# ClaytricSurface: Interactive Deformable Surface Display with Dynamically Controllable Softness

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ITS'12, November 11-14, 2012,
Cambridge, Massachusetts,USA.

## Abstract

In this research, we proposed a new display with a dynamically changeable softness parameter called "ClaytricSurface". While conventional displays generally have fixed softness, we focused on interactive displays with a controllable softness property. We developed a prototype system by using polystyrene particle material and dynamic negative pressure control techniques to dynamically change display softness. We also developed a prototype application for entertainment use and further explored the interaction possibilities with this type of surface.

## Author Keywords

Tabletop; Interactive Surface; Dynamic Softness Control

## ACM Classification Keywords

H.5.2. [Information Interfaces and Presentation]: User Interfaces - Graphical user interfaces

## General Terms

Human Factors; Design; Measurement.

## Introduction

Surface "softness" is an important factor for interactive displays as soft displays allow the users to deform the display shape at will. Moreover, with direct touch input,

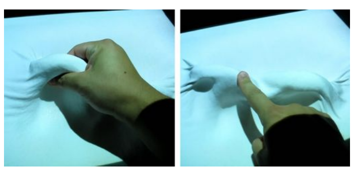

**Figure 1:** ClaytricSurface in a Soft State(left) and Hard State(right)

the degree of surface softness allows for the generation of various touch sensations as well as tactile feedback. Recently, there have been many attempts to provide a softness element with the display surface to extend the possibilities of interaction by utilizing flexible materials, such as elastomer, sand or clay However, in conventional interactive surfaces, this element of the "softness" has been considered as a fixed element. Therefore, even though hard and soft surfaces can be presented explicitly, the possible interaction on each surface are inherently different, and thus the applications are also limited surface-wise. In this paper, we present a new display with dynamically changeable softness and explore the possibilities of applications utilizing variable softness.

## ClaytricSurface

We identify the requirements as follows: First, the dynamic change of display softness from soft to hard states should be possible. Second, it is necessary to be able to change the surface shape using direct user interaction (hand interaction) and fix this deformed shape on the surface.

In order to achieve a display that meets these requirements, we focused on developing a technique to harden the surface by controlling the internal air pressure of the surface body that has small particle materials sealed inside. The polystyrene particles exhibit liquid-like behavior due to the lightweight and low friction characteristics (Figure 2 (left)). However, if you seal these particles into an airtight bag and extract the air from the bag, the particles within will be compressed and the bag will gradually harden (Figure. 2(middle)). If the pressure approaches vacuum pressure levels, the container's surface and body will become completely hard (Figure.2 (right)).

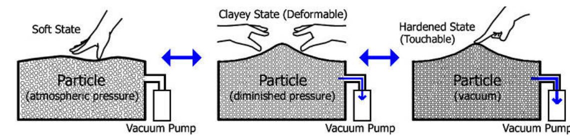


**Figure 2:** Pressure-based Hardness Control

We applied this technology to develop a visual tactile display with a dynamic pressure control technique that allows the surface to have variable softness with a smooth change from soft, intermediate and hard states[4]. When the pressure of the display is at atmospheric pressure, the surface behaves as a soft surface. In this state, the surface provides soft touch sensation like sand or clothing, and enables the user to change the shape easily with simple hand manipulation or with tools. Once the pressure starts to decrease, the surface gradually becomes harder. In the median state, the user can deform the surface with his/her hands like clay. Furthermore, once the internal pressure approaches the maximum level determined by the degree of vacuum, the surface becomes very firm and its current shape is fixed.

## Implementation

*System Hardware*

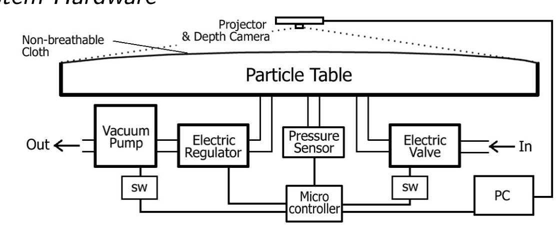


**Figure 3:** System Hardware

Figure 3 describes hardware configuration of our prototype system. This system consists of particle table, pressure

**Figure 4:** Hand area(left), touch region(center), mask image(right)

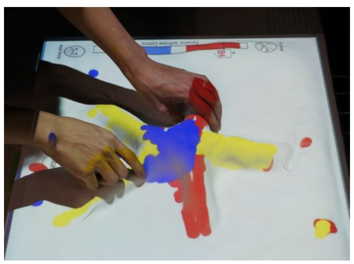

**Figure 5:** 3D Modeling application

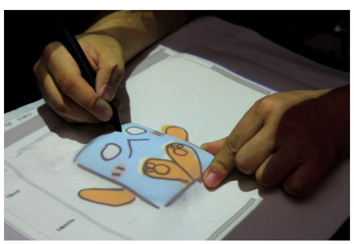

**Figure 6:** Pen-based Interaction

control unit, and a camera-projector unit that will be used for interactive application. The particle table is composed of 655mm x 505mm x 35mm box filled with 1mm expanded polystyrene particles which is then covered and sealed with non-breathable spandex material. The pressure control unit consists of a vacuum pump, a pneumatic sensor, an solenoid valve and a digital electric regulator are attached to the particle table.

*Softness Control*
In this system, pressure inside the table is attained by the adjustment of air pressure through: the increase of pressure via the opening of a solenoid valve connecting to atmosphere (compression), and the decrease of pressure via a vacuum pump (decompression) according to measured pressure levels by a pneumatic sensor. After the desired pressure is attained, the internal pressure is isolated by closing all the solenoid valves. When an air leakage is detected by pneumatic sensor, the desired pressure is preserved by the using electric regulator and vacuum pump.

*Image Projection and Touch Detection*
Image projection and touch detection is performed using a depth camera (Kinect) and a projector mounted about 1m above the display. Basically, touch detection is used by the background subtraction of the initial surface depth data and current depth input frame by detecting any region within 5-15mm from the surface as a user's finger (Figure.4 ). Simultaneously, the background depth image is updated every frame from latest depth image by using exclude mask created by user's hand regions that are detected within a range of up to 400mm from the surface and are extended from outside the display into the inner boundaries of the display. These methods combined allows for multi-touch detection on a dynamically shape changing surface.

## Application
We proposed prototypes of applications to demonstrate the usability of our system, and to futher explore the possibilities of surface with dynamically changable softness.

*Three-Dimensional Modeling Application*
We developed a three-dimensional modeling application that enables the user to directly form a 3D model and paint a texture on top of this surface. The user can control the surface softness state with simple slider and button GUI that can be operated with touch input directly on the surface. This allow the user to easily create original and unique models by using variety of touch input such as "gathering with both hands", "pulling and tugging" and "finger painting" while experiencing the touch sensation of a dynamically-changing material (Figure.5).

*Pen-based interaction tool*
We have also developed an application to augment pen-based interaction with variable tactile sensation. In this application, the users pen input is detected using electromagnetic device placed under the table. The user can dynamically change the friction between pen tip and the surface by controling the softness state (Figure.6).

*Highly Deformable Interactive 3D Surface*
We proposed a design for a deformable surface such that the height is not constrained by the surface material flexibility. The system allows for additional height capabilities via protrusion of the volume using a cloth excess method and airbag base (Figure.7). By allowing height transition from a flat 2D surface to a fully exposed 3D shape, large variations of shapes and their corresponding interactions became possible.

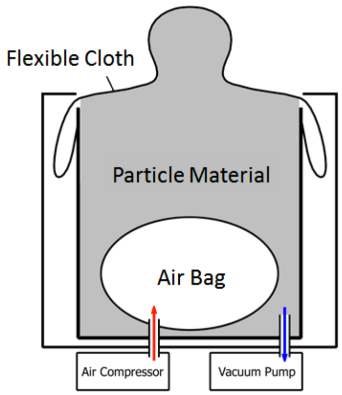


**Figure 7:** Design of Highly Deformable Surface

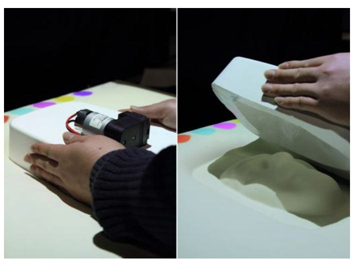

**Figure 8:** Shaping Support Device

## Discussion

We suggest that to date, deformable materials with controllable softness are yet to be fully explored compared to that of other shape changing materials. There have been many attempts and research on self-reconfigurable devices for shape changing displaces like those of pin-array displays. However, this kind of approach still have issues like low-resolution due to actuator scalability and other hardware implementation difficulties.

On the other hand, ClaytricSurface uses small particles and air pressure for actuation, which gives a high resolution detailed malleable surface at a easy, low cost implementation. However, in the current system surface shapes are yet to be self-automated and rely on human input. In the first attempt of automation, we have developed a handheld device using a pre-prepared mold and vacuum technique to support 3D modelling and copying (Figure.8). Currently, we are also considering creation of basic shapes like a hemisphere to protrude out automatically from the surface by pushing a mold from underneath the surface volume.

## Related Work

With regards an implementation of small particles and pneumatic control to change the material state, HoverMesh[3] proposed a tangible user interface that allows mesh deformation by actuating an air chamber inside while solidify the surrounding surface mesh. Robot hands[1] applies this particle control technique to create a versatile grasping system for a robot arm. The Jamming User Interface [2] also applies a softness control technique for I/O devices focusing on mobile user interfaces. Our system, however, focuses on surfaces with controllable softness which allows model shaping and various touch sensations.

## Conclusion and Future Work

In this paper, we proposed a new display that can dynamically change the softness level, and implemented a prototype system. We developed prototype applications to demonstrate the possibility and usability of surfaces with controllable softness. As a practical feature, we plan to develop a technology that presents haptic feedback by changing the surface softness locally as well as also by changing the shape dynamically. We also plan to develop an interactive ball device with pneumatic controller in the inside and a particles layer on the surface, allowing for haptic softness changes and free shape deformation while being used for interactive gaming.

## References

[1] Brown, E. e. a. Universal robotic gripper based on the jamming of granular material. In *Proceedings of the National Academy of Sciences (PNAS)*, vol. 107 (2012), 18809–18814.

[2] Follmer, S. e. a. Jamming user interfaces: programmable particle stiffness and sensing for malleable and shape-changing devices. In *Proceedings of the ACM symposium on User interface software and technology* (2012), 519–528.

[3] Mazzone, A. e. a. The hovermesh: a deformable structure based on vacuum cells: new advances in the research of tangible user interfaces. In *Proceedings of the SIGCHI International Conference on Advances in computer entertainment technology* (2004), 187–193.

[4] Sato, T. e. a. Interactive surface that can dynamically change the shape and touch sensation. In *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces* (2011), 1–1.