Running gestures: hands-free interaction during physical activity

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ABSTRACT
This paper presents Running Gestures, an interaction technique that relies on foot gestures while running. A prototype and evaluation of one of the proposed gestures, a mid-stride skip, is presented in detail. The developed prototype is used by runners to change the currently playing music track, and the evaluation compares users' performance in relation to other methods of changing tracks while running. The results show that Running Gestures is a highly effective way of interacting with a system when running.

Author Keywords Interaction technique, running, music player, foot gestures

ACM Classification Keywords H.5.2 Input devices and strategies, Ergonomics

General Terms Design, Music, Sports

INTRODUCTION
This paper presents an interaction technique that is suitable for hands-free interaction during physical activity. This type of interaction technique can be useful in environments where users' hands are occupied, and at the same time the users are moving or performing some kind of physical activity and require hands-free and eye-free interaction. Examples of such situations include soldiers wielding two handed rifles or athletes pumping with their arms during a run.

A significant body of work on gestural interaction has targeted interaction with fingers and hands [1]. More recent work has explored gestures using other parts of the body. For example, Schöning et al [2] developed a multi-modal interaction technique for both hands and feet, but did not consider active environments. Park et al [3] focus on recognition and segmentation of whole body gestures, such as walking, running, and sitting, but do not attempt to extract specific gestures in those contexts. There has been relatively little work done on hands-free gestures for interacting with systems during physical activity. The work presented in this paper presents a hands-free interaction technique suitable for use during physical activity, which relies on foot gestures.

IMPLEMENTATION
There are multiple gestures that users may perform while running, and these can be mapped to actions or controls of a system. For example, skipping several times may change the volume on a runner's headphones and switching to sidestep may answer a phone call. The prototype presented here used individual skips to change the currently playing music track. A skip occurs when a runner makes two one-footed jumps instead of one full stride. The benefits of this gesture are that it does not directly involve the user's hands and does not require visual attention.

Running Gestures uses data from an accelerometer attached to a strategic position on users' legs to detect gestures. The prototype uses the accelerometer in a Nintendo Wii remote (http://en.wikipedia.org/wiki/Wii_Remote) which is strapped securely in order to minimize noise. After experimenting with several positions on the lower body, including the foot, the lower leg and the knee, the exterior of the leg was the location that yielded the least noise (Figure 1). Readings from the accelerometer (a stream of 3-tuples representing acceleration values in the X, Y, Z axes) are processed in realtime by a desktop. When skips are detected the music player of the desktop changes tracks. Skip detection relies on the fact that when running, users perform foot strides with a relatively regular period. When

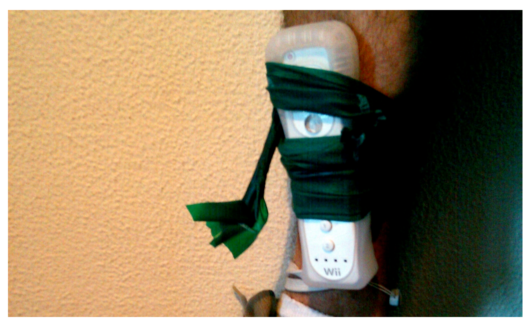
Figure 1: The prototype attached to a runner's leg

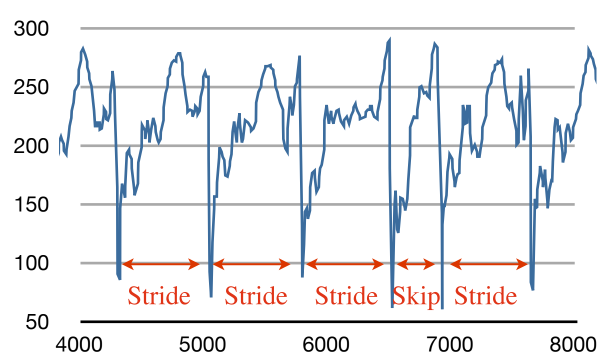

Figure 2. A graph of strides and skips. X-axis: time (milliseconds); Y-axis: acceleration.

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they skip during running, the regularity of their strides is interrupted. For the purposes of skip detection, foot strikes are well represented by acceleration in the Y axis, as shown in Figure 2.

The skip-detection algorithm works as follows. Values are first smoothed using a moving average function, and then peaks in the data are identified using the first derivative of the values. Further noise is eliminated by applying a high-pass filter on the detected peaks. The resulting peaks represent foot strides, and the time between adjacent peaks is calculated. These times indicate how long it takes between foot strides. The mode of the last 5 strides was shown to provide a good approximation for the ongoing step frequency. Skips are detected as steps that occur more rapidly than the main tempo. A typical skip appears as a stride whose duration is between 50% to 85% of the ongoing stride frequency.

USER STUDY

A within-subjects study was designed to compare users' performance under three conditions for changing music tracks: via direct interaction with a smart phone's touch screen (Condition A), clicking on a button integrated into the headphone cable (Condition B), and the skip gesture involving a Wii remote strapped to the participant's right leg (Condition C). Seven participants were recruited (mean age: 25.5; two females) to run laps at a comfortable and steady pace around an oval path with approximate length 30 meters. The experimental trials required participants to change music tracks on command. Each participant received some initial training, and for each condition they completed 8 trials. The software recorded the time between the command being issued and successful track change. Conditions were randomized to avoid sequence bias. After completing all tasks, an informal interview was conducted to establish how distracting, enjoyable, effective and reliable each track skip method was.

RESULTS AND DISCUSSION

The average time per trial for each condition is shown in Table 1, along with the standard deviation. An ANOVA showed a significant effect of the system used on the time taken to complete the trials ($F(1,137)=1625.04$, $p<0.0001$). The algorithm had an accuracy of 90%, and trials where the skip was not detected were discarded.

Touchscreen (A)	Headphone (B)	Skip (C)
10.03s (2.72s)	3.14s (0.97s)	2.70s (0.86s)

Table 1. Mean track change times per condition (standard deviation in brackets).

The timing data show that changing tracks with a touchscreen phone is far slower than the other methods. Users commented that taking the phone out of their pocket was annoying, and that the interaction to change a track was difficult, requiring the user to turn the phone on, unlock it, tap the skip button and turn the phone off again. The complexity was only exacerbated by the difficulty of operating a touch screen device while running, such as the screen rotating based on the phone's orientation.

The headphone remote provided a much more compelling experience as it did not require interacting with a touch screen nor removing the phone from the pocket. Four participants, however, commented that it was hard to find the remote button because the motion of running caused the wire and their head to bob. Furthermore, having to move their hands up to their head distracted them from their exercise.

Based on the interviews we conducted, six of the seven participants preferred Running Gestures for changing tracks. Participants reported that the skip gesture was fun and engaging and added variety to their running routine. However, the timing data does not show a big performance gain between the headphone remote and skip conditions. Although it let them keep their arms in the natural running position, two participants noted that it broke their stride. In some cases, they found it difficult to coordinate a skip in the middle of the run.

FUTURE WORK AND CONCLUSION

Several limitations of the prototype were highlighted in the user study. The use of a desktop computer meant that participants could only venture within a bluetooth range radius of the host, making a long distance running study difficult. Porting Running Gestures to a mobile phone would solve this issue. Some disliked the bulkiness of the Wii remote strapped to their leg, and indicated a preference for a smaller form factor. In practice, they would likely prefer to use an accelerometer integrated into their shoe. Finally, lack of a sensor on the left leg meant that users would have to wait for their right leg to become engaged before performing a skip, impacting their skip time. Having an accelerometer in both legs would remedy this issue.

The study presented here shows that the skip running gesture is an enjoyable and effective method for a runner to interact with a music player. This technique allows for hands-free and eye-free interaction, and the study results show that it is also quick. The mid-stride skip is just one of many possible Running Gestures that can potentially be exploited for hands-free use during physical activity.

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