VRsneaky: Stepping into an Audible Virtual World with Gait-Aware Auditory Feedback

Felix Dietz
LMU Munich
Munich, Germany
felix.dietz@campus.lmu.de

Matthias Hoppe
LMU Munich
Munich, Germany
matthias.hoppe@ifi.lmu.de

Jakob Karolus
LMU Munich
Munich, Germany
jakob.karolus@ifi.lmu.de

Paweł W. Woźniak
Utrecht University
Utrecht, Netherlands
p.w.wozniak@uu.nl

Albrecht Schmidt
LMU Munich
Munich, Germany
albrecht.schmidt@ifi.lmu.de

Tonja Machulla
LMU Munich
Munich, Germany
tonja.machulla@ifi.lmu.de

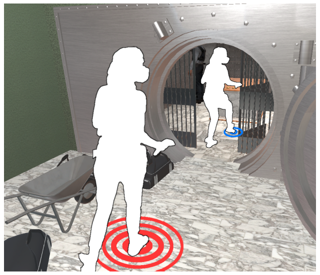

Figure 1: Depiction of a user walking inside the virtual bank vault. *VRsneaky* analyzes the user's gait — heavy (red) vs light (blue) footsteps — and induces step sounds accordingly.

Abstract

New VR experiences allow users to walk extensively in the virtual space. Bigger tracking spaces, treadmills and redirected walking solutions are now available. Yet, certain connections to the user's movement are still not made. Here, we specifically see a shortcoming of representations of locomotion feedback in state-of-the-art VR setups. As shown in our paper [2], providing synchronized step sounds is important for involving the user further into the experience and virtual world, but is often neglected. VRsneaky detects the user's gait and plays synchronized gait-aware step sounds accordingly by attaching force sensing resistors (FSR) and accelerometers to the user's shoe. In an exciting bank robbery the user will try to rob the bank behind a guards back. The tension will increase as the user has to be aware of each step in this atmospheric experience. Each step will remind the user to pay attention to every movement, as each step will be represented using adaptive step sounds resulting in different noise levels.

Author Keywords

Auditory feedback; virtual reality; gait awareness; presence.

CCS Concepts

•**Human-centered computing** → **Auditory feedback;** *Virtual reality; Sound-based input / output;* Empirical studies in HCI;

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Introduction and Related Work

Most of today‘s VR experiences limit their user's input possibilities to positional and rotational tracking of the user's head and hands. Buttons integrated into hand-held controllers are used to mimick the input possibilities of classical platforms such as video game consoles. Most VR applications neglect fine-grained input possibilities that would be possible by full-body tracking. As a result, they miss out on high immersion [6, 9], ultimately leading to a lower sense of presence for the user.

The implementation of full body tracking, including a conclusive representation of auditory and haptic feedback - especially in the context of locomotion - remains a challenge. Slater et al. [7] showed an approach where users make steps in the same spot while moving forward in the virtual world - a technique worth considering when the dimensions of the virtual world exceed the physical available walking space. Recent work by Boysen et al. [1] and Wilson et al. [12] further showcased a solution to limited tracking space by either upscaling the user's size or the speed of movement.

Figure 2: A user carefully walking into the virtual bank vault.

RealWalk are haptic shoes that can simulate ground material deformation while walking on multiple virtual surfaces such as mud and sand by changing the viscosity of the fluid attached to the user's shoes [8].

Figure 3: 3D-printed casing mounted on a participant's leg containing the ESP32 micro controller and accelerometers. The force-sensing resistors (FSRs) are attached under the user's shoe.

In *VRsneaky*, we focus on the auditory aspects of VR immersion in the context of locomotion. Research has shown that subtle feedback cues like walking sounds can alter the user's perception of their own speed and body weight [4, 10]. In this demonstration, we showcase an approach for synchronized gait-aware auditory feedback that works independently from visual tracking systems but through pressure sensors and accelerometers embedded into the user's shoes. In our sample scene, the system distinguishes between soft and hard steps thus helping users to control their movements while breaking into a bank vault. We evaluated our approach in a user study involving 28 participants which showed an increase in perceived presence [2].

Concept

While evaluating different aspects from related work, we concluded three main design specifications. Previous work implemented non-gait-aware step sounds either via microphones attached to the user's shoes and ground [5] or by attaching force-sensing resistors (FSR) in the shoe's sole [3], each connected to the setup using a cable. *VRsneaky*, on the other hand utilizes Wifi to send collected data to the PC, ensuring the user's freedom of movement.

Secondly, we use FSRs and accelerometers which provide a direct and accurate representation of the user's steps. Not suffering from occlusion, they deliver more robust input compared to optical tracking solutions.

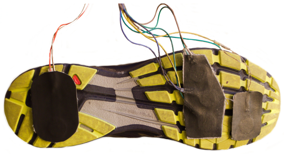

Figure 4: Five FSR sensors attached to a participant's shoes. Placement layout has been adapted from [13].

Figure 5: A user stretching towards the virtual money to reduce the amount of steps he has to make.

The played sound samples have been prerecorded to avoid interference that can occur when using real-time audio input from microphone recordings [5]. At each step, the system detects the appropriate gait and randomly selects one sound sample to play - providing a natural variance for each step as shown by Turchet et al. [11]. Utilizing the spatial sound capabilities of modern VR sound engines, we place the sound source for the steps underneath the user's feet to further support a coherently perceived proprioception.

Implementation

We implemented our prototype of *VRsneaky* using a ESP32 micro controller, that acts as the main control unit and handles the Wifi connection to the PC. The electronics are embedded in a 3D-printed case that can be attached to the user's leg (see Figure 3). All components were powered by a Lithium-polymer battery stored in the 3D-printed case. The array of FSRs has been attached to the user's shoe soles (see Figure 4). A HTC Vive is used to display the Unity3D VR scene. The user also wears noise-canceling headphones to prevent them from hearing the own physical footsteps and only perceive the induced step sounds in VR.

VRsneaky

VRsneaky is a single-user virtual reality experience showcasing the usage of gait-aware auditory feedback in an engaging scene. The users find themselves inside the anteroom of a bank vault (see Figure1) with the task of stealing money and gold from inside the vault. But there is a catch: inside the vault is a guard, gibbering along minding his own business.

The user's task is to steal all the valuables behind the guard's back while remaining undetected by the guard. When close to the guard one therefore has to sneak on tip-toes in order to make less noise. Outside the vault the users can walk normally, since the guard cannot hear them outside. This allows for a thrilling and suspense-packed experience that forces the user to be aware of their every move.

Conclusion

This demonstration proposes a new way to provide immersive auditory feedback in VR. *VRsneaky* is a low-cost solution for room-scale locomotion which offers synchronized and gait-aware step sounds that help reducing the gap between thee virtual and real world. We evaluated our approach through a user study in a scenario including a bank robbery - further specified in [2] - which showed an increase in perceived presence and depicted an alteration of gait metrics, such as stride length and walking speed (see Figure 2 and 5). We believe *VRsneaky* to be a great possibility for VR developers to be integrated with relatively less effort but huge potential for more immersive experiences.

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