Whirlstools: Kinetic Furniture with Adaptive Affordance

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Figure 1: Whirlstools concept renderings.

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Abstract

Despite the deepening integration of digital technology into architectural space, kinetic (i.e., *shapeshifting*) architecture has found few applications outside of installations in art galleries. Clearly, a major culprit is cost—complex transformation mechanisms can rarely be built and operated at costs low enough to justify their often unclear benefits. In this paper we argue that by drawing on the psychological theory of *affordance*, we can design low-cost kinetic architectural systems that nonetheless bring about beneficial, sizable changes in human behavior. To illustrate the idea we introduce *Whirlstools*, a kinetic furniture system that uses modest adjustments of seat angles to foster spontaneous conversations among strangers in public spaces.

Author Keywords

Kinetic architecture; kinetic furniture; affordance

ACM Classification Keywords

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

Introduction

Kinetic architecture [16] has long captivated the imagination of both architects and the general public, but examples of its successful deployment in the real world have so far been limited—excluding novelty uses





Figure 2: Ticket gate in a Tokyo train station.

Note: Norman has proposed a new term, *signifier* [10], to resolve the discrepancy between Gibson's original concept of affordance and its (mis)interpretation within HCI/design communities. For now we are sticking to the term affordance, however, in light of its more widespread usage and recognition. in gallery installations, revolving restaurants, etc.—due mainly to the often prohibitive costs of its construction, operation and maintenance. Relying on small-scale kinetic mechanisms may alleviate the cost to some extent, but this will also reduce both the size and range of potential spatial transformations.

However, small-scale transformations need not always result in small-scale *impact*. Findings in environmental psychology [3] teach us how tiny details in the design of the environment can unconsciously affect our behaviors in profound ways. In particular, the concept of *affordance* (introduced by Gibson and popularized by Norman [9]) has found wide support among designers, with a long list of documented uses in actual product developments corroborating its practical efficacy.

In this paper we argue that through clever employment of affordance theory, we can build small-scale kinetic architectural systems that nonetheless trigger palpable changes in human behavior. We make this argument using as a case study the design of *Whirlstools* (Figure 1), a novel kinetic furniture system that uses simple, one-axis rotations to subtly encourage communication between strangers in public spaces. Though a full-scale implementation of Whirlstools has yet to be realized, we will offer in-depth discussions of its design rationale, highlighting insights that may be applied generally to future designs of kinetic architecture/furniture.

Adaptive Affordance

Affordance (according to Norman [9]—this is the most commonly used definition in HCI/design) refers to *perceived action possibilities* within an environment. It is through affordance that we can determine whether or not an office chair (or a tree stump, large rock, etc.) is suitable for sitting on, or tell which elements are clickable on a GUI. An often used example to illustrate the relevance of affordance to design is the door handle—depending on its form a handle can "afford" either a pulling or pushing motion, and if a handle is not designed to be congruent with the door's opening mechanism (e.g., a handle that affords pulling motions is fixed to a push-open door) there will likely be many instances of frustrated people clutching and tugging at the handle in vain. One example of a widely-used product whose design makes good use of affordance is the RFID ticket gate in Tokyo train stations. While an early prototype of the gate had a completely flat top surface, in the final design a modest angle marks the area where the RFID reader circuit is embedded (Figure 2). After introducing this slight angle, it is reported that users began to explicitly touch the reader area with the cards (instead of skimming the cards *over* the gate as they did with earlier prototypes), drastically reducing the rate of reading errors [15]. The modest angle suddenly made it clear to users how to interact with the new RFID technology, acutely altering their behaviors.

We believe that affordance can be used to *leverage* the power of kinetic architecture. The ticket gate example shows us that even minute differences in physical form can afford (and *induce*) widely divergent types of behaviors. If that is the case, we should then be able to design simple, small-scale transformation mechanisms which, through calculated alterations of affordance, induce a broad range of targeted behavior within people. Using such principle of *behavior control through adaptive affordance* may allow us to bring down the cost of kinetic architecture, while retaining its ability to affect and shape people's behaviors in sizable ways. (The wealth of know-how that already exists regarding





Figure 3: Stool design.

the use of affordance in design will scaffold this process.) Our investigations have so far focused only on kinetic systems, but the same principle may be applicable to digitally enhanced architecture in general (i.e., *responsive architecture*).

Related Work

In spite of HCI's recent fascination with physically transforming interfaces [13], kinetic architecture has so far had only a minor presence within the community, with a small number of works typically presented outside the main technical tracks of HCI conferences [8]. More generally, architecture itself has attracted little interest in HCI. There are nascent efforts to rectify this situation, however [4, 14], and considering the diversifying settings of HCI research and architecture's powerful role in shaping human behavior, it is imperative that the community shed its indifference and initiate further investigation in this domain. On the other hand, in architecture/design circles there has been sustained, active discourse surrounding kinetic architecture [6, 16]. Although the concept of affordance has frequently been featured as an aesthetic device in such discussions, in this paper we instead focus on the concept's potential for *implicit behavior control*—using it to compose a practical strategy for building low-cost, but still potent, kinetic architecture.

Our interest in designing mechanisms that implicitly control human behavior makes our work related to prior research on persuasive technology [5] and ecofeedback systems [7]. A considerable amount of work exists within HCI literature in these domains; how theories and techniques devised in such works can be incorporated into the design of kinetic architecture is a topic we plan to explore in future research. Our work is also influenced by precedents in innovative public architecture/furniture [1, 11], and from the growing movement of urban intervention [2], where citizens employ DIY methodologies to implement ad hoc improvements to their cities in bottom-up manners.

Whirlstools

To demonstrate our idea of adaptive affordance, we are designing Whirlstools, a novel kinetic furniture system for public spaces. As illustrated in Figure 1, Whirlstools is made up of a group of cylindrical stools, each with a characteristically angled top. This angle has the effect of making the stool most comfortable when seated in a particular direction (Figure 3, top). However, the angle has been carefully selected so that it is still entirely possible to sit in the other directions, albeit requiring slightly more effort—i.e., the stool does not dictate seating direction, but instead exerts "soft" steering of behavior via affordance. The system thus maintains the flexibility of use expected for public furniture.

A servo is embedded within each stool, that allows the top part of the stool to rotate to arbitrary orientations (Figure 3, bottom). Together with the aforementioned slanted seat, this enables the system to exercise some level of control over the directions in which people will choose to sit on the stools. A set of proximity sensors is also installed, to constantly monitor whether each stool is currently being seated or not.

Every time a person newly sits on a stool, all the other unoccupied stools in its vicinity also rotate, in ways so that when another person comes along and sits on any of the remaining stools, s/he will be more likely to sit face-to-face (and consequently more likely to have spontaneous conversations) with people already seated





needed the algorithm can be reversed, to instead lower the likelihood of spontaneous conversations.

The design is built on an assumption that guiding people into sitting face-to-face through such kinetic optimizations leads to heightened chances of social interactions. This assumption is not entirely supported by psychological theory, however; while many studies do exist on the relationships between seat layouts and frequencies of conversations [12], we failed to find in existing literature findings or theories that are directly applicable to our setting of public space. Instead, the design has been informed by the authors' informal observations of passenger behavior in Japanese trains, under different types (row seating / face-to-face) of seat layouts. As we have yet to complete a full-scale implementation of Whirlstools, whether our assumption holds true or not in actual deployment is still unverified.

The design was also motivated in part by the wellpublicized issue of urban isolation in Japan, epitomized by the *kodokushi* (literally "lonely death") phenomenon that has become the subject of nation-wide attention in recent years. Though we are not as naive as to think that kinetic furniture alone can solve such deep-rooted social ills, we considered it necessary for the design to be both situated in a real-world context and also to have a clear social goal—i.e., we wanted to avoid engaging in a purely academic exercise irrelevant to (and hence will likely yield little insight applicable to) real-world architecture or public furniture projects.

Prototyping

The size and shape of the stool, and most importantly the angle of the seat surface, was determined through building a series of cheap, static mockups—first using



Figure 5: Static mockup.

cardboards and then with laser-cut plywood boards (Figure 5). We have verified, although informally, the effect of the angled seat on seating orientations; people (from children to adults) generally chose to sit in the "correct" orientation (as illustrated in Figure 3) without being presented with any instructions. The comfort level of the stool evidently differs depending on the person's body size/shape, however. The current angle of 11 for some people is apparently too steep for extended seating; finding the optimal seat angle for all body types will require further empirical studies.

We built a custom simulator (Figure 6) to fine-tune the stool rotation algorithm. Particular attention was paid to ensure that the algorithm retains its effectiveness over a wide range of stool numbers/layouts—an expensive and laborious task with physical models, but one that is relatively effortless on a digital simulator.



Figure 6: Simulator software.

Once we settled on a rough initial design we created a fully-functional model (Figure 7) that implements all of the basic functions, albeit on a smaller scale (7/30 scale—stool diameter is 7cm as opposed to 30cm). The mechanical and electronic components were selected so that both the wiring and programming will be nearly identical between the model and the full-scale system. The external shell of each stool was crafted from 3D printed parts, with openings to insert both a miniature servo and an optical sensor. Stools are fixed to a lasercut acrylic base, inside of which wirings and electronic components are concealed. A custom software running on an iMac (that doubles as the aforementioned simulator) controls the entire system; all stools are connected to the iMac by cable via Arduino Uno boards. We have also made human models at the same scale as the stools. By moving around the models by hand, we



Figure 7: Fully-functional scaled model.

attempted to obtain a general sense of the actual experience of interacting with Whirlstools.

The static mockups, simulator and scaled model all assisted the design in different ways. The mockup was vital in verifying whether the angled seat actually does "afford" seating in a specific direction, the simulator allowed us to test whether the rotation algorithm was robust to various stool configurations, and the scaled model helped us understand and discuss with clarity the interactions that may occur with and around Whirlstools. Though a complete evaluation obviously will require a full-scale implementation, the prototypes have allowed us to validate the core design rationale in a quick-and-dirty, but nonetheless effective, manner.

Universal Affordance

If the strategy of adaptive affordance proves to be as effective as we hope, eventually we will accumulate a wealth of know-how regarding its use, in the same way we possess significant know-how about how to employ affordance theory in non-kinetic architecture/furniture/ product design. We will gain an understanding of how to use minute kinetic transformations to control not only the frequency of communication, but also a range of physical movements, postures and maybe even emotions/thoughts. Adopting a rather speculative stance, we can envision that in the future, we may be able to use the accumulated know-how to build a space where an army of mechanisms (kinetic and otherwise) dynamically creates, erases and alters various types of affordances throughout the environment. Such room with universal affordance can freely induce a myriad of behaviors in its inhabitants-unconsciously steering them to become more talkative, lethargic, vigilant, etc.

Conclusion

In this paper we described how by using the theory of affordance we can design low-cost kinetic architecture that nonetheless exerts sizable effects on human behavior, using as example the design of Whirlstools, a kinetic public furniture system that fosters face-to-face communication in public spaces. While our work may at first seem peripheral to HCI, in light of the community's enthusiasm toward shapeshifting UIs and the emerging acceptance of architecture as a viable HCI research interest, we see our work instead as spearheading a vital new research domain for the field, i.e., kinetic architecture as next generation user interface.

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