# Challenges of Multitouch Interactions on Deformable Surfaces

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## Abstract
When enabling touch interactions on a deformable surface, the user is faced with a number of novel interaction challenges not present on firm surfaces. For example, the material used for the deformable surface can completely change the set of interactions that can be used. In addition, touching with one finger affects the overall shape of surface, and deformation for each touch individually can be hard. In this paper we discuss two prototype systems designed to enable us to study such challenges. We discuss how such challenges also present design opportunities to enhance interaction vocabulary of touch interactions on deformable surfaces and offer guidance to future designers of such interactions.

## Author Keywords
Touch; deformable interactive surfaces.

## ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces: Input Devices and Strategies.

## Introduction
The technology behind touch interaction is rapidly evolving, allowing us to use touch-based interfaces to interact in new ways with familiar objects. Recent advancements allow us to extend the capabilities of

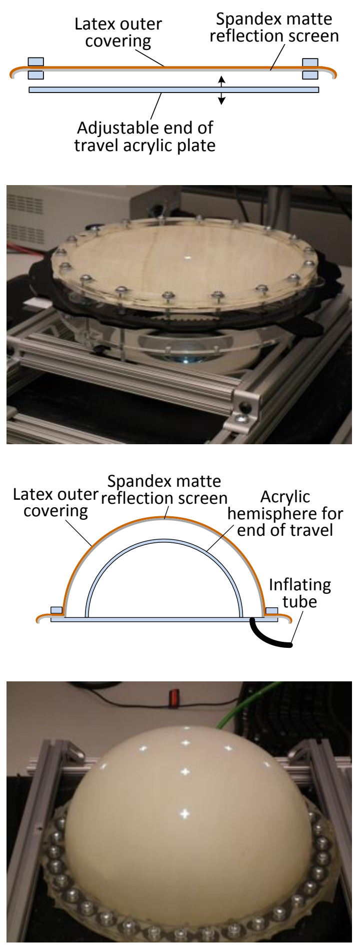


Figure 1 – Two prototypes of deformable touch surfaces: an initially flat at the top, and a hemispherical surface.

regular interaction surfaces. For example, non-flat shaped objects, such as a sphere [1], allow users to interact with applications that can be better mapped to the surface of that object. In the case of a sphere, for example, the surface of the earth can be directly mapped to the display to provide more intuitive interactions. However, such UIs, flat or curved, may not be suitable for every application, such as 3D user interfaces, which may require more than two dimensions for interaction.

Deformable touch surfaces can be used to overcome these limitations. We argue that, without touch or compliant force feedback from the elastic surface, it can be hard to perform gestures normal to the surface and control how close the finger is from the surface, and without travel, it can be hard to precisely estimate the amount of pressure being applied to the surface. We believe that providing both touch and force feedback combined with travel for interaction with the depth dimension can significantly improve the user experience. However, current approaches for building such interfaces bring several challenges for implementing interactions that use deformation.

## Related Work

While gestures can be used to interact with a third dimension, they do not provide the direct, intuitive mapping that is provided for the other dimensions on the surface. A solution for this problem is provided by pressure-sensitive touch devices, such as the one presented by Rosenberg and Perlin [6]. With it, users can use a normal force on the physically static touch surface as an extra dimension, and new types of gestures and interactions can be realized. The problem with this approach, however, is that while the depth dimension can be used, is that it still flattens out 3D interaction with the non-movable surface, where important cues such as position in space normal to the surface are only provided by force-feedback. This could make it difficult, for example, for users to estimate how much force is necessary to effect a travel along the depth axis. One approach to address these problems is to provide different interactions above the touch surface [3], either with direct manipulation of tangible objects or gestures in the air. Although this approach provides travel as a new dimension, it does not provide any sort of tactile feedback that indicates where the interaction happens in space, if the user moved, or how much movement was performance. With this, precision, issues arise for both position and depth [10]. Finally, surfaces that deform as the user applies force to them can be used to overcome these limitations.

Several applications that can use this approach to enhance usability have been proposed, such as surface sculpting using an initially flat deformable membrane [10] and interacting with Google Earth which inflates or deflates a hemispherical deformable display based on zoom level [9]. In addition, we do have a fairly good understanding of how people interact with flat surfaces [5], and some understanding of how surface curvature affects pointing [7] but knowledge about how deformation affects usability is still limited. In order to understand deformation and how it affects commonly used gestures in regular touch surfaces, we built prototypes of deformable touch surface.

## Deformable Touch Surface Prototypes

We built and tested two prototypes with two different shapes: an initially flat surface and a hemispherical surface. Figure 1 shows both prototypes schematics for

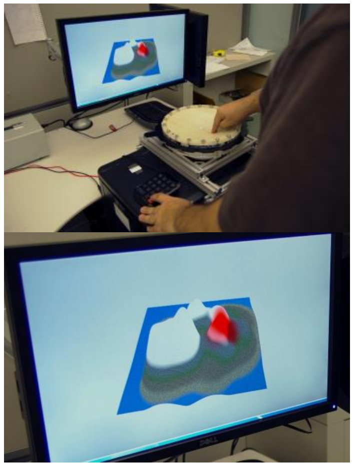

Figure 2 – 3D surface manipulation with a deformable surface.

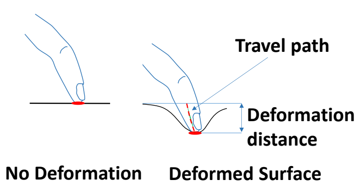


Figure 3 – Illustration of surface deformation.

the deformable surfaces and pictures of the devices. These prototypes use IR illumination and a camera to track the position of the fingers and deformation on the surface, and served as both input and output devices. We used latex for the surface material because it provides elasticity and compliant force feedback, and also because it has been used in previous work [9]. We glued a layer of Spandex on the inside of the deformable surface (facing the camera) to create a diffuse reflecting surface for tracking. The hemispherical prototype also had air pressure inside to maintain its shape, while the flat one was not inflated. While these prototypes may not be an exact representation of future deformable touch surfaces, it allowed us to understand and explore the limitations of these types of devices.

## Challenges for Multitouch Interactions

The use of surface deformation can be used to measure how much travel normal to the surface has been performed by each finger that touches it. We call this metric deformation distance (illustrated in Figure 3). This could be useful for creating new dimensions when interacting with 2D applications. For example, deformation could also be used in painting applications to determine the brush size, or opacity. Similarly, deformation can be used to manipulate a 3D surface for modeling, like the application shown in Figure 2. However, performing commonly known interactions from regular touch surfaces can be challenging.

For example, the simple action of sliding a finger on the surface is greatly affected by the properties of the surface material used. If the surface produces enough friction, one can push and shear, and if it is oily, one can slide and glide. With current implementations, however, achieving both is difficult. Using our prototype as an example, if deformation distance is close to zero, the finger(s) could slide easily enough to move a window to a new place on the screen. However, when deformation distance is greater than zero, users suffer from stiction where their finger sticks to the surface and can only move a small distance due to the elastic behavior of the surface, and may perform shear instead. Differentiating between shear and regular movement also requires improvement in the tracking of deformations on the surface.

An important challenge for these interfaces is how to independently track the deformations for each finger touching the surface and effectively use multitouch. If the surface is inflated, like our hemispherical prototype, or uses some liquid displacement technique [4], the amount of force required to deform the surface with one finger can be very different than with multiple fingers. If it is not inflated, like our flat prototype, touching with one finger will deform the entire surface, and ultimately change how much deformation can be used for other fingers. Figure 4 illustrates both situations. While a foam type of material could be used to solve this problem, it could generate problems for sliding, for example.

Another challenge is the pinch gesture, which can be performed in different ways depending on the surface material. If there is enough friction, the fingers could actually pinch the surface to perform a pinch gesture. Otherwise, users could simply get their fingers closer together, like in regular flat touch surfaces (Figure 5).

If the surface is curved and deformable, even more challenges arise. Deforming the surface with one finger

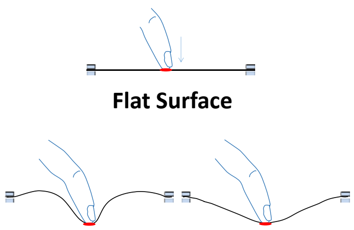


Figure 4 – Surface deformation when the deformable surface is inflated and not inflated.

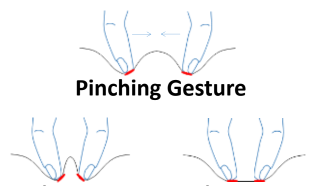


Figure 5 – Pinching gesture with and without friction on the deformable surface.

will probably have a different travel path than when deforming with multiple fingers. In fact, on our hemispherical surface we have observed that when deforming with a single finger the user tries to maintain the travel path along the normal vector to the surface at that point. However, when using multiple fingers, the travel paths tend to be parallel, even though each finger is touching at a different point of the curve (and therefore has a different initial normal vector to the surface).

## Discussion and Future Work

This paper presented a discussion about the challenges that arise when using deformable touch surfaces as an augmentation for regular touch gestures. We hope that adding deformation to the standard multitouch interactions can greatly enhance the interaction vocabulary of interactive surfaces.

In the future, we plan to study how much these issues affect the usability of deformable touch surfaces. We also plan to study an interesting alternative to using deformation distance as a new dimension for multitouch interaction, which is to use the surface deformation as a medium for new gestures. For example, Sato et al. [8] used silicone tangible objects to represent virtual models, and since they were tracked, deformations in the surface were directly applied to their virtual representations. Follmer et al. [2] presented the concept of Jamming User Interfaces, in which a malleable device can jammed into different shapes and be used as input devices. In both these cases, the shape deformation is used as an input, and these could be used to achieve even more interesting interactions. For example, on an inflatable hemispherical surface, such as the ones in Figure 1, users could apply force to one side of the hemisphere to inflate the other and create a menu.

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