International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2019)
Y. Kakehi and A. Hiyama (Editor)

Preliminary Study on Surface Texture to Manipulate Perceived Softness of 3D Printed Objects

Motoki Miyoshi[1], Parinya Punpongsanon[1,2], Daisuke Iwai[1], and Kosuke Sato[1]

[1]Graduate School of Engineering Science, Osaka University
[2]Institute for Advanced Co-Creation Studies, Osaka University

Abstract

Previous studies have attempted to manipulate the elastic properties of products from elements such as different materials and internal structures. In this paper, we investigate whether we can manipulate the softness perceived by the surface texture when using the FDM-3D printer. We investigated the perceived softness of the surface texture provided by Tymms et al., in which cones of 1 mm in height are arranged, by a subject experiment. From the experimental results, it was found that the hardness perceived by increasing the arrangement interval of the cones decreased and the subjects perceived softer the objects with the surface texture.

CCS Concepts

• ***Human-centered computing*** → ***Human computer interaction (HCI);*** *Graphical user interfaces;*

1. Introduction

Softness is one of the essential factors to recognize and evaluate an object. Its can be one of the criteria when a consumer decides to buy a product. Therefore, the softness requirement for each product should freely adjustable to serve among personal need.

Several researches have been constructed a system that allows manipulate softness perception based on the fabricated internal structure and materials. Christian et al. proposed a framework, which automatically assigns the microstructures to achieve desired softness characteristics [SBR*15]. Torres et al. proposed a data-driven technique to manipulate the objects' mechanical properties [TCKP15]. Piovarči et al. proposed the mechanical models to estimate either physically and perceptually softness properties [PLR*16]. While these studies manipulate the softness properties by adjusting internal structure and materials, it is not clear whether the surface texture influence the perceived softness.

In this paper, we preliminary investigate the effect of surface texture on perceived softness. Unlike the previous work, we consider both the effect of internal structure and the surface texture deformation on perceived softness, which allow to extend the range of softness perception in 3D printed materials.

2. Stimuli

Previous work has demonstrated that different surface textures could modify the roughness perception due to the stimulus to a mechanoreceptor in our brain [TGZ18]. This receptor is the one that also stimulate the perceived softness, but the relationship is stills unclear.

In this work, we prepare 5 different textures for the subjective experiment. We adopted a texture from the above previous work, which previously used to investigate the perceived roughness in 3D printed objects. As shows in Figure 1, the textures are in the cones shape with 3*mm* in diameter and 1*mm* height, placed at a certain distance (λ[m]) with randomness. We printed the textures on the top of the 3D model with 15*mm* radius and 13*mm* height cylinder shape using a standard Fused Deposition Modeling (FDM) 3D printer (Ultimaker 2+). The 3D model is printed with a thermoplastic polyurethane flexible material (Ultimaker TPU95A). The internal volume of the cylinder is set at 20% and the internal structure is set as the concentric pattern, which was provided softer perception among different internal structure pattern based on our pre-

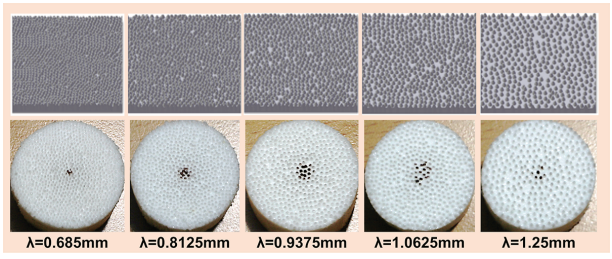

Figure 1: *The stimulus textures to manipulate softness perception. The textures are in a cone shape with* 1*mm height.*

DOI: 10.2312/egve.20191296

liminary test. While the previous work printed the texture with a high-resolution inkjet 3D printer, our work solved the resolution issue with FDM printer by printing along vertical direction.

3. Preliminary Experiment

We aimed to investigate the possibility of manipulating perceived softness of 3D printer output by modifying the surface texture. Twelve participants, aged between 22 to 24 year-old participated in the experiment. In each trial, the five 3D printed objects with texture as the stimulus and one object without texture as a reference are shows to the participant. To eliminate the visual influence, we presented the objects by preventing the participants to see the objects' textures as shows in Figure 2.

Each participant is free to press each 3D printed object as many times as he/she want while determines the softness of each stimuli compared to the reference. Then, they were asked to sort 5 target objects in the order they felt softer, and then answered the softness value of each stimuli compared to the reference object follows the magnitude estimation method [PIS15]. In this experiment, the participants determined the ratio of softness they felt for each stimuli when the softness of the reference was 100. For example, if the subjects feel the target object (i.e., stimuli) softer than the reference, they responded with a value lower than 100 and vice versa.

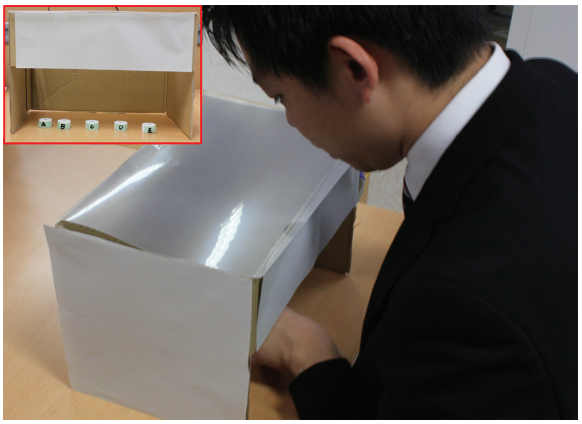

Figure 2: *Experimental setup.*

4. Results

Figure 3 shown the result of the preliminary experiment. The value on the horizontal axis represents the spacing of cones. The value on the vertical axis represents the softness ratio, which reflected the perceived softness participants felt. We found that the less number of cone placement spacing (i.e., smooth surface) are the more participant felt the object is softer and vice versa.

The result suggested that it is possible to manipulate the softness perception by manipulating the surface texture density in addition to modify the internal volume (i.e., infill) of the 3D printer output. The smoother surface such that the denser cones are likely make the object feel softer similar to the textures of the real-world objects such as sponge and towel. However, we believe that other

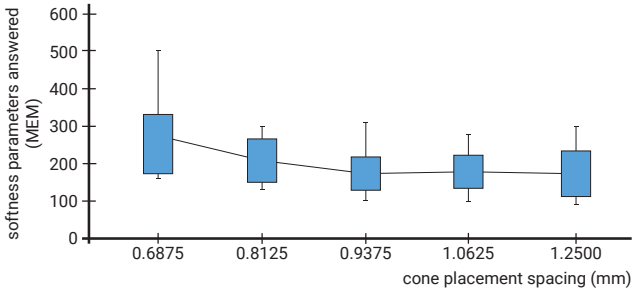

Figure 3: *Preliminary result. The higher ratio value (MEM* > 100*) refers to the softer surface.*

type of surface textures will also affect the softness perception of 3D printed object, and this considering as our future study.

5. Conclusion

We investigated the effective of surface textures to influence the softness perception of the 3D printed objects. Our method considered the surface texture, which consisted of the random arrangement of the small cone shape with varies density. In the experiment, we found that the participants perceived the 3D printed object with smooth surface (i.e., less cone placement spacing) to be softer than the rough surface (i.e., higher come placement spacing). In future work, we will investigate the more types of the surface textures that effect to modify the perceived softness.

6. Acknowledgement

This work has been supported by the JSPS KAKENHI under grant numbers 15H05925 and 19K20321.

References

[PIS15] PUNPONGSANON P., IWAI D., SATO K.: Softar: Visually manipulating haptic softness perception in spatial augmented reality. *IEEE Transactions on Visualization and Computer Graphics 21*, 11 (Nov 2015), 1279–1288. 2

[PLR*16] PIOVARČI M., LEVIN D. I. W., REBELLO J., CHEN D., ĎURIKOVIČ R., PFISTER H., MATUSIK W., DIDYK P.: An interaction-aware, perceptual model for non-linear elastic objects. *ACM Trans. Graph. 35*, 4 (July 2016), 55:1–55:13. 1

[SBR*15] SCHUMACHER C., BICKEL B., RYS J., MARSCHNER S., DARAIO C., GROSS M.: Microstructures to control elasticity in 3d printing. *ACM Transactions on Graphics (TOG) 34*, 4 (2015), 136. 1

[TCKP15] TORRES C., CAMPBELL T., KUMAR N., PAULOS E.: Hapticprint: Designing feel aesthetics for digital fabrication. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (2015), ACM, pp. 583–591. 1

[TGZ18] TYMMS C., GARDNER E. P., ZORIN D.: A quantitative perceptual model for tactile roughness. *ACM Transactions on Graphics (TOG) 37*, 5 (2018), 168. 1