"Shoes-Your-Style": Changing Sound of Footsteps to Create New Walking Experiences

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ABSTRACT
With "Shoes-Your-Style" we introduce the entertaining possibility to change auditory feedback and sound of footsteps when walking indoor and outdoor, to alter the nature (or "style") of shoes and contacts with the ground. This approach requires two components: a step detector and a sound generator. Artificial sounds of footsteps can be generated and tuned by the system, or by the user, to simulate any type of shoes (high-toe, sneakers, flip-flops, etc) or ground (marble, snow, mud, gravel, etc), generate artificial walking events (collisions, cracking objects, etc) or even unrealistic sounds (noises, words, music, etc). Such new kind of feedback should pave the way to creative interactive walking experiences. Potential applications range from entertainment and multimedia, to sport training and medical rehabilitation and reeducation.

Categories and Subject Descriptors
H.5.1 **[Multimedia Information Systems]**: *Audio input/output;* H.5.2 **[User Interfaces]**: *Auditory (non-speech) feedback.*

General Terms
Design, Human Factors.

Keywords
Shoes, auditory feedback, footstep, sound, walking.

1. INTRODUCTION
Footwear has considerably evolved in the long history of humans. Shoes have always been considered as a way to improve and support safety, protection and comfort of human locomotion. They have also been soon after considered as an esthetic product revealing the style but also other social messages of their owner.

More recently, shoes have evolved towards high technology, and began to incorporate electronic and computerized systems [2] as well as sensing devices. As an example, they can embed pedometers to gather input about human walk, such as for sport training.

The current appearance of shoes is mostly *visual* including shape and colors, but also occasional lights and visual effects; and *auditory*, due to the sounds generated at each footstep. Sound of footsteps is highly dependent on the type of shoe-ground contact and of the materials involved, but it can also reveal important properties of human walker [1].

Indeed, when we walk, the main source of feedback and exchange with our surrounding is often the sound of contacts between our feet and the ground. It is a very strong and varied source of explicit or implicit information. Sound of footsteps informs about the type of shoes that we are wearing, the type of ground that we are walking over, and, potentially, about many other events that can occur during the walk (cracking objects, unexpected events, etc). It can also inform about the physical or mental state of the walker, such as his/her fatigue, stress or hurriedness.

In this paper we introduce the possibility to modify auditory feedback corresponding to sounds of footsteps when walking indoor and outdoor, for implicit or explicit feedback and control of human walk. In this approach, that we called "Shoes-Your-Style", the auditory feedback corresponding to the shoe-ground contact (or footstep sound) is manipulated at will by the user and/or the system. Sound of footsteps is therefore considered here at the basis of a new and dynamic feedback during indoor and outdoor walk for different kinds of mobile interactive experiences.

2. RELATED WORK: FROM AUGMENTED SHOES TO VIRTUAL GROUNDS
The idea of augmenting shoes has been around for quite some time already. Famous modifications, already available today in many footwear shops, involve simple luminescent laces that glow in the dark, sneakers with led-blinking soles and capable of sensing foot-floor contact, "heating" shoes, "massaging" shoes, "self-lacing" shoes, or even shoes that eliminate smells.

Sounds have already been incorporated, such as with GaitSpots pair of additional "squeakers" but providing only a basic "squeaking" auditory when in contact with the floor or a ball. GaitSpots system is commercialized for reinforcing gait training skills or for heel strike. Other "gadget" shoes embed audio or CD players and loudspeakers to play music at the level of the shoes.

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However, all these auditory feedback are rather limited and uncorrelated from user's activity.

Recent works led to more sophisticated shoe-based applications. The "Nike+" sport kit consists in an accelerometer placed in (or on) Nike shoes, and a receiver attached to an iPod or iPhone. The sensor is able to detect each step that a runner takes, and from this information the runner's speed and the distance he has traveled can be calculated. The dedicated iPhone application stores statistics of the exercises. The "CabBoots" [2] are even more complex shoes embedding contact sensors and tactile feedback, and connected to a pedestrian navigation system. The shoes can then guide the user during his walk along predefined paths.

More recently, Adidas made shoes with Augmented Reality codes (visual patterns) which enable the consumer to play interactive games on-line with a webcam. The shoes can become controllers and input devices for various applications and videogames [3] [6]. Actually, feet-based interactive floor technologies [5] are already available for entertainment and videogames such as with Konami's "Dance-Dance-Revolution-Stage", or Nintendo's "Wii-Fit". However, all these interfaces have been not concerned with the sound modality as a mean to convey prominent floor cues when walking outdoor or indoor.

3. "SHOES-YOUR-STYLE" CONCEPT

3.1 Initial idea and extensions

The initial idea of "Shoes-your-style" is to give a walker the novel experience that he is potentially walking with shoes other than his/her. To do so, whenever a step is detected, a sound is played, related to the kind of shoes to be simulated.

Beyond this idea, the purpose of our approach is to introduce new possibilities of mobile interaction, relying on new entertaining walking sensations, and be able to share it with the people around. Even if it is possible to use this concept in videogames and virtual environments, the primary goal is here to do it in the real world during indoor and outdoor walk. With Shoes-Your-Style, it becomes possible to give sensations of walking over different grounds, and to suggest walking in other places, and/or to step on very unusual reliefs or objects.

3.2 Technical description

Technically speaking, the Shoes-Your-Style approach requires two main components: a step detector (input), and a sound generator (output). It is meant to be a wearable system for large-scale use. This global scheme is illustrated on Figure 1. Sounds are generated and played by a simulation/computer in response to the detection of steps. A controller enables to select and interactively set up the parameters of the simulated sound at will.

The most natural implementation of this concept probably consists in embedding all the input/output components directly inside the shoes of the user. This option will be described in details in the next section. However, many options exist considering that the input/output components could also be located on other parts of the body or in other equipments such as in Smartphones. Indeed, novel generations of Smartphones include high-quality audio feedback and accelerometers which could serve respectively to play the walking sounds and to analyze body motion and detect steps. The input and output components could also be split and located at different places. For instance, walking sounds could be played by a Smartphone while a pedometer could detect steps, such as in the existing Nike+ application for iPhone, for which sneakers with force sensors can communicate with a Smartphone and a pedometer simulation.

In the next section we detail one implementation of this concept which involves a all-in-one peripheral: the "Sonic Shoes". Future work could consider testing other solutions based on accelerometers for tracking steps for instance.

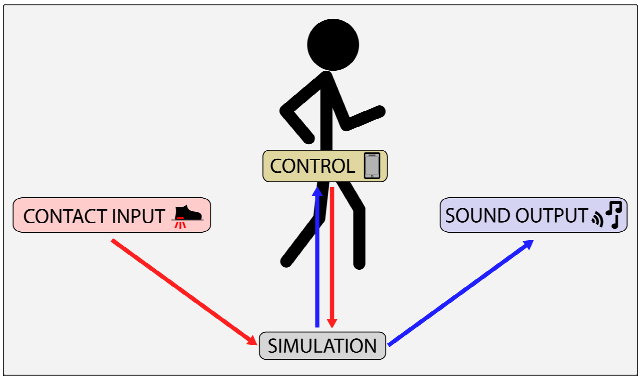

Figure 1: "Shoes-Your-Style" schematic diagram.

4. THE "SONIC-SHOES"

4.1 Input/output shoes

Our "Sonic-Shoes" are displayed on Figure 3. On each shoe there is a pressure sensor embedded both at the back (heel) (Fig 2:1) and at the front (toe) (Fig 2:2) with an additional sole on top (Fig 2:3). There is also one speaker per shoe which is attached to the middle strap (Fig 2:4). The outgoing cables are sent to the parallel port (Fig 2:5) of a controller box.

In the controller box, there is an "Arduino Duemilanove" micro-controller which is wired to the parallel port cables coming from the shoes and to a jack port for incoming sound. This box is then connected to the computer through USB and a double headed jack cable (the computer is here the main source of the sound).

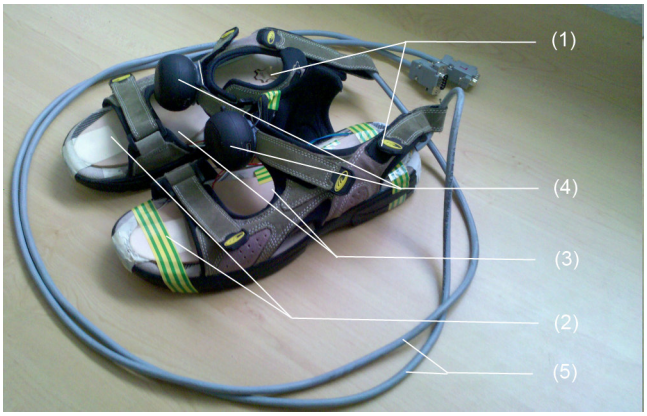

Figure 2: The Sonic Shoes.

4.2 Software components

Our software application is then capable of displaying all the data received from the sensors (Fig 3:1), playing different sets of sounds (Fig 3:2) creating/modifying/using XML configuration files (Fig 3:3) and communicating with a smart phone which then becomes a remote controller (Fig 3:4). Our software architecture is composed of different independent modules for handling either the different ways of playing a set of sounds, a GUI, a WiFi server for Smartphone communication, a USB communication module and an XML parser. The application is based on Qt (http://qt.nokia.com/) and FMOD (http://www.fmod.org/).

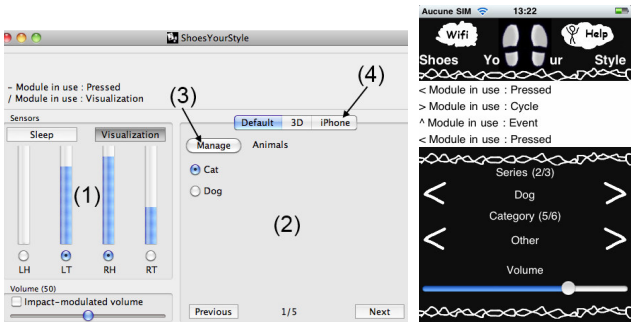

Figure 3: Software components
(Left) Main application running on computer,
(Right) Smartphone application and user interface.

Figure 3-Right also depicts the iPhone application which lets the user control the computer program through WiFi, i.e., choose the sounds played and the volume. It is also capable of displaying sensor information: shoes icons on top of the screen change colors when the corresponding sensor is active. The white area beneath the shoes (Figure 3-Right) is a console which echoes the main program running on the computer.

4.3 System in use

The whole system as worn by the user is displayed in Figure 4. It consists of the Sonic-Shoes (Fig 4:1) and the controller box and computer both placed in a backpack (Fig 4:2). Additionally, there is the iPhone (Fig 4:3) connected to the computer through WiFi used as a remote control.

For implementation details, the computer used was a MacBook-Pro running MacOS X 10.6.4 with an i7 2,55GHz processor, 4GB RAM and integrated sound. The phone used was an iPhone 3G. With this system, we could obtain a response time of the Sonic-Shoes (time between a step detection and the auditory feedback generation) smaller than 20 ms.

5. WALKING SOUNDS

Sounds are emitted by the Sonic-Shoes when a step is detected. In our current implementation, steps are detected by using only the force sensors located at the back of the shoes. A sound is therefore played each time a contact occurs between the heel and the ground.

All the sounds used were derived from audio files containing multiple sounds of footsteps from open-source sound libraries (www.freesounds.org). Each sound was manually worked out using Audacity software.

We could propose and test various kinds of sound, which are listed and briefly described hereafter.

5.1 Shoes sounds

The first category of sounds corresponds to different kinds of shoes potentially worn by the user. Among them we can stress: *high-toes* (in an echoing corridor), *clogs*, *spurs* (evoking "cow-boy boots"), and *flip-flops* (the sound is played here when the foot is taken off the ground as if the flip-flops is slapping on the heel).

5.2 Ground sounds

The second category corresponds to different types of relief the user is walking over. Among them we can first stress "aggregate" grounds: *gravel*, *leaves* (steps in a forest during autumn, when the leaves lay dry on the ground), *ice* (steps over a small amount of ice, thus a crackling sound), or *snow* (steps in a huge amount of fresh snow). Then we find "solid" grounds: *wooden parquet* floor, *metal* (metallic catwalk), or *concrete*. Such sounds can also evoke a whole place and being in a different location such as with echoing walking sounds in a *forest* or in a *cave*.

5.3 Event sounds

The third category comprises different sounds of walking over animate or inanimate objects, and other unexpected events. We can evoke for example walking over the tail of a *cat* (meowing suddenly), or over a deforming *can*. We can also play the sounds of a dog's *bark*, a *shooting*, an *explosion* or *thunderbolts*. As an example, these sounds can be randomly generated by the system at one step to surprise the user.

5.4 Unusual or abstract sounds

The fourth category corresponds to the simulation of very unusual, and sometimes poetic, sounds. This is the case for instance with walking over *water* (with steps in a small amount of water, such as in a water patch), or with *beeps* or strange *noises.*

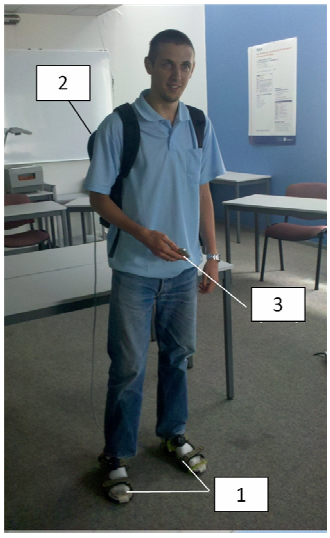

Figure 4: The system as worn by the user.

5.5 Sequences and cycles

The fifth category corresponds to the playing of different sounds at successive steps, in sequence or cycle. As an example, we can

use a sequence of steps to pronounce different syllabuses or a sentence such as *"I-am-your-fa-ther"* (the famous quote from Stars War's movie and Darth Vader character), or a music play such as the basic *"do-re-mi-fa-sol-la-si-do"* tune.

These categories and the corresponding examples are helpful to illustrate, in a non-exhaustive way, the richness and variety of sounds that can be used. They can be easily extended with other sounds and other approaches, using for instance more semantics and other parameters of the walk.

6. DISCUSSION

We believe Shoes-Your-Style concept has various kinds of possible application and extension. The first, and major, application concerns the entertainment field, and the design of mobile and entertaining "augmented walking experiences". Shoes-Your-Style could spread by extending existing technologies (e.g., Nike products) and, later, apply to Smartphone technologies.

Shoes-Your-Style might also support fitness and training shoe-based applications that could include auditory feedback related to steps, movements, or performance of runners. Shoes-Your-Style could also apply for medical applications and treatment of balance disorders or motor deficiencies. Indeed, this new source of sensory feedback might influence and alter the real walk of the user and induce specific walks. But future work is now needed to design the corresponding auditory feedback, and assessing the potential impact of this technology.

As a result, we think that Shoes-Your-Style concept could open an interesting path of research on feet-based mobile interaction with auditory feedback, and the study of novel kinds of walking experiences.

Future work could first consist in conducting a series of experiments to evaluate the design of our system and the potential applications of Shoes-Your-Style. We could also study and design a Smartphone version of Shoes-Your-Style based on inertial sensors and loudspeakers of an iPhone for instance. This solution could be compared to the shoes-based solution.

Besides, we could also study the design of other kinds of sound and other walking experiences based on auditory feedback. For instance, we could propose to use the force sensors located at the level of the toes for other kinds of rendering and sensations. We could also give the possibility to record sounds using a microphone (such as the one embedded in a Smartphone) to display them later with the system. The volume of the sound could be set proportional to the intensity of the contact or to the detected pressure. Physical simulation of sounds [4] could also be incorporated to increase the realism of played sounds.

7. CONCLUSION

We have introduced the "Shoes-Your-Style" approach, meant to enhance the walking experience by displaying artificial sounds of footsteps during mobile indoor and outdoor walks.

This concept is illustrated with "Sonic-Shoes" which embed both pressure sensors (to detect foot-floor contacts) and loudspeakers (to display sounds of footsteps) within a "all-in-one" system.

We could propose and test various kinds of sound, such as sounds of other shoes, of varied grounds, or of unexpected events. The applications envisioned for such new feet-based interaction scheme belong to various fields ranging from multimedia and entertainment, to sport training and medical rehabilitation/reeducation.

8. ACKNOWLEDGMENTS

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