北京航空航天大學
BEIHANG UNIVERSITY

Final Design Report

<Introduction to General Engineering> Engineering Design Projects (GEDP)

School of General Engineering, Beihang University

A walking assistance system for USN patient

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1 Summary

This report introduces the designing process and details for a walking assistance system for USN.

The system is able to detect the obstacle and remind the user as well as deal with emergency. The high light firstly is on the **dynamic stereo sound** that was specially selected and edited for USN patients, of which the characteristic of catching attention is proved to be more **effective on direction reminding** compare to others. The **algorithm of obstacle detecting** based on ultrasonic sensor and spatial relation setting gives a **high cost performance** to the obstacle avoiding system. **Cellphone application** with emergency dealing function is also adopted to make the system **convenient to use** and have a quite good **expansibility in modern society**.

The report also contains PR iterated base on our recent work and detailedly introduces three experiments on obstacle avoiding, direction reminding and emergency dealing for improving the system and proving its validity. The process of developing the system is briefly given by showing how we came up with each idea and selected the proper hardware.

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2 Iteration of PR

2.1 Problem Statement

2.1.1 Introduction of USN

USN is the abbreviation of unilateral spatial neglect. It is a brain damage, especially stroke that many people suffer from that causes unilateral spatial neglect. Neglect patients can't focus their attention on the offside. Therefore, they can't notice staffs that will do harm to them.

A buzzer, hot and cold stimulation, trunk rotation training and prism adaptation are existed methods to treat patients, but they all need a lot of exercises. Also, it is hard to find an industrialized product which is special designed for USN and largely put into market.

For patients' goodness, to deal with patients' inconvenient lives and patients' financial burden, and for economic benefit of both patients and clients, we decide to make A walking assistance system for USN patient.

2.1.2 Problems

We try to make a product which can help patients walk more safely with lower price. Meanwhile, it should have as less impact of the device on the patient's normal life as possible.

2.1.3 Scope

We mainly focus on patients who only have intersection of extra personal space neglect according to the spatial scale and egocentric neglect according to the space representation, without disabilities, cognitive disorders and mental problems.

Our product could only be used in the environment with flat terrain and without high speed or sudden appeared object.

2.2 Objectives

Table 1 Objectives

Objectives	Avoid Obstacles	Identify obstacle on user's neglected side and access its relative parameters, then output something to help users avoid it.
	Emergency Dealing	Develop an alarming system which alerts the passerby, call 120 and contact with user's family member.
	Portable	Be light enough.

	Safe	Never hurt people
	Low Threshold	Cheap, easy and convenient

2.3 Functions

Table 2 Functions

Functions	Obstacle avoidance	Our device can detect all the obstacles in a certain range around the user, and it will analyze whether user will hit the obstacle. If the result is yes, then it will remind the user the direction of the obstacle.
	Alarming system	The device should detect whether the collision take place. If so, it will make lights and sounds. Under certain condition, the device will do corresponding remedies automatically.
	Interact with APP	The application will record the relevant information during the user's use and sort out and analyze the information.

2.4 Constrains

Table 3 Constrains

Constrains	Working Constraints	Detect obstacles within at least 7 m in the front
		Maximum responding time is 1.5s
		Working temperature is between -10℃ and 45℃
		The water proofing grade is IPX4
		Stable performance in different weather
	Product constraints	Total cost<=20,000RMB
		No precise conclusion on illness symptom
		the gross weight<=1kg
		Minimum lasting time is 6 hours
		Meet people's psychological needs and physical needs
		suit different body shape
		No harm to users
	Social	Friendly to the human beings in society and the natural environment
		Must obey corresponding rules

	constraints	(including medical rules, traffic rules, etc.)
		Automatic call to relatives and police for help
		Automatic call to relatives and police for help

2.5 Others

Table 4 Stakeholders

Stakeholders	Client	1, found the demand in market 2, fulfill his requirement 3, benefits him
	User	1, judge our product 2, do the designing at user's view
	Hospital and sanatoriums	1, possible usage scenario
	Dealer	1, care about market competitiveness 2, design a good outlook and competitive function
	Manufactory	1, decrease the cost and production difficulty

Table 5 Service Environment

Service Environment	Physical environment	0~40 centigrade
		Obstacle in 8m and between 6-15 degree
		lithium cell
		Avoid obstacle with low velocity
		Have phone signal
	Social environment	Age between 40 to 60
		Ideal user
		Ideal walking habit
		Protects users' privacy
		Satisfies the change of patients' conditions

Table 6 Human Factors

Human Factors	The range of hearing and tactility
	Habits of walking
	Ergonomics
	The need for privacy
	The change of patients' conditions

Table 7 DFX

DFX	Design for manufacturing	1. Low cost 2. Manufacturing efficiency
	Design for safety	1. Protect user 2. Do no physical and mental harm to user
	Design for maintenance	1. Choose durable material 2.Choose long service life devices
	Design for environment	1. Environmentally friendly material 2. Little affection to passers
	Design for reliability	1, high success rate
	Design for beauty	1, nice appearance
	Design for reality	1, acceptable price 2, easy to use

3 Brief Summary of Conceptual/Preliminary Design Process

3.1 Conceptual Design

Based on our deep insight of USN patients' need, we plan to help user avoid obstacles with our product and deal with emergency.

The whole system is divided into four subsystems: Obstacle detecting, direction reminding, emergency dealing and Bluetooth communication.

Bluetooth communication between APP and the other peripheral equipment is the primary subsystem, because almost every process involves communicating with APP, whether sending or receiving message. Obstacle detecting monitors the surrounding and give the precise position of possible obstacles judging from a well-designed algorithm. Direction reminding alert users according to the analysis of the relative position using highly efficient stereo dynamic alarming. Emergency dealing monitors whether users fall. If not, it should take corresponding emergency measures to lower the risks and cut down the loss automatically.

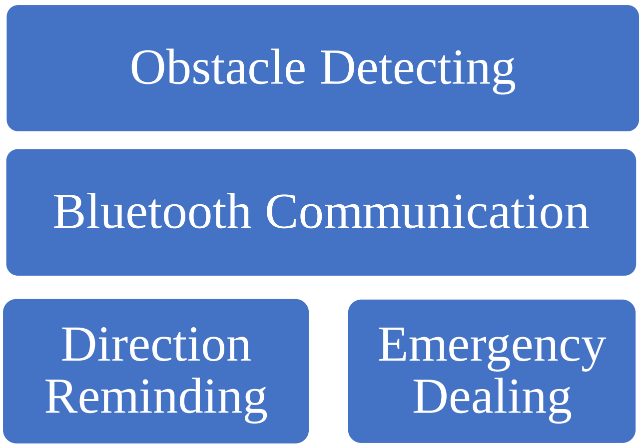


Figure 1 Sub-systems

3.2 comparison and preliminary design

3.2.1 obstacle detecting

1.Carrier and Layout

To carry the detecting hardware, we design a helmet as the carrier, whose structure is shown below in figure 2. Meanwhile, considering the ordinary height and our demand for the

Project, through computation, each sensor needs an angle of 15° from adjacent ones. And the whole layout is shown in figure 3.

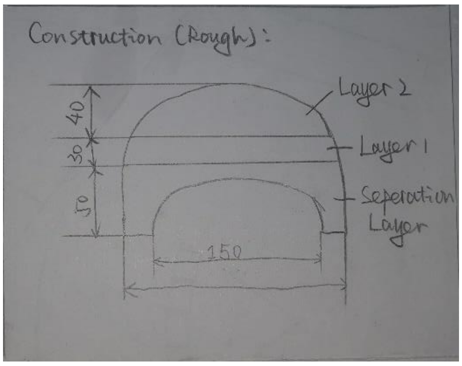


Figure 2 Structure of Helmet

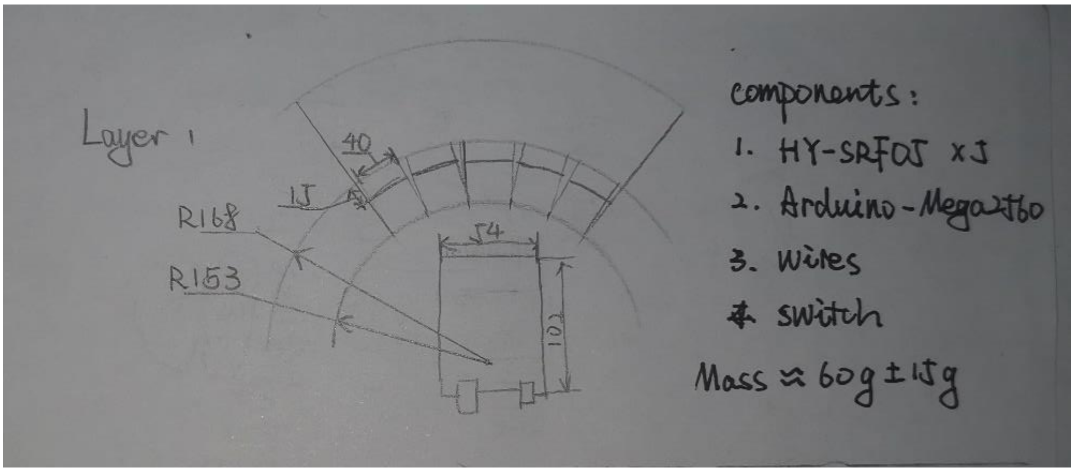


Figure 3 Layout of Hardware

2.Working Part Introduction

(1) General working process

Arduino board will execute the specific algorithm we write before head and control sensors to detecting whether there are dangerous obstacles. If the circumstance meets the requirement of obstacle judgement, the Bluetooth module will send the shortest distance and related sensor number to mobile phone.

(2) Hardware Selection

Sensor

After comparing among general sensors in the market, such as open mv, ultrasonic sensor, millimeter-wave sensor, infrared range sensor and laser sensor, we made a matrix to show their advantages and disadvantages and finally we select ultrasonic sensor HC-SR04 as its low price, low difficulty and enough performance for our project.

Controller

As we have chosen ultrasonic detectors, our choices on controller are limited in single chip microcomputers. Finally, we choose Arduino Uno board as its low threshold and high performance.

Communicator

Considering that our detecting part needs to upload detecting results to APP in mobile phone and nowadays most mobile phones are equipped with Bluetooth module, we use Bluetooth module HC-05 to serve as communicator between Arduino and mobile phone.

3.2.2 Direction Reminding

Comparison Between Solutions

The patients with USN will ignore obstacles which are in their ignored side. What makes our project feasible is the fact that we can capture patients' attentions by applying stimulations, according to researches of experts.[1] Also, we consulted to a doctor at Peking University Third Hospital about the syndromes of those patients, and got an answer that proper stimulations can capture patients' attentions.

Therefore, we came up with five solutions to capture the attentions, including stereo sound, vibration, force, voice prompt and electrical stimulation. After comparing the features of these five solutions like safety, connection, immediacy and so on, we eventually selected the stereo sound as our output of direction reminding system. The details of comparison and selection will be shown in the appendix.

Preliminary Design

Patients loss attention and have visual impairment on the neglect side while perceptual compensation can reduce it, therefore, we decided to make a compensation through auditory.

Stereo sound is the use of speakers to mimic sounds that appear to exist but are actually imaginary. The phase difference of sounds to left ear and right ear is different, so it is possible to edit sounds which can remind direction.

So, we set up a preliminary solution. The main solution is to divide the field of vision into 4-6 areas and use stereo sounds to represent them. The processor analyses input information and play the corresponding edited stereo sound through the earphones. Not only can it remind directions, it can also remind distances through different frequency. The patients receive the sound stimulus and pay attention to the direction the sound refers to. Thus, patients can notice obstacles and avoid them successfully.

3.2.3 Emergency Dealing

As for the emergency dealing, at the beginning we didn't consider this subsystem. However, in a meeting, one of the team members raised the question of what to do if obstacle avoidance fails. Indeed, we have to admit that no matter how well the device performs, sometimes the collision is unavoidable, and in this moment, our system should do something to save the user rather than just waiting. In this way, we design the alarming system, acting as a safeguard. And we hope to realize the function of alarming system through sound, light and alarm call.

After our discussion, we come up with this emergency dealing system. The system has two parts, fall detecting and alarming.

We decide to use acceleration sensors to judge whether user falls. If the processor analyzes the information and makes a judgement that the patient falls down, it will make a phone call to hospital to save time as much as possible. Therefore, patients could have more chance to receive immediate and effective assistances

We decide to build an app to implement these functions. We consider that the users are mainly elderly people, so app is easy to use for them. Also, cellphone has acceleration sensors which can used to fall detecting, and everybody has cellphone and they always carry around it. These factors determine that mobile phone app is a very good carrier.

4 Detailed Design Process and Analysis

4.1 General structure & System working flow

Our product makes use of our phone. Almost everyone has a phone, even the old generation. Convenient resources, no extra expense!!! So, what we offer is a well-designed APP. Besides, we equip our user with a specialized helmet.

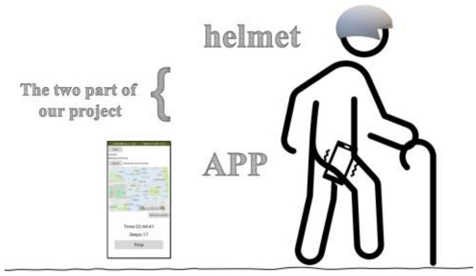


Figure 4 Devices

It has three layers: the solid shell, the layer of electronic device and the sponge protection layer. The secret is on the middle layer

There are ultrasonic detectors, HC-06 Bluetooth module and Arduino mega board. So, it can do detection and communication with our phone.

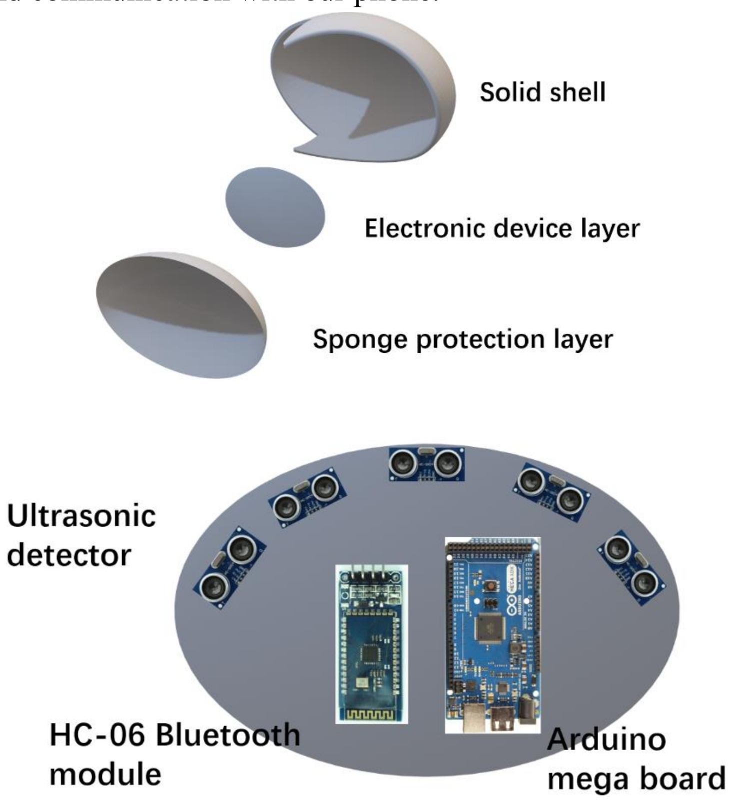


Figure 5 Helmet Structure

The overall working mechanism is shown in the picture.

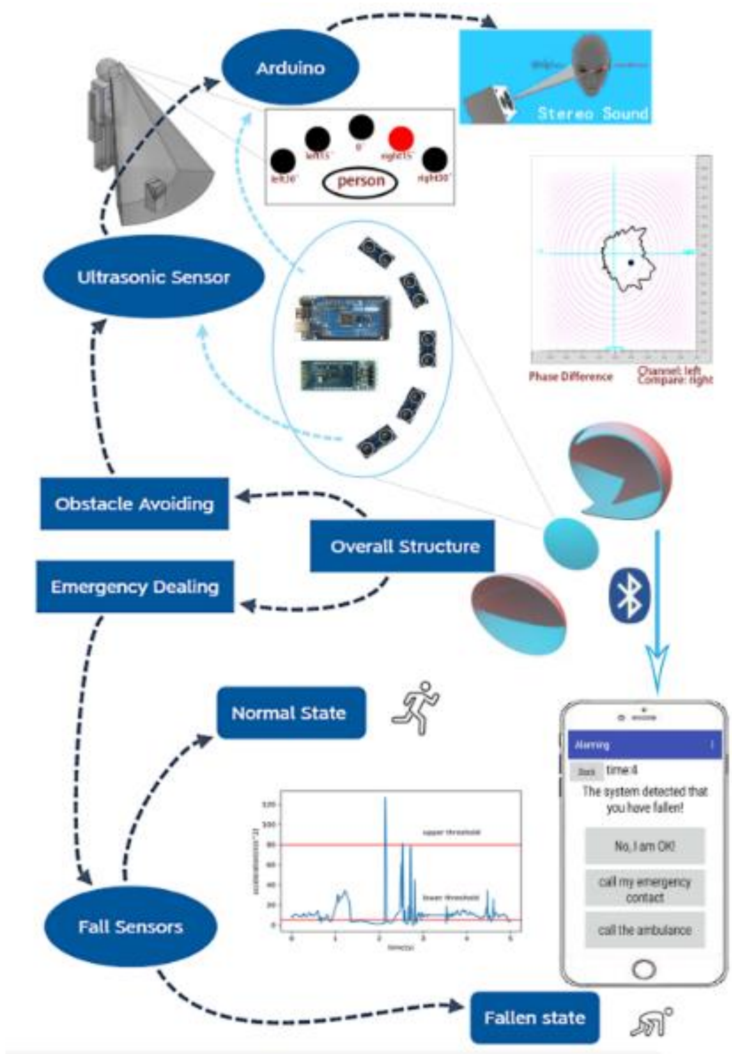


Figure 6 Working Mechanism

The detectors buried inside wearable devices send distance to the closest object in different angles to the APP through Bluetooth communication on a regular basis, say 0.5 seconds. The APP then judge from the received information the precise position of possible obstacles based a reliable algorithm. Then judgments will be sent back to the wearable device to generate corresponding stereo dynamic alarming.

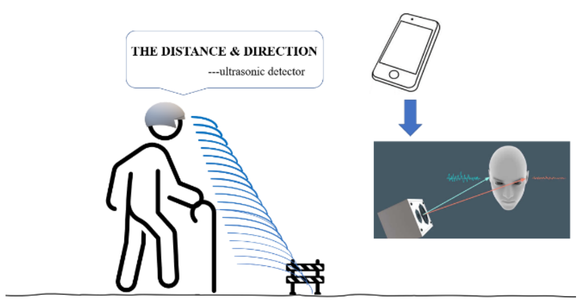


Figure 7 Obstacle Avoiding

Simultaneously, the APP is monitoring whether user fall based on some well-developed analysis process. If it finds out that the result is yes, then the APP will run the predesigned emergency dealing code automatically.

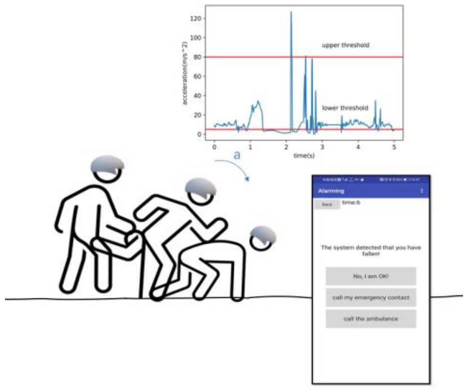


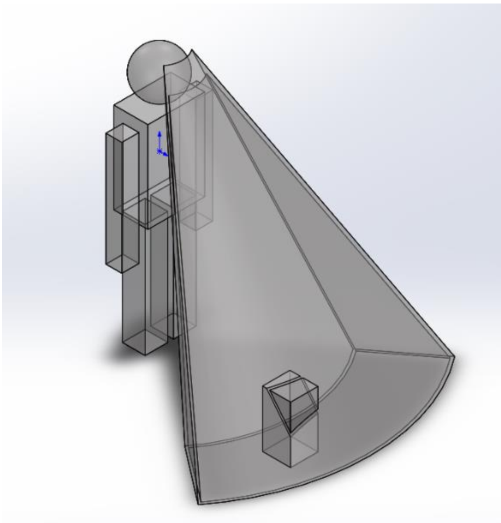
Figure 8 Dealing with Emergency

4.2 subsystem

4.2.1 obstacle detecting

Detecting range of sensors

Based on parameters of ultrasonic sensor, we make a detecting range model and list the attributes of this model below.



Attribute	Value
Height	175cm
Angle with respect to horizontal	30°
Argument	15°
Range	100cm

Figure 9 Detecting Range Model

circuit

To connect Arduino board, ultrasonic sensors and Bluetooth module, we make a circuit diagram as shown below. In addition, to make the diagram tidier and pellucid, there is an extra bread board to centralize some wires. Also, different colors represent different kinds of wires: green wires send commands from controller to components, yellow wires receive message from components, red wires connect to anode while black ones connect to cathode.

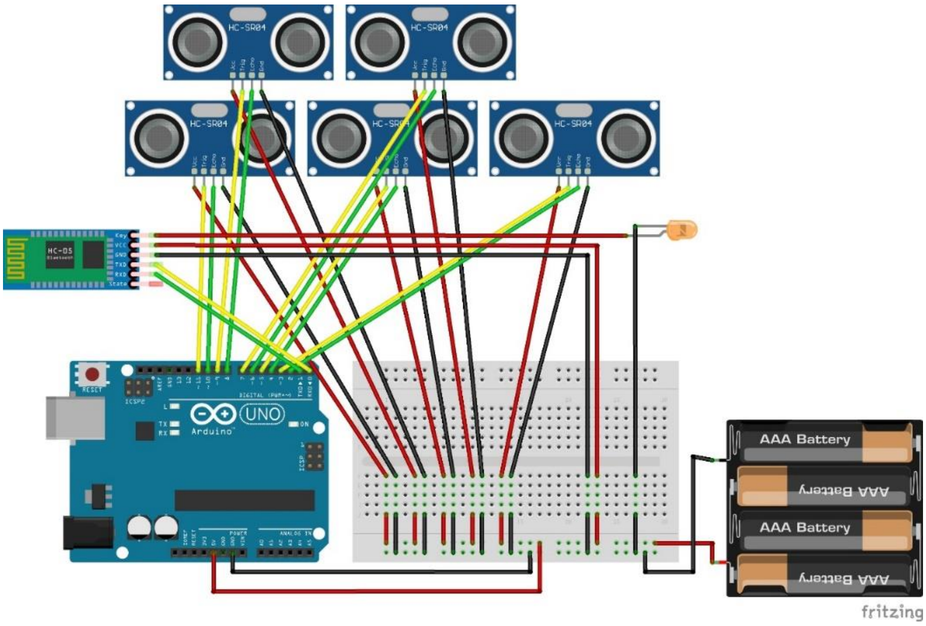


Figure 10 Circuit Diagram

Algorithm

To make the detecting algorithm precisely recognize obstacle without mistakes, we use two parameters to judge whether it's an obstacle or not, which are shortest distance and relative distance. The relative distance is the main parameter, which is calculated by subtract the minimum distance by maximum distance, and we keep this number within 5cm. This numerical value is calculated by simulation of detecting, which will be represented later. When the relative distance meets this standard, it means that the circumstance in front of the patient is flat, so this algorithm won't make mistake when meeting slope or step. In addition, to ensure some flat obstacles with dangerous height can be detected, we use the other parameter, which is shortest distance, to detect obstacle like table or horizontal board. The flow chart of our algorithm is listed below, and some screenshots of the code is also listed in the appendix.

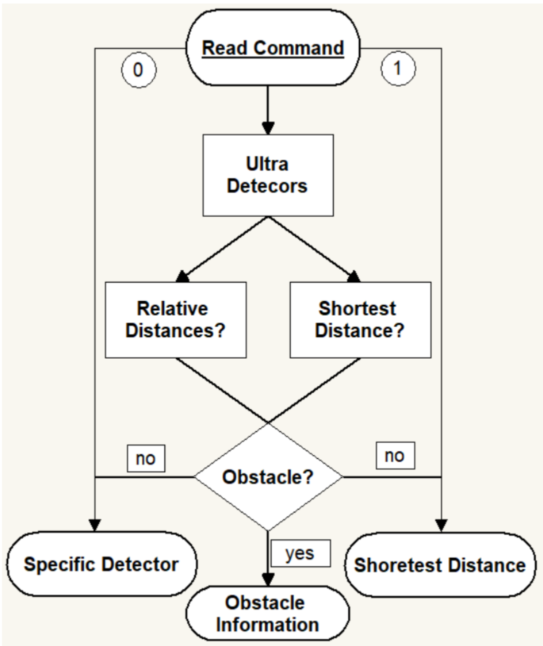


Figure 11 Flowchart of Detecting Algorithm

4.2.2 Direction Reminding

Researches show that people can distinguish directions through sounds with the sound level difference, time difference, phase difference and tone difference. And the resolution of human ears is 10°~15°.[2] Also, the detecting range of our ultrasonic detectors is 75°. Therefore, we divided the whole region into five sub-regions, consist of left37.5°~left22.5°, left22.5°~left7.5°， left7.5°~right7.5°, right7.5°~right22.5°, right22.5°~right37.5°. For each of these five directions, we designed a corresponding stereo sound.

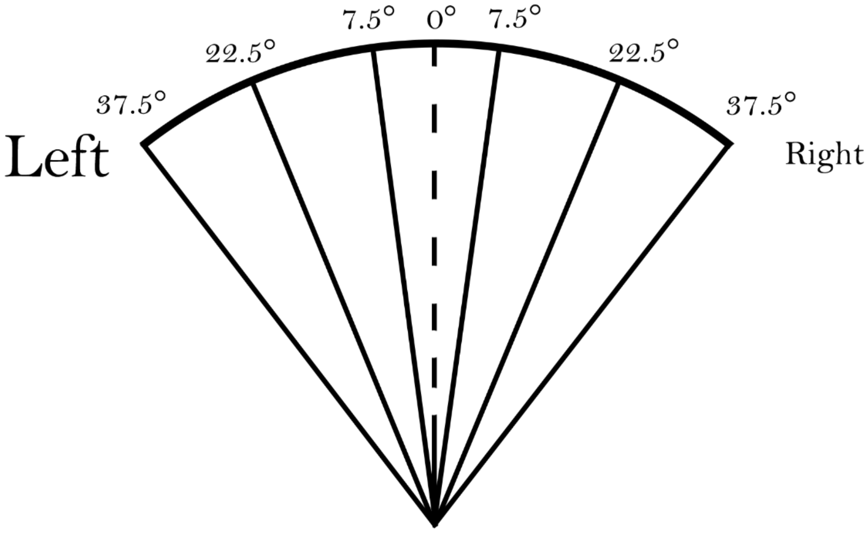


Figure 12 Five Sub-Ranges

When an obstacle is detected by ultrasonic detectors, the system plays the corresponding stereo sound. Distinguishable phase differences of different directions are shown on the right, which is visible under the Phase analyzer.

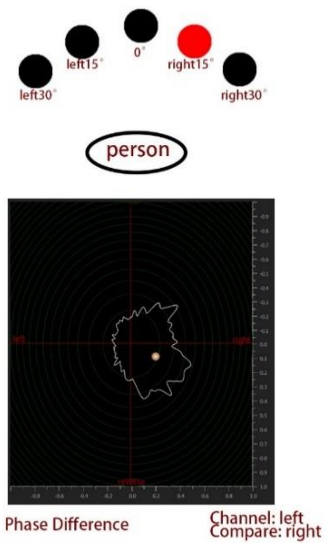


Figure 13 Reminding Mechanism

There are two ways of making stereo sound. One is to use the Panorama, and the other is to adjust the acoustic image directly. We compared the efficiency of these two methods, and decided to use the Panorama.

Figure 14 Panorama

At first, we edited sounds as static stereo sounds, which would not move when they were played. Users would hear a sound fixed in one direction. But the correctness of distinguishing is low, so we need to improve it.

We finally applied the dynamic stereo sound into the reminding system, since stereo help users get intuitive sense of direction, and dynamic catch their attention when it moves. Users would hear that the sound is moving and their attention could move to the direction of the obstacle following the sound.

Test shows that more reference, which means larger range of movement, could raise the correctness. Considering the distance and speed, we calculated that it would take 35 seconds for patients to reach the obstacle. So, we expended the range of movement and provided more reference to reduce users' illusion.

We also added a voice telling the direction directly after each sound to make sure users know the existence of obstacle even if users still couldn't notice the obstacle.

4.2.3 Emergency Dealing

Emergency dealing system is a remedial measure of obstacle avoidance system. When the user fails to avoid the obstacle and bump into the obstacle, our device should detect this collision and raise the alarm. So, this system can be generally divided into two parts: detecting collision and alarming. In addition, the system can also the historical data, which we think can help the doctor to analyze the state of the illness of the patient.

Detect the collision

In the first part, we need to detect collisions while excluding other everyday activities. In today's age, smart phones are becoming more and more popular, almost everyone has a smart phone. And, unlike ever before, the convenience of smartphones means that people now take phones with them when they go out. Hence, we decide to use acceleration sensors in smart phone to detect the collision. We first measure the acceleration in daily activity. The result is shown below.

Table 8 Acceleration in Daily Activity (Excerpts)

Time (s)	Acceleration x (m/s^2)	Acceleration y (m/s^2)	Acceleration z (m/s^2)	Absolute acceleration (m/s^2)
0.004005	-2.860141993	2.543753147	8.696822166	9.501884449
4.003998	-7.5429039	-5.570455074	-0.893238366	9.41930166
8.003998	-13.37383747	-8.488920212	1.569696069	15.91807906
12.004	-0.858915091	4.280325413	8.93719101	9.946471933
16.004	-7.233333588	-0.083950289	5.805191994	9.275150485
20.004	-15.46638012	-0.277832747	-3.456365347	15.85031755
24.004	0.10384132	-14.84309292	3.043930769	15.15234982
28.004	-1.409140825	-9.789229393	0.596500993	9.908102917
32.004	9.527179718	-8.013555527	-0.124910295	12.4498927
36.004	-7.480998993	-12.45658112	-12.05382919	18.87926262
...	...	...	...	...

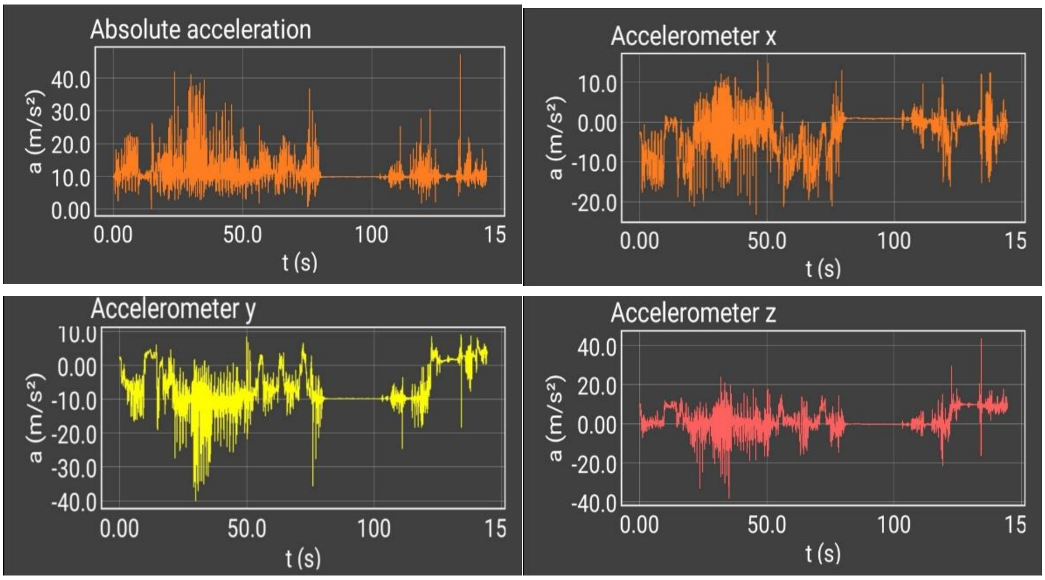


Figure 15 Acceleration in Daily Activity

We then measure the acceleration when collision happens. We drop the smartphone from the height of 1m to simulate the collision. This operation repeats for 20 times. And the result is shown below.

Table 9 Acceleration of Collision (Excepts)

Time (s)	Acceleration x (m/s^2)	Acceleration y (m/s^2)	Acceleration z (m/s^2)	Absolute _acceleration_(m/s ^2)
2.7559	-70.85949707	-71.96466064	52.19416046	113.6847
2.7599	-66.93531036	-75.6737442	35.37644577	107.0437
3.2519	-0.056464851	-68.5079422	57.31227875	89.31987
3.2559	24.45986366	-63.77429199	74.69668579	101.2178
7.0759	59.45858383	-23.88367653	-73.6129837	97.59418
7.0799	30.87084579	-37.63022232	-77.24452972	91.30038
10.56	48.33946228	-66.52010345	-18.12582016	84.20317
10.564	52.66212463	-71.70898438	-23.05035019	91.90645
10.568	55.56535339	-76.30177307	-27.4208107	98.29227
10.572	56.71668243	-77.92944336	-30.42494965	101.0715
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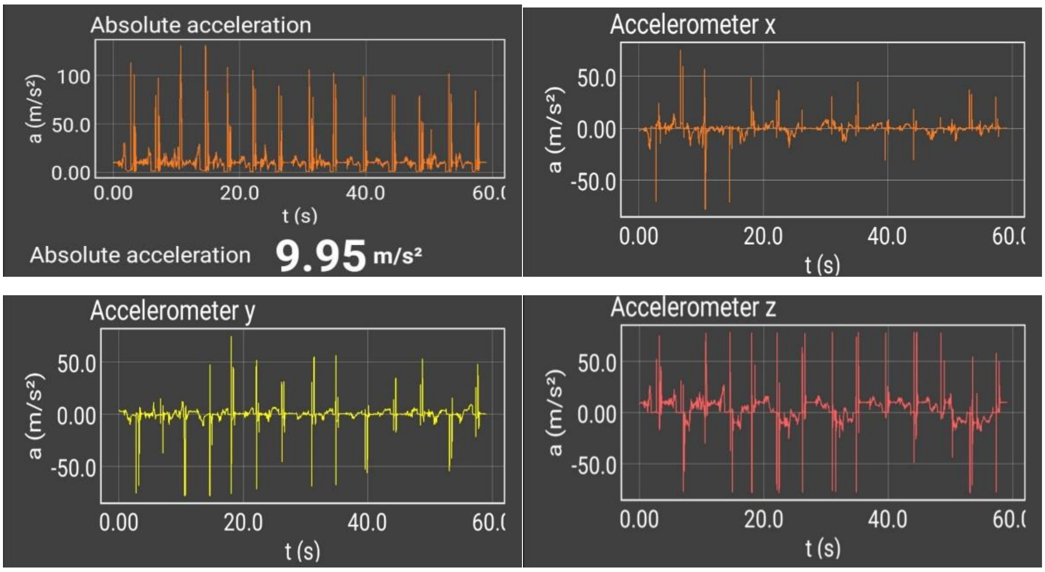
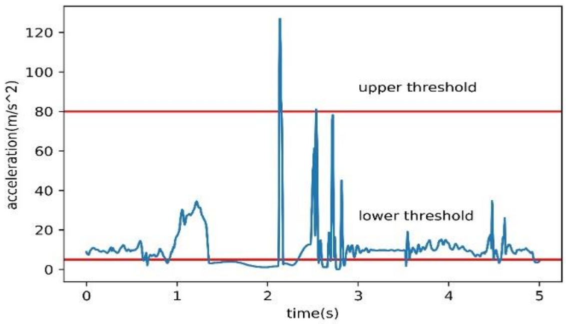


Figure 16 Acceleration of Collision

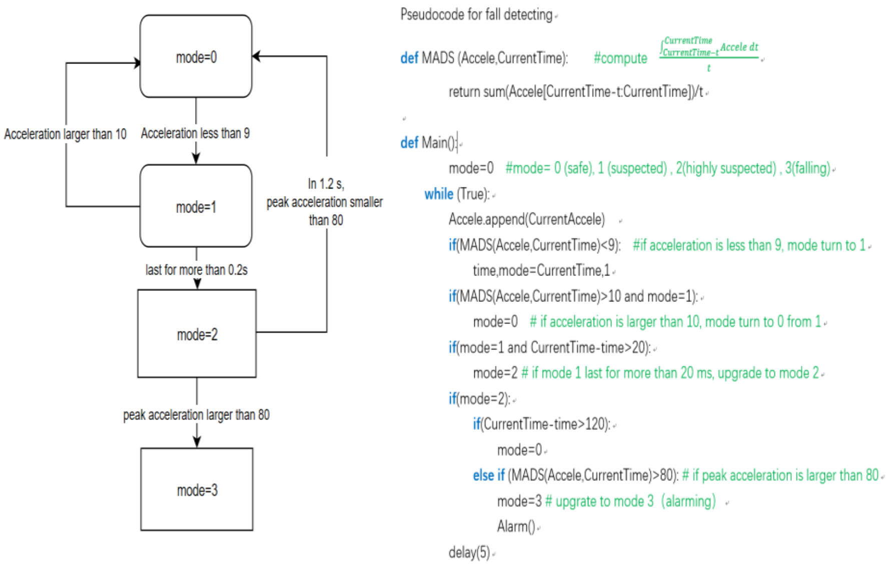
Through the data we can spot that the acceleration in daily activity are less than 60 m/s^2 and the acceleration in collision are large than 80 m/s^2. So, we think the upper threshold value of collision is 80 m/s^2.

On the other hand. When someone fall done, there will be a stage when the person is weightless. In another word, there will be a period of time that the acceleration is smaller than acceleration of gravity. So, we think only consider the upper threshold is not enough. We also need a lower threshold to enhance the success rate of detection.

We have done many simulation and real experiment to figure out the duration and the property of both weightless stage and the overweight stage. The figure below (figure 14 a) shows a representative example. According to this information, we set two thresholds and design a fall detecting algorithm (figure 14 b c).



(a)



(b) **(c)**

Figure 17 Acceleration of a Single Fall and Fall Detecting Algorithm

Alarming

In the second part, we first ask the user to input the telephone number of his emergency contact person. Then after our system detecting the collision, we design to make the buzzer ring, the luminous diode flash and make the phone pop up an interface, asking the user whether he is getting hurt. The interface is shown as below.

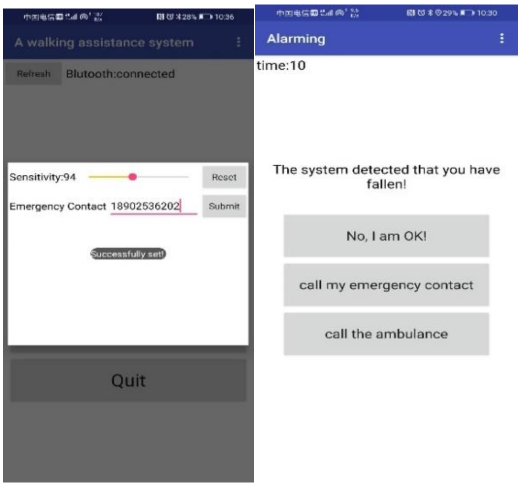


Figure 18 APP Interfaces

If the user did not get hurt, he chooses 'NO, I am OK' and the alarming will be canceled. If choosing "call my emergency contact", the APP will directly call the telephone number set previously by the user. If "call the ambulance" is chosen, the APP will directly call 120 (in China).

If the user doesn't respond after 60 seconds, the system will determine that the user is seriously injured and automatically send a text message to the emergency contact.

Historical data

Each time the emergency dealing system is triggered, the system will record the time, position and condition of the user. These data will be plotted into tables and graphs with respect to time. In this way, users can clearly see their data of this month compared with that of last month. The increase and decrease of these data can also reflect the user's illness condition to some extent. These data can also help doctors make a diagnosis when patients go to the hospital for a reexamination.

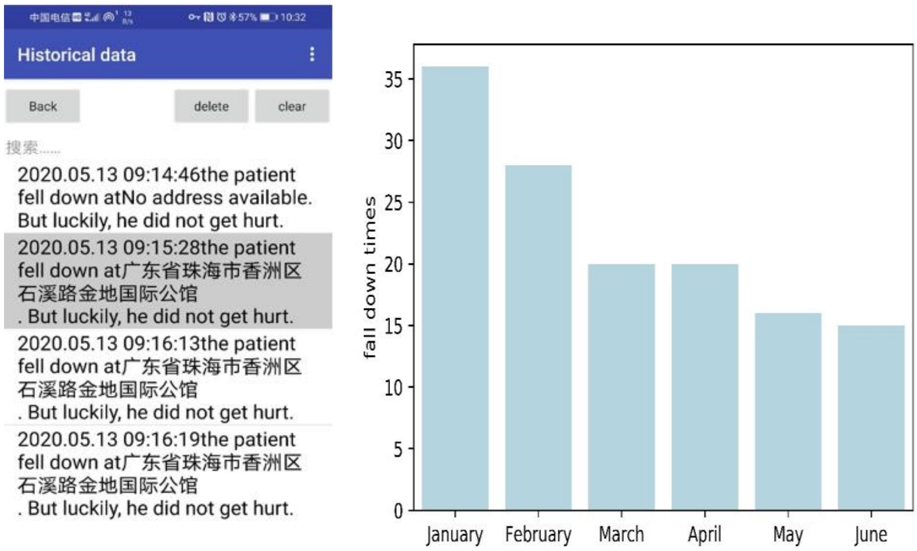


Figure 19 Historical Data and Fall Down Times Graph

5 Test Result Analysis Including Impact on the Design

5.1 Simulations for obstacle detecting

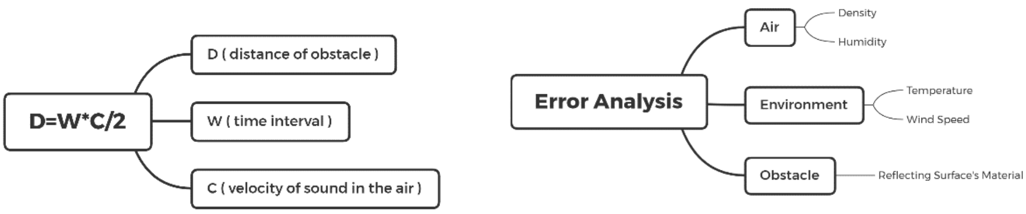
- **Platform:** Spyder
- **Language:** Python
- **Components:** 5 ultra-detectors & a virtual space
- **Parameters:** air density & wind speed

Figure 20 Parameters of Simulation

Instead of making a real obstacle detecting system, we decide to do simulations on spider using python.

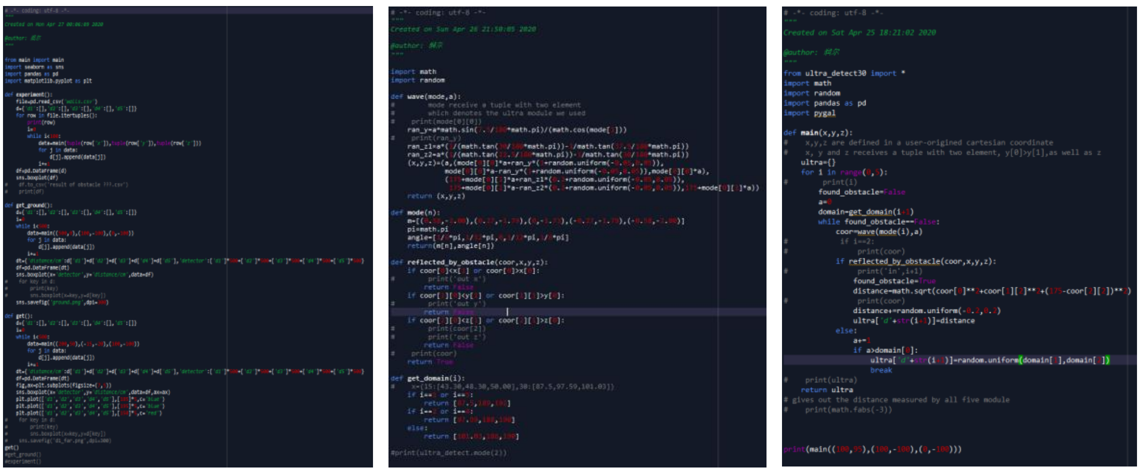
According to the paper we've read, the whole process of how the ultrasonic sensor works can be concluded as follows.

A SCM gives signal to the censor, which leads to a high-level signal in the TRIG pin. Then the sensor transmits an ultrasonic wave out. The wave spreads in the air and reflected by the obstacle. The ultrasonic sensor receives the back wave and lead to a high-level signal in the ECHO pin. Time interval between the two high-level signal is recorded. And the distance of the obstacle is computed by the formula: D= W*C/2. Here, D stands for the distance of obstacles. W is the recorded time interval. C is the velocity of sound in air, which is approximately 340m/s.



(a) (b)

Figure 21 Formula and Error Analysis



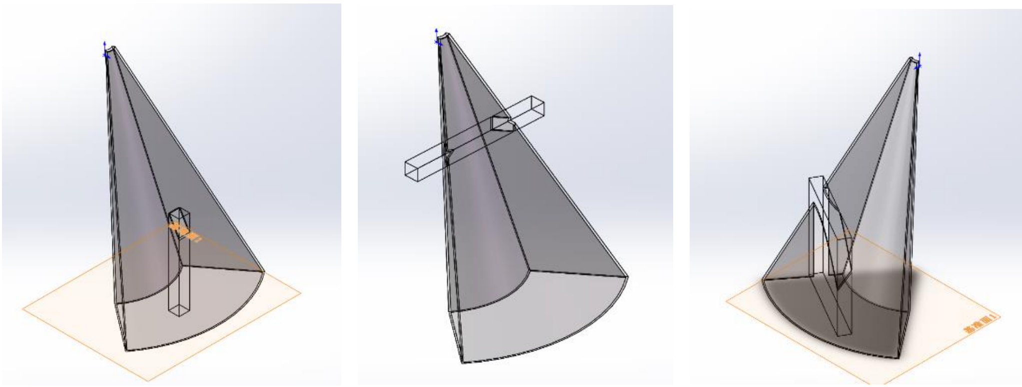
(a) (b) (c)

Figure 22 (a) Experiments (b) Functions (c) Main

We have also done some error analysis. According to the paper we have read the fluctuating value mainly comes from three parts: air, environments and obstacle. Firstly, the property of air which includes air density and air humidity. The environment's temperature and wind speed can also have some influence on the ultrasonic wave. However, under our simple circumstance, most of them have only slight impact on the result. Thus, only air density and wind speed are considered.

Based on the theory we learned, we simulate five ultra-detectors and virtual space for obstacles.

We generally set three types of obstacles. Obstacles in real life can be roughly simplified to those three or their combinations. By setting different positions for different obstacles, we have approximately done simulations on over a hundred different types of obstacles.



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

Figure 23 (a) Vertical Bar (b) Horizontal Bar (c) Walls

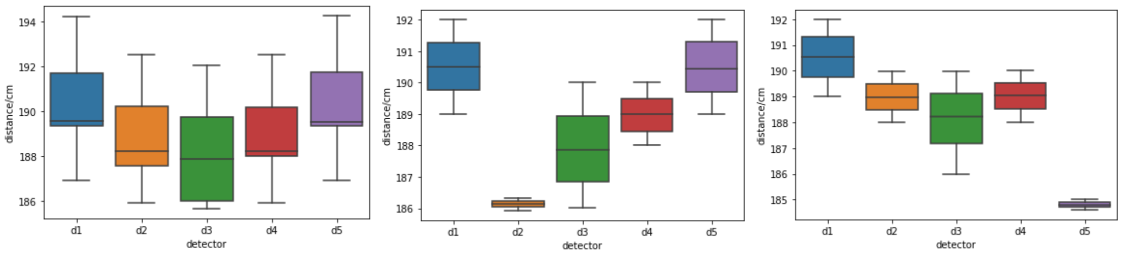
For each obstacle, its position is defined by a user originated cartesian coordinate. The range in each direction, obstacle type and the direction it should be detected are given. all the data of pre-set obstacle is stored in csv file, which can be visited automatically by our simulation program. Example of obstacle data is shown below.

Table 10 Examples of Data Settings

	A	B	C	D	E
1	x	y	z	type	direction
2	(93,90)	(25,-25)	(175,0)	wall	(2,3,4)
3	(93,90)	(75,25)	(175,0)	wall	(1,2)
4	(93,90)	(-25,-75)	(175,0)	wall	(4,5)
5	(73,70)	(25,-25)	(175,0)	wall	(2,3,4)
6	(73,70)	(75,25)	(175,0)	wall	(1,2)
7	(73,70)	(-25,-75)	(175,0)	wall	(4,5)
8	(73,70)	(25,-25)	(175,0)	wall	(2,3,4)
9	(73,70)	(75,25)	(175,0)	wall	(1,2)
10	(73,70)	(-25,-75)	(175,0)	wall	(4,5)
11	(53,50)	(15,-15)	(175,0)	wall	(2,3,4)
12	(53,50)	(35,20)	(175,0)	wall	(1,2)
13	(53,50)	(-20,-35)	(175,0)	wall	(4,5)
14	(33,30)	(10,-10)	(175,0)	wall	(2,3,4)
15	(33,30)	(30,20)	(175,0)	wall	(1,2)
16	(33,30)	(-20,-30)	(175,0)	wall	(4,5)

By detecting each obstacle for 500 times, a box graph is drawn to help analysis the data.

When there's no obstacle, the sensor just returns the distance of the ground, as shown below. When obstacle occurs, the distance in corresponding direction just reduces significantly.

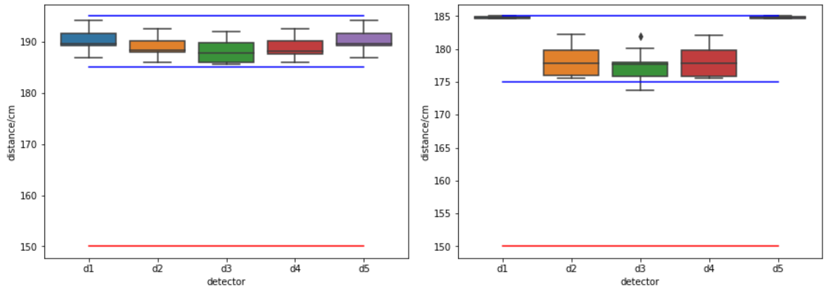


(a) **(b)** **(c)**

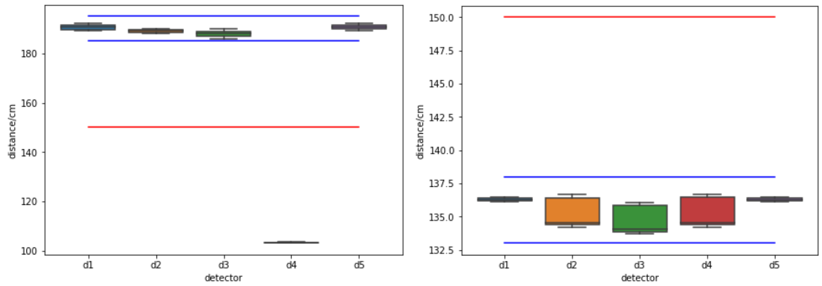
Figure 24 (a) Ground (b) Obstacle in 15° Left (c) Obstacle in 30° Right

After analyzing data and modifying many times, we finally decide to identify the obstacle based on two parameters: Shortest distance of 5 directions and their relations. By those two parameters, our system is able to differentiate different types of obstacles and avoid being triggered by roads. As you can see below, the blue lines roughly give the idea of relations while red line stands for threshold of shortest distance.

When there's no obstacle in the detecting range, the distance in five directions just accorded to the pre-set relation while the shortest distance threshold wasn't trespassed. Even for the ground that is slightly inclined or rugged. However, when something is about to block the way of the user, one or both of the rule will be violated.



(a) **(b)**



(a) **(b)**

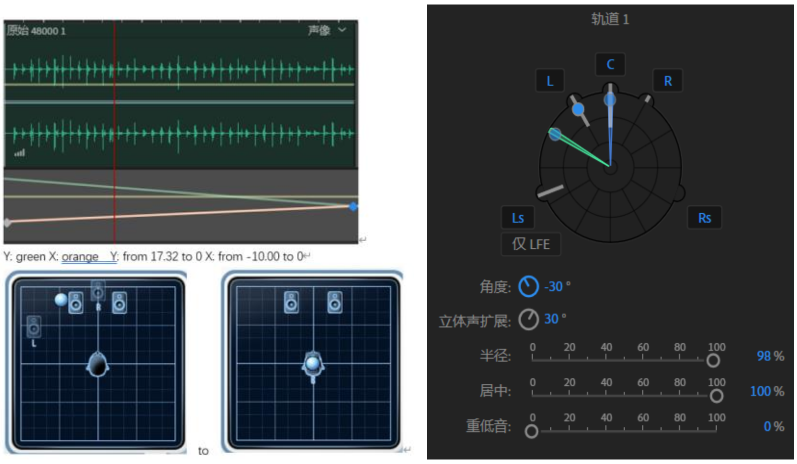
Figure 25 (a) Flat Ground (b) Ground with Slope (c) Obstacle in 15° Right (d) Obstacle: Table

5.2 Direction Reminding

During the experiment on stereo sound, we did four tests.

5.2.1 Test One: Editing Methods

The first test is to compare the two methods of stereo sound editing. We set three groups of stereo sounds, one was made with Panorama, one was made with Acoustic Image, and the left was made with the combination of these two methods. The result is shown in the table below.



(a) **(b)**

Figure 26 (a) Editing with Panorama (b) Editing with Acoustic Image

Table 11 Comparison of Editing Methods

Type	Correctness (%)
Panorama	73
Acoustic Image	46
Combination	53

Panorama gave higher correctness, so, we chose the Panorama as our stereo sound editing tool.

5.2.2 Test Two: Static and Dynamic

Test two was set to find out the most effective pattern of the stereo sound, we compare state sounds and dynamic sounds. Testers listened to two groups of stereo sounds, consist of five static stereo sounds and five dynamic stereo sounds, with earphones and judged the directions.

Table 12 Comparison of Static Sound and Dynamic Sound

	Static Sound (5 directions)	Dynamic Sound (5 directions)
Correctness (%)	84	90

The result shows that dynamic stereo sounds are more effective. It can give intuitive sense of direction and draw the attention towards the obstacle. So, we applied the dynamic stereo sound.

5.2.3 Test Three: Reliability

In test three, we intend to proof the reliability of the 5 directions' dynamic stereo sounds. Testers listened 10 dynamic stereo sounds and judged the directions.

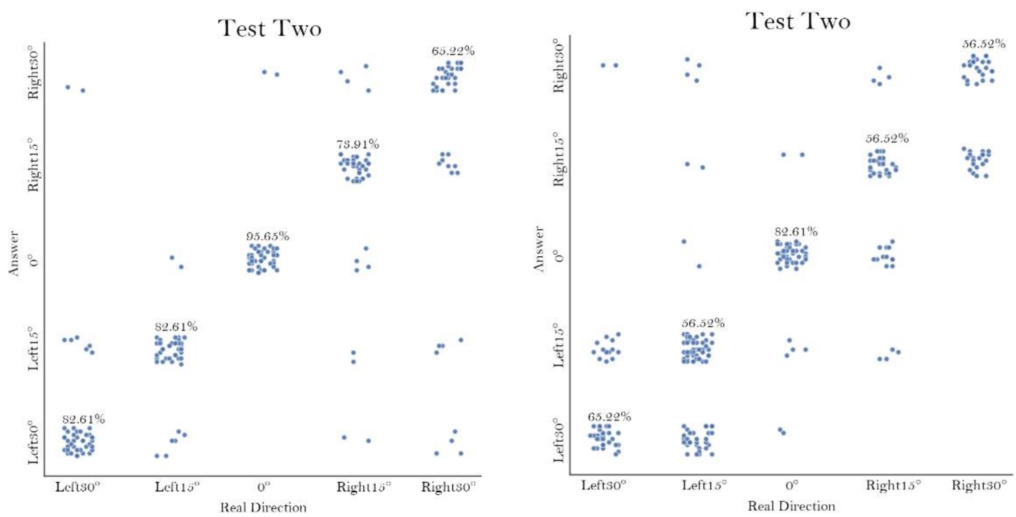


Figure 27 Correctness of Dynamic Stereo Sound

The x-axis refers to the real direction of the stereo sound while the y-axis refers to the answer of testers. The points on the diagonal are correct answers, and the density of the points shows the correctness.

The result shows that the orders will influence correctness, which means that people may have illusion. Besides, based on the distance and speed, we figured out that it would take 35 seconds for USN patients to reach the obstacle.

5.2.4 Test Four: Larger Moving Range

Test four, another small test, shows larger range of movement gives higher correctness.

Therefore, we expended the range of movement and provided more reference to reduce illusion.

5.2.5 Another Improvement: Adding Voice

Since the correctness could not reach 100%, we also add a voice telling the direction directly after each sound to make sure users know the existence of obstacle even if users still couldn’t notice the obstacle.

5.3 Experiment for fall detecting algorithm

This experiment is for testing whether the emergency dealing system can be triggered when the user falls down. Because we use the smartphone to check the acceleration to see if the user has fallen, almost the entire test was conducted around the phone. This test consists of three parts, reality test, free fall test and simulated test.

5.3.1 Reality Test

This test is aimed to simulated the real condition of Falling. However, considering to protect experimenter from getting hurt, the reality test was conducted on a cushion. Putting the smartphone in his pocket. the tester fell down on the cushion head-down and back-down respectively. For each phone and for each fall position, we repeated for 5times and tested whether the emergency dealing system would be triggered.

According to the condition set above, we have done reality test for 50 times in total. Among these, 43 times the emergency dealing system was triggered. So the success rate is 86%.

5.3.2 Free Fall Test

This is an experiment that simulates a user dropping his phone when he falls. In free fall test, we installed our APP on 5 smartphones of different brand. The tester placed the phones on 1m height and release the phone. Smartphones will fall free onto the cushion. We repeated the test for 10 times for each smartphone and observed whether the alarming interface would be popped up.

In this test, we have also repeated it for 50times in total and 47 times it was successful. So, the success rate is 94%.

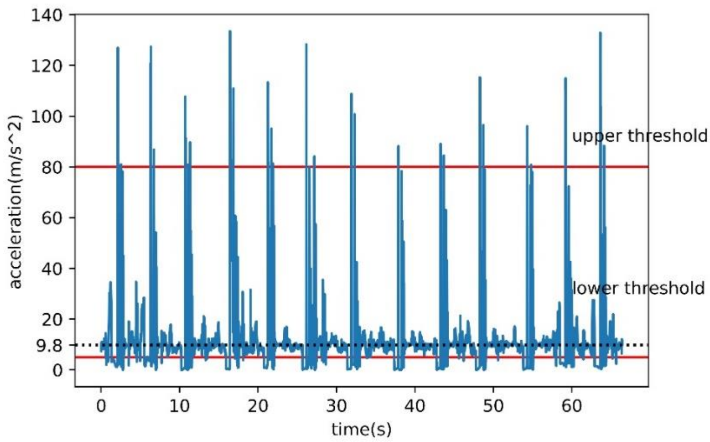


Figure 28 Acceleration in Free Fall Test

5.3.3 Simulated test

When we were doing the reality test, we found that we cannot avoid self-protecting. That is, when we fall down on purpose, we cannot react like what we actually do when we fall down. So, we design the simulated test, targeting to avoid this self-protecting. In the third test, we tied the cellphone on a stick and let it fall free from its upright position. We want to use this way to eliminate the effect of self-protection of the tester in the first test.

This test was also repeated for 50 times in total and 42times it was successful. The success rate of simulated test is 84%.

5.3.4 Analyses

It should be mentioned that the success rate of the fall detection algorithm in the actual conditions will be higher than in the experiment. Because we cannot avoid self-protection in reality test and also all the experiments were done on the cushion instead of ground. These factors will reduce the change of acceleration, which means the emergency dealing system will be harder to trigger in experiments. Considering the results of three experiments (shown on the table below), we think that the fall detection algorithm is reliable in practice.

Table 13 Result of Experiments

Test	Reality Test	Free Fall Test	Simulated Test
Successful/total	43/50	47/50	42/50
Success rate	86%	94%	84%

6 Conclusion and Future Work

6.1 Conclusion

That's all for the introduction of design and proof of reliability to our walking assistance system for USN. We innovatively use dynamic stereo sound to catch attention from USN patient and remind the direction of obstacle, which has 90% success rate via test on ordinary people. Besides, our obstacle detecting system use a powerful algorithm and has an effective detecting range of 100cm, which is computed and proved to be excellent by simulation. In addition, the usage of APP on mobile phone not only makes our system have a low threshold, but also has at least 86% success rate of fall detecting with the usage of inner sensors. Totally speaking, our system has a low cost of ￥327 and a high cost performance in helping USN patient to avoid obstacles and search for aids when emergency happens.

In a word, our design is a portable, safe and low threshold product which can deal with emergency, analyze information and interaction, and help USN patients to avoid obstacles with a high success rate.

Table 14 Necessary Attributes of System

Attribute	Parameters
Detection Range	100cm
Obstacle Avoidance Warning Time	35s
Success Rate of Fall Detection	>86%
Total Cost	¥327
Endurance	>30h
Weight	<400g
Volume	350x350x120(mm)

6.2 Future

About the future of our project.

Besides helping USN patients, the system and techs it contains can also be used in other fields.

As we design the system under the perspective of perceptual compensation, it can be directly used as a guiding system for blind people. The obstacle detecting function can be used with a high cost performance in automatic driving for small robot vehicles. The mechanism of direction reminding can also be used in medical attention training.

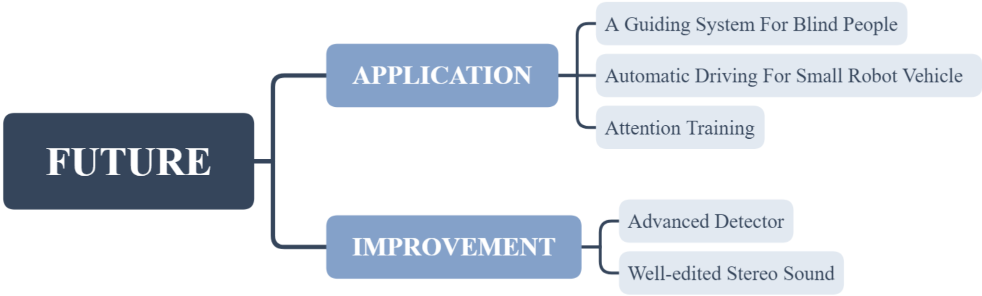


Figure 29 Future

Certainly, some improvements should be considered.

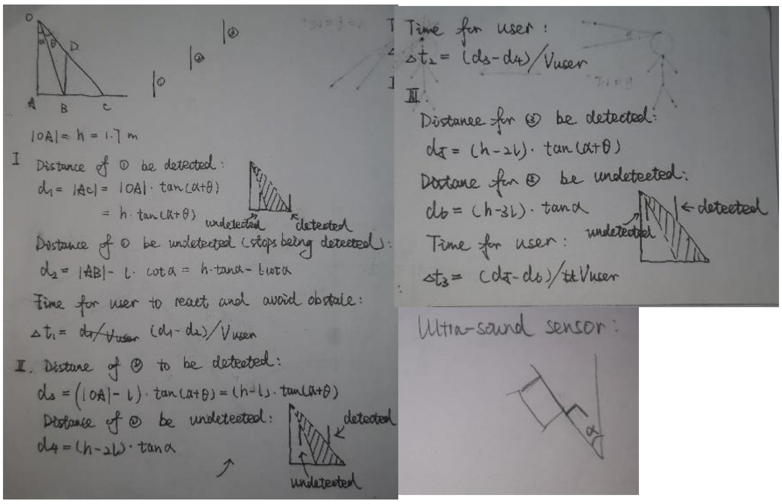
Firstly, as the ultrasonic sensor can only provide simple one-dimensional information, an advanced detector should be selected so that we can improve our algorithm for identifying the obstacle and get closer to real life situations. Due to our unprofessional skills on audio editing, a well-edited stereo sound should also be considered to provide sufficient reminding to the user of the obstacle.

7 List of Reference

[1] 陈卓铭.视觉忽视的机制及康复[J]. 中国康复, 1999, 14(2): 71-73
[2] 何万龄,刘凤英. 人耳对声源方位的判定[J].生物学通报,1991,3:13-14

Appendix

Appendix 1: Computation for Layout



Appendix 2: Comparison and Analysis of Sensors

Table 15 Comparison of Sensors

Varieties	Open Mv	Ultrasonic Wave Sensor	Infrared Range Sensor	Laser Distance Sensor	Millimeter-Wave Radar
Precision	1	4	4	5	3
Distance	2	4	2	5	3
Measurable Angle	3	4	4	1	4
Data Processing Complexity	2	5	5	5	5
Antijamming Ability	1	4	2	4	3
Response Speed	3	3	5	5	3
Price	2	5	5	2	4
Sum	14	29	27	27	25

Analysis:

1. Open mv
   Although it has an integrated visual processing system, which is convenient and exquisite, the camera is fragile and it's working ability is seriously enslaved to surroundings, such as light and color of obstacles, letting alone its high price, slow processing speed and limited angle of view.
2. Ultrasonic Wave Sensor

Ultrasonic wave sensor almost has balanced performance in ranging. Although its measurable precision, distance and angle are not best, and it has lower response speed comparing other sensors relying on light, which relies on sound wave instead, considering the user's moving speed and precision requirement, and it gets the highest score between all kinds of sensors, the ultrasonic wave sensor is most suitable.

3. Infrared Ranging Sensor
   The most obvious outcomings of infrared ranging sensor are weak antijamming capability and short range, despite of its low price and fast response speed based on light emission and receiving.
4. Laser Distance Sensor
   This is the most expensive one among mentioned sensors, which uses high-energy light, laser, as its ranging method, so it has incomparable ranging precision, distance and response speed with light speed. However, considering that our users have no chance to move very fast, too much ability is wasted, while the high cost will add to the price of product. It is not ideal.
5. Millimeter-Wave Radar
   millimeter-wave radar has many things in common with ultrasonic wave sensor, except their frequency. Millimeter-wave radar has lower frequency, so chances are that the sound wave can be blocked by small garget or absorbed by water or specific material, which may cause malfunction during rainy days.

Appendix 3: Output Module of Obstacle Avoidance System

Solutions

The patients with left neglect will ignore obstacles which are in their ignored domain. What makes our project feasible is the fact that we can capture patients' attentions by applying stimulus, according to researches of experts[1]. Also, we consulted to a doctor at Peking University Third Hospital about the syndromes of those patients, and got an answer that proper stimulations can capture patients' attentions.

Therefore, we come up with five solution to capture the attentions.

Solution 1 3D sound

3D sound is the use of speakers to mimic sounds that appear to exist but are actually imaginary. The phase difference of sounds to left ear and right ear is different, so it is possible to edit sounds which can remind direction.

The main solution is to divide the field of vision into 4-6 areas and use 3D sounds to represent them. The processor analyses input information and play the corresponding edited 3D sound through the earphones. Not only can it remind directions, it can also remind distances through different frequency. The patients receive the sound stimulus and pay attention to the direction the sound refers to. Thus, patients can notice obstacles and avoid them successfully.

Solution 2 vibration

Vibration can stimulate the patients apparently when it occurs on the skin. There exist some miniature vibrations, such as Mobile phone 1027 flat vibrating motor.

Several vibrators form a half circle, and each vibrator represent a direction. The processor analyses input information and drive the corresponding vibrator. Not only can it remind directions, it can also remind distances through different frequency. When patients feel the vibration, they will pay attention to that direction as well as realize there’s an obstacle in that direction. Thus, it makes the obstacle avoiding possible.

Solution 3 force

Thruster is one of the most widely used actuators in spacecraft controlling. It controls the spacecrafts’ posture through reaction thrust[2]. It could be a reference of our project.

As for this solution, we put some thrusters on patients’ bodies. When the analysis process finishes, the processor drives the corresponding thruster to generate a force towards the opposite direction of the obstacles. So, patients can feel this stimulation apparently, pay attention to that direction and avoid the obstacles.

Solution 4 voice prompt

Words are effective signals which can convey information clearly and easily. Single words like *left*, *left front*, can point the exact directions without any misunderstandings.

The main solution is to divide the field of vision into 4-6 areas and use voices to represent them. The processor analyses input information and play the corresponding voices through the earphones. Not only can it speak exact directions, it can also remind distances through words. The patients receive the voice prompt and pay attention to the direction the sound refers to. Thus, patients can notice obstacles and avoid them successfully.

Solution 5 electrical stimulation

Electrical stimulation is mainly by increasing the proprioceptive input of the ignored limb and trunk to attract more attention to the ignored space [3].

Several electrical stimulators form a half circle, and each electrical stimulator represent a direction. The processor analyses input information and drive the corresponding electrical stimulator. Not only can it remind directions, it can also remind distances through different frequency. When patients feel the electrical stimulation, they will pay attention to that direction as well as realize there’s an obstacle in that direction. Thus, it makes the obstacle avoiding possible.

Comparison

There are some features of five solutions respectively.

Solution 1 3D sound

Advantages:

Safe: the stimulation is just sound, which won’t do any harm to patients in normal use.

Immediacy: the patients can identify the direction no sooner than the sound be played.

Information-rich: not only can it remind directions; it can also remind distances through different frequency.

Connection: it can be played directly by mobile phones through earphones.

Comfortableness and appearance: the patients only need to wear a pair of common earphones (just output module). Earphones can be chosen according to patients’ preferences.

Technique: we just need a computer and a software.

Disadvantages:

Limited: it is not precise and it is possible that sometimes patients can’t identify the direction.

Hardware requirements: some earphones can’t mimic real sounds. Only those 3D earphones can do that (most earphones can do, but those earphones with higher price do better). Also, the player needs to support the decoded output of this 3D effect (most computers and mobile phones today have this power).

Solution 2 vibration

Advantages:

Safe: the stimulation is just vibration with low current, which won't do any harm to patients in normal use.

Immediacy: the patients can identify the direction no sooner than the vibrators be driven.

Information-rich: not only can it remind directions; it can also remind distances through different frequency.

Hardware requirements: the miniature vibrations, such as Mobile phone 1027 flat vibrating motor is cheap.

Technique: this solution doesn't have special technique.

Disadvantages:

Comfortableness and appearance: patients' need to wear the circle vibrators formed, it could be a hair band or a belt. Some patients will feel uncomfortable with the vibration on their heads or on their waists.

Limited: the circle would be a hair band or a belt, but the skin on heads and waists is not sensitive enough to identify precise direction.

Connection: it can't be driven directly by mobile phones through earphones and needs single chip microcomputer to control.

Solution 3 force

Advantages:

Immediacy: the patients can identify the direction no sooner than the thrusters be driven.

Precise: this stimulation is strong and clear enough for patients to identify the directions.

Disadvantages:

Unsafe: it applies forces to patients, which would increase the risk of falling down.

Information-poor: it can only remind the directions, but it has no thing to do with the distances.

Connection: it can't be driven directly by mobile phones through earphones and needs single chip microcomputer to control.

Comfortableness and appearance: patients' need to wear the thrusters which could be a belt. Some patients will feel uncomfortable with the forces on their waists. Also, it will make patients look strange.

Hardware requirements: there's no such thrusters that could be worn by humans and there's no processors could drive the thrusters.

Technique: the technology is immature.

Solution 4 voice prompt

Advantages:

Safe: the stimulation is just sound, which won't do any harm to patients in normal use.

Information-rich: not only can it speak exact directions; it can also remind distances through words.

Connection: it can be played directly by mobile phones through earphones.

Comfortableness and appearance: the patients only need to wear a pair of common earphones (just output module). Earphones can be chosen according to patients' preferences.

Technique: we just need a tape recorder.

Precise: this stimulation is clear enough for patients to identify the directions as well as distances.

Hardware requirements: this solution only need a pair of common earphones.

Disadvantages:

Hysteresis: it takes time to listen to the whole signal, which means patients can't get the information immediately.

Solution 5 electrical stimulation

Advantages:

Immediacy: the patients can identify the direction no sooner than the electrical stimulators be driven.

Information-rich: not only can it remind directions; it can also remind distances through different frequency.

Disadvantages:

Unsafe: the stimulation is electrical stimulation. Although it is in low current, it still has risk.

Hardware requirements: the electrical stimulators must meet medical standards.

Technique: we need consult to sophisticated experts about the electrical stimulation to decrease the risk as much as possible.

Comfortableness and appearance: patients' need to wear the circle electrical stimulators formed, it could be a hair band or a belt. Some patients will feel uncomfortable with the electrical stimulation on their heads or on their waists.

Limited: the circle would be a hair band or a belt, but the skin on heads and waists is not sensitive enough to identify precise direction.

Connection: it can't be driven directly by mobile phones through earphones and needs single chip microcomputer to control.

Table 16 Metrix of Goals of Output Solutions

Goals	Safe	Im-me-dia-cy	Inform-ation-rich	Pre-cise	Low thres-hold techn-ique	Low hardware requirem-ent	Comfortableness and appearance	Convenient connection	score
Safe	…	1	1	1	1	1	1	1	7
Immediacy	0	…	1	1	1	1	1	1	6
Information-rich	0	0	…	0	1	1	1	1	4
precise	0	0	1	…	1	1	1	1	5
Low threshold technique	0	0	0	0	…	0	0	0	0

Low hardware requirement	0	0	0	0	1	…	0	1	2
Comfortable -ness and appearance	0	0	0	0	1	1	…	1	3
Convenient connection	0	0	0	0	1	0	0	…	1

Table 17 Comparison Among Output Solutions

Solutions / Goals	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
Safe (7)	4	4	2	4	1
Immediacy (6)	4	4	4	1	4
Information-rich (4)	4	4	1	4	4
Precise (5)	2	2	3	4	2
Low threshold technique (0)	3	4	1	4	1
Low hardware requirement (2)	3	4	1	4	1
Comfortableness and appearance (3)	4	3	2	4	1
Convenient connection (1)	4	3	1	4	1
Total	100	98	66	94	63

*Scoring instructions: very good-4, good-3, just so-so-2, bad-1

Therefore, we choose Solution 1 3D sound as our output module.

Appendix 4: Screenshots of Code

```
int inData;
float distances[5];
int inthreshold=5;
int outthreshold=150;
int res_detector;
float sho_distance;
float max_distance;
float min_distance;
void setup()
{
  Serial.begin(9600);
  for (int TrigPin=2;TrigPin<12;TrigPin+=2){
    pinMode(TrigPin,OUTPUT);
  }
  for (int EchoPin=3;EchoPin<12;EchoPin+=2){
    pinMode(EchoPin,INPUT);
  }
  //2,4,6,8,10 are trigers of altrasonic sensors
  //3,5,7,9,11 get echoes from altrasonic sensors
}

void trigger()
{
  for (int detector=2;detector<12;detector+=2){
    digitalWrite(detector,LOW);
    delayMicroseconds(2);
    digitalWrite(detector,HIGH);
    delayMicroseconds(10);
    digitalWrite(detector,LOW);
    distances[detector/2-1]=pulseIn(detector+1,HIGH)/58.00;//cm
  }
}

void judgement()
{
  for (int detector=0;detector<4;++detector)
  {
    max_distance=max(distances[detector],distances[detector]);
    min_distance=min(distances[detector],distances[detector]);
  }
  if ((max_distance-min_distance<inthreshold) and (min_distance>outthreshold))
  {
    res_detector=0;
    sho_distance=-1;
  }
  else
  {
    sho_distance=min_distance;
    for (int detector=0;detector<5;++detector)
    {
      if (distances[detector]==min_distance)
      {
        res_detector=detector+1;
      }
    }
  }
}
```

```
void loop()
{
  if (Serial.available()){
    inData=int(Serial.read());
    trigger();
    judgement();
    if (0==inData){
      Serial.println(res_detector);
    }
    else if (1==inData){
      Serial.println(sho_distance);
    }
  }
}
```