Streaming Haptic Feedback in Multiplayer VR Games via 5G

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Omar Abdellatif[1]

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[1] omar.abdellatif@stud.hshl.de

Abstract: The rapid evolution of Cyber-Physical Systems (CPS) has enabled novel ways of connecting human users with digital environments through real-time physical feedback. In this context, haptic feedback in Virtual Reality (VR) environments represents a powerful method for enhancing immersion and interaction, especially in multiplayer scenarios. However, delivering reliable and ultra-low-latency tactile feedback remains a significant challenge. This paper investigates the integration of 5G networks into VR-based CPS applications to support streaming haptic feedback in real time. By leveraging 5G features such as Ultra-Reliable Low-Latency Communication (URLLC) and edge computing, we propose a system architecture for enabling tactile interaction across networked VR environments. Through this approach, we demonstrate how human sensations and actions can be transmitted, synchronized, and experienced with minimal delay, opening new opportunities in gaming, training, and remote collaboration. The findings contribute to the broader goal of enabling responsive and immersive CPS with seamless cyber-physical feedback loops.

1 Introduction

With the rapid expansion of commercial fifth-generation (5G) networks and the anticipated arrival of 6G technology by 2030 [RP22], the demand for ultra-reliable low-latency communications (URLLC) growing, aiming to achieve end-to-end latencies of 1–5 milliseconds or less, thereby replacing conventional connectivity methods.In 2010, the United States enacted the Communications and Video Accessibility Act, which mandates that modern communication technologies and video broadcasting services be accessible to individuals who are deaf, blind, or deaf-blind. While the Act's relevance to video game streaming has not yet been directly addressed, video game systems are currently included under its scope. This suggests that video game streams might also fall under its requirements in the future. If so, the concepts discussed here could help ensure such streams meet accessibility standards.[Mo16]

2 From Virtual Worlds to Physical Feedback

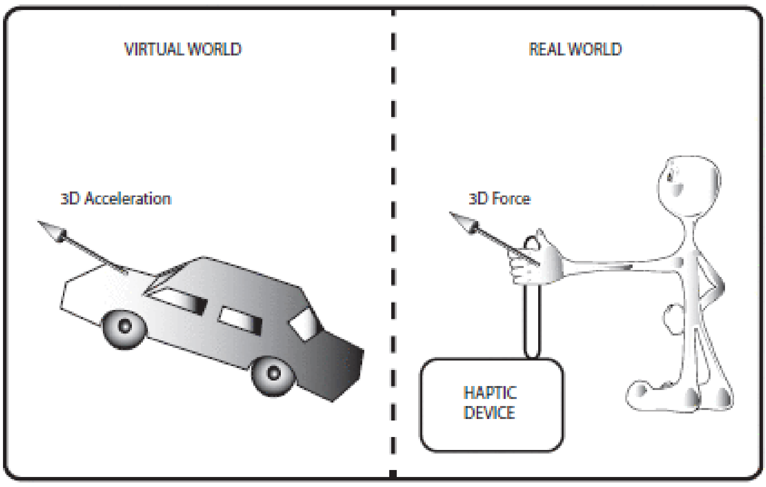

Fig. 1: Illustration of haptic feedback in a virtual environment [Ri06]

In a physical environment, many studies have proposed that feedback is important during reach-to-grasp movements [Fu19]When we reach out to grab something, our brains take into account a variety of details — not just where the object is located (its position in space), but also what it's like physically, such as its shape and size. These kinds of actions become more complicated in virtual environments because the rules of interaction aren't exactly the same as in the real world. In virtual settings, we might be dealing with virtual objects, physical objects, or a mix of both — and the kind of feedback we get from them can influence how well we perform simple tasks like reaching and grasping. That's why it's important to figure out which types of feedback matter most in virtual environments, especially if we want to design systems that feel just as natural and effective as real-life interactions. Still, there's surprisingly little research out there that looks closely at how physical and virtual feedback affect the way we interact in these digital spaces.[Fu19]Haptic basically means how we use our sense of touch to explore or interact with the world around us like feeling something to learn about it or moving things around.[SL97],These haptic interactions can cover many subjects such as reaction forces and tactile stimuli as well as temperature and motion[Ri06]

- **Temperature Feedback**
  Feeling warmth or cold in VR environments to enhance realism.
- **Biometric Feedback**
  Using heart rate, breathing, and other body signals to adapt experiences in real-time.
- **Spatial Feedback**
  Guiding users through space with directional sound or subtle vibrations.

- **Emotional Feedback**
  Detecting users' emotional states through voice or facial cues to personalize content.
- **Customisable Feedback**
  Letting users fine-tune intensity, scent, and other sensory settings for a tailored experience.
- **Full-body Feedback**
  Using wearable tech to simulate physical sensations across the whole body.
- **Multi-sensory Integration**
  Combining visuals, sound, touch, temperature, and scent for a fully immersive VR experience.[Te23]

3 System Architecture for Haptic Streaming

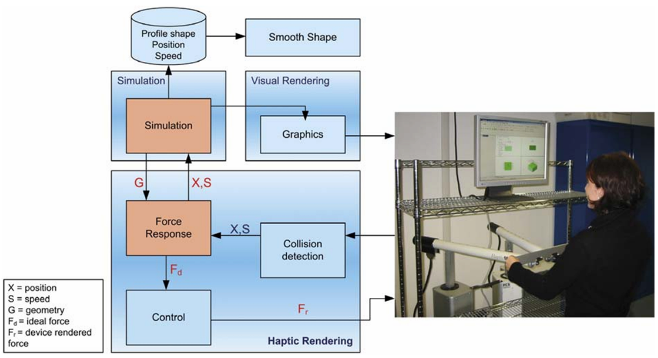

Fig. 2: System Architecture for haptic feedback
[Ch06]

The system architecture, illustrated in Figure 2, is composed of several key components that work together to enable an immersive and realistic haptic modeling experience. At its core is the FCS-HapticMaster, a high-fidelity haptic device operated by the user. This device is equipped with specialized tools designed to support design and modeling tasks. When the user interacts with a virtual object, the device responds by rendering realistic contact and reaction forces. These forces vary based on the nature of the collision and the physical properties of the simulated material, creating an intuitive sense of touch within the virtual environment.[Ch06]

The haptic rendering system handles the complexity of this interaction. It includes a collision detection module, which identifies contacts between the virtual representation of the haptic device (also known as the avatar) and the virtual object. Once contact is detected, a force response module calculates the interaction force, and a control module translates this into a haptic response that the user can feel—adapted to the limits of the physical device's capabilities.

A simulation engine manages the dynamic updates of the object's shape based on the tool's motion, speed, and position. For efficiency, the engine operates on a simplified version of the geometry during the interactive session, which is later smoothed into a refined shape when the session concludes.

The haptic tools themselves were designed through a user-centered approach, drawing on technical requirements and practical modeling needs. The project introduced two specialized tools: a scraping tool, which allows for virtual material removal similar to sculpting with a real rake, and a sandpaper tool that lets users gently smooth curved surfaces, with the added benefit of tactile feedback that reflects the surface's curvature.[Ch06]

Most conventional haptic systems support only three degrees of freedom (DOF), which limits interaction complexity. However, to accommodate more advanced tasks that require full six-DOF manipulation with both force and torque feedback, this system leverages the FCS-HapticMaster's unique capabilities. It offers a five-DOF powered interface with a six-DOF virtual tool, enabling detailed manipulation in a workspace roughly the size of a human arm's reach. The first tool implemented in the system closely resembles a physical rake, allowing users to grip and maneuver it in a familiar, intuitive way, bridging the gap between virtual and real-world modeling.[Ch06]

A study proposed a system architecture for real-time streaming of visual and haptic feedback using a Kinect sensor, a haptic controller, and Web Real-Time Communication (WebRTC), The system integrates multimodal data streams—specifically, color and depth information from the Kinect sensor and force-feedback data from the haptic device—within a browser-based environment.[Pa15] The Kinect sensor captures both color and depth frames, which are transmitted to a dedicated Kinect webserver responsible for data streaming. This information is then forwarded to a browser application that simultaneously communicates with the haptic controller, sending device position data and receiving force feedback. This closed-loop interaction enables users to manipulate virtual objects in a physically meaningful way, enhancing immersion and realism.

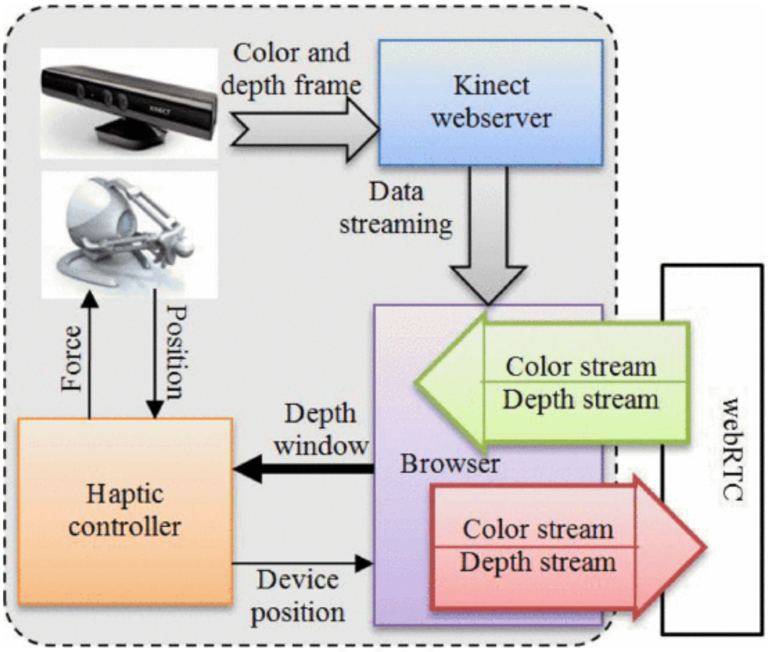

Fig. 3: System Architecture for haptic feedback
[Pa15]

The depth window rendered in the browser is aligned with the haptic device's position to maintain spatial coherence between the visual and tactile feedback. The use of WebRTC ensures low-latency, peer-to-peer transmission of visual data to remote clients, allowing real-time interaction and visualization. This architecture demonstrates the feasibility of supporting applications such as remote surgery simulation, telepresence, and collaborative virtual environments through the integration of spatial visual feedback and physical interaction cues in a networked context.[Pa15]

4 Security and Reliability Concerns

The underlying network must be architected for both low latency and security. Modern VR/haptic systems leverage 5G/6G technologies: network slicing can reserve an ultra-reliable low-latency (URLLC) path for haptic data, while Software-Defined Networking (SDN) and Network Function Virtualization (NFV) allow on-demand creation of secure "haptic slices"[SL97] In practice, a VR haptic application might run over a virtualized core with strict QoS and encryption, or use a dedicated VPN/VXLAN to the cloud. Edge or cloud servers processing haptics are placed behind firewalls and often in "trusted zones," but all traffic should still be end-to-end encrypted[Sa17] For lower layers, some proposals include physical-layer security (e.g. directional antennas, beamforming in mmWave/THz) to make eavesdropping harder, although cryptography remains primary. Wide-area deployments may even use authentication tokens or SIM-based credentials for device validation. Overall, a secure haptic network combines: low-level link encryption (e.g. WPA3 for wireless VR), network-level isolation (5G slices or VPNs), and end-to-end crypto protocols (TLS/DTLS/QUIC) to protect the data as it traverses multiple hops.[Ro24]

5 Outlook and Conclusion

Virtual and augmented reality (VR/AR) systems are among the most rapidly advancing fields in modern technology, driven by a diverse range of impactful applications—from immersive entertainment and social interaction to healthcare, advanced training, and human–machine collaboration. Traditionally, haptic feedback in these systems has centered around the hands, using tools like gloves, handheld controllers, or finger sleeves to deliver tactile interaction. However, a newer and increasingly prominent direction in this field involves the development of large-area, skin-integrated devices that allow touch-based feedback across the entire body. This approach aims to create a deeper sense of presence and realism by incorporating the sense of touch into a full-body VR/AR experience, moving beyond the visual and auditory cues that currently dominate.

This vision depends on the advancement of soft, skin-like haptic platforms that are lightweight, minimally invasive, and capable of conforming to curved and sensitive parts of the body without restricting natural motion. Ideally, such systems would operate at high speeds, with precise programmability, and could be used either independently or integrated into wearable garments. Research in this area spans multiple domains, including soft materials, actuator design, low-profile electronics, power delivery, and wireless data communication. The ultimate goal is to enable touch-based interaction in virtual environments that feel as natural and rich as real-world experiences—something current screens and speakers cannot fully replicate.

Importantly, while visual and audio technologies in VR/AR have seen significant refinement over the years, haptic interfaces are still in an early stage of development. This leaves ample room for groundbreaking innovations that could dramatically enhance user immersion, functionality, and realism. As such, full-body haptic systems represent a critical frontier in next-generation VR/AR research and development.

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