To: Dr. Severinghaus
From: Team 1 - Navigation Helper Helmet
Date: March 26, 2021
Subject: Testing Results Report

Project overview: (The hardware connection diagram is in appendix 7)

To help the visually impaired have a better normal life, Dr. Razi and our team designed a deep learning device. This device can help the visually impaired obtain basic information about the surrounding environment. The equipment we designed is divided into 5 subsystems, recognition system, voice prompt system, rotation system, LIDAR system, and user interface system. The voice prompt system collects the recognition system's information, the rotation system, and the LIDAR system and then broadcasts the user's voice through the logically processed language. In this way, the user can obtain basic information about the surrounding environment. The recognition system is responsible for identifying the type of target object and judging the name of the target task. The rotation system is responsible for judging the target direction. The LIDAR system is accountable for measuring the distance between the target and the user.

Executive summary:

In our system test, we need to perform a total of 6 different tests. In these tests, we will use 4 different test methods. They are unit test step by step (UTS), unit test matrix (UTM), integration testing, and inspection. Since each team member has other subjects' homework and tasks completed, these tests are expected to take our team 3 days. In these 3 days, we need to complete all the tests and repair and retest the errors as much as possible. After our team members' cooperation, we completed all the tests within 3 days as planned and ensured that our equipment could meet all the most important needs. We have also improved some software details in this test, allowing users to get a better experience when using the device. For example, we adjusted part of the voice prompt system's logic, which makes the voice system more stable and clearer. However, there are still shortcomings in some small parts. For example, when the detected object is too far away from the user, LIDAR will have an error of +/-10 cm. Most of these errors are caused by the hardware.

Introduction to the system (The finished appearance of the product is in Appendix 6)

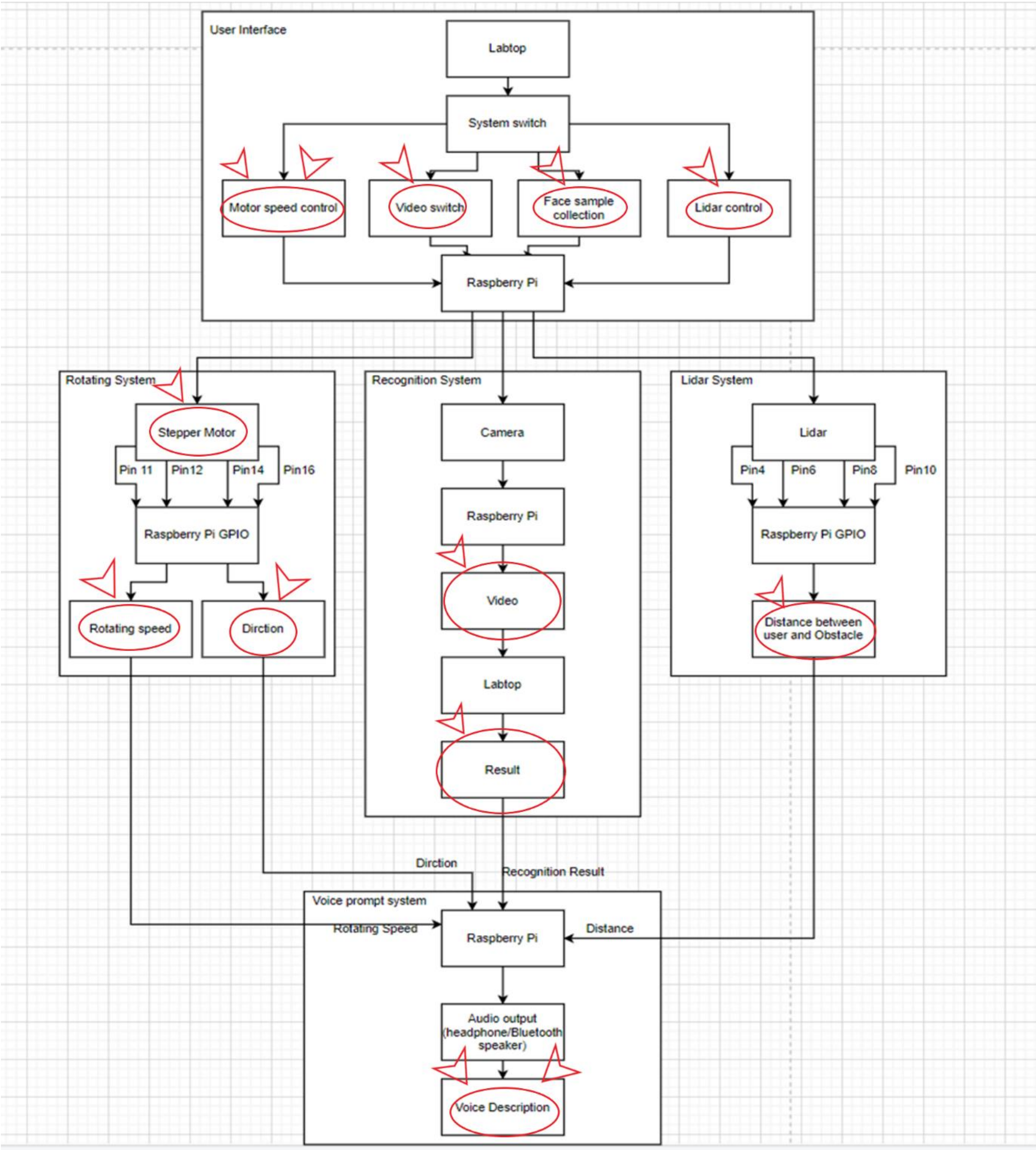
Our Client is Dr. Razi. Abolfazl Razi is an assistant professor of electrical engineering and computer science at Northern Arizona University. His current research interests include AI-enabled technology networks, image processing, biomedical equipment design, ground and aerial robotics, and predictive modeling.

The most important way for humans to obtain information is to collect information about the surrounding environment through their eyes. However, there are many visually impaired people in the world, and their lives are very inconvenient and may even face safety issues at any time. They cannot take care of themselves in their lives, and most visually impaired people need another person's care. Therefore, in order to enable these visually impaired people to carry out their essential lives independently, our Client and team decided to design a device that can help these visually impaired people collect and process surrounding environmental information.

In order to complete this design and achieve our expected goals, we need to make this device have object recognition, face recognition, distance measurement, direction judgment, and voice prompt functions. Therefore, our group learned and used deep learning knowledge and used YOLOv4 and HAAR based on Python to perform object recognition and face recognition, respectively. Then we use GTTS to convert the collected information into voice information. And the distance between the target object and the user is judged by using LIDAR measurement and the motor rotation. The voice prompt system will finally make a voice description to the user through the collection, summarization, and logical arrangement of this information. After our team's ongoing efforts and Client and GTA's help, our team has basically completed all the above ideas and requirements.

System Architecture:

Although there are 13 arrows here, because the individual tests are combined to test them, in fact, only 6 tests are needed to complete all the tests marked by the arrows.



Requirement, status, type of test:

Type of Test	Status	Req #	Requirement
		1	Recognition System
Integrate	Finish*	1.1	Object recognition for a variety of common objects.(talbe, chair, bottle, tree, car, bicycle, train, monitor, cat, dag)
Integrate	Finish*	1.2	Face recognition of familiar people.
		2	Rotating System
Inspect	Finish*	2.1	Can drive the camera and LIDAR to rotate together.
UTM	Finish	2.2	The stepper can swing left and right.And the angle range is +90 degrees to -90degree
UTM	Finish	2.3	The motor rotates 45 degrees each time.
		3	LIDAR System
UTM	Finish	3.1	Can detect distances from 0 to 400 cm.
UTS	Finish	3.2	The error does not exceed 5cm
		4	Voice Prompt System
Integrate	Finish*	4.1	Object: It can describe the type of object, the distance and direction relative to the user.
		4.1.1	When the object recognized by the object recognition system is an unrecorded object, the voice prompt system will still prompt the user that there is an obstacle.
Integrate	Finish*	4.2	Person: It can describe whether the line being detected is a person familiar to the user.
		4.2.1	When the detected object is a person familiar to the user and the sample has been collected, the voice broadcast is used to explain the detected object's identity. If the detected object is not recorded, the user needs to be notified that the object is an unknown person
Integrate	Finish	4.3	Describe the direction by the angle of rotation of the motor.
Integrate	Finish	4.4	The distance between the object and the user can be described according to the measurement result of LIDAR.
		5	User Interface
UTS	Finish	5.1	The user can djust the range of LIDAR detection, the adjustable range is 30 cm to 300 cm.

UTM	Finish	5.2	The user can adjust the speed of the motor.
Inspect	Finish	5.3	Allow users to turn on or off the video recording function.
Inspect	Finish	5.4	Allow users to turn on or off the motor rotation function.
Inspect	Finish	5.5	The user needs to use a user name and password to use it.
Inspect	Finish	5.6	Allow users to turn on, turn off or restart the device through the user interface.

Most important requirements:

- 1.1: Object recognition for a variety of familiar objects. (table, chair, bottle, tree, car, bicycle, train, monitor, cat, dog):

  This requirement is very important to customers, because only when this requirement is met can our equipment have enough information to describe the surrounding environment to the customer. It is also the most important link to ensure that our equipment can function.

  If this requirement is not met, our equipment will not have the most basic function to describe the user's surrounding environment. In this way, when the user uses our device, the accuracy that the device cannot describe cannot guarantee the user's safety.

- 1.2: Face recognition of familiar people:

  This requirement is as important as requirement 1.1. They are the basis of our equipment. This requirement ensures that our equipment can describe people familiar to the user. If this requirement is not met, our equipment will not accurately tell the environment around the user.

  This is also different from our original vision when designing this product. Although this requirement will not affect the user's safety if it is not fulfilled, it will affect the integrity of our device functions and the user's experience.

- 2.1: Can drive the camera and LIDAR to rotate together.

  This item requires the motor to be able to drive the LIDAR and the camera at the same time. It is very important for customers. Our equipment mainly determines the direction of the target relative to the user through the motor's angle of rotation. Therefore, the motor's synchronization, LIDAR, and the camera can ensure an accurate and detailed description of our equipment's surrounding environment.

  When this item is not satisfied, the user will not know the first position between the detected object and the user. This will cause the user to be unable to know the target's exact location even after learning the type and information of the object, so the user cannot avoid obstacles or dangers. This is very dangerous, so this requirement is very important.

- 4.1: For the object, it can describe the type of object, the distance, and direction relative to the user.

  This requirement is the basic way to provide customers with a description of the environment. Since our users are visually impaired, it is the only way to describe the user's environment through voice. Therefore, it is very important for users.

  When this requirement is not met, the user will not know any information about the surrounding environment. Even if our equipment has identified and positioned the surrounding environment, users still cannot obtain any information.
- 4.2: For the person: It can describe whether there are familiar people around the user and does not describe familiar people's names.

  This requirement is equally important because audio is the only way for our users to understand the surrounding environment.

  If this requirement is not met, the user will not know whether the identified person is familiar to him. This will affect the integrity of the functional basis of our equipment.

Types of tests:

- Unit Test Matrix (UTM): When the inputs are structurally the same and differ only in their value.

  When the input and output of the system I test are the same or similar types, I will choose to use this test method because this method allows me to observe the results and rules of the test more intuitively.
- Unit Test Step-by-step (UTS): Instruction for generating the test and checking the results. They are used for flowcharts and multiple selections.

  I will use this method when the system I need to test requires different choices during testing or when the test needs to follow certain procedures and steps. It can ensure that I have a rigorous process when testing and discover the impact of different conditions or choices on the test results and whether the system is suitable for various conditions.
- Integration: Checks that the major modules of the overall system operate correctly together.

  I will use this test when a test needs to be transferred to other systems because some requirements or procedures are tested separately. Using this test method can detect the results when multiple systems cooperate.
- Inspection: In general, inspection means the process of evaluating or examines things. It is also called the formal practice of reviewing things.

  When the system to be tested is simple, such as yes or no, I will use this detection method. This kind of detection method only requires simple observation or inspection to get the detection result.

Major tests:

- Test 1: (A complete schematic is shown in appendix 1)

Test Case Name: The angle of each rotation of the stepper motor.

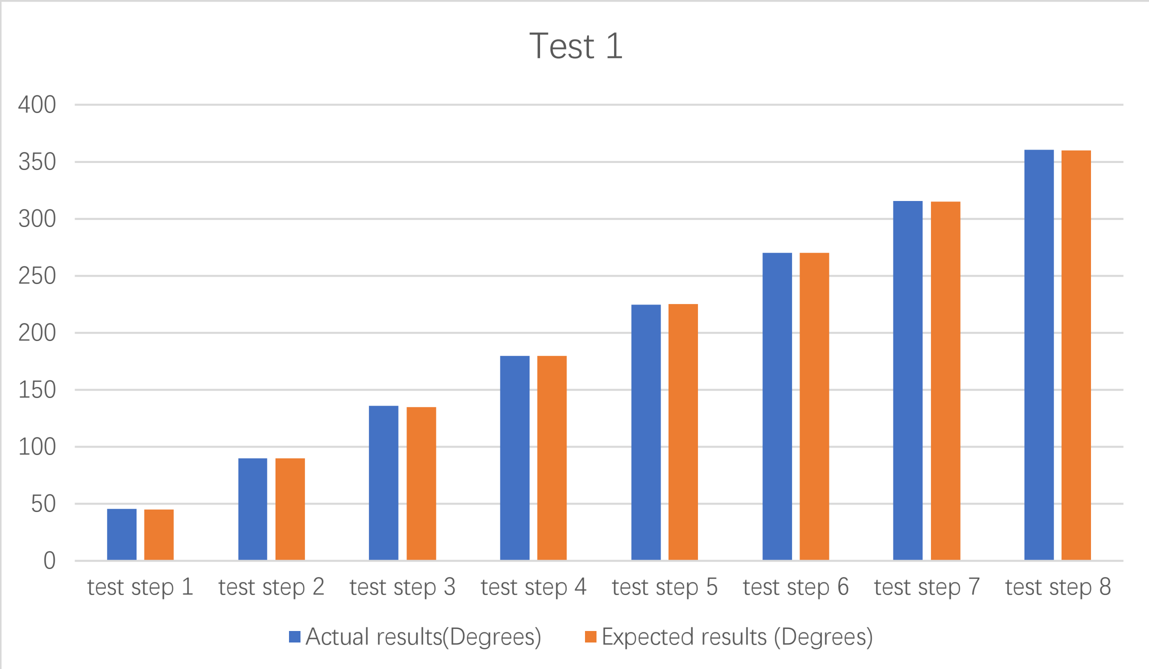
Tester: Alfred Ranasinghege Madushan Gunasekara

Date: February 22, 2021

Our team tested whether the angle of each rotation of the motor is 45 degrees. The requirement for this test is “2.2 The motor rotates 45 degrees each time.” Since we know the principle and we can deduce the expected result, it is a white box.

First, the setup instructions are turned on the stepper motor to verify that the stepper can work normally. According to the product manual of 28BYJ-48, we can know that it is a 4-phase 5-wire stepper. Therefore, this stepper motor needs to run 2048 steps per revolution. From this, we know that if we need the motor to move only 45 degrees each time, we need to make the stepper move only 2048/8=256 steps each time. Therefore, we add a counter with an initial value of 0 to the stepper's code and then increase the counter by one every time the stepper moves by one step. Then, every time the counter increases by 256, we stop the motor for 30 seconds. Then the tester measures the angle that the motor has moved. Therefore, the total angle of each motor movement should be 45 degrees higher than the previous record. This test understands its working principle can also predict its results, so it is a white box. Since each input is 256 steps, and the same number of steps separates each time, the difference should be 45 degrees. This test should be a unit test (matrix).

The specific operation is as follows. We will record the angle between the position and the starting position after each 256-step movement of the motor and record it. We can easily calculate the ideal result according to the principle mentioned before. Then subtract the actual result from the ideal result. If the result's absolute value is not more than 5 degrees, then it means that there is no problem with this function.



Bar graph 1

- Test 2: (A complete schematic is shown in appendix 2)

Test Case Name: Motor speed control.

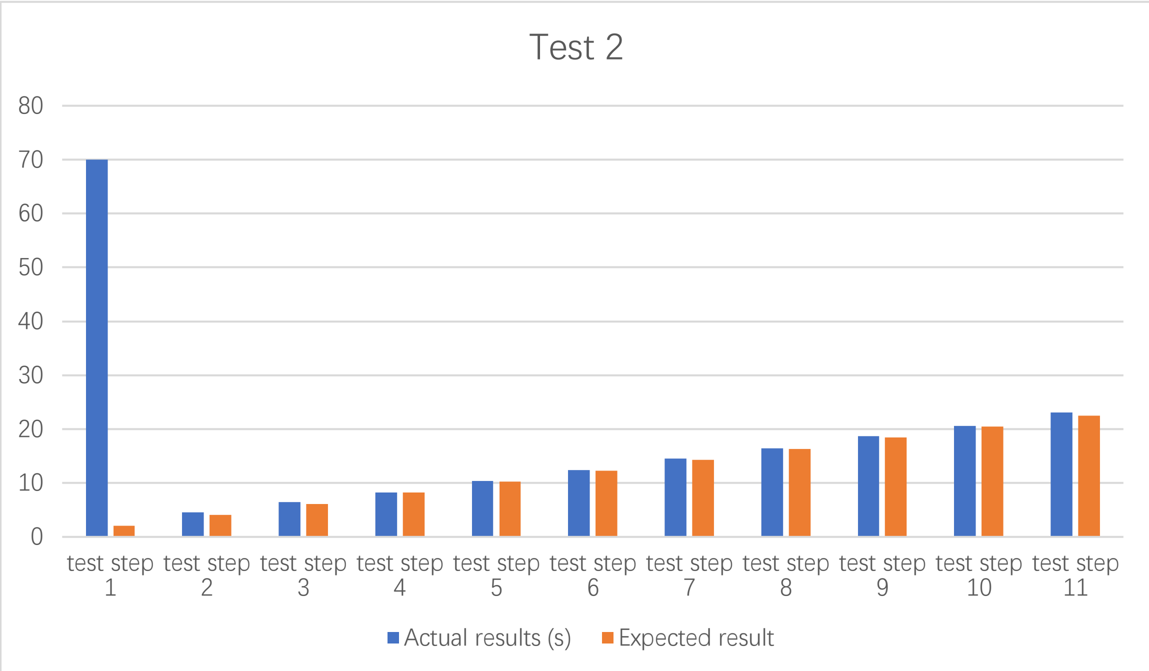
Tester: Jingwei Yang

Date: February 24, 2021

This test aims to detect whether the user can accurately control the motor's speed through the user interface. The requirement for this function is "5.2 The user can adjust the speed of the motor." Since we know the principle and we can deduce the expected result, it is a white box.

In our user interface, the user can manually set the motor speed. We change the motor's speed by changing the delay time between each step of the stepper motor. Because the 28BJY-48 stepper makes 2048 steps per revolution, the time used for each revolution should be 2048* (delay time). The user can fill in the number to be an integer greater than 2. The delay time is (the number entered by the user)/1000. And the delay time unit is seconds. Therefore, the time required for each rotation of the motor = 2048 * (number entered by the user) / 1000. Because the input of this test is an integer, and the output is also a certain regular number. Therefore, the test of our group's task is Unit Test (Metrix).

During the actual test, we performed a total of 12 steps. The first and second steps failed because the motor cannot normally rotate in these two cases. Every step of the work after that is normal. However, due to mechanical errors, the actual measured value will be slightly larger than the theoretical value. Therefore, our team believes that the error is less than 1 second to pass. Because our group's idea is that every time the parameter increases by 1, the actual motor rotation time increases by 2 seconds. Through testing, we found that the larger the input parameter, the larger the error produced. Therefore, we will control the parameters that users can enter between 2 and 10.



Bar graph2

- Test 3: (A complete schematic is shown in appendix 3)

Test Case Name: LIDAR control function detection

Tester: Bo Sun

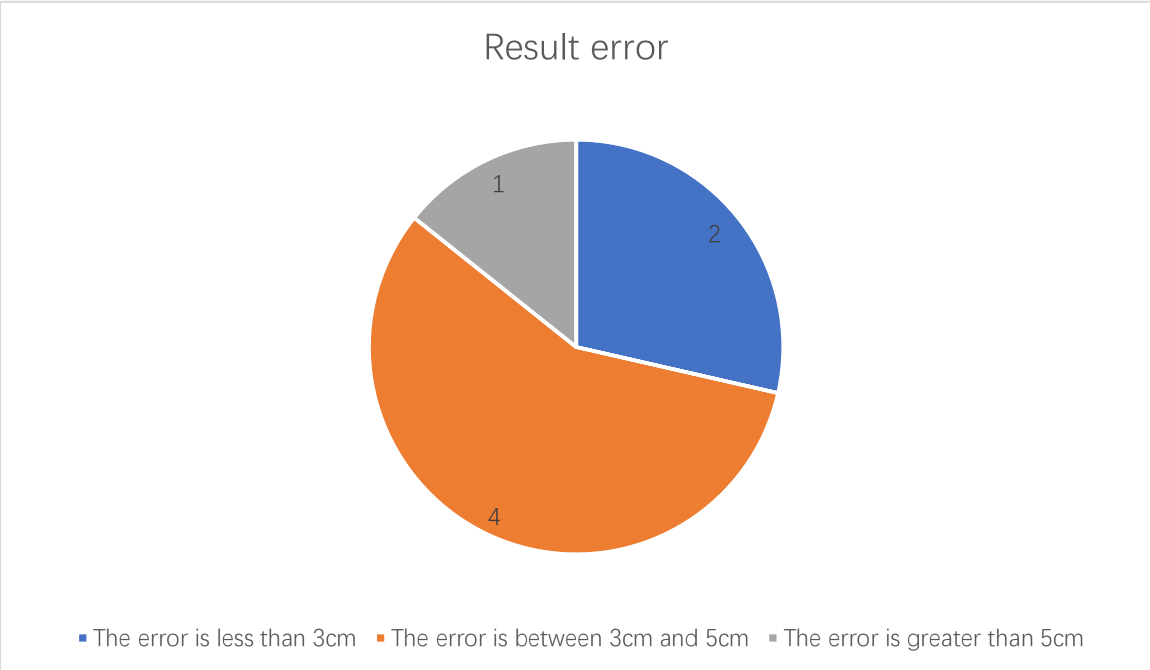
Date: February 24, 2021

This test is to test that the user can control the Lidar's monitoring range by inputting parameters. This test requirement is "5.1 The user can adjust the range of LIDAR detection; the adjustable range is 30 cm to 300 cm. " Since we know the principle and we can deduce the expected result; it is a white box.

By limiting the LIDAR distance measurement range, we can effectively reduce the frequency of object recognition so that the voice prompt function can more effectively describe the user's environment. This can also reduce unnecessary interference and improve the accuracy of the voice prompt system description. For this test, we need to place the chair in advance and then use the user interface to adjust the LIDAR range. LIDAR is used to measure the distance between the user and the chair. When the user and the chair's distance exceed the user's range, the program will print "Out of Range." When the distance between the user and the chair is less than the user's range, the program will print this value, and the unit is cm. Because in this test, we need to frequently change the chair's position, frequently reset the system, and set the parameters. Therefore, our team believes that this test should be Unit Test

(Step-by-step)

In the test, we first place the chair in a position and measure the distance between the user and the chair. Then enter a Lidar parameter. This parameter should be greater than the distance of the chair. So, we can detect the chair. Then record the position of the chair and compare it with the predicted value. Then place the chair outside the user's parameters and compare the results obtained with the predicted results. Finally, adjust the parameters to be greater than the distance between the chair and the user. Then compare the predicted value with the actual value. By repeatedly repeating the above steps, we can judge whether the user can accurately control Lidar's monitoring range. Because LIDAR itself has errors, and measurement errors will also occur during measurement, we allow an error of 5 cm.



Pie chart 1

- Test 4: (A complete schematic is shown in appendix 4; The user login interface is in Appendix 8; UI function interface is in Appendix 9)

Test Case Name: User integration testing

Tester: Junlin Hai

Date: February 25, 2021

This test's primary purpose is to determine whether the voice system can accurately describe different people's descriptions in different locations. Its corresponding requirements are: "1.4 Face recognition of familiar people. 4.3 The voice system can use voice to describe whether the user's task is familiar to them. 4.4Describe the direction by the angle of rotation of the motor. 4.5 The distance between the object and the user can be described according to the measurement result of LIDAR." Because we understand the internal organization of the system used in this test, and we can predict its results. Therefore, our group considers it a white box.

Through face recognition of different people, the voice prompt system will perform different voice descriptions. And according to the person's location and distance, the voice system will also change the words used in the book to ensure that the description is more accurate. This test will use more than three different systems to complete a specific function. Therefore, we consider it an Integration Test.

We used four different detection objects in this test: Jingwei, Bo, Alfred, and Jingwei's roommate. First, we let Jingwei stand in a different position to be detected. We anticipated and outdated, according to the location of Jingwei, different voice systems will also change the description of the direction and the description of the distance. Then we describe different people. Since Jingwei, Bo, and Alfred are all familiar people, the voice system will indicate their names. But Jingwei's roommate is not recorded, so the voice system will notify you, "You don't know this person." From the second step to the sixth step, the test's main content is to detect whether the voice system can accurately describe the detected object's location. The first step to the ninth step is to test whether the voice system can accurately distinguish between familiar people and strangers. Due to the LIDAR measurement errors, the actual results may deviate from the predicted results in terms of distance description. But if the error is within 5 cm, we consider it passed.

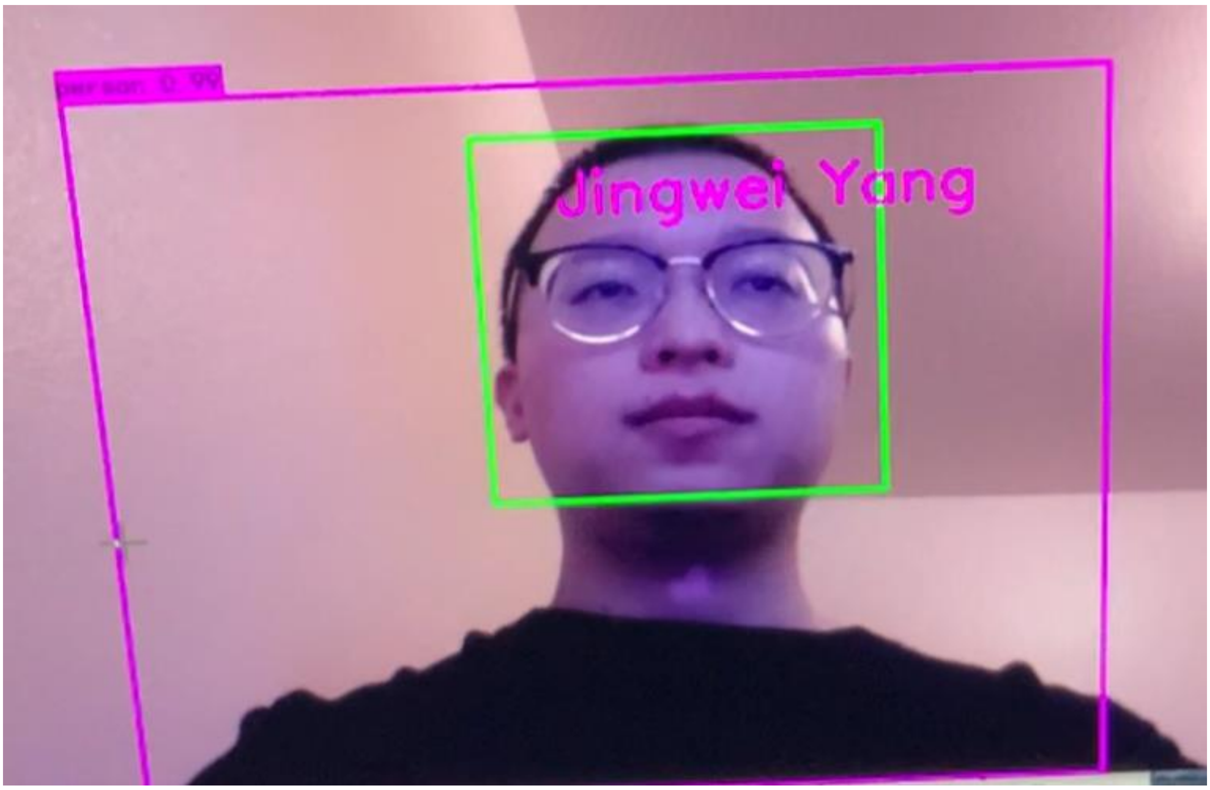


Image 2

Image 3

- Test 5: (A complete schematic is shown in appendix 5)

Test Case Name: Comprehensive test of the speech system

Tester: Jingwei Yang

Date: February 25, 2021

This test's main purpose is to determine whether the voice system can accurately describe objects of different types and different orientations by receiving data from the recognition system, LIDAR system, and motor system. This will use more than 3 requirements for testing at the same time. So, this test will be an Integration test. Among the requirements is 1.1 Object recognition for a variety of common objects. (table, chair, bottle, tree, car, bicycle, train, monitor, cat, dog); 4.1 Object: It can describe the type of object, the distance, and direction relative to the user; 4.3 Describe the direction by the angle of rotation of the motor; 4.4 The distance between the object and the user can be described according to the measurement result of LIDAR. Since we understand how these systems work and maliciously infer the test results under ideal conditions, we consider this test to be a white box.

In this test, we used a total of three common objects: water bottle, chair, and monitor. And each object was tested in a fixed position and three random different positions. Therefore, a total of 12 tests were performed. First, we put the water bottle in front of the tester. This step is to test whether object recognition can accurately identify the object. Then, let another team member move the water bottle randomly within the detection range when the tester is not moving, and use the equipment to detect it. Finally, the voice system will describe the detection of the object's type, location, and distance. This is to test whether the device can accurately describe the distance between an object's direction at any position and the user.

These are the 1 to 4 steps of our test. Then we tested the chair in 5 to 8 steps. The test procedure for identifying the chair is the same as the test procedure for the water bottle. In steps 9 to 12, we repeated the previous operation and tested the recognition of the monitors. According to the test result, the test result's error in the test chair and the monitor is only less than 5 cm, but an error of more than 10 cm occurred in the test of the water bottle. Our team believes that the water bottle's error comes from the level of too small volume, and LIDAR did not correctly measure the distance between the water bottle and the tester.

Image 4

Image 5

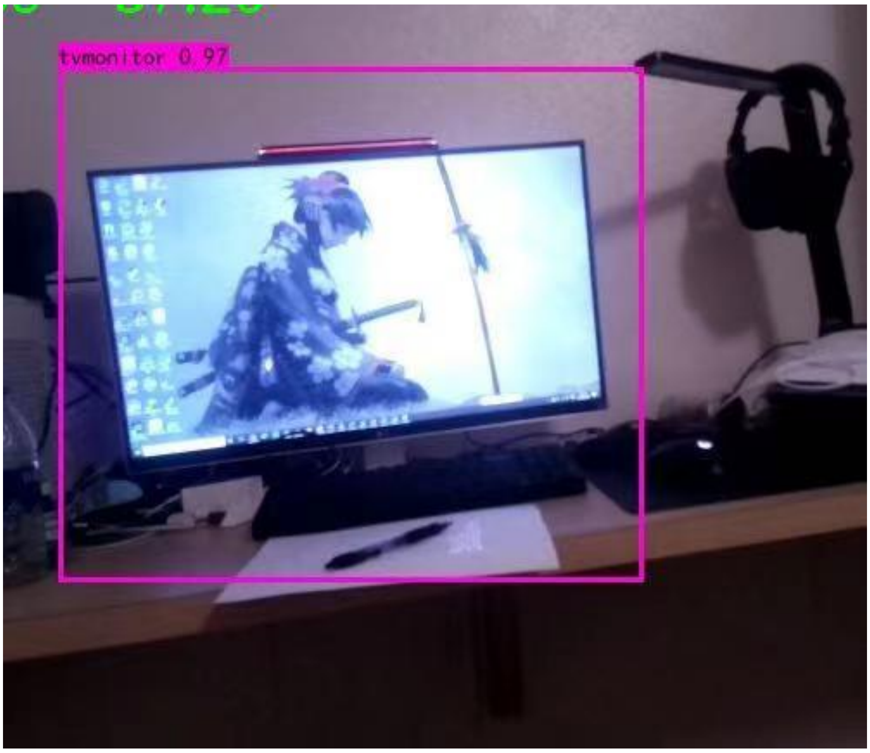


Image 6

Analysis of results:

In the test conditions, all of our tests have basically passed the requirements in addition to LIDAR detection for objects that are too small, such as water bottles. There was an error that exceeded expectations. Because hardware conditions limit part of this error, our team considers this to be an acceptable error. Also, most of the test results are what we expected. Our five most important requirements have all passed the test. Although there are still shortcomings, they have basically met the requirements for accuracy and stability.

Lessons Learned:

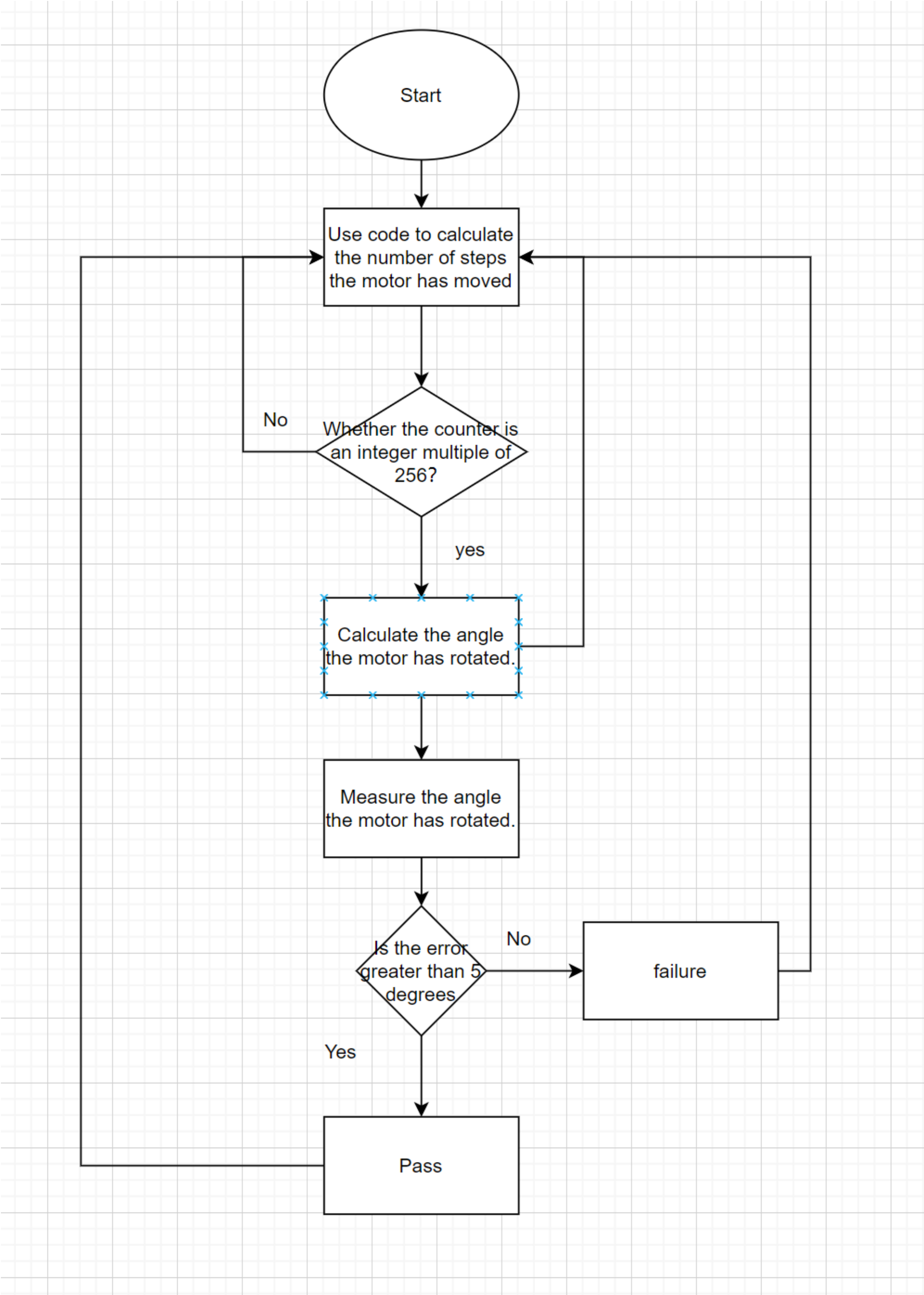
In terms of LIDAR, when measuring objects that are too far or too small, there will be larger errors than expected or acceptable. Since a large part of the error comes from the hardware itself, in order to improve the user experience and the accuracy of the description of the detected. Our group restricts that users can only set the monitoring range between 30 cm and 300 cm in the user-defined LIDAR detection range. In addition, since the data cable used by the camera of our product is strip-shaped, it is very wide and therefore should not be rotated. After discussing with Client, we decided to modify the original 360-degree detection range to a 180-degree monitoring range. We have no requirements that are difficult to test, and the requirements are clear.

From the test, we learned a more effective way to find and solve problems. When we do not know how to improve the product or are not clear about the product's current deficiencies, we can use the method of systematic testing to find the product that needs to be improved and the errors that need to be avoided.

We performed regression testing after modifying the functionality of the UI. This test also successfully helped us avoid trouble. Since we forgot to set the initial value for the motor rotation angle after this modification, the motor rotation cannot be reset, which also caused other systems to fail to start normally. Through regression testing, we checked the modified places and finally found the problem.

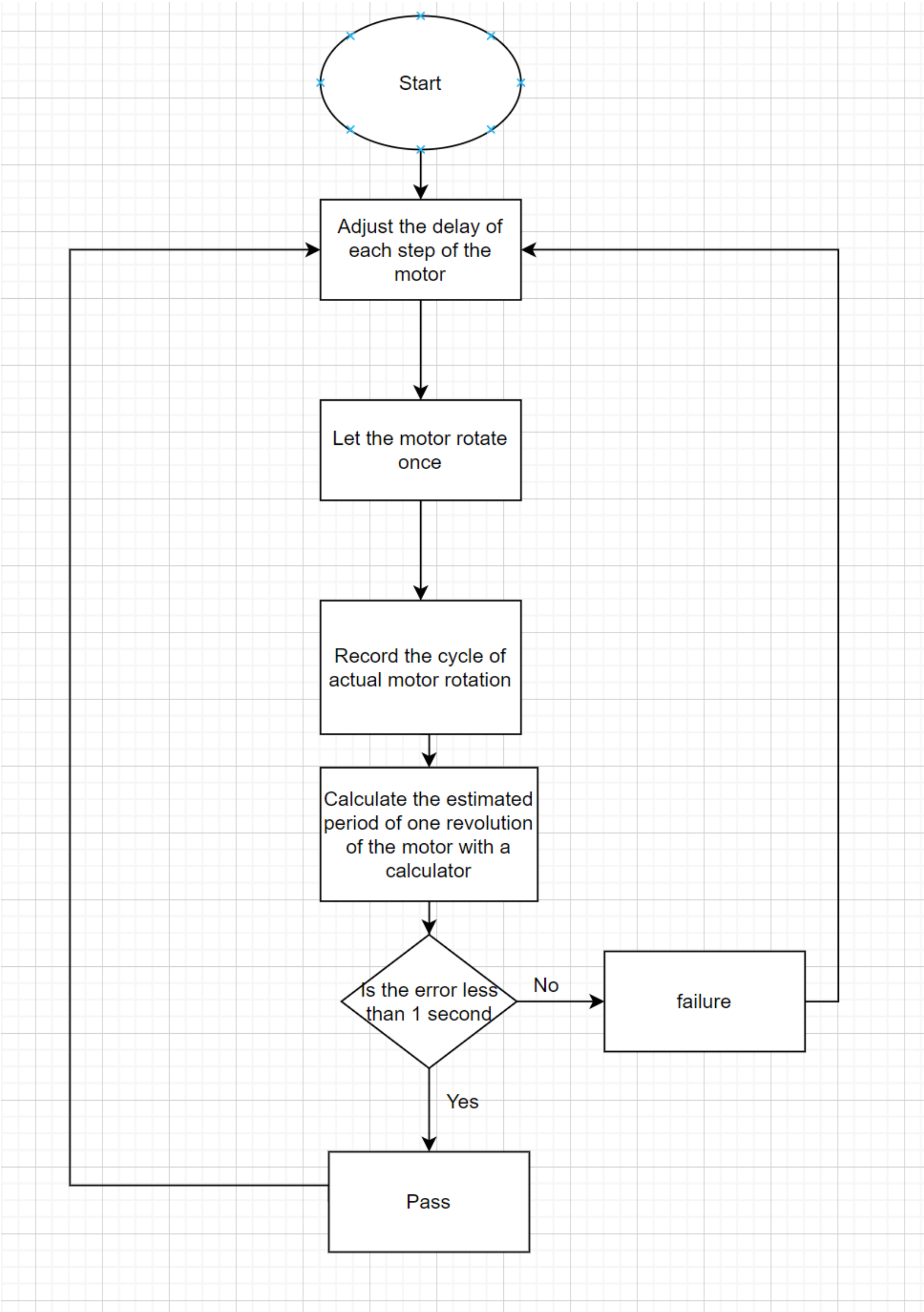
Appendixes:

Appendix 1 describes the process of test 1 and the criteria for determining whether the test has been performed.



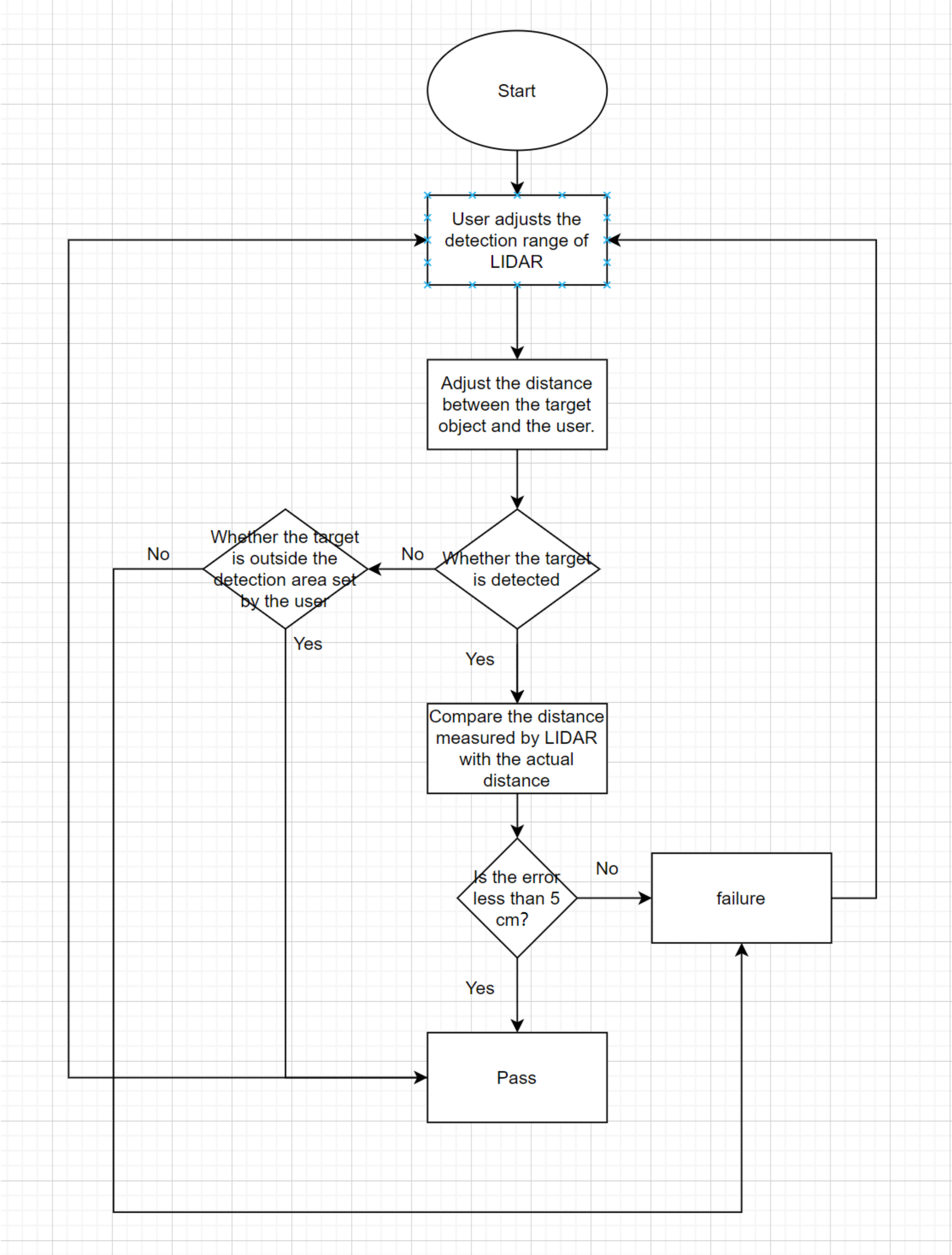
Appendixes 1

Appendix 2 describes the process of test 2 and the criteria for determining whether the test has been performed.



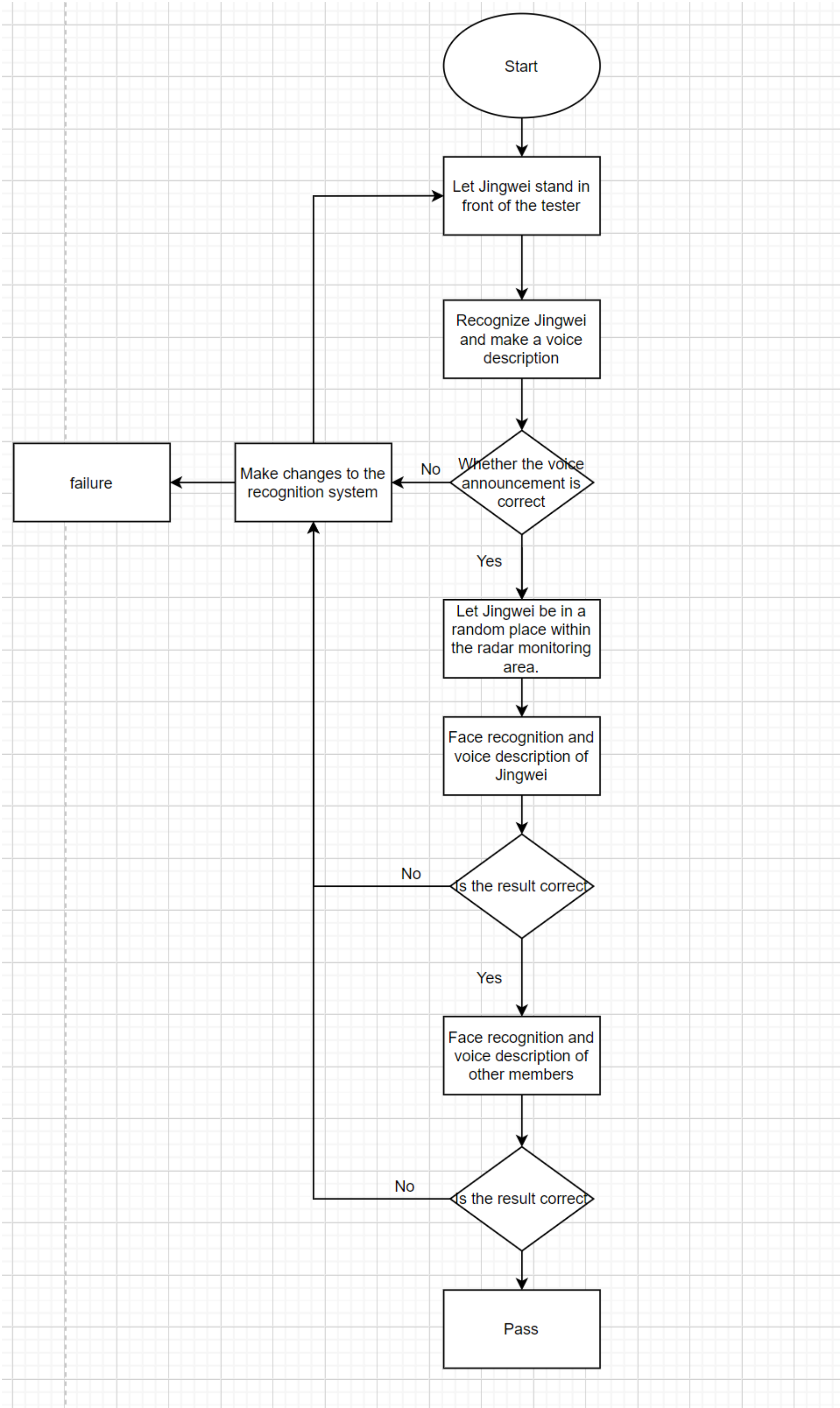
Appendixes 2

Appendix 3 describes the process of test 3 and the criteria for determining whether the test has been performed.



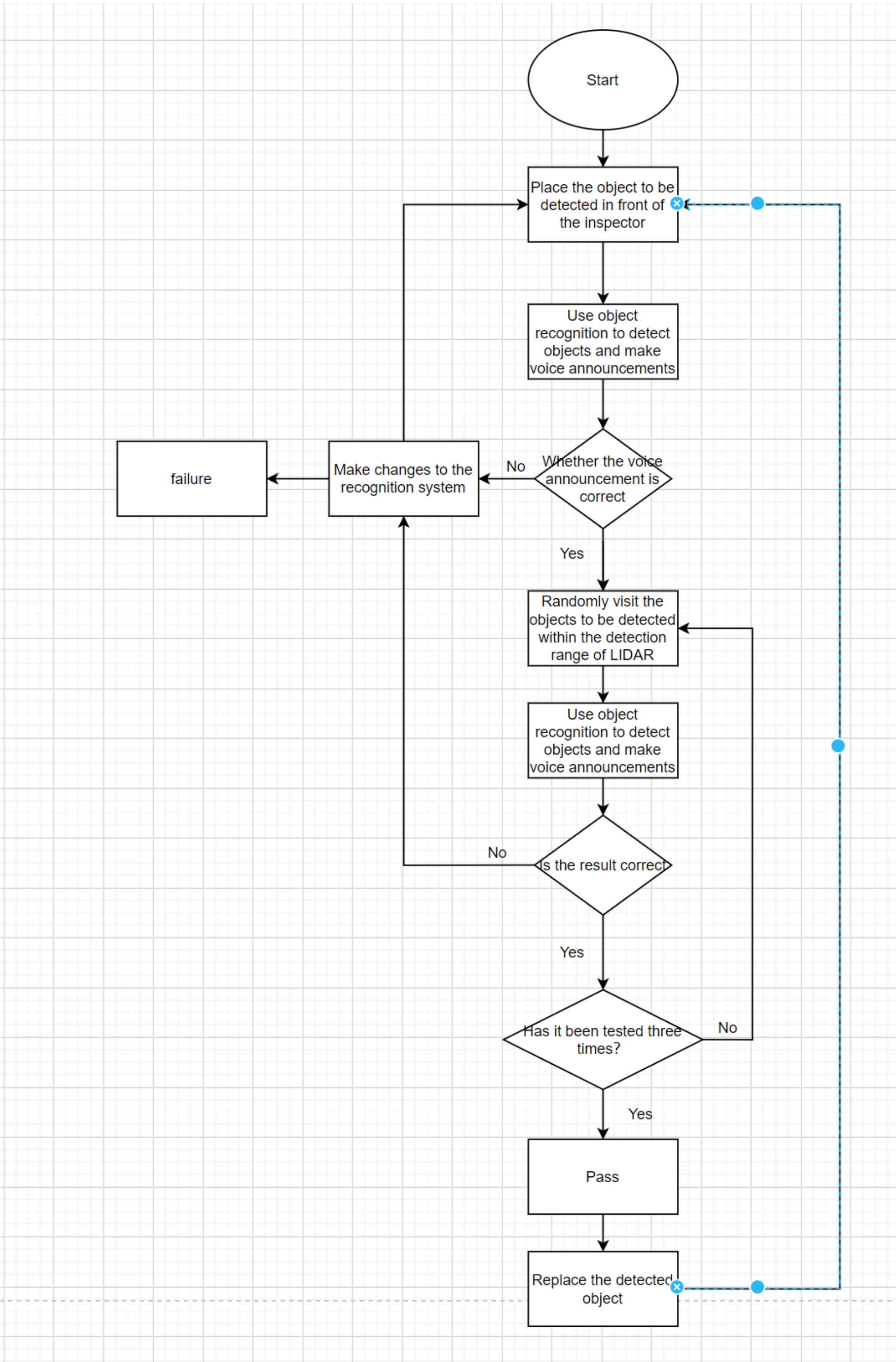
Appendixes 3

Appendix 4 describes the process of test 4 and the criteria for determining whether the test has been performed.



Appendixes 4

Appendix 5 describes the process of test 5 and the criteria for determining whether the test has been performed.

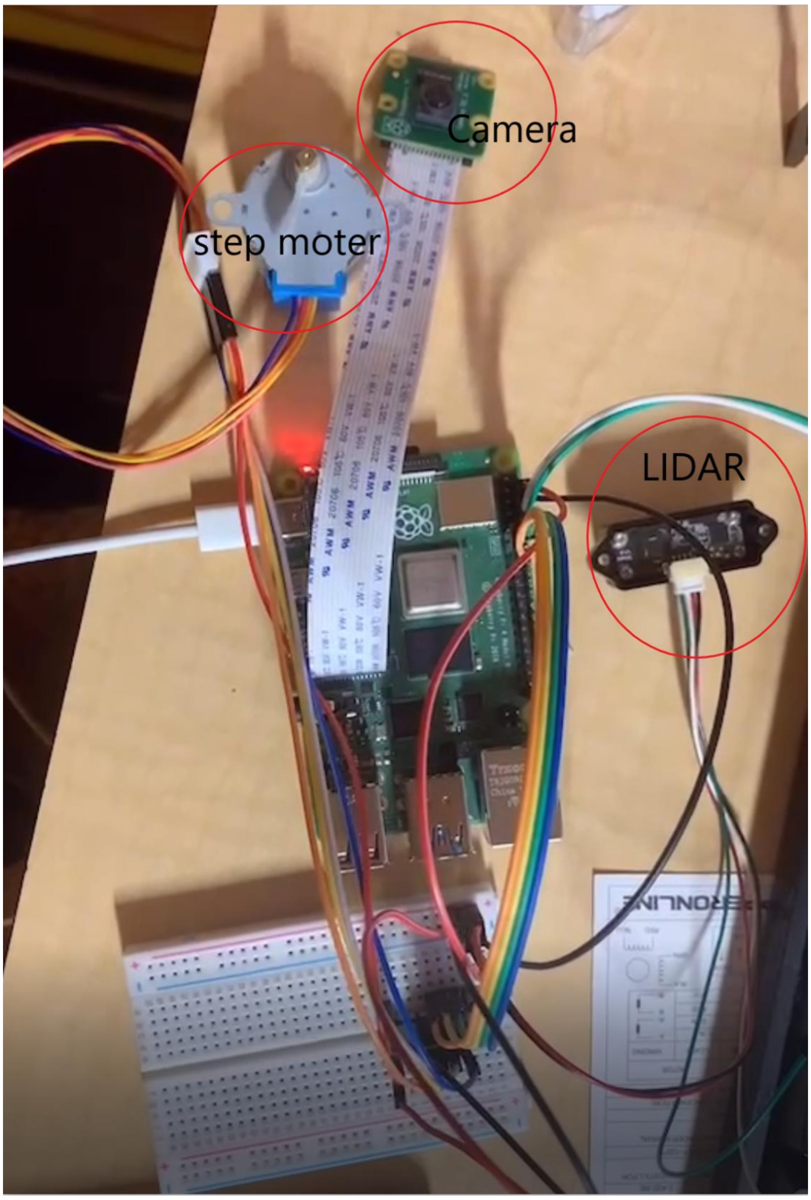


Appendixes 5

Appendix 6 is the finished model of the hardware product, which is a helmet. The user may have him on his head.

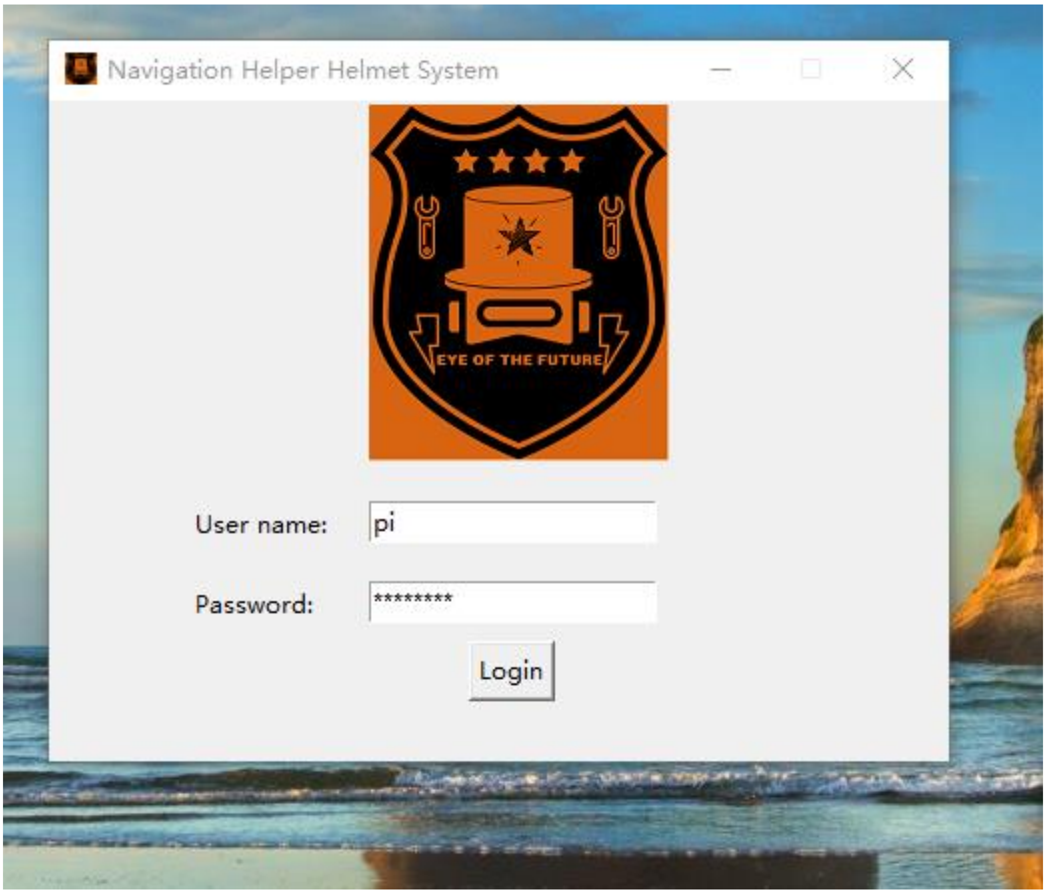
Appendixes 6

Appendix 7 is our hardware schematic connection diagram, which clearly shows the connection methods of Raspberry Pi, motor, camera and LIDAR.



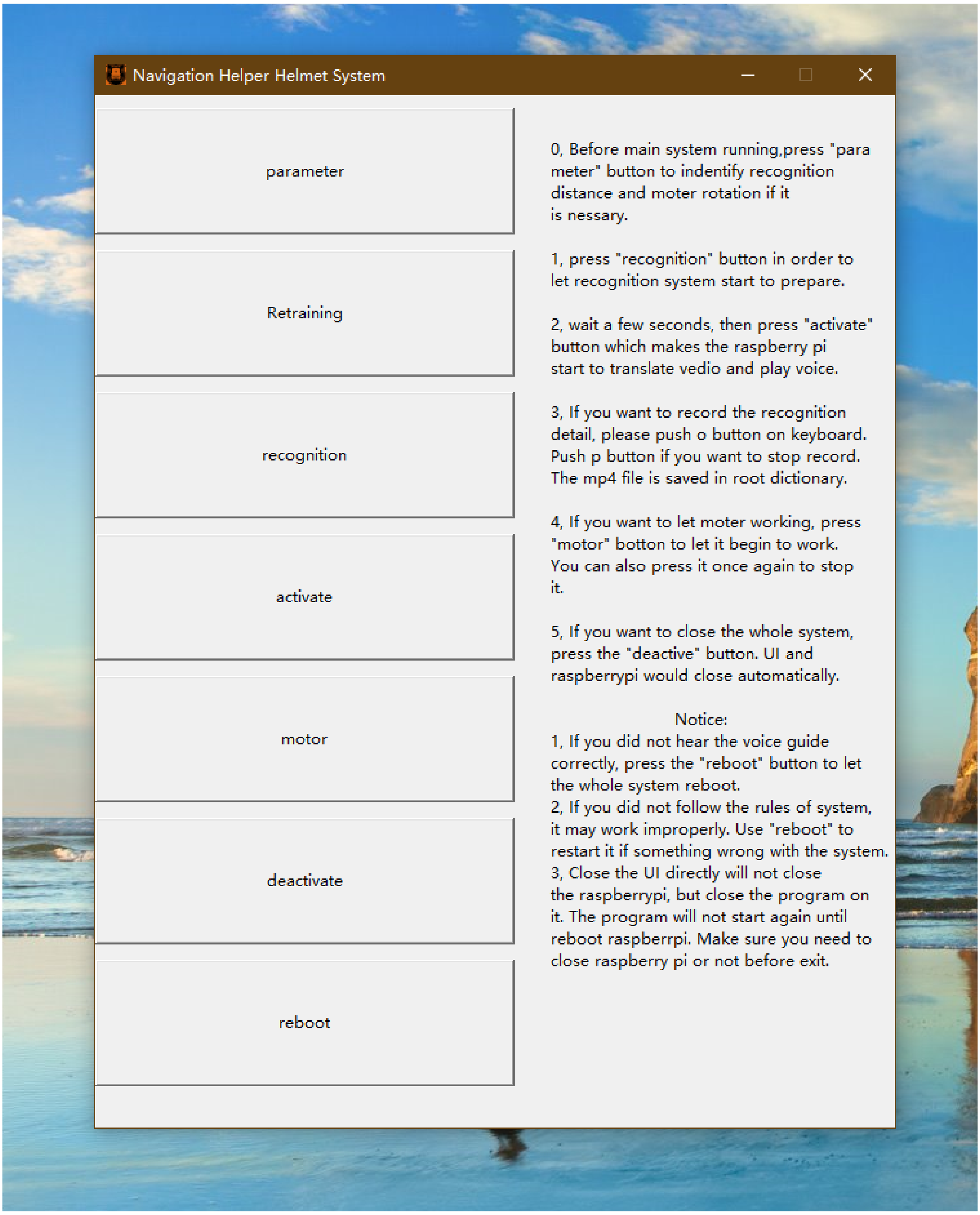
Appendixes 7

Appendix 8 is the user login interface. The user needs to enter the correct user name and password when logging in. The user name is: Pi, the password is: 12345678



Appendixes 8

Appendix 9 is the UI function interface, with function keys on the left. The user can turn on or off the development function through these keys. Instructions for use are on the right.



Appendixes 9