2018 Fall Introduction to Biomedical Engineering Final Report

Smart Assistant Chair - An Intelligent Assistive Device Aimed for the Elders

Team 6
電機三 趙冠豪　電機四 莫絲羽　電機四 陳 曦

1. Abstract

The elders are often incapable of standing up from a chair on their owns due to the lack of strength in their knees. As a result, they need an assistive technology device which can serve as their muscles. Our product "Smart Assistant Chair" is made to solve this problem. The device can alleviate the elders' pain by utilizing a motor to elevate their buttons, which is activated by sensors noticing one is about to stand up. When their buttons are high enough, they could comfortably stand up and walk. Moreover, an Android app was developed for data visualization and statistics of this chair. In this project, we have successfully constructed a prototype "Smart Assistant Chair" and underwent some testing with people sitting on it. In the future, we look forward to making it more stable and even finally commercialize it.

2. Motivation

I am Szu-Yu Mo. My own grandfather has long been unable to get up from a chair by himself. When I was 18, I tried to make a paper mini prototype of a mechanically auto control chair. One's button would be lifted up if he or she steps on the pedal of the chair below your feet. However, after four years of training as an engineer, I would like to apply what I have learned into a real-size electronic product. I hope that by making a completely automatic assistant chair with sensors that can make my grandfather's life as well as others' life more comfortable.

In addition, lots of rehabilitation and assistive technology for cancer were taught by Professor Guo in class. It is revealed that those devices for patients and the elders are extremely inevitable nowadays. Considering the aforementioned importance, my teammates liked this idea very much as I did. Thus, we started to search for the solution and made it happen.

3. Competitive Products Review

Aiming one the market of assistive chair for elders, we made wide research and narrow down to three products which have most similar concepts to ours. They are the Bard Single Electric Sofa, Shiang-le Assistive Chair, and Yue Cushion. We will later discuss the pros and cons respectively.

(1) Bard Single Electric Sofa

This product has the most powerful system and actuating force above all. Basically, it's an ideal assistive chair for elders because of its high flexibility in adjusting angles and comfort. However the biggest disadvantage is its high cost (around ten to twenty thousands) and dependency on remote controller. Our object is to build a automatically assistive device concerning the remote controller might be inconvenient and "user unfriendly" for the elders. Moreover, the reasonable price is also a concern.

(2) Shiang-le Assistive Chair

This chair relies fully on mechanical structure. The disadvantage is the heavy weight and lack of controlling system. This chair also costs a high price and has less functions comparing to Bard Single Electric Sofa.

(3) Yue Cushion

This is the cheapest device above all. The critical defect of it is its powerless structure. One can barely notice the help from the cushion when trying to stand. Moreover, it doesn't has any components to help fix the cushion. It might results in device sliding while standing and cause more dangers.

Based on the above research, we decided to make a light-weighted, automatically controlling, detachable, and powerful device with approachable price.

4. Design Concept

a. System structure

The whole system consists of four parts: appearance design, circuit connection, Arduino code, and Android app. For the starter, appearance design is how our "Smart Assistant Chair" looks and what it is made from. Next, circuit connection includes the interconnections among the motor, sensors, Arduino board, the wifi module, and the power. Arduino code is the main software that runs behind the system, performing the whole control mechanisms for this chair. Last but not least, our Android app is aimed for data visualization and statistics about the elders using the chair, with the target audience being their children. Some reminders according to the statistics will be sent to the children's phone. The overall system can be quickly understood by looking at figure 1 below.

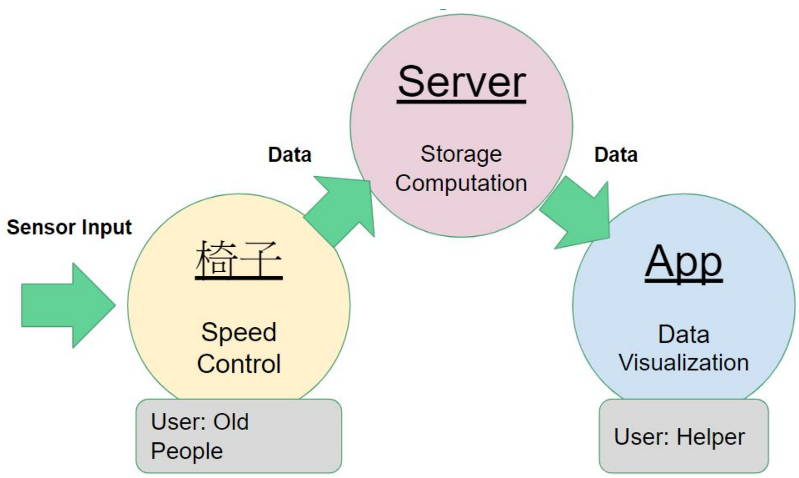

Fig. 1 The overall system structure

b. Appearance design

Based on the competitive product research, we at first decided to make a detachable device with higher stability than the Yue-cushion for safety concern. Regarding to the difficulty of manufacturing a device all by our own, we bought the Yue-cushion and made some improvement.

For the power-less lifting part, we bought a strong linear motor and control it with our controlling system. It will motion based on data sent by sensors.Considering of the habitual movement: pressing the handle while standing, we built two handles on the both side and add pressure sensors. We also added fixtures on both side to strengthen the stability of the cushion for safety reason we mentioned before while still keeping the detachable feature. Last, we add a back to make it more comfortable. The final appearance can be seen through the following pictures (fig. 2, fig. 3, and fig. 4).

Fig. 2 lateral view

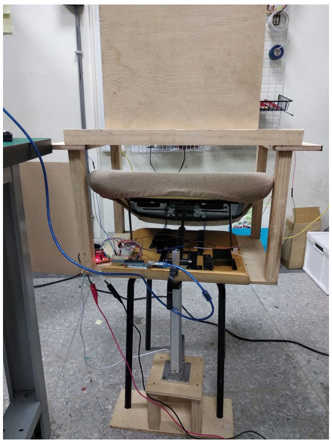

Fig. 3 back view

Fig. 4 front view

c. Circuit connection

The computing process unit is base on Arduino Uno R3 (fig. 5). Sensors are connected to Arduino's analog input, including two FSR pressure sensors (fig. 6) and one infrared distance sensor (fig. 7). A linear actuator (fig. 8) which can perform strength of 100N is attached to Arduino via a motor driver L298N (fig. 9). We connect L298N to the digital output (i.e. pwm control) of Arduino. By writing 0~255 to the particular pin, we can control the speed of the motor. L2989N also allows us to control the orientation of the motor, so that the linear actuator would extend or be shortened. Moreover, since the linear actuator requires power of dc 12V, we supply it with a power supplier (fig. 10), which can be replaced with some 12V batteries. As for the wifi connection, we utilized the ESP8266 wifi module (fig. 11). It is simply another processing unit to which we transfer data, and then it can send request to a server to upload the information.

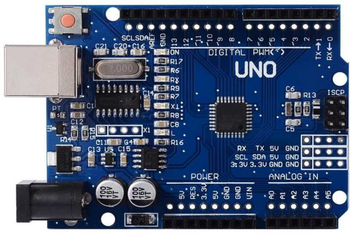

Fig. 5 Arduino Uno R3

Fig. 6 FSR sensor

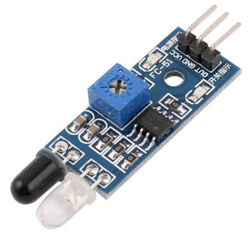

Fig. 7 IR sensor

Fig. 8 Linear actuator

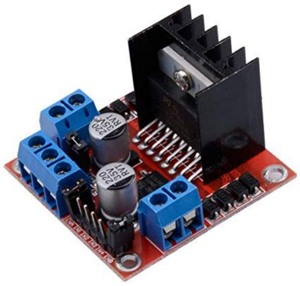

Fig. 9 L298N motor driver

Fig. 10 power supplier

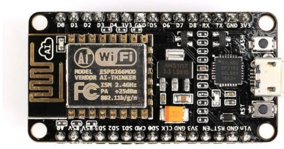

Fig. 11 ESP8266

It is worth noting that the 5V power of Arduino and the 5V output of L298N are connected together so that we can maintain the voltage value as 5V, since the voltage may be pulled down by the sensors with internal resistors. What's more, the ground of the whole systems is connected together to keep the system stable.

As for the FSR sensor, it actually serves as a variable resistor. Thus, we put a 10k resistor in series and take the voltage divider as the input of Arduino analog pin, as shown in fig. 12 and fig. 13.

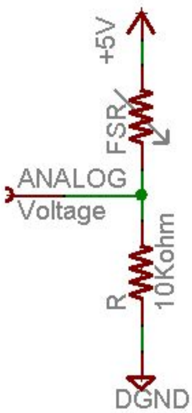

Fig. 12 FSR circuit

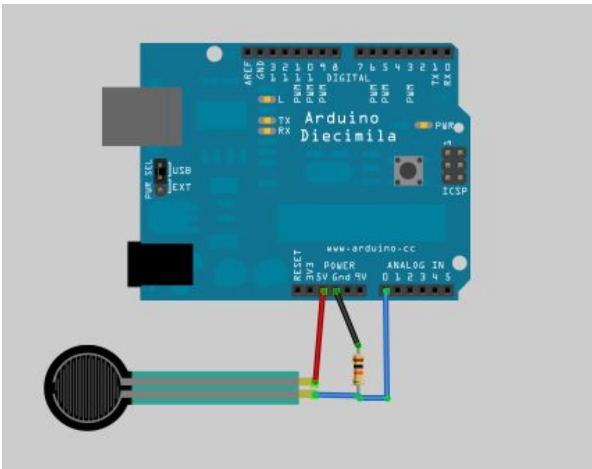

Fig. 13 FSR vs Arduino connection

d. Arduino code

The code contains two main parts: setup and loop. For the setup part, we simply defined several pin numbers of sensors and motors as well as some variables for recording the value of sensors. We have also created a variable “mode” to keep track of the mode, whether someone is trying to stand up from the chair or the system is currently unnecessary. The mode “1” indicates that the system is in rest, while the mode “2” indicates someone is standing up.

For the loop part, a few algorithms are implemented. First of all, to detect the moment that a person is about to stand up, we constantly record the value of two FSR pressure sensors. If both sensors report a value bigger than 500 for 50ms continuously, we judge this situation as the mode “2”. As soon as the mode is turned into “2”. the motor will be turned on at full speed, serving as the main strength that lifts one’s button up.

During the elevating process, a motor speed control algorithm (fig. 14) is implemented to meet the goal of feedback controlling. On one hand, when the motor is acting too fast, we would like to slow it down. We access the speed information by measuring the differentiation value of IR distance sensor. After calculating the difference of the current speed and the target speed, we times the value 0.1 to be the partial contribution of the motor acceleration. On the other hand, if one has to use their hands badly to stand up, the motor speed is probably not enough. As a result, the FSR pressure value serves as a contribution to the motor acceleration too, after timing 0.005. Adjusting the parameters (0.1 and 0.005) is the important part of this control system. We have to find the fittest value by trial and error. The output motor acceleration will then be added to the current motor speed, being the speed for the next loop.

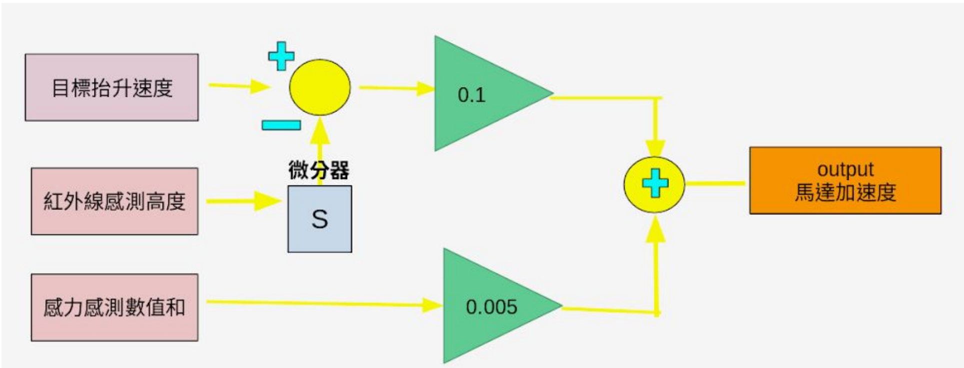

Fig. 14 motor speed control algorithm

We need to determine when to stop the motor when the person has stood up successfully. The algorithm is that when the IR distance is larger than a specific threshold, which is 990 by experiment, than we call it a complete mission. We let the motor work in the opposite orientation to shorten its length and wait for another trigger. Every variable is also reset to the original value, including resetting the mode back to “1”. After resetting, the system awaits another stimulation and works forever.

e. Server establishing

The server code is written in python flask, which is a lightweight web framework. The operating system of the server is Ubuntu 17.04 LTS. The video of the server (link) and figure 15 shows the terminal output when receiving data from both sensor and app update request.

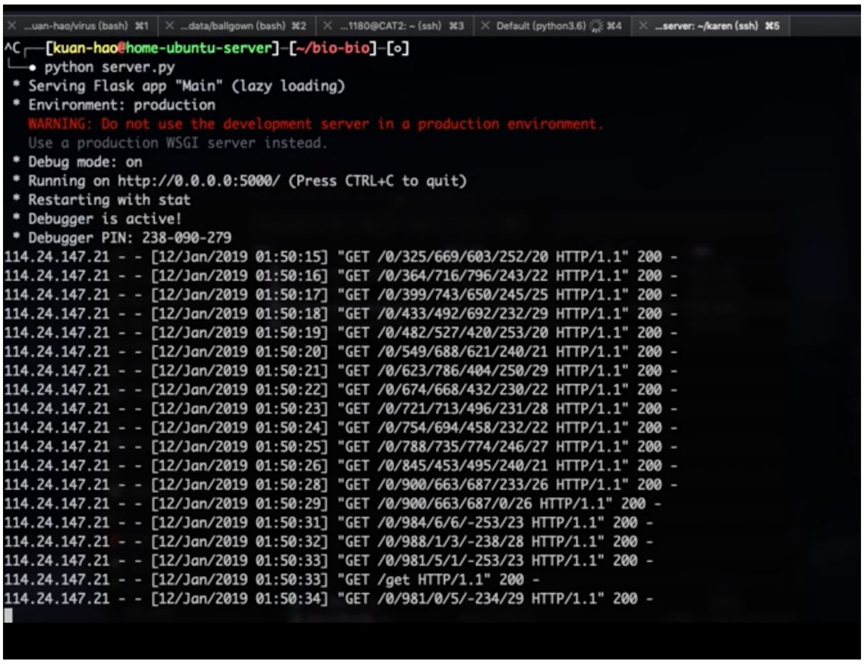

Fig. 15 the terminal output of the server code

f. Android app

The chair is designed for elders, therefore, we simplify the design and avoid using remote controller or panel to control the chair. Thus, the Android app is not designed for the elders, instead, it is designed as a monitor interface for elders' family. This app is a bridge between elders and their families which provides a convenient approach to understand the standing condition of the elders.

The Android app is developed by Android Studio as a native app. The logic programming language is written in Java, the structure code is XML and the whole project is compiled by gradle. There are three main pages in this app: the main page (fig. 16), the basic information page (fig. 17) and the statistics visualization page (fig. 18). The main page shows the structure of the whole system. Users can grasp the design concept of the whole system at a glance. The second page is the most important part, dynamic visualization of sensor information. We provide two types information, the height of the seat cushion recorded by IR sensor and the corrected motor speed recorded by motor. The third page is the designed for user to input the elders basic information. Users can switch on some notifications button like daily report, abnormal condition alarming, long-time sitting etc.

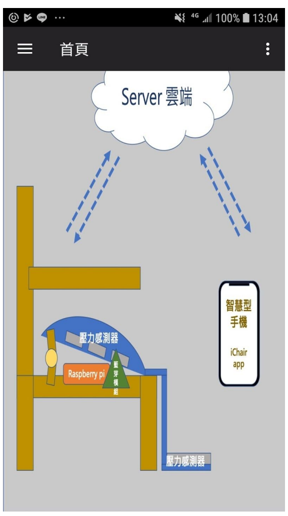

Fig. 16 Main page

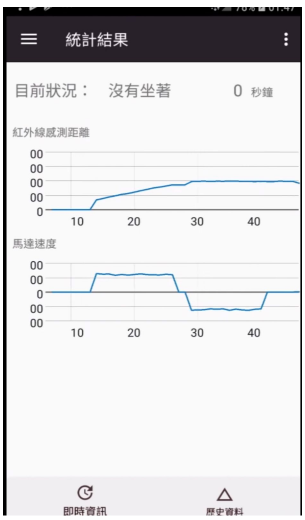

Fig. 17 Statistics Visualization

Fig. 18 Basic information

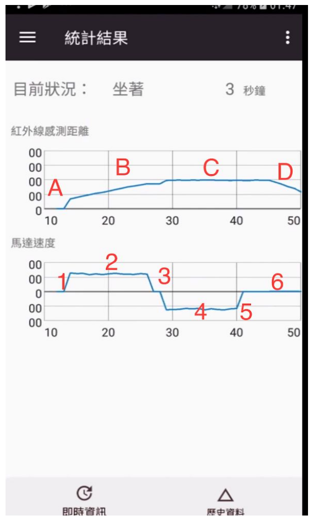

Fig. 19 Statistics Visualization

5. Result

a. Trying on the chair

A demo video is recorded and could be watched at https://goo.gl/iSkrHS. In the video, Hsi Chen sat on the chair first. Next, her hands pressed on the two handles to help her stand up, which triggers the system through the two FSR sensors. Consequently, the linear actuator started to work and elevated Hsi Chen’s button. When the height is enough for Hsi Chen to stand up without effort, the system reset.

b. Android app data visualization

The sensors would generate a lot of data which would be hard to understand. Therefore, we visualized the data by line chart which makes it easy for users to know data changing. Furthermore, we also provide real time information from the server that updated by sensors. Every second, the app would do http request and update the information as well as redraw the figure on the page. The video of the dynamic visualization (link) reveals how fast the seat cushion rises which represents the standing condition of the elders. Following are the detailed explanation of the sensor data during the elders standing (Fig. 19).

- Seat cushion height recorded by IR sensor :
    - line A : The origin hight from chair to seat cushion is about 10 centimeters.
    - line B : This curve shows that the old man is standing up and the height is increasing.
    - line C : This curve shows that the seat cushion has reached its highest height and go into a steady state.
    - line D : This curve shows that the old man starts to sit down and the height drops abruptly.

- Motor speed recorded by motor :
  - line 1 : The motor starts to push. This curve shows that the speed of the motor accelerate from zero to fastest speed.
  - line 2 : The rising speed of the motor is in constant velocity.
  - line 3 : The rising speed of the motor starts to decrease and finally stop rising. Then, the motor starts to descend and reaches constant velocity.
  - line 4 : The decreasing speed of the moto is in constant velocity.
  - line 5 : The velocity of the descending speed is decreasing.
  - line 6 : The stick of the motor reaches its lowest position and stops moving.

6. Discussion

Our product, smart assistive chair, is designed to help elders while they are standing up. In this course, we have built the prototype of the chair .There are three main features of smart assistive chair:

1) Automatic control system:

   In the control system, the value of the IR sensor and FSR sensor would change the rising speed of the motor. The algorithm is well-constructed and has been tested several times to ensure the elders would feel comfortable during the seat cushion is rising. Therefore, the speed of the motor would be personalized and solve the problem that elders met.

2) Android AppReal-time information

   In order to create a platform for elders families, we develop an Android App which work as a monitor system. The information of sensors would be visualized in line chart and updated every second in the statistics visualization page . The dynamic charts are easy to understand and are helpful for users.

3) Two-step rising

   There are two steps during the rising of the seat cushion. In the beginning, the motor would start pushing once the old person pushes the FSR sensors. During this step, he/she do not need to exert any strength and the seat cushion would be raised. At the second step, he/she could stand up with the help of the gas pressure bar. When the angle between the chair and the seat cushion is zero, it would be hardest for old person to stand up. Thus, our two-step design would solve this problem.

   Although the design idea of the chair is great, however, there are still some problems on the prototype chair that we should solve in the future.

1) Portability

   Portability issue is in the first priority among our problems. Our original idea is to make the seat cushion portable and could be applied to most kind of chairs. However, due to the size of the motor, the whole structure of the chair becomes bulky and hard to move. In order to solve this problem, we plan to change the motor into a smaller one with the same pushing power as the current one.

2) Power Supply

We use DC power supply on the prototype of the chair. We would switch to batteries which can be installed on the seat cushion in the future.

3) Price of the product

The price of our prototype chair is roughly around 4000 NT dollars, which might be too expensive. Our goal is to reduce the cost of each materials that we used in the process of manufacturing.

4) Stability

The overall system has been built but the connection between sensors, server and Android app should be improved.

7. Conclusion

In this project, we try to make a smart assistive chair with automatic control system. With the former research, we made clear object of producing the device with strong power, high safety, and approachable price. For hardware, we made the device light-weighted and detachable but still keep the stability. In controlling part, we use sensor in our feedback loop and design an algorithm to make sure the motor acts in proper speed, fast enough for lifting and slow enough for safety. The most important is that we record the data through sensors constantly and represent it through the application wrote by ourselves. The information can not only be used for users to browse but also to evaluate the condition and habits of users. The rough data is also a potential resource for personal medical care and rehabilitation. We believe, with proper enhancement and further research, this product would definitely be a helpful and useful device for every family.

8. Work Distribution

a. 趙冠豪
   i. Android code implementation
   ii. Server establishment
   iii. Presentation
   iv. Report writing

b. 莫絲羽
   i. Arduino code implementation
   ii. Material searching and buying
   iii. System circuit design
   iv. Presentation
   v. Report writing

c. 陳　曦
   i. System structure design
   ii. Hardware design and produce

iii. Presentation
iv. Report writing