Object Deformation Illusion on a Tactilely Enhanced Large Tabletop Device

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Abstract

Haptic illusions on tactilely enhanced interactive tabletops have rarely been explored to date. We report on a project in which we have tried to take a more planned approach to system design based on recent achievements in the field of pseudo-haptics. We decided on an object deformation scenario that combines simple haptic and tactile stimuli with a modulated visual action feedback. Modulation is performed first, in terms of variations of the control-to-display ratio of the perceived finger position on the tabletop device as soon as the finger is entering the space occupied by a deformable virtual object. We secondly exploited a modulation in the tactile domain when the finger is being attracted by a piece of rubber placed onto the tabletop's surface. This is meant to convey the sensation of a growing contact region and an increased contact pressure as the virtual object is being deformed. An informal user trial suggests that we are on a good way, but a formal evaluation is still to be done.

Index terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces---Haptic I/O; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems---Artificial, Augmented, and Virtual Realities; I.3.6 [Computer Graphics]: Methodology and Techniques---Interaction Techniques

Additional keywords: Pseudo-haptics, large tabletop interaction, desktop Virtual Reality, multisensory conflicts

1 Introduction

Haptic feedback at all scales has become an important, integral part of modern user interfaces. It can be offered through a variety of actuators and simple passive devices. But there is more about how haptic sensations can be evoked in users. Since the late 1990s, researchers have explored ways to alter a user's haptic perception, mainly (but not only) using manipulated visual feedback. The phenomenon we are dealing with in this paper is sometimes referred to as *perceived physicality* [3] or *optically simulated haptic feedback* [5]. Probably the most prominent term is *pseudo-haptics* (PH, for a survey, see [4]).

Within the domain of PH, we are interested in producing effects that make users actually feel a certain (modulated) haptic property without requiring them to "interpret" what they perceive. In this context, PH can also be talked of a haptic illusion [4, 6]. The basic idea behind PH can be summarised as the deliberate modification of a given real haptic (or tactile) percept by means of multimodal displays in such a way that the user's brain can still "make sense" of the resulting feedback. In other words: The user perceives a haptic feature of an object differently when being exposed to a pseudo-haptic simulation. In [6], a much more sophisticated framework has been proposed explaining the principles of exactly this illusion facet of PH based on two well-known, complementary models of human perception, cognition and action: Interacting Cognitive Subsystems [1] and Bayesian Multimodal Cue Integration [2]. The authors also provide a step-by-step guidelines catalogue which is rooted in the theoretical foundations of PH to facilitate the development of new PH-enabled systems.

We followed both the reflexions about these foundations as well as their implications on system and user interface design when we developed our object deformation prototype.

2 Prototype and User Interface Design

Key to the evolution of our prototype (see Fig. 1) was a deeper understanding of how a user would interact with a deformable object placed on a table(top). Questions we have asked include: Which actions would take place in a similar task in reality? What information would be available for multisensory processing? How to deliver a haptic sensation richer than and different from the original one? Which (manipulative) means could we employ? What are the risks of exploiting multisensory conflicts in our specific scenario? And how to avoid or mask potentially critical feedback ambiguities?

We hope to answer most of these questions with the following design: First of all, to deform an object, it has to be pushed. While sliding with the fingertip over the tabletop surface (see Fig. 1a), one way to produce a deformation is to translate horizontal movements into plastic deformations of the material (see Fig. 1c). The applied force has to exceed the deformation resistance of this material. Unfortunately, a (nearly) unconstrained finger movement on the surface would quickly contradict the visual contact and deformation cues displayed on the computer screen. This bears the risk of visuo-haptic mapping conflicts becoming "unmergeable" (i.e., impossible for the brain to compute a coherent percept). We thus considered applying visual gains or control-to-display (C/D) ratios alone not to be enough to induce a convincing and stable deformation illusion (see Sec. 3). We tested various support materials (to be placed onto the tabletop's surface) that would instantly react to lateral finger movements and constrain them "naturally", stimulate the fingertip appropriately, but would not affect the tabletop's capacitive tracking too much. We finally chose a simple piece of rubber and attached it to a wooden frame (see Fig. 1b and the caption for details).

The virtual scene consisted of a 3D model of the tabletop and a high resolution 3D cube placed such that, for simplicity, its equator be aligned with the tabletop's surface. The fingertip was represented by a 3D sphere (see Fig. 1c) which itself deformed when the user pushed the finger downwards. Collisions between the finger and the

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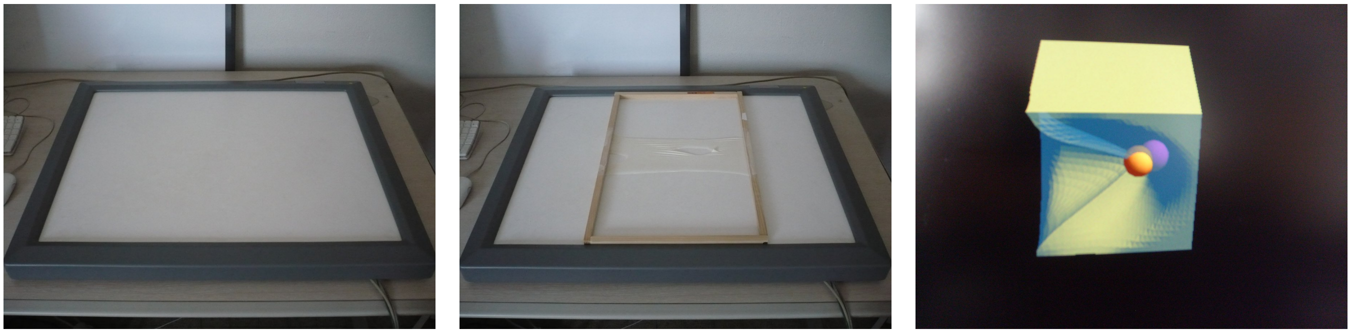

(a) (b) (c)

Fig. 1: The prototype from physical to virtual.
(a) The MERL DiamondTouch table. (b) The table equipped with a wooden frame holding a stretched piece of rubber which has been cut out of an ordinary rubber glove (see the hole at the former position of the thumb). (c) On-screen deformation of a virtual cube (here without table for better visibility) using a radial gradient modifier. Orange sphere: Displayed finger position. Pink sphere: Real finger position (gain < 1, i.e., less visual deformation for the same effort applied suggesting a harder material).

cube have been determined on a per triangle basis by ray casting (i.e., ray = finger movement vector). The deformation shape (in our case radial, but could have been anything else) served the selection of the cube vertices to be displaced along with the moving finger. Displacement weights depended on the vertex distance to the contact point and lead to a smooth shaping gradient. Deformation gains (i.e., modifications of the C/D ratio in the direction of the finger movement vector, see also Fig. 1c) have been used to model varying material resistances.

3 Evoking the Illusion

The goal of the described design is to evoke an object deformation illusion during interaction with a tactilely enhanced tabletop device. Putting all rationales together, how do we finally seed the illusion? Suppose the user is presented with a scene as in Figure 1c and the finger is entering the zone covered by the rubber add-on, whenever a minimum force is applied to it, friction makes it being pulled by the fingertip producing a specific haptic carrier stimulus [6]. This (complex) basic cue (here composed of a force directed against the current finger movement vector and the tactile sensation around the fingertip) can be understood as the sensation a user would have, if no manipulation of incoming multisensory data would take place. According to [6], the existence of such a cue and its meaningful association to what the user observes are crucial prerequisites to forming the illusion, because it will then undergo integration with both the visual cursor displacements and object deformations on the screen. The rubber, when being pulled, begins to "suit" the fingertip and simulate a larger contact region as well as an increased contact pressure – just as if the finger touched and pushed the virtual object.

The evoked sensation should be that of a soft, but somewhat resisting and deformable object. The gain can be used to alter the virtual object's perceive level of resistance by controlling for how much finger movement will be translated into object deformation (see also Fig. 1c and the caption for more). However, exceeding the limits of a robust multisensory information blending, or introducing too many, too strong ambiguities would have serious consequences on the whole experience [6]. We may therefore want to keep our simulation parameters at a conservative level.

In a first informal trial with lab members we could nevertheless see participants being caught by the illusion. But there is still a way to go to validate this first impression.

4 Conclusion and Future Work

We have designed and developed a novel pseudo-haptic system using a large tabletop device. We chose object deformation (in the tabletop's surface plane) as the main task and optimised the design in accordance to [6]. We received promising feedback from an informal trial and hope to confirm it by a complete experimental evaluation in near future.

Various fields of applications may benefit of our development, for instance, virtual object and landscape modelling, experiencing (virtual) materials modelled with different properties, haptically enriched user interfaces for learning and rehabilitation, and more fundamental studies of human perception and action.

To support the illusion, we wish add audio cues and replace the cursor by a faithful hand representation. An MS Kinect could be mounted to the ceiling so as to scan the interaction space for "hands" and reconstruct their shapes and shades in realtime – if overall latency permits to maintain temporal stimuli coherence. After all, we are very optimistic about the versatility of our testbed.

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References

[1] Barnard, P. J., and Teasdale, J. D., "Interacting Cognitive Subsystems: A Systematic Approach to Cognitive-Affective Interaction and Change", In Cognition and Emotion, 5 (1), pp. 1 – 39, 1991.

[2] Ernst, M. O., "A Bayesian View on Multimodal Cue Integration", In Human Body Perception From The Inside Out, pp. 105 – 131, 2006.

[3] C.-H. Lai, M. Niinimaki, K. Tahiroglu, J. Kildal, and T. Ahmaniemi, "Perceived Physicality in Audio-Enhanced Force Input", In Proc. of ICMI, 2011.

[4] A. Lécuyer, "Simulating Haptic Feedback Using Vision: A Survey of Research and Applications of Pseudo-Haptic Feedback", In Presence: Teleoperators and Virtual Environments, 18 (1), pp. 39 – 53, 2009.

[5] K. van Mensvoort, D. J. Hermes, and M. van Montfort, "Usability of Optically Simulated Haptic Feedback", In Int. J. of Human-Computer Studies, 66 (6), pp. 438 - 451, 2008.

[6] A. Pusch and A. Lécuyer, "Pseudo-Haptics: From the Theoretical Foundations to Practical System Design Guidelines", In Proc. of ICMI, 2011.