EmuPlayer: Music Recommendation System Based on User Emotion Using Vital-sensor

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Abstract of Bachelor's Thesis

EmuPlayer: A Music Recommendation System Based on User Emotion

EmuPlayer is a Music Recommendation System Based on User's Emotion which tracks the user's emotion and suggests songs by providing a playlist sorted relevantly in regard to the user's current emotion. For a particular emotion of the user, the system evaluate songs according to the qualification assessed by two factors which are: songs' relevancy to the user's preference, and songs' mental influence on the user's feeling. In this proposing system, user's emotion is not input manually by the user, but detected automatically by the machine. In order to do that, user's biosignal data is captured from sensors, and then used as inputs for emotion detecting process.

The motivation behind this system is the lack of a context-aware Music Recommendation System where automatically detected user's mood plays the most important role as a contextual key. The need of such system is made obvious by the fact that digital music libraries are constantly expanding, which thus makes it remarkably difficult for listeners to recall a particular song matching their present mood.

By training the system to recognize user's emotional state only by Skin Temperature and Heart Rate, it is made possible for listeners to generate a playlist which suits with their current emotion, and of which songs are rated also by the potentially mental influence on user's emotion, with very few sensors worn on them.

Keywords: Music Recommendation, Emotion Recognition, Vital-sensor, Emotional Model

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EmuPlayer:ユーザーの感情を基づいて曲を勧めるシステム

本論文で提案するEmuPlayerは利用者の感情に合わせて，音楽のレコメンデーションを行うシステムである．

本システムは，ユーザの音楽に対する趣向と，その楽曲が利用者の現在の感情にどのような影響を及ぼすかを考慮して，楽曲のレコメンドを行う．EmuPlayerは，ユーザが現在の感情を手動で入力することなく，利用者の感情を自動的に判断する手法を用いる．

この機能の実現にあたり，本システムでは，生体情報を生体センサから取得し，感情抽出へ利用するという手法を用いる．

本研究の背景として，自動的に利用者の感情を認知し，それを主な入力として曲を提示するレコメンデーションシステムが現存しないことが挙げられる．利用者の持つデジタル楽曲数は拡大を続けているため，利用者は，利用者自身の感情に一致する楽曲を選択することが難しくなってきてる．

皮膚温度と，脈拍数によって，利用者の感情を抽出することにより，利用者は自分の現在の感情に合わせたプレイリストを生成できるようになる上，そのリスト中にある曲は利用者の趣向を満たすかどうかだけではなく，利用者に与える心理的な影響でも評価を行うことができる．さらに，これらを数少ない小型のウェアラブルセンサのみで実現可能であるという特徴も兼ね備えている．

キーワード:　音楽レコメンデーション，感情認識，生体センサ，感情モデル

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Chapter 1

Introduction

1.1 Motivation

It is undeniable that music plays a very important role in human's life. In the need of transmitting music among the community, many means have been employed, for example, via oral way such as singing, or technical ways such as cassette tape, CD, or DVD. However, only until music started to be digitalized into the sequence of 0 and 1 bit in 1991, the transmission of music changed to a way that made music become more popular than ever.

Music in its digital form can be listened in a number of different ways, as it can be downloaded and listened from the computer, burned into a compact disc, and especially, played by portable music devices which have made music spread out and available almost everywhere. The storage of those portable music devices is continuously increasing and now has reached to the number of 160GB, allowing users to load thousands of songs into their libraries. However, besides the convenience, that characteristic on the other hand troubles the users as they may experience the confusion while choosing songs. For that reason, Music Recommendation System becomes a very essential subject in current context.

Up to now, various studies on this field have been done, proposing content-based, context-based, collaborative, music-mood-based, and community-sharing music recommendation sys-

tems. Even though, a music recommendation system which tracks user emotion automatically and continuously in order to suggest him songs is not yet introduced. In fact, the user emotion should be considered crucial input in regard to the actual habit of listeners to choose songs by considering the relevancy between their own feelings and the feelings those songs bring to them. Particularly, such systems are very useful in the case when the users want to fing songs which match their current emotions but can't reveal what their emotions are, or are unable to declare or input their emotions to the system.

Moreover, because music influences on the listener's emotion, it is necessary to evaluate the effect of a song after it is played for him. This work helps not only with providing a better song suggestion, but also improving user's listening habit by acknowledging him of the influence brought by the music he heard.

Hence, above reasons are motivations behind the proposition of EmuPlayer system.

1.2 Research goal

As EmuPlayer is a Music Recommendation System Based on User Emotion, there are two requirements this system needs to solve which are (1) to detect the user mood, and (2) to recommend songs relevantly. The goal of this research is to train the system to recognize user's emotion with as few sensors worn on the user as possible, and to propose an ideal of evaluating a song based on its two factors which are its relevancy to user's listening taste, and its influence on user's emotion. In order to do that, firstly, an emotional model, which is a graph demonstrating emotions in their relationships with each other, will be utilized and then combined with the use of vital-sensor to detect emotion. Secondly, a recommending list will be made by appraising and rating songs according to the two factors that are mentioned above.

1.3 Thesis Structure

The thesis is organized as follows. Chapter 2 provides a brief introduction to the concept of emotion and emotion in the relationship with music, as well as demonstrates various techniques of detecting emotion and recommending songs with respect to their relevance to the project. Chapter 3 discusses the approach to EmuPlayer, proposing an emotional model and song rating principles. Chapter 4 shows particular design for hardware and software. Chapter 5 is the implementation of EmuPlayer, explaining which sensor to be used and how the system is executed. Chapter 6 presents evaluation on the work of emotion recognition and the performance of EmuPlayer system. Finally, chapter 7 raises the conclusion of proposing system and its future works.

Chapter 2

Background

2.1 Introduction

This chapter is divided into two sections corresponding to the two majors of proposing thesis which are Emotion Recognition and Music Recommendation System. In each section, concepts along with various techniques and related studies will be reviewed with respect to their relevance to this project.

2.2 Emotion Recognition

2.2.1 Section Introduction

In this section, methods and related studies on Emotion Recognition field will be discussed in details. Starting with the concept of emotion, Concept of Emotion subsection provides grasp knowledge of emotion as well as its construction and factors, giving ground to lately proposed emotion recognition methods.

Emotion and Music subsection contains two main parts which are demonstration on the relationship between emotion and music, and demonstration on influences music does on listeners' emotional state of mind. Discussing on the relationship between emotion and music, the first part clarifies the habit of listeners when they choose song, thus reasons the

need of such a Music Recommendation System Based on User's Emotion. The second part figures the reason why and in which manners music influences on user emotion, reasoning the need of Music Recommendation System's feedback after each song played.

Following, available methods for detecting emotion will be demonstrated in Emotion Recognition subsection. Correlatively, analysis of the reason why vital-sensor is more suitable to apply to a Music Recommendation System than other methods will also be discussed.

This section ends with demonstrations on biosignal and emotional model which are tools employed in vital-sensor method.

2.2.2 Concept of Emotion: Construction and Factors

Concept of Emotion

"Everyone knows what an emotion is, until asked to give a definition". Above quotation, from Beverly Fehr and James Russell, remains the truth that emotion is rather an abstract concept than an obviously definable one. Although emotion is part of each human-being, they are barely able to reveal what it is. Since that, there have been researches on this field which led to numbers of definitions of emotion. Certainly, none of proposed definitions can absolutely be admitted by all researchers. However, generally, emotion is known as the complex psycho-physiological experience of an individual's state of mind as interacting with biochemical (internal) and environmental (external) influences. In humans, emotion fundamentally involves "physiological arousal, expressive behaviors, and conscious experiences" [20].

Emotion: Expressive words and Terms

Humans are capable to experience an infinite number of emotional states. As such, there exist many terms as well as expressional words of emotion. For instance, affect, mood,

emotion, and feeling are terms which are often used interchangeably emphasizing emotional state. Though, they are not as relevant to each other as they appear to be.

Like what mentioned above, in two factors influencing on structuring a person's state of mind, surrounding environment functions as an external factor. For that environmental factor can be absent or present, there thus created two versions of mood and emotion, corresponding to the object-less and the object-directed types [27]. For example, if a person says "I feel blue", the feeling "blue" in here is object-less and therefore is a mood. However, in the instance of "I am afraid of the dark" where "the dark" is an intentional object directed at by "afraid" feeling, "afraid" is an emotion. For the rest, "activation", "affect", "mood", and "feeling" are judged to be functionally the same [27]. That explains why, along with "emotion", these terms are often used interchangeably.

Construction and Factors of Emotion

Emotions can manifest themselves in a variety of ways, most of which are very expressive. According to P.R.Kleinginna and A.M.Kleinginna's study of emotion, "Emotion is a complex set of interactions among subjective and objective factors mediated by neural/hormonal systems, which can (a) give rise to effective experiences such as feelings of arousal, pleasure/displeasure; (b) generate cognitive processes such as perceptually relevant effects, appraisals, labeling processes; (c) activate widespread physiological adjustments to the arousing conditions; and (d) lead to behavior that is often, but not always, expressive, goal-oriented, and adaptive" [24] [27]. R.Kleinginna and A.M.Kleinginna's study, along with many other authors' researches, figures out that the change of emotions can be observed whether visually and observably through facial expression, vocal expression, an individual's level of arousing action; or biologically through arousal and valence (pleasure/displeasure) states.

These evident clues are important and precious in providing ground to form many cor-

relative methods of recognizing emotion that will be discussed in later chapter.

2.2.3 Emotion and Music: Relationship and Mutual Influence

Music has grown to be an important part of human's life. The close relationship between music and emotion is undeniable, as music has the ability to affect and manipulate humans' emotions as well as their brain.

Listeners' song choosing habit

For listeners, if they choose a new song to listen, they tend to choose it by predicting the song's contained affective content, in corresponding with their listening taste. Nevertheless, when listeners are to pick up one song from the playlist they have listened, they often rely on their current emotion to select a song that they feel like wanting to listen to the most. As such, there is a need of a Music Recommendation System which is capable to not only understand the user's current emotion, but also understand the songs will that user want to listen to under conditions of the same emotion.

One approach for such a Music Recommendation System is that to classify songs by their expressing mood, and then let the user pinpoint his current mood to have songs of that mood played for them. In this approach, the technique called Music Mood Classification is employed. Up to now, there have been many researches on Music Mood Classification proposed in order to enhance the efficiency of music recommendation system. However, a great problem arises from studying about the music mood that is the remarkable subjectiveness of music's emotional content. More specifically, how music is emotionally powerful to an individual depends much on his sensitiveness towards music; and also, music is experienced in much different way by each person who hears. Though, researchers have studied that there are some common effects caused by music on every listener. These effects has

been reported and raised as common rules applied in Music Mood Recognition field. Such that rules include: major keys and rapid tempos cause happiness, whereas minor keys and slow tempos cause sadness, and rapid tempos together with dissonance cause fear, and so on [9] [3]. Still, even the Music Mood of songs is made clear, not until both user emotions as well as song's emotion are coherently revealed, could the work of music recommendation system meet the user's expectation.

Music and its mental effect on listeners

As mentioned above, music can better or worsen the emotional state of a listener. It was found that the varying degrees of dissonance caused increased activity in the paralimnic regions of the brain, which are associated with emotional processes [5]. Remarkably, one recent experiment measuring the activity in the brain while subjects were played previously chosen pieces of music which created feelings of intense pleasure for them showed that activity was seen in the motivation, emotion and arousal areas of the brain [21]. All these results, once again, have evidently affirm that music does produce significant emotional responses inside the brain, so that to influence on listener's emotion.

Taking advantage on that characteristic of music, up to now, music has been employed in several medical treatment purposes. There is evidence that music can lower levels of cortisol in the body (associated with arousal and stress), and raise levels of melatonin (which can induce sleep), which make it capable for producing relaxation, calmness, or giving peace [1]. Therefore, as a practical instance, music is often used in the background of hospitals to relax the patients, or in mental hospitals to calm potentially and aggressively provoked ones. Music also helps in releasing endorphins inside the body, and therefore helps in relieving the pain [17]. The scientific study done by The Chelsea and Westminster Hospital also found that patients who listen to live music, which is mostly classical one, need fewer drugs and

recover more quickly than those who do not listen [12]. Additionally, it is also acknowledged that babies respond to music while they are still in the womb [28]. This has become a great motivation for parents to play classical music for their babies, hoping it helps in brain development.

However, in other hand, playing music in an inappropriate way can unexpectedly bring harm to listeners. It is reported that hard rock music, with Anapestic Beat which consists of 2 rapid beats followed by a long beat as in tahta tara, causes stress to the body, lessened work performance, learning problems along with behavior problems in children, and a general malaise in adults. For rap music, it causes tolerance increasing for and predisposition to violence, even promotes materialism, and reduces interest in long term success and academic study. Besides, according to Dr Hawkins, punk rock, death rock and gangster rap music makes listeners go weak, confirming earlier observations made by Dr. John Diamond [12]. Whereas, "the music of Bach makes everyone go strong, even if they don't personally like it, just as heavy metal music makes all subjects go weak, even if they personally prefer it.", concluded Dr Hawkins [12]. That explains troublesome problems often found in our everyday life, such as listeners feel annoyed by loud music played for a long time especially when they are concentrated at work, or listeners get tired of listening to music through a headphone for so long.

All above mentioned studies and evidences bring us to a conclusion of that, even listeners are perceptively aware or not, their affective states of mind are influenced by the music that they hear. This is a crucial motivation behind the need of emotional changing feedback after user's every listened song in proposing Music Recommendation System Based on User Emotion.

2.2.4 Emotion Recognition: The Methods

Methods for Emotion Recognition Field

Detection of User's Emotion has become an increasingly essential topic by the need of to improve interacting qualification between humans and computers. Users, being emotional persons, are supposed to be able to interact more effectively with computers which can account for those emotions of them. On the other hand, computer which understands the emotions of its users will have the potential of deducing and performing appropriate courses of actions towards users, which otherwise will never be done if the computer is unable to comprehend.

For that reason, emotion recognition is for certain a very interesting, but also really challenging subject. There are a number of means employed in method used to analyze humans' emotions, varying from physiological components (for example, facial expression, vocal intonation, pulse and so on) to subjective ones (for instance, written or spoken language). As such, many methods of emotion recognition have been proposed. They are via facial expression, speech, eyes movement, brain wave, gesture and yet a variety of many other physical and physiological cues, of which two most researched methods up to now include speech and facial expression [4]. It was reported that people can recognize emotional speeches with about 60% accuracy and emotional facial expressions with about 70-98% [29] [23]. The same evaluation was done on emotion recognition systems to estimate those systems' performances. However, that is for certain another difficult task to declare, since systems' accuracy depends much on the number of emotional categories that the system attempts to clarify. The more emotions a system has to deal with, the harder the stuff becomes; because there exists a fuzziness of affect terms which makes the work of recognizing emotion turn out to be very complicated. Though, recognition rate has approached to the number of

50-60% for emotional speech recognition and 80-90% for facial expression approximately [29].

Vital-sensor Method

Among methods used for detecting emotion, the use of vital-sensor transcends in advantages. First of all, it's the convenience this method brings to the users, in comparison with being watched by cameras in facial expression method for instance. Secondly, less number of problems will the system have to deal, concerning with outer factor or background noises. Facial expression will be hard to manage when the light levels used in the experiment are low or when the user is moving; there is often too much background noises in speech recognition, and so on, are examples for usual problems found for other methods. Thirdly, there are solid evidences proving that emotion can give rise to effective experiences such as feelings of arousal, pleasure/displeasure (see 2.2.1 Concepts of Emotion). All these affective changes can be measured by vital-sensors; therefore, data recorded by relevant vital-sensors potentially reflects the emotion of the subject. Finally, it is the fact that sizes of vital-sensors are increasingly reduced which makes it possible for users to wear those sensors on without so much consciousness, keeping them from unexpected discomfort they might have to undergo.

Above mentioned advantages reason why vital-sensor appears to be capably employed in Emotion Detecting part of a music recommendation system, of which the portability and convenience are highly desired. However, which method is actually to be used in EmuPlayer will be analyzed further in chapter Approach, in regard to specific requirements for the system's Emotion Recognition work.

Details of Bio-signal and Emotional Model, which are two tools often cooperatively used in vital-sensors method, will be discussed more in next subsections as follows.

2.2.5 Bio-signal

Human's body reacts properly in regard to nervous changes. When a person is frightened, his heart races, his breathing becomes rapid, his face goes pale, and he even trembles. Those of these symptoms which can be observed from the outside merely are bodily reactions, but those which can be monitored and measured are referred to as biosignal ones. All these changes are mediated by the autonomic nervous system.

The autonomic nervous system is a part of peripheral nervous system that acts as a control-system functioning largely below the level of consciousness and controls visceral functions [8]. Autonomic system can be divided into two subsystems which are the sympathetic and the parasympathetic ones [29]. Although several visceral functions are controlled predominantly by only one of the two subsystems, and although sympathetic and parasympathetic nervous systems exert opposing effects on innervated target tissues, it is the balance of activity between the two that helps maintain the internal stable environment under the change of external conditions [2].

In the following, some of the most employed biosignals in emotion recognition field will be introduced.

- **Skin Temperature** is the temperature measured on the surface of the skin. Under the strain, muscles become tense and thus the blood vessels will be contracted which therefore leads to the decrease in temperature. Skin temperature also helps with distinguishing between pleasure and displeasure, as skin temperature tends to rise up for pleasure, and decrease otherwise.

- **Electrodermal activity**, also referred to as skin conductivity (SC), basically measures the conductivity of the skin which increases when an object sweats. Skin Conductivity is sensitive to stress or differentiating between fear and anger.

- **Electrocardiogram (ECG)** signal is the manifestation of contractile activity of the heart. It can be measured directly on the surface around the chest, or on the limbs. From ECG, Heart rate (HR) and inter-beat intervals (IBI) are extracted. HR and IBI will then help to determine the heart rate variability (HRV). Low HRV indicates a state of relaxation, whereas increased HRV indicates a potential state of mental stress or frustration. HR functions relatively alike with HRV. HR is often used in measuring objects' arousing state, as high HR approaches to the arousal and low HR shows a more relaxing state like sleepiness or calm.

- **Blood volume pulse (BVP)** measures the amount of blood currently running through the vessels. BVP can be used to measure vasoconstriction and the heart rate.

- **Respiration** tells how deep and fast a person is breathing. Fast and deep breathing indicates excitement such as anger or fear, or sometimes even joy. Rapid shallow breathing indicates tense anticipation including panic, fear or concentration. Slow and deep breathing indicates relaxation or resting state. Slow and shallow breathing indicates states of depression or calm happiness.

- **Electromyography (EMG)** refers to the muscle activity or frequency of muscle tension. Hence, EMG is often used in detecting stress as under stress muscles strain.

- **Electroencephalography (EEG)** is the recording of electrical activity along the scalp produced by the firing of neurons within the brain. There are 6 types of brainwave patterns which are Alpha, Beta, Delta, Theta, Gamma, and Mu. Each of these 6 waves behaves differently toward a particular state of emotion. For example, Alpha emerges with closing of the eyes or relaxation, low amplitude beta with multiple and varying frequencies is often associated with active or anxious thinking, and so on.

2.2.6 Emotional Model

Emotional model is a graph representing specific emotions and their relationships in a regarded concept. Emotional Model has been applied widely to help with classifying or identifying human's emotions. Based on the approaches, emotional model can mainly be divided into two major types which are categorical and dimensional ones.

A categorical emotional model is the model composed of several distinct emotional words representing classes which form the basis for other words' classification. An example of remarkable study on categorical emotional model field is the work of researcher Paul Ekman. In order to propose a category of basic emotions, Ekman did a research on the Fore tribesmen of Papua New Guinea, who come from an isolated culture, testing their ability to identify emotions in photographs of people coming from cultures which are not familiar with them. The result that the Fore could reliably realize those emotions led Ekman to a final conclusion that there existed some expressive emotions basic and biologically universal to all human beings. And, he released a list of basic emotions as in Fig.2.1. These emotions are manifested as human being's facial expression like in Fig.2.2

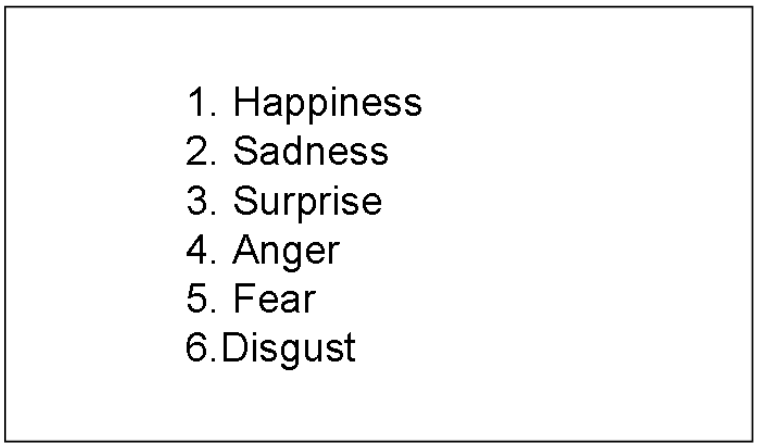


Figure 2.1: Ekman's Six Basic Feelings

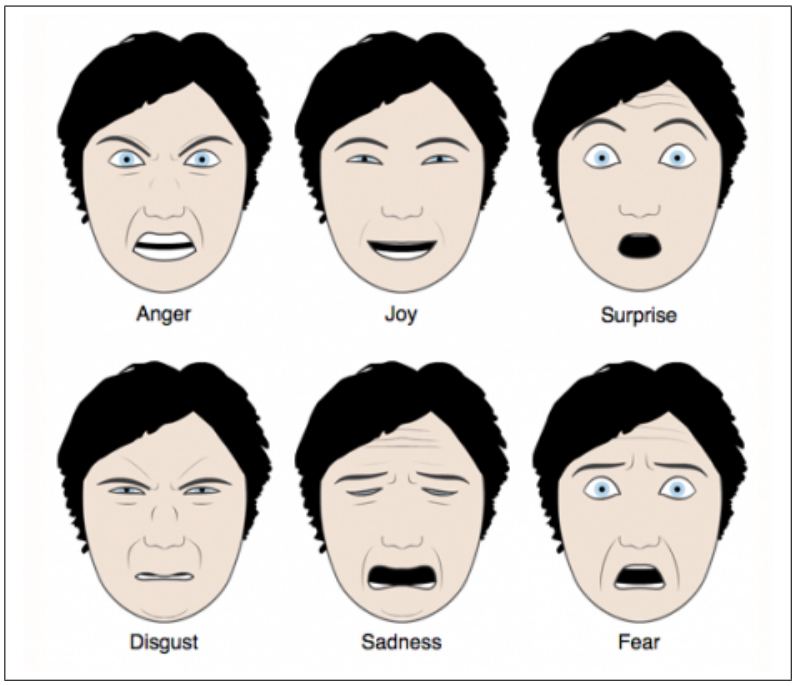


Figure 2.2: Ekman's Six Basic Feelings Through Facial's Expression

Then, in 1990s Ekman expanded his list of basic emotions with a new range of both positive and negative emotional words as demonstrated in Fig.2.3

1. Amusement
2. Contempt
3. Contentment
4. Embarrassment
5. Excitement
6. Guilt
7. Pride in achievement
8. Relief
9. Satisfaction
10. Sensory pleasure
11. Shame

Figure 2.3: Ekman's Expanded List of Eleven Basic Feelings

Dimensional emotional models, the second type of emotional model, are to classify an emotion by its values along axes. Those include James Russell's twodimensional bipolar

space, of which axes are defined by valence and arousal, and in which a collection of 28 emotions were chosen and represented. Another model applying this approach is Robert Thayer's energy-stress two dimensional unipolar model. According to Robert Thayer's model, specifically chosen emotions will be identified on the graph by its levels of stress and energy (Fig.2.4 and Fig.2.5) [30]. After two dimensional models, three dimensional models are also proposed such as Albert Mehrabian's model with pleasure - arousal - dominance axes.

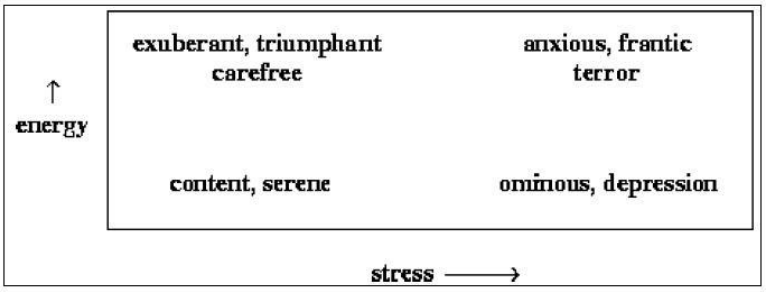


Figure 2.4: Thayer's energy-stress two-dimensional unipolar model

From the basic two and three dimensional models, emotion representation has subsequently improved into circular models such as Russell's circumplex model (see Fig.2.6) [26], or Kate Hevner's circle of elements of expression in music as in Fig.2.7 [13]

In two approaches, categorical approach seems to be more suitable for the use of classifying word, whereas dimensional approach seems to be more capable of emotion identification. With a combination of relevant bio-signal values, user's emotional state can be easily mapped on dimensional model, making it possible to deduce the user's emotion afterwards. That is the reason why dimensional approach is mostly chosen to be used for emotion detecting purpose.

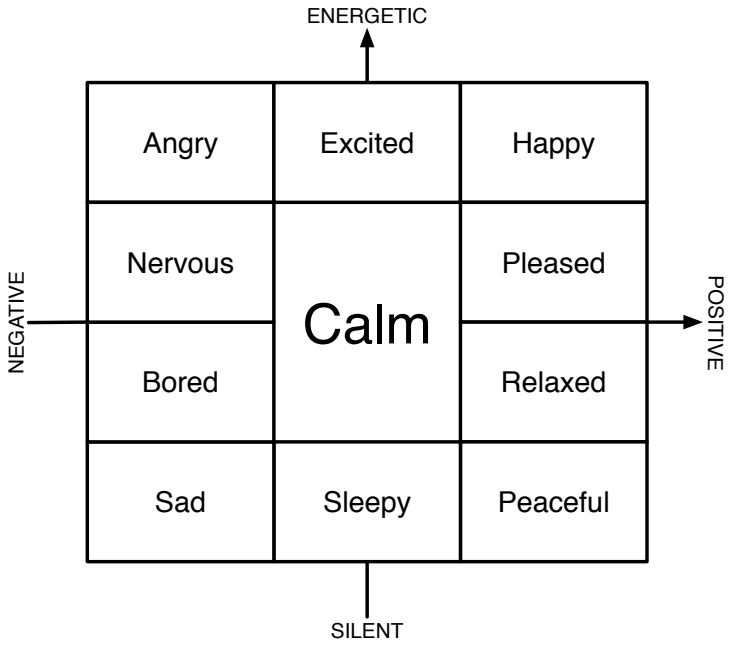


Figure 2.5: Thayer's energy-stress emotional model version 2

2.2.7 Section Conclusion

Throughout this section, we have discussed about emotion and its related topics. First of all, Concepts of Emotion gave grasp knowledge on definition and structure of emotion. Understanding of the fact that emotional changes can be observed visually through facial expression, vocal expression, level of arousing action; or biologically through arousal and valence level gave clues and a firm background to build up methods for emotion detection. The reason for the need of user's emotion in recommending music was clarified by the "Listeners' song choosing habit" as stated in 2.2.3. The fact that listeners choose songs relying on their own feelings shows that the understanding of user's current feeling plays an important role in suggesting music. Besides, apparent proof of influences of music on listeners' mental state (Music and its mental effect on listeners 2.2.3) brought out the conclusion that listener's affective state of mind is really influenced by the music that they hear, even if they are aware

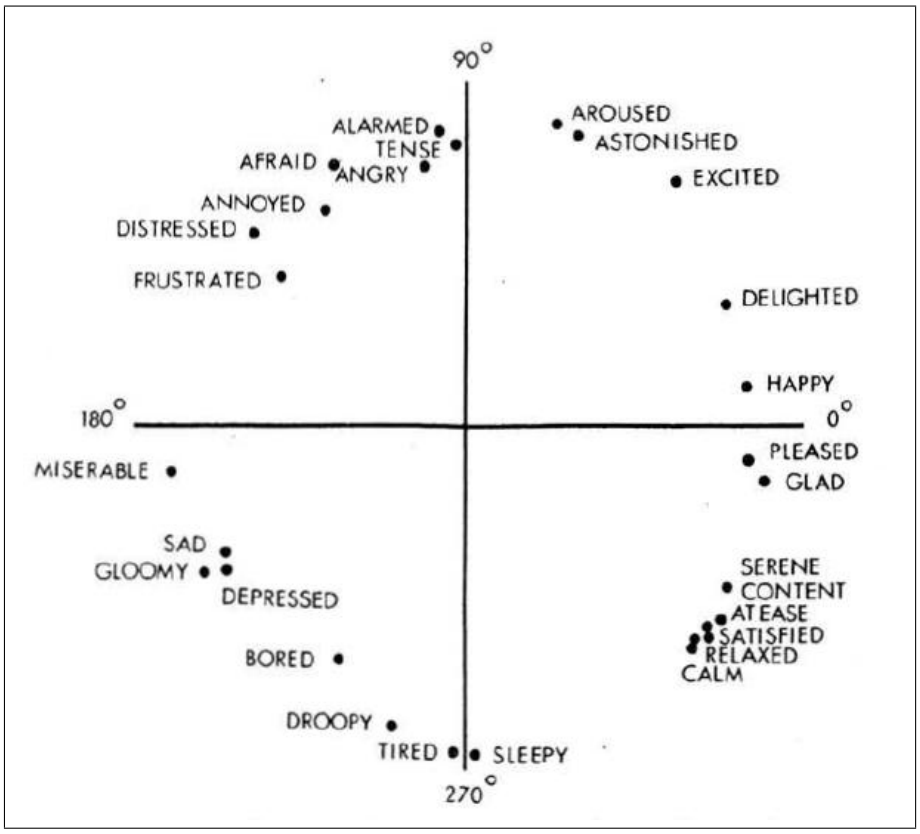


Figure 2.6: Russell's circumplex model of 28 expressive words

of it or not. Therefore, evaluating songs' emotional influence and giving feedback to users are two highly desired functions of a Music Recommendation System. Respectively, methods for Detecting Emotion were presented, where vital-sensor method transcended in advantages (Vital-sensor Method 2.2.4). Finally, various types of emotional model and bio-signal which are two tools employed by vital-sensor method were also presented. In summary, this section has demonstrated the need of employing user's emotion in music recommendation system and evaluating also song effect in order to make right suggestion, as well as background for proposing approach.

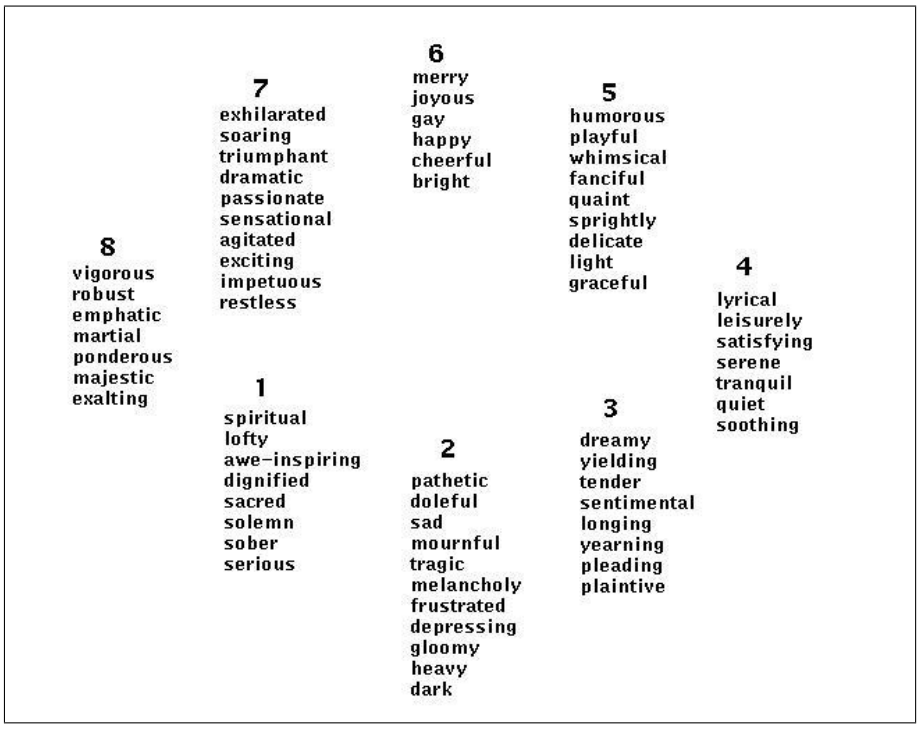


Figure 2.7: Hevner's circle of elements of expression in music

2.3 Music Recommendation System

2.3.1 Section Introduction

Music Recommendation System is a music recommending tool reasoning with user's preference and a great range of other aspects. Generally, Music Recommendation System (shortened here to Music Recommendation System with MRS) can be classified into three main major categories which are Collaborative MRS [22], Content-Based MRS [7] [10] [25], and Context-Based MRS [15] [11] [14]. Each of these three MRSs will be discussed further in the following. Besides, a closer view to some popular currently-in-used MRSs, as well as some MRSs based on Emotion will also be taken.

2.3.2 Collaborative MRS

The concept of this method is that users will be clustered into groups according to their listening preferences. After that, music will be shared and suggested between users coming from the same group. This classifying process is often based on the content of genre, artist or album extracted from user's listening and downloading history. A strong point of this method is that there is a high possibility users can experience unexpected but familiar-to-their-taste songs from the recommendation. However, receiving too many unexpected songs in the recommending list is certainly this method's weak point too.

2.3.3 Content Based MRS

In Content-Based MRS, content of all songs listened by the user in the past will be analyzed in order to elicit a common rules that mostly reconstitute user's listening behavior. Songs which have content relevant to that rules will be recommended. As such, Content-Based MRS has the ability to suggest songs that highly meet the user's listening profile.

2.3.4 Context Based MRS

Context-Based MRS considers many kinds of aspects coming from surrounding environment and reasons them in combination with user's listening song at the same time. This work helps to better learn about the user's listening habit, since there exists a relationship between what a person listens to and environmentally outer factors. Because this method considers many factors while recommending song, it seems to have higher possibility of suggesting songs that meet user's preference.

2.3.5 Summary of Popular currently-in-used MRS

Most of currently-in-used MRS are the collaborative ones, and based on the concept of community sharing. Instances of such popular systems are shown as following.

iTunes Genius

iTunes Genius is a Content-Based Music Recommendation System. iTunes Genius gives song recommendations within iTunes, and it's the portability of iTunes via iPods and iPhones that makes iTunes become such a widespread phenomenon. By following and studying user's iTunes behavior, iTunes Genius offers user remarkable services, such as to recommend relevant songs and artists, based on the rating, play count and so on extractable features from user's listening history (suggestions are displayed as in Genius sidebar). Another example is the ability to allow the user to select any song in his library, thence to create him a custom playlist based on musical elements of that song (feature in lower right hand corner button) (Fig.2.8)

Figure 2.8: iTunes screen

iLike

http://www.ilike.com/ iLike is a social music discovery, with an user-friendly website and impressive iTunes and Windows Media Player add-ons. iLike allows user to view related artists and songs to the currently playing song, extracted from both the user's own playlist and the iLike recommendation. iLike also allows users to see what other people in their social network are currently listening to. In order to do that, iLike bases on the listening behaviors of other iLike members to display related artists and songs. Hence, iLike is able to benefit from a numerous group of listeners' accuracy and neutrality points of view, which makes it an excellent tool to discover music.(Fig.2.9)

last.fm

http://www.last.fm/ Last.fm is a UK-based Internet radio and music community website, founded in 2002. Last.fm is very popular with 21 million active users based in more than 200 countries. Users are able to create and manage playlists, view related artists and songs, plus love, share, and tag tracks. Based on that listening behavior of users, Last.fm allows users to view their listening history and patterns, as well as those of their friends and others who have similar tastes (neighbors).(Fig.2.10)

MyStrands

http://www.strands.com/ MyStrands is another famous social recommendation and music discovery service. MyStrands performs as a content-based MRS, basing on features of songs or artists that users either upload from their iTunes playlists or add as favorites on the site to recommend relevant albums, artists and songs. As a social recommendation system, MyStrands also allow a user to collect information on who is currently listening to the same music, to update friends' new preferences of music, or to keep track of the music that his

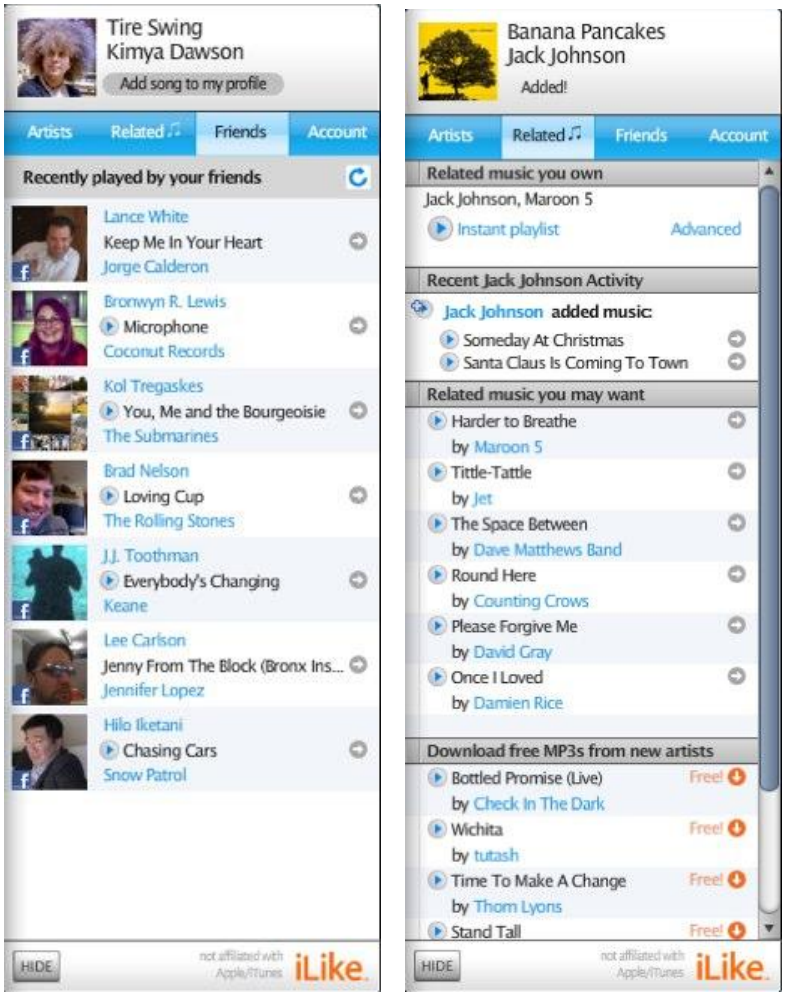


Figure 2.9: iLike screen

friends are listening to.(Fig.2.11)

2.3.6 Summary of Music Recommendation System Based on Emotion

Up to now, most studies on Music Recommendation System Based on Emotion often exploit "Emotion" in the favor of an overwhelming mood of a song, or a piece of music, but not the user's emotion. More specifically, those systems make users appoint an emotion, and then give them a recommendation list of songs which carry the mood. Instances of such

Figure 2.10: lastfm screen

system include emotion based music recommendation by association discovery from film music [10], or recommending music by a mood-based music classification [18]. Besides, some other context-based Music Recommendation Systems also employ user's mood as one factor while considering; however, the user's mood yet detected automatically by the system, but inputted by the user.

2.3.7 Section Conclusion

Up to now, many types of Music Recommendation System have been proposed. However, a Music Recommendation System which tracks user emotion and evaluates emotional effect to recommend music is not yet introduced; whereas it was discussed that user emotion

Figure 2.11: MyStrands screen

should be considered a crucial input for the system. Even for recently popular in-used Music Recommendation Systems, they focus more in social sharing among community than that issue. Meanwhile, EmuPlayer is proposed under the perception of that problem. The main subject EmuPlayer deals with while suggesting song is the user's emotion in a current time.

2.4 Conclusion

In this chapter, common knowledge and related studies on two majors: Music Recommendation System and Emotion Recognition were presented. Between methods for detecting music, vital-sensor appears to be mostly applicable to proposing system. Many types of biosignal and emotional models used in detecting mood by vital-sensor are introduced as a foundation for system's approach. Besides, we can conclude that a MRS which tracks user emotion to recommend music is promising and desired, observing the trend of currently

popular MRS and the work of proposed MRS based on Emotion.

In next chapter, we will propose the approach to this system.

Chapter 3

Approach

3.1 Introduction

This chapter is also demonstrated through two main sections corresponding to the two majors: Emotion Recognition and Recommending Music.

3.2 Emotion Recognition

3.2.1 Section Introduction

This section is presented by the following order: specific requirements for Emotion Recognition part regarding to practical aspect of EmuPlayer, reasoning for vital-sensor method, applying of Russell's model of emotion in this system, the two employed biosignals which are Skin Temperature and Heart Rate, and finally the work of mapping user's emotion onto Russell's emotional model as overall approach for Emotion Recognition part.

3.2.2 Concrete Requirements regarding to practical aspect of EmuPlayer

For that portability is the deciding characteristic which makes Digital Music Player popular, integrating MRS into Digital Music Player should not make them less portable than their

original. In addition to the effort of reducing in size, using fewer devices also makes the system become more portable and compact. Therefore, a method to recognize subject's emotion using as few devices as possible is the primary objective of this proposal. This work on the other hand also helps to improve user's comfort while using the system.

Besides, in order for the system to gain the capability of tracking user's emotion while recommending, the continuity and the sensitiveness towards changes of emotion of captured data is highly required.

Finally, choosing which method should also be considered in the favor of user's comfort.

3.2.3 Vital-sensor method Reasoning

Among methods for emotion recognition demonstrated in subsection 2.2.4 , vital-sensor appears to be mostly applicable. For example, in the case of detecting emotion via facial expression, the great number of surrounding cameras will make the system become cumbersome, as well as potentially discomfort to the users, and make the users barely able to move freely while most of them actually tend to when playing songs.

On the other hand, detecting emotion via speech is also considerably difficult to deploy due to the habit of staying silent while listening to music of some users, especially when they are in public places such as inside the office or on the train.

Therefore, vital-sensor transcends in its ability to bring the user comfort, and more importantly, its captured data's continuity and sensitiveness regarding to emotional changes. Besides, vital-sensor's size is also rapidly decreased. However, how to reduce the number of sensors employed while still assuring the precision as well as the efficiency of the mood acquiring process is yet another problem.

The comparison of methods' characteristics in regard to specific requirements of EmuPlayer system is shown as in Fig.3.1.

Requirement / Method	**Portability** if integrated in Music Player	**Continuity** of output data	**Sensitiveness** towards changes in emotion while listening to music
Facial Expression	X	X	△
Speech	△	X	△
Eyes movement	△	△	△
Brainwave	X	○	◎
Gesture	X	X	△
Bio-sensor	○	○	○

Figure 3.1: Comparison of Emotion Recognition Methods' characteristic in regard to specific requirements of MRS system

3.2.4 Russell's model

If it is considered using vital-sensor, Russell's model of Emotion, in which affective states are represented as a circle in a two-dimensional bipolar space, with horizontal axis defined as valence (pleasure/displeasure) and vertical axis defined as arousal, is employed. (Fig.3.2).

As both arousal and valence express themselves very well through particular biosignals, user's emotion can be detected by applying a specific set of appropriate signals' value to Russell's model.

There exist four versions of Russell's model in total, three of which contain 28 affective states, and the fourth contains 8 emotions among those 28 ones. The fourth version is also the original and core model on that other three models are based to expand. (Russell's core model of 8 emotions is shown as in Fig.3.3)

To locate emotions onto the graph, Russell has performed a number of experiments to de-

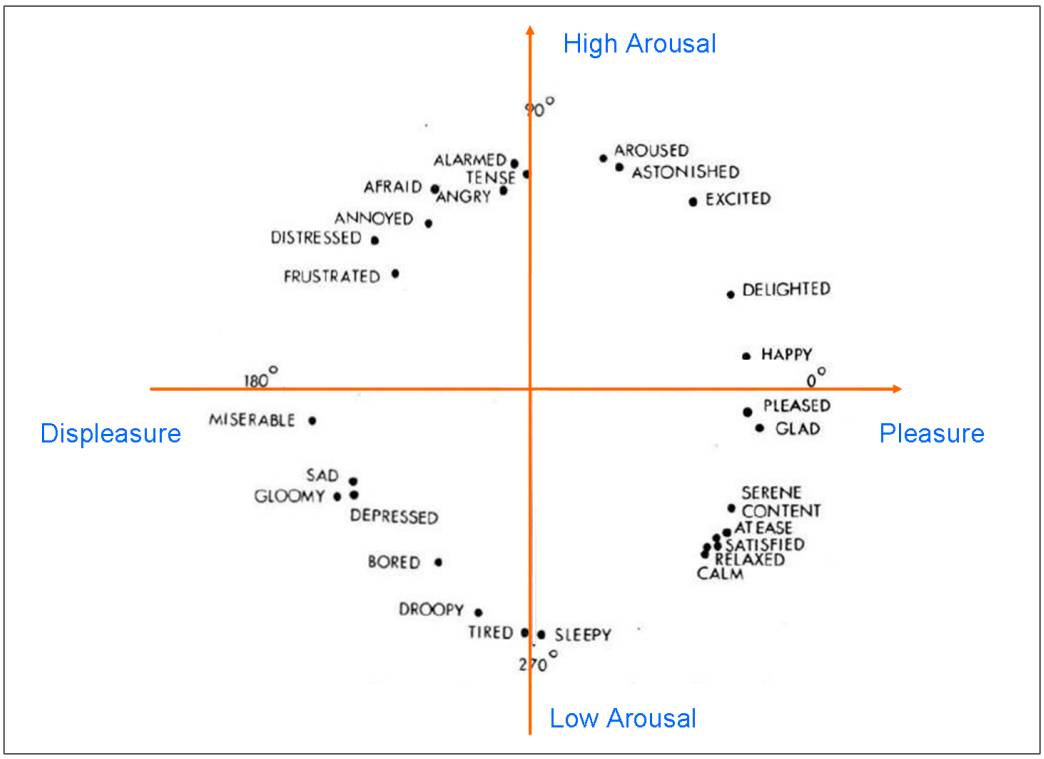


Figure 3.2: Russell's model with arousal-valence axes

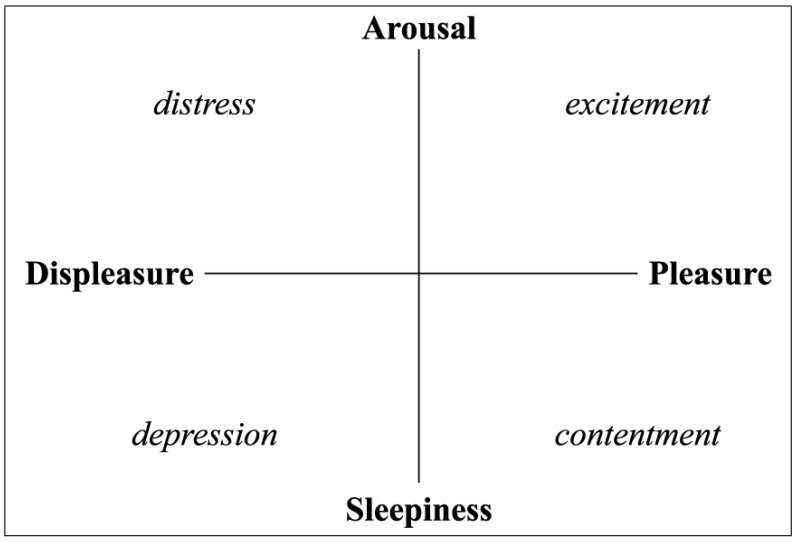


Figure 3.3: Russell's core model of eight emotions

termine the angel between these emotions and the horizontal axis. Although all 28 emotions are mapped onto the graph under the same policy, only angles of the eight emotions in the

Emotion	Pleasure	Excitement	Arousal	Distress	Displeasure	Depression	Sleepiness	Relaxation
Cicular Order (degree)	0	45	90	135	180	225	270	315

Table 3.1: Circular ordering of Eight Emotions in Russell's model

core model are verified. [26] Therefore, the model of those eight emotions will be employed in this system for emotion recognizing purpose. The circular orderings of those 8 emotions including Pleasure, Excitement, Arousal, Distress, Displeasure, Depression, Sleepiness and Relaxation (contenment) in Russell's model are declared as in Table.3.1.

3.2.5 Heart Rate and Skin Temperature: The two Biosignals

It is proved that Skin Temperature is applicable for detecting the level of valence, in the manner of increasing towards pleasure and decreasing on the contrary [19], while in the other hand, Heart Rate (or Pulse) is adaptive in regard to arousing changes. High arousing state results in fast heart beat, and low arousing state or sleepiness results in low pulse [16] [6].

For that reason, Skin Temperature and Pulse in combination with Russell's model are used to help deciding emotional state of a user without having him wear many sensors on. With a particular set of Skin Temperature and Pulse's value, a point representing user's emotion will be mapped onto the graph (see Fig.3.5). The mapping policy will be presented in next section.

3.2.6 EmuPlayer Emotion Mapping

Conception of Russell's circumplex model is based on the relation between emotions manifested by their relative angels. In Russell's model, as the formation is circular and the arrangement order of each emotion is fixed; it is possible to determine users' emotion only through their bio signals' reading, basing entirely on the relative location of the reading on

the model specified by its angel to horizontal axis.

The direction of the vector with the neutral state as the initial point and the reading as the terminal point points toward the user's emotion. The exact emotion can then be approximated by rounding the angel of the described vector to the closest emotion's angel.

More specifically, in order to do that, the system has to go through two steps which are 1) to determine the regions of those 8 feelings, and 2) to calculate the angel representing user's emotion and refer it to defined region to extract the exact emotion. The first step can be done based on the study of the fuzziness of emotional words, and the second step can be done by the process that is demonstrated as following.

Emotions' Regions Determining: The Fuzziness of emotional words

Fuzziness is a characteristic of natural language categories in general, as concluded by the works of Hersh and Caramazza, 1976; Labov, 1973; and Lakoff 1973 [26]. Given that existing a fuzziness between two affective words, these two words are supposed to overlap each other in meaning, which partly explains why affective terms can be represented in a circle as what can be seen in Russell's model.

For example, "pleasure" and "excitement" are close in the circular ordering because their fuzzy boundaries overlap considerably. Therefore, a series of overlapping regions with fuzzy borders would result in the continuous placement of those affective terms on the affect space. This provides the foundation to respectively divide Russell's model into eight equal parts (Fig.3.4). Within each part, points represent the same feeling approximately.

Mapping

Based on above discussions, we propose an approach for detecting user's emotion as following. Firstly, Russell's model with its eight regions corresponding to the eight emotions is applied.

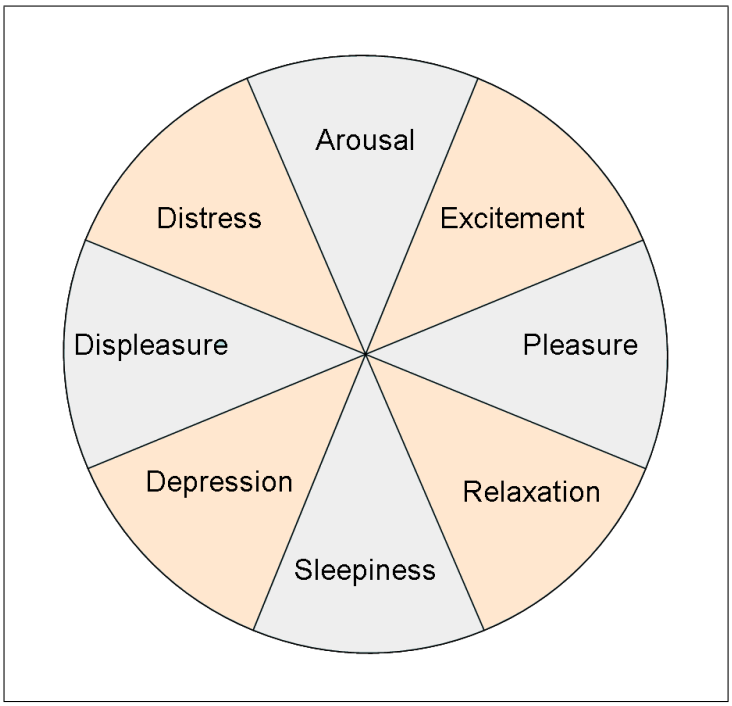


Figure 3.4: Division of Russell's model into eight regions

Region	Pleasure	Excitement	Arousal	Distress	Displeasure	Depression	Sleepiness	Relaxation
Angel (degree)	-22.5 ~ 22.5	22,5 ~ 67,5	67,5 ~ 112,5	112,5 ~ 157,5	157,5 ~ 202,5	202,5 ~ 247,5	247,5 ~ 292,5	292,5 ~ 337,5

Table 3.2: Angle of Eight Regions

The vertical axis, arousal, is defined by user's pulse, and the horizontal axis, pleasure/ displeasure, is defined by user's skin temperature.

Based on circular ordering of eight emotions (Table.3.1), boundary of each region is declared as shown in Table.3.2.

Given a set (x,y) as user's reading of Skin Temperature and Heart Rate, a point representing user's current state named A is mapped onto the model by user's reading. Angel alpha (Figure.3.5) between user's direction OA and the horizontal axis is calculated by the formula as follows

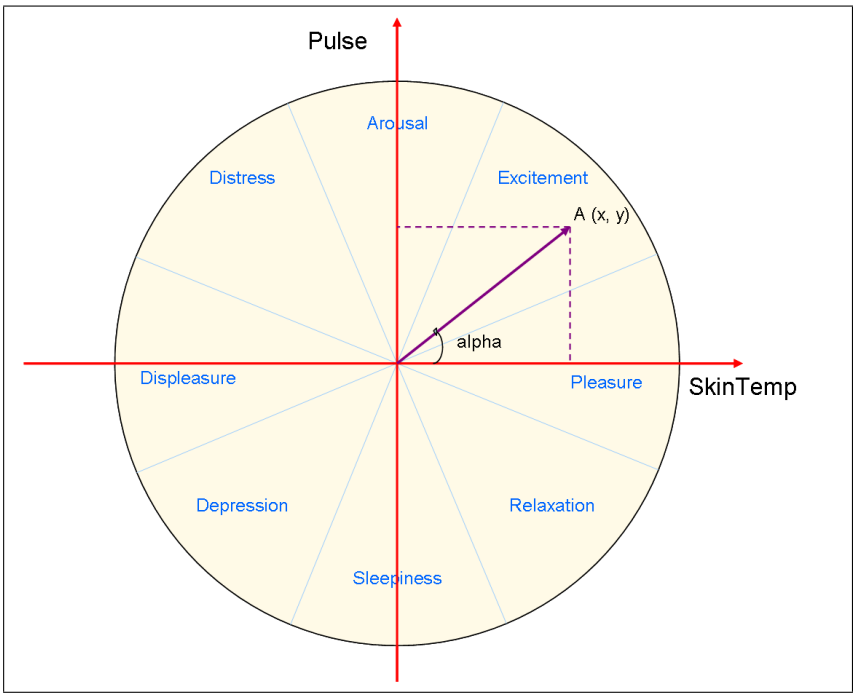


Figure 3.5: Mapping a point representing user emotion onto Russell's graph

$$\alpha = \arcsin\left(\frac{y}{\sqrt{x^2+y^2}}\right) \ (x, y \geq 0)$$
$$\alpha = 180 - \arcsin\left(\frac{y}{\sqrt{x^2+y^2}}\right) \ (y > 0, x < 0)$$
$$\alpha = 180 + \arcsin\left(\frac{y}{\sqrt{x^2+y^2}}\right) \ (y < 0, x < 0)$$
$$\alpha = 360 - \arcsin\left(\frac{y}{\sqrt{x^2+y^2}}\right) \ (y < 0, x > 0)$$

Then, by referring alpha to regions of the eight emotions (Table.3.2), the exact emotion of the user will be extracted (Figure. 3.5). The exact emotions corresponding to each particular range of alpha is shown as in Table.3.3.

3.2.7 Section Conclusion

This section described the approach used in Emotion Recognition. By dividing Russell's model into eight equal regions corresponding to eight emotions, in combination with employing Heart Rate and Skin Temperature to define vertical and horizontal axes, user emotion

alpha	Emotion
-22.5 ≤ alpha ≤ 22.5	Pleasure
22.5 ≤ alpha ≤ 67.5	Excitement
67.5 ≤ alpha ≤ 112.5	Arousal
112.5 ≤ alpha ≤ 157.5	Distress
157.5 ≤ alpha ≤ 202.5	Displeasure
202.5 ≤ alpha ≤ 247.5	Depression
247.5 ≤ alpha ≤ 292.5	Sleepiness
292.5 ≤ alpha ≤ 337.5	Relaxation

Table 3.3: Angel alpha and Extracted Emotion

can be mapped and determined.

3.3 Music Recommendation

3.3.1 Section Introduction

This section focuses on discussing the importance of employing two following factors in evaluating a song. They are the relevancy of a song to the user taste, and the influence of that song on user emotion. The evaluating processes of these two factors will be discussed in detail, followed by the rating policy. Finally, the system overview will be introduced.

3.3.2 Two factors in evaluating songs

There is the fact that current Music Recommendation Systems only refers to the satisfaction of the user's taste while suggesting music. However, in order to give users good recommendations, Music Recommendation System should consider each song by both two factors which are the relevancy to users' preference, and the emotional influence after users listen to that song. Moreover, if the system is able to evaluate the effect of a song on user's emotion, it will have the capability of preventing users from songs which potentially harm them in a

mental way, thence to enhance their listening habit.

In this system, a method of evaluating songs which uses both of those factors is proposed as described in the followings.

3.3.3 Study on Song's Emotional Effect Definition

As EmuPlayer is able to detect user emotion, by comparing emotions before and after that user listening to a song, the song's effect on the user emotion can be decided. Hence, the only one left question need to be solved is to define which movements of emotions emphasize good/bad effect.

The main purpose of evaluating emotional effect of songs towards the listener is to avoid recommendations which are potentially harmful to his mental state. For example, a heavy metal rock song which makes the user's emotion change from relaxation to displeasure is considered to have bad affect, and should not be suggested next time when the user is under the similar condition. In order to do that, firstly, affective words emphasizing bad emotion are separated from the eight emotions. They are Distress, Displeasure and Depression marked as pink zone as seen in Fig.3.6. The rest of them including Pleasure, Excitement, Arousal, Sleepiness and Relaxation are marked in blue zone.

The movement of which initial emotion belonging to the blue zone destines in a region belonging to the pink zone represents the bad change of emotion. Conversely, the movement of which initial emotion belonging to the pink zone destines in a region belonging to the blue zone shows the good emotional change.

The issue is more delicate to assess the movements of emotions coming from the same zone. Within the pink zone, emotions are considered to get worse according to the order of Distress, Displeasure and Depression, as Depression falls into the corner where data of both vertical and horizontal axes which are Pulse and Skin Temperature gets negative values;

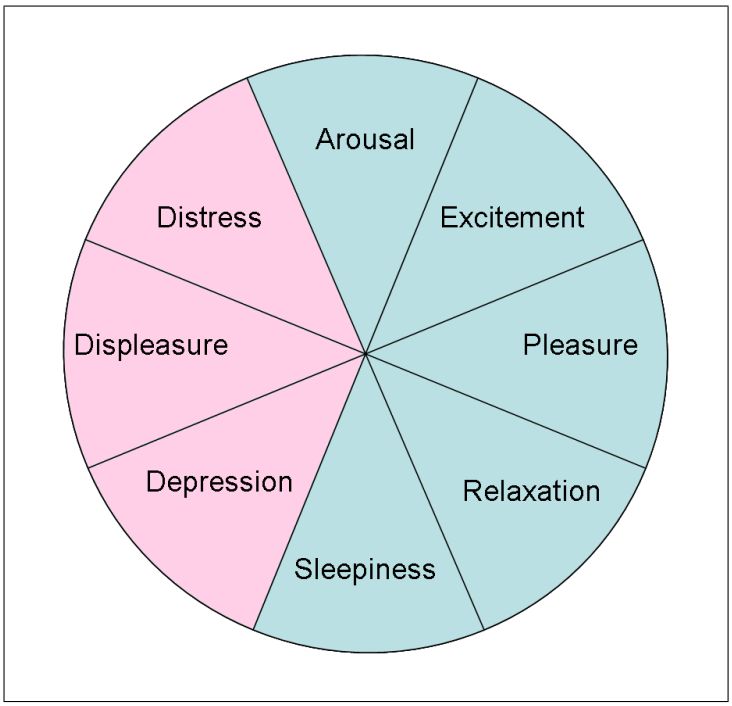


Figure 3.6: Defination of good/bad region

whereas Distress falls in the corner of positive value for vertical axis and negative value for the horizontal axis; and Displeasure lies on the horizontal axis on the left side of the centric O. Therefore, within the pink zone, the movement in which former emotion is better than the later emotion represents a good change of emotional state, and vice versa.

Inside the blue zone, because to declare which emotion brings better effect to the user is a very subjective problem, emotions belonging to this zone are impossibly ranked regarding to all users. As such, movements between points within the blue zone are not assessed as giving good or bad influence on the user, but to not potentially harm his mental state of mind. They are stated as Normal.

Summarization of good/bad influence of emotion changing movement is shown in Table.3.4.

In order to verify the policy proposed as above, a survey was carried out where twelve

Emotion / Changing Movement	Good	Bad
Pink zone → Blue zone	○	
Blue zone → Pink zone		○
Depression → Displeasure	○	
Depression → Distress	○	
Displeasure → Depression		○
Displeasure → Distress	○	
Distress → Displeasure		○
Distress → Depression		○

Table 3.4: Summary of Influence caused by Emotion changing movement

Survey / Proposed in Thesis	Good	Normal	Bad
Good	14	5	0
Normal	1	13	0
Bad	0	0	15

Table 3.5: Accuracy of Assessing affects caused by emotion changing movement [over totally 48 cases of emotion changing movement's possibility]

participants were asked to rate if each movement of emotions is Good, Normal or Bad. The survey result showing that 87.5% of the defined effect matched with user's subjective evaluation, while the missing rate was caused only by the confusion between good or normal influences, has affirmed the precision of this policy. (Table.3.5)

3.3.4 Study on User Preference

The idea of evaluating song based on user preference is not new as many current systems have already been utilizing this method. The system learns users' preference by letting them

Rating Factors	Score
Like	+1
Dislike	-1
Good influence	+1
Bad influence	-1

Table 3.6: EmuPlayer's Rating rate

rate Like or Dislike for each song they play. The data is stored inside the database so that the system can later refer to it.

3.3.5 Songs Rating

In order to sort out the songs, each song is rated on the two factors which are the relevancy to users' preference and the emotional influence (Table.3.6).

After each time it is played, a song will be reassigned the mark by the system using the formula as follow

$$Score = \frac{((current\ score * listened\ times) + new\ score)}{listened\ times + 1}$$

where new score = like/dislike point + effect point

For example, Haiti is feeling depressed and the system suggests her song "Everybody hurts". Haiti listens to it feeling much better and she likes it so much so that she rates Like to the song. And the system recognizes a good change of Haiti's emotion. Thus far, the rate of "Everybody hurt" is 1 and it has been listened for 50 times. Hence, the new overall score is calculated as

$$Score = \frac{(1 * 50 + 2)}{50 + 1} \approx 1.01$$

Score	Possibility	
+2	Good/Like	
+1	Good/Nor	Nor/Like
0	Good/Dis	Bad/Like
-1	Bad/Nor	Nor/Dis
-2	Bad/Dis	

Table 3.7: Possibilities of song's affect that can occur according to each case of song's score

The above rating policy assures that, given that over a great number of times being listened (under the same emotional condition of user) the song always gives the user a stable affect, then the overall estimated score of the song shouldn't be changed dramatically and so suddenly if for only a single listening time the new score raises up too high or reduces too low in comparison with the current score.

The work of rating songs also assures that high quality songs always rank higher, so that users will be able to get the best recommendation by picking the song from the top of the recommending list. Possibilities of song's affect that can occur according to each case of song's score are resumed in Table.3.7.

3.3.6 Section Conclusion

This section discussed about approach for Recommending Music. In order to make a suggestion, the system refers to two factors of evaluating a song which are the relevancy to user preference and the mental influence to rate. Rated song are then ranked and showed as the system's recommendation.

3.4 Approach Summary

When the system is started, biosignal data is captured from the sensors and sent to the system. Based on that data, the system specifies user emotion to compose a recommending list in which songs are ranked by the relevancy to user preference and the mental influence on user emotion in the case of that detected emotion. When the user finishes listen to one song, the system resumes evaluation including Like/Dislike, influence of the song, studies and memorizes it. New process repeats until the system is ended, starting with capturing data from the sensors.

3.5 Chapter Conclusion

In this chapter, we have discussed the approaches to Emotion Recognition and Music Recommendation. Using the combination of these two methods, we proposed a Music Recommendation System Based on User Emotion, which detects user's current emotion to suggest appropriate songs to both of his favor and emotional condition state.

Chapter 4

Design

4.1 Introduction

In this chapter, we will propose the EmuPlayer's design, employing methods, formulas and consequences presented in Approach chapter. The design of EmuPlayer is separated into two sections of Hardware Design and Software Design as follows.

4.2 Hardware Design

Following Figure.4.1 shows the structure of EmuPlayer's hardware

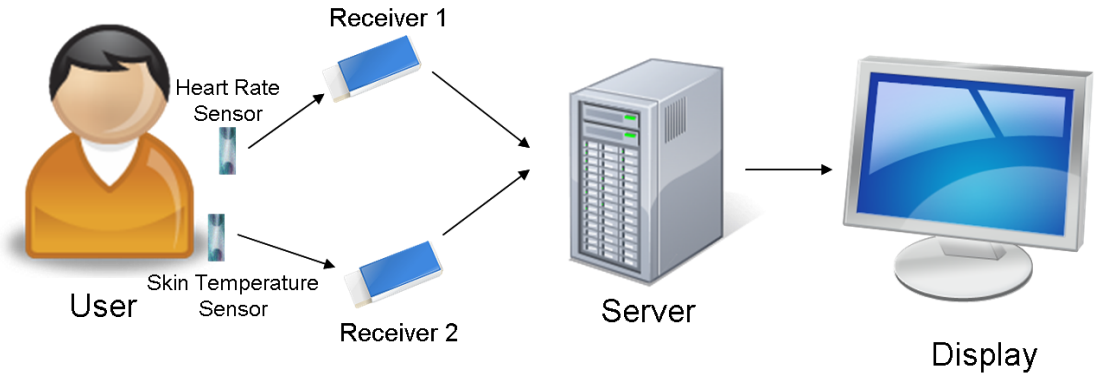


Figure 4.1: EmuPlayer Hardware

Sensors Hypothetically, there are two sensors employed in this system. They are Skin Temperature and Heart Rate sensors used to measure subject's temperature on his surface of the skin and his heart rate. These sensors are attached on the user's body.

Receivers There are two receivers in proportion to the two sensors which are receiver for Skin Temperature sensor and receiver for Heart Rate sensor. These receivers are to receive signals from the sensors and to record data to the computer.

System System contains module which receives data from sensor's receivers, modules functioning in the main music recommending part of EmuPlayer, and the database.

Output devices Output devices include display and speakers. Besides the use of playing music to the user, the display individually is used to interact with user, letting them choose song, vote like or dislike, manage the library and see the feedback about their current emotional state.

4.3 Software Design

4.3.1 System Overview - Procedures of EmuPlayer

A requirement for EmuPlayer is to evaluate the influence of songs on user emotion after each time one song is played. Therefore, one routine of EmuPlayer procedures consists of two main phases: actions taken until the user picks up a song to listen to, and actions taken after that song ended. Concrete procedures are shown as in Fig.4.2

A routine of EmuPlayer starts with (1) the system requests for data from the sensor, so that signals from sensors are sent to data receiver. (2) Data from Data Receiver then goes into Data Pre-Processors to be processed into appropriate data format which (3) sub-

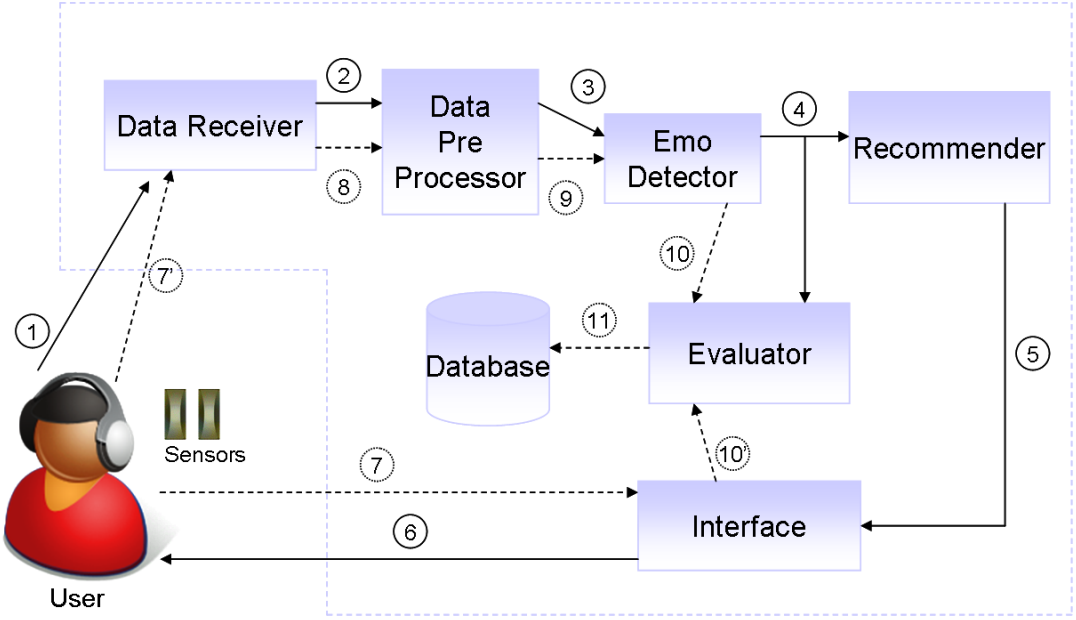


Figure 4.2: System overview - Procedure of the system

sequently is inputted into Emotion Detector. In Emotion Detector, emotion relevant to that biosignals data is extracted. (4) Specified emotion from Emotion Detector is then passed to both Evaluator as emotion before listening to a song, and Music Recommender. Music Recommender uses the emotion as a key to refer to the Database and extracts records of songs which are used to be listened under that emotion. Based on those records, Music Recommender takes appropriate steps to compose as an output a recommending list of songs. (5) The recommending list is after that sent to Interface. (6) Interface shows this list to the user, lets him choose a song and plays that song for him. Up to here, actions taken before the user listens to a song finish.

When the song the user chose to listen is stopped or finished, phase of actions occurring after a song is played starts. (7) Right after the song finished, user's song choice and feedback of Like or Dislike are sent to Interface. (7') At the same time, signals from sensors are sent to Data Receiver to examine user emotion after listening to that song. (8) Data from

Data Receiver is then transferred to Data Pre-Processor. In here, operation is taken like what have been done in step 2. (9) Data Pre-Processor passes processed data to Emotion Detector. (10) Emotion Detector goes through steps as demonstrated in action 3 in order to determine user emotion after listening to the song and passes the result to Evaluator. (10') Simultaneously, user' song choice and the feedback of Like or Dislike is also sent to Evaluator. (11) Based on three factors which are user's preference of the song, emotions of user before and after listening to that song, Evaluator rates that song under user's emotion and writes that record into the Database.

From here, one routine of EmuPlayer is finished. A new routine will start automatically unless the user terminated the system.

4.3.2 System Structure

EmuPlayer consists of five main modules which are Data Process, Emotion Detector, Recommender, Evaluator, and Interface. (Fig.4.3) Details of each module are presented as follows.

Module 1: Data Process Data Process contains two submodules which are Data Receiver and Data PreProcessor. Data Receiver covers the communication with sensors, receiving signals to send to Data PreProcessor submodule. Data PreProcessor firstly collects a group of data, calculates the average value and finally round it to have a final appropriate data format.

Module 2: Emotion Recognition The input of this module is processed data, and the output of it is user's current emotion relevant to the inputted data. There are two main steps executed in this module which are to calculate the angle and to specify the region following algorithm demonstrated in 3.1.6, in order to determine user feeling.

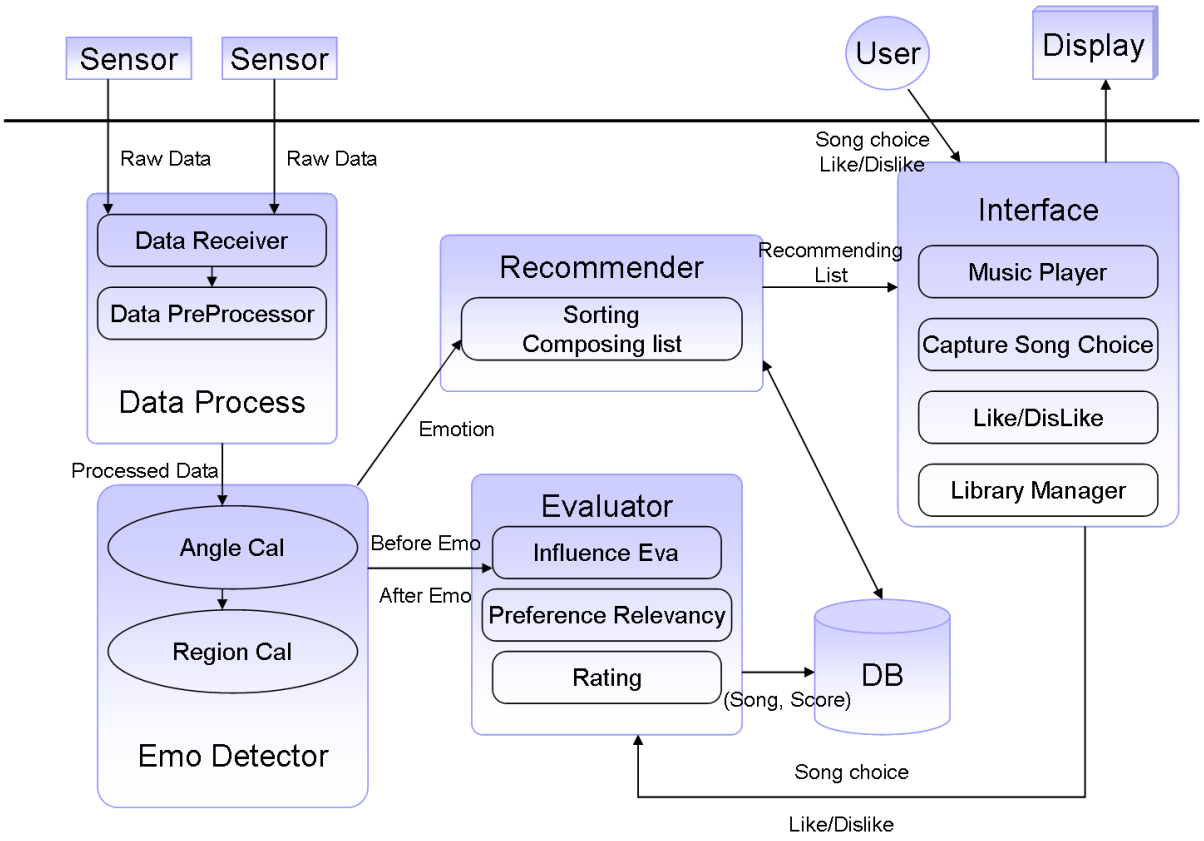


Figure 4.3: EmuPlayer - System Structure

Module 3: Recommender Emotion detected from module 2 is passed to Recommender. Based on this emotion, Recommender searches inside the database to collect all records about songs listened when the user had the same emotion in the past, sorts them in consideration with both songs that haven't listened by the user in this case of emotion and composes a recommending list. The policy of rating as presented in 3.2.4 assures that the recommending list does express the quality of songs ranked in regard to user's current emotion.

Module 4: Evaluator Evaluator requires three information as the input which are the just listened song, user's emotion before and after listening to that song, and user Likes or Dislikes the song. This module consists of three submodules where: Mental Influence

processes user emotion before and after listening to the song applying policy stated in 3.2.2, Relevancy to Preference processes Like/DisLike, and Rating gives final score to the song considering all the two factors by the formula shown in 3.2.4 The output of this module including a set of emotion, song choice and its score will be written in Database.

Module 5: Interface This module is structured by four sub-modules: Music Player, Capture Song Choice, Like/DisLike and Library Management. Each sub-module is named after its function inside this module.

4.4 Conclusion

In this chapter, we have proposed the design of EmuPlayer system following two main parts which are Hardware and Software Design. Each module structuring system's software is also demonstrated along with their functions and methods applied.
In the next chapter, we will propose the system implementation, manifesting the work proposed in this chapter.

Chapter 5

Implementation

5.1 Introduction

In this chapter, the work of implementing EmuPlayer will be described. Starting with the implementing environment, this chapter will go through introduction of the sensor used in this system, and finally system software implementation which is written in Java language.

5.2 Enviroment

In proposing system, EmuPlayer main system, Database, Sensor Software and User Display are all operated in one computer. Technical information of employed computer is shown as in Table.5.1

5.3 Sensor

In order to reduce the number of sensors that users have to wear, RF-ECG sensor (Fig.5.1) is chosen for its ability to measure both Heart Rate and Skin Temperature.

RF-ECG is worn on the chest of the user, right at the position of his heart. Skin Temperature is also measured from that surface of the skin. An advance point in measuring skin temperature in that area is the robustness against surrounding environmental changes.

CPU	Intel® Pentium® Dual Core 1.60 GHz
RAM	2.GB
OS	Windows Vista Home Premium
javaVM	JRE 6
Database	MySQL

Table 5.1: System Enviroment

Figure 5.1: RF-ECG Sensor and Receiver

RF-ECG Receiver is designed as a USB, to receive signal from the sensor and then pass it to RF-ECG main program. RF-ECG program written in Visual C++ functions as a client which sends signals from the USB receiver to Data Receiver module in Java main program continuously via socket. Therefore, Java program is able to receive signals from sensor in real time.

5.4 System Software Implementation

In this section, we will introduce and manifest the operation as well as how data run and exchanged within modules of the system. The section starts with introduction of the database.

5.4.1 Database

MySQL server deployed right on the computer is used to store database of the system locally. The information of all songs in user library is stored in table "song", including data about "songid", "title", "artist", "album", and "path". "Normal state" table stores values of normal pulse and skin temperature of user. And "listen to" table is used to keep records about under what emotion which song is heard, along with the information the song's listened times and overall score. (Fig.5.2)

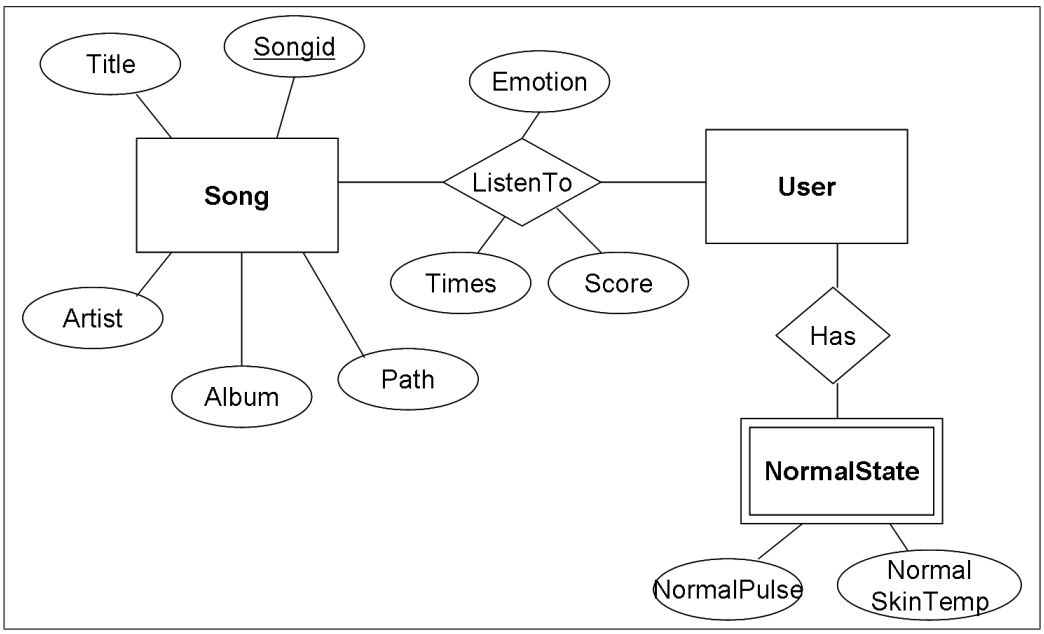


Figure 5.2: Entity-Relationship Model of EmuPlayer's Database

5.4.2 Capturing Data in Data Process Module

Data Process module is built by two submodules which are Data Receiver and Data Pre-Processor. Data Receiver extracts and writes data from RF-ECG sensor into an array of 20 elements each 100 milliseconds. After the array is filled which also means after each 2 seconds, Data Receiver passes that array to Data PreProcessor. Data PreProcessor then calculates the average value and rounds it up to two numbers after decimal point, finishing the data processing procedure.

5.4.3 Emotion Detector

Besides being sent to Evaluator module as Before or After listening song's emotion, and to Recommender module, output of Emotion Detector is also used to display feedback of current emotional state to user as in Fig.5.3

Figure 5.3: Feedback of current Emotion

5.4.4 Composing recommending list in Recommender Module

The procedure of composing a recommending list is made as follows. First of all, Recommender referred to table "listento" inside the database to extract all records of songs which were listened in the past when user had the same emotion like input. After that, Recommender updates those songs' score to the "song list" subject which contains all songs from

user library. After that, this song list is sorted and displayed to the user by the order of ranking from higher to lower score. Songs which haven't been heard by the user under the case of input emotion is rated as 0. Output of Recommender therefore is a list of all songs from user library with the scores attached to them. (Fig.5.4)

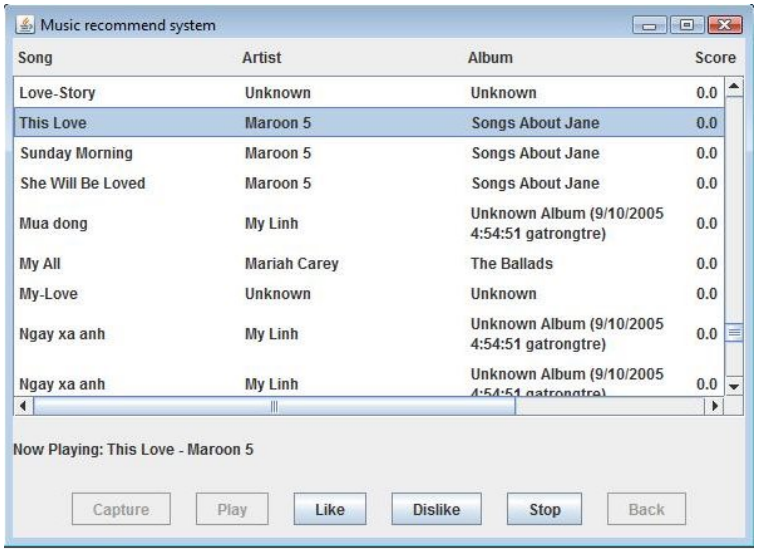


Figure 5.4: Recommending list Screen

5.4.5 Interface

There are three main screens in system's interface. The first screen shows data of the user's normal state and contains function buttons to go to the other two main screens (Fig.5.5). Within the left two main screens, one screen is for managing the music library with relevant functions usage (Fig.5.6), whereas the other one is for interacting with Music Recommendation System as shown in Fig.5.4.

5.5 Conclusion

In this chapter we have discussed in details and illustrated the work of EmuPlayer system. In EmuPlayer system we use RF-ECG sensor to capture both user's skin temperature and

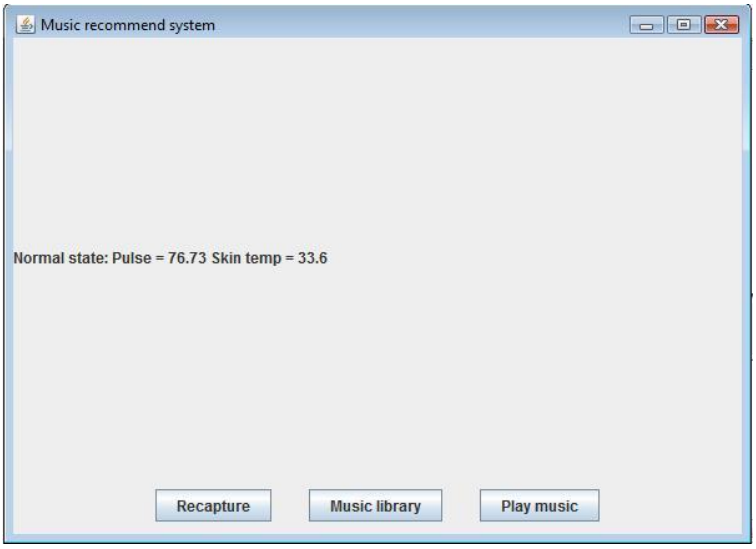


Figure 5.5: The Main Screen

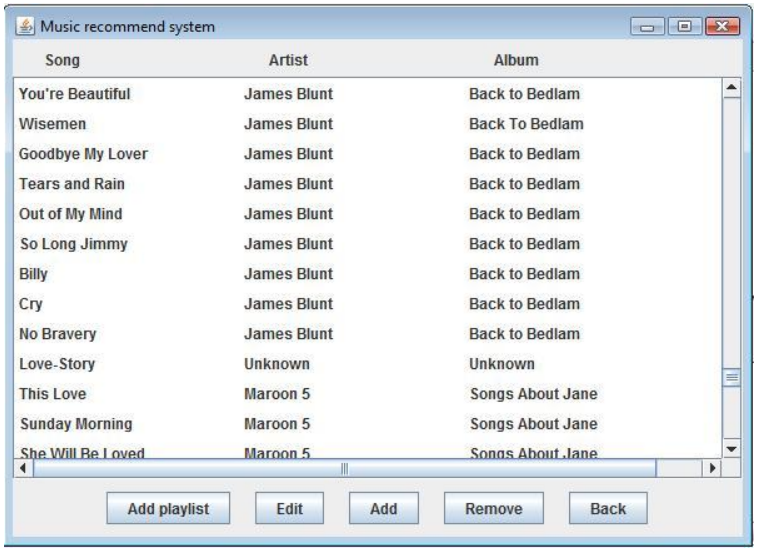


Figure 5.6: Music Library Screen

heart rate data. Data used in the system is stored inside MySQL database installed on the same computer with the system. Once the system is turned on, it will continue to run automatically until the user terminates it because data from sensor is automatically and continuously captured. In the next chapter, EmuPlayer system's evaluation will be

presented.

Chapter 6

Evaluation

6.1 Introduction

This section demonstrates the result of evaluations on proposing EmuPlayer system, in order to verify the work of the whole system. The section begins with observations regarding to the accuracy of Emotion Recognition module. Following, evaluation on EmuPlayer Music Recommendation Efficiency will be demonstrated. Finally, EmuPlayer Overall Survey will also be presented.

About 10 to 12 participants took place in each following experiment. They are wll male. Average age is 21 years old. Experiments were carried in laboratory enviroment.

The raw data is uploaded in http://www.ht.sfc.keio.ac.jp/ sunny/rawdata/

6.2 Evaluation on Emotion Recognition

The first experiment was performed in order to evaluate the accuracy of Emotion Recognizing part. In this experiment, participants were driven into particular feelings by arranged situations. At the same time, the machine detected user's current emotion. Matching between experimental emotion and the output of the machine exposes the accuracy of Emotion Recognition module. In order to affirm whether participants really felt that pre-determined

experimenting emotions or not, after each situation, participants were asked (1) if they experienced the emotion which was intentionally expressed through the situation, and (2) if they experienced any emotions rather than the emotion mentioned in question 1.

5 emotions tested in this experiment include Relaxation, Excitement, Pleasure, Arousal, and Depression. Situation for each emotion is described as follows.

- **Relaxation**: to let participants listen to classical music with soft melody, and talk to them tenderly in low and monotonous voice.
- **Excitement**: to make participants read funny stories or to discuss in pair about the topic that both of them interested in.
- **Pleasure**: to ask participants to relax themselves and engage in any activities that makes them pleasant.
- **Arousal**: to observe participants when they were playing computer games and getting very excited.
- **Depression**: to make loudly unpleasant noises while participants were peacefully relaxing in silence or concentrated at their stuff.

Table 6.1 shows the experiment's result. Matching pairs of input/output emotions is marked in blue. In here, input emotions are the five emotions tested through arranged situations as listed above, verified by participants through surveys; and output is emotions detected by the engine. Emotions which are expressively close to the one in blue are marked in green to manifest the fact that most of mis-detected parts fall into closest emotions of the experimenting ones. Besides, answers collected from participants for question number two showed that during experiments of blue emotions, some participants also experienced the corresponding green emotions. Therefore, together with principle number shown in the blue

In \ Out	Arousal	Excite-ment	Pleasu-re	Relaxa-tion	Sleepi-ness	Displea-sure	Distress	Depres-sion
Relaxation	4.25	7.96	22.77	55.58	9.44	0	0	0
Excitement	10	63.34	21.66	5	0	0	0	0
Pleasure	1.4	10.87	66.86	20.87	0	0	0	0
Arousal	81.68	5	0	6.66	6.66	0	0	0
Depression	8.33	0	0	0	6.66	20	10	55.01

Figure 6.1: Experiment on the accuracy of Emotion Recognition module

square, numbers in green squares partly reflect the accuracy of Emotion Recognition module of proposing system.

The second experiment was carried out in order to (1) verify whether the system can realize user's emotional changes, and (2) verify songs' influence on listeners' emotions.
In this experiment, participants' emotions were made changed by listening to music. There are four cases examined in this experiment as follows:

- **Case 1**: To calm aroused participants from playing computer game by making them listen to classical music or music with soft melody. Songs used in case 1 experiment were "Four seasons" from Vivaldi and "Nortune" played by Secret Garden. If the system runs properly and the music does influence on participants emotions, the system should be able to acknowledge the change of participants' emotions from arousal to a more relaxing state.

  And the result shows that, emotion changed from the initial of mostly arousal to Pleasure and Relaxation as shown in Fig.6.2

- **Case 2**: To make participants become more Pleasant from their current normal states

by letting them listen to the music genre they like.

The result shows the percentage of Pleasure increased from 66.86% to 93.33%. (Fig.6.3)

- **Case 3**: To make participants become more Excited from their current normal states by letting them listen to fast-beat dance music. Music played in this case were songs from Lady Gaga. The result showed a remarkable increase of Excitement from 10.87% to 62.12%. (Fig.6.4)

- **Case 4**: To make paticipants undergo bad emotion from their Normal state by playing them music that they don't like and to play heavy metal music loudly, for a long time. As experiment in this case raised up question on the morality as influencing badly on participants' mental state, only three participants took part in this examination. However, the achieved result is satisfactory. The result showed 80.02% of Depression when participants' dislike music or heavy metal music was played so loudly for long. (Fig.6.5)

Summary of those four experimenting cases and their results is shown as in Table. 6.6. The result shows that the system does response precisely to the changes of participants' emotion. For example, in case number one where arousal participants playing computer game were made to listen to classical music to chill down, the average percentage of arousal level at initial state of 81.68% reduced to 1.41%. Equivalently, level of pleasure changed from 0% to 54.91%; and relaxation increased from 6.66% to 38.94%. Other cases also proved system's acknowledgement of participants' emotional changes.

Through the two experiments above, the following conclusion can be deduced.

- (1) The system achieves the estimated accuracy of 64,5% og Extracting User's Emotion;

- (2) The system is strong at detecting bad emotions;

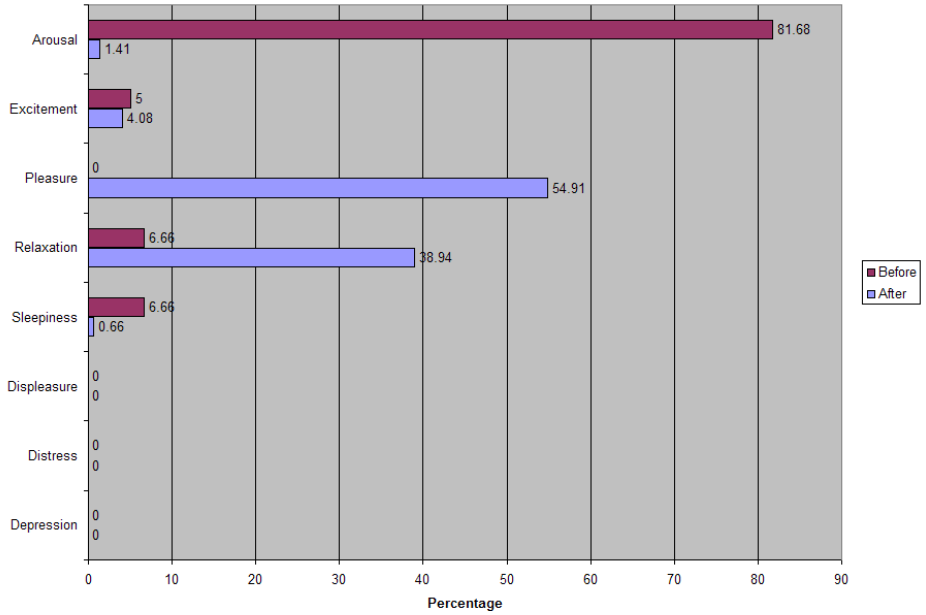


Figure 6.2: Case 1: Arousal -> (Pleasure/Relaxation)

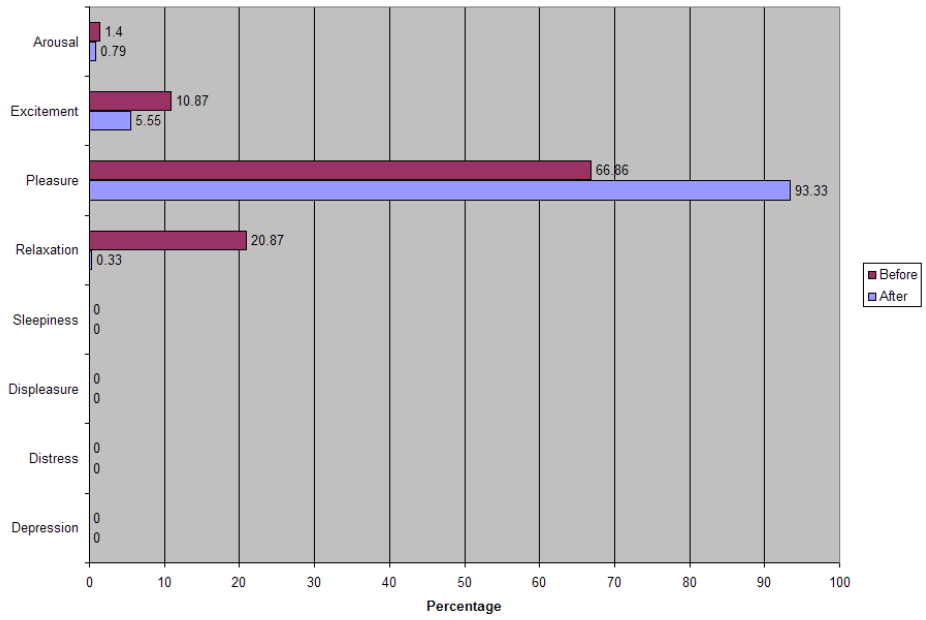


Figure 6.3: Case 2: Normal -> Pleasure

- (3) Emotion Recognition module detects precisely regarding to changes in users' emotion;

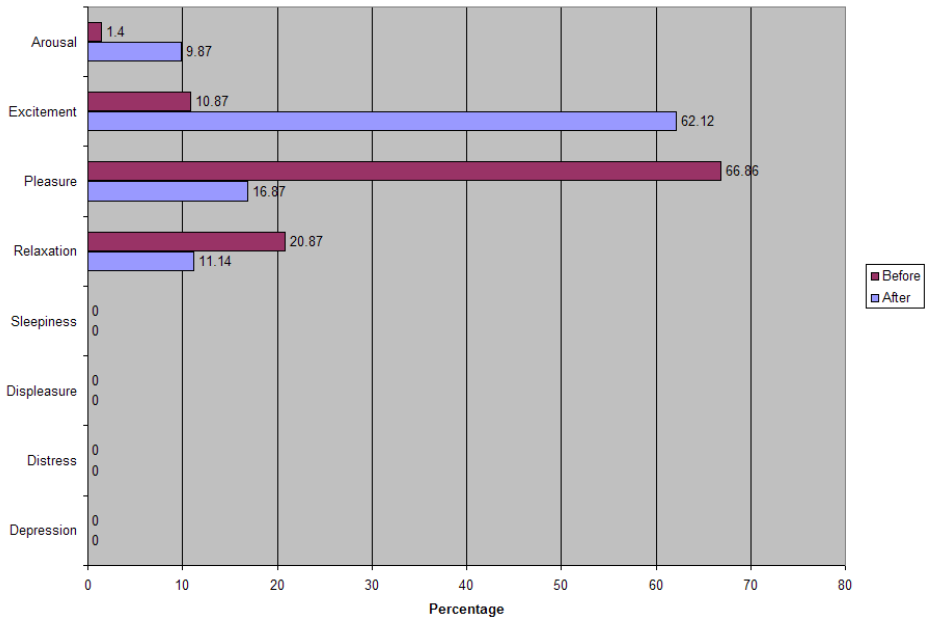


Figure 6.4: Case 3: Normal -> Excitement

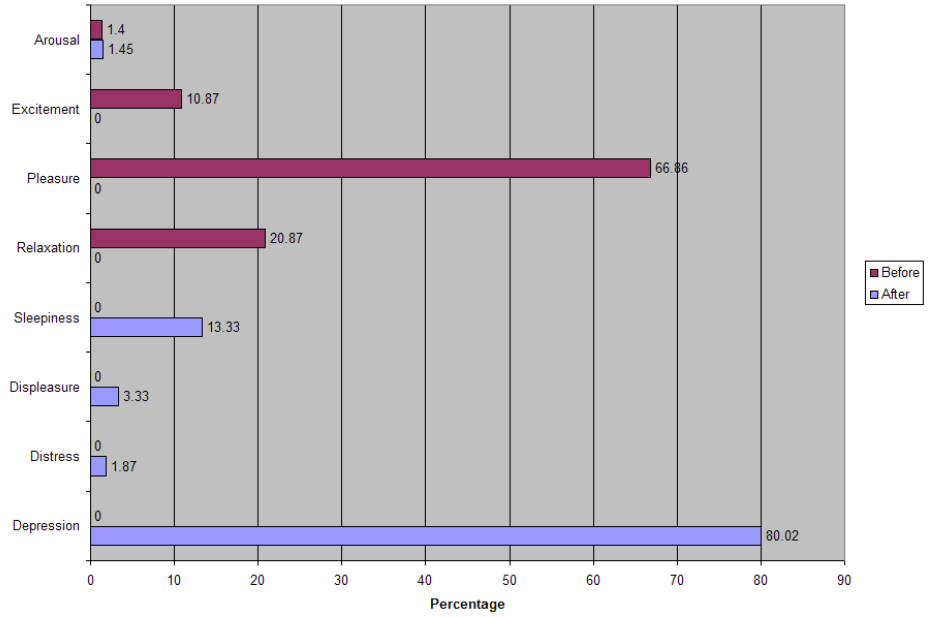


Figure 6.5: Case 4: Normal -> Depression

- and (4) Hypothesis of Music influencing on users' emotion is true.

Case	Experiment	Mean	Result
1	Arousal →Pleasure/Relaxation	Classical music	Arousal:81.68%→1.41% Pleasure:0%→54.91% Relaxation:6.66%→38.94%
2	Normal →Pleasure	Music participants like	Pleasure: 66.86% → 93.33%
3	Normal →Excitement	Fast beat Music	Excitement: 10.87%→62.12%
4	Normal →Depression	Loud Heavy Music played in long time	Pleasure:66.86%→Depression: 80.02%

Figure 6.6: Summary of the four cases in experiment number 2

6.3 EmuPlayer Music Recommendation Efficiency

In order to evaluate the performance of EmuPlayer, records of users' listening history was studied to observe: firstly the status of high-rating songs, as due to the proposal, high-rating songs mean good recommendations for the user by his current emotion which thence makes the work of observing high-rating songs' status important in evaluating the quality of recommending policy; and secondly, how emotion changes in cases where songs were "liked" by the users.

6.3.1 Observation of status of high-ratings songs

In here, listening history of all participants was studied to extract the following information: (1) percentage of high-score songs picked by users from recommending lists being "disliked" after users listened to them; (2) percentage of high-score songs picked by users from recommending lists paying "bad influence" on users' emotion after users listened to them; and (3) percentage of high-score songs become reduced in score after users listened to them.

As the scale of a song raises from -2 to 2, high-score songs are the ones of which scores are

greater than 0 which means that they satisfy at least one in two factors of evaluating a song which are the relevancy to users' taste and having good emotional influence on the user.

The result shows that (1) There is 6.66% of high-score songs picked by users from recommending lists being "disliked" after users listened to them; (2) 0% of high-score songs picked by users from recommending lists paying "bad influence" on users' emotion after users listened to them; and (3) 8.57% of high-score songs become reduced in score after users listened to them. More specifically, 6.66% of high-score songs were reduced in score because they were disliked by users after users listened to them. 1.91% of high-score songs were reduced in score because they did not influence badly on users' emotions; however they were no longer "liked" by users. 0% of high-score songs were reduced in score because of influencing badly on users' mood. (Table.6.7)

State of high-score songs after users listened to them	Percentage
Disliked	6.66%
Bad effect on user emotion	0%
Reduced in score	8.57%

Reasons of being reduced in score	Percentage
Disliked	6.66%
No longer "Liked"	1.91%
Bad effect on user emotion	0%

Figure 6.7: Status of high ranking songs after being played

From those results, it can be concluded that the Rating algorithm precisely helps to recommend songs which meet the two requirements which are to be relevant to users' preference and not to influence badly on user's emotion, as 0% of high-score songs influencing badly on user's emotional state and only 6.66% of high-score songs were "disliked" by users after they listened to them.

6.3.2 Emotional changes in ”liked” songs

Table 6.8 shows emotional changes in ”liked” songs case. According to the count on emotional movements in “liked” songs’ cases, though there was no recommendation giving good effect on users’ emotion referring to the definition of good effect proposed as above, there was no recommendation causing bad emotion effect on users either. Therefore, the system has achieved its goal of avoiding recommendations which are potentially harmful to users’ emotion.

Emo Before	Emo After	Percentage
Arousal	Relaxation	1%
Arousal	Sleepiness	1%
Excitement	Arousal	1%
Excitement	Pleasure	2%
Pleasure	Excitement	2%
Pleasure	Pleasure	77%
Relaxation	Arousal	1%
Relaxation	Pleasure	2%
Relaxation	Relaxation	7%
Sleepiness	Sleepiness	4%
Displeasure	Displeasure	2%

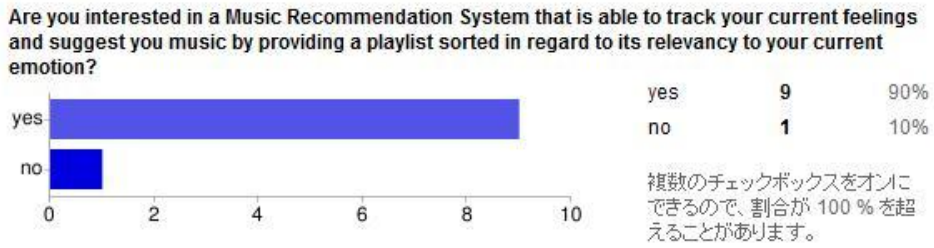
Figure 6.8: Emotional changes in ”liked” song cases

6.4 EmuPlayer Overall Survey

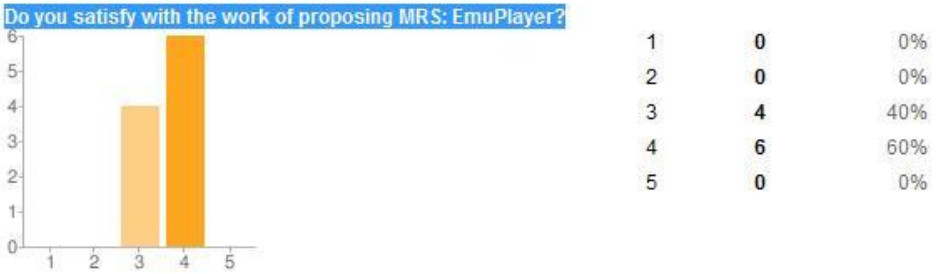
In order to evaluate the work of overall system, following survey (Fig.6.9) was done by participants who had used the EmuPlayer.

The result shows that

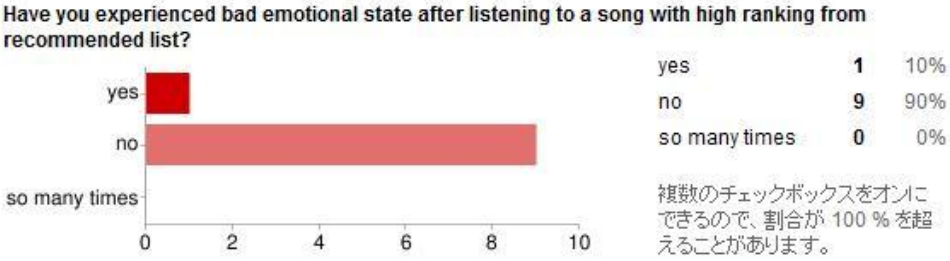
- 90% of participants are interested in such MRS system;



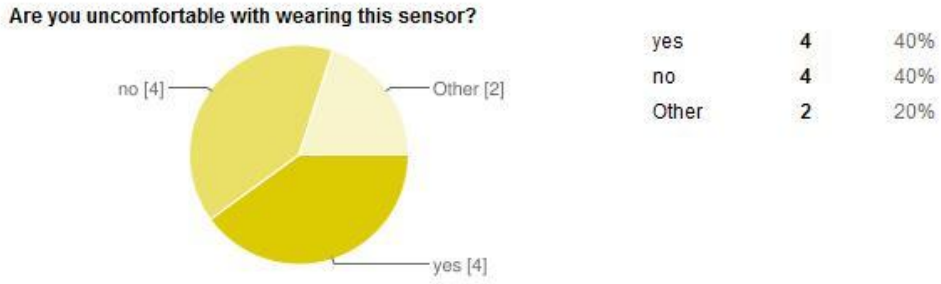
(a) Survey on the work of EmuPlayer: Question 1



(b) Survey on the work of EmuPlayer: Question 2



(c) Survey on the work of EmuPlayer: Question 3



(d) Survey on the work of EmuPlayer: Question 4

Figure 6.9: Survey on the work of EmuPlayer

- average scale for the satisfaction of EmuPlayer's work is 3.6/5;
- 40% of participants felt uncomfortable with wearing RF-ECG on;
- 10% of participants experienced bad emotion after listening to high ranking score. Here, according to the count of percentage of high-rating songs causing bad influence on users' emotion acquired from system's database, the result is 0%; whereas it is 10% according to users' survey. This conflict in number reflects the truth that the proposing Emotion Recognizing method responses to only intense and strong emotions. Hence, slight changes in emotion that are felt by the users may not be recognized by the system.

Besides, in free comment about EmuPlayer system question, two main received comments were on: (1) the fact that EmuPlayer doesn't play the highest-score song, which also means the most appropriate song to users' current emotions automatically; and (2) wish for a more accurate Emotion Detector. While the (1) problem can be repaired without difficulties, the (2) requires more research to give out a good solution.

6.5 Conclusion

In this chapter, evaluation on the accuracy of Emotion Recognition part, and EmuPlayer as the whole system has been demonstrated. Although the accuracy of detecting emotion in general is not very high, approximately 64.5%, the accuracy of detecting bad emotion is much higher. This characteristic of being strong at detecting bad emotions will help with informing users when they are under bad emotional conditions. Besides, though the song rating algorithm was quite successful as achieving over 90% of satisfaction of meeting both users' preferences and requirement on not to influence badly on users' emotional state,

this algorithm is still simple and need to be developed more to give better recommending solution.

Chapter 7

Conclusion and Future Works

In this chapter, the overall conclusion summarizing the good as well as bad aspect of EmuPlayer system will be demonstrated. From that, future works for EmuPlayer will be discussed later on.

7.1 Conclusion

Experiments on Emotion

Experiments on emotion are time consuming. It is also very difficult to drive participants into pre-determined particular emotions, not mentioning questions arising on morality to make participants undergo bad feelings. Besides, level of concentration of participants influences much on experiments' result. Particularly, in experiments which try to change participants' emotion throughout arranged situation, there are two problems occurring which are: firstly, it's hard to change participants' emotional state; and secondly, after they are driven to particular states, it takes a lot of time to make them become normal again. In addition with, if let be skin temperature the input for detecting emotion, the surrounding environment's temperature also effects much on the final result; as for instance, participants' skin temperature can hardly raise up during the low temperature in the winter. Therefore, in

order to perform a good experiment on emotion, besides requirements for a big amount of time, a good test of arranged situation, participants' concentration, outer factors such as surrounding environment as mentioned above must be taken care of too.

Emotion Detection

Although the accuracy of detecting emotion in general is not very high which is 64.5%, the system is much stronger at detecting users' bad emotions. Therefore the system is determined to be suitable for the use of informing users' about their bad emotional condition. More specifically, the system is supposed to give appropriate alert when participants' listening music influences badly on them, or when the fact of playing music in particular context is unconsciously harmful for their mental state.

Furthermore, besides Skin Temperature and Heart Rate, additional means should be employed in order to archive higher accuracy of emotion extracting result. Other hardware than RF-ECG should also be experimented on, as there is a need of verifying RF-ECG's exactness and sensitiveness towards changes of skin temperature and pulse.

Also, though music does influence on users' emotion as changing their feelings; in fact, only effect caused by extremely influencing song such as heavy mental music or dramatically sad songs manifests clearly in emotional changes; and only those changes can be acknowledged by the system.

EmuPlayer Although EmuPlayer has proved its efficiency in suggesting songs which meet the two requirements of to be relevant to users' preference and to not influence badly on users' emotion; still, the system's recommending policy need to be much improved.

Throughout this thesis, we can prove that: (1) it is true and advancing to evaluate

one song based on its two characteristics which are its relevancy to user's preference and its mental influence on user's emotion; (2) it is true to acknowledge users' current emotions as crucial and essential input for a Music Recommendation System; and (3) it is needed to inform users about their mental state while listening to music.

However, besides above three advantages, the ideal Music Recommendation System must be the one which bases on the combination of user's current emotion, the context and the content of played music to suggest the user songs. Such system will be discussed in more details in the Future works.

7.2 Future Works

As mentioned above, in order to create a stronger Music Recommendation System Based on User's Emotion, firstly, additional biosignals besides Skin Temperature and Pulse must be employed in Emotion Detection part. Secondly, it is needed to do further study on context-based MRS and music content to be able to integrate them together with proposing approach to better suggest users music. More specifically, the system should use the user's current emotion as essential input, along with the surrounding context as second input to extract the user's condition and use it as a base to suggest him songs. Next, user's emotion, context, as well as analyzed content of listened songs in relevant conditions, and two characteristics of a song must all be considered in order to give out the right suggestion.

Finally, with the advantage of giving feedback about users' current emotional states and their emotional changing after listening to a particular song, this system is believed to be useful as a musical treatment method for mental diseased patients.

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