Wind-Blaster: a Wearable Propeller-based Prototype that Provides Ungrounded Force-Feedback

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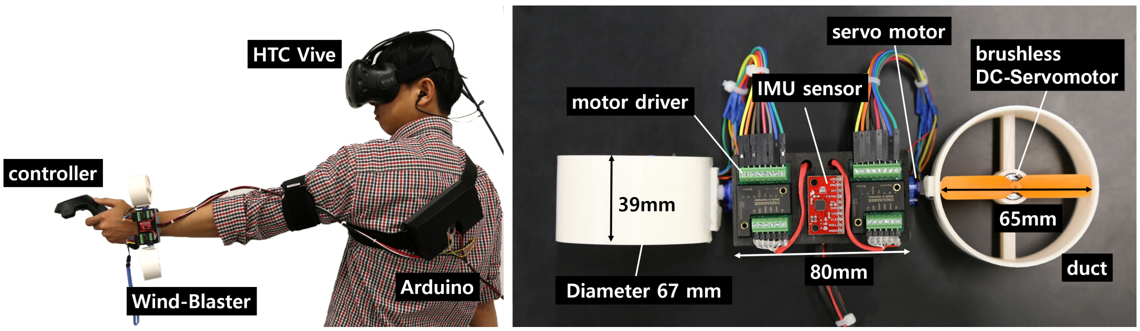

Figure 1: The Wind-blaster system (left), and the details of the hardware prototype (right).

ABSTRACT

Ungrounded haptic force-feedback is a crucial element for applications that aim to immerse users in virtual environments where also mobility is an important component of the experience, like for example Virtual Reality games. In this paper, we present a novel wearable interface that generates a force-feedback by spinning two drone-propellers mounted on a wrist. The device is interfaced with a game running in Unity, and it is capable to render different haptic stimuli mapped to four weapons. A simple evaluation with users demonstrates the feasibility of the proposed approach.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**;

KEYWORDS

Haptic feedback, ungrounded force feedback, wearable, propeller

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1 INTRODUCTION

Providing a realistic haptic force-feedback to enhance Virtual Reality (VR) applications is a challenging goal, pursued by both academic research and commercial products. The main challenge is that immersive VR applications require users to be free to move in a physical space, so that any force feedback should be ungrounded (not fixed to any specific place). Past examples of ungrounded wearable force-feedback devices include the usage of wires pulled through motors [Nagai et al. 2015], electrical muscle stimulation (EMS) [Lopes et al. 2017], air jets [Gurocak et al. 2003], and flywheels [Gugenheimer et al. 2016]. However, these methods share similar limitations. Systems that use motor-controlled wires and flywheels are generally heavy, while air-jets usually require bulky air compressors. EMS systems are more wearable but require calibrations prior usage.

We propose Wind-Blaster, a novel haptic wearable device that generates ungrounded force feedback using two propellers mounted on a wrist. Wind-Blaster is lightweight (166.7g) and suitable for VR applications that require high mobility of users, such as video games and immersive simulations. Moreover, it is capable of rendering a force of up to 1.5N, which is higher than the 1N threshold for ungrounded perception. In this paper we present the description of the prototype and a demonstration of how it can be used to enhance the immersive experience for VR games.

2 PROTOTYPE

Wind-Blaster is a propeller-based kinaesthetic haptic wearable device. It consists of two ducted-propellers, a main body, and a strap for fasting the device on the wrist. Two drone propellers (Hobbyking SKU-329000417-0, 65mm, CCW) are mounted on two brushless DC motors (Faulhaber 1226S012B) and placed in the middle of two

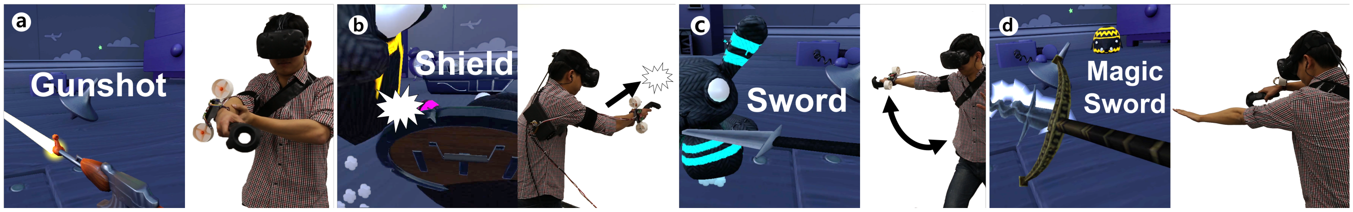

Figure 2: Haptic feedback for four types of weapons. From left to right: a shotgun, a shield, a showrd and a magic sword.

3D printed ducts (diameter 67 mm, height 39 mm), which are designed to maximized the airflow and prevent that the propeller blades accidentally hit the users. The two motors are capable of spinning up to 33,000rpm at 18V (1.18A), and are powered by two 5V motor drivers (Faulhaber SC1801S-3530). The motors speed is dynamically controlled using Pulse Width Modulation (PWM) from an Arduino board, and it is monitored through two magnetic encoders mounted on the motors. The motor drivers are placed on the main body strapped to the wrist. The main body (80x33x41 mm) also houses an IMU sensor (Sparkfun-MPU-6050), and two servo motors (SG-90) that control the orientation of the propellers. Our system continuously reads the inertial data from the IMU sensor and use it to compute the real-time tilting angle of the propellers, so to control the direction of the exerted force. Finally, the controlling electronics and the Arduino board are placed in a 3D printed box (90x175x50 mm) mounted on a shoulder-belt. They are interfaced through a USB cable and serial connection with a PC running an application written for the Unity game engine. The overall system is powered by an external power supply set at 18V DC.

At 33,000rpm, Wind-Blaster generates a force of 1.5N perpendicular to the propellers' axes, which was measured using a load-cell sensor (Variense FSE103). The propellers' airflow was measured with a UT362 anemometer and amounted to 10.8 m/s, while the noise was measured with a UT352 sound-level meter and amounted to 41 dB.

3 APPLICATION

To demonstrate the potential of Wind-Blaster as a wearable haptic device, we developed a first-person shooting game for VR, where the player can use four different weapons, each mapped to a different force-feedback. The game was developed using the Unity engine and the HTC Vive system, and it is a modified version of the *Survival Shooter* Unity tutorial. In the game, the user wears the Vive head mounted display and a pair of headphone for complete immersion and masking the propellers' sound. The Vive controllers are used to provide input functionalities, such as weapon selection and usage. The user can select among four weapons, each providing a different haptic feedback that we designed through iterative experimentations. Specifically we modulated the propellers using time- and intensity-varying patterns.

When the player presses the trigger of a shotgun, a single burst at the propeller's maximum speed (33,000rpm) and for a duration 250ms provides the sensation of firing a bullet (Figure 2a). When a user is attacked by an enemy and enables a shield (Figure 2b), Wind-Blast provides a continuous haptic sensation at the maximum speed for the whole duration in which the enemy is in contact with the shield. In both these two cases, an haptic feedback was achieved by simply modulating the duration of the Wind-Blast activation. More complex haptic feedback are possible by modulating also the intensity of the feedback. For example, when the player swings a sword (Figure 2c) a feedback of decreasing intensity is generated to simulate the sword's inertia. The swing corresponds to a 700ms feedback with the propellers spinning at maximum speed for 300ms, and then linearly decreasing their speed for 400ms until they stop. Finally, the feedback of using a magic sword (Figure 2d) is modulated as sine wave (200ms from halting position to full speed, 200ms at full speed, and 200ms to stop the propellers' blades).

4 EVALUATION AND CONCLUSIONS

We conducted a preliminary evaluation with four users (3 females, average age: 25.75, SD: 0.5). Participants' reactions and comments indicate that Wind-Blaster transmits force feedback and increases enjoyment in the VR game. However, participants responded that the strength of force feedback of the gun and shield were weaker than expected. Interestingly, a participant responded that in the sword feedback the resistance of the air could be felt and made the experience more realistic.

In this paper we presented a novel wearable and ungrounded haptic devices capable of generating force-feedback using the trust of two propellers mounted on the wrist. We described the system and demonstrated its feasibility through an immersive VR game application with four different force feedback stimuli generated by modulating the duration and speeds of the propellers. The main limitations of the system are the limited set of haptic stimuli currently supported, and the systems power requirements. Future work will investigate the usage of batteries and different propellers designs.

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