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▶ **To cite this version:**

Sinjae Lee, Sangbin Kim, Junghyun Han. Promoting Stretching Activity with Smartwatch - A Pilot Study. 15th International Conference on Entertainment Computing (ICEC), Sep 2016, Wien, Austria. pp.211-216, 10.1007/978-3-319-46100-7_19 . hal-01640290

HAL Id: hal-01640290

https://inria.hal.science/hal-01640290

Submitted on 20 Nov 2017

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Promoting Stretching Activity with Smartwatch - A Pilot Study

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Abstract. It has been claimed that wearable devices are useful for healthcare applications by providing functionalities such as idle alerts, pedometer, heart-rate measurement, and calorie calculation. However, these functionalities have the limitations of providing only passive assistance. In order to prompt users to do physical activities, we developed a prototype application for active assistance, which works on smartwatch devices. It guides users to stretch their arms periodically during their daily lives. For effective guidance, we integrated motion recognition and gamification elements. We performed a user study to confirm the usefulness of our approach.

Keywords: Smartwatch, Physical activity, Stretching, Motion recognition, Hidden Markov Model, Gamification

1 Introduction

In recent years, the field of wearable technology has grown rapidly especially for wrist-worn devices such as smartbands and smartwatches. Since the devices are integrated with not only high-performance CPU and GPU but also accurate micro-electromechanical system (MEMS) sensors, it is possible to implement various services on user's wrist, which include idle alerts, pedometers, exercise recording/management, and calorie monitoring, claiming to assist in healthcare.

The medical community has reported that sedentary work over many hours can be very harmful to health [1][6]. It is generally recommended that workers do not remain in the same posture for long periods at the workplace [2][7], and the public have thus taken an interest in wearable devices that can help in this context. Such devices often adopt an idle alert function to tell users to move or change their posture. However, we believe it is difficult for these functionalities to effectively encourage physical activities. We call them *passive assistance*. In this paper, we propose an *active assistance* functionality that can effectively prompt the users physical activities.

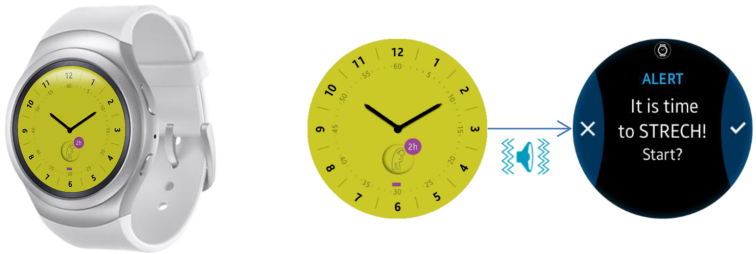
Promoting physical activities has mainly been studied from the perspective of games [3][5][8]. However, game activities have their own limitation that people are made to get fully devoted to them in a certain place and for a certain period of

time. Our approach presented in this paper aims at promoting physical activities using wearable devices in daily environments.

We have developed a prototype application based on smartwatches. It prompts physical activity by informing the users that it is time to stretch, guiding and evaluating their motion, and providing feedbacks. Additionally, gamification elements are added to further motivate the users' activities. Our approach is the first study to prompt physical activity and evaluate it using a wearable standalone device.

2 Active-assistance operations

The objective of our work is to investigate whether it is possible to effectively prompt physical activities by promoting arm stretching with the assistance of a wrist-worn smartwatch (Figure 1-(a)).



(a) (b)

Fig. 1. A smartwatch and its interface. (a) Smartwatch. (b) The watchface mode reminds the user of stretch.

In the smartwatch, the watchface mode provides *reminder* when the user has not stretched for a certain period of time. See Figure 1-(b). In this study, the watchface mode is set to provide reminders between 10am and 6pm, when the user is assumed to be working at his or her chair. The stretching reminder is set off one hour after the last stretching time. The user can perform arm stretching according to the application's direction or turn down the reminder message. The reminder time is then updated to one hour later.

Figure 2 shows the arm-stretching flow guided by the application. If the user accepts the reminder message, stretching guide is provided, as illustrated in Figure 2-(a). The first layer of the guide provides character images together with simple text whereas detailed text is given in the second layer that can be accessed by scrolling. The way to stretch is explained with spreading/shrinking wave animation of circles, as shown in Figure 2-(b) and -(d). At the peak state of stretching, the user is supposed to retain the stretched posture for five seconds. Figure 2-(c) shows the five-second countdown animation. Haptic feedback is

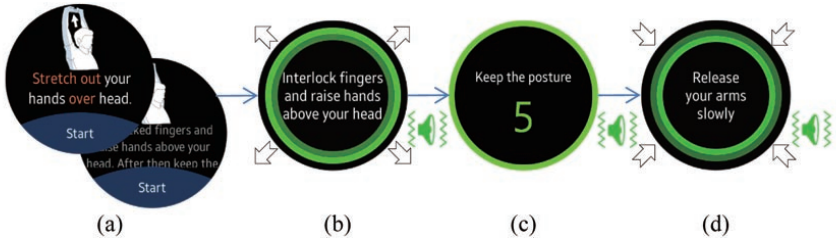


Fig. 2. User interface for arm-stretching flow.

provided at the start and end times so that the user does not need to take a look at the display during stretching.

3 Evaluation and feedback

The user's stretching motion can be represented by sequential time series data. We used a Hidden Markov Model (HMM) algorithm[4], which processes sequential data in real time on embedded systems. We acquired the accelerometer data at 100 Hz and used a Kalman filter to compensate for the noise in the raw sensory data. The observation vector, containing acceleration and some processed data, was evaluated in real time during the stretching action. When the users action was done, we compared the probability given by the motion recognition algorithm with the proper threshold to determine whether the user succeeded or failed. For this purpose, we need off-line pre-training stage and per-person training stage. Ten volunteers were involved in the pre-training stage. Each volunteer provided ten motions for the vertical stretch. We assume that the arm movement is symmetric and can safely rely on the data from a single sensor on one wrist.

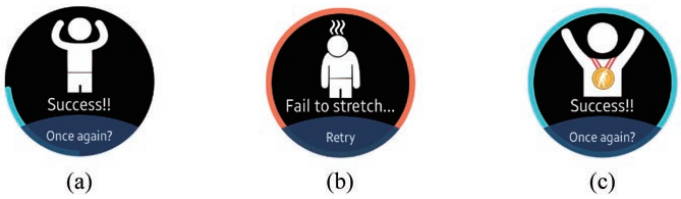


Fig. 3. Gamification elements. (a) For the success case, the progress bar is displayed at the boundary area. (b) The fail case. (c) Daily goal achievement.

We also added gamification elements. When user succeeds, the application displays the progress bar for the pre-set daily goal. See Figure 3-(a). The progress bar is increased by 20% per successful stretching motion. When the goal is

achieved, the application congratulates the completion of daily goal and displays a virtual reward. In the current implementation, it is the gold medal, as shown in Figure 3-(c).

4 User study: Result and Discussion

We conducted an experiment to assess our approach of providing stretch reminders, guiding the motion, and evaluating the user's motion. The smartwatch used in the experiment is Samsung Gear S2[1] with Tizen OS (wearable profile version 2.3.1). The prototype application is implemented in C++ for the native environment[2]. Before and after the experiment, participants were asked to fill in questionnaires. We informed the participants that the acquired data would only be used for the present study.

4.1 Procedure

We recruited 17 participants (15 males and 2 females) aged 23 through 41 (with M 29.875 and SD 4.177). They included graduate students, engineers, and office workers. The participants were paid $10 for their involvement. Nine out of them had experiences in healthcare services based on mobile or wearable devices.

We first conducted an initial survey before the experiment. Then, after being instructed in the usage of the application, the participants performed a training for stretching activity in order to enhance the motion recognition rate. The experiment lasted three days, during which the participants wore the device and continued their normal daily activities. The application recorded the log data during the experiment, e.g., how many times stretching was done, whether the user failed or succeeded, etc. After the experiment, we extracted the log data from the device and asked the participants to fill in the final questionnaire.

4.2 Questionnaire and result

The initial questionnaire asked participants how much time they typically spend doing sedentary work and how frequently they do stretching per day. The participants do approximately 8.5 hours of sedentary work and stretch on average 1.84 times per day.

We analyzed the recorded log data. For three days of experiment, the participants received on average 7.147 reminder messages per day, of which 64% were accepted. On average, they attempted 18.201 stretches per day. In the three-day experiment, the goal (at least five intermittent stretching motions) was achieved for two days on average. See *Data analysis* part of Table 1.

The result of the final questionnaire is shown in *Questionnaire analysis* part of Table 1: (1) The "effectiveness of stretching" is meant to measure the personal

[1] http://www.samsung.com/global/galaxy/gear-s2/
[2] https://developer.tizen.org/development/api-tutorials/native-application

perception on how much the muscles seem to be relaxed as a result of stretching; (2) With respect to the "effect of gamification," the participants were asked how much they were motivated by the reward, i.e., gold medal for achieving daily goal; (3) The final question asked the participants whether, if given a chance, they intend to use same application in the future.

Table 1. Results of the experiment. The values of the *Questionnaire analysis* show 5-point Likert-scale from 1 (low) to 5 (high).

Data analysis	*M*	*SD*
Number of reminders per day	7.147	2.398
Number of stretches per day	18.201	7.968
Number of daily goal achievement	2.000	1.110
Questionnaire analysis	*M*	*SD*
Effectiveness of stretching	4.000	0.791
Effect of gamification	3.059	0.899
Intention to reuse	4.471	0.514

4.3 Discussion

In general, we received positive responses from the participants. According to the results, the participants performed stretches as much as 18 times per day. Recall that, in the initial survey, they answered that they stretched on average 1.84 times over 8 hours. They also appraised highly the effectiveness of the stretch-promoting system and most of them wished to use this kind of application again.

The gamification element was expected to motivate the user to perform stretching more actively, but the score on "effect of gamification" (M 3.059 and SD 0.899) does not lead to the conclusion. It can be analyzed from two perspectives. First of all, adding gamification elements might not be effective for prompting physical activities, as claimed by [9]. Secondly, the reward in the current prototype system, the gold medal, is too simple to be assessed. When the prototype application is extended into a pervasive game, a more elaborate rewarding system could be added and evaluated more formally.

5 Conclusion

We have presented an attractive approach to encourage user's physical activity by using smartwatch-based prototype application. During the experiment, participants wore a smartwatch which reminds stretching time periodically. The experimental results show that participants were made to conduct more stretching activity and provided positive feedback for our approach although the static time-based reminder might be able to annoy them when they do not want to stretch.

We concluded that it is possible to encourage user's physical activity with an active assistance manner for people wearing smart wearable devices. We are currently extending the system and also designing more elaborate experiments.

Acknowledgement

This work was supported by Institute for Information & Communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No. R0115-15-1011) and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. NRF-2016R1A2B3014319).

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