Interval Training Guidance System with Music and Wireless Group Exercise Motivations

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***Abstract*— Interval training is a well known exercise protocol which helps strengthen and improve one's cardiovascular fitness. It interleaves high intensity exercises with rest periods. Despite the known benefits, proper scheduling and completion of interval training routines are not easy to perform. For example, without expensive equipment such as a treadmill, there is almost no way to figure out one's speed for proper imitation of a given exercise protocol, and thus interval training is heavily dependent on individual motivation levels.**

In this work, we use behavioral cueing using music and performance feedback to provide motivation during interval training exercise sessions. We have developed an application program on the popular iPhone platform. Our game-like and social networking application guides the user using exercise music. By measuring performance of the user through sensor readings, specifically accelerometers embedded in the iPhone, we are able to play the right song to match the user's workout plan. A hybrid of a collaborative, content, and context-aware filtering algorithm incorporates the user's music preferences and the exercise speed that will enhance performance. Additionally, adherence to an exercise protocol and the amount of calories burned is translated into a score that is sent to the user's social network group.

Keywords-component; exercise guidance system, interval training, music recommendation, social network, iPhone

I. Introduction

Interval training consists of interleaving high intensity exercises with rest periods. The high intensity activity is followed by low intensity activity, referred to as the recovery period. Advantageously, the time required for an interval training exercise session may be less than the amount of time of an equivalent continuous session and yet have the same effect. This interval training method is a well known exercise protocol which helps strengthen and improve one's cardiovascular system ([3] – [9]). Moreover, it has been shown to help with weight loss, rehabilitation, general fitness, and the reduction of heart and pulmonary diseases, as compared with other continuous exercise methods. During interval training, the body's energy production system is utilized, and both aerobic and anaerobic energy sources are activated. Energy from these two sources is then efficiently distributed throughout the body for the duration of the workout period.

Despite interval training's health benefits, properly following given interval training protocols is not simple. Without equipment such as a treadmill, there is almost no way to figure out one's exercise speed to follow a given exercise protocol. As such, the usual interval training methods suffer from the limitations that the individual subject may not be able to monitor the current and future level of effort. And as a result, the individual may not be able to follow an optimal training plan. Moreover, a challenge exists in establishing the proper level of intensity for each exercise cycle. If the intensity is insufficiently low for an exercise session plan, then the desired stress level is also insufficiently low. Accordingly, the outcome benefits can be degraded. On the other hand, if the exercise session design prescribes a level of intensity that is excessive, then the subject will either be subjected to the ill effects of excessive exertion or may be unable to complete the prescribed interval training. Consider an interval training protocol which requires walking for 5 minutes at 3.5 MPH, walking for 1 minute at 4.2 MPH, and then repeating this sequence several times. Without the proper fitness equipment, following the model is very difficult. This is in addition to the space and cost restrictions of traditional fitness equipment. Thus, individuals without strong motivation can be discouraged from following an interval training protocol.

To provide motivation and guidance in interval training exercise sessions, we present our behavioral cueing system developed for the popular iPhone platform. It uses music, sensor readings, and social networking to encourage and motivate users to follow a healthy exercise plan. As iPhones are very light, small and embedded with sensors, it can serve as a cheaper, a more convenient, and a multi-purpose alternative to traditional exercise equipment.

By analyzing a user, user group, and the exercise context, our system recommends suitable songs for interval training. Also, based on general characteristics of human beings, competitive group exercise methods incorporated into the system may motivate users to participate in interval training type exercises. By using social networks, such as sending emails to friends and uploading rankings on a shared website, etc., users can be effectively motivated.

II. INTERVAL TRAINING MOTIVATIONS

A. *Light Weight Wireless Smartphone*

Without fitness equipment, interval training is very difficult to follow, since individuals are unable to accurately determine or guess their current exercise intensity. On the other hand, traditional fitness equipment has significant space and cost restrictions. Therefore, the use of an inexpensive mobile handheld device can be an effective means for guiding interval training exercises. Ease of use, compatibility, and communicability are key issues related to mobile device use and adoption by individuals (Kleijnen [31]).

Sarker [30] mentions factors influencing the use of mobile handheld device by individuals, including technology, communication/task characteristics, modalities of mobility, and context (Fig 2.1.). Those same features support our choice of a smart phone platform for our system.

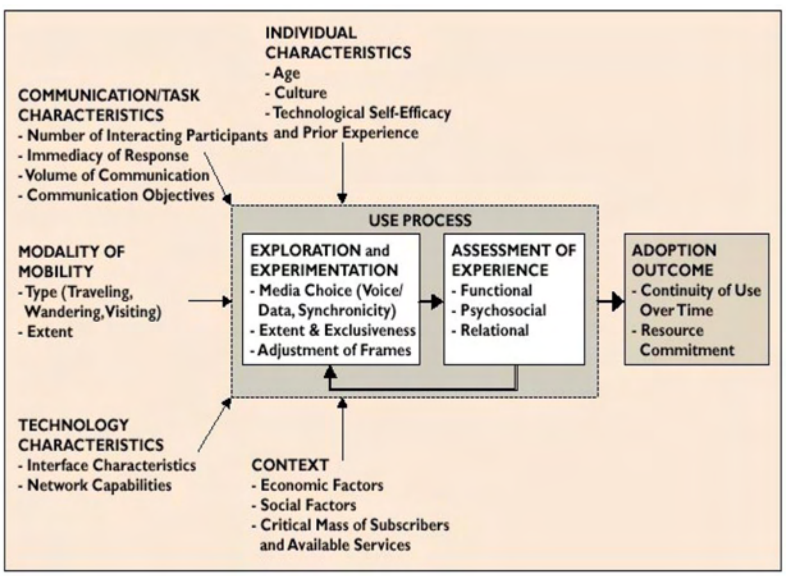

Fig 2.1. Factors influencing mobile handheld device use and adoption [30]

With technology, the easy interface of a mobile device is important. An iPhone's 3.5 inch multi-touch display with 480-by-320-pixel resolution makes users navigate by touching the screen. The multi-touch display layers a protective shield over a capacitive panel that senses touches using electrical fields. It then transmits that information to the LCD screen below it, and the iPhone software enables the flick, tap, and pinch. The iPhone display also supports multiple languages and characters for users worldwide.

Poor network characteristics act as severe inhibitors to use and adoption. For example, the lack of coverage in many areas tend to reduce the sense of freedom and safety in many subject's minds. The iPhone 3G uses a technology protocol called HSDPA (High-Speed Downlink Packet Access) to download data quickly over UMTS (Universal Mobile Telecommunications System) networks. Accessing the internet to load information is twice as fast on 3G networks as on 2G EDGE networks. Since the iPhone 3G meets worldwide standards for cellular communications, a user can make calls and surf the web from practically almost anywhere. When a user is not in a 3G network area, the iPhone uses a GSM network for calls and an EDGE network for data.

Fig 2.2. The size and weight of an iPhone

According to the market research group NPD, Apple's iPhone 3G topped the sales charts in the third quarter of 2008. Therefore, many iPhone users and developers share information regarding iPhone systems and applications via several websites or magazines. In addition, the number of interactions among iPhone user groups and developer groups continues to increase.

Research has shown that, for a variety of reasons, humans are attracted to the natural environment (Knoph [32], [33], and Kaplan [34]). These investigations have shown that when encountering or presented with images of natural environments, subjects experience a variety of positive psychological, social, and physiological outcomes. Since an iPhone's weight is only 133g, it is easy to carry to a natural environment setting where interval training can be performed. Whereas in a gym the person is limited to a treadmill, the only limitation is the possession of a light 3G smart phone.

Sarker [30] also emphasizes on the modalities of mobility for the use of adoption in mobile devices. Traveling, wandering, and visiting are seen as three ways to qualifying the essence of mobility (Kristoffersen [35]). Traveling is defined as the process of going from one place to another in a vehicle. Wandering refers to an extensive local mobility where an individual may spend considerable time walking around. Visiting refers to stopping by at some location and spending time there, before moving to another. Three different types of motilities are associated with different motivations of a user. For instance, safety is an important concern for a person traveling frequently. Therefore, the iPhone's 3G internet connectivity, and light size can be a good source of motivation to use in this system for all three different groups.

B. Music Motivation

Terry et al. [10], Karageorghis et al. [11], and Mohammadzadeh et al. [12] examine how the rhythm of music related to personal factors and situational factors promotes more exercise with less stress. Athletes respond to the rhythmical qualities of music by synchronizing movement patterns to its tempo. Rhythm related to the user's preference and situational conditions affect exercise and stress level. Working out in time to music increases the likelihood of strenuous exercises for longer periods of time for users in a broad range of level of fitness. Listening to music provides benefits such as improvement in mood, pre-event activation or relaxation, dissociation from unpleasant feelings such as pain and fatigue, and reduced rating of perceived exertion (RPE), especially during aerobic training. For example, the change in tempo helps prolong the exercise time to fatigue (Szabo et al. [28]). And the tempo speeds up in order to motivate the user to speed up by synchronizing one's steps with the music (Wijnalda [29]). Thus, music can be a good source of motivation during interval training, especially when the exercise method is tedious and repetitious. In our system, if the user correctly follows the existing exercise schedule, music plays at a constant tempo to motivate the user to synchronize one's steps with the music for enhanced endurance. If the speed of the actual exercise is slower than the scheduled exercise, the system recommends faster music to speed up the exercise.

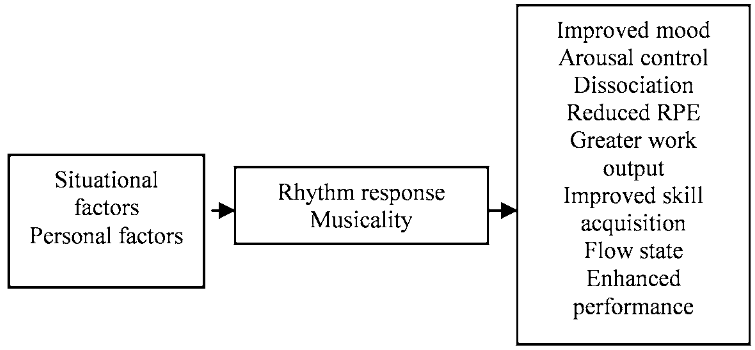

Fig 2.3. Benefits of listening to music in sports and exercise contexts.

C. Competitive Group Exercise

Competitive group interval training is another form of user motivation, with known beneficial effects on physiological functioning. The experimental results (Kilpatrick et al. [13], Fig 2.4.) indicate that sport participants are more motivated to engage in physical activity as a means of enjoyment and to achieve positive health benefits. Sports participation is strongly related to affiliation, competition, enjoyment, and challenge. In addition, a program of aerobic, and endurance activities such as interval training, undertaken in a group setting, stimulates and improves physiological and cognitive functions and subject wellbeing (Williams et al. [14]). Since doing exercising together can help people maintain affiliation with friends and promote more exercise, our designed system relates to social networks.

Subscale	Ranking
Affiliation	**2**
Appearance	12
Challenge	**4**
Competition	**1**
Enjoyment	**3**
Health pressures	14
Ill-health avoidance	13
Nimbleness	8
Positive health	7
Revitalization	5
Social recognition	**9**
Strength and endurance	6
Stress management	10
Weight management	11

Fig 2.4. Ranking of exercise motivation: Range = 1(most important) to 14 (least important)

Accelerometers are currently among the most widely studied wearable sensors for activity recognition. They are also very useful for interval training. By analyzing data obtained from 3 different axes, the accuracy of exercise and the caloric consumption can be calculated (Fig 3.7). Additionally, accelerometers are commonly embedded in smart phones, such as Apple iPhone, Google G1, and Nokia N95. Moreover, smart phones can help individuals to follow scheduled speeds, during a specific time period, and can also give feedback using the cell phone's sound, vibration, and other graphical interfaces. Additionally, their calculation functionalities can also be leveraged.

III. System Design

In our system, we use the iPhone [19] and a web server system for our development. The iPhone is a 133g, 3.5 inch multi-touch display smart phone that supports both Wi-Fi and Bluetooth. Furthermore, the iPhone has an in-built accelerometer, a light and a proximity sensor. By using an embedded 3-axis accelerometer on the iPhone, activity patterns are detected. QuickTime, a proprietary digital media player application, is embedded in the iPhone, and it is capable of handling various formats of digital video, media clips, sound, text, animation, music, and interactive panoramic images. Also, the iPhone features the Safari web browser with 3G and Wi-Fi, which allows the user to access the Internet almost anywhere. When songs and users' information are stored on a web server, the 8 or 16 gigabytes storage of an iPhone doesn't have to be wasted. The remaining data storage can be used for other purposes.

Unlike the Nike + iPod combination [20], and other existing wireless exercise systems, our proposed system has no restriction on the kind of shoes and other equipment that is necessary, such as a Nike + Sportband or a receiver plugged into an iPod. Also, plugging devices into your computer is not necessary to transfer data. Updated exercise information can be sent to the existing web database by accessing the internet. In addition, there is no restriction on the quantity and choice of music that the user can listen to, since the streaming music data is stored on the web database and additional data storage is not required. Moreover, the streaming music data is selected by the music recommendation system. Thus, the probability that the music corresponds to the user's taste is higher than randomly selected music.

A. Music Recommendation

Music is a source of motivation during exercise by synchronizing movement patterns to the rhythm of the music. In addition, personal factors such as one's age, sex, cultural background, and education level also affect one's taste in music. Therefore, the group of users who share a similar choice in music can be generated by collaborative filtering techniques. A user's choice in music in the past can affect the list of recommended music by content-based filtering. Content-based recommendation systems with collaborative filtering analyze the content of the objects that a user has preferred in the past, and they recommend other relevant contents by using one's history and the nearest neighbor's information (Park [15], Adomavicius [16], Balabanović [23]).

Based on training data, a user model is induced that enables the content-based filtering technique to classify unseen items. The training set consists of the items that the user found interesting. These items form training instances that all have an attribute. This attribute specifies the class of the item based on either the rating of the user or on implicit evidence. With the class information, the list of recommended items is determined. A content-based filtering system selects items based on the correlation between the content of the items and the user's preferences, as opposed to a collaborative filtering system that chooses items based on the correlation among people with similar preferences. Collaborative filtering is the process of filtering for information or patterns using techniques involving collaboration among multiple agents who share similarities in attributes. The LIBRA system (Mooney [37]) recommends books by using content-based and collaborative filtering. Many systems use hybrid features of content-based and collaborative filtering to recommend items. Those systems combine knowledge about users who liked a set of items with knowledge of a particular content feature associated with the item in one user's set.

User context is any information that can be used to characterize the situation of an entity. Context includes location of use, the collection of nearby people and objects, accessible devices, and changes to these objects, etc. It may include lighting, noise level, network connectivity, communication costs, communication bandwidth, time, proximity, activity, and even social situations (Kwon [36]). A context-aware system is to provide a user with relevant information and services based on one's current context, and filter recommended contents for the context (Van Setten [22]). The PILGRIM recommendation system (Brunato[21]) uses mobility-aware filtering techniques with a GPS system. CAMA (Kwon [36]]) also applies a user's clicking behavior context to recommend websites. Van Setten [22] developed the mobile tourist application which takes into account the user's interests and contextual factors such as the place mostly recently visited.

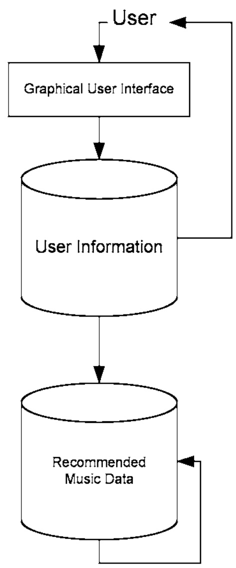

Fig 3.1. Content-based filtering technique in music recommendation system

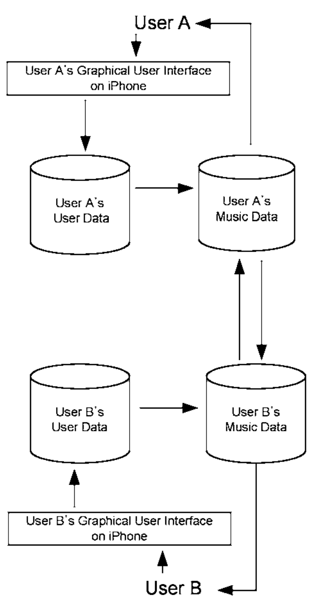

Fig 3.2. Collaborative filtering technique in music recommendation system

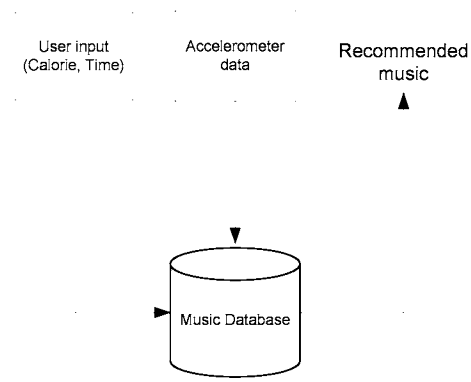

Fig 3.3. Context-aware filtering in music recommendation system

The preference of music can be determined by a listener's age, gender, ethnic group, residential area, family and peer group, etc. LeBlanc ([24], [25]) examines that the age of a music listener exerts a strong influence on overall preferences of music style and the speed of music. Christenson [26] denotes gender is central to the ways in which popular music is used and tastes are organized. Even though the underlying structure of music preference cannot be accounted for by reference to two or three factors, there are crucial difference between males and females in terms of their mapping of music types. In addition, preferences in popular music also vary according to the neighborhood in which the music listener lives (Johnstone [27]). People can also be affected by their family and peer groups, or the background of the listener, such as the listener's music training experience and level of education. There are additional factors which also affect the music preference shown in Fig 3.4.

Cano [18] presented the MusicSurfer in order to provide content-based music recommendations. It extracted descriptions related to instrumentation, rhythm and harmony from music signals using similarity metrics. Kuo [17] proposed a personalized music filtering system which learned the user preference by mining the melody patterns from the user's music access behavior. Park [15] proposed a context-aware music recommendation system using Bayesian networks. Our system recognizes the exercise context by using user input such as exercise time, the amount of calorie to be burned and data stream from an accelerometer. By using this information, the system can recommend suitable music for the exercise situation.

Our system classifies songs by genre and the speed of music, and it recommends them to the user based on the user's information. The system classifies users based on age, gender, and residential location. Recommendations for users in the same group are affected by the annotations of other members of the group by the collaborative filtering technique. In addition, music which corresponds to the speed and the intensity of interval training is recommended to the user. A 3-axis accelerometer embedded in the iPhone and the user's preference are used to select a suitable song. The system filters music using a comparison between the target speed and the current speed. For instance, when the user runs slower than the targeted speed, faster music is played. The exercise output can be extended through synchronization of music with movement. Furthermore, it can be enhanced when rhythm or association is matched with required movement patterns. Additionally the music increases the likelihood of athletes achieving flow states. Therefore, our system realizes the collaborative, content, and context-aware recommendation by analyzing the user's information, the group the user belongs to, and the speed of the exercise. As the user's annotation is accumulated in the database, the list of the recommended music is also updated. And as a result, the system is able to find a more suitable music selection for the user and the exercise context. Thus, the recommended music is modified and adapted, as the number of annotation data increases.

The music database currently stores 822 mp3 files, which is around 4.64 gigabytes. Since songs are not stored on the iPhone, the remaining storage can be used for other purposes.

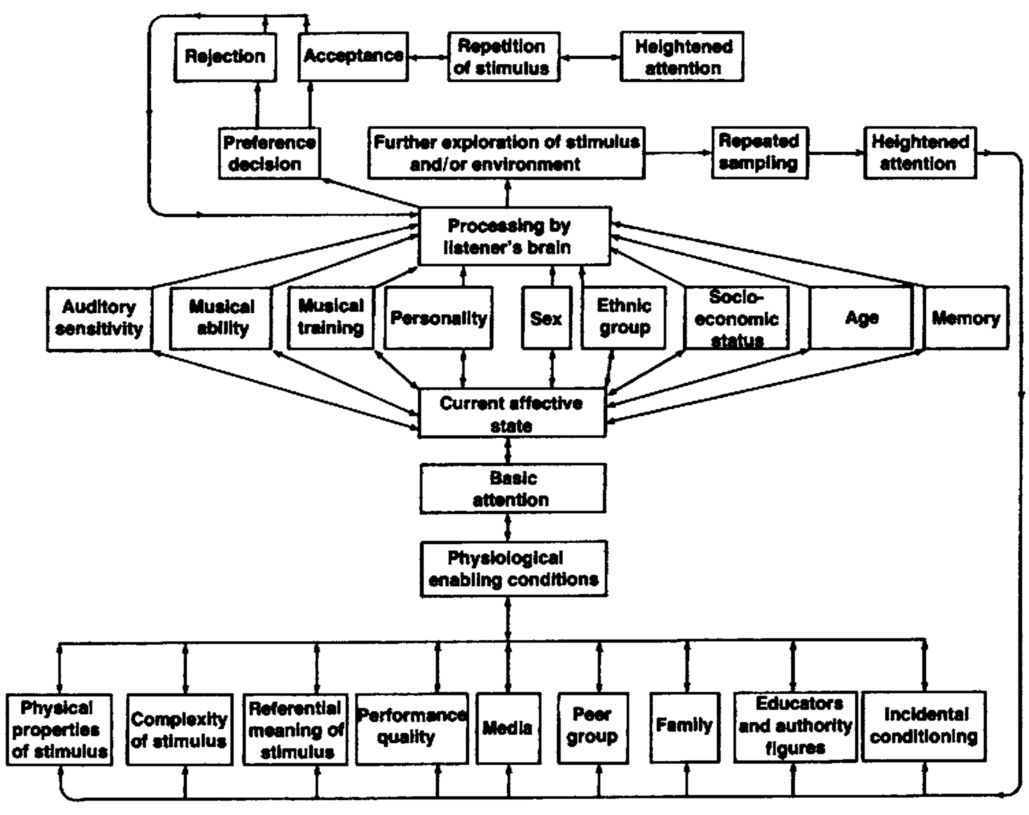

Fig 3.4. Sources of variation in music preference

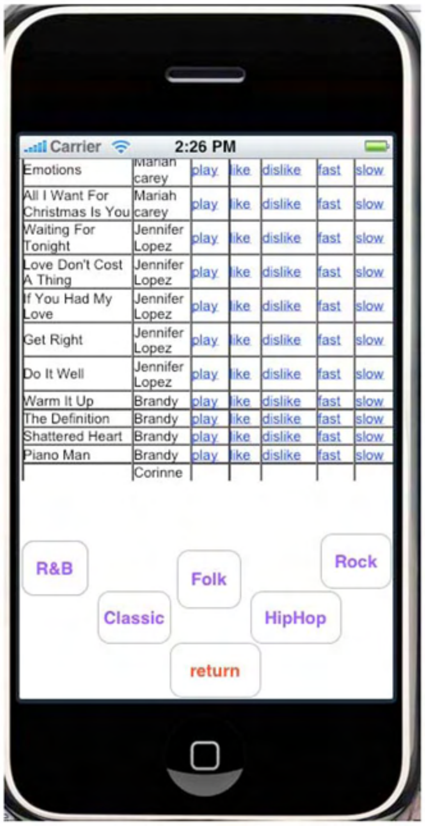

Fig 3.5. An example of the music recommendation part in our system

Genre	Number of songs
R & B	292
Hip-hop	96
Folk	233
Classic	22
Rock	179

Fig 3.6. Genres and the number of songs in our music database

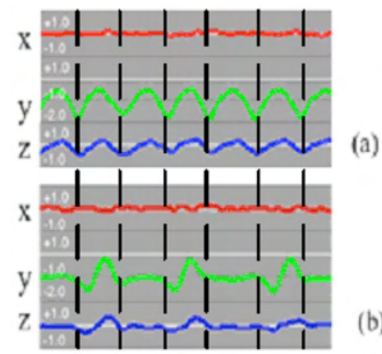

Fig 3.7. Scheduled interval training (a) and the accelerometer data for the exercise (b)

B. *Interval Training Game with Social Network*

With the inserted user input, the system design is customized to an interval training protocol. The user input screen requires user information including weight, height, the amount of time to exercise, and the amount of calories to be burned. By using the following equation, the system designs a customized exercise plan for the user.

$$W = m \cdot g \cdot h \cdot h\_rate \cdot v' \cdot t + ½ \cdot m \cdot v^2 \cdot t \text{ (J)}$$

m: mass (kg)
g : the gravitational constant (kg/m2)
v : the speed of running (m/s)
v' : the number of steps per second (steps/s)
t : collapsed time (s)
h : height (m)
h_rate : the rate of height lifted up when walking/running

An iPhone provides a 3.5 inch 480-by-320-pixel resolution multi-touch display, an audio system which has a frequency rate from 20Hz to 20,000Hz, and vibration functionality. Our system gives 3 different feedback commands to the user through the use of sound, vibration and animation based on the developed schedule.

By comparing the determined schedule of the interval training exercise with the exercise data collected via a 3-axis accelerometer embedded in an iPhone, the accuracy of the exercise is calculated. The system gives a lower score to the user who does not complete the interval training session accurately in order to motivate the user to exercise more and more precisely in an effort to get a better score. For instance, the accuracy of the exercise in Fig 3.7. is 50%, since only 3 steps among 6 given commands are done.

$$\text{Accuracy} = \frac{\text{The number of correct steps}}{\text{The number of times commands are given}}$$

The user's interactions with the iPhone are synchronized with the user's online profile registered in the web database of our system and the user's friend group, a group of users who participate in the iPhone interval training guidance system. E-mails containing the accuracy of the exercise sessions, exercise session time, and the amount of calories burned, etc. can be sent to other members in the user's social networking group after an exercise session is completed in order to increase the interaction among the user's friend group and to use the sharing of the information to increase the motivation to exercise, in the hopes of competing with friends.

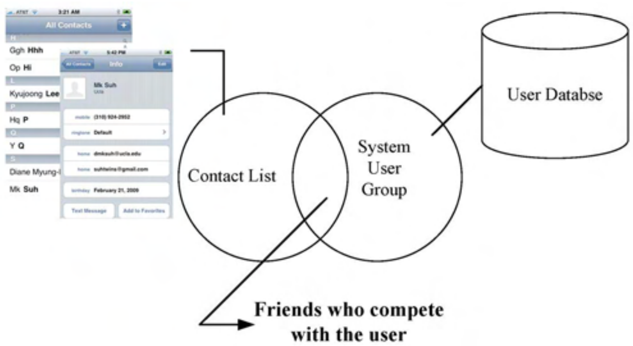

Fig 3.8. The method to get the friend group who compete with the user in our system

IV. EXPERIMENTAL RESULTS

As shown in Table 4.1, eight different individuals participated in the experiment to test the effectiveness of our system. All of them are individuals between the ages of 20 and 30, and they all live in Los Angeles, California. Exactly half of the participants are female.

	Individual 1	Individual 2	Individual 3	Individual 4	Individual 5	Individual 6	Individual 7	Individual 8
Gender	**Female**	**Male**	**Male**	**Female**	**Female**	**Male**	**Male**	**Female**
Age	25	24	27	28	25	29	27	25
Weight (kg)	51	61.4	73	49.5	50.5	62	70	51
Height (cm)	158	170	175	163	164	172	175	158
Residential District	Los Angeles, CA	Los Angeles, CA	Los Angeles, CA	Los Angeles, CA	Los Angeles, CA	Los Angeles, CA	Los Angeles, CA	Los Angeles, CA

Table 4.1. Information about individuals who participated in the experiment

A. The Effect of Interval Training Guidance Systems

Compared with the uncontrolled condition, the experiment (Fig 4.1) shows that exercise commands generally help users to exercise more accurately. Especially for individual 4, the accuracy of the exercise is improved from 53.97% to 88.71%.

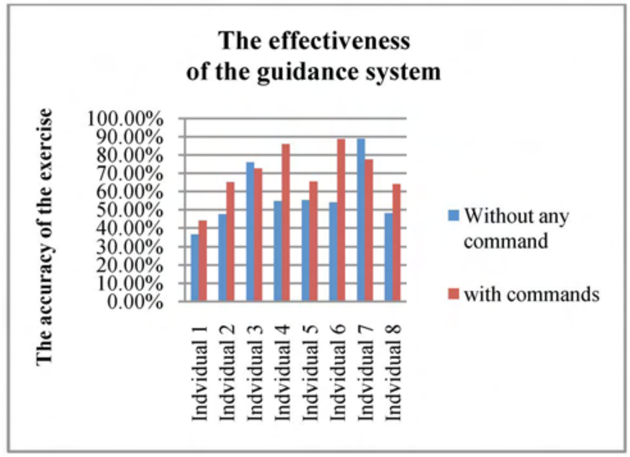

Fig 4.1. The effectiveness of the guidance system compared with systems without any commands or guidance

B. A Music Recommendation System Suitable for Interval Training Exercise

Each individual who participated in the experiment was requested to annotate his/her preference in music by using the music annotation user interface. Members in each individual group share gender, age, and the residential area.

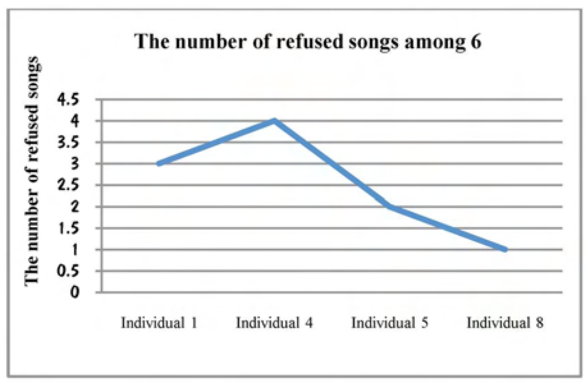

Fig 4.2. The number of refused music items among 6 recommended music items during exercise in the female user group

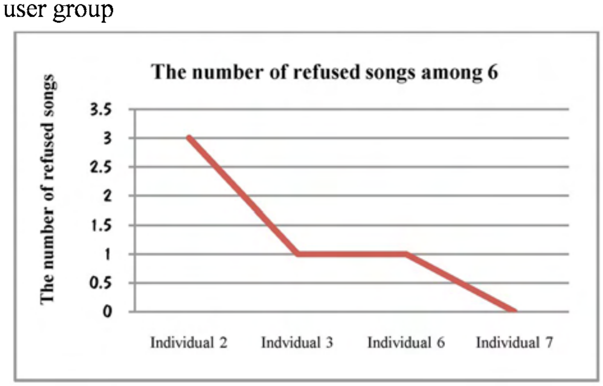

Fig 4.3. The number of refused music among 6 recommended music during exercise in the male user group

The experimental results in Fig 4.3 show that the percentage of refused songs is reduced from 50% to 0% as many users annotate the music played. Since individuals 2, 3, 6, and 7 are in the same user group, their opinion about the songs are reflected in the selection of the next recommended songs. In addition, by using content-based filtering, if there is music that only a specific individual does not like, this song will not be recommended to the user, but still will be recommended to others until the rating is below the threshold level. Music is also selected by the intensity of the interval training. The appropriateness of music in the context is higher than in the uncontrolled condition using random music. This collaborative, content, and context-aware music recommendation system will choose suitable music to the user that is engaged in the interval training.

V. CONCLUSION

Interval training involves a series of intensive exercises to provide proper stress to cardiovascular and musculoskeletal systems with recovery periods. Interval training exercises includes establishing a period for high intensity activity, followed by a period of low intensity activity referred to as a recovery period, a frequency with which this cycle is repeated, and finally a number of cycles corresponding to one complete session after which the subject ceases activity. Interval training is beneficial for weight loss, rehabilitation, general health, and cardiovascular build up. However, conventional interval training methods have the limitation that an individual subject may not be equipped with the capability to predict the level of effort required to provide an optimal training intensity.

To prompt participation in the interval training without any large or expensive equipment, our game-like and social networking application with a music recommendation system on a light and small smartphone can be used. The performance of the user can be measured by sensor readings, specifically accelerometers embedded in the iPhone. Additionally, the exercise information of the user is sent to the user's friends group. Our experiments show that the customized interval training schedule and commands generated based on the user information increases the accuracy of the interval training up to 88.71%.

A collaborative, content, and context-aware filtering algorithm incorporates user music preferences and the exercise speed to play music to enhance performance. Based on user information combined with the other individuals' information in the same group and the speed of the interval training, the list of recommended music is generated and evolved. As more data related to the music is accumulated, the experiments show the improvement in the selection of recommended music.

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