L-Shift: Encoding Material Properties and Shapes with Phase-shifting Liquid

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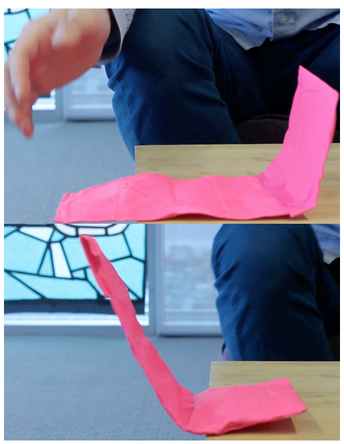
Abstract
Forces of gravity and the concept of a fixed center of mass severely limit the opportunities for product design and user interaction with those products. In this paper, we present L-Shift, a fictional material in which the weight distribution of physical objects is manipulated dynamically. Designing with this material that shifts its phase between solid and liquid and therefore allows changing its weight distribution and rigidity, products can be re-shaped and re-balanced. Exploring future possibilities, we envision that it is possible to manipulate such physical properties of objects through the computer. We think that this concept of weight-shift would enable new ways of designing products as well as user interactions.

Author Keywords
Phase-shifting materials; Dynamic mass distribution; Radical atoms; Flexible design

ACM Classification Keywords
H.5.2. Information interfaces and presentation: Prototyping

General Terms
Design, Experimentation



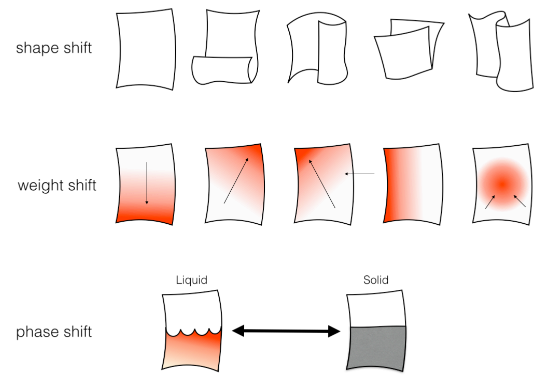
A sheet of material without weight-shifting capability cannot balance itself (top), whereas weight-shifting enables it balance stably (bottom)

Introduction

Symmetrical geometric shapes have a dominant presence in the world we live in. Furniture is a good product category to illustrate this. Generally speaking, there are three different kinds of furniture designs: 1) engineering-based, with an emphasis on functions and stability of materials and structure, 2) design-based, with a focus on the human factors, and 3) art-based with often a more freeform, non-functional foundation. However, it is difficult to create an optimal design that takes into account all three approaches, mainly because we lack the medium that promises both flexibility and stability in structure.

What if we could mold a sheet of material into every organic and geometrical shape, and move the center of mass to allow for functional use by rebalancing the object? Not only does such a mechanism enable users to create and use any form of a single type of furniture, but also can be used to change shape and/or form from one type to another. For example, a chair can be turned into a table. Not just any table, a table that has a unique shape that was previously impossible to give any functional use to.

We present a mechanism that enables controlling the shape and weight distribution of objects to render various shapes or material properties. This mechanism can be considered "pre-programmed" and enabled or activated through manual interaction. As a proof of concept, we developed prototypes to demonstrate how shifting the weight: 1) makes it possible for objects to dynamically balance themselves (on the edge of a table) 2) along with a phase-shifting material could create various shapes and sustain balance in otherwise impossible ways 3) impacts the sound of a musical instrument such as a guitar by manipulating physical characteristics of materials.

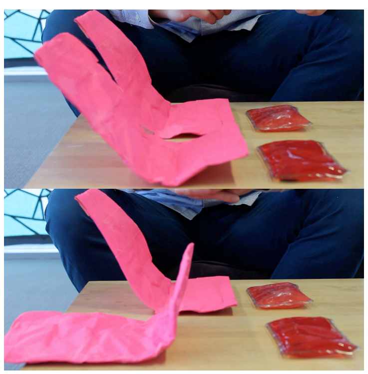


Figures 1. Using material which can shift between liquid and solid phases, materials can be differently shaped and weight-distributed.

Related Work

Tonski [1] demonstrated the balancing of a 170-year old sofa in an "impossible" position. Romanishin et al developed modular self-assembling robots called M-Blocks, which could form different shapes such as a chair or table. Jifei et al [3] developed layer jamming to design interfaces which enabled various shapes by controlling the rigidity of the material.

These works presented novel ways of building shapes by incorporating processes of changing spatial configuration of unit parts or by modifying a material property (stiffness) itself. However, they still are limited in their application to building asymmetric structures because they do not enable change in weight distribution that could properly balance such structures.



Once the L-Shift material turns into solid state, it will fix its weight distribution. Unlike in liquid state where leaning the object changes weight distribution, it will stand up and come back to the encoded balance automatically after being pulled back. (Bottom)

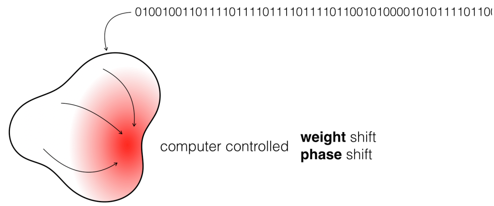


Figure 2: An object could be programmed to learn how to balance itself in seemingly impossible ways, such as at the edge of a table.

L-Shift Material

We present L-Shift (Liquid-Shift), a fictional material that can shift its shape, weight distribution, and phase between liquid and solid. This allows changing and encoding its shapes freely into any form with virtually any different weight distribution, making them balances stably. Also by turning the material into solid state, the shape and balance can be fixed semi-permanently. Not only manually, this material can be computer-controlled dynamically. The process of encoding and releasing shape and weight distribution is illustrated by a few steps following:

Shape/Weight-shifting

In Liquid state, the material becomes flexible so the users can easily change the shape and distribute the weight differently.

Phase-shifting

By triggering the phase shift from liquid to solid state, the users can fix the shape and balance (weight distribution). This allows for the fixed shape and balance to afford a specific functional use for its users.

Reverse p*hase-shifting*

By providing energy to the material, they can be shifted back to liquid state - again allowing reshaping and weight-redistribution.

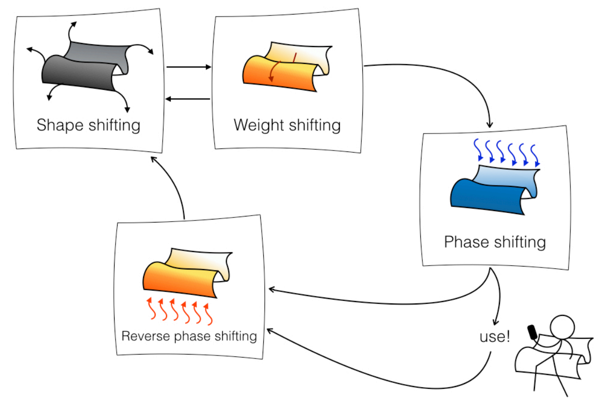


Figure 3. Full cycle of encoding/releasing shapes and weight distribution.

Applications

Product Design

Designs such as Jacob Tonski [1] render visual appeal and represent rich metaphors. We envision practical examples of such concepts would be a lamp that could balance itself in a new way or tools such as knives or hammers which could balance themselves without falling dangerously. If material itself could control its weight distribution, the weight-shifting capability can be embedded into products without interfering with visual design.

Sodium acetate in room temperature. Super cooled liquid state (left) and solid state (right)

Construction

L-Shift could be useful in installing temporary structures in outdoor events for entertainment or a variety of other purposes. For instance, modular structures made of L-shift materials could be used in the fluid state during design stages to try out different shapes. Then, just prior to the event the phase-shifting material could be triggered to change into solid state to fix the structure. After the event is over, the entire structure could be taken apart by triggering the material back into fluid state, thus providing an easy interface to re-use materials in temporary constructions.

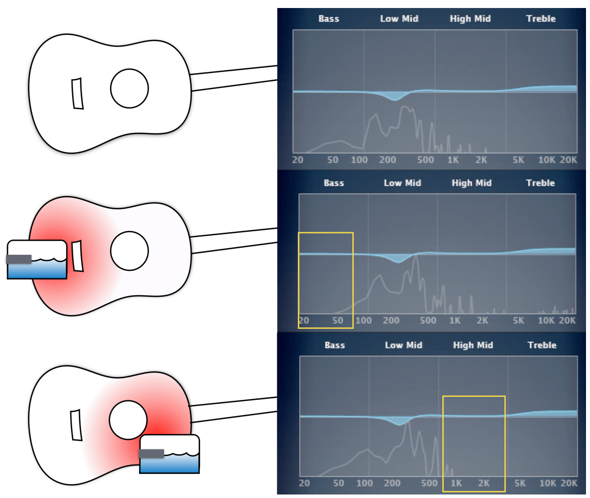


Figure 4. Using the L-Shift concept, we explored how weight-change impacts sound.

Musical Instrument

Shifting mass distribution inside an object not only changes its balance or rigidity, but also modifies its acoustic resonance characteristics. Acoustic instruments built with L-Shift materials would allow for players to alter their instruments' sound characteristics in a fully analog way without need of any electronic effects. We also experimented with an acoustic guitar and water pumps to simulate weight-shift on top of the guitar's body. By differing the weight attached on different parts on the body of the guitar, we demonstrated that the guitar changes its sound characteristics. (Fig 4)

Prototypes

We built prototypes each for phase-shifting material, and dynamically controlled balance.

Phase-shifting Liquid

We used a phase-shifting liquid, sodium acetate in sealed bags to control the weight of a structure shaped as an envelope made out of thin steel wire. Using the wire envelope, we made different shapes of furniture (chair, sofa, and table). These configurations however, would not balance even on flat surfaces without bags containing the liquid. After adding the bags with sodium acetate, we were able to make various configurations balance by controlling the flow of the liquid. To fix a particular configuration, we made the liquid crystalize by inducing agitation (clicking a metal disk inside). Primarily used in heat pads, sodium acetate is very good at super cooling. It freezes at 130°F (54°C), but can stay liquid and stable at a much lower temperature. Clicking/bending a metal disk, however, has the ability to force a few molecules to flip to the solid state, and the rest of the liquid then rushes to solidify as well. This process is called "nucleation", during which the solute molecules in the solvent start to gather into clusters on a nanometer scale. This solid form of sodium acetate can be easily restored to liquid state again by placing the heat-pad (or any sealed bag containing the solid) in boiling water for fifteen to twenty minutes. This process of shifting between liquid and solid phases can be repeated multiple times using the described procedures.

Dynamic Control

To simulate dynamic control over the weight distribution of an object, we embedded a linear actuator with a weight inside a box. The actuator which is controlled electronically, allows the weight to move on a slider thus shifting mass dynamically. It can create an effect in that box appears to learn to balance itself when placed on the edge of a table. Without the actuator, the box would fall when placed at the edge of a table.

Limitations and Future Work

We are aware that the prototypes we built may be in their initial stages and therefore have more limitations, but they demonstrate possible directions for future research. One possibility is to build on the jamSheets [3] and build phase-shifting materials such that they also make it possible to manipulate weight distribution in objects. Another direction is to design products using actuators that could change the center of mass within the product material itself. This would make it possible to build configurations as illustrated by Jacob Tonski [1] or even construct different shapes on demand at real-time. We would also explore programmatically balancing objects with different shapes having narrow ends or curved edges such as a pen or cylindrical block.

Conclusion

This paper presents the idea of dynamically controlling the weight distribution of objects to render various shapes or configurations. The concept of dynamic weight-shift suggests a wide array of interesting possibilities and applications. At the same time, more work is necessary before this mechanism could be made available in everyday objects. More meaningful metaphors could be further explored to create new designs and interactions through dynamic weight control.

Acknowledgements

We thank all the guest lecturers and the students in the Tangible Media Interfaces class who provided helpful comments. We are grateful to the guidance, encouragement and constructive criticism from Dr. Hiroshi Ishii. We thank Sheng Kai Tang and Jifei Ou for their feedback.

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