Demonstration of Drag:on – A VR Controller Providing Haptic Feedback Based on Drag and Weight Shift

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Figure 1: Different states of the *Drag:on* controller that participants can experience in this demonstration, differing in surface area and weight distribution.

Abstract

While standard VR controllers lack means to convey realistic, kinesthetic impressions of size, resistance or inertia, this demonstration presents *Drag:on*, an ungrounded shape-changing interaction device that provides dynamic passive haptic feedback based on drag, i.e. air resistance, and weight shift. *Drag:on* leverages the airflow at the controller during interaction. The device adjusts its surface area to change the drag and rotational inertia felt by the user. When rotated or swung, *Drag:on* conveys an impression of resistance, which we previously used in a VR user study to increase the haptic realism of virtual objects and interactions compared to standard controllers. *Drag:on*'s feedback is suitable for rendering virtual mechanical resistances, virtual gas streams, and virtual objects differing in scale, material and fill state. In our demonstration, participants learn about this novel feedback concept, the implementation of our prototype and can experience the resistance feedback during a hands-on session.

Author Keywords

Haptic virtual reality controller; dynamic passive haptic feedback; shape-changing devices; air resistance feedback.

CCS Concepts

•Human-centered computing → Human computer interaction (HCI); Virtual reality; Haptic devices;

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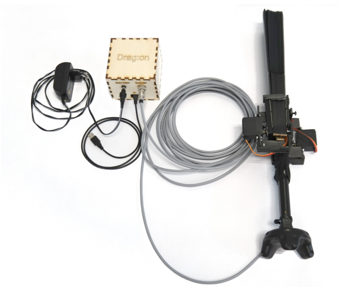

Figure 2: Top: The *Drag:on* is connected with a long cable to a box holding the microcontroller and circuits. Motor power is provided by an external power adapter. Bottom: A servo motor and connected arm opening a fan.

Introduction

To experience the real world, we heavily rely on our visual, auditory and haptic senses. For virtual reality (VR), head-mounted displays (HMDs) and headphones enable users to perceive virtual environments (VEs) visually and auditorily in immersive ways, but today's VR systems only provide very limited haptic impressions. Lightweight hand-held controllers for consumers primarily offer vibrotactile feedback but cannot provide different kinesthetic impressions such as the feeling of weight, resistance or inertia. In this demonstration, we present a novel and unique concept for providing such haptic effects for VR, showcasing a combination of air resistance and weight shift as a means of generating haptic feedback.

Past research investigated different approaches to haptics in VR, ranging from complex active haptics using robotic actuation [2] to purely passive haptics using physical props [1]. We recently introduced a mixed haptic feedback concept called *dynamic passive haptic feedback (DPHF)* that aims to combine the strengths of both active and passive haptics while minimizing the drawbacks of both approaches [4]. Dynamic passive haptics relies on transforming physical props that use simple actuation to reconfigure themselves. Through this transformation, DPHF props dynamically adjust their passive haptic feedback to optimize their haptic response, enhancing immersion in VR. Recent research especially focused on techniques that can be integrated in hand-held controllers [3, 4, 5].

In this demonstration, we present the novel shape-changing VR controller *Drag:on* [5], which leverages the airflow that occurs at the controller during interaction to provide a range of different haptic sensations. *Drag:on* is an interaction device based on the DPHF concept in the form-factor of a VR controller. The device can increase or decrease its surface area and by this also adapts its mass distribution. For this, *Drag:on* uses actuators only to change the physical configuration of the device to change how it feels when moved through the air.

This demonstration aims to introduce the underlying haptic feedback concept and our low-cost and mechanically simple prototype implementation to demo participants. In our demo, participants can get hands-on with the *Drag:on* to feel the resistance feedback produced during swing and roll movements. This demonstration focuses on the physical device and its feedback, and will be presented without a VR application or the need to wear an HMD. By this, we make it possible for groups of participants to experience the feedback, see the physical prototype design at work and learn about this novel and unique concept to generate kinesthetic haptic sensations. The hands-on demonstration is accompanied by explanations of the demo presenter and explanatory video footage.

The full paper about *Drag:on* was published at CHI 2019 [5] and contains more details about the concept, device and evaluation results. The device itself has not been previously presented as an interactive demonstration on any scientific conference.

Drag:on – Design & Implementation

Feedback Concept

During many VR interactions, users swing, drag, throw or rotate virtual objects. Doing so, rotational and translational motions are performed with the controller (see Figure 5), during which an air stream forms at the device as the user pushes its resisting surface through the air. The central feedback concept of *Drag:on* is to adjust this surface area to produce different sensations of resistance when the controller is moved.

To achieve this, the device transforms its shape to adjust its surface area at runtime. *Drag:on*'s unique fan-based design leverages foldable surfaces, i.e. two fans (Figure 1), and is mechanically simple, low-cost and easy to replicate. During interaction, the fans are opened and closed symmetrically or asymmetrically on the left and right side of the controller. These transformations change *Drag:on*'s air resistance but also its mass distribution, which affects its haptic response when rolling or swinging it and can be felt by the user.

Prototype Implementation

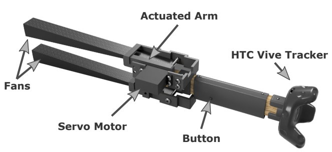

Figure 3: 3D rendering of the *Drag:on* prototype.

The 3D rendering in Figure 3 shows the main components of the *Drag:on* device. The actuation mechanism depicted in the bottom image of Figure 2 is located at the top end of the controller. Both sides hold an MG996R servo motor using custom 3D-printed parts, each actuating a 3D-printed arm attached to the topmost layer of a commercially available flamenco hand fan. The fans are $31cm$ long and made out of wood and fabric. The bottommost layer of the fan is rigidly attached to a 3D-printed support structure. By actuating the servo, the arm opens or closes the fan.

The top image in Figure 2 shows the prototype with its main system components. The device is connected to a controller box containing an Arduino Nano microcontroller and the necessary circuits. An external power adapter connects to this box to provide $7.6V$ to the motors. The Arduino can interface with a PC via USB serial communication (115200 baud). *Drag:on* can increase its surface area by up to $\frac{2400cm^2 - 320cm^2}{320cm^2} = 650\%$ in $570ms$.

Virtual Reality User Studies

To evaluate *Drag:on*'s feedback, we performed VR user studies [5] in which we explored rotational and translational controller movements. We let participants interact with *Drag:on* in five different interactive VR scenarios and could

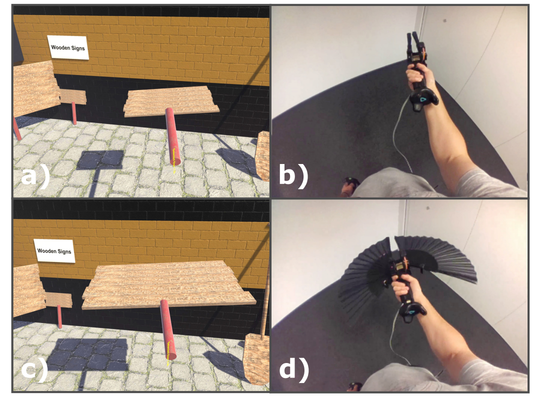

Figure 4: One of the VR user study scenarios: a) the avg. virtual object scale (1.33) participants associated with b) the *closed* state is significantly smaller than c) the avg. scale (2.38) associated with d) the fully *opened* state.

show that *Drag:on* delivers distinguishable levels of haptic feedback. We demonstrated that its resistance feedback is suitable for enhancing the perception of virtual objects differing in scale (see VR example in Figure 4) or material, and even for perceiving relative differences in the strength of virtual gas streams. *Drag:on* further improved the perception of resistances felt when turning virtual ratchets and of the weight felt when moving virtual wagons, which significantly increased the haptic realism compared to standard VR controllers. More details about the evaluation are available in the full publication about *Drag:on* [5].

Hands-on Demonstration of *Drag:on*

Goals

This interactive demonstration focuses on the design and implementation of *Drag:on* [5], as well as its unique feedback approach. As such, the demo aims to

1. make demo participants familiar with the novel drag- and inertia-based feedback concept behind *Drag:on*.
2. let demo participants physically experience the resistance effects *Drag:on* can achieve when *rolling* and *translating* the device (Figure 5).
3. allow demo participants to observe the 3D-printed mechanics implemented in our prototype at work.

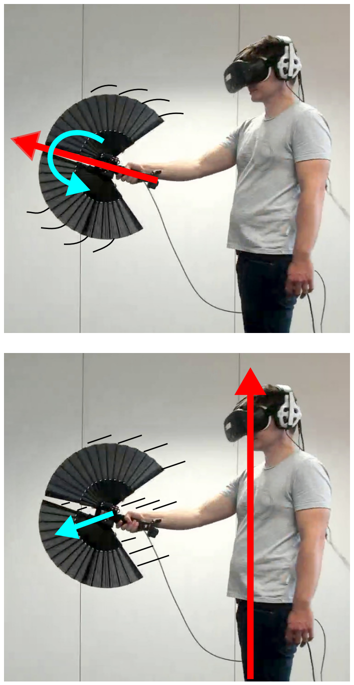

Figure 5: The two demonstrated types of interaction with the movement direction (blue), the rotational axis (red) and the motion (black lines) highlighted. Top: rotational movements (rolling the controller). Bottom: translational movements (swinging the controller).

Demonstration

To realize this, our demo is organized to allow for small groups of up to 5 people to be introduced to the *Drag:on* concept and device at once. Participants will first be made familiar with the current state-of-the art in the field of commercial VR controllers, their capabilities and limitations through video footage, hands-on with a standard VR controller and explanations of the presenter. Upon that, participants will be introduced to the novel feedback concept of *Drag:on* and its unique design. The presenter will explain in detail how the feedback is achieved when *rolling* and *translating* the controller, and how this feedback was used in the VR user studies to enhance the perception of virtual objects. This explanation is accompanied by illustrative video footage and renderings. After this introduction, each participant will have the chance to interact with the *Drag:on* device and physically feel the different resistance effects it can achieve when rolled and translated in *three symmetric* (closed, half-opened, fully-opened) and *two asymmetric* (right-opened, left-opened) states.

This demo is intentionally designed to not involve a VR installation, as this allows to present the most important aspect, i.e. the haptic effects of the device, in a much more time efficient way, allowing more participants to get hands-on with the *Drag:on*, learn about its unique feedback concept and physically experience the device itself. By focusing the demonstration on the device and leaving the interaction in the real world, the demonstration is more inclusive, as there is no need to wear an HMD while fostering face-to-face discussions amongst demo participants and the demo presenter during the experience.

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