Recompose: Direct and Gestural Interaction with an Actuated Surface

Matthew Blackshaw
MIT Media Lab
75 Amherst St
Cambridge, MA 02139
mab@media.mit.edu

Anthony DeVincenzi
MIT Media Lab
75 Amherst St
Cambridge, MA 02139
tonyd@media.mit.edu

Dávid Lakatos
MIT Media Lab
75 Amherst St
Cambridge, MA 02139
dlakatos@media.mit.edu

Daniel Leithinger
MIT Media Lab
75 Amherst St
Cambridge, MA 02139
daniell@media.mit.edu

Hiroshi Ishii
MIT Media Lab
75 Amherst St
Cambridge, MA 02139
ishii@media.mit.edu

Copyright is held by the author/owner(s).
CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

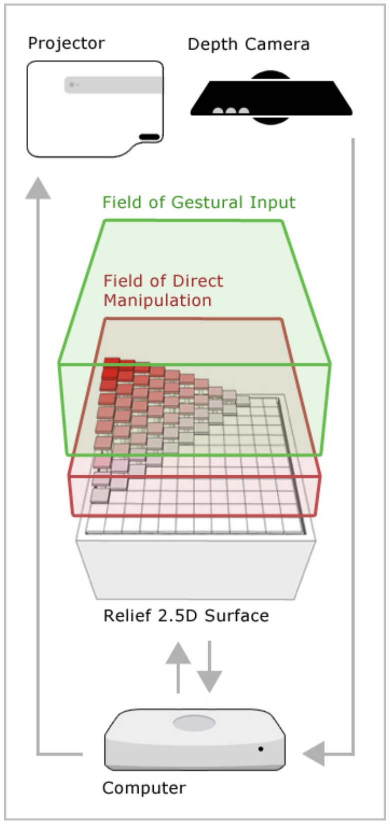
Abstract
In this paper we present *Recompose*, a new system for manipulation of an actuated surface. By collectively utilizing the body as a tool for direct manipulation alongside gestural input for functional manipulation, we show how a user is afforded unprecedented control over an actuated surface. We describe a number of interaction techniques exploring the shared space of direct and gestural input, demonstrating how their combined use can greatly enhance creation and manipulation beyond unaided human capability.

Keywords
Gestural Input, Tangible Input, Direct Manipulation, Actuated Surface, Shape Display

ACM Classification Keywords
H5.2. User Interfaces

General Terms
Design, Experimentation, Human Factors

Introduction
Human beings have long shaped the physical environment to reflect designs of form and function. As an instrument of control, the human hand remains the most fundamental interface for affecting the material



world. In the wake of the digital revolution, where we have extended our existence beyond tangible form, we ask this question—what if we could dynamically reshape, redesign, and restructure our environment using the functional nature of digital tools? To address this, we present *Recompose*, a framework allowing direct and gestural manipulation of the physical environment. *Recompose* complements the highly precise, yet concentrated affordance of direct manipulation with a set of gestures allowing functional manipulation of an actuated surface.

Related Work

Previous related work has utilized physical materials as a direct interface for CAD modeling. The physical material in these projects is modified by the users hands, but cannot be programmatically changed. We propose to combine previous work in tangible CAD modeling and actuated tangible interfaces to overcome this limitation.

Illuminating Clay by Ben Piper et al. [1] explores the computational analysis of three-dimensional models by imaging the topographical state of a physical object. By observing depth information, *Illuminating Clay* exemplifies the power of repainting malleable objects with projected data where the feedback loop between physical alteration and digital analysis is instantaneous.

Sheng et al. use a physical proxy to modify a CAD model rendered on a computer display [2]. The shape of the interface provides passive feedback on the modeling operations, but does not represent the geometry of the CAD model.

Both *Project Feelex* by Iwata et al. [3] and *Lumen* by Poupyrev et al. [4] present shape displays with input sensing capabilities. However, these interfaces could not support precise sensing of the surface deformation and where not utilized for CAD modeling. The *Relief* platform of Leithinger and Ishii improves the sensing and actuation speed of these interfaces [5]. The main reason this interface was not used for CAD modeling is a lack of input dimensions through direct touch deformation.

This idea of extending direct touch interaction with gestures above the interface is inspired by the work of Hilliges et al. [6], where a Microsoft surface table is combined with a depth camera for additional input.

Tovi Grossman et al. demonstrate interaction techniques for volumetric displays [7]. These techniques are modeled to overcome the constraints of volumetric displays, which prohibit touching content directly.

Further, synchronicity between spatial coordinates and computational representation has been explored in spatial operating environments (SOE) such as the g-speak system from Oblong Industries [8], and the study of gestural input in *g-stalt* [9].

Design

Our system builds upon the Relief table, developed by Leithinger [5]. The table consists of an array of 120 individually addressable pins, whose height can be actuated and read back simultaneously, thus allowing the user to utilize them as both input and output. Building upon this system, we have furthered the design by placing a depth camera above the tabletop surface. By gaining access to the depth information we are able to detect basic gestures from the user.

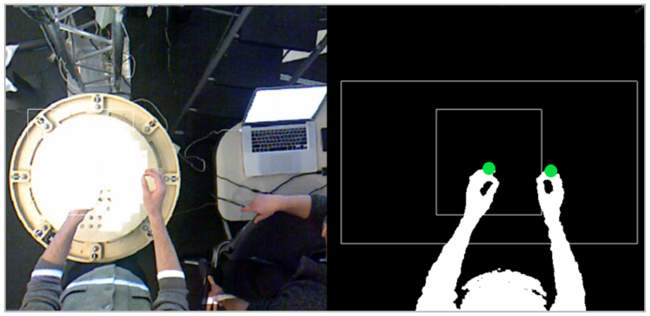


Figure 2. Image threshold and gesture detection

In order to provide visual feedback related to user interaction, a projector is mounted above the table and calibrated to be coincident with the depth camera. Computer vision is utilized to determine and recognize the position, orientation, and height of hands and fingers, in order to detect gestural input.

A grammar of gestures has been implemented to explore basic functions used to interact with an actuated surface. Initial explorations have found that the most fundamental set of gestures includes: selection of a subset of the surface, translation of the selection, rotation of the selection, and scaling of the selection. Further description of these techniques follows:

Selection – In order to select a subset of the surface the user forms two parallel vertical planes with their hands. We find this gesture to be highly intuitive, as it is the gesture commonly used to indicate dimension. The system indicates selected areas with color-coded visual feedback. A two-finger pinch on either hand locks the selection dimensions, enabling manipulation through a number of gestures.

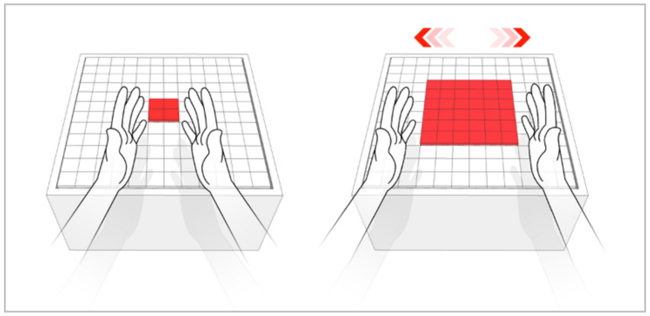


Figure 3. Gesture for selection

Translation – By adjusting hand position along the X, Y, or Z axis, the user can simultaneously manipulate the height and position of the selection. After reaching the desired height and position the user can release the pinch gesture, saving surface state, and resetting the interaction state back to selection mode.

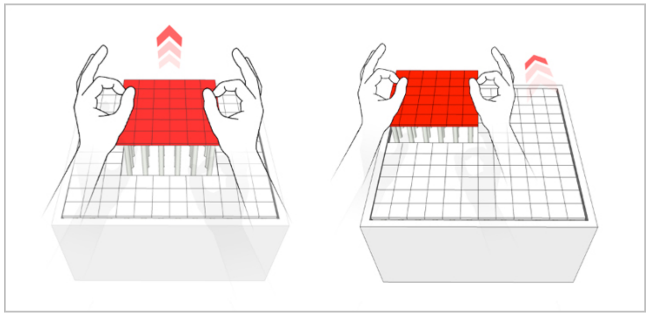


Figure 4. Translating the selection along the X, Y, and Z-axis

Rotation – By rotating the locked hands on the horizontal plane, the selection rotates accordingly as indicated in *Fig. 5*.

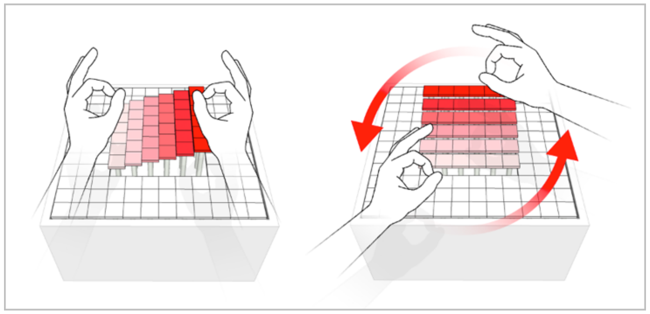


Figure 5. Rotating the selection

Scaling – Similarly, *Fig. 6* illustrates a gesture for surface scaling. By changing the distance between the locked hands, the selection scales proportionally. This method has evolved from

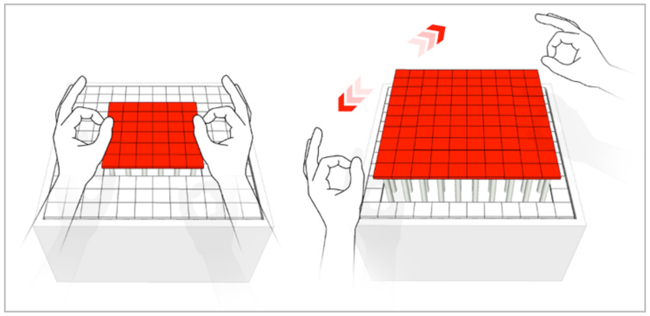


Figure 6. Scaling the selection

the ubiquitously popular pinch-zoom technique in natural user interfaces [10]. We find that the implementation of transforms greatly enhances the capability of human interaction beyond what is possible with direct manipulation alone.

Direct manipulation – Direct manipulation is achieved by pushing or pulling the physical surface as shown in *Fig. 7*.

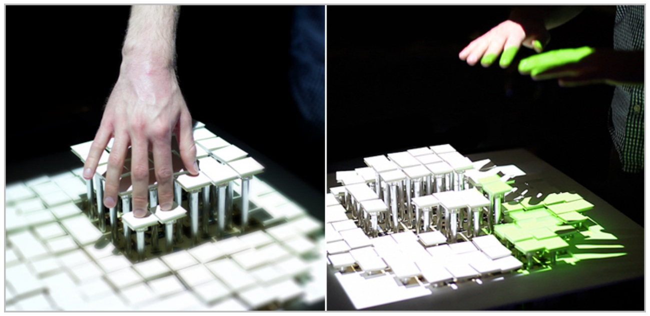


Figure 7. Direct manipulation (left) and gestural input (right)

Discussion

Direct manipulation of an actuated surface allows us to precisely affect the material world, where the user is guided throughout the interaction by natural haptic feedback. However, direct manipulation is incapable of affecting large areas of a surface due to constraints of the human body. We believe that gestural input solves this problem, through low precision, but expansive interaction.

Together, these two input types provide a full range of fidelity from low-to-high precision. We designed the system such that a user can fluidly change context from gestural to direct manipulation without modal state changes. Through these features, we believe to have achieved a seamless expressive interface.

During development we encountered issues while translating common design techniques from a planar display to an actuated surface. Because our display is volumetric, uncertainty arises when translating a selection to a new position – what happens to the volume where the selection originated? The current behavior is to set vacated space to a height of zero. Similarly, both scale and rotation produce scenarios where the transform may intersect an existing volume. In these cases, we are left to decide the behavior of the combined volume. We intend to further address these edge cases through additional interaction exploration and user testing.

In traditional computer-aided design a user must shoehorn 3D ideas into the digital world through a 2D display. *Recompose* moves digital modeling into the physical space adding the intuition of hands-on design. We believe that the *Recompose* system may contribute significantly to fields where rapid iteration and visualization are fundamental to the process of learning and creation; these fields could include but are not limited to architectural design, three-dimensional product design, and medical imaging.

Future Work

We intend to further the *Recompose* system by implementing a number of additional interaction features beyond the previously explored select, translate, and transform functions. In the near future we would like to explore and implement the following features:

Timeline Controls – A full-scale timeline of all surface manipulation captured during a session allowing for time reversal, state saving, and undo type functions.

We believe that implementing a set of gesture controls to explore the dimension of time grants the user additional power currently impossible by the constraints of the physical world.

Copy and Paste – Allows users to quickly duplicate their digitally mediated creations in the physical world.

Advanced Drafting Techniques – The implementation of techniques commonly found in drafting and 3D modeling tools, such as spline lofting and Boolean operations. These advanced functions are proven cornerstones in three-dimensional modeling and shape design.

In regards to the mechanical system, we intend to pursue both higher fidelity gesture recognition coupled with higher resolution actuated surfaces to allow for a greater range of expression and interpretation.

Conclusion

In this paper we present *Recompose*, an interaction framework for direct and gestural manipulation of an actuated surface. Building atop Relief, we have shown that direct manipulation gives users the ability to precisely alter a single point, while gestural interaction allows for functional manipulation of larger areas.

Our ability to express ourselves must extend beyond what we can manipulate with our hands alone. We intuitively use gestures to express intent and desire, and if the surfaces around us could better understand such notions then digital design could be a more transparent and seamless experience.

Acknowledgements
We would like to thank the members of the Tangible Media Group at the MIT Media Lab for their input and advice, the students and researchers from the Tangible Interfaces course of spring 2011, and the entire MIT Media Lab community for constant and continued support.

References

[1] B. Piper, C. Ratti, and H. Ishii. Illuminating clay: a 3-d tangible interface for landscape analysis. In *Proceedings of the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves*, CHI '02, pages 355–362, New York, NY, USA, 2002. ACM.

[2] Jia Sheng, Ravin Balakrishnan, and Karan Singh. 2006. An interface for virtual 3D sculpting via physical proxy. In Proceedings of the 4th international conference on Computer graphics and interactive techniques in Australasia and Southeast Asia (GRAPHITE '06). ACM, New York, NY, USA, 213-220.

[3] Hiroo Iwata, Hiroaki Yano, Fumitaka Nakaizumi, and Ryo Kawamura. 2001. Project FEELEX: adding haptic surface to graphics. In Proceedings of the 28th annual conference on Computer graphics and interactive techniques (SIGGRAPH '01). ACM, New York, NY, USA, 469-476.

[4] Ivan Poupyrev, Tatsushi Nashida, Shigeaki Maruyama, Jun Rekimoto, and Yasufumi Yamaji. 2004. Lumen: interactive visual and shape display for calm computing. In ACM SIGGRAPH 2004 Emerging technologies (SIGGRAPH '04), Heather Elliott-Famularo (Ed.). ACM, New York, NY, USA

[5] D. Leithinger and H. Ishii. Relief: a scalable actuated shape display. In *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction*, TEI '10, pages 221–222, New York, NY, USA, 2010. ACM.

[6] Otmar Hilliges, Shahram Izadi, Andrew D. Wilson, Steve Hodges, Armando Garcia-Mendoza, and Andreas Butz. 2009. Interactions in the air: adding further depth to interactive tabletops. In Proceedings of the 22nd annual ACM symposium on User interface software and technology (UIST '09). ACM, New York, NY, USA, 139-148.

[7] T. Grossman, R. Balakrishnan. 2008. Collaborative interaction with volumetric displays. In *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems* (CHI '08). ACM, New York, NY, USA, 383-392. DOI=10.1145/1357054.1357118 http://doi.acm.org/10.1145/1357054.1357118

[8] Oblong Industries. 2010. G-speak, spatial operating environment. http://www.oblong.com

[9] J. Zigelbaum, A. Browning, D. Leithinger, O. Bau, and H. Ishii. g-stalt: a chirocentric, spatiotemporal, and telekinetic gestural interface. In *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction*, TEI '10, pages 261–264, New York, NY, USA, 2010. ACM.

[10] S. Jord #224;, C. Juli #224;, and D. Gallardo. 2010. Interactive surfaces and tangibles. *XRDS* 16, 4 (June 2010), 21-28. DOI=10.1145/1764848.1764855 http://doi.acm.org/10.1145/1764848.1764855