Smart Devices as Proxy Objects for Virtual Reality Position Paper

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Figure 1: A smartphone is tracked by external camera installed on VR headset. This allows the device to be overlaid with virtual information, rendering the device a smart haptic proxy object.

ABSTRACT

Previous work has shown that the integration of everyday proxy objects into virtual reality improves the virtual experience in terms of feedback and immersion. However, challenges remain in the tracking of everyday objects and in the limited generality of basic static proxies. Smart devices are ubiquitous nowadays and as we believe can address these challenges. In this position paper, we review related work and offer a discussion about the role of our smart devices in virtual reality (VR). To study this concept, we build a framework that allows a smart device to be tracked in VR such that users can use its features for input, control, and feedback. We envision future applications to include a wider range of smart everyday objects.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Ubiquitous computing**; **Haptic devices**.

KEYWORDS

Proxy objects; virtual reality; position paper.

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1 INTRODUCTION

Virtual Reality (VR) solutions are slowly being integrated into everyday life as they gradually find their place on the consumer market. While being immersed in a virtual environment (VE), a user is able to experience exciting artificially created worlds in a convincing manner. Moreover, VR technologies have proven to increase task performance, specifically for education, sports, and entertainment. However, there exists a disconnect between the VE and the world

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of everyday physical objects, devices and technologies around us. We propose to make these worlds meet by investigating the problems that arise, the approaches that can be introduced to support the connection between the worlds, and the potential benefits this blend can bring for users.

While previous work has already attempted to utilize real-world objects in VR, most approaches cannot be immediately used on the consumer market. Challenges remain in tracking, control, and feedback, many approaches are expensive or not universal enough. We focus on the concept of using everyday objects to improve the experience in VR. To limit the search, we defined the list of criteria that these objects should meet. First of all the objects should be available in most environments. The objects should provide additional features to support VR experience. And at last, the objects can be positioned and tracked in VR. We can find a number of potential objects like TVs, robot vacuum cleaners, smart home devices, air conditioners, coffee machines, smartphones, tablets, smartwatches, and so on. All these objects fulfill preset criteria and can withstand a deeper discussion on how their features can improve VR experience.

Currently, we are focused on building a framework that allows your phone, tablet, or smartwatch to be tracked in VR such that you can use its features and physical body for input, control, and feedback. Smartphones possess a number of potentially useful features like touch input, vibration, proximity sensor, audio output. It is fair to expect that over time smartphones will get even more functionality and hence can be used in VR with more flexibility. The additional strong point which motivates to use smartphones in VR is the fact how people attached to their devices and know them very well. While currently, our approach focuses on smartphones, we envision future applications to include a wider range of smart everyday objects.

2 RELATED WORK

To motivate and frame our approach, we shortly review work related to our methods.

2.1 Haptic Interaction in Virtual Reality

Researchers have attempted various approaches to mitigate the lack of haptic information in VR. Ideally, a haptic interface has to translate both tactile and kinesthetic sensations to the user. However, there is no general solution to provide haptic feedback for every possible virtual object. Instead, depending on the application, there are different approaches how to address the task, focusing on the either tactile or kinesthetic aspect. These approaches can be divided into three categories, namely *active*, *passive* and *hybrid* approaches [4], depending on how haptic feedback is translated.

The concept of active haptic feedback assumes leveraging computer-controlled actuators to provide force or tactile feedback. Devices with active haptic feedback continuously react to user actions and provide haptic feedback based on a description of the virtual objects in the scene. In the simplest way, active haptics can simulate touch events by providing vibration sensations to the skin. While this mechanics cannot simulate forces, it provides haptic ques. Devices with mechanical actuators add force feedback to the user, they can restrict fingers movement if they are in contact with a virtual surface and able to render physical object shape. Grounded interfaces, in turn, can exert forces on the fingers and the hand, this way weight and inertia of the virtual objects are simulated realistically as well.

A good balance of complexity and haptic fidelity is present in the PHANToM haptic interface [16]. The device tracks the user's fingertip movement and continuously checks for collisions with objects in a VE. After a collision, the device exerts forces on the finger, creating the illusion of contact with a physical object. Both tactile and kinesthetic sensations are part of the experience offered by Game Racing Wheel by Logitech[1]. Actuators simulate steering resistance in turns and vibrotactile feedback hints if the car is off the track.

Unlike the Active Haptics approach, Feedback in Passive Haptics is rendered using static physical objects. Both tactile and kinesthetic sensations are delivered through tangible so-called proxy objects — physical counterpart for a virtual object [10]. A proxy object do not necessarily need to replicate every detail of its virtual counterpart. When visual and tactile perception channels are in conflict, but the difference is not too large, then visual information will dominate over tactile [24]. This phenomenon is called *visual capture* or *visual dominance* [10].

The vanilla passive haptic feedback approach is limited in terms of generalization and scalability. For every unit of a virtual object ,the user interacts with there should be exactly one physical proxy object. The aforementioned phenomenon of visual dominance opens the doors for researchers to experiment with different approaches to overcome the limitation of passive haptics. Simeone et al. in their work introduce the concept of *Substitutional Reality* providing extensive analysis and recommendations on incorporating physical objects in VR [21]. Another technique that helps to reuse the same physical prop is *haptic retargeting* [2]. In larger scale locomotion experiments, a similar methodology perceptually increases the virtual space and allows to reuse passive haptic prop in VE [13, 15, 18]. Features of human vision, in particular, temporal blindness between saccades can be used to imperceptibly synchronize the virtual world with the real environment [22].

Purely active and purely passive approaches have their limitations. Active haptic devices often are not realistic, complex, bulky, and rather expensive, when passive haptic devices are lacking generality. To overcome this, research has focused on hybrid approaches. The concept of hybrid haptics assumes the usage of passive props together with computer-controlled actuators to make the proxy multipurpose, altering its physical or tactile properties such as inertia, weight distribution, temperature, or texture feel.

A class of approaches in this direction is *Dynamic Passive Haptic Feedback (DPHF)*. In the DPHF paradigm devices do not exert forces directly on the user, but alter their own properties, like a shape or weight distribution in order to change user perception [26, 27]. Excepting DPHF, there exist other types of hybrid haptics, for example, *encounter type haptics (robotic graphics)*. In this approach actuators continuously move passive proxy with respect to the user position and pose, and predicting where the user's interaction will happen [1].

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[1] www.logitechg.com/products/driving/driving-force-racing-wheel.html

The focus of our work is on the integration of smartphones into VR to improve the experience in one way or another. One of the possible function of the smartphone is to serve as a basic passive haptic feedback prop. Except having a physical body, smartphones can translate vibrotactile feedback using a build-in vibromotor. Some models of the phones are sensitive to how hard it is gripped or how hard the screen is pressed, it can be used in providing visuo-haptic feedback.

2.2 Everyday Objects for Interaction

Interaction is a major part of our perception of the environment, be it real or virtual. As in real life, any interaction assumes some interface. In VR we are limited in terms of available tools for interaction with the simulated environment.

The concept of Instant User Interfaces presented in the work of C.Corsten et al. shows how everyday objects could be reconsidered as input devices in real life, when a dedicated controller is missing or out of reach [8]. In the WorldKit system by R. Xiao et al. [25] authors show how to use any everyday surface for interaction with touch-based interfaces. In one of the authors' example applications, they use a living room table to project an interface for controlling a TV-set. M. Hachet et al. [9] propose an approach called opportunistic music as an alternative to traditional physical and graphical interfaces for music writers. This work focuses on blending fine-control of physical devices together with the flexibility of graphical interfaces. The authors show how different office supplies can be turned into widgets for music control. Moving a staple box along a magazine, stretching the folder's rubber band, or adjusting a table-lamp; all these actions with naturally constrained affordances are mapped to music-controls with similar behavior.

iCon system is focused on using everyday objects as auxiliary desktop controllers [6]. According to their field studies, they found that almost no one keeps their working desk empty; smartphones, wallets, water bottles, and stationery were among the typical objects on a table. Using designed software users can bind certain functions to click, rotate, or drag gestures performed on the everyday objects. These objects are tracked by the system and serve as an input controller for the current user's task. By design, everyday objects cannot compete in input precision with a mouse or keyboard but can help in secondary tasks, like changing context when multitasking, zooming in and out in a photo viewer, or for some background processes, like music playback control.

One of the challenges in bringing everyday objects to use in the digital world is the lack of knowledge about them. Digital systems typically do not possess any information about position, shape, material, and other features of the real object. Researchers in MIT Media Lab came up with a solution to how everyday objects could be identified and used in learning tasks [7]. The authors presented a device with an integrated RFID reader, the device is worn on the user's hand and can support different gesture-based interactions when the user grabs some RFID-enabled object. This enables users to create tangible user interfaces using objects of their taste.

In the following example, authors turn everyday objects into game controllers for a pervasive gaming experience [28]. In this work, a "smart" clamp is attached to a household object and maps physical actions with real objects into game-events. Instead of using gesture based abstract control like Wii Remote, authors offer to transform everyday objects into game-controllers.

I/O Brush by K.Ryokai et al. is another example of how everyday objects can be used to support the connection between the real and the digital worlds [19]. The design of the I/O Brush resembles a typical paintbrush and contains a video-camera, touch sensors, and light bulbs inside. The device is designed to pick up color or texture from real surfaces and paint using the picked-up sample on a large Wacom Cintiq screen.

Bringing everyday objects into virtual reality is a relevant topic in research for a number of reasons: First, physical objects provide haptic feedback. Second, familiar affordances and functionality of everyday objects help interaction in VR, supporting presence and plausibility. And last but not least, this approach does not require any additional equipment and keeps the environment unchanged.

The concept of a substitutional reality approach leveraging the use of everyday objects is presented in the work by Simeone et al [21]. The idea is to replace every physical object in the environment with its virtual counterpart in virtual reality. This setup provides users with a virtual environment that is fully tangible. Authors then increase the level of mismatch between the real and virtual objects in different layers to investigate how these changes impact the believability of experience. Starting from the exact virtual replica, followed by minor changes in aesthetic, then geometry alteration, changes of functionality, and at last, placing the virtual object into a completely different category compared to its real counterpart. Conducted studies showed that in some scenarios participants even preferred approximation of a virtual object instead of a complete physical replica. For example, they choose a flashlight as a real counterpart for a virtual lightsaber, while an exact physical replica of the lightsaber was rated lower due to heavy weight [21].

A complete pipeline to generate a virtual environment based on the real surrounding was presented in the Reality Skins paper [20]. In this work, the virtual environment is generated based on the on-the-fly 3D reconstruction of the objects in the room. Real objects are semantically interpreted and replaced by virtual analogue suitable for this particular in-game style. Reality Skins solves several problems at once: it uses available user's space; reduces mismatch between real and virtual environment; introduces haptic feedback; improves presence and helps to avoid unwilling collisions with objects in the room. When it comes to interaction with the real objects a number of researches [14, 21] showed that for a proxy object being as close in its shape and size to its virtual counterpart is crucial for the user's suspension of disbelief. Authors of the concept of Annexing Reality are focused on objects in their work, rather than on the environment. Their framework seeks for suitable shape in the user's surroundings and minimizes mismatch in size by scaling the virtual object towards its physical proxy.

Purpose-centric appropriation of everyday objects as game controllers was presented by Todi et al [23]. Since we know how these objects affect real life, if we use them in a game we can naturally transfer their functionality toward virtual objects. Thanks to the direct association virtual function of these tangible objects is easily predictable and can potentially improve usability and immersion.

Mobile devices is another group of everyday objects that has rich integration potential. A wide and yet expanding set of input and output sensors can serve as a good basis for interaction. The built-in accelerometer can be efficiently used as a 3DOF pointing device for public displays [17] or for mobile HMD systems [11]. With the expansion of SLAM technology on mobile devices, it is possible to use a smartphone as a full-fledged 6DOF controller [3]. A combination of optical tracking and SLAM for positioning and tracking a smartphone with relation to the HMD is presented by Mohr et al. In both previous works, authors use the touch-screen as a complement to positional tracking for additional input, like rotation.

In the recent work, Y. R. Kim and G. J. Kim use a smartphone with a hovering function to improve the user experience when typing on a smartphone's touch-screen in a virtual reality setting [12]. Boustilla et al. employed the confirm-on-release paradigm as a form of visual feedback when typing on a touch screen in virtual reality [5]. Despite smartphones do not outperform VR controllers in the given studies, it shows competitive performance and clearly is a more familiar and directly available input device.

3 SMART MOBILE DEVICES AS PROXY OBJECTS IN VR

Our work focuses on utilizing smart devices around us as proxy objects to improve immersive virtual experiences. First, we explored how the lack of haptic feedback is being addressed with existing approaches. Then we did an overview of the work related to the topic of using everyday objects in VR. This analysis can serve as a source of inspiration for our main topic of discussion: using smart everyday objects in VR. To set discussion outlines, we also set requirements towards the feature of the proxy objects. Devices such as smartphones and tablets can be tracked; they are connected so can communicate with the virtual environment and have active tactile capabilities as they can track touch and respond with vibrations.

In our current approach, see Figure 1, we are investigating adaptive visual tracking methods using a ZED mini as an external camera attached to the VR headset. Depending on the distance to the VR headset, the accompanying app on the smartphone displays optical markers of suitable size. This setup serves as a sandbox for testing ideas and use cases of how smartphone features can be used in VR. With the expansion of VR headsets that use inside-out tracking, we envision this technique to be compatible with common HMD setups. We can use smart devices as a haptic proxy with visual overlays, as a versatile input device, or for immersive notifications handling in VR. We consider these directions as most promising for further discussion.

In the workshop on Everyday Proxy Objects for Virtual Reality, we would love to discuss our ongoing work and receive input and feedback from the community.

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