Leveraging Everyday Deformation for Shape-Changing Interfaces

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Abstract
We present the results of a focus group that aims at exploring deformable and shape-changing objects that are already surrounding users in their daily life. The reason why we are doing this is that, although shape-changing interfaces are becoming more popular, it is currently not clear what type of shape-changes are relevant for the design of these new devices. With our approach we hope to elicit new ideas of shape-change interaction. We discuss the implications for design and the future direction of this work.

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Shape-Changing TUI; deformation objects;

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Introduction
Shape-changing interfaces have been proposed to provide dynamic affordance or physical feedback on tangible interfaces [1] [2]. Various mechanisms of shape-changing interfaces have been explored, e.g., changing orientation [3], inflating an object [4], changing viscosity [5]. They have resolved problems with their physical interactivity, visual intuitiveness and tactile feedback. However, still there are large design spaces unexplored.

Figure 1: Idea collection of deformable objects in daily life, during a workshop facilitated by authors for Master students.

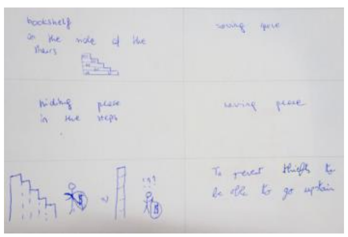

Figure 2: Idea examples of deformable stairs. Left: deformation mechanisms, right: purposes

We noticed that deformable and shape-changing objects are already surrounding users in their daily life. These objects have different deformation mechanisms and purposes for deformation. One example is a height-adjustable chair, whose axis is extended (deformation mechanism) to fit the sitting person's height (deformation purpose).

In this position paper, we want to report on a Focus Group study where we collected participants' ideas of everyday deformable objects in order to inspire the design of shape-changing interfaces. Our aim is twofold: First, the deformation mechanisms that we found can be applied to interfaces. This can bring new benefit to users, but also shorten the learning time thanks to its everyday inspiration. Second, the purpose for deformation that we found in everyday objects could also benefit to interaction.

By exploring everyday deformable objects or objects users wish to be deformable, we discovered unexplored areas in the design space of shape-changing interfaces. We hope the results form our study will provide HCI researchers with a design baseline for new shape-changing interfaces.

We first report in related work in this area. We then present our study and its results. We then discuss the unexplored areas that we found in the design space of shape-changing interfaces.

Methodology

To collect deformation mechanisms and purposes from users daily life, we moderated a workshop with 9 Master's students (7 male, 2 female). Before the workshop, they were asked to collect pictures of deformable or shape-changing objects from their own daily life (taking pictures themselves or getting them from the Web)

At the beginning of the workshop, participants were separated into two groups. One moderator participated in each group. From the images they brought, each participant was first asked to choose their three favorites pictures. Then they were asked to write what deformation mechanism was proposed by the object, and for what purpose.

To generate more ideas, each participant was then passed the images and asked to suggest: (a) new objects with similar deformation; (b) other deformation mechanisms; (c) purposes for the same object.

After a few rounds (40 min), they paused and were given different mechanisms of deformation from design space for shape-changing UI [1] [2] [6] to prompt ideation. The two groups swapped their ideas, and a second ideation activity followed (30 min).

Finally, all deformation ideas were grouped according to their mechanisms and purposes.

Results

A total 116 ideas were collected. Their deformation mechanisms were grouped into the 20 mechanisms described in Table 1. Table 1 shows all deformation mechanisms categories, even though some categories counted few items (e.g., change slipperiness with a single idea) and others had little relation with deformation (e.g., change temperature). We believed that they could nevertheless inform the design of shape-changing interfaces. Ideas were also grouped into 46 deformation purposes described in Table 2. We now detail the categories and ideas that we found.

Deformation mechanism	#	Existing /New
Fold/Unfold	25	17/8
Extend (1D)	14	7/7
Change Orientation	10	7/3
Combine/Uncombine	8	7/1
Change Volume (3D)	7	3/4
Change Viscosity	7	1/6
Change Color	6	2/4
Inflate	6	4/2
Change Porosity	4	2/2
Reorganize	4	1/3
Free-Formed Change	4	0/4
Expand (2D)	3	0/3
Change Thickness	3	0/3
Change Transparency	3	1/2
Adjust Length	3	3/0
Slide	3	1/2
Change Temperature	2	2/0
Adapt Space Between	2	1/1
Change Brightness	1	0/1
Change Slipperiness	1	0/1
Total	116	59/57

Table 1: Forms of deformation in daily objects. Ordered by frequency

Deformation Mechanisms

The 20 deformation mechanisms that we found are:

1. *Fold/Unfold* (e.g., E[1]: folding fan, N[2]: unfoldable bag to make a blanket to sit on the grass);
2. *Extend (1D)* (e.g., E: trombone to play music, E: telescope to see farther, N: length of stairs' steps to adapt to individual's step length);
3. *Change Orientation* (e.g., E: radio antenna to capture signal, N: variously bended cane's handle to improve ergonomics and dress up well);
4. *Combine/Uncombine* (e.g., E: ninja sword sheath to adopt experience level, detachable display to have bigger screen or parallel browsers, N: combining 2 bikes to have 4 wheels wagon);
5. *Change Volume (3D)* (e.g., E: luggage to carry more object, N: volume-changing fridge to reduce energy consumption);
6. *Change Viscosity* (e.g., E: water turns to ice, N: make bag firm to block bullet);
7. *Change Color* (e.g., E: lamp to change mood, N: color-changing umbrella to adapt user's fashion);
8. *Inflate* (e.g., E: long balloon to fold into characters, N: change shape of hot air balloon from round to streamlined to travel faster);
9. *Change Porosity* (e.g., E: tent ceiling to cool off or illuminate, N: water proof bag to make swim vest);
10. *Reorganize* (e.g., E: string puppet, N: window and door in a room to fit furniture);
11. *Free-Formed Change* (e.g., N: making fridge walls fit to food inside to reduce energy consumption, emerging floor to make furniture such as couch);
12. *Expand (2D)* (e.g., N: map to zoom in);
13. *Change Thickness* (e.g., N: changing pen thickness by user preferences);
14. *Change Transparency* (e.g., N: making a wall transparent to say hello to a neighbor);
15. *Adjust Length* (e.g., E: adjusting sleeping bag length to fit to user's height);
16. *Slide* (e.g., E: stair drawers, N: sliding every second stair back to have sitting places);
17. *Change Temperature* (e.g., E: changing fridge temperature to keep food or wine properly);
18. *Adapt Space Between* (e.g., E: adapting space between fridge shelves, N: adjusting space between wires of drying rack to dry thick clothes);
19. *Change Brightness* (e.g., N: making map fluorescent to see it in dark);
20. *Change Slipperiness* (e.g., N: making bottom of tent slippery to move it easily).

[1] Already existing in daily life or as a product or research
[2] New idea

From these categories we hypothesize that:

- Deformation mechanisms that gathered more ideas (e.g., *Fold/Unfold, Extend (1D), Change Orientation*) are common in daily life. Designers can build on them to shorten the learning phase of a deformable interface. In addition, deformation mechanisms that gathered more ideas may be easier to implement.
- On the other hand, categories with newer deformation mechanisms (e.g., *Free-Formed Change, Expand (2D), Change Viscosity*) may mean they are difficult to implement, but show high flexibility, and were applied to new target objects.

Purposes of Deformation

Among total 46 purposes, 13 purposes that had at least 3 frequencies are introduced in Table 2. Because of their large frequency, we share overall findings:

Purpose of Deformation	#	Existing /New
To Save Space	10	6/4
To Carry	8	5/3
To Adapt Space	8	4/4
To Fit to User Body	8	5/3
To Store	7	4/3
To Decorate	6	1/5
To Adjust Light	5	3/2
To Store/Carry	4	4/0
To Display Better	4	2/2
To Handle Bad Weather	4	2/2
To Improve Ergonomics	3	0/3
To Play with	3	1/2
To Show Information	3	3/0
Etc.	43	19/24
Total	116	59/57

Table 2: Purposes of deformation in daily objects. Ordered by frequency

- Making object compact (*To Save Space, To Carry, To Adapt Space, To Store, To Store/Carry*) formed 31.8% (37/116): *To Save Space* (E: sofa bed, N: hole-size-changing colander to adapt objects from rice to pasta.); *To Carry* (E: tooth brush, N: making tent bottom slippery to move it easily was an exceptional deformation mechanism.)
- Another significant groups were related to visible change (*To Decorate, To Adjust Light, To Display Better, To Show Information*) with 18 frequencies.
- Personalizing objects according to user's body size, preference, and emotions was another significant finding (*To Fit to User Body, To Decorate, To Improve Ergonomics, To Dress Up* in Etc.) with 19 frequencies.

Implications for Shape-Changing UIs

We found several meaningful comparisons between deformable daily objects and shape-changing UIs.

- *To Save Space* is represented by changing size of container depending on its containing object. (For example, luggage.) This feature has a similarity with Thrifty faucet [3].
- Based on the second finding in purposes, relating changing UI shape to information navigation seems more reasonable [7] would be generalized in future shape-changing products.

We suggest that there are still empty spaces to explore in shape-changing UIs.

- *Folding*: Folding techniques are applied to build shape-changing UIs. However, they allowed little shape change from folded paper to control the UI, without allowing complete folding or unfolding
- *UI Size*: Less research papers are contributed to large size shape-changing UI. We might need bigger scale study for future scenarios.

We think that these initial investigations look at the design problem in a different way and could contribute to relevant discussions during the Shape Changing UI workshop in CHI 2016.

References

1 Majken K. Rasmussen, Esben W. Pedersen, Marianne G. Petersen, and Kasper Hornbæk. 2012. Shape-Changing Interfaces: A Review of the Design Space and Open Research Questions. CHI '12, 735–744.

2 Anne Roudaut, Abhijit Karnik, Markus Löchtefeld, and Sriram Subramanian. 2013. Morphees: toward high "shape resolution" in self-actuated flexible mobile devices. CHI '13, 593–602.

3 Jonas Togler, Fabian Hemmert and Reto Wettach. 2009. Living interfaces: the thrifty faucet. TEI '09, 43–44.

4 Lining Yao, Ryuma Niiyama, Jifei Ou, Sean Follmer, Clark D. Silva and Hiroshi Ishii. 2013. PneUI: pneumatically actuated soft composite materials for shape changing interfaces. UIST '13, 13–22.

5 Yvonne Jansen, Thorsten Karrer, Jan Borchers. 2010. MudPad: tactile feedback and haptic texture overlay for touch surfaces. ITS '10, 11-14.

6 Miriam Sturdee, John Hardy, Nick Dunn, and Jason Alexander. 2015. A Public Ideation of Shape-Changing Applications. ITS '15, 219–228.

7 Daniel Leithinger, Sean Follmer, Alex Olwal, Samuel Luescher, Akimitsu Hogge, Jinha Lee, Hiroshi Ishii. 2013. Sublimate: state-changing virtual and physical rendering to augment interaction with shape displays. CHI '13, 1441–1450..