Final Report

Phase: 5
Course: EECS 4441
Professor: Melanie Baljko
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Design Brief

At the beginning of the course project, our priorities were in a state of disarray. For Phase 1, we focused on the “Develop” phase of the double diamond model. This lead to us generating possible solutions to a non-existential problem. Some of these ideas included a motorized trash can, motorized chalkboard, to name few. After realizing that we were on the wrong end of the double diamond model, we decided to step back and figure out a number of problems for which we could design a solution for. At that point, we noted that the ideas we generated before all fit into one underlying domain: assistive technology.

Problem Statement

In today’s society, people with disabilities have come a long way in terms of gaining their independence with the help of assistive devices. However, there is still a long way to go as there are still tasks for which an assistive device does not exist or is too expensive for people to buy. The accessibility-first approach is hardly undertaken by companies when designing products. This can be attributed to a very high cost associated with performing market research and producing prototypes. As a result, people with disabilities usually take a backburner to the company’s goals. This makes for products that offer a very subpar user experience for people with disabilities.

One such example of a subpar user experience for those with involuntary hand movements would be to open a locked door. The traditional method would be to stick a key in a keyhole, and to turn it after to unlock a door. There also exist other methods such as using a RFID card or a PIN code, however they all require some level of hand-eye coordination. People with physical disabilities, specifically those with involuntary hand movements, such as cerebral palsy or Parkinson’s disease, suffer from poor hand-eye coordination and cannot partake in such methods. Seeing that there were not many solutions to overcome this challenge, we thought it might be a problem worth solving.

Objective

The objective for our project is to create a digital artifact that allows those who have a disability or disorder that strictly causes involuntary body movements, gain independence in an everyday task. The everyday task that we focused on is opening a locked door.

This digital artifact encompasses the whole accessibility-first aspect in its design. As previously mentioned, when companies design a product, they tend to focus on the needs of normal user first, accessibility issues are usually the least of their concerns. As learned in a previous course, companies usually do accessibility testing to meet general guidelines set forth by a governing body. With considering accessibility first, not only can the solution benefit those with involuntary hand movements, it can also benefit normal users. An example of such a device is a wheelchair ramp. It was originally designed for helping people in wheelchairs bypass stairs, however nowadays even normal users benefit from it.

Success Criteria

Generally speaking, the solution would be an intuitive, efficient and automated device that has a small learning curve. Furthermore, we hope that after development, the solution can also operate under stressful conditions and be readily available for use. Listed below is the type of evaluation to undertake and the data we collect to see how successful we were in meeting the success criteria mentioned above.

Evaluation Type: Controlled Setting

- Good at revealing usability problems
- Results can be generalized to the wider population

Method: Usability Testing

- Involves investigating how users perform on typical tasks
- High level of control over what gets tested
- Semi-structured interviews will be used to elicit users' opinions

Quantitative Performance Measures

- Time to complete a task. (Efficiency)
- Number and type of SYSTEM errors. (Effectiveness)
- Number of users completing a task successfully. (Utility)

Proposed Solution

We propose a solution which aims to solve the problem mentioned above. It prioritizes the needs of users with involuntary hand movements, and reduces the cognitive and physical work for some task. Not only do these benefits cater to those with involuntary hand movements, they extend to normal users interested in an easier and secure alternative. Our solution is to make a two-step verification system that can be used to unlock and open a door with no user interaction with a door. The two technologies required to make this system work are facial and passphrase recognition. Both help verify that it is indeed the correct user wishing to unlock and open a door, and also solidify the security of the system. As mentioned before, the benefits of this system for people with disabilities are pretty obvious, however, the benefits don't just stop there. The system also helps people from a cognitive standpoint by not having them to remember to bring a key with them. Furthermore, the system also reduces the physical stress undertaken in such a task, since users do not need to waste time look for a key in their pockets or handbags. This can be extremely cumbersome for people who are carrying groceries for instance.

Technical Specification

Graphical User Interface (GUI)

The user is presented with a graphical user interface to indicate the four states of the system with prompts and icons. The first state is a welcome state which greets the user when they approach the system. The second state is the facial recognition state, where an external application opens to verify, by using the registered person's face, that they want to unlock the door it is attached to. The third state is the passphrase verification state, where a passphrase is used to verify that it is, as before, a registered user wishing to unlock the door. In the final state, a signal is sent to the locking mechanism to unlock the door, indicating to the use that they are free to enter. The prompts and icons are updated based on each state and outcome after attempting to verify the user, and each user is given four attempts for the second state (facial recognition) and the third state (passphrase recognition). If all the attempts are exhausted, the device is locked for a minute.

Facial Recognition

The facial recognition module was implemented using the OpenCV Computer Vision library. This library is available free-of-charge and is supported by many programming languages. The programming language used to implement facial recognition module was Python.
The program is divided into three stages: dataset creation, training, and face detection. In the dataset creation phase, the user puts their face in front of the camera so that pictures can be taken for the purposes of building a dataset from which the program can train on (see Figures 1, 2, and 3). When the dataset creation phase is complete, the pictures are processed by the algorithm and an training file is created. This training file is utilized in the last step: detection. This is the main step used to recognize and verify faces based on the training data in the previous step. If the program is able to recognize the face from the training file, it accesses the person's name from a database and displays it as a way to indicate that a match was found. Furthermore, the user is now authorized to proceed to the next phase. If the user's face does not exist in the training file, the word 'Unknown' is displayed. As an aside, the user has to put their face in front of the camera for eight seconds before the algorithm makes a decision whether or not the person is a verified user.

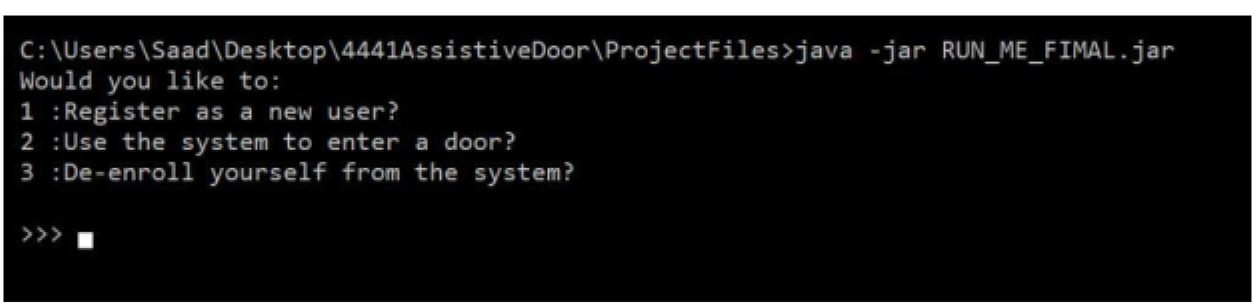

Figure 1: Shows the first prompt when the main program is run.

Figure 2: This input box allows the user to enter their name when they enroll into the system for the first time.

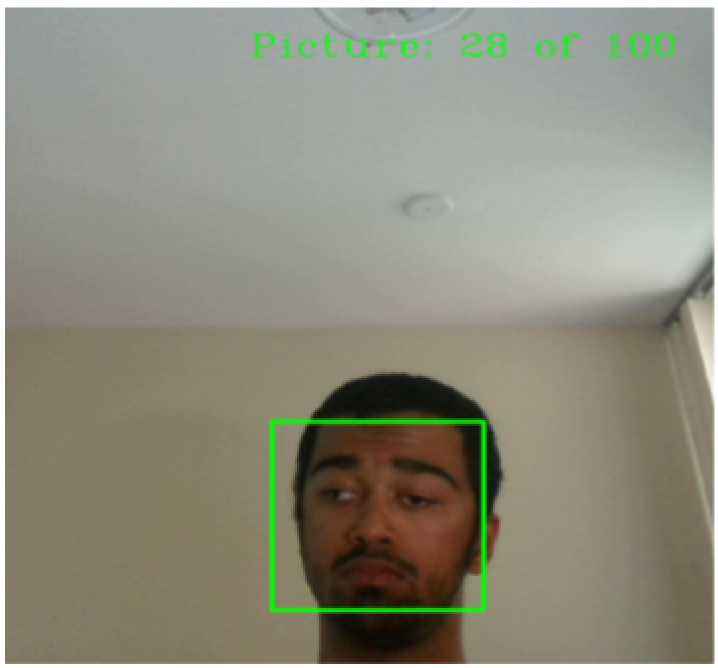

Figure 3: The system then takes 100 pictures of the user's face and builds a dataset for recognition purposes

Passphrase Recognition

The passphrase recognition module was implemented using a custom-made sound recorder class and Microsoft's Bing Speech API. The name of the verified face is passed to this module and the module retrieves the correct passphrase from the system storage. The sound recorder class is then used to record the passphrase of the active user. A .wav file is created and is sent to the Microsoft Azure server using the Bing Speech API. The server then returns the text that was parsed from the .wav file. Both texts are compared, and if they match then the user may proceed with the system (see Figures 4 and 5 for voice recognition setup).

```
C:\Users\Saad\Desktop\4441AssistiveDoor\ProjectFiles>java -jar RUN_ME_FIMAL.jar
Would you like to:
1 :Register as a new user?
2 :Use the system to enter a door?
3 :De-enroll yourself from the system?

>>> 1

Facial recognition is all set up!

Now working on the Voice Recognition

This process will repeat 3 times. Say the same passphrase
Each recording session lasts 5 seconds


1 of 3
Start capturing...
Start recording...
Finished
```

Figure 4: Once the facial recognition enrollment phase is complete, control is passed over to the voice recognition module. Here, the user says a passphrase three times. Each recording session lasts 5 seconds.

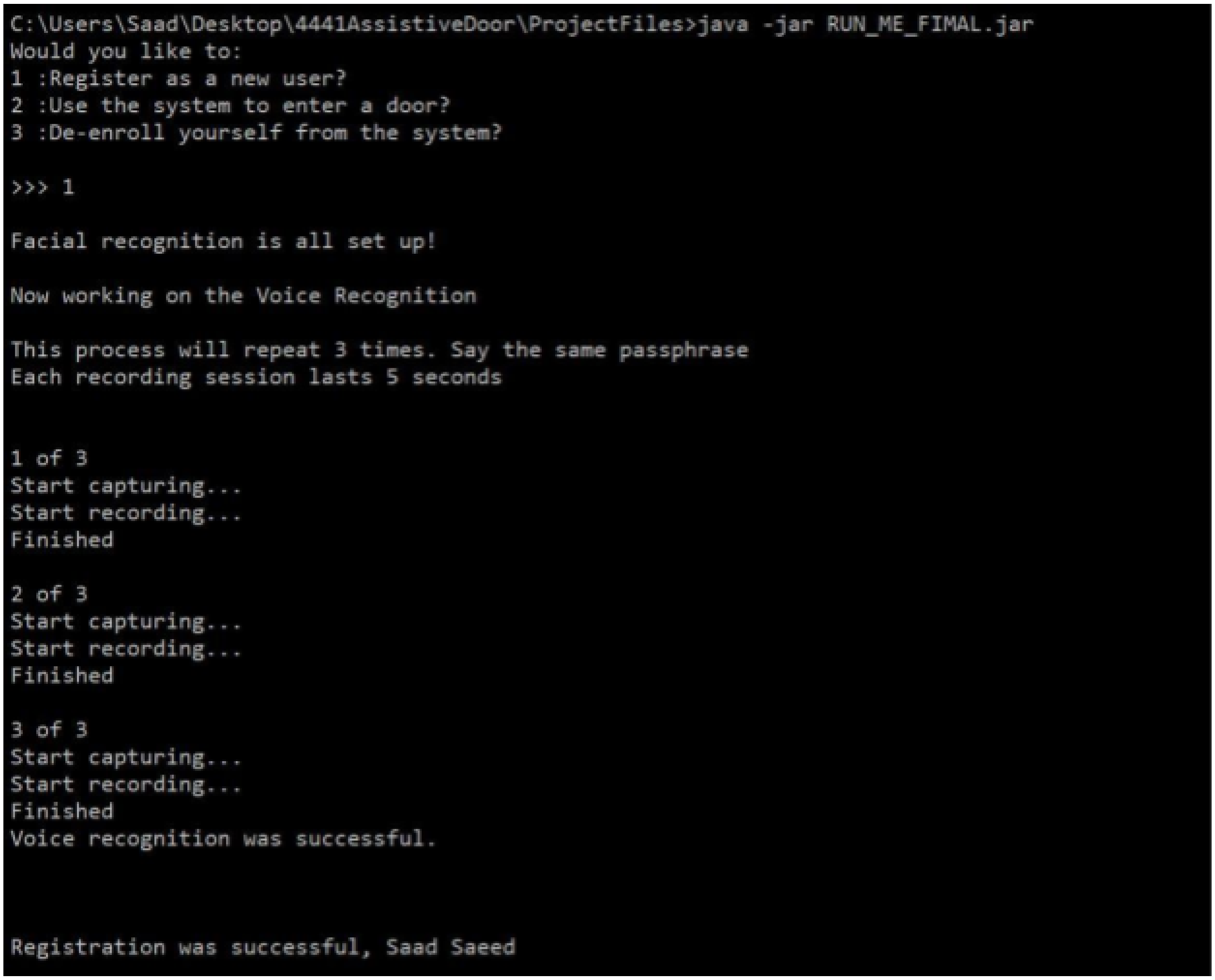

Figure 5: Once the final step of voice recognition enrollment is complete, the user is prompted that enrollment as a whole, completed successfully. Now the user is allowed to use options 2 and 3 from the first prompt, i.e. use the system to unlock a door or de-enroll themselves.

Hardware

This system can be run on any operating system, and this may affect the system's performance. For optimal results, it is better to run the system on a Windows machine with good hardware. The other components required are a webcam and a microphone. For this project, we ran it on a Raspberry Pi with a Raspberry Pi camera module and a USB microphone, where some minor modifications need to be made to the operating system's configuration. For instance, to mount the camera we had to execute a command on Terminal, and to use the USB microphone we had to change a system configuration file.

Caveats

Both recognition technologies encapsulate the idea of a model to provide security. Each model is made up of data consisting of a user’s face, and a passphrase attached to that user. For the accessibility aspect, both technologies do not require the use of hands. With respect to every user, this system will act in the exact same manner for everyone regardless of whether the users have a disability or not.

User Profiles

1. **Person with a Permanent Physical Disability**
   A person with a permanent physical disability, such as cerebral palsy, has limited-to-no-control over at least one of their limbs. As a result, they require the use of assistive devices to complete tasks that require precise movements, such as drinking liquids. If there is no assistive device available, they usually ask someone else-a normal user-to perform that task for them. As a result, they usually lack the independence that a normal user would take for granted. Furthermore, they are very crafty at discovering new ways of figuring out how to approach practical problems from different angles due to the fact that their disability has afforded them with opportunities to try something new.

2. **Person with a Neurological Disorder**
   A person with a permanent neurological disorder, such as essential tremor, experiences uncontrollable shaking in different parts and on different sides of the body. The areas affected often include the hands, arms, head, larynx (voice box), tongue, and chin. The lower body is rarely affected. Most people are able to live normal lives with this condition -- although they may find everyday activities like eating, dressing, or writing difficult. As a result, they require the use of assistive devices to complete tasks that require precise movements.

Use Case Scenarios

Main Course

1. The user approaches the facial recognition system.

2. The system’s camera detects a face in its perception.
3. The system’s first LCD icon changes colour to dark gray to signal to the user that it is active. Furthermore, the user is prompted to position their face in front of the camera (see Figure 6).
4. The system automatically scans the user’s face for 8 seconds (see Figure 7).
5. The system processes the image and searches for a match in the database.
6. The system’s second LCD icon changes colour to dark gray to signal and shows a “smiley face” to indicate to the user that there is a match. Furthermore, the user is notified that the microphone is being turned on for voice recognition (See Figure 8).
7. The user will say their five-second phrase to the microphone (see Figures 9).
8. The system parses the words and searches for a match in the database.
9. The system’s third LCD icon changes colour to dark gray to signal to the user that there is a match.
10. A signal is sent to the locking mechanism to unlock the door (see Figure 10).
11. The system’s fourth LCD icon changes colour to dark gray and shows an “unlocked lock” to signal to the user that all the requirements are satisfied and that they are free to enter (see Figure 11).

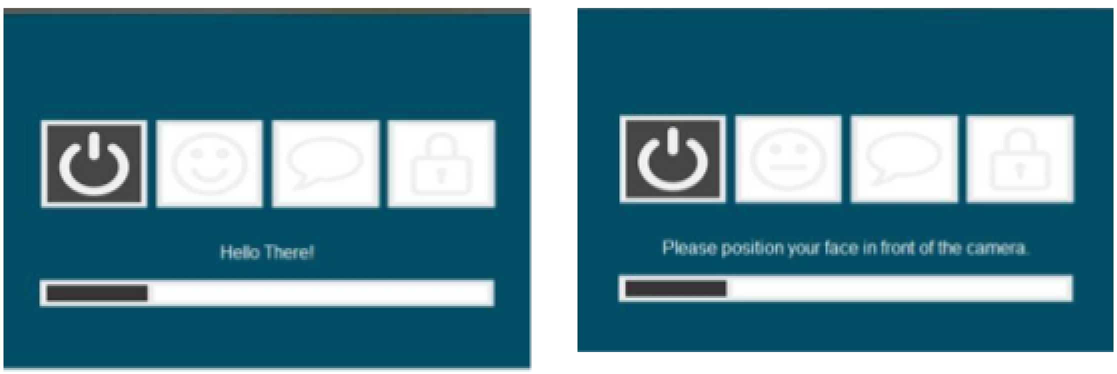

Figure 6: This shows the states of the Graphical User Interface (GUI) when someone approaches the system from a distance

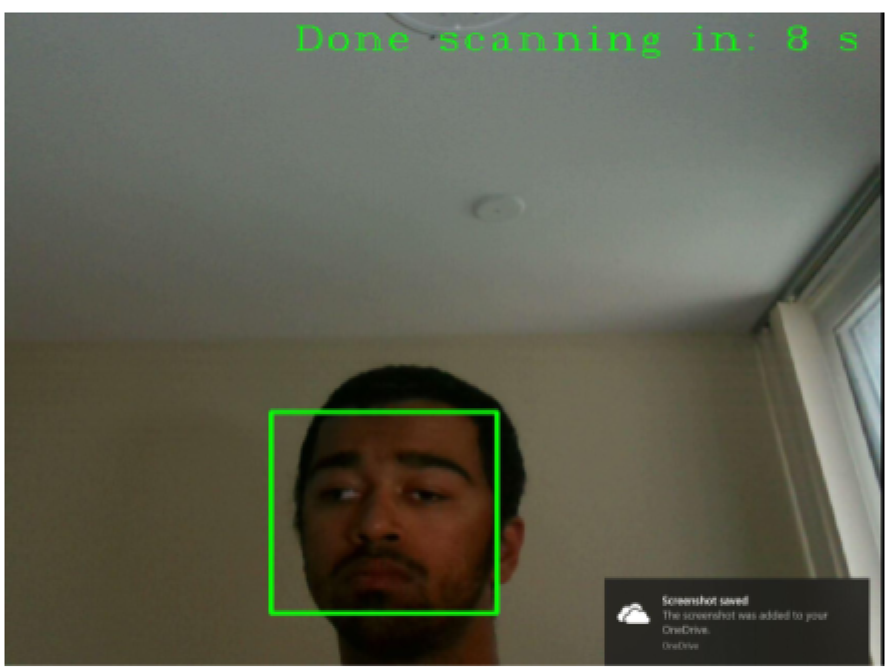

Figure 7: This shows the program scanning the user’s face for a potential match.

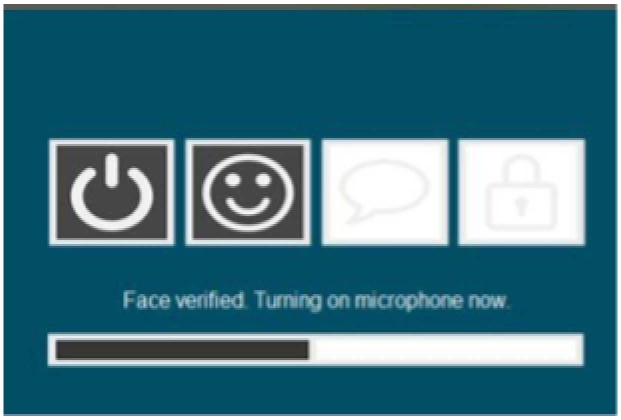

Figure 8: Shows the state when the face is verified.

Figure 9: The user says the passphrase within 5 seconds.

Figure 10: Shows the state of the GUI when there is a passphrase match.

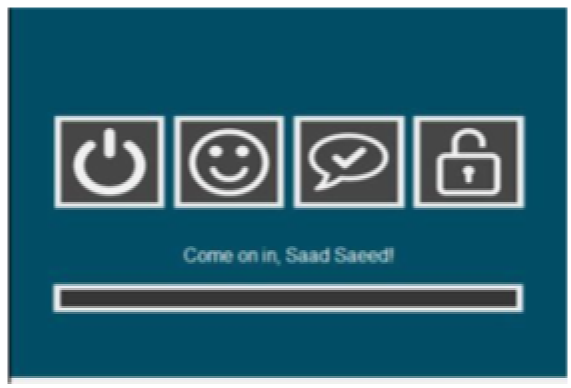

Figure 11: The user is prompted to enter once everything else passes

Alternative Courses

6. If a facial match cannot be found in the system:
    6.1 The second LCD icon turns red and shows a "sad face" to indicate invalidity of the user (see Figure 12).
    6.2 If all four attempts are exhausted:
        6.2.1 The system locks up for one minute (see Figure 13).
        6.2.2 The system returns to step 2
    6.3 If all four attempts are not exhausted:
        6.3.1 The system returns to step 3
9. If a passphrase match cannot be found in the system:

9.1 The third LCD icon turns red and shows a speech bubble with a “X” mark to indicate invalidity of the user (see Figure 14).

9.2 If all four attempts are exhausted:

9.2.1 The system locks up for one minute (see Figure 13).

9.2.2 The system returns to step 2

9.3 If all four attempts are not exhausted:

9.3.1 The system returns to step 7

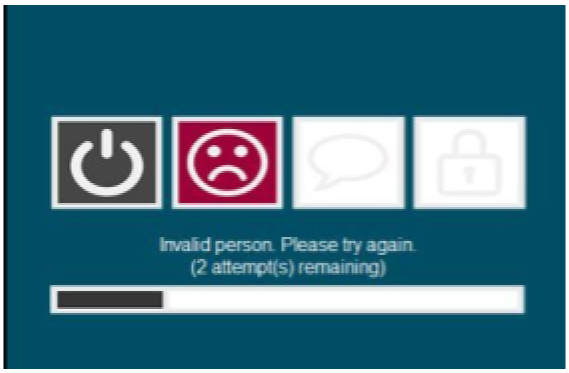

Figure 12: Shows the state of the GUI when the user’s face isn’t verified.

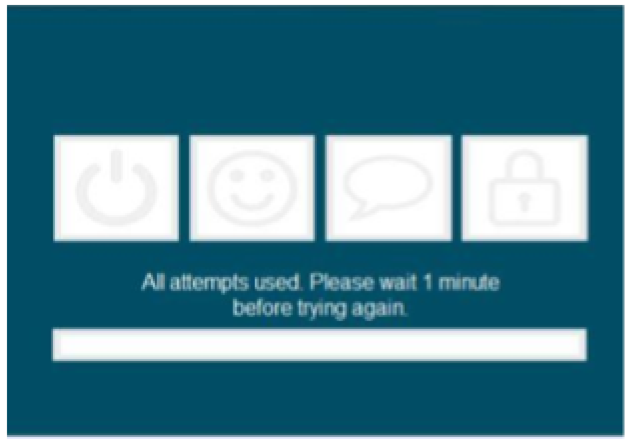

FIgure 13: The system locks up for one minute once the user exhausts all their tries.

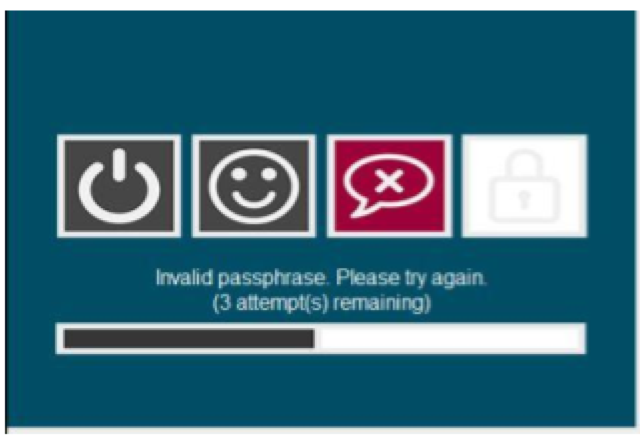

Figure 14: Shows the state of the GUI when the system cannot validate the passphrase

Empirical Question

Our empirical question is stated as follows:

> *For people with involuntary hand movements, is the two-step verification system a quicker way of unlocking a door when compared to the traditional method of unlocking a door?*

Answer to Empirical Question

The data used to answer the empirical question was collected through a semi-structured interview. A list of predetermined questions were asked and the interviewee had a chance to expand on the answers (see Appendix for a list of questions that were asked). Given the fact that the system was classified as an assistive device, we had a hard time finding participants that suited our test population. In the end, we were only able to find one person that was able to fit our participant criteria. For testing purposes, we had the participant undergo three pairs of usability tests (a pair is defined as unlocking a door with a key and our device). The same door was used for the duration of the usability test and times were recorded for a successful unlock. As for the testing environment, the user was situated in a dimly lit room to mimic an apartment hallway. The times are tabulated as follows:

Iteration	**Time to unlock door using key (seconds)**	**Time to unlock door using system (seconds)**
1	72	40
2	86	42
3	90	38

Numerical Analysis

As one can clearly see, the participant's disability significantly hindered his ability to unlock the door using a key. This explains the significant variance in time for each iteration. Furthermore, the average unlocking time using a key was 82.67 seconds with a median of 86 seconds. On the other hand, the time to unlock the door using our device was significantly lower than with a key and nearly consistent between iterations. This is due to the fact that each iteration ran under optimal conditions (i.e. no system errors and the user was recognized by the system on their first try). In light of all this, the average unlock time for our device was 40 seconds with a median of 42 seconds. On average, our system was approximately twice as fast when compared with the participant's data for using a key. Given the lack of participants in our study, and the fact that we were using a relatively high-end Windows machine for testing purposes when compared to the Raspberry Pi, it is still a bit inconclusive to say that our system is faster for people with involuntary hand movements. However, the results gathered in our usability study do support this claim.

Participant's Reactions

The participant found the waiting time for facial recognition to be faster than expected. However he found the waiting time for the passphrase recognition to be an issue as he was unsure as to when five seconds passed. In terms of the graphical user interface, he found the icons to be effective in indicating his progress with the system, the instructions to be effective as they were thorough, and felt neutral about the colours since he was not attentive to them. When asked about the system in general, he said that he liked using it as it provided him with a better and easy-to-use alternative to opening a door which only required one's face and their passphrase. He did not have any dislikes about the system but suggested an improvement with the passphrase recognition component in terms of notifying the user about the remaining time for passphrase recording. If this system was available for purchase at an affordable price, he would be willing to purchase it. He also agreed that this system would be beneficial for people with physical disability, especially after fixing the minor issue he mentioned earlier with the passphrase recognition component. Based on this semi-structured interview, it appears that this system is indeed beneficial for its target group.

Video Demonstration

https://youtu.be/s7ngS4GIqaI

Appendix

Study Setting (Controlled Setting)

The study will take place in a controlled setting in order to remove outside influences.

User Group

Users with involuntary hand movements

Consent Form

Please see below.

Methods

Observation (using the Quantitative Performance Measures)

"In HCI we might observe people interacting with an interface and collect information about their interactions, such as the number of times they consulted the manual, clicked the wrong button, retried an operation, or uttered an expletive" (p. 122, MacKenzie).

- ➔ Record the time it takes for a user to unlock the door from when the system becomes active to when the system passes the voice recognition phase. (Efficiency)
- ➔ Record the number and type of errors that the system makes (such as being unable to detect true positives). (Effectiveness)
- ➔ Record the number and type of errors the system makes
- ➔ Record the number of users who were able to successfully complete the task. (Effectiveness)
- ➔ Did the door accurately detect their face in a dimly lit setting? (Yes/No)
  - ◆ If no, how many tries did they have to do?
- ➔ Did the door accurately detect their passphrase in a moderately quiet setting? (Yes/No)
  - ◆ If no, how many tries did they have to do?
- ➔ Did the door unlock after it verified their face and passphrase? (Yes/No)
  - ◆ If no, how many tries did they have to do?

We will also be recording the system's screen to ensure that the collected data is accurate. A consent form will be given prior to the study to let the user know of this.

Semi-structured Interview

Timeliness (or Efficiency)

- ➔ What was your perception of the waiting time when the system was searching for a facial match in the database?
  (Likert Scale: 1 (Too long), 2 (Neutral), 3 (Very good))

- ➔ What was your perception of the waiting time when the system was searching for a passphrase match in the database? (Likert Scale: 1 (Too long), 2 (Neutral), 3 (Very good))

Effectiveness

- ➔ Was the graphical user interface effective in explaining the states of the system?
    - ◆ Were the icons effective in explaining what to do? (Yes/No).
    - ◆ Were the instructions effective in explaining what to do? (Yes/No)
    - ◆ Were the colours aesthetically pleasing? (Yes/No)

Improvements

- ➔ What did you like about this system?
- ➔ What did you not like about this system?
- ➔ What improvements do you believe can be made? (Short answer)

Overall Satisfaction

- ➔ How satisfied were you with using this method to unlock the door? (Likert Scale: 1 (Bad), 2 (Neutral), 3 (Good))
- ➔ If this door was available on the market at an affordable price, would you use this method to unlock the door? (Yes/No)
    - ◆ If no, please explain. (Short answer)
- ➔ Do you think this door would be beneficial for people with physical disability, more specifically, people with involuntary hand movements? (Short answer)

Informed Consent Form

Date: May 4th, 2017

Name of Participant: Saad Saeed

Study Name:
The Two-Step Verification System for opening a door

Researcher:
Lindan Thillanayagam lindan4@my.yorku.ca

Purpose of the Research:
The purpose of this research is to conduct a usability study in order to collect data.

Your Task:
As a participant, you will have your photo taken and passphrase recorded before using the interface. Once this data is collected, the system has to be able to detect a match in the database when it scans your face and hears your passphrase, in order to grant you access through the door.

The estimated time to perform this task is a minimum of one minute, if the system is able to correctly find a match in the database. At the end, you will be interviewed and will fill out an online questionnaire, in order to help the researchers gauge your experience with the interface. The total time for this entire process will be less than 30 minutes.

Risks and Discomforts:
There are common risks involved in using a tablet computer application, but they do not commensurate with the time required to participate or task itself.

- Excessive screen time can harm the vision in the long term. However, you will be spending less than ten minutes looking at the screen during our data collection. You do have the choice to opt out at any time.
- Neck pain is a possible side effect when using these technologies. However, the duration of our test minimizes such risks. We will provide support to ensure that you are comfortable before, during and after the study. You do have the choice to opt out at any time.
- You have the right to not answer any questions during the interview and when filling out the questionnaire.

Benefits of the Research and Benefits to You:
This research will help with the betterment of the design of this system, which could potentially help people with a physical disability.

Voluntary Participation:
Your participation in this study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer will not influence the relationship with the researchers, or the nature of your relationship with York University either now, or in the future. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Confidentiality:
Unless you choose otherwise, all information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research. The data will be collected with help of video recordings, questionnaires and handwritten

notes. Your data will be safely stored and only research staff will have access to this information. Confidentiality will be provided to the fullest extent possible by law.

Questions About the Research?
If you have questions about the research in general or about your role in the study, please feel free to contact the researchers or our professor, Dr. Melanie Baljko, either by telephone at (416) 736-2100, extension 33348 or by email at mb@cse.yorku.ca.

Legal Rights and Signatures:
I, ________Saad Saeed_________, consent to participate in The Two-Step Verification Door Study conducted by ______Lindan Thillanayagam________. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

___Saad Saeed___________________________ ____May 4, 2018______________
Participant **Date**

_______Lindan Thillanayagam_____________ _____May 4, 2018______________
Principal Investigator **Date**

Imagery (photograph and/or videos) Consent:
I, _______Saad Saeed_______, agree to allow video and/or photographs in which I appear to be used in teaching, scientific presentations and/or publications with the understanding that I will not be identified by name. I am aware that I may withdraw this consent at any time without penalty.

__________Saad Saeed_____________________ ____May 4, 2018______________
Participant **Date**