BeatSync: Walking Pace Control through Beat Synchronization between Music and Walking

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***Abstract*—Walking has been attracting attention as an important means for prevention and improvement of lifestyle diseases such as high blood pressure and diabetes. In contrast of its importance, not many people know the appropriate pace or amount of walking for themselves. In our previous research, we proposed a system to recommend a route with appropriate walking speed/pace for consuming target calories while keeping load within a moderate range by predicting heart rate variation if walking along the road. However, no system is available which enables a user to naturally adjust his/her walking speed to the specified one while walking. In this paper, focusing on the entertainment effect of the music, we propose a smartphone application called BeatSync which leads everyone to walk naturally and accurately toward the target walking speed.**

I. Introduction

In recent years, walking activity has been highlighted as a major solution of preventing lifestyle diseases such as high blood pressure and diabetes. Against such a background, the necessity and demand for a walking support system are rising. In our previous research, we developed a walking support system based on heart rate prediction [1] [2]. This system suggests a walking route and pace for each walker according to his/her requirements (target calorie expenditure, walking time, etc) and conditions (gender, age, exercise habit, etc). However, the system does not have a support on how to control each one's walking pace while walking.

To control a walking pace, there is a method of advising increase or decrease of walking speed through screen and/or voice of a smartphone, but this method cannot accurately lead a walker to a target speed. Moreover, this method could enforce walkers to watch smartphone while walking, which may lead to accidents.

In this paper, we propose a system of using entertainment effect induced by rhythmic music, which we believe the best way of guiding walkers to naturally and accurately to a target walking pace.

Several studies already developed walking support systems using the entertainment effect. For example, Watanabe et al. [3] proposed a method of attaching a vibration sensor into shoes to control a walking pace. However, this method requires special devices and hard to be spread. Oliver et al. [4] proposed a system called MPTrain which prepares several different types of rhythmical music and changes the music according to the walker's walking speed. However, this method takes a lot of costs for preparing various types of music. Therefore, we propose a way to control walking pace by using only one or a few songs so that the system is useful to everyone. Specifically, we develop a smartphone application which enables users to control walking pace only with a smartphone.

In order to investigate the effectiveness of the proposed system, we conducted a walking control experiment with 6 participants. The result showed that all participants were accurately guided to the target walking pace within a range between 102 and 120 steps per minutes.

II. Proposed System

A. Outline

The proposed system consists of two phases: synchronization phase and control phase. The entertainment effect is easily induced when rhythms of the music and the body movements are close to each other. Thanks to this fact, instead of first controlling a walking pace by music, in the synchronization phase, the proposed system plays back a music with the same BPM (beats per minute) as the pace of the walker's footsteps and prompts synchronization of music and the walking pace as shown in Fig. 1. When the synchronization is completed, in the control phase, the speed (i.e., BPM) of the music is changed to control the walking pace of the walker as shown in Fig. 2.

B. Beat Synchronization between Music and Walking

In the synchronization phase, as the first step, the SPM (steps per minute), which is the number of steps per minute is detected. The number of steps can be measured by a library provided for smartphone (iOS), but it does not support to calculate SPM in real time. In order for this system to operate properly, it is necessary to measure the SPM accurately in real time. Therefore, we use a step counting library [5] developed by one of the authors. This library can perform step counts in real time and high accuracy using the acceleration and motion information of the smartphone. This system records the time when recognizing a step. Then, walking SPM is calculated from the elapsed time for 10 steps. This walking SPM is calculated every time a new step is recognized.

We empirically regard that the walking is stable when the average of the change in the SPM over 10 steps is less than 1.5 SPM and proceed to the second step. While the average of SPM change is more than 1.5 SPM, we regard that walking

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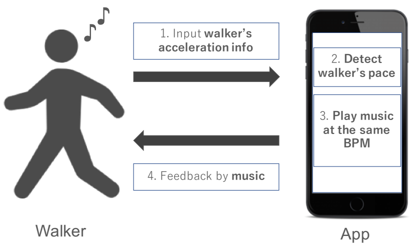

Fig. 1. Synchronization between Music and Walking

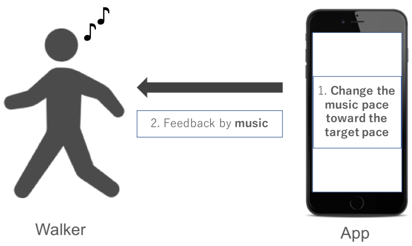

Fig. 2. Walking pace control by music adjustment

is not stable yet and continue this step until walking becomes stable.

Next, the playback speed of the music is changed so as to synchronize BPM and SPM with the same tempo. Each of different musics has its own BPM, but the BPM can be adjusted by changing the playback speed. The original BPM of a music is analyzed when the music is selected. As a procedure for this process, first the music data is delimited into fixed time frames, the volume of each frame is obtained, and the increasing amount of the volume between the adjacent frames is calculated. BPM can be calculated by frequency component analysis of the temporal change of the increasing amount.

In general, adjusting the playback speed of music usually changes the pitch of the sound. To prevent this, time stretch approach is applied to change the playback speed while keeping the pitch of the sound. This is done using SuperPowered [6] which is a media processing library. The SPM and BPM are synchronized with each other by playing back the music with the modified BPM.

C. Walking Pace Control by Music BPM Adjustment

As soon as SPM and BPM are synchronized, our system starts to control walking pace by changing the music playback speed. BPM is incremented by 1 (or -1) at regular time intervals and it is repeated until it reaches the target SPM.

The target SPM is changed according to walker's natural walking pace. Currently, for the purpose of the experiment, it is limited to a simple control, but in the actual walking support system to be developed in the future, it will induce walker toward the target walking speed determined based on the gradient of the target route and the target intensity of the exercise.

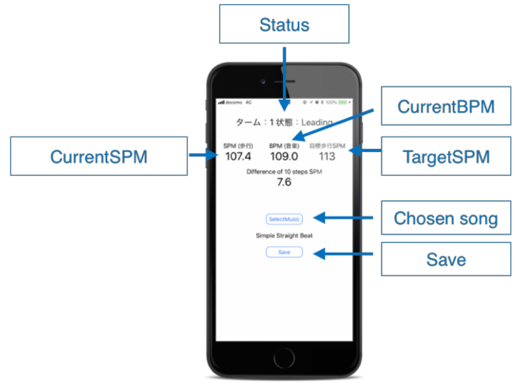

Fig. 3. Screenshot of application

III. Implementation of Walking Pace Control Application: BeatSync

In this section, we describe implementation of our walking pace control application called BeatSync. The code for the application was written in Swift language [7] with SuperPowerd [6] which is an open source library for music playback. By using this library, time stretch processing for changing only the playback speed while maintaining the pitch of the sound becomes possible without deteriorating the sound quality as compared with the iOS standard music playback library.

A screen shot of the developed application is shown in Fig. 3. On the upper part of the screen, the current phase status (synchronization or control) is shown. In the lower part, the SPM (on the left), the BPM of the music being played (at the center) and the target BPM (on the right) are presented. Below this part, the average value of the SPM change over 10 steps is shown, which is used to judge whether the walking pace is stable or not.

In this application, first the user selects a music to use. All of the musics stored in the smartphone are available. Thereafter. the user starts walking while holding the smartphone.

When the application determines that the walking is stable, music playback starts with the same BPM as the walking SPM at that time. After a certain period of time, it slowly changes the playback speed of the music toward the target SPM.

IV. Experiment and Evaluation

To investigate the effectiveness of the proposed system, we conducted an evaluation experiment with 6 participants aged between 20 to 30. The purpose of the experiment is to clarify to what extent the walking pace of each participant can be controlled by applying the proposed system using the music entertainment effect. For this purpose, we changed the BPM of the music within $\pm$ 20 range from the participant's normal SPM, and compared the difference between SPM and BPM.

As shown in Section II-B, SPM measurement uses a step counting library [5]. The participants walked for about 10 minutes while using this system and recorded BPM and SPM during the walk. In the experiment, the walking speed control

TABLE I
RESULT OF 6 PARTICIPANTS

Participant	Max SPM	Min SPM
A	138	98
B	120	93
C	120	100
D	120	84
E	120	102
F	124	97

with a fast pace and that with a slow pace were carried out by increasing BPM change steps. Experiments were carried out on flat routes in the university campus, and fluctuations in walking pace due to stopping in the course of walking, ascending and descending stairs, etc. were not considered.

Ishizaki et al. [8] report that user does not feel uncomfortable when the playback speed is within a certain range. Therefore, we used a music "Simple Straight Beat" (Artist: LumBeat) which has BPM close to 100, a typical walking pace. This music includes a simple drum sound.

V. Evaluation Result

As a result, we could confirm that our proposed system can adjust the pace of walking to some extent, although there are some individual differences. Table I shows the maximum and minimum values of SPM induced by music BPM change for 6 participants.

These results suggest that walking pace can be controlled between 102 to 120 SPM for all participants. It is reported that the average stride of the Japanese is about 70 cm [9], which corresponds to about 4.3 km to 5.0 km / h for walking.

Figs. 4 and 5 depict graphs showing changes in SPM and BPM of participants A and B, respectively.

In Fig. 4, it can be seen that the participant A's SPM follows the BPM. Two (A and D) of the six participants had the similar result. In Fig. 5 showing participant B, it can be seen that the B's SPM follows the BPM initially, but it fails to follow when the target SPM is high (or low). The remaining four (B, C, E, F) of the six participants had the similar tendency. These results suggest that there is a difference in the target SPM that can be followed among individuals. In addition, as a reason for failing to follow BPM, a comment was obtained from the participant that there were some silent periods in the music. In the future, we need to consider which part in the music should be selected.

VI. Conclusion

In this paper, we proposed a system to control walker's walking pace by changing beat of music with smartphone (iOS) and evaluated the system through an experiment. The proposed system first synchronizes the pace of walking with beat of music, then controls the walking speed by changing playback speed of music. The experimental result showed the feasibility to accurately control walking pace in real time within some specific range of walking speed. In our future work, we will develop a system that allows automatic selection of the tunes suitable for walking and integrate into the system our previous work [2] which shows appropriate walking speed for each segment of the recommend walking route and its gradient.

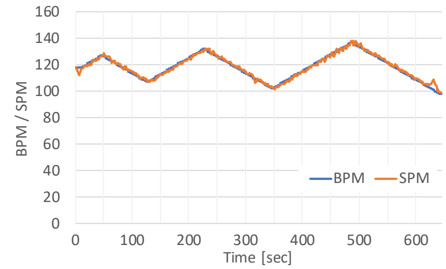

Fig. 4. Result of participant A

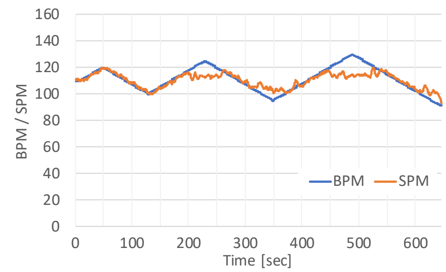

Fig. 5. Result of participant B

Acknowledgments

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