Empowering Makers to Create Reconfigurable Objects

Hyunyoung Kim
Université Grenoble Alpes
Grenoble, France
Hyunyoung.kim@univ-grenoble-alpes.fr

Céline Coutrix
Université Grenoble Alpes
Grenoble, France
celine.coutrix@univ-grenoble-alpes.fr

Anne Roudaut
University of Bristol
Bristol, UK
roudauta@gmail.com

Presented at the ACM CHI 2018 workshop: Maker Movements, Do-It-Yourself Cultures and Participatory Design: Implications for HCI Research.

Abstract
Reconfigurable – manually deformable or automatically shape-changing – objects form many applications from toys, ambient displays, to prosthetic legs. However, not many makers seem involving in creating reconfigurable objects in spite of democracy of fabrication tools (3D printer, laser cutter, etc.). It may be because they have little ideas on applications, have little knowledge implementation method (e.g., deformable structure), or the design process requires lots of effort (e.g., 3D modeling). In this paper, we propose three directions that HCI researchers can empower makers to create reconfigurable objects.

Author Keywords
Participatory design; reconfigurable object; shape-changing interface

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces.

Introduction
Reconfigurable objects are objects that can be deformed manually by the user or have a system automatically actuate their shape [6]. They can take deformation as input and change their shapes to transfer information to users. There is increasing

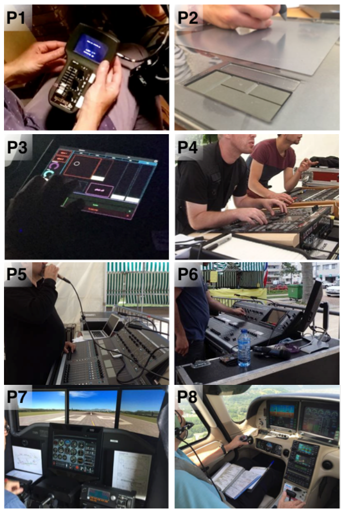

Figure 1. Participants using knobs and sliders in their professional activity: (P1) a cameraman with 4 knobs and a slider on a custom made device; (P2) a graphic designer using a graphic tablet and a slider placeholder; (P3) a light artist using custom knobs and sliders on a tablet in a dark environment; (P4) a light engineer using physical knobs and sliders while observing a stage; (P5) a sound engineer communicating with musicians on the far stage while using sliders; (P6) a sound engineer controlling a knob while watching a screen; (P7) a pilot using flight simulator for his training; (P8) a pilot using physical controls in a flight.

interest in creating those objects, and HCI researchers can empower Makers by 1) defining user needs on reconfigurable objects/interfaces, 2) refining design frameworks for creating new ideas, and 3) implementing prototyping knowledge and tools to accelerate and ease fabrication process.

Participatory Design: Defining User Needs

Many makers are motivated to solve their own problems and effectively do it. When they can look into others' problems that they are not well aware of, they would be able to make more positive impacts on the world. HCI researchers can help makers here, by letting them discover other problems. As HCI researchers have knowledge and experience in user studies and participatory design, they can better define what users' problems and needs are. By revealing and sharing user needs, HCI researchers can provide ground for makers to investigate new fabrication ideas.

For instance, we investigated professional users' needs regarding shape-changing interfaces in a recent publication [1]. We targeted widespread professions that use physical input control. Eight participants (ages 25-63, 2 females, Figure 1) were recruited, who use knobs and sliders in their professional activities: 1 movie operator (P1), 1 graphic designer (P2), 2 light engineers (P3, P4), 2 sound engineers (P5, P6), and 2 pilots (P7, P8). By observing their activities and interviewing during/after the activities, we could draw a set of user needs.

The user-needs guided us to implement KnobSlider, a shape-changing interface for parameter control (Figure 1). However, we believe that there can be many other ways to fulfill those needs, especially by motivated makers. Here we share the user needs we found, to encourage makers to jump into the problem and more HCI researchers are willing to conduct participatory design and organize user needs to encourage makers.

N1. Interaction with a large number of parameters was requested by all participants. The cameraman had the least (10). The sound and light engineers can deal with more than 100. Types of parameters were diverse: some were discrete (e.g., tool in Palette) or continuous (e.g., sound volume). Some were bounded (e.g., flaps' angle) or not (e.g., shift between cameras). Some were cyclic (e.g., projector's angle).

N2. Fast interaction. Quick access to parameters can be supported by placing devices within users' reach. Rapid manipulation of parameters can be supported through smooth trajectories. Fast observation of parameter value can be carried by visual and/or haptic displays, including min/max value or value of interest.

N3. Precise interaction can be supported through a large interaction area (multiturn knob or large slider) and little friction. Enough space between devices prevents errors. A stable grip on the device also allows its operation without slipping.

N4. Eyes-free interaction. Eyes-free access to parameters can be supported by spatial stability of the device to leverage motor-spatial memory. Eyes-free manipulation of parameters can be supported through physical trajectory guide (e.g., slider's rail, knob' rotational axis) and haptic feedback. Eyes-free observation of parameters' value can be supported through a physical cursor or haptic feedback (detent).

N5. Mobile interaction can be supported by small devices.

Openable lamps (#18) change lamp shadows to change light quality

Blender (#36) can change the blades and containers according to the purpose.

Tea pots and cups (#48) are combined to store, and detached to drink tea

Figure 2. Examples of collected everyday reconfigurable objects. The full collection of 82 objects with pictures is available at [24]. Photo credits (from left to right): the authors, Paul Goyette, Counselling.

N6. Retro-compatibility with current interaction: it is arduous for users to give up current UIs — even though new ones can be beneficial in the long term. This can be supported by standard operations of standard devices and customizability.

Not many shape-changing interface papers have defined user needs before implementing prototypes. The list of user needs guided us during the design process and helped to choose a right solution. When there are clear unmet user needs provided HCI researchers, makers will jump into the topics, create more and better solutions, and even may find new business opportunities.

Taxonomy: Refining Design Framework

Taxonomies often not only help HCI researchers describe new interfaces but also encourage designers to generate new ideas. For instance, shape-changing interface taxonomies [1,9,11] have been used to describe the reconfigurability of interfaces and to design new interfaces [7,8,10,12]. However, there has been little effort to refine taxonomies and share them with makers to date.

In our Morphees+ paper [6], we solve the problem of refining and sharing the taxonomies. To refine the taxonomies, we first collect a list of 82 everyday reconfigurable objects (e.g., Figure 2) that are accessible and extendable by the public [4]. We then refine the taxonomies and add *Size* and *Modularity* features. The taxonomies should continue evolving and help makers, designers, and HCI researchers.

In addition to the taxonomies, our research contributes to the knowledge of how to implement reconfigurable interfaces. For instance, we found an additional method to implement changing Porosity [9] or Permeability [11] other than the revolute pair that was used in Shutters [1]; a ventilation window (#17) can open holes through a prismatic pair (sliding, Figure 3).

Figure 3. Example of changing porosity/permeability. Sliding window (left) and prismatic low pair (right).

Design Knowledge and Tool: Empowering Fabrication Process

Custom 3D objects – static or actuated – are typically designed with digital CAD software. CAD software enables complex geometries and simulates mechanical movement. However, CAD software requires a long learning phase to be able to use advanced functions such as movement simulation. Moreover, the interactivity of the 3D models is limited to 2D screen. Printing can last for hours and slow down the design process. For instance, it does not allow users to put the model in a target environment and evaluate if the model has the right size or its movement does not interfere with other objects [1].

To overcome this problem, HCI researchers can create physical tools that help to design and simulate physical interfaces. Here we suggest Lego-like bricks that are low-cost, passive, and modular whose structure and movement is recognized by a sensor plate. Lego bricks that are easy to use and invites many types of users –

from children, adult, early to the blind – to physicalize their imagination. Here we illustrate possible features of the tool.

1. *Digitization*. The sensor plate should be able to recognize the bricks' 3D structure and transfer it to CAD software.
2. *Low-cost*. The tool should be produced at a low cost to increase accessibility. Ideally, makers should be able to 3D print the bricks and make the sensor plate by themselves.
3. *Passive bricks*. The bricks should be passive and do not include electronics, to enable 3D printing with a common 3D printer.
4. *Modularity*. The tool can consist of Lego-like modular bricks. The bricks have different shapes including deformable joints, to allow various design vocabularies for makers.
5. *Using software power*. The software allows easy modification of model and duplicating same designs. The digitized 3D structure should be editable in the software.

We envision that the tool can empower my makers who do want to create deformable or shape-changing objects but do not have knowledge or time to design such structures. Also, the tool can provide a good entrance to people who do not have fabrication experience but are interested.

Conclusion

In this paper, we suggested three directions to empower makers – contributing their knowledge of user needs and design framework, and providing physical modeling tool. These directions will help 1) experienced makers go one step further to create solutions for other people and their business, 2) all makers to generate creative deformable designs, 3) novice makers easily design and test 3D structures.

References

1. Agrawal H., Umapathi U., Kovacs R., Frohnhofen J., Chen H., Mueller S., Baudisch P. Protopiper: Physically Sketching Room-Sized Objects at Actual Scale. UIST '15. https://doi.org/10.1145/2807442.2807505
2. Coelho M., Maes P. Shutters: a permeable surface for environmental control and communication. TEI '09. https://doi.org/10.1145/1517664.1517671
3. Coelho M., Zigelbaum J. Shape-changing interfaces. Personal Ubiquitous Comput. 15, 2 (February 2011). http://dx.doi.org/10.1007/s00779-010-0311-y
4. Kim H., Coutrix C., Roudaut A. Collection of Everyday Reconfigurable Objects. 2017. https://cdn.rawgit.com/shape-changing-interfaces/Reconfigurable-Daily-Objects/c3b35dd8/everydaydeform/visualizations/CollectionOfImages/Web/ObjectsPresentation.html
5. Kim H., Coutrix C, Roudaut A. KnobSlider: Design of a Shape-Changing UI for Parameter Control. CHI'18. https://doi.org/10.1145/3173574.3173913
6. Kim H., Coutrix C., Roudaut A. Morphees+: Studying Everyday Reconfigurable Objects for the Design and Taxonomy of Reconfigurable UIs. CHI '18. https://doi.org/10.1145/3173574.3174193
7. Kwak M., Hornbæk K., Markopoulos P., Alonso M.B. The design space of shape-changing interfaces: a repertory grid study. DIS '14. http://dx.doi.org/10.1145/2598510.2598573
8. Nørgaard M., Merritt T., Rasmussen M.K., Petersen M. G. Exploring the design space of shape-changing objects: imagined physics. DPPI '13. http://dx.doi.org/10.1145/2513506.2513533

9. Rasmussen M.K., Pedersen E.W., Petersen M.G., Hornbæk K. Shape-changing interfaces: a review of the design space and open research questions. CHI '12. http://dx.doi.org/10.1145/2207676.2207781
10. Rasmussen M., Troiano G., Grave Petersen M., Simonsen J., Hornbæk K. Sketching Shape-changing Interfaces: Exploring Vocabulary, Metaphors Use, and Affordances. CHI '16. http://dx.doi.org/10.1145/2858036.2858183
11. Roudaut A., Karnik A., Löchtefeld M., Subramanian S. Morphees: toward high "shape resolution" in self-actuated flexible mobile devices. CHI '13. https://doi.org/10.1145/2470654.2470738
12. Sturdee M., Hardy J., Dunn N., Alexander J. A Public Ideation of Shape-Changing Applications. ITS '15. https://doi.org/10.1145/2817721.2817734
13. Troiano G.M., Pedersen E.W., Hornbæk K. Deformable Interfaces for Performing Music. CHI '15 https://doi.org/10.1145/2702123.2702492
14. Wang W., Yao L., Zhang T., Cheng C., Levine D., Ishii H. Transformative Appetite: Shape-Changing Food Transforms from 2D to 3D by Water Interaction through Cooking. CHI '17. https://doi.org/10.1145/3025453.3026019