants on a Likert scale, as shown in Table **2**.

The study discovered that visually impaired people who need to temporarily store private or important goods can benefit greatly from the voice-activated storage locker system. This is because most survey respondents provided favourable feedback, scoring agree or strongly agree with more than 80% of respondents, according to the Likert scale. However, 20% of participants are not interested in using this voice-activated storage locker due to the smaller size of the locker and the restricted quantity of goods that may be stored. Some of them also think that the storage locker was tough to utilise in an emergency due to the complicated passwords. The participants who are blind also made a few improvements to the current voice-activated storage locker system:

1. In urgent situations, emergency voice commands could be introduced to make it easier to unlock the storage locker.

2. Increasing the capacity of the storage locker.

3. Mic sensitivity and accuracy need to be increased.

5. CONCLUSIONS AND FUTURE RECOMMENDATIONS

A voice-activated storage locker for the visually impaired was demonstrated in this work. The goal has been accomplished when the storage locker system involves a voice recognition module that can recognize the user's spoken digit passwords, a braille keypad that can be used as an alternative input for passwords, a feedback speaker that can help users use the system, and a locking mechanism to lock and unlock the storage locker door. The results of a test conducted on 20 people with visual impairments showed that accurate passwords spoken by the user could lock and open the storage locker with an accuracy of up to 95%. In addition, a poll of them revealed that over 80% of those with visual impairments approve of the usefulness of this voice-activated storage locker system.

On the other hand, a confusion matrix was used to examine the failed root cause and augmentation strategies were proposed. Future sensitivity and accuracy will have an impact on how useful this storage locker system is. As a result, the research study for the software component may now concentrate more on the voice detection algorithm, and a high-quality microphone can be placed to completely remove the potential of low and high inherent noise input. The size of the storage locker can be increased for the hardware component, and the storage locker can be constructed using firmly anchored materials. Additionally, a solenoid can be used to replace the locking mechanism, providing a more stable lock, and making system break-ins more difficult.

The visually impaired participants in the experimental study have also suggested a few improvements to the current system of storage lockers, which includes: It would be more beneficial for the visually impaired if additional "Emergency" voice commands could be included to unlock the storage

Table 2: Usability Survey Data Carried on the Voice Activated Storage Locker

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1 The storage locker was easy to use	0 Persons	0 Persons	2 Persons	12 Persons	6 Persons
Q2 The voice activation system helped me lock/unlock the locker easily	0 Persons	1 Persons	2 Persons	11 Persons	6 Persons
Q3 I would use this storage locker for putting my personal/valuable belongings	0 Persons	2 Persons	2 Persons	11 Persons	2 Persons

locker in emergency situations. Additional training phases can be incorporated into the system to make it dependent in nature. This means that the system cannot recognise the voice of a group of people. As a result, locking and unlocking the storage locker without disclosing the passwords will be safer for the user. As the existing microphone on the voice recognition module V3 was occasionally confused of the uttered digits by the user, the brand of mic needs to enhance or further analysis on the mic sensitivity/accuracy is needed. Further investigation into the field of speech detection algorithms was encouraged to attain the effectiveness and accuracy of the user's voice input. Future works will address each of them.

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Received on 24-08-2022 Accepted on 20-09-2022 Published on 02-10-2022

DOI: https://doi.org/10.31875/2409-9694.2022.09.05