



FurAir: Non-contact Presentation of Soft Fur Texture by Psuedo-haptics and Mid-air Ultrasound Haptic Feedback

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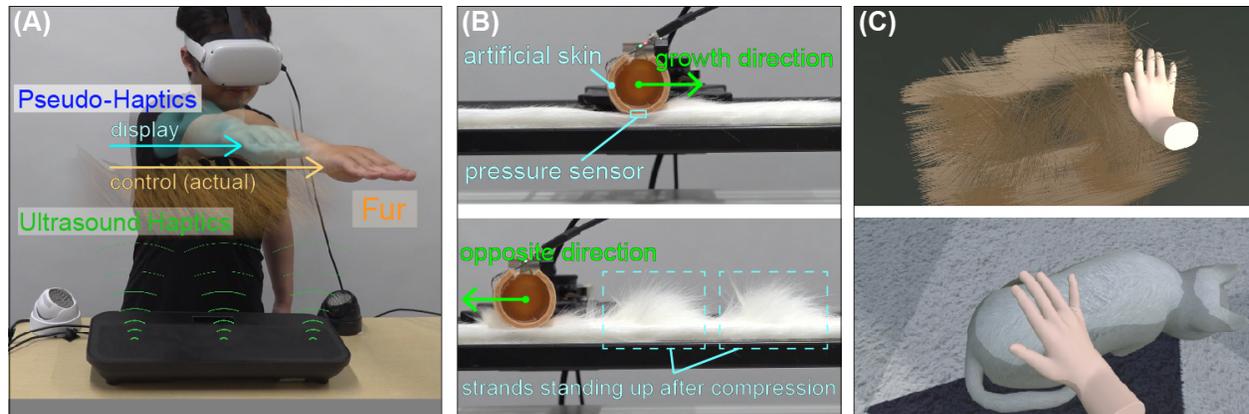


Figure 1: (A) Concept of non-contact presentation of fur tactile sensation using combination of pseudo-haptics and mid-air ultrasound haptic feedback (B) Difference in fur behavior depending on stroking direction and measurement system for pressure of fur (C) Scenes of VR experience of stroking fur and a cat with interactive visual and haptic feedback

ABSTRACT

We propose a non-contact method to present the tactile sensation of soft fur texture using ultrasound haptic feedback and pseudo-haptics. By responsively adjusting haptic and visual feedback according to user interaction, our approach effectively simulates a realistic fur stroking experience.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices; Virtual reality.**

KEYWORDS

hair, haptic, mid-air haptics, pseudo-haptics, virtual reality

ACM Reference Format:

Juro Hosoi, Du Jin, Yuki Ban, and Shin'ichi Warisawa. 2023. FurAir: Non-contact Presentation of Soft Fur Texture by Psuedo-haptics and Mid-air Ultrasound Haptic Feedback. In *SIGGRAPH Asia 2023 Emerging Technologies (SA Emerging Technologies '23)*, December 12–15, 2023, Sydney, NSW, Australia. ACM, New York, NY, USA, 2 pages. <https://doi.org/10.1145/3610541.3614585>

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SA Emerging Technologies '23, December 12–15, 2023, Sydney, NSW, Australia

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ACM ISBN 979-8-4007-0312-6/23/12.

<https://doi.org/10.1145/3610541.3614585>

1 INTRODUCTION

Tactile sensations hold a significant impact on our emotional well-being. In particular, the tactile experience of stroking soft animal fur can be satisfying and enjoyable. In previous research, these tactile sensations of fur have been presented using real fur or fur-like devices [Lee et al. 2021; Nakajima et al. 2011]. However, such methods have several inherent limitations. Firstly, the range of tactile sensations that can be presented is limited to those associated with the specific fur or fur-like devices used in their systems. Secondly, the location of haptic feedback in their systems tends to be fixed. An alternative approach that could possibly overcome these restrictions is to employ wearable haptic devices. However, it remains challenging to generate the softness and delicate nature of fur contact with the rigid devices. Though a previous research has successfully presented the roughness of fur using thin and flexible wearable devices capable of delivering electrical stimuli [Lin et al. 2022], the presentation of soft and deformable fur texture has not yet been achieved.

Therefore, in this research, we propose a novel, non-contact method that utilizes a combination of pseudo-haptics and mid-air ultrasound haptic feedback to present the soft fur texture. Specifically, pseudo-haptics simulates the horizontal resistance one feels when stroking fur, achieved by inducing a discrepancy between actual hand motion and its visually represented counterpart within the virtual environment. Concurrently, the ultrasound haptic feedback presents the vertical reaction force to the hand in the form of ultrasonic waves from an array of parametric speakers. Using

this method, versatile replication of various fur tactile sensations can be achieved simply by adjusting the system's output patterns. Moreover, the feedback location can be swiftly and freely adjusted within the defined area, enabling a more seamless and realistic user interaction. To further enhance the perceived fineness and softness of the fur, a visual representation of fur that can interactively move with hands is simultaneously presented in the virtual scene.

2 SYSTEM AND DESIGN

2.1 Characteristics of Soft Fur Texture

The moving pattern and tactile sensation of fur differ depending on the way our hand moves (Figure 1(B)). In this study, for simplicity, we constrain hand movements to be parallel to the direction of the soft fur. According to our observations, when the fur is stroked along the natural direction of growth, the strands yield to this direction and subsequently return to their initial angles. This leads to a smooth tactile sensation characterized by weak, consistent haptic feedback. Conversely, when the fur is stroked against its growth direction, the strands initially in contact with the hand are gradually pushed to the opposite side, resulting in a compression of the strands along the path of the stroke. As the hand moves, it leaves the tips of one group of strands and starts to engage with the next group, leaving the previously compressed strands untouched. This unique interaction pattern results in a distinctly rough tactile sensation characterized by large, cyclic changes in haptic feedback. The frequency of this cycle is determined by the fur's length and the relative height of the hand.

In order to obtain objective and quantifiable results of the tactile sensations described above, we identified two key types of forces. The first, the vertical reaction force, signifies the upward force exerted by the fur strands when they are compressed. The second, the horizontal resistive force, represents the resistance encountered by the hand as it pushes against the growth direction, primarily caused by the standing fur that blocks the way. These two types of forces were measured using a measurement system consisting of an artificial skin sheet, a pressure sensor, and a piece of real fur. Figure 2 shows the measurement results when the artificial skin is moved horizontally along both directions on the fur at 5 cm/s. The time when the measurement system first hits the fur was set to 0 second. The horizontal resistive force in the growth direction cannot be measured since there is no standing fur. The obtained results align with our initial observations, reinforcing the fidelity of our method's implementation.

2.2 Design of Visual and Haptic Feedback

To present the visual representation of fur in the virtual space that can follow the aforementioned moving patterns, we designed a fur model based on the Unity Hair Simulation System [Pedersen et al. 2022] with some modifications. In terms of the vertical reaction force, we designed a mechanical model where the compressed strands are treated as an air spring so that the reaction force is inversely proportional to their volume. This is based on the measurement results as well as the fact that the strands in the real fur are densely distributed in space and are sufficiently soft. Using this model, the intensity of the ultrasound haptic feedback is dynamically adjusted in response to hand movements and the condition of

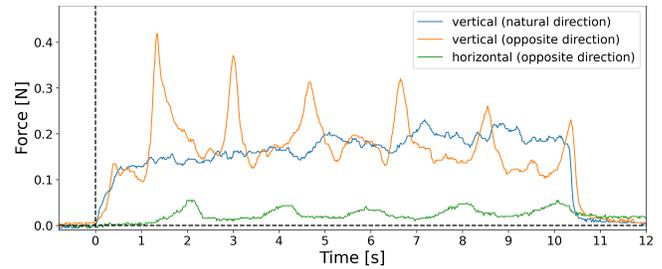


Figure 2: Results of horizontal and vertical force measurements when stroking fur in natural and opposite directions

the fur. The shape of spatiotemporal modulation (STM) pattern for the ultrasound haptic feedback was a circle with a circumference of 20 cm, and the frequency of STM was set at 30 Hz when stroking in the natural direction, providing a smooth tactile sensation, and at 80 Hz when stroking in the opposite direction, offering a rough tactile sensation [Ablart et al. 2019]. Additionally, we simulated the pattern of the horizontal resistive force, which is characterized by an initial increase and subsequent decrease in each cycle, by adjusting the control-to-display ratio as the hand moves. Through the integration of these tactile stimuli with the visual representation, we were able to convey the sensation of touching soft fur.

3 USER EXPERIENCE

Our non-contact approach makes it possible to present a variety of fur tactile sensations, accommodating different interaction positions and variations in fur properties. At SIGGRAPH Asia 2023 Emerging Technologies, We plan to demonstrate a range of fur tactile sensations, as well as an interactive experience of petting a virtual cat. Our technology is expected to contribute to the prototyping and promotion of the apparel industry and to the realistic interactions with animals for the entertainment and education.

ACKNOWLEDGMENTS

This work was supported by JSPS KAKENHI Grant Numbers JP23H04333, JP21H03478.

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