Computational Objects and Expressive Forms: A Design Exploration

Heekyoung Jung
School of Informatics (HCI Design)
Indiana University
919 E. 10th St. Bloomington IN 47408
jung5@indiana.edu

Youngsuk L. Altieri
School of Fine Arts (Digital Art)
Indiana University
1201 E. 7th St. Bloomington IN 47405
lee237@indiana.edu

Jeffrey Bardzell
School of Informatics (HCI Design)
Indiana University
919 E. 10th St. Bloomington IN 47408
jbardzel@indiana.edu

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Abstract
We suggest the concept of *expressive forms* as a rising design theme to explore aesthetics of computational objects. The theme, exemplified in our design exploration, attempts to synthesize a concept-driven design process and exploratory engagement with new forms and materials available to computational objects. We report the detailed process of designing the soft-spiky mouse including prototyping and a pilot user study, leading to a discussion about the experiential qualities and design implications of *expressive forms* for research on aesthetic interaction.

Keywords
HCI, interaction design, aesthetic interaction, design, tangible interfaces, computational objects

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

General Terms
Design

Introduction
Advanced tangible computing technologies are not only introducing novel computer interfaces but also transforming the ways we interact with everyday objects and environments into computational activities. Computers

are no longer constrained to flat screens or black boxes, but are objectified in various forms [10]. Specifically, development of interface and material technologies has enabled diverse aesthetic qualities of interaction by dynamically changing various formal properties, such as color, texture, shape, material characteristics, etc. Hence the meaning and the context of interaction are diversified to include affective, embodied, and experiential values of digital artifacts. However, established task-based and experiment-focused approaches in HCI research are not sufficient to investigate those emerging properties [4]. In particular, user-centered design approaches, starting from user needs and requirements, have strongly prioritized functionality of interactive systems at the expense of their forms [5]. The motivation of our study comes from the increasing need for a designerly approach to explore forms of computational objects and their meanings as central issues of aesthetic interaction.

Expressive forms: A design theme

Bringing the trajectories for tangible interfaces from design and HCI together, we suggest *expressive form* as an important rising design theme for computational objects. This theme involves an effort to explore new types of interaction developed by attending to the aesthetics of forms. In this section we introduce key concepts of our approach.

Designerly Approach

A distinguished feature of our approach is to integrate traditional design approaches into HCI research with its emphasis on forms. The approach from traditional design disciplines, characterized by a combination of exploratory practice with materials and critical judgment [7], could invigorate research on tangible interface in the context of HCI with insight on how to create aesthetic forms of computational objects beyond making technical prototypes. At the same time, viewing design as an activity of crafting things instead of communicating with users, our approach complements traditional user-centered design perspectives.

Living Creatures and Expressive Forms

The fundamental theme in this work concerns how ecosystems, societies, and life itself form an interconnected web where the disturbance of any part affects everything. In particular, we were interested in the ways that certain animals change shape in response to external stimuli. For example, the skin of a hedgehog responds adaptively to sudden movements in the environment by changing from soft and smooth to rough and spiked. Our perspective as designers was that a metaphor of living creatures including hedgehogs, starfish, or carnivorous plants could provide interesting design narratives to tightly couple the meaning of form (i.e., reaction to a perceived threat) and its form-changing properties (i.e., becoming spikier) (Fig 1). Likewise, an interactive object can be thought of as an organic entity taking on different functional forms to express its design intentions in response to environmental changes or user actions.

Design Elements: Form, Interaction, and Function

To develop unique design intentions of *expressive forms* into an embodied object, we reinterpreted the model of rich interaction suggested by Frens [3] as intellectual design strategies. It contains three major design elements—form, interaction, and function. By *form*, we refer to the physical properties of objects, such as shapes or materials (i.e., textures, malleability, tension), which can be enhanced through computa-

Figure1. Metaphors from living creatures (i.e., hedgehogs and potato bugs showing defensive behaviors by erecting spines or crouching bodies when approached by other animals, flower opening its petals to absorb more light)

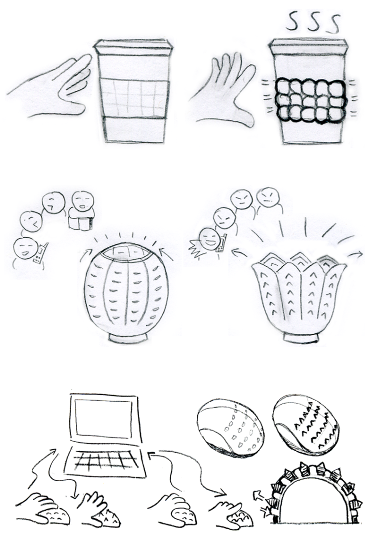

Figure2. Example design concepts for *Expressive Forms* (from top to bottom: an inflatable cup, a sound-sensitive lamp sculpture, and a soft-spiky mouse)

tional process (i.e., transformation, kinetic motion) [5, 10]. By *interaction*, we refer to the relationship between the user and object, which can be specified at the level of user action/perception and object input/output. In particular, temporal dimensions of forms enabled by computational processes need to be considered in close relation with interaction for its dynamic affordance. Lastly, *function* refers to the purpose or context of use in terms of how dynamic forms and interactivity could evoke certain meanings and/or display information. With new types of forms and interactivity enabled by tangible and organic interfaces [5], the notion of function probably should be expanded beyond practical or purposeful use, defined as *para-functionality* [2]. The model could enable design specification of an initial idea into a meaningful object through iterative conceptualization of a coherent synthesis of these elements.

Exploratory design workshop

Based on the design principles outlined above, we conducted design workshops to explore concepts of *expressive forms*. Two researchers, one with a background in Fine Arts and another in Interaction Design, explored design concepts through four sessions of weekly meetings by brainstorming and sharing individual survey of inspiring metaphors, visual images, relevant objects, and new material technologies.

The process began with exploring ideas inspired by interesting forms (e.g., body structure of living creatures such as hedgehogs, potato bugs, jelly fish and their behaviors), material technologies (e.g., shape-memory alloy, smart fabrics, diverse actuators), or intriguing scenarios (e.g., emotional refreshment, persuasion for behavioral changes, context-sensitive affordances through transformation of objects). During this first phase, most of our concepts were explored as design thought experiments with little consideration for technical implementation or practical functions. Then, meaningful concepts were selected and specified by considering the sensible relationships among forms, interaction, and functions as described above.

We mostly attempted to transform existing inanimate objects into "expressive ones" using metaphors of living creatures. By expanding already familiar functions of such objects with additional computational features, we could specify unique design intentions of *expressive forms*—to give awareness of user behaviors or situations through dynamic forms—into various design concepts. Some of the explored concepts include a sound-sensitive lamp-kinetic sculpture that changes its shape according to the sound level when it is loud (introduced in [6]), an inflatable cup that inflates its surface like bubbles when hot water is poured, a spiky mouse that changes its surface textures according to the amount of time that user works with the mouse, etc. (Fig 2).

The collection of these design concepts helped us explore our design space with various potential form properties (i.e., visual patterns, tactile feelings) and specify its problem space by questioning how such form properties could be materialized, interacted and interpreted. In what follows, we describe the process of designing one of the explored concepts—the spiky mouse.

The soft-spiky mouse

The concept of the soft-spiky mouse was inspired by the skin of starfish, which is flexible enough to transform its body shape but at the same time solid enough to be fixed with small pieces of bones on its skin (Fig 3).

Figure 3. Metaphors and materials for the soft spiky mouse (starfish, jellyfish, and rubbery materials from toy balls.)

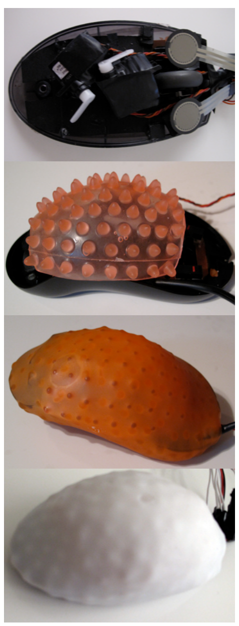

Figure 4. Prototype development (by using servo motors, force-sensitive resistors, and rubbery covers from toy balls.)

The form inspired us to imagine a scenario where tactile forms would be applied to interactive objects. We sketched its function and interactivity by applying the initial concept of tactile forms into the mouse; by changing its surface textures according to the amount time that user works with the mouse (Fig 2).

Personality and Emotion Embedded in Objects

Not only do we see the external forms of other creatures, but we also "read" and respond intelligently to their emotions from their behaviors. In the design of the "soft-spiky mouse", we recreated movements in a manner similar to the way in which creatures express emotions. The purpose is not simply to mimic natural movement but rather to provide a subjectively rich account of the changeable forms observed in nature to metaphorically depict relationships between creatures. For example, if the user works for long, the mouse would display spiky textures to raise awareness to the passage of time and/or the need for refreshment or break time. At the same time, we leave room for the interpretation of the form with regard to its para-functionality, such as hedonic or arousing tactile feelings. Diverse tactile properties of the surface could introduce new ways of interacting with digital objects.

Making The Mouse

We searched for proper materials and structures to subtly transform the surface by switching between different textures within a given shape and to continue wiggling in response to a user's press or squeeze. We used two layers of different tactile patterns and materials—the smooth cover (soft rubbery piece of a stress ball) and the spiky plate underneath (hard rubbery piece of a toy ball) (Fig 4). When the mouse is activated entering a break time, the spiky plate underneath moves up pushing the cover upwards. During rest-time, the mouse responds to the user's press by undulating. The harder the mouse is clicked or squeezed, the more intensively it begins to wriggle. Servomotors were used to move the two layers up and down in a wave. Force-sensitive resistors detect the intensity of press and control the degree of motor rotations in Arduino [1].

Preliminary User Interpretation

We had conversations with seven graduate students from HCI and Cognitive Science in two group sessions, each lasting 30 minutes. The main objective of this discussion was to demonstrate the prototype to some users and to explore questions pertaining to the concept of *expressive forms*, not so much to evaluate our prototype as an early instantiation of a "real" commercial product. The coordinator asked participants to interact with the mouse without any explanations of its function. After interacting with the mouse for a while, participants were asked 1) whether they had recognized any changes from the mouse, 2) what they thought the mouse could be used for, and 3) their reactions to interactive behaviors of the mouse and initial ideas for its use. The following is a summary of responses:

- All the participants quickly got the idea of how the mouse works—something moving up and down inside the cover in response to button clicks. It was interesting that most participants expressed themselves using analogies between the flexible/organic movement of the mouse and the behaviors of living things, such as pumping heart, alien, squirrel, etc. They also mentioned that the sound when the servomotors operate sounds like mice or squealing noises, so the sound subjectively reinforced the visual and tactile metaphors.

- Most participants thought the movement was for fun, relaxing, or massage. Some considered it is for encouraging users to press more (by intriguing them with interesting tactile movement) or less (like saying "it's okay to press soft"). A few of them thought the response was related to some functional feedback when specific buttons clicked or certain applications opened in the computer. No one guessed the use we had initially intended (but the session did not simulate the intended use).
- Once they were informed of the intended purpose of the mouse—to remind of the need for a break—many liked the idea: "Sometimes I have to do repetitive work. My brain knows it's killing me to click mouse buttons hundreds of times, but my hand just continues. It just keeps going on without thinking." "I would need it so badly, I also want it for my keyboards."
- Participants instantly distinguished the different tactile feelings of movement when different mouse covers were used. Even though they could not articulate the differences, they could tell their preferences—some liked soft and cushiony feelings while others liked the thinner cover through which they could feel more spiky textures of the plate underneath. Interesting issues on material properties were discussed as well: "I like this soft cover. It feels relaxing. Can I have just the cover for my mouse?" "Isn't this from a stress ball? It makes me keep pressing it" "I like this soft feeling, but not the sticky one. This will easily get dirty and gross with everyone's bacteria stuck all over it."
- For other possible applications, they mentioned a mobile phone getting spiky when used too much or when a speaker was too loud for a given setting, a chair wiggling when you need exercise, or public mice buzzing if used for long for individual purpose.

These conversations helped us not only understand how people interpret the spiky mouse but also explore potential experiential qualities of *expressive forms*.

Reflection and discussion

With a design theme of *expressive forms*, we started our design by exploring design concepts from inspiring metaphors or materials instead of from specific user needs. This approach is common for practicing creativity in arts and design, but has limitations to be applied as a formal research method due to its lack of rigor and somewhat serendipitous nature in discovering innovative ideas. Still, this synthetic way of thinking could complement the current user-centered design approaches if they benefitted from proper guidelines—not step-by-step instructions but relevant design narratives, systematic survey of materials, and critical judgment. In this study, we applied metaphors of living creatures as one way of exploring forms and their meanings. Collections of diverse metaphors and materials could invigorate research on aesthetic forms by guiding exploratory thought experiment and practice with diverse materials, which we will continue working on.

The ambiguous meaning of physical forms also could enable users' subjective interpretation [9]. As seen from the preliminary study of the mouse, users could link its use to different applications based on their engagement with its physical interaction. However, their subjective interpretations were not just random but showed some relevance to each other rooted from its initial metaphor. The value of a design moves onto its provocative meaning from its accurate representation of function. We expect this approach could drive "creating user needs" as well as design innovation beyond understanding current status by exploring potentials of new material and interface technologies. Although our approach emphasizes on forms, ultimately it is aimed to enrich aesthetic qualities of computational objects by expanding existing conceptualization of their interaction or functions through new forms.

Another insight from this study is that users are very sensitive at perceiving subtle differences of formal factors and easily determine their preferences among them. For example, users in our demonstration-conversations compared the wave movement from the mouse to cyclic vibrations, which they considered more mechanical, and also talked about material qualities of the rubbery covers both in terms of practical or pleasurable purposes. These details might not influence on performance of practical functions, but they would play a potentially significant role in user experience [8]. This implies that we must become methodologically rigorous in factoring aesthetics and experience into our prototypes, distinguished from technical prototypes for early evaluation of functions.

Regarding the subtleties of aesthetic qualities, evaluation is complicated by the need to evaluate too many variables as a whole object. In other words, it would be meaningless to measure and control for individual design variables such as shape, color, texture, historical/cultural reference, and so on separately, because these variables are perceived, experienced, and interpreted holistically. This holistic approach to aesthetic experience with interactive objects underscores the need for theoretically sound strategies to *craft* the delicate aesthetic qualities of computational forms.

Conclusion

This study offers a designerly approach for aesthetic forms of computational objects by illustrating our design process and reflection as transparently as possible instead of suggesting conclusive design guidelines through formal evaluation. We expect this approach to contribute to research on aesthetic interaction with alternative design perspectives. Future research will be continued as discussed in the reflection.

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