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Blind area target aiming system and preference selection training system design

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BLIND AREA TARGET AIMING SYSTEM AND PREFERENCE SELECTION TRAINING SYSTEM DESIGN

By

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Abstract

A cyber-physical system (CPS) is a system of leveraging computational elements controlling physical entities that is widely applied in our daily life for all kinds of purpose. It helps us build smart devices and make life become much easier. In this report, two projects were designed to show the idea that how cyber-physical system works in human daily life. The first project is designed for personal security, especially for one of the most dangerous job: security service. It helps user defend his back while he/she is in a tough situation while he or she is alone. First there will be a passive infrared sensor working as a threshold and it also helps make sure the target is a human being. Then a web camera will start to work and take pictures of the user's blind area. A face detection algorithm will be applied to those pictures to locate the position of the target. Finally two servo motors will work together to rotate to a certain degree, pointing the laser pointer to the target's body to show the warning. A prototype is built to show that the idea works. The second project is focused on the mental stress problem in daily life. Based on the fact that proper light and music can help people get relaxed, a system is designed to help people find out the right choices. The system will be trained to learn a user's preferences on the brightness and hues of colors, as well as the speed and emotion tone of the music. A commercial product of galvanic skin response sensor is used to indicate the stress level of the user as the response of the training process.

Keywords: Cyber-Physical System, Security, Passive Infrared Sensor, Face Detection, Mental Stress, Galvanic Skin Response

PART A

Blind area target aiming system based on face detection algorithm

1. Introduction

This project is focused on personal security, especially for people whose work may cause great danger of injury or even death when they are working. For police officers, they usually build two-member team to help each other protect their backs when they are fighting with criminals. But for other security service staffs that are not trained so well as police officers, the blind area behind their back will become a really dangerous place for them to protect. In this project, I designed a blind area target aiming system to help a single user defending his/her own back, so that he/she will be safe when he/she is alone. A passive infrared sensor with 3 meters effective range will be the threshold of the system. Targets that enter this effective range will trigger the activation of a web camera. The camera starts taking photos continuously of user's blind area using the same file name (simply cover previous photo) till the target is located and aimed. A face detection algorithm will be applied to the current photo to find out if there is a face in it. If there is one, the face detection algorithm function will output a coordinate of the center of the target's face. Based on the coordinate, another function will calculate and output two angles for both vertical and horizontal servo motors to rotate. Since it is just a prototype design, a laser pointer is fixed on the vertical servo motor instead of a real gun. When the entire aiming process finishes, the laser pointer will point right at the target's body.

2. Backgrounds

Face detection technology is widely applied in human computer interaction [2], marketing [3], biometrics [4], energy saving [5] and many other fields. Unlike face recognition technology, it is not good enough for access control system since it can only tell the location of target's face. Other positioning technology, like ultrasound positioning technology, cannot tell the difference between human targets and other animals. While in this project, face detection technology works really well. It helps distinguish human target from wild animals and locate the position of target's face for the following aiming process. The entire system is based on Python programming, the face detection algorithm comes within the Python samples (Open CV interface). The face detection algorithm is based on the Haar-like features. Haar-like features is popular in pedestrian detection [6], license plate recognition [7], hand gesture recognition [8], tracking [9] and other area. There is one similar design in robot platform [10] and they also use face recognition technology to make it possible for the robot to recognize and track faces. Another existing work that focused on automatic aiming technology is based on Broadband Antenna Tracking Systems (BATS) [11].

3. Techniques

3.1 Main Ideas

The way to expel criminals for security service should be aiming and shooting with a firearm. So the idea is to design a helmet with a mini gun and a camera which is embedded inside, which can accomplish auto-aiming and shooting. The system is designed for short range defense so no powerful firearm is needed as it is also harmful for the user (because of the recoil). Similar designs only appear in movies & science fictions. This kind of system is not reliable in wars because it can't tell the difference between allies and enemies. But when he/she is on a mission, it is possible for him/her to give warnings to innocent people to stay away from the available range so that anyone who enters this range will be either an enemy or an ally. A Bluetooth device can be added to the helmet for all allies, so when an ally enters the user's range, the helmet can recognize him/her.

The system contains a camera, a microcontroller board, a PIR sensor, two servo motors and a laser pointer. In order to make the system more reliable, a face recognition algorithm is used to locate the target. A PIR sensor is used to make sure it's a human target (not just a human-shape paper board). Two servo motors are equipped for aiming:

one rotates vertically while the other rotates horizontally. A laser pointer will be used instead of the mini gun for this prototype design.

3.2 Module Description

3.2.1 Microcontroller-Raspberry Pi

The entire system is based on a Raspberry Pi control board shown as figure 1.1.

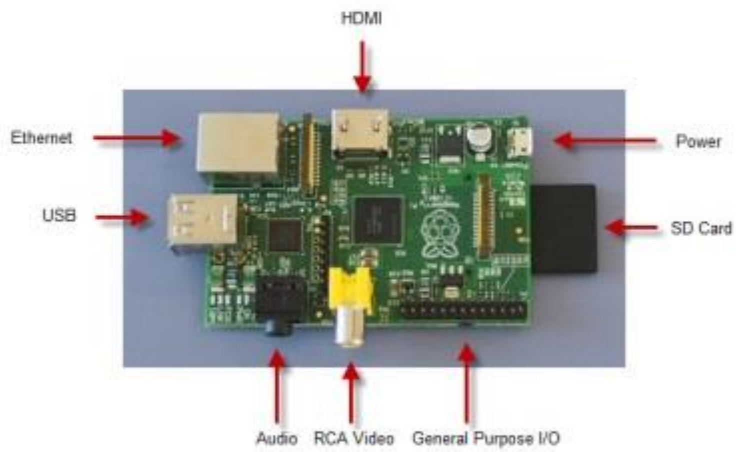


Figure 1.1: Raspberry Pi control board [12]

The Raspberry Pi is a credit card-sized single-board computer developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools.

Raspberry Pi with a 700 MHz single-core ARM CPU is powerful enough for the face recognition algorithm. The Linux operating system makes it possible to program in Python.

Raspberry Pi offers two USB ports for peripherals like mouse, keyboard and web camera. A camera is connected to Raspberry Pi in this project since we want it to take pictures for face recognition. Pi also offers enough I/O pins for PIR sensors and servo motors controlling. More sensors can be added to the system for future improvement.

A figure for Pi's general purpose I/O is shown in figure 1.2. Pi offers both 5v and 3.3v on-board power supply that can handle most of the sensors and servo motors. GPIO ports can be connected to PIR sensor for human detection input and to servo motors as its PWM input signal, and to Bluetooth module for future ally recognition part design.

Figure 1.2: Raspberry Pi's GPIO [13]

Product information:

Name: RASPBERRY Pi Model B system board

Model: R Pi B

Brand: Raspberry Pi

Price: $32.99 from EBay

3.2.2 PIR Sensor

To increase the accuracy and to avoid useless shooting, the system is designed to tell the difference between human being and wild animals and between lively human being and human like object. PIR is short for passive infrared sensor, is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view. Human body radiates infrared lights (also wild animals) and can be recognized by PIR sensor.

Figure 1.3: Infrared PIR motion sensor detector module

A regular PIR sensor has 3 pins, working under 3.3v, with an output of digital signal 1 or 0 (1 indicates human target when appearing in effective range). The effective range of my PIR sensor is 3 meters, so it means when the human target is within 3 meters from the PIR sensor, it gives an output of digital signal 1. Otherwise, it gives a stable 0.

Product information:

Name: Infrared PIR Motion Sensor Detector Module

Model: HC-SR501

Brand: BAYITE

Price: $2.95 from EBay

3.2.3 Servo Motor

A laser pointer is used to simulate the aiming process instead of a real gun. The way to achieve auto-aim by pointing the laser to the target is based on the rotation of two servo motors.

Figure 1.4: SG90 micro servo motor

A servo motor is widely used in the field of robot design and manipulators (robotic arms) design. It acts like the human joints that can rotate a certain degree in a finite range. The input is a PWM (Pulse-width modulation) and the degree to rotate is decided by the duty cycle. So in this system, we use one servo motor to rotate horizontally and another servo motor to rotate vertically to cover the entire area of a person's back.

Product information:

Name: Micro servo motor

Model: SG90

Brand: Tower Pro

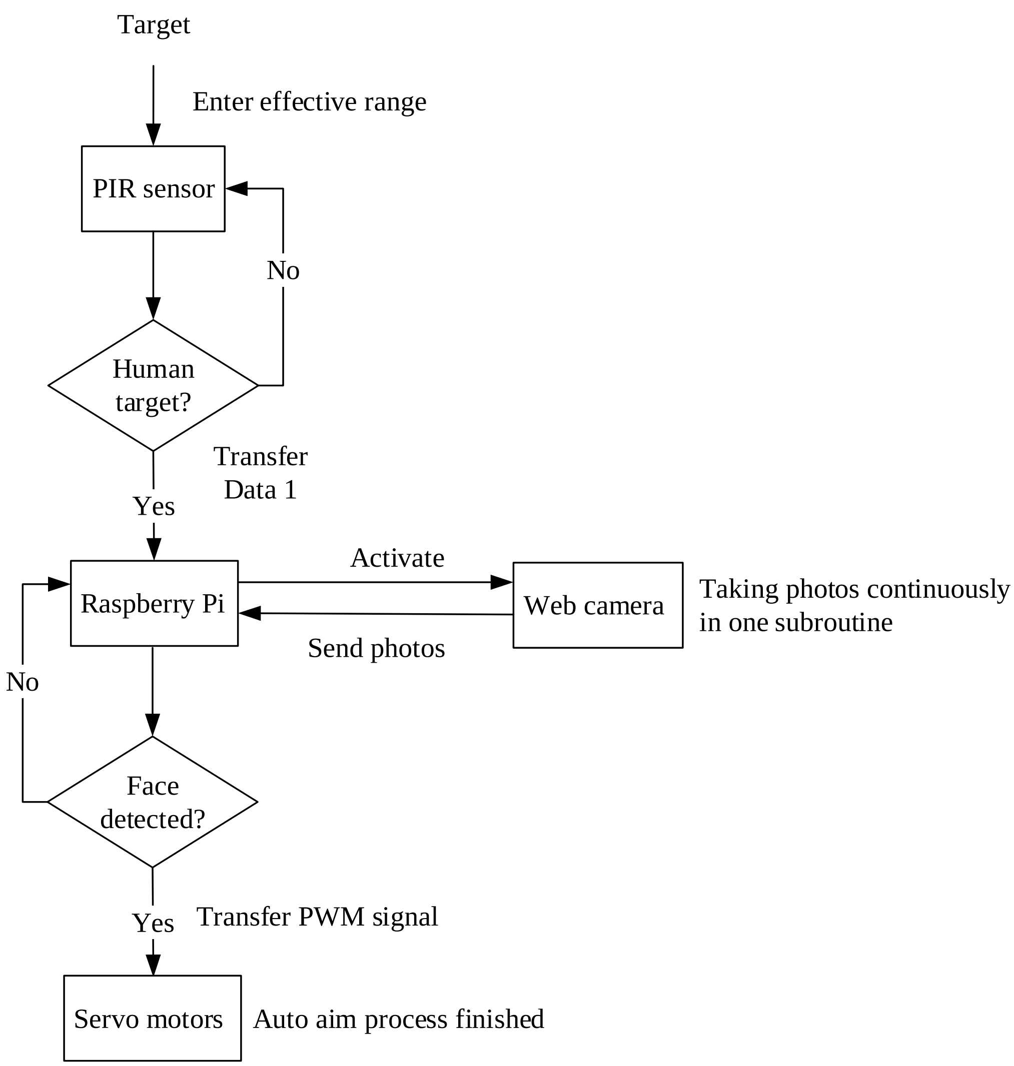
Price: $1.89 from EBay

3.2.4 Other modules

Name	Laser pointer	Web camera
Model	EC014	-
Brand	OEM	-
Price	$2.57 from EBay	$3.71 from EBay

Table 1: Other modules' product information

3.3 Flow Chart



The entire system is shown as above. The main routine of the system includes a PIR sensor (act as a threshold) and Raspberry Pi. In order to save energy, when there is no human being target appears in effective range, the web camera and the servo motors will not be activated. The web camera will be deactivated when PIR sensor stop sending 1 to Raspberry Pi (which indicates no human target appearing in effective range). When activated, the web camera runs in a subroutine that will not influence the face detection algorithm in Raspberry Pi. Web camera takes two photos each second and saves all the photos in a same address in Raspberry Pi with a same file name (keep over writing) and the face detection algorithm will load the current photo and starts to detect face.

When a human face is detected, the algorithm shows the position of the center of the face. A function will calculate the duty cycles of the PWM signal (for both vertical and horizontal) based on the position of the face and then the system will start a subroutine to control servo motors. To make sure that the servo motor will not reset when Raspberry Pi is doing new face detection, a subroutine is necessary to keep sending the same PWM signal to both servo motors to keep aiming at the same position while Pi is recalculating. Otherwise, the laser pointer will aim at the target right after human face is detected then rotates to the original position (where it points when no face was detected) immediately.

After the first face detection finishes, the laser pointer will move to aim at the new position of the target with the update of the new position of the face from Raspberry Pi. When the target no longer exist in effective range, both web camera and servo motors will be deactivated (the camera stop taking photos; the servo motors rotate to original position) to save energy.

3.4 Face Detection Algorithm

Since the entire system is based on Raspberry Pi and the system is programmed in Python, the face detection algorithm comes within the Python samples (Open CV interface). The face detection algorithm is based on the Haar-like features. It comes out as a function with an input of a picture and an output of the same picture with faces circled out with a green rectangle.

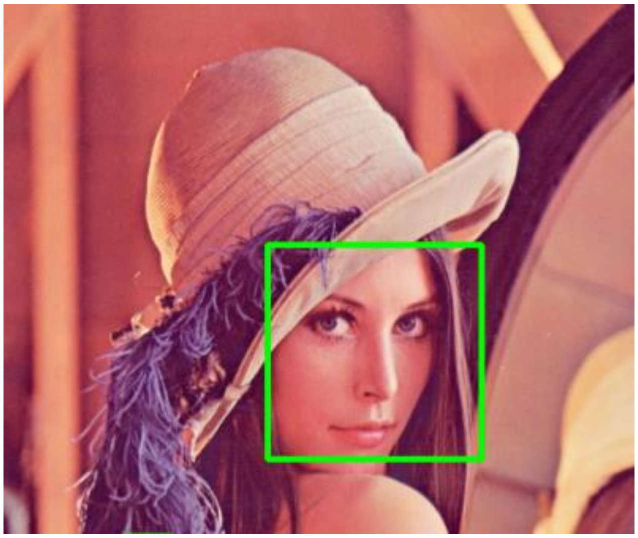


Figure 1.5: Face detection program example

Then the position of the center point of the green rectangle can be extracted from the function for aiming in the following steps. The face detection algorithm offers the center position of the face that appears in the photo with its coordinate (the upper left corner with a coordinate of (0, 0) and the bottom right corner with a coordinate of (600,600) if the photo is taken under a 600 ×600 resolution).

The Python 2.7 Open CV samples come from opencv.org, included in the Open CV interface files for Python 2.7.

3.5 Aiming Techniques

The effective range of the system is determined by PIR sensor. The area is a sector with a radius of 3 meters.

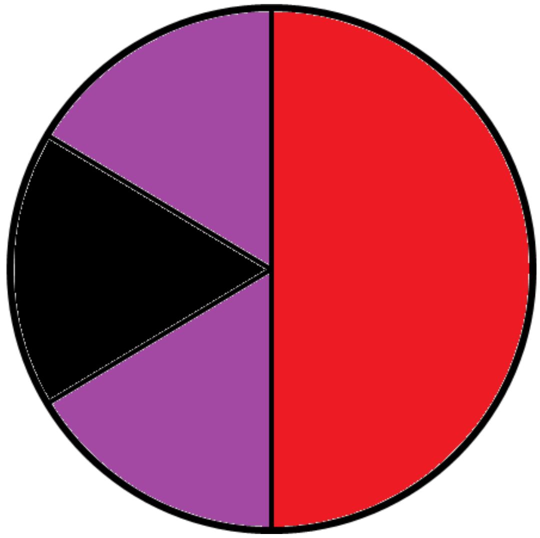


Figure 1.6: Vision range based on personal experience

Figure 1.6 shows vision range of a person standing at the center of the circle. The red area is the vision and peripheral vision range that can be easily observed by his/her eyes. The purple area shows a range that can be observed by turning his/her head to left/right just for a little bit which means dangers come within this area can be easily noticed. Finally the black area shows where the most dangerous are. It is the blind area that requires fully turning around for actions when enemy comes in this range which means danger coming in this way is hard to notice. The central angle of this sector is approximately 60 degrees. So this system will only focus on the aiming of target within this blind area.

The blind area sector can be simplified to an Equilateral triangle with a side length of 3 meters (shown in figure 1.7). The aiming method will only take care of the target on the edge of the left side of the triangle (dash line) because a mini gun will be equipped to expel the target. The target is not expected to move all the way towards the user. Right now only a laser pointer is used to simulate the aiming process, so it would be possible for the target to move closer to the camera, which means, the aiming method will not work perfectly since we all know that when taking photos, the closer a person is to the camera, the bigger his/her face looks. When taking this into consideration, a distance sensor can be added to the system to find the connections between the size of the face and the distance between the target and camera.

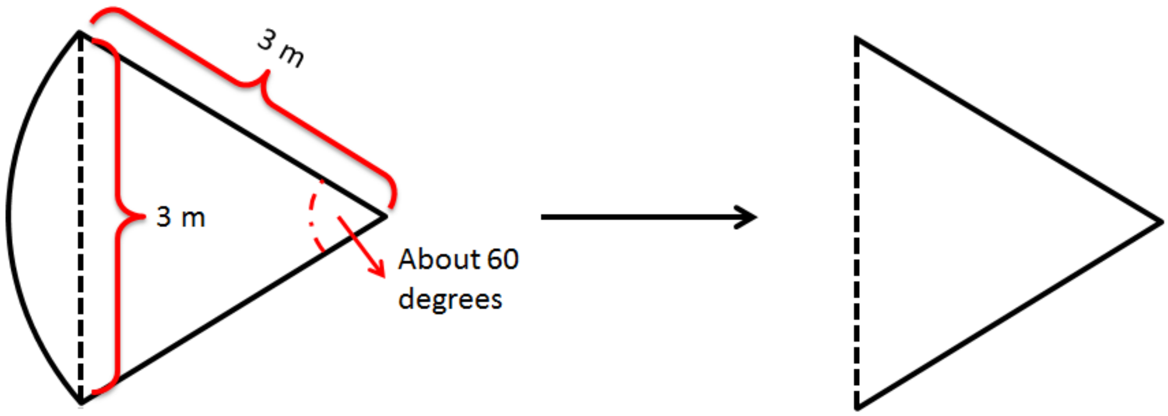


Figure 1.7: Simplified blind area sector

To make the aiming process easier, the target's body is aimed at rather than his/her face. The area of the body is much bigger than the area of the face. The width of one's body can be up to 3 times of the width of his/her face.

Note that low cost servo motor can't recognize 1 degree level difference PWM input signal so sub-area aiming method is used instead of rotating the servo motor continuously by 1 degree. The sub-area aiming method starts with dividing the vertical plane of the left side (dash line in figure) of the triangle area into several sub areas. The sub area should be small enough that there won't be more than one position of the target appearing in the same sub area. The width of human body is about 0.5 meters, so each sub area will be a square with a side length of 0.5 meters. Since target's body height and posture may vary, a 1.5 meters range should be enough. So the entire vertical plane is divided into 18 sub-areas as shown in figure 1.8:

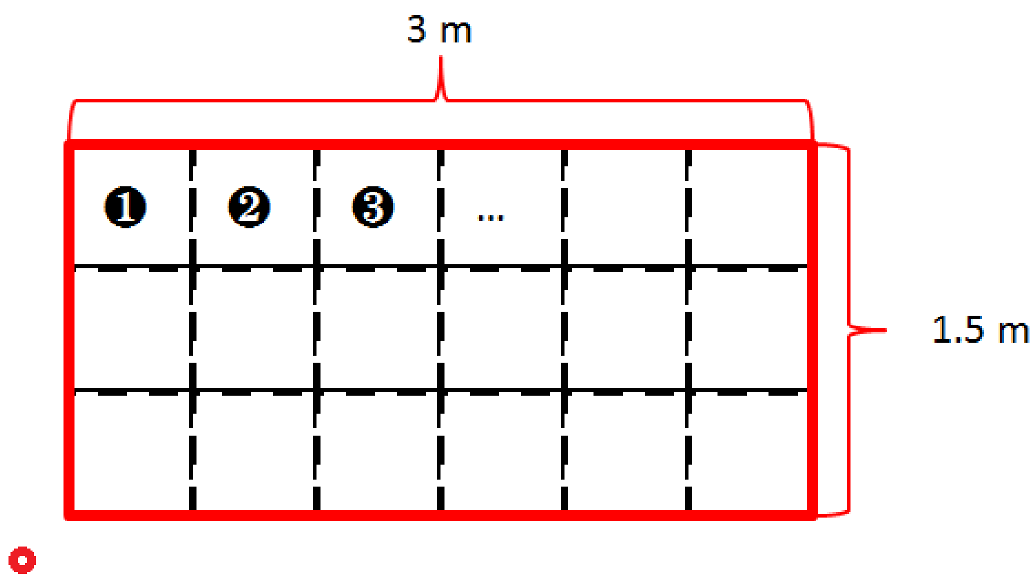


Figure 1.8: Sub area on vertical plane

The original position that the laser pointer will point to when no target is in the effective area is set to the ground with both vertical and horizontal servo motor rotate 0 degree. As shown in the figure above, the red cycle on the bottom left side of the red rectangle is on the extension of the diagonal of the bottom left sub area. In this system, both servo motor will only rotate to one direction. For each sub area, a servo motor will rotate 10 degrees to aim at the target. So the vertical servo motor will rotate from 0 to 30 degrees while the horizontal servo motor will rotate from 0 to 60 degrees. For example, if target appears in sub area number two (as shown above), the vertical motor will rotate 30 degrees towards up direction and the horizontal servo motor will rotate 20 degrees towards right direction. The web camera takes 600×600 resolution photos. The coordinate system is built to let the up left corner of the photo be (0, 0) and the bottom right corner of the photo be (600, 600). The face detection algorithm will offer the coordinate of the center of target's face. Then a certain number is added to its vertical coordinate to make the position move from face to body (about 80). Finally where the position locates is known and both servo motors will rotate to aim at the target. An example is shown in figure 1.9:

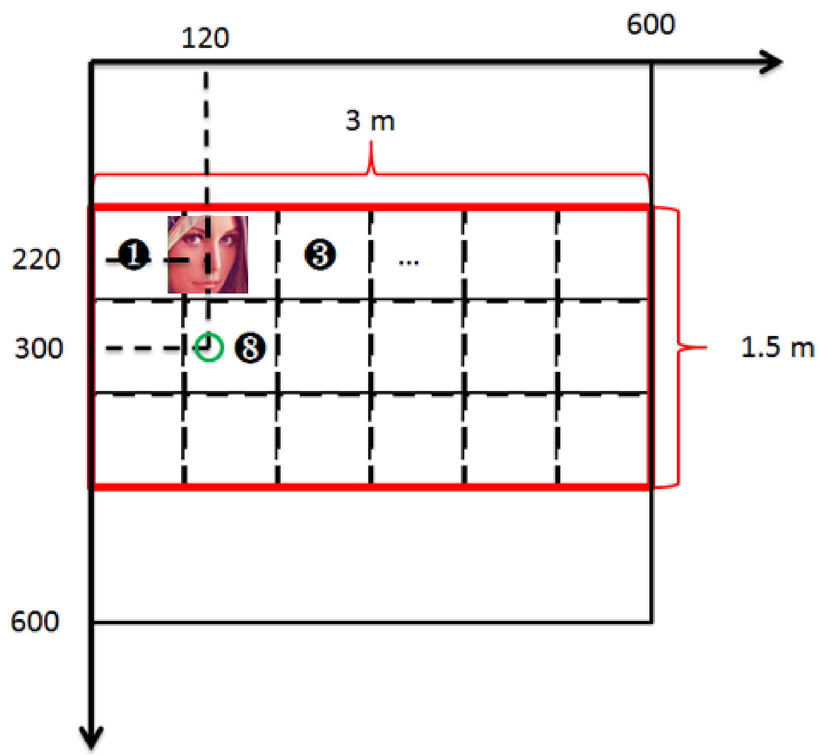


Figure 1.9: Aiming example

The target's face appears within sub area number two and was detected by the face detection algorithm. The function offers a coordinate result of (120, 220). Then add 80 to its vertical coordinate and get (120, 300), which is shown as the green circle in the figure. The new location to point at is sub area number eight, so the vertical servo motor will rotate 20 degrees and the horizontal servo motor will rotate 20 degrees as well.

Note that if target's face center point appears exactly on the edge of the sub area, it will be considered in its right/underneath sub area.

4. Experiment Results

The programming part is written in Python, includes 3 parts: main routine PIR sensor receiving and face detection algorithm, sub routine web camera taking and saving, sub routine PWM signal servo motor controlling. The entire system hardware is shown as follows. Since right now it's just prototype design, everything looks big and the entire system is powered by 110V AC. In future improvement, the system can be minimized to a size that can be embedded in a helmet, and the power supply should switch to battery.

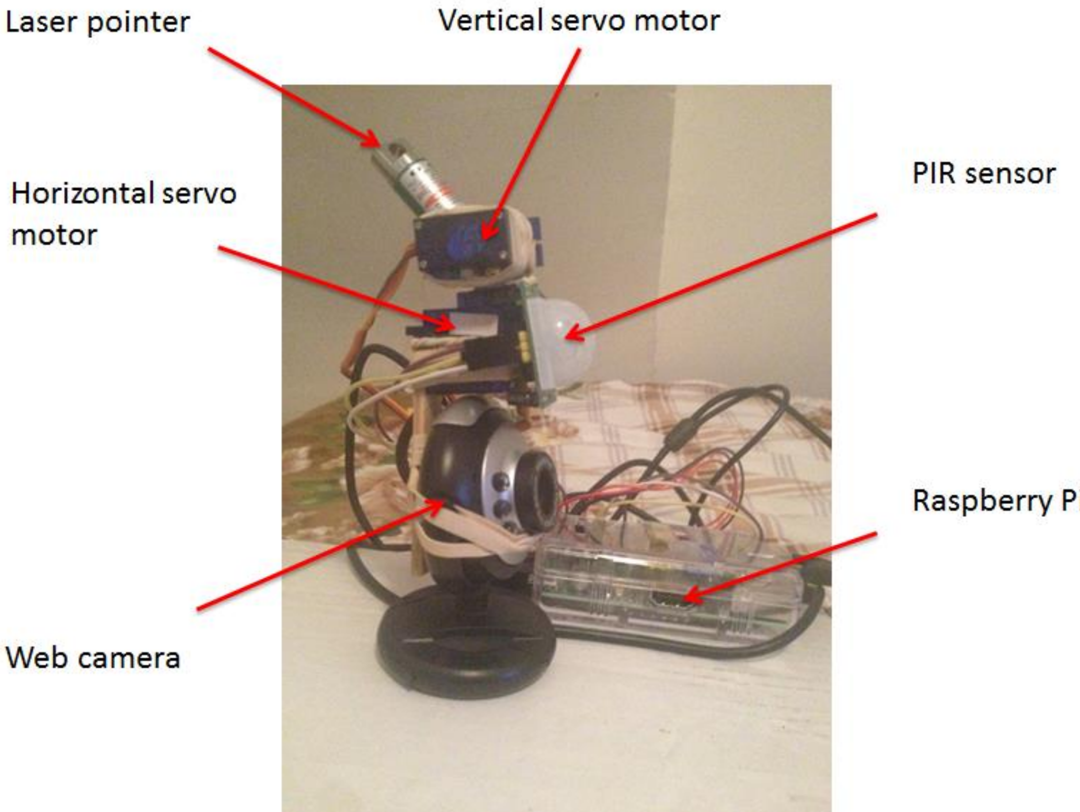


Figure 1.10: Prototype showing

The result of the system running is recorded as a video and a screenshot of the video is shown in figure 1.11:

Figure 1.11: System running screenshot

The red point in the middle of my chest is the position that the laser pointer point at. The place I stand is about 3 meters away from the camera, which is right on the edge of the effective range of the PIR sensor.

5. Summary and future work

In this project, a blind area target aiming system based on face detection algorithm is designed for security purpose. This system can distinguish real human being targets from other animals and human-shaped objects. Another advantage is that the web camera and servo motors will not work until the PIR threshold is triggered which helps save a lot of energy. Also the cost of the entire system is reasonable.

The prototype shows that my idea works, but it still shows some defects that can be improved in the future. Some of them are shown as follows with a possible solution that I can think of:

(1) The running speed is really slow. The face detection algorithm runs fast on my PC and can achieve synchronous tracking, but when applied to Raspberry Pi, a huge delay occurs.

Possible solution: Choose another more powerful microcontroller. Since the same algorithm runs much faster on PC, the CPU on raspberry Pi may not be good enough to handle the calculation and processing. Try to rewrite the face detection algorithm in C language. Python program may take longer time to run than same program written in C language does.

(2) Multiple targets appear in range at the same time. The laser pointer will jump from one target to another since the face detection algorithm offers multiple coordinate.

Possible solution: Save all coordinates in an array, fix laser pointer on the first one, after several seconds (target considered expelled) then move to next target.

(3) The position of the camera (if the user who wear this equipment is much taller/shorter than the target) will influence the accuracy of auto-aiming.

Possible solution: A calibration should be made before being used in real mission for each specific user to adjust the original position of the laser pointer.

(4) If the target is not expelled after detected by the system and he/she keeps approaching the user, the system will become inaccurate.

Possible solution: A distance sensor can be added to the system to find the connections between the size of the face and the distance between the target and camera.

(5) A Bluetooth module can be added to the system. When allies approaching each other, the Bluetooth module can send/receive signals from allies to prevent accidental injury. Also a buzzer can be added to the system to inform user there is an enemy behind his/her back before auto shooting.

PART B

Preference selection training system based on weighted sum model

1. Introduction

Physiological data is collected for research purpose in all kinds of experiments. Users that participate in the experiment will wear several different kinds of sensors and a researcher will record the data from the sensor for each section of the experiment. Traditional experiment requires the researchers to do manual recording frequently and it costs a lot of extra time. In order to make the results more reliable, researchers prefer a larger group of people to participate in the experiment which will make the data collecting and processing part become even more complicated. It is necessary to develop an automatic system that can be applied to each user for data collecting and processing. Here in this part, a preference selection training system is designed as a demonstration to show how to find the connection between a galvanic skin response sensor and a personal computer to build an automatic data collecting and processing system.

Modern life brings people all kinds of pressure. Sometimes pressure helps people become more efficient but after being in that condition for a long time, it may cause anxiety, irritability or even physical illness. It is a good choice to take a rest when people feel stressful, but it is not that easy to do so. First, it is hard to tell if someone is overstressed or just getting appropriate stress. Too much stress gives people mental or physical illness while appropriate stress makes people work better. Second, what is the best way to get relaxed? For example, doing physical exercise might be a good way to help, but for some people, it can only make them feel stressed. The favorite hobby of someone may not be the best way for him/her to relax. Third, what is the fastest way to relax? Watching a movie might work but it takes about 1-2 hours. It’s hard to find such a long time break. Fourth, when is the time to go back to work? It is a waste of time if someone has already got relaxed but still keeps taking a rest.

Previous research showed that different colors [14] and music [15-17] can influence people's stress level. It is possible to offer a room with proper lights and songs to help stressful people get relaxed in a short time by sitting inside it. A good way to know what kind of color/brightness of the light and what type of music should be perfect for the user would be doing experiment to let the user try all of them and choose his/her favorite ones. It will be a really long and boring experiment since there are so many different kinds of colors and songs. Some users might be insensitive for music, color or even both of them, so the long and boring experiment will be a waste of time. What's more, the user will get tired of the same color and song after a certain time, so the database of colors and songs should update frequently. Again, it will be really boring to ask the user to come back for another training to pick his/her new colors and songs. For all the problems mentioned above, it is necessary to teach the computer to learn the user's preference in a short training process and let the well trained computer finish the rest of the work. Then the users only need to sit down in the room and enjoy the lights and music.

The training process is based on the data collected from a GSR (short for galvanic skin response) sensor. Four weighted features are set to describe the user's preference of colors and music: bright/dark, warm/cold, fast/slow and sad/happy. All four weighted features will be added up together to form a sum named S, represent how bad the color and music combination is. A good choice of color and music combination should end up with an S lower than a certain number. When training is in progress, colors/music in different levels of those four features will be presented to user. Based on the feedback GSR sensor data, the weight of those four features will be adjust to a certain value so that the computer can make the right choice for the work in future.

2. Backgrounds

Galvanic skin response, also known as electro dermal activity (EDA), is the property of the human body that causes continuous variation in the electrical characteristics of the skin. The traditional theory of EDA holds that skin resistance varies with the state of sweat glands in the skin. Sweating is controlled by the sympathetic nervous system, and skin conductance is an indication of psychological or physiological arousal. If the sympathetic branch of the autonomic nervous system is highly aroused, then sweat gland activity also increases, which in turn increases skin conductance. In this way, skin conductance can be a measure of emotional and sympathetic responses [18]. Previous research shows that GSR sensor is reliable in emotion recognition, stress detection, deception detection and other similar fields [19-28]. Other research combined GSR sensor with electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), heart rate and respiration rate to improve the accuracy of the result, can be taken into consideration for future work [29-37].

In decision theory, the weighted sum model (WSM) is the best known and simplest multi-criteria decision analysis (MCDA) / multi-criteria decision making method for evaluating a number of alternatives in terms of a number of decision criteria [38]. It is good enough to handle this simple training system.

3. Techniques

3.1 Theory

Physiological or biological stress is an organism's response to a stressor such as an environmental condition or a stimulus. Stress is a body's react to a challenge. Facing stress, the body reacts through sympathetic nervous system activation which results in the fight-or-flight response. Since the body cannot keep this state for long period of time, the parasympathetic system returns the body's physiological conditions to normal (homeostasis). For humans, stress typically describes a negative condition or a positive condition that can have an impact on a person's mental and physical well-being [39].

When stress factor begins to influence sympathetic nervous system, human’s body starts to react. For example, your heart beats faster, your blood pressure rises, your muscle tightens and sweat production increases. Figure 2.1 briefly shows how the sympathetic system reacts when stress factor appears. When someone feels stressful, his/her sympathetic nervous system will react to make his/her body produce more sweat, leading to a changing of skin conductance, which can be detected by a GSR sensor. Based on the analysis of the GSR data, we can roughly know if a person is stressful or relaxed, which makes it possible to design a system to find someone's most appropriate way to relax.

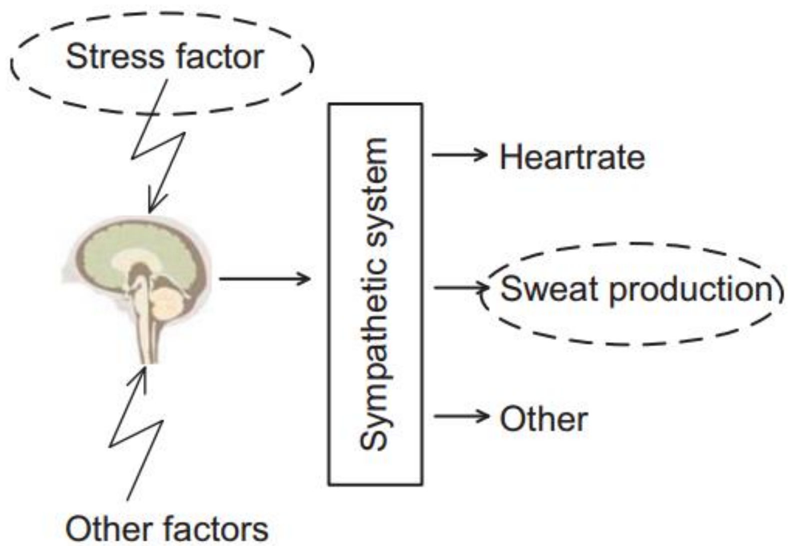


Figure 2.1: Sympathetic system reaction [40]

Figure 2.2 shows an example of acute stress pattern observed from GSR data and how it can be mapped to the symbolic (time-stamped) representation of person's stress. According to the figure, when someone is in the normal state, which means he/she is not stressful at all, his/her GSR sensing signal should be roughly stable in a relatively low level. When he/she starts to feel stressful, there will be some unstable rising or falling of the GSR signal.

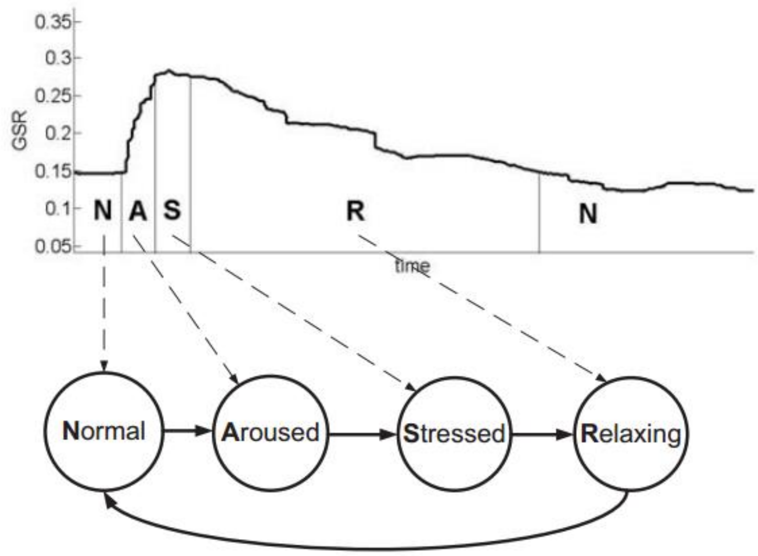


Figure 2.2: Example of stress pattern observed from GSR data [40]

3.2 Main Ideas

The goal of the project is to design a system that can pick proper colors and songs according to user's preference. When users feel stressful in the future, the system will offer a perfect environment that can help them relax. In order to find out the preference of colors and music of a specific user, four features are selected to distinguish different types of colors and music. For colors, there are X1 and X2, representing the level of brightness and hues. For music, there are X3 and X4, representing the level of speed and emotion tone. The weights for four features are W1, W2, W3 and W4. Then we have the equation for the level of satisfaction for a specific combination of color and music S:

$$\mathrm{S} = \mathrm{X1} \cdot \mathrm{W1} + \mathrm{X2} \cdot \mathrm{W2} + \mathrm{X3} \cdot \mathrm{W3} + \mathrm{X4} \cdot \mathrm{W4} \qquad (1)$$

Note that W1, W2, W3 and W4 have an original value of 0.25 before the training process start. X1, X2, X3 and X4 are in the range from 0.1 to 0.9. For example, X1 represents the brightness of the color, so a red color with 10% brightness will have X1 for 0.1 and a red color with 90% brightness will have X1 for 0.9. Since all the four features are linear, it doesn’t really matter which side is 0.1, the system will adjust in the training process. For each color and song, X1, X2, X3 and X4 will be determined by experience. For GSR sensor data, a dynamic curve can be collected simultaneously while the training is in progress. When there is an emotion arousal, the signal will keep rising until it reaches a higher level, just as shown in figure 2.2. If the user feels uncomfortable for the color/music combination, this signal rising stage will last longer or appears more than once. So the relative range R is selected to represent the level of reaction to a specific combination of color and music:

$$\mathrm{R} = \frac{\text{Maximum value} - \text{Minimum value}}{\text{Average}} \qquad (2)$$

For example, for a combination of music and color, there will be 50 data collected during the testing of this combination. First rearrange the order of those 50 GSR data, find out the average of the array, then pick out the 5th and 45th as the maximum and minimum value (in order to get rid of noise) to calculate the value of R.

It is obvious that a smaller R means fewer emotion arousals which indicate that the color and music are good. As the training starts, colors and songs with huge differences in all the four features will be offered to user, respectively. It means one of them is to be changed while the other three stay in the same level. Color/music with X1, X2, X3 and X4 from 0.1 all the way to 0.9 will be presented. When training begins, for $\Delta R = N \cdot \Delta S$:

(1) N is negative: W stays the same, change the polarity of X (0.1 side become 0.9).

(2) N is close to 0: the value of W changes to 0.01

Those two rules shown above describe the adjustment of the weight of a specific feature within a single loop in the training process. After the system finishes training for all four features, W1, W2, W3 and W4 should be able to tell the user’s preference of colors and songs. A proper value of S should be figured out for the future selection of colors and songs. It will act like a threshold, the input color and music with a value of S lower than the threshold that will be selected and added to the database for user's service in the future.

Note that the polarity of X will change according to user's preference. The value of R will be recorded and when the lowest value of R appears, it indicates that the current combination is the optimal one. So the best value of those four features can be determined as well, the polarity of X will change according to the best solution. An example is shown in figure 2.3 and 2.4.

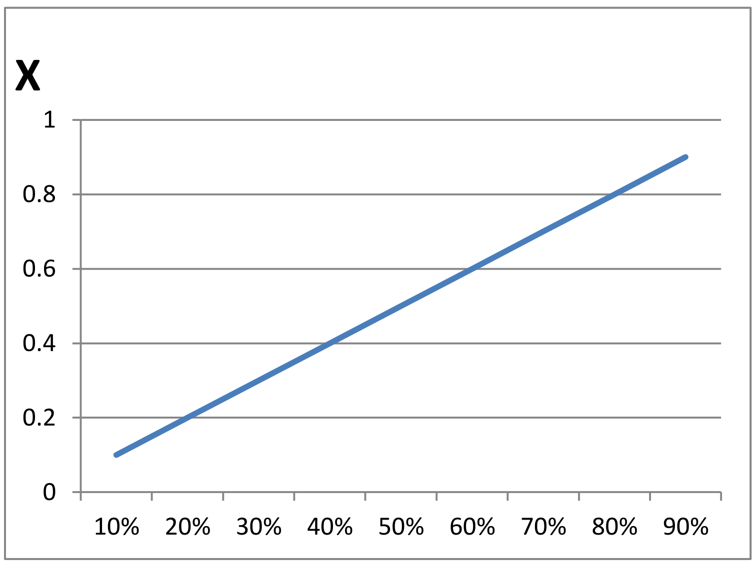


Figure 2.3 Original polarity of X1: Brightness of the color

Assume when the lowest value of R appears, the color has a brightness of 70%. Then the polarity of X1 will changes to Figure 2.4.

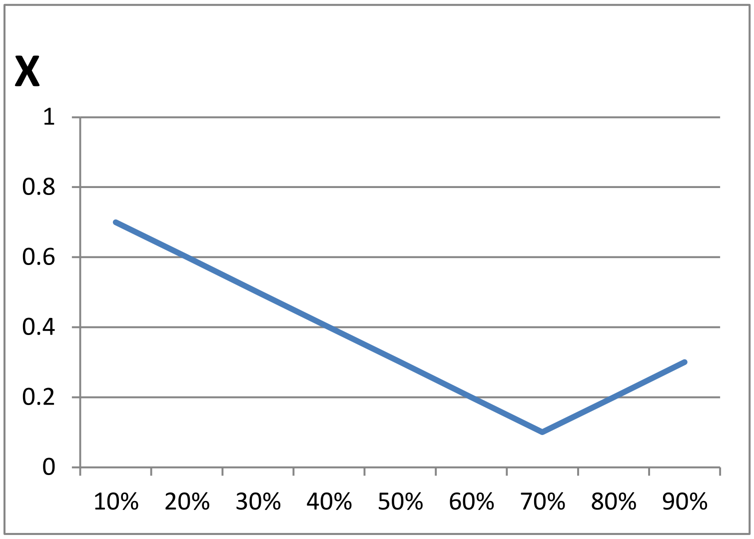


Figure 2.4 Polarity of X1 after adjustments

3.3 Module Description

3.3.1 GSR Sensor

The GSR sensor I used in this project is a comercial product from NeuLog, more information can be found on https://neulog.com/gsr/, a photo of the product is shown in figure 2.5:

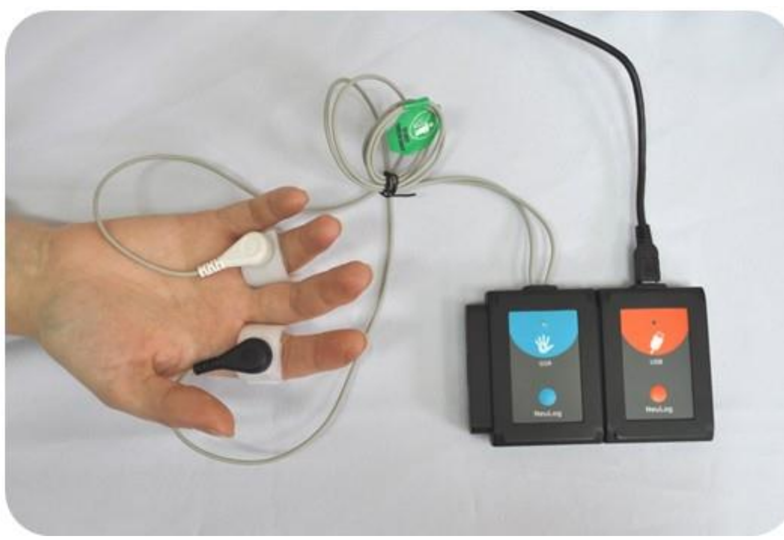


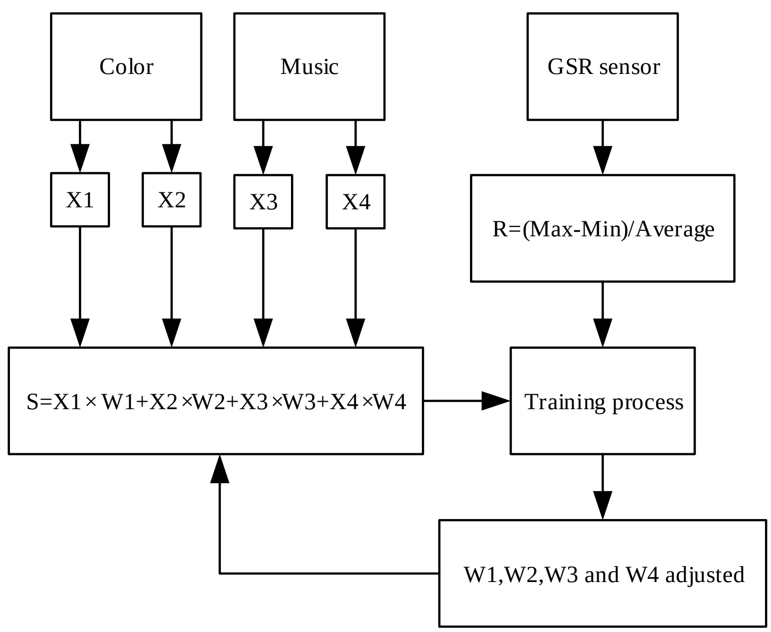
Figure 2.5: GSR sensor module [41]

The blue module is the GSR sensor module. Two electrodes are connected to the module. The red module is USB module. The GSR sensor module will only work when connected to a USB module. A good point of this commercial product is that the company developed powerful software for experiment and application programming interface (API) [41] that can be accessed from other software like C, C++ and python which makes it possible to build the automatic system. The API is based on HTTP protocol. All the software and API can be downloaded from the company's website for free.

3.3.2 Other Modules

A personal computer handles all the rest of the work. The entire system is programmed in Python. Windows Photo viewer is used for picture showing and Duomi Music player is used for music playing.

3.4 Flow Chart



The follow chat shows the brief idea of the training process. The weights adjustment loop will repeat 20 to 30 times to cover all the possible situations with different X-features. After the system is well trained, the training part will disappear and a threshold of S will be set to select proper combinations of colors and songs for future use.

3.5 Program description

The system is programmed in Python. Key part of the program will be shown as follows with comments:

```
def getdata():
 outfile=open("output.txt","w")
 outfile.write(urllib2.urlopen("http://localhost:22002/NeuLogAPI?GetSensorValue:[GSR],[1]").read())
 outfile.close()
 f=open("output.txt","a+")
 data=f.readline()
 finaldata=data[19:25]
 float_finaldata = float(finaldata)
 return float_finaldata
```

The function getdata() is defined to receive GSR sensor data from the NeuLog API. Since the API is based on HTTP protocol, it can be read from IE explore at the address: http://localhost:22002/NeuLogAPI?GetsensorValue:[GSR], [1]. A 26 bytes string can be read from the address and the 19th to 25th bytes are the GSR sensor value which is useful to the system. So this function saves the entire string in output.txt and extracts the useful 6 bytes to a float named finaldata.

```
def calculation(testdata):
 for j in range(0,48):
  for k in range(0,48-j):
   if testdata[k]>testdata[k+1]:
    m=testdata[k+1]
    testdata[k+1]=testdata[k]
    testdata[k]=m
    k+=1
   else:
    k+=1
  j+=1
 delta=testdata[44]-testdata[4]
 aver=sum(testdata)/49
 result=delta/aver
 return result
```

The function calculation() is defined to determine whether the color/song is good or not. Here as I programmed in the system, the relative range is used to show the measures of dispersion. In the function, the input is an array of 49 GSR data. First rearrange all the data ascending/descending. Then calculate the range by finding the difference between the 5^{th} and 45^{th} data in the array and the average value of the entire array. Finally divide the range by the average to get the relative range. This parameter may not be accurate but right now it has to be set to continue the designing of the system. In future research, better parameters will come out to replace this temporary one.

```
im = Image.open("0.1.jpg")
im.show()
for i in range(0,49):
 out=getdata()
 print(out)
 testdata[i]=out
 i+=1
outt=calculation(testdata)
testresult1[0]=outt
print(outt)
```

After all functions are defined, the training begins. For the first feature X1, three red colors with X1=0.1，X1=0.5 and X1=0.9 will be shown to test user sensitivity to the brightness of a certain color. 50 GSR data will be collected (1 for each second) and saved in array testdata as an input to the determination function. The relative range of this specific color will be calculated and saved in another array named testresult1. Three red colors with different brightness are shown in figure 2.6:

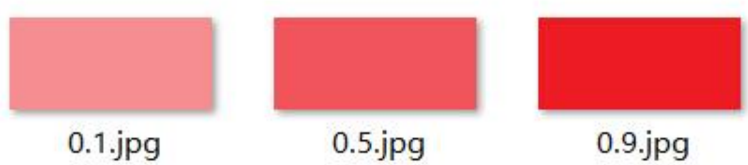


Figure 2.6: Three red colors with different brightness for X1

Then feature X2 will be trained. Five colors with different hues(from warm to cold) will be presented to the user to test if user is sensitive about the changing. Colors are shown in figure 2.7 with their X2 value as their file name:

Figure 2.7: Five colors with different hues for X2

Then feature X3 and X4 will be trained. X3 is the speed of the music and X4 is the mood. The differences of the songs are not able to be found out from the photo, so there will not be any figure for them.

```
R=testresult1[1]-testresult1[0]
if R < 0.05:
  W1=0.01
if testresult1[1]<P:
 PP=0.5
```

The codes above shows the training process after photo 0.5.jpg, a red color with 50% brightness, is presented to user. R is the difference between two relative ranges for 0.1.jpg and 0.5.jpg. S= (0.5-0.1) ×0.25= 0.1. The relative range is saved in variable P while the corresponding feature X1 is recorded in variable PP. After the training of X1, the value of X1 will be rearrange to a new order with the lowest value appears at the brightness level with the minimum number of relative range. The training processes of X2, X3 and X4 are similar to X1.

```
W1=0.01
W2=0.25
W3=0.25
W4=0.01
f=open("test.txt","a+")
value=f.readline()
X1=value[1:3]
float_X1=float(X1)
X2=value[4:6]
float_X1=float(X2)
X3=value[7:9]
float_X1=float(X3)
X4=value[10:12]
float_X1=float(X4)
S=W1*float_X1+W2*float_X2+W3*float_X3+W4*float_X4
if S < 0.1:
 print("Good choice!")
else:
 print("Sorry! Try another one!")
```

After training, the system gets user’s preference and can be applied to select proper color and music in the future. The information for the upcoming color and music will be saved in test.txt, including four features X1 to X4. The program will read from the file and calculate the value of S, then check with threshold to decide if it is good or not. For example, the training result shows that I am not sensitive to brightness of the color and the mood of the music. W1=W4=0.01. I set the threshold of S to be 0.1. When user is sensitive to all four features, threshold 0.1 means X1 to X4 should all be 0.1. When user is sensitive to three, two or one features, it means the acceptable level for X1 to X4 can be up to 0.1, 0.2 and 0.3.

4. Experiment Results

The system is built and tested on my personal laptop. Figure 2.8 shows a screenshot of feature 2 training, with showing a red color picture 0.1.jpg. An array of data can be found on the left side of the screen which shows the real time GSR sensing data.

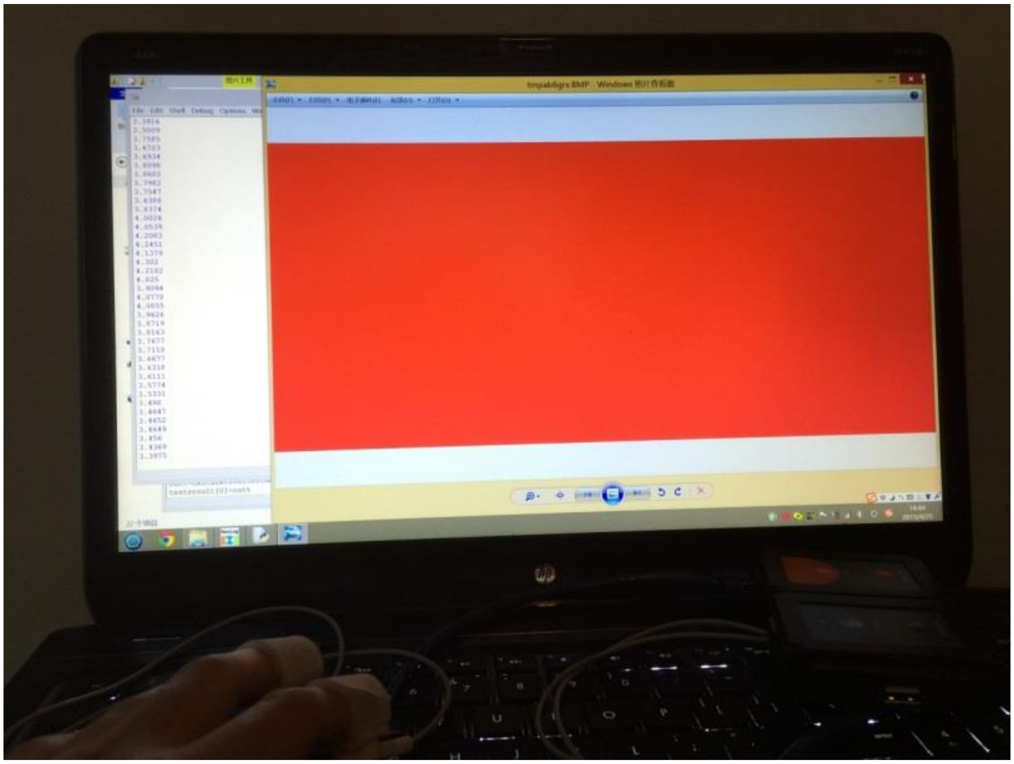


Figure 2.8: X2 training screenshot

The training process for X1, X3 and X4 are similar to figure 2.7. Note that there are a lot of things that may influence the training result. For example, sometimes taking deep breath can cause a huge noise to galvanic skin response signal, as well as other body movements. Also the relative range may not be the perfect parameter to describe the satisfaction level of a color/song, I will discuss about it in the summary part.

The system is trained three times with W1 to W4 shown as follows:

(1) W1= 0.01, W2= 0.25, W3= 0.25, W4= 0.01

(2) W1= 0.01, W2= 0.25, W3= 0.25, W4= 0.01

(3) W1= 0.01, W2= 0.25, W3= 0.01, W4= 0.01

Result No.1 and No.2, W1= 0.01, W2= 0.25, W3= 0.25 and W4= 0.01 is picked out which means I am not sensitive about the brightness of color and the mood of music. The lowest value 0.1 of each feature moves as follows: X1: 90%, X2: blue, X3: 10% low speed and X4: 10% happy. The lowest recorded R is 0.22. Then the well-trained system will be applied to test a certain combination of color and music.

A color with X1= 0.3, X2= 0.2 and a song with X3= 0.1, X4= 0.1 was selected by the system with S= 0.079. The relative range of GSR testing for this combination is 0.31.The result shows that my body's reaction for the selected combination is just a little higher than the lowest value 0.22.

A color with X1= 0.1, X2= 0.3 and a song with X3= 0.2, X4= 0.1 was denied by the system with S= 0.127. The relative range of GSR testing for this combination is 0.70. The result shows that my body's reaction for the selected combination is much higher than the lowest value 0.22.

This entire project shows the fact that it is possible to build an automatic system for GSR data collecting experiment. Based on the python program, more sensors can be added to the system to complete more complicated experiment.

5. Summary and future work

As is mentioned in the previous part of this report, it is necessary to discuss about the key parameter (the relative range) that is used for both part 1 and 2. With the help of my workmate, I collected the GSR data of him when taking test with the presenting of different colors and different types of music. The results are shown in figure 2.9:

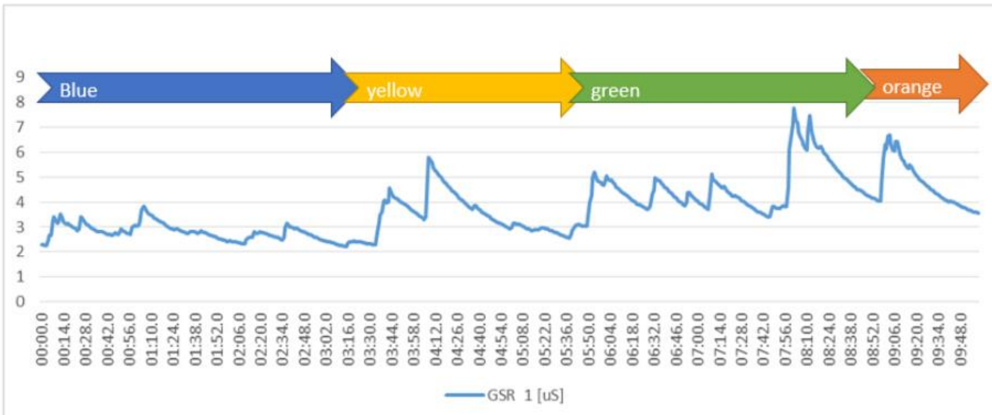


Figure 2.9: GSR data for color testing

This shows the figure of GSR data when he took the color test of blue, yellow, green and orange. According to the figure, color blue is the best one since there is no huge peak appears during the test (compare to other colors); color green is the worst since there are a lot of huge peaks. A peak means emotional fluctuation, in other words, user feels uncomfortable for this color.

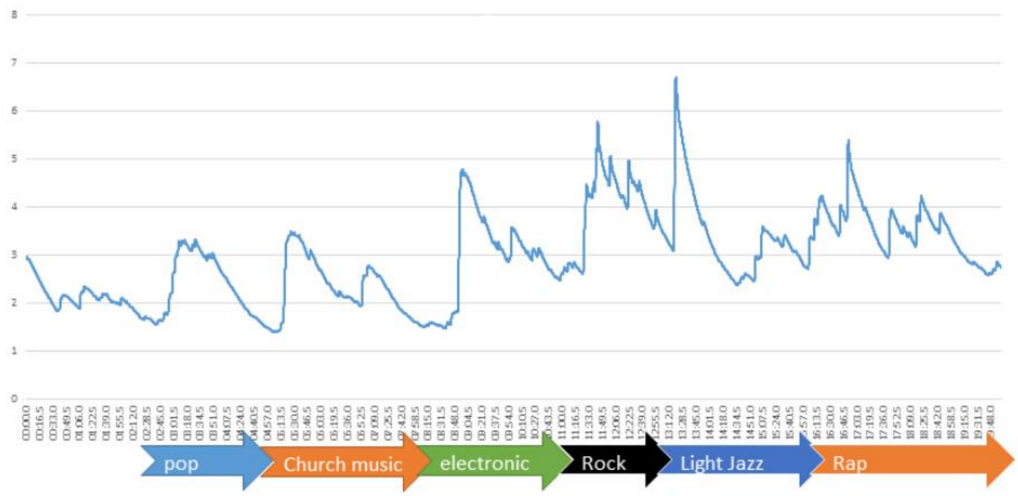


Figure 2.10: GSR data for music testing

Figure 2.10 shows the GSR data when he is taking the music test of pop, church music, electronic, rock, jazz and rap. According to this figure, we can see rock, jazz and rap is not good while pop and church music looks better.

The relative range might be able to help pick out the best colors and songs because it shows how smooth the GSR signal is during the testing of a specific color/song. But there is a problem. Based on his testing result, whenever there is a change from one color to another (or one song to another), there will always be a peak. This is normal because the change of color/song in a sudden will cause the user's emotional fluctuation. After the user got used to the color/song, his/her GSR signal will become smooth and flat. In this case, the rate that his/her GSR signals is getting down which shows how good this color/song is. The system is designed to find the fastest and best way to make people feel relaxed, so this makes sense. Then jazz will be a good choice because according to the figure shown above, His GSR peak drops really fast when the computer is playing jazz. However at the same time, jazz's relative range is not good enough to convince the system to save it to the second part of the program.

This project shows a way to build a system that can train the computer to learn to help people make choices by collecting data from a commercial product. On one hand, the system is automatic, no more manual recording or calculating is needed. On the other hand, the system can help people pick appropriate colors and songs that are close to their preference.

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