STARTING FROM THE MICRO

A Pedagogical Approach to Designing Responsive Architecture

CATHERINE HU
School of Design, The Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong.
sdcathhu@polyu.edu.hk

AND

MICHAEL A. FOX
The Southern California Institute of Architecture
Office of KDG: 1725 Abbot Kinney Blvd., Venice, CA 90291
Tel +1(310) 577-8383 Fax +1(310) 943-2609
mafox@mit.edu

Abstract. The paper outlines a pedagogical approach whereby a number of technology-intensive skills can be quickly learned to a level of useful practicality through a series of discrete, yet cumulative explorations with the design goal of creating intelligently responsive architectural systems. The emerging area of responsive architecture serves as a practical means for inventing entirely new ways of developing spaces, and the designing and building environments that address dynamic, flexible and constantly changing needs. Responsive architecture is defined here as spaces and objects that can physically re-configure themselves to meet changing needs. The central issues explored are human and environmental interaction and behaviors, embedded computational infrastructures, kinetic and mechanical systems and physical control mechanisms. Being both multidisciplinary and technology-intensive in nature, architects need to be equipped with at least a base foundational knowledge in a number of domains in order to be able to develop the skills necessary to explore, conceive, and design such systems. The teaching methods were carried out with a group of undergraduate design students who had no previous experience in mechanical engineering, electronics, programming, or kinetic design with the goal of creating a responsive kinetic system that can demonstrate physical interactive behaviors on an applicable architectural scale. We found the approach to be extremely successful in terms of psychologically demystifying unfamiliar and often daunting technologies, while simultaneously clarifying the larger architectural implications of the novel systems that had been created. The authors summarize the processes and tools that architects and designers can utilize in creating and demonstrating of such systems and the implications of adopting a more active role in directing the development of this new area of design

1. Introduction

The emerging field of Intelligent Responsive Architecture is gaining prominence in recent years. Increasing presence of sensors and actuators in domestic contexts calls for the need of architects and designers who can design intelligent and adaptive architectural systems. The majority of students of architecture or environmental design however have not been exposed to this new field. The challenge in developing a course on Responsive Kinetic Systems lies in the highly technology-intensive nature of the subject matter, involving knowledge and skills that cross boundaries into engineering, computer, and behavioral sciences.

From the onset, the authors of this paper were conscious of the difficulties design students might experience. We contend however, that such difficulties are best tackled by removing the psychological barrier design students tend to have towards computing and engineering. We believe that this is best achieved by having students work on a series of small, explorative hands-on model-making exercises that are incremental in nature, and which gradually incorporate engineering and computing components. Based on this approach, the authors developed a short course to enable undergraduate students to have hands-on experience in designing Responsive Kinetic Systems. This paper reports on the design, delivery, and project outcomes of this course. The authors also argue that when the design tools evolve together with the developing design concept, crossing of boundaries becomes easier, facilitating the acquisition of new knowledge in other domains.

2. A five-week course on Responsive Kinetic Systems

2.1. COURSE OBJECTIVES

This course is conceived as a skill-based subject for both environmental design and interactive systems design students at the School of Design of the Hong Kong Polytechnic University. The objective is to enable students to acquire the skills necessary to develop intelligently responsive kinetic structures and systems. The course addresses kinetic function as a technological design strategy for building types and objects that are efficient in form, and inherently flexible with respect to various contexts and a diversity of purposes. The idea is to create spaces and objects that can physically reconfigure themselves to meet changing needs.

2.2. COURSE DESIGN

The course was predominately workshop based and supported by lectures that provide the necessary conceptual framework. The course began with an introduction to theoretical concepts and precedent in architectural applications of Responsive Kinetic Systems. Basic engineering concepts in mechanical structures were also introduced. Simultaneously, students were asked to explore various mechanical motions and joints from found objects and structures that intrigued them, and then select one structure to examine closely its underlying mechanics. They were then required to re-build and re-model the mechanical structure to replicate and expand its basic kinetic capabilities.

Next, students were introduced to basic concepts in electronics, as well as BasicStamp, a programmable IC chip with an integrated circuit for the incorporation of sensors and motors. While learning to work with BasicStamp, students were asked to think about applying the motors to their mechanical joint explorations, as well as using sensors to trigger the motion. At this point, the concept of behaviours was introduced, and students were asked to both design and rationalize the intended behaviours of their mechanical structure, and apply these interactive behaviors towards an architectural application. It is in this manner that the students' initial model explorations gradually grow in complexity, integrating first automatic functions, and later, more complex autonomous behaviors, and lastly architectural applicability and conceptual insight.

2.3. STRATEGIES OF DELIVERY

Most of the topics on electronics, computation and mechanics were covered only in a very basic, introductory manner. The approach used in this course was different from typical design courses in that rather than starting from *macro*: finding a problem, then research, then design, we started *micro*: designing the mechanical structures first, then 'grow' the system by adding sensors and motors, then designing the behaviour of this system, then develop the application of this system in the larger context of use. The objective behind this methodology was to allow students to focus on the core of the responsive system itself, that is, the fundamental mechanical structures and how to embed this with interactive and intelligent behaviors. This approach also minimizes the daunting psychological effects students might experience if from the onset, they were told that they have to develop a structure or building that is intelligent and that can physically demonstrate interactive behaviors. By going micro, students did not feel the pressure of confrontation by venturing into unknown territories. This hands-on demystification process is very important for crossing interdisciplinary boundaries.

The challenge here lies in having the students learn a minimum, in order to be able to achieve a greater sum than the additive parts, in the sense of being able to embed kinetic structures with behaviors that demonstrate, as opposed to simulate, one's design ideas and intents in intelligent and responsive systems. Through discretely gaining elementary interdisciplinary confidence, the ultimate goal is for students to be able to overcome psychological barriers and have the confidence to communicate with engineers and programmers their design intentions in an effective manner. Such confidences can have a strong effect in architects taking a more active role in directing the development of interdisciplinary design directions. To do this, designers need to have at least a superficial knowledge base of both the engineering in terms of mechanics and fabrication and also the computational substructures in order to develop the necessary skills and the conceptual and intellectual framework for designing.

2.4 APPLICATION EXAMPLES

Several student projects from the course are outlined below that illustrate the methods and processes used in designing intelligent responsive structures and systems.

2.4.1. Kinetic Chair/Table Systems

This interactive design project for kinetic chair/table systems demonstrates the simplified prototypical kinetic attributes that first grew from a simple exercise in mechanical design. The simple mechanical model of cardboard that demonstrated the motion grew to a precise mechanism with gears and motors and sensors. The design in its final stage retained the base mechanical principles yet grew discretely to demonstrate a full range of attributes relative to kinetic function, human interaction, adaptive control and realistic operating conditions. The model incorporated sensors and motorized control in order to prototype the behaviours of the systems as opposed to simulating them. The project is a specific application scenario that actually affects the nature of the architectural construct (the room). Specifically, the design project is a networked system of individually responsive chairs that function together, transform from an invisible floor module to a congregation of six chairs when half-risen, or a table when fully raised. Primary design considerations were to affect the physical space and to create a module of furniture that is adaptable both to the number of users as well as to be physically present when it is necessary and invisible and out of the way when it is not in use.

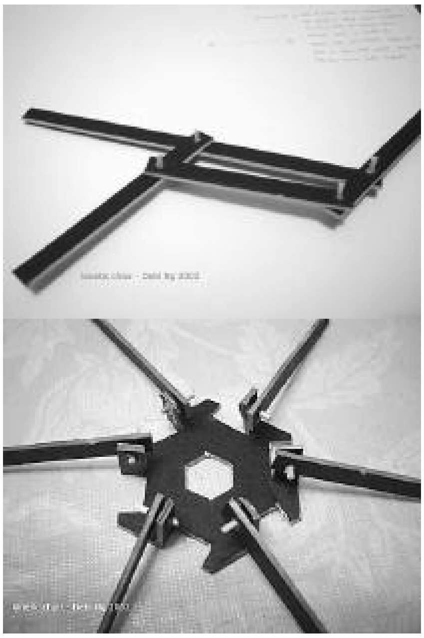

Figure 1 and 2. Early mechanical joints explorations

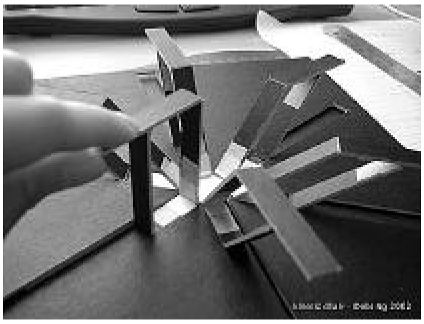

Figure 3. Assembled structure.

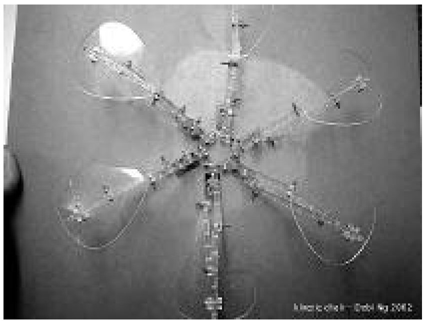

Figure 4. Final kinetic model.

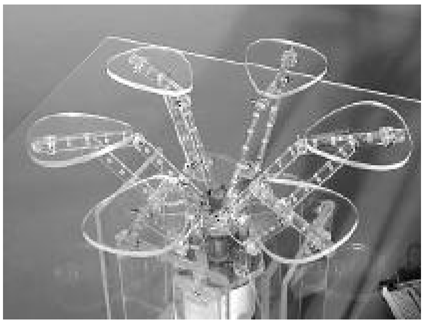

Figure 5. Chair module (half-risen).

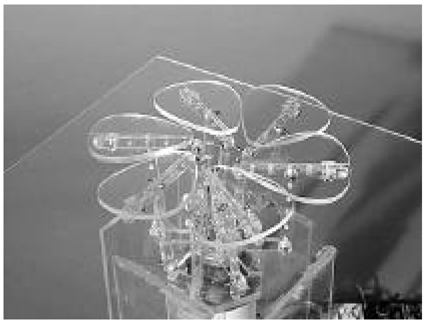

Figure 6. Table module (fully raised).

2.4.2. Caterpillar Kiosk

The Caterpillar Kiosk project has employed a mixture of prototyping tools and techniques from early mechanical joints explorations throughout to final design implementation. It demonstrates how tools and design co-evolve, with the tools facilitating the design process as opposed to directing it, an argument that will be further discussed in the paper. The final design is a hybrid structure: the core mechanism, responsible for the piston-like motion, is built with fabricated materials; this is further integrated with, and also affecting, the navigation mechanism built with LEGO gears and motors. Primary design consideration was to provide a temporary shade and shelter in areas where it is most needed, and when it is needed. The idea is to embed this mobile caterpillar structure with both light sensors and motion sensors, such that it will navigate autonomously towards the direction of strongest UV index, but will stop once it senses human motion within it. When it is not moving, people can then gather inside the structure and enjoy being shaded from strong sunlight or even heavy rain. Application environments are perceived to be vast open areas like parks or beaches. While not in motion, the caterpillar structure could be used for other temporary activities like public performances, or as a temporary catering facility. The final model here also incorporated sensors and motorized control to in order to demonstrate through prototyping the behaviors of the systems as opposed to simulating them.

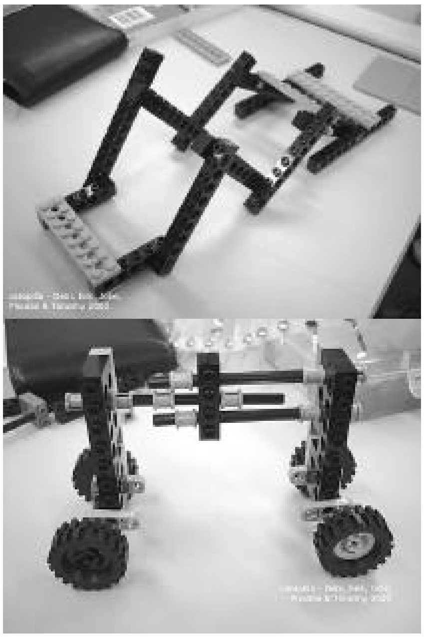

Figure 7 and 8. Early mechanical joints explorations using LEGO parts.

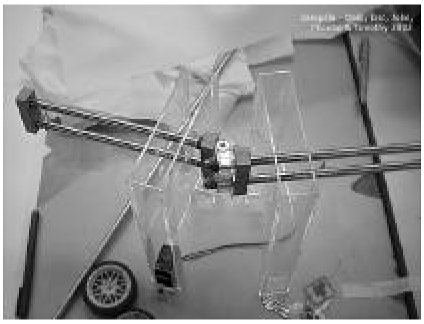

Figure 9. LEGO parts replaced with fabricated steel and acrylic modules.

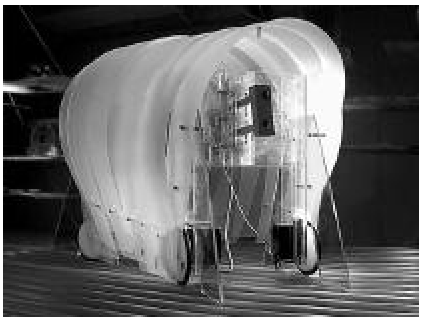

Figure 10. Final model incorporating sensors and motors.

2.4.3. Additional Examples

Several additional projects are shown below that demonstrate a wide range of application examples in architecture. The applications grew out of the simple mechanical explorations with varying degrees of complexity. A diverse range of prototyping materials were also employed in these final models in order to clarify architectural issues of structure, transparency, lighting, etc. Typically it was desired that the computation, (control boards and sensors) be seamlessly embedded into the structures rather than being openly expressed as an architectural quality, and that the mechanics and motorization be openly expressed. We find it important to note these differences in attitudes towards mechanics and computation and although such differences are not quantified here, we note that perhaps they are a result of the familiarity and acceptance that students have with mechanics in the real world as opposed to things computational and that architectural expression may change as more designers explore, design and familiarize themselves with such systems.

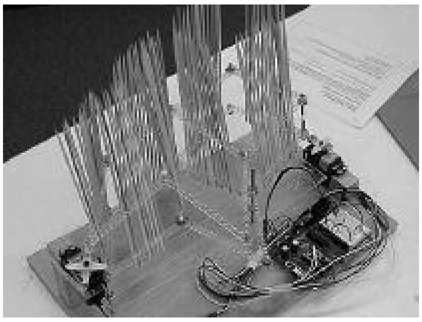

Figure 11. Wall system combining intelligence with traditional materials.

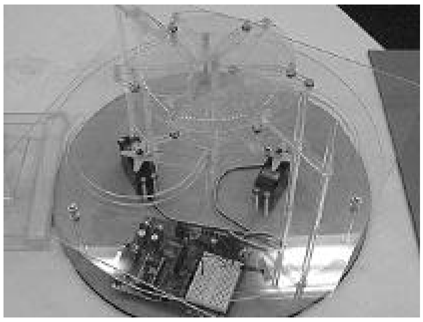

Figure 12. Transparent materials employed for intelligent skylight system

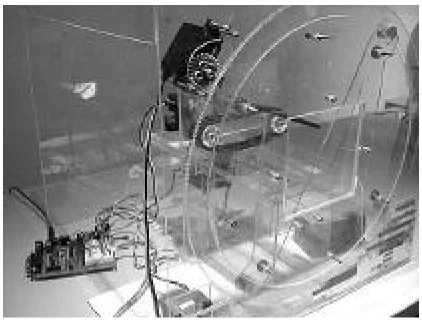

Figure 13. Exposed mechanics with hidden computational control system

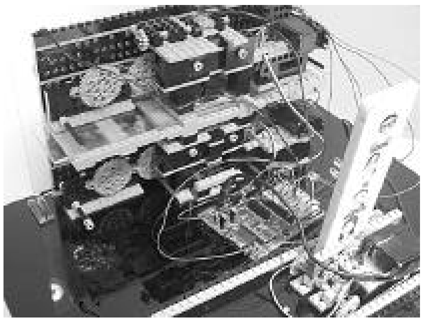

Figure 14. Complex behavior hidden behind simple architectural interface

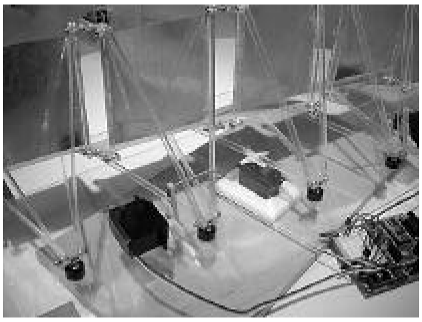

Figure 15. Intelligent solar reflectors with hidden mechanics and computation

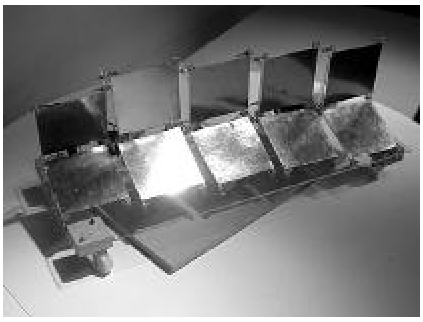

Figure 16. Full scale prototype of intelligent solar reflectors

3. Evolving the design tools with the design

This paper also argues that the design tools (most of which were borrowed from other disciplines) used in the design and prototyping processes, plays an important role in the evolution of the design itself. In particular, how the tools used in prototyping behaviors with real-time feedback influences the processes utilized in designing, and consequently, have a profound effect upon that which is actually designed. The integration of such tools for simulation (rather than representation) into the process of designing lies in an understanding of anything as malleable to idiosyncratic designing needs. In computing, this is comparable to chunks of codes easily becomes reusable 'tools', facilitating individuals in developing other codes. The tools as used in teaching this course in Responsive Kinetic Systems, we argue, develop new heuristics if such methodologies can in turn be tracked; they can more aptly facilitate novel tools. The tools and the design, on the generalized level as well as the specific, ought to evolve together. When we are designing with a tool, the heuristics of the process are thereby directed through the affordances and limitations of the tool. However, when the tools used evolve with the design, the heuristics are facilitated by the tools, and not necessarily limited by their parameters. Process then is directed or guided by the tools in the former, and facilitated by or directing the development (both in the general and the specific) of the tools in the later.

To exemplify, we observed that in the course, while experimenting with different fabrication options to develop their prototypes, we saw students actually modifying LEGO pieces by cutting them up or drilling holes into the pieces, hence creating new parts. Other students dissembled bought mechanical or electronic parts, and reassembled these with other found modules, discovering new motion capabilities for their intended structures along the way. This co-evolution of the design with the design tools has in part, been made possible by the lack of preconception to limitations of the tools themselves on behalf of the design students. In this sense, designers very naturally 'break the rules' and consider the tools as pliable as the developing design concept. This in turn has actually facilitated the crossing of boundaries and subsequent acquisition of hands-on knowledge in the said domains.

4. Architects directing the development

Building is a hugely complex endeavour and it is not possible to design a building without consulting many specialists (architects, engineers, construction managers, lighting consultants, mechanical engineers, acoustical experts, financial advisors, and legal experts, etc.) [Cuff 1991]. But collaboration is difficult as each specialist comes from a different educational foundation [Kalay 1999], and has goals and criteria and methods that are different from others. Intelligent responsive architecture, being a more complex building type, will require the collaboration of even more specialists. However, the heterogeneous backgrounds of the participating professionals in the building industry are often a source for misunderstandings and misinterpretations of the communicated information, leading to errors and conflicts. [Kalay 1999.]

To overcome this, the paper proposes that architects should take courses on simple mechanics and computation in order to accumulate a superficial knowledge base in these domains. This will enable the architect to share the perspectives and general concerns of other specialists, and to better communicate his design intentions, ultimately facilitating better collaboration amongst the team. Further, we are really at a point in the profession where intelligent responsive systems are possible and even feasible from an economic standpoint. It is both timely and important that architects should take on a more active role in directing the development of this area of design. The idea is not for architects to do structural calculations on a building, nor to develop the computation that controls the behaviour of a responsive system. The traditional role of the architect will not change, but he will have new roles of engineering and consultancy, defining and designing the next generation of responsive buildings.

5. Concluding remarks

This paper has described a course in responsive kinetic systems as an exemplar of a pedagogical approach to nourish the future generation of architects and interactive systems designers. Design artefacts in the new millennium, whether it is a building or an object, will inevitably be increasingly technology-based. Objects and environments will be smart and responsive, capable of complex behaviours. It is therefore, timely for architects and designers to equip themselves with foundational understandings in domains like engineering and computation, in order to assume a leading role in helping to shape this future. In fact, the evolving design thinking is one of holistic and experience-based, with the user's needs and experience taking central stage. That is, the success of intelligent responsive architecture not only lies in designers becoming more fluent with technology, but also having a paradigm shift from 'space-and-flow-conscious' to 'human-need-and-experience-conscious'; from the mindset of designing a library building, to a mindset of designing the enabling factors to support the experience of acquiring knowledge.

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