Eliciting Care for Virtual Objects: A Work-in-Progress on Pseudo-Haptic Fragility via Dynamic Visual Feedback and Direct Hand Interaction

João Anisio Marinho da Nobrega, Davi Duarte de Freitas, Gabriel Paes Landim de Lucena,
Marcos Arthur da Silva Melo, Felipe Fausto Azevedo de Lima, Alyson Matheus Carvalho de Souza

UFRN / AKCIT IMD
Natal RN, Brasil

joaoanisiomn@gmail.com, davi.duarte11@gmail.com, gabriellucena23@gmail.com,
marcos.marcos.arthur291@gmail.com, fellipe.fausto10@gmail.com, alyson@imd.ufrn.br

Abstract. This paper presents a work-in-progress on a virtual reality (VR) system designed to elicit a sense of "care" towards virtual objects without relying on traditional haptic hardware. Our method translates the user's physical grip strength into a dynamic, multi-layered feedback system: a diegetic UI on a robotic hand visualizes the applied force, while a procedural shader generates real-time micro-fractures on the object's surface. This approach aims to create a credible perception of fragility and measurably promote "careful" user behavior, exploring a novel, perception-based pathway for emotional and behavioral response in VR. The system uses Unity and the Meta SDK on Meta Quest 3, focusing on planning a user study to evaluate the impact of incremental sensory feedback. The outcomes of this project have the potential to provide designers with evidence-based techniques for creating more nuanced and emotionally compelling virtual experiences.

1. Introduction

Virtual Reality (VR) is evolving from a simulation tool into a platform for profound human experiences. With accessible Head-Mounted Displays (HMDs), the focus in Human-Computer Interaction (HCI) has shifted from **if** a user can manipulate virtual objects to **how** that interaction feels and what emotions it evokes. While touch is key to realism, high-fidelity haptics remain largely inaccessible. In the Brazilian academic context, this challenge is addressed through innovative applications in health, with VR exergames for motor physiotherapy (De Agostini et al., 2019), and education, using serious games for students with ADHD (Júnior et al., 2024). These works highlight the strategy of using strong visual and auditory feedback to guide interaction in the absence of physical haptics.

This approach aligns with the principle of **visual dominance**, a robust perceptual phenomenon where, in cases of sensory conflict, the brain preferentially weighs visual information. This effect, often termed "visual capture," is the foundation of pseudo-haptics—the use of visual stimuli to create illusory tactile sensations (Lécuyer et al., 2000). Our research extends this concept to ask the central question: *Can carefully designed, dynamic visual feedback, delivered via controller-less hand interactions, substitute for physical haptics to create a believable perception of an object's fragility and measurably promote "careful" user behavior?.*

This paper documents our work-in-progress towards answering this question. We first review the state-of-the-art, then detail our system's implementation, the challenges encountered, and our current development status.

2. Related Work

Our work is built upon two established research areas: pseudo-haptic interaction and the visual communication of material properties.

2.1. Pseudo-Haptic Feedback

Pseudo-haptics induce illusory sensations by creating a controlled discrepancy between a user's physical actions and their virtual representation (Lécuyer et al., 2000). The field primarily focuses on simulating weight and resistance through several well-documented techniques. A foundational method is the manipulation of the **Control/Display (C/D) ratio**, which defines the mapping between the user's physical movement and the resulting movement in the virtual environment. By setting a C/D ratio of less than 1, the virtual object moves less than the user's hand, forcing the user to exert more physical effort to achieve the desired visual displacement. The brain interprets this additional motor effort as the object having properties like weight, inertia, or friction (Lécuyer, 2009).

Beyond manipulating motion ratios, another powerful technique involves **procedural visual deformation**. Studies show that the way an object visually deforms under force is a dominant cue for its material properties, often overriding its static appearance. Techniques like "Elastic Images," which procedurally deform a 2D image in response to interaction, can create a convincing perception of elasticity without any force feedback (Lécuyer, 2009). Our work builds directly on this principle, using a custom shader to create procedural micro-fractures as a novel form of visual deformation to communicate the more complex property of fragility. The choice of input modality is also critical; bare-hand tracking offers superior *body ownership*, while controllers provide greater tracking stability (Argelaguet et al., 2016).

2.2. Visual Affordances and Materiality

Our ability to interact with the world depends on perceiving "affordances"—cues that signal how an object should be used (Norman, 1999). In VR, users rely heavily on visual cues, leading to phenomena like the Material-Weight Illusion (MWI) (Buckingham et al., 2021). In the national context, research has used visual and auditory feedback in VR systems for health and education to guide user behavior. Our work extends this principle to communicate an intrinsic property (fragility) to elicit a behavioral quality (care). This addresses a notable gap in the literature, which lacks studies on the specific visual cues for fragility.

3. System Implementation and Current Progress

Our system is developed in Unity for the Meta Quest 3, leveraging its controller-less hand-tracking capabilities.

3.1. Interaction and Collision Model

After finding that an initial OpenXR-based approach was unstable, we migrated to the **Meta Interaction SDK**, which provided a robust foundation for hand tracking and collision. To create a more deliberate and natural interaction, our implementation avoids unrealistic "snapping." Instead of the object instantly attaching to the hand's center upon a grab gesture, the system requires the user's virtual fingers to physically close and make contact with the object's colliders. A grip is only established once sufficient contact is made, forcing a more mindful grabbing motion.

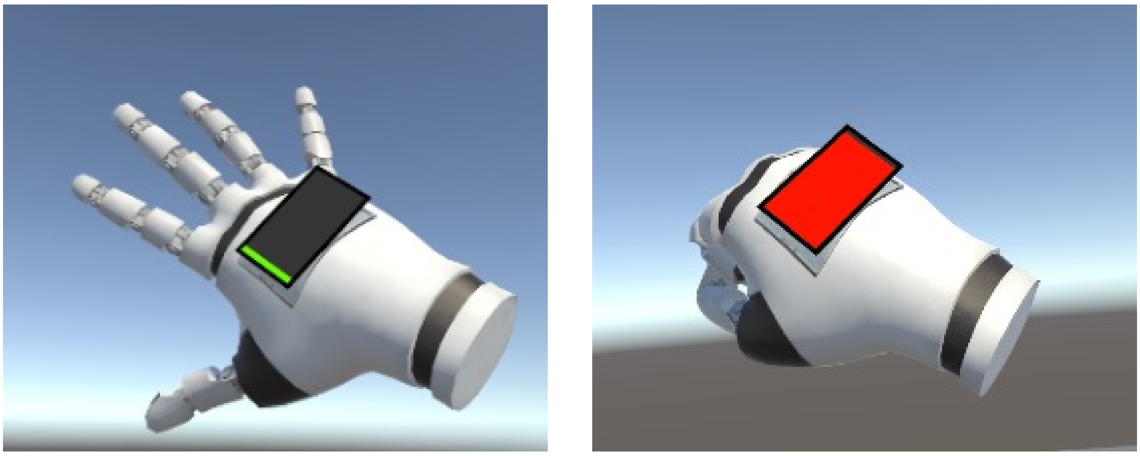
3.2. Dynamic Feedback System for Fragility

The core of our system is a closed feedback loop where the user's grip intensity directly influences the object's state.

- **Grip Force Proxy:** We calculate a "grip force" based on 'GetFingerPinchStrength()' and finger tracking confidence from the Meta SDK.
- **Visual Feedback:** To provide clear, diegetic feedback, the user's virtual hands are rendered as robotic models. These hands feature an integrated display with a bar that changes from green (safe) to red (critical) to show the force being applied. In parallel, the grip force drives a multi-layered shader on the manipulated object itself, creating procedural micro-fractures to visually represent stress (see Fig. 2).
- **Auditory Feedback (In Development):** We plan to add audio cues, such as cracking sounds, that intensify with grip force.
- **Fracture System:** Objects are pre-fractured using Blender's Cell Fracture. If the grip force exceeds a resistance threshold, the object shatters.

4. Future Work

Our primary focus is on refining the core interaction mechanics before conducting formal user studies and developing a dynamic audio feedback system.



(a) Open hand state, representing low applied force, indicated by the green bar.

(b) Closed hand state, representing high applied force, indicated by the red bar.

Figure 1. The diegetic UI on the robotic hand. The display provides real-time visual feedback on grip force, progressing from green (low force) to red (high force) as the hand closes.

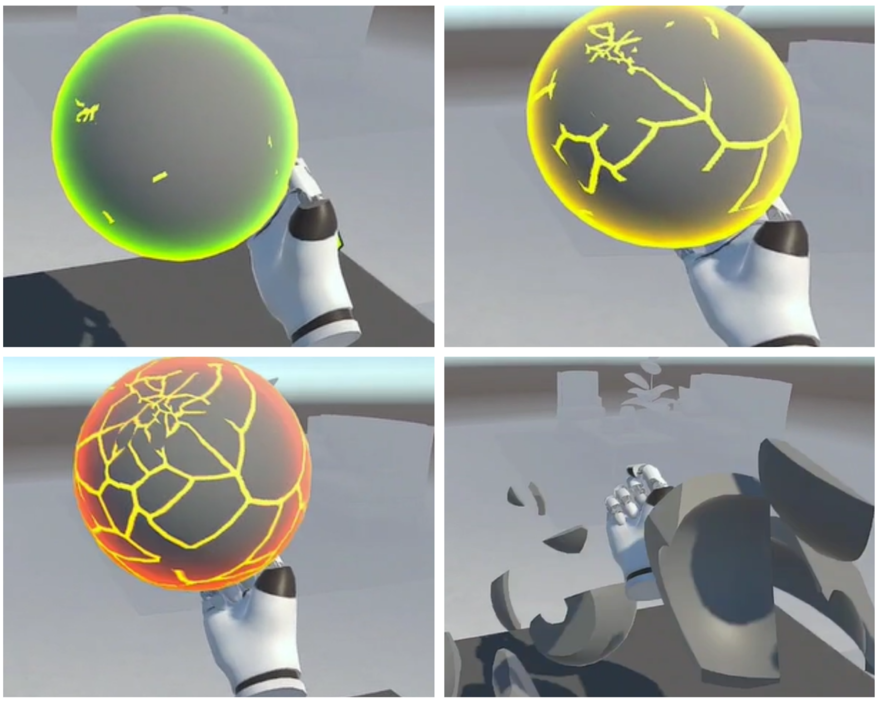


Figure 2. Here's the complete visual feedback sequence for object fragility, from top-left to bottom-right: (a) Initial safe state with a green glow. (b) Moderate stress applied, showing yellow cracks. (c) Critical stress with red cracks and a red glow. (d) The object shattering after the force threshold is exceeded.

4.1. Planned User Study: An Ablation Approach

To test our central hypothesis, we will conduct a within-subjects ablation study to isolate and evaluate the impact of each sensory feedback layer on user behavior. Participants will be tasked with handling three objects with distinct fragility thresholds, representing a scale of care required: a resilient **clay vase**, a standard **teacup**, and a highly fragile **test tube**. They will interact with these objects across four sequential conditions:

- **Baseline Condition:** Interaction with only the basic grabbing mechanic, without any cues about fragility or applied force.
- **Auditory Feedback:** The baseline is augmented with sound cues that correlate with the applied grip force.
- **UI Feedback:** In addition to audio, the diegetic UI bar on the hand is introduced to explicitly visualize the force level.
- **Full Feedback:** The final condition incorporates all previous layers plus the custom fragility shader, showing visual stress directly on the object.

We will analyze whether participants adjust their behavior (e.g., grip force modulation, movement kinematics) more significantly as feedback channels are added. This will be measured using behavioral metrics, performance data, and subjective questionnaires.

4.2. Future Narrative Application

Beyond the controlled empirical studies, we plan to apply our fragility interaction system to a full-fledged narrative experience. The proposed game is set in a post-apocalyptic world where the protagonist, a robot, awakens in a decaying bunker. The core gameplay will revolve around solving environmental puzzles that require the careful manipulation of objects, directly leveraging the fragility and handling mechanics. The player's primary objective will be to escape the crumbling bunker while protecting a fragile plant, testing if the interaction system can elicit a stronger emotional connection and sense of responsibility.

5. Conclusion

By implementing a closed-loop system where direct hand-tracking inputs drive dynamic visual feedback for fragility, we are exploring a novel, perception-based pathway for emotional and behavioral response in VR. Our current efforts are focused on solving key technical challenges to create a robust platform for a formal empirical study. The outcomes of this project have the potential to provide designers with evidence-based techniques for creating more nuanced and emotionally compelling virtual experiences.

6. Acknowledgments

The authors would like to thank all those who contributed to this work.

This work **has been fully funded** by the project 'Investigation of Immersive Technologies for the Development of New Experiences in the Arts', supported by the Advanced Knowledge Center in Immersive Technologies (AKCIT), with financial resources from the PPI IoT/Manufatura 4.0 / PPI HardwareBR of the MCTI, through grant number 057/2023, signed with EMBRAPII.

The authors are grateful for this financial support and for the opportunity to conduct this research.

References

Ferran Argelaguet, Franck Multon, and Anatole Lécuyer. Pseudo-haptics for weight perception in VR: controller vs. bare hand interactions with tracking delay and vertical offset. In *2016 IEEE International Conference on Virtual Reality (VR)*, pages 31–36. IEEE, 2016.

Gavin Buckingham, Manuela Tacca, Micaela Giammarco, Chiara Begliomini, and Sonia Betti. Using immersive virtual reality to examine how visual and tactile cues contribute to the material-weight illusion. *Journal of Neurophysiology*, 126(6):2050–2060, 2021.

Luciano De Agostini, Gabriel Nador, Jean Brand, Gabriela Weiler, Gelson Avelar, and Márcia de Souza. Motion Rehab 3D AVE V2: um novo VR-exergame para fisioterapia motora. In *Anais Estendidos do Simpósio de Realidade Virtual e Aumentada*, pages 25–28. SBC, 2019. doi: 10.5753/svr$_{e}stendido.2019.12948$.

Geraldo Viana Júnior, Williams Ramos de Lacerda, and Mário Chaves Ferreira. Desenvolvimento de um Jogo Sério com Realidade Virtual para Ensino de Frações para Alunos com TDAH. In *Anais do XXXV Simpósio Brasileiro de Informática na Educação*, pages 2685–2695. SBC, 2024. doi: 10.5753/sbie.2024.235940.

Anatole Lécuyer. Simulating haptic feedback using vision: a survey of research and applications of pseudo-haptic feedback. *Presence: Teleoperators and Virtual Environments*, 18 (1):39–53, 2009.

Anatole Lécuyer, Sabine Coquillart, Abderrahmane Kheddar, Philippe Richard, and Philippe Coiffet. Pseudo-haptics: a new way to provide force feedback in virtual environments. In *ACM SIGGRAPH 2000 Conference Abstracts and Applications*, page 157. ACM, 2000.

Donald A. Norman. Affordance, conventions, and design. *Interactions*, 6(3):38–43, 1999.