UM–SJTU Joint Institute

Introduction to Engineering

VG100

Final Report on Project 2

Motion Tuner

Group 3 Trinity

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1 Executive Summary

Our team members have great passion in dancing and music. Dance and music promise people a colorful life. However, limited time and space in our daily life limited our possibility to enjoy this entertainment, and the traditional dancing machine is too big and expensive. For these reasons, we developed a product to solve these problems.

Our product can be accessed by a mobile phone or a PC. First, in mobile phone part, we use the sensor inside of the iPhone, while in PC part, we use an extra sensor. Both sensors are used to detect our motion then transfer the data collected to the terminal. Next the algorithm stored in the terminal will analyze the data. Finally, the terminal will give out a piece of music according to the data. We have two types of function, matcher and scaler. On one hand, matcher can provide the music immediately when you are doing a motion. On the other hand, scaler can record your motion, then generate a piece of music later.

A lot of people will benefit from our design. Our design build a bridge between music and dance. Both music lovers and dancer lovers can have entertainment in a city life freely, where time and space is limited.

2 Acknowledgements

Thank Prof. Yanfeng Shen, the instructor of VG100 for the technical part, for his valuable lectures and technical instructions.
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Thank all members in our group, for their unremitting endeavor and team spirit during the whole project.
Thank all classmates in our section, for their help and competence in the section.

3 Introduction

Our group is consisted of five students: Xie Shuxiang (group leader), Ma Kerui, Wang Ren, Zhu Boying and Guo Chengzhang. Figure 1 shows a photo of us.

Figure 1: Team members of TRINITY.
(From left to right: Xie Shuxiang, Wang Ren, Guo Chengzhang, Ma Kerui and Zhu Boying)

We are UM-SJTU JI freshmen who are taking VG100 course. And successfully completing project 1, we focus our attention on designing a new product that can help stressful people relax themselves. Since some of our members have great interests and talents in dancing, we decide to explore for a convenient way for daily dancing. Its function is to detect users' motion and create corresponding music.

4 Problems

4.1 Statement of the Problems

Many citizens find themselves under the pressure over moderate and too busy to pursue for happiness. They are in unhealthy mental conditions but lack for convenient ways to get happiness. People have tried to get happiness since the happiness lesson in Haward, aiming to teach people to be happy, has become one of the most popular courses. According to China Daily, many high school students find themselves under high pressure, which is shown in the graph below. Even though they want to do some exercise sometimes, the space is limited.

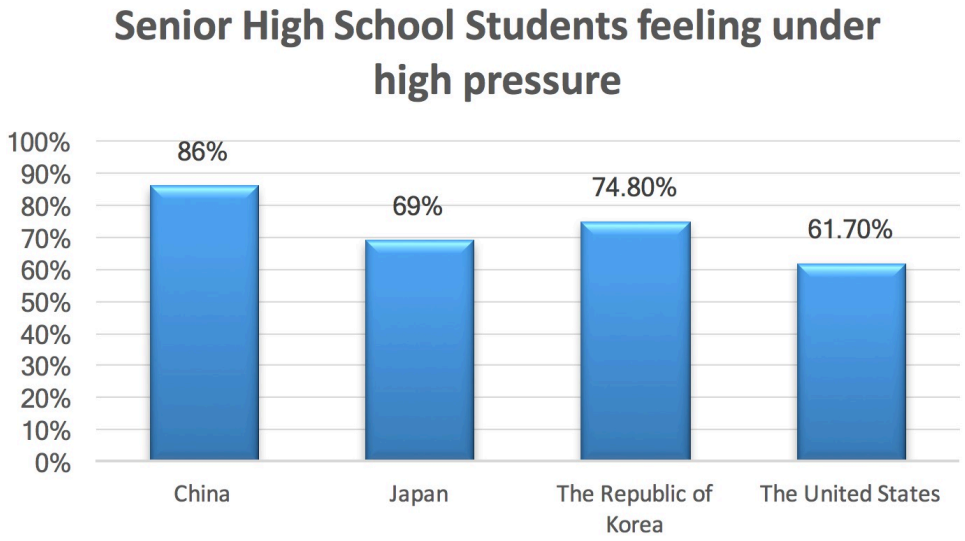

Figure 2: Proportion of Senior High School Students under High Pressure

We choose dance to help people relax because it is convenient and low cost. Compared to other healthy relaxing ways like jogging and walking, dancing can be indoors, not influenced by the weather or the air pollution. The cost for dance is quite low. Traditional dancing machines are not suitable enough for people who want to get happiness from dancing.

1. It does not meet homeentertainment needs well because of large area occupation and high price.
2. It is unavailable for people with jobs and students in the work places or study rooms.
3. It stresses acrobatics, which is difficult for beginners.

As a result, traditional dancing machine cannot provide users with anytime and anywhere dance.

4.2 Summary of Problems

In summary, people need ways to relax because they are busy and under pressure. Dance can help people to get happiness, but traditional dancing machine exists these problems:

1. Large area occupation and high price

2. Unavailable in most places
3. Difficult for beginners

5 Need and Validation

5.1 Needs

Our product is to provide people with convenient ways to get happiness. To make our product convenient, the device should meet the needs of:

- Portable: The device should be able to be carried anywhere, like an App or a bracelet
- Low cost: The price should not be a burden for most people
- Multi-function: There should be more than one kinds of motion detected and more than one types of music produced.

There are also some constrains:

- Database: To make different functions, we need to build a large database to analyze, which may be too large for an iphone.
- Budget: Smaller the chip, higher the price.

5.2 Validation

Our device can meet with the criteria:

- For portable, our chip is only 1mm*1.5mm, which can be put into a bracelet.
- For affordable, our device is only 130 RMB, which is only one thirds of the prices of dancing machines and one tenths of the prices of motion detectors in the market. So, it will be affordable for most people.
- For multi-function, our chip will transmit 9 groups of acceleration per second, quickly enough for detecting motions and creating music. We also simplify 9 numbers to 1 to save space.

6 Objectives

6.1 Difficulties

Since we divided Part 4&5 into two parts, the mobile terminal part and the PC terminal part, we will divide the Objective parts into these two parts as well. They share many general objectives.

6.1.1 General Difficulties

- Have enough audio source to generate variable music
- Produce a harmonic music

6.1.2 Mobile Terminal part

- How to call the inner sensors in mobile phone
- The calling of the speaker and the flashlight in mobile phone

6.1.3 PC Terminal part

- Transform data from the sensor to the PC terminal

6.2 Objectives of General Difficulties

6.3 Objectives of Mobile Terminal Part

6.4 Objectives of PC Terminal Part

7 Solution

7.1 Mobile Terminal Part

7.1.1 Flow Chart

First the motion of one person is detected by the sensor and become raw data. Then the raw data is filtered into acceleration data.

The filter mainly did two things. One is to abandon the useless data such as temperature and the other is to map the acceleration data into float point value between 0 to 5.

After that, the acceleration data will be processed through one of the following function, which are the **Matcher** and the **Scaler**.

After the the process of **Matcher** or **Scaler** function, one sound track is created and finally the multiple sound tracks are mixed into the final audio.

7.1.2 Index Script

The Unity Engine first recognize the index script and hand over its control to it. Thus, we use the index script to get access to the **gyroscope**, **speaker** of the mobile phone, ask for **memory**, create **main loop** (the loop in which the program will be in after initial setup), and call for **Matcher** and **Scaler** functions. The flow chart of the index script is shown in Figure 3.

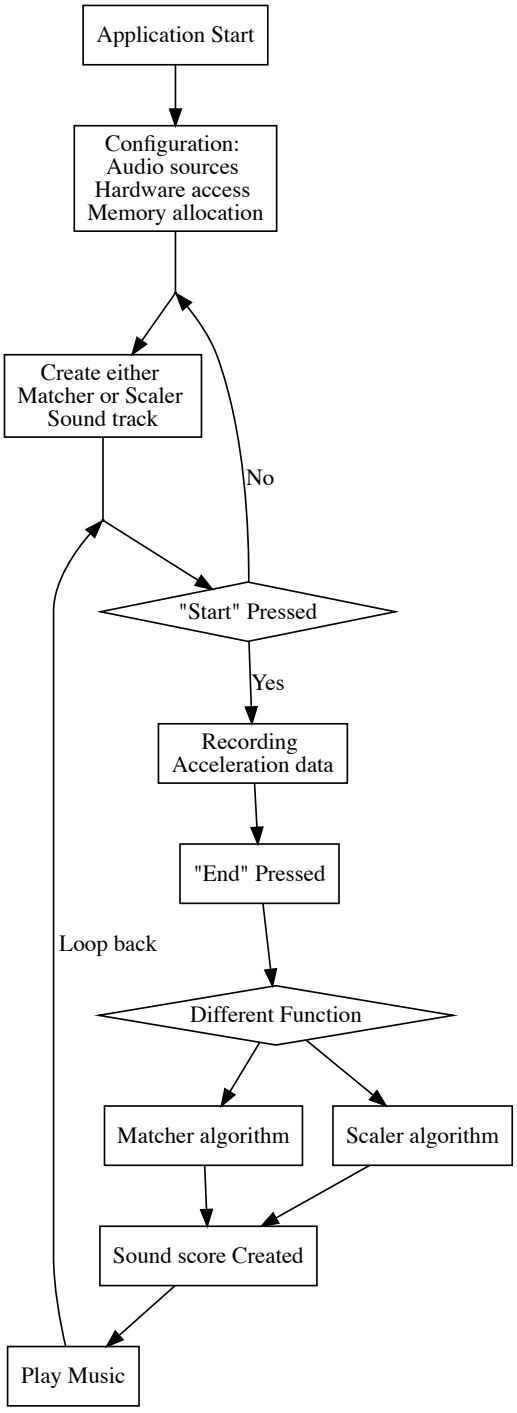

Figure 3: Flow Chart of the Index Script

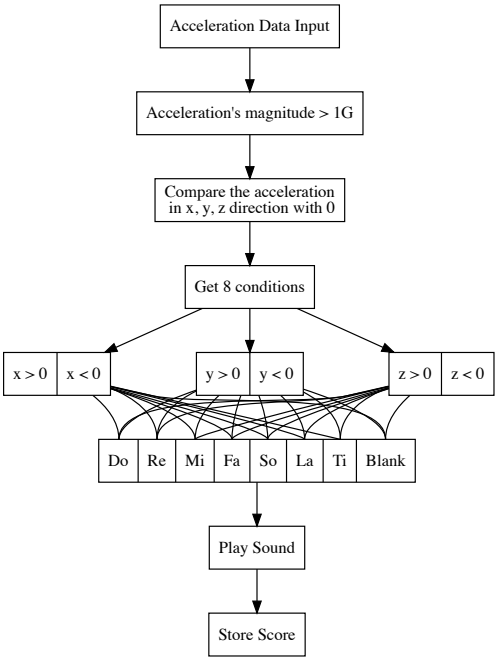

Figure 4: Flow Chart of Matcher

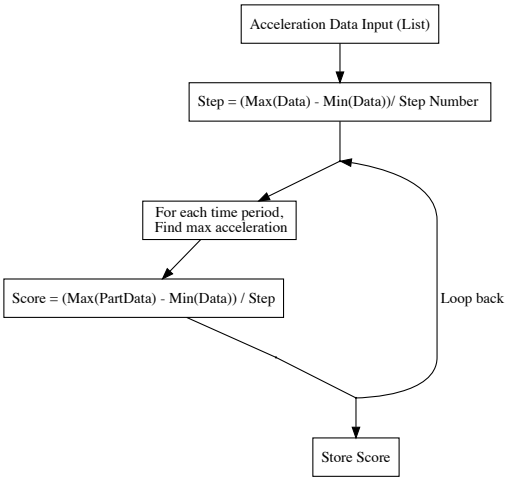

Figure 5: Flow Chart of Scaler

7.1.3 Scaler algorithm

For the **Scaler** part, also suppose we have the acceleration data. Then we separate them into 10 time intervals equally. And we find the max value in each interval. Then the ruler is created based on the max value and the min value of the acceleration data. The ruler create 7 blanks vertically for there is 7 tones in one music period, which are "do re mi fa so la ti". Fill in the blank and finally a music score is created and it produces one sound track.

The visual of the **Scaler** process is shown by step in Figure 6 to Figure 8.

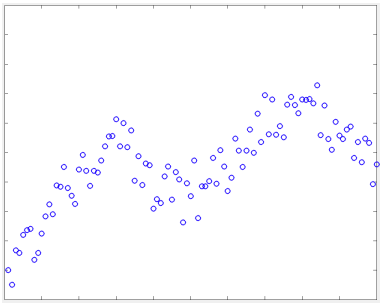

Figure 6: Scaler Process, original data

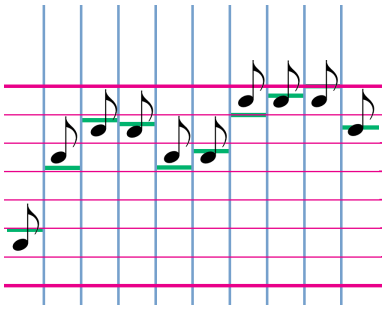

Figure 7: Scaler Process, split and create ruler

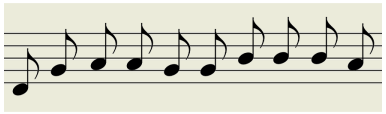

Figure 8: Scaler Process, final music score

7.1.4 Matcher algorithm

For the **Matcher** part, suppose we have the acceleration data, then we compared it with three pre-configured answers, calculate the difference between answers and real data. The one that has the least sum of absolute value is the audio clip we select. Then the corresponding sound track is created.

The visual of the **Matcher** process is shown in Figure 9 and Figure 10.

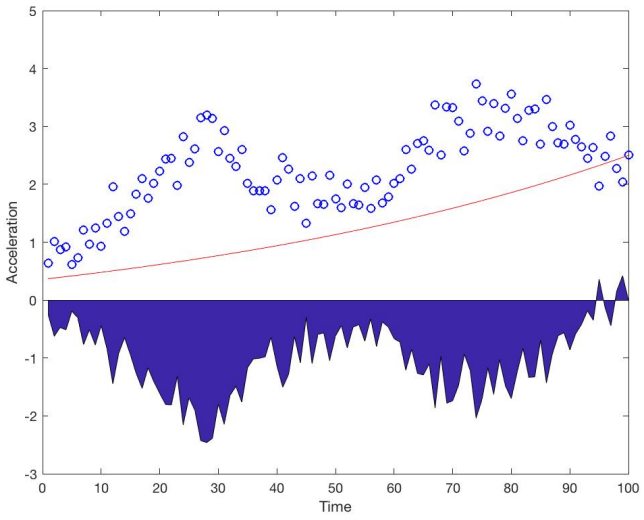

Figure 9: Matcher Process, Wrong music

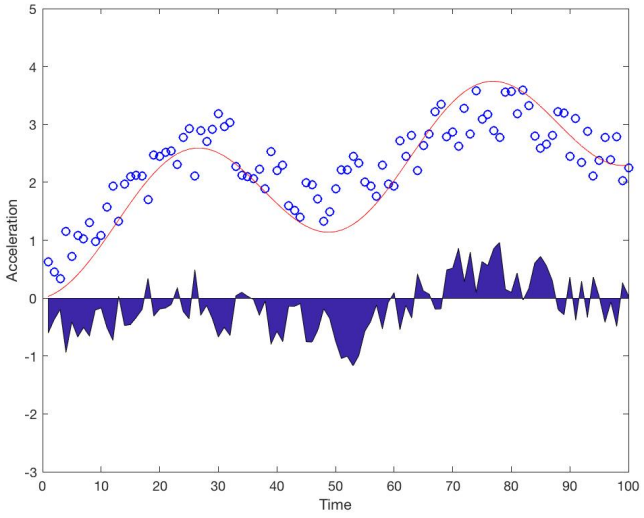

Figure 10: Matcher Process, Right music

7.1.5 Mixer

After we have multiple sound tracks through either of the previous process, we mix them together and create the final audio. Feel free to play it.

7.2 PC Terminal

Besides the cellphone terminal part, we also designed a PC terminal part, because when users dance, cellphones in hands are not safe enough. Cellphones might be thrown out and hurt someone and then be broken. Moreover, the cellphones are too heavy to carry when doing some fierce action. So developing a safer and lighter bracelet is necessary. The second part of our product can exactly satisfy the needs.

The second part consists of a bracelet and a PC terminal. The bracelet contains the sensor JY901, the bluetooth module and batteries. More specifically, the sensor JY901 can detect data, the bluetooth module can transfer data to the terminal and the batteries can power both JY901 and bluetooth. Overall, the bracelet mainly does the detecting job. On the other hand, the PC terminal mainly does the analyzing and generating jobs. The software on PC terminal developed by Unity3D can apply several different algorithm to analyze the data, so that the origin motion kind of the users can be defined. Then by comparing different conditions prepared previously, the software can mix and play all kinds audio source.

7.2.1 Hardware

7.2.1.1 Attitude Sensor JY901

The sensor JY901 is a attitude sensor that can detect the acceleration, the angle of avertence and angular velocity. The sensor itself consists of three-axis gyroscope, three-axis acceleration sensors, three-axis digital compass and some other motion sensors. The sensor JY901 has the following characteristics:

- Flexible data outputting ports. (I2C, SPI, TTL are supported)
- High speed data outputting rate. (Highest 500Hz)
- Low power consumption. (17mA)
- Short and stable initializing time.
- Support software development.

7.2.1.2 Bluetooth Module

It is connected with the JY901 sensor used for data transmission. In the serial protocol, the bluetooth plays a role of an imaginary COM port whose name is COM6 on the Windows platform.

7.2.1.3 Battery

We use two chargeable batteries to power both JY901 sensor and the bluetooth module. Each batterys size is about 1cm*2cm*0.3cm which is very small. However, each battery can provide 3.3V voltage and about 200 mAh electric charge. Since the consumption of sensor JY901 is very small, the batterys life is able to ensure the normal work of our product.

7.2.1.4 Fabrication

We totally use two 3.3 V batteries to power both the bluetooth module and the sensor. The reason why we dont use one battery to power the device is that the voltage is too small and can not last long. The assembling detail is that, the positive side connects with the VCC port and the negative side connects with GND port. The communication between the sensor and the bluetooth is realized by the connection of RX ports and TX ports.

7.2.2 Software

7.2.2.1 Data collection algorithm (same with the Mobile terminal part)

7.2.2.2 Data transmission algorithm

Programming Language: C#

Input: All kinds of data collected by the sensor JY901, including acceleration, angular acceleration, temperature and so on in 16 hexadecimal.

Output: Acceleration readings of three axises in 10 hexadecimal.

Algorithm: The algorithm includes mainly two functions which are" "ReceiveData()" and" "ReadData()" and they each has their own thread. In the initialization part void Update() function, we create and open two threads one by one which can ensure that the data path is clear and efficient.

Then in function "ReceiveData()", an empty string and a buffer byte are created to store and transport the data collected. Since the 55 in 16 hexadecimal equals to 85 in 10 hexadecimal and all the data we need starts with 55 in 16 hexadecimal, the if sentences are applied. After all the suitable data have been collected, we add the string to the queue created as a data pool using the order queueDataPool.Enqueue(string).

In function "ReadData()", we first use the thread different from the previous one. All the data source in the part are from the queue acting as data pool. Here another buffer is created to store the data read out of the queue. We read data out one by one, when the length of the buffer reaches 22 which is the length we need, the buffer will be stored as formal data and then be cleared. Please note that since in the ReceiveData part we already judge what kind of data to collect, in the queue the data should starts with 85 in 10 hexadecimal and we dont need to set conditions again. Then there is the calculation part, take the data starts with 5551 in 16 hexadecimal as example. After 5551 the three axises accelerations are stored in two digits. The data format of the queue is string, so we need to transform data which is string in 16 hexadecimal to int in 10 hexadecimal. The function Int16.Parse(stroutpool[4].ToString(),System.Globalization.NumberStyles.AllowHexSpecifier) is applied. Thus we can calculate the accelerations out one by one.

7.2.2.3 Data analysis algorithm (same with the Mobile terminal part)

7.2.2.4 Audio source generating algorithm (same with the Mobile terminal part)

8 Tasks

8.1 General Tasks

8.1.1 Collecting and recording audio source

In order to collect all kinds of audio source, we search the Internet to find some short music with strong rhythm and can be looped. Since we have several modes, different types of music may be useful. Moreover, we use the software Garageband which consists of hundreds of audio source that we need. We record each element we need in the software and then save them for future use.

8.1.2 Combine each audio source in a harmonic way

Base on the theory of music such as the modal theory, we develop an algorithm that can generate each audio source in a relatively harmonic way. Since it wont change the fact that if your motion is random and your music will also be random, we can only try to reduce the effect of this problem. And further development are still need in the future.

8.2 Mobile Terminal Tasks

8.2.1 Call the inner sensor in the iPhone

The function of calling the sensor of iPhone has already been natively built. We include a library and call a line of system function to get the sensor data, which is in the form of 3-dimension vector. The vector is preceessed later by separating its component in each direction.

8.2.2 Call the speaker and flash light in the iPhone

We use a group of Game Object which is designed to get access to cellphone's hardware to call the speaker. The object is very flexible, for we can change its volume, its source clip easliy. We use Vufuria library (Widedly used in augmented reality field) to get easy access to the flash light of iPhone.

8.3 PC Terminal Tasks

8.3.1 Learn to transfer data from the sensor to the computer by bluetooth

First we need to learn the C# language, which is used on the Unity platform. Then search for information of serial port communication under the background of C#.

9 Schedule

Our group's work on this project lasts for 40 days. The schedule shown in Figure 2 is divided into four main parts. The first three parts, detecting, analyzing and generating are corresponding to our software, which is the crucial part of our product. The final task is about further improvement, including testing and improving user-friendly design.

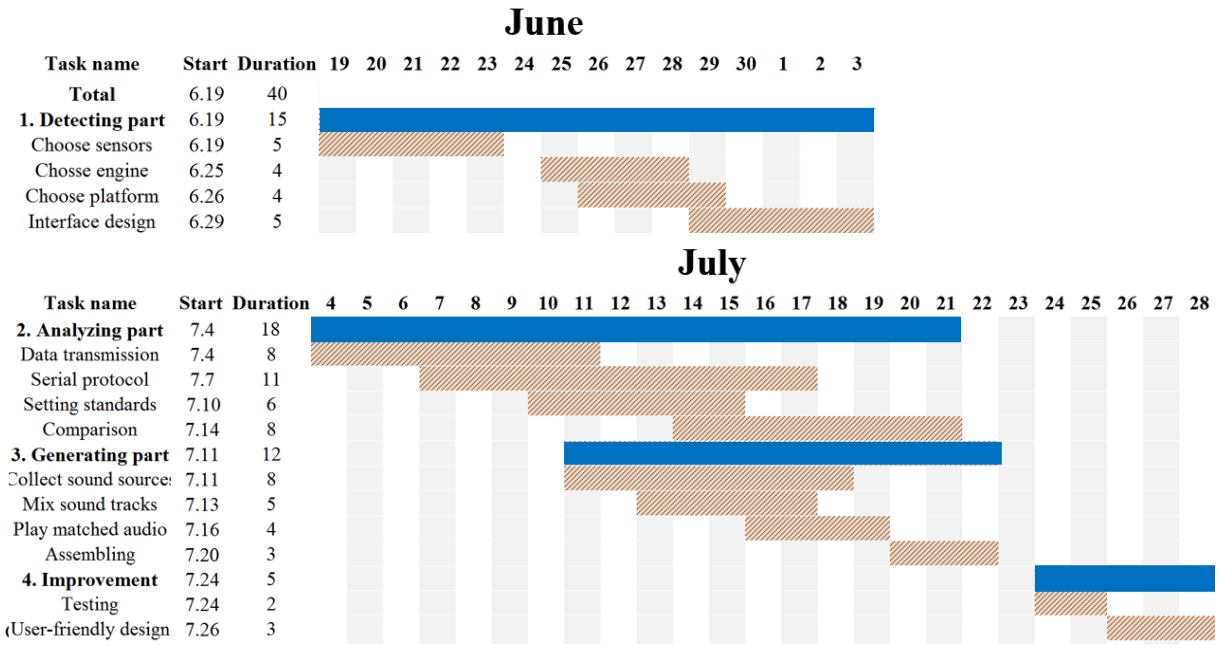

Figure 11: Gantt Chart

10 Budget

To detect user's motion, we need a sensitive sensor, a Bluetooth developing board and two batteries to transmit the information of user's motion to terminals. Table 1 shows the costs of our project. Hyperlinks of these materials are listed in Appendix. The total budget is less than 150RMB. The inexpensive price makes our product affordable for most people.

Item	Number	Cost(RMB)
JY901 sensor	x1	92.0
Bluetooth developing board	x1	22.3
Battery	x2	22.0
Total	-	136.3

Table 1. Budget.

11 Key Personnel

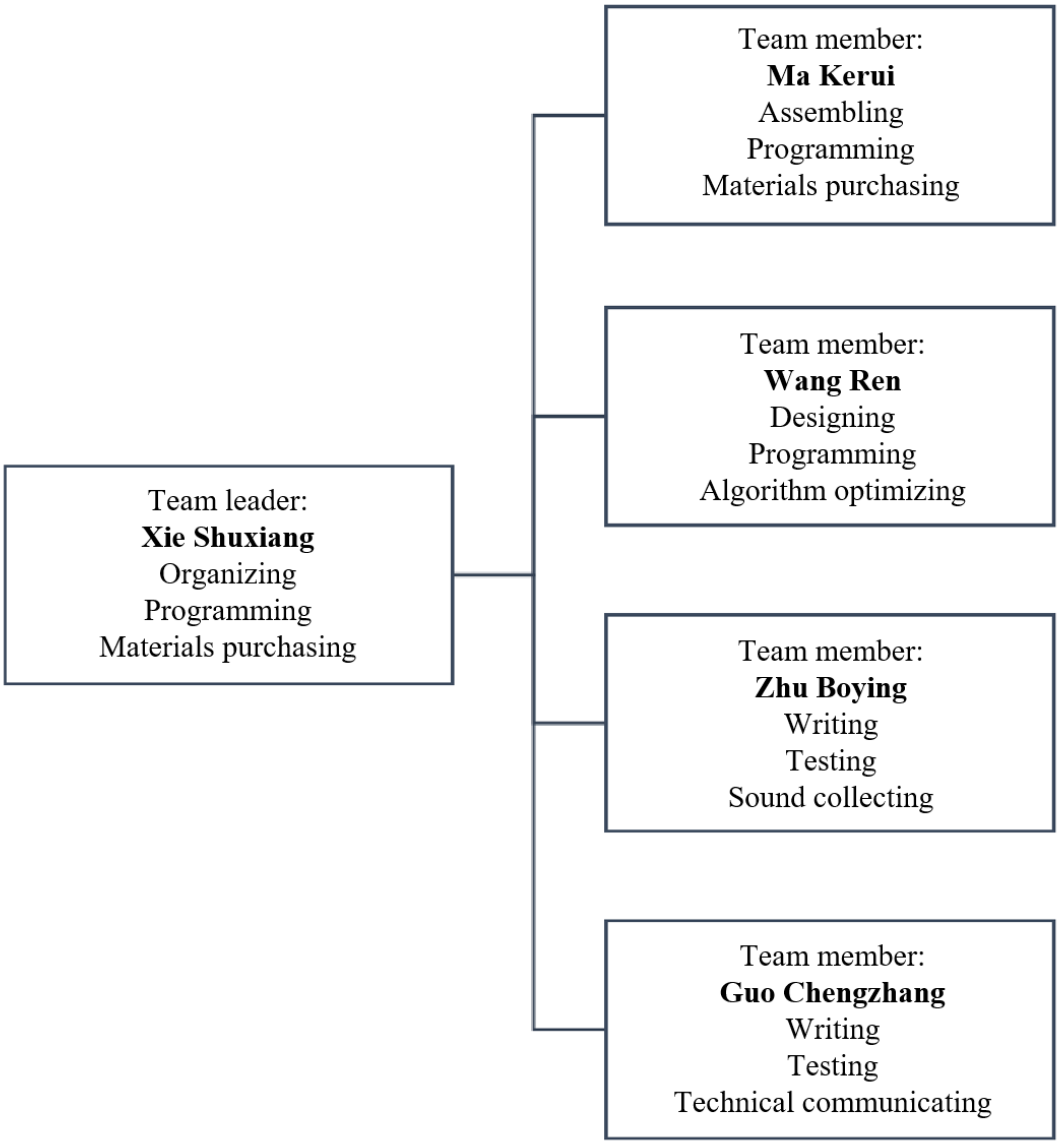

Figure 12: Key Personnel.

12 Conclusion

12.1 Current Achievement

Our product, motion tuner is able to detect users? motion and play corresponding music. The key part to achieve this goal is to analyze users? acceleration and create music with corresponding volume and tone. First, it transmits the information of uses? motion to terminals with the help of sensors. Then it analyzes the raw data from sensors and filters acceleration by serial protocol. Finally, it compares the acceleration with pre-set standards and creates matched sound tracks with acceleration. To create final audio, it is also able to mix different sound tracks to make music fluent.

Our product is designed for everyone living under pressure in everyday life. It provides them with a new option for relaxation. Due to its portability and low cost, it is convenient and inexpensive for users to dance whenever and wherever. This advantage makes our product surpass traditional dancing machines. Also, its sensitivity creates a nice platform for dance lovers to practice by themselves and it always encourages users to explore new movements with unique music on their own. Therefore, it can even act as an instrument for dancers to give improvisation performances on stage.

12.2 Future Development

In the future, we are going to focus on improving user-friendly design as well as bringing in more dancing modes. For user-friendly design, we will beautify the interface of our app to make it more elegant and attractive. Up to now we have two modes including power mode and story mode. In power mode, users are encouraged to create their own music by dancing freely. In story mode, users need to carry out a certain series of movements to the rhythm of played music. According to our plan, there will be more than three modes with different functions in our app to meet all the requirements of users.