ROBO STUDIO: TOWARDS ARCHITECTRONICS?

Kinetic architecture on control systems: a responsive environment

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Abstract. Contemporary architecture can be seen as a dynamic system that causes change to its environment, or even as system that can modify itself. Interactive or responsive environments are not totally new to architecture however the possibilities in architecture have only been lightly referred to. This interdisciplinary design studio, with mechatronics engineers and architects collaborating, explored possible applications with real world equipment, sensors and knowledge. Development of responsive architecture requires architects to have a fluency in sensors, actuators and their control system programming. New potential application of technologies requires a re-framing of what that technology could do in a different social application. Together these issues challenged architecture and engineering students in a collaborative design environment. The resulting projects – kinetic architecture on control systems – challenge our understanding of what our built environment could be.

Keywords. Architecture; mechatronics; robotics; kinematics; design.

1. Introduction

The impact of the digital environment on design practice and its education is now massive due to the proliferation of computer aided design in problem modeling and simulation, numerically controlled design fabrication, algorithmic design and now the emergence of responsive, performative architecture informed by mechatronics and robotics. This paper, recognising the importance and interdependence of these trends in contemporary design, focuses

on investigating the application of mechatronics[1] and robotics[2] in architecture. The word *architectronics* in the title is coined from the combination of architecture and mechatronics as it defines the emerging field of research, practice and design education.

Today, through the use of mechatronics, design can be seen as verb or action: a system that causes change to its environment, or even that can modify itself via information feedback. Clearly architecture need not be static, as it can adapt to changing conditions with the performative feedback loop relationship being its essential aspect. The argument for an architecture on a control system is strengthened when we consider the ubiquitous nature of control systems in our environment: from a thermostat to traffic lights to anti-lock brakes to driver-less public transit. The question of why it is not yet in widespread use in architecture comes to mind. And since it is not in widespread use, there is no concept yet developed as to what mechatronics could bring to architecture and, further, what might or might not be beneficial applications of this technology in architecture. A mechatronic system affords the opportunity for a responsive form of design: one that interacts with environmental conditions, occupancy, input from other systems and even input from prior use.

Interactive, or responsive, environments are not totally new to architecture. Le Corbusier's Phillips Pavilion for the 1958 Expo was integrated with the first electronically controlled multimedia exhibition. Its performative nature was amplified decades later in Archigram and Archizoom projects. In 1967 Peter Cook described architecture as "intermittently intermeshed series of happenings". The Open Form Aesthetic introduced by TeamX recognised the importance of framework open to user and context input. The sustainability agenda present in the contemporary discourse brings a new dimension and importance to responsive, interactive and networked architecture.

However, design of a responsive environment demands that architects understand basic electronics, control systems, sensors and actuators. Trying to understand and develop detailed knowledge of this type of technology can be accomplished by an interactive relationship with mechatronics engineers, who are experts in mechatronics but perhaps not in creating new applications for their expertise. In order to seriously engage the discussion of the technical requirements for interactivity, engineering students with expertise in mechatronics were included in ROBO studio. Both engineering and architecture students worked collaboratively on research and projects; in this way there was a detailed working knowledge of the requirements, possibilities and limitations at every step in the project.

Design studios in architecture are project based learning environments guided by critical feedback of instructors and peers. The goal of the ROBO studio was to develop a culturally relevant and socially accountable design which includes new technical, creative and environmental aspects and incorporated them into a comprehensive design. This design studio methodology is common in architecture, but less common although equally valuable in engineering education. By exposure to this methodology, engineering students become able to make judgements on a more global level about their technical decisions and the application of technologies. By working in a collaborative studio environment, both disciplines are challenged to explain clearly their perspective on the design project but are also required to learn and consider the other discipline's perspective and expertise. This enriches the learning of the students as they see what they understand from a different perspective. The term Robot, originally coined by Czech writer Karl Capek in 1920's, stood for android-like mindless servant/workers, was quickly adopted by the architecture students as a humorous label for studio whose participants worked hard on integration of mechatronics into design.

2. Interdisciplinary design studio

ROBO studio was a project-based course offered by School of Architecture in collaboration with the Departments of Mechanical Engineering, Electrical Engineering and Engineering Physics. The initial goal was to bring together students of architecture and engineering to explore the possible application of robotics, mechatronics and kinematic structures in architectural projects. In order to introduce students to the new environment, a period of research began the studio. This stage introduced the architecture students to the technology of mechatronics and introduced the engineering students to the culture of design. Case studies involving kinetic art, kinetic architecture, mechatronic applications in design and industrial applications of mechatronics were researched. In addition, basic theories of control systems were introduced and a database of sensors and actuators was compiled.

This short period of research was followed by the two problem sets: the first was framed very tightly in order to limit the design considerations and allow a fluency to develop with the new technology. The second was framed more loosely so that students could apply their newly found knowledge to a range of architecture applications. Further, the projects were framed architecturally such that investigations with the first problem set addressed the issue of essential need, and the second one of electronically assisted transfigurations and the revisitation of collective memory. The project studies ranged from concrete problem-solving to investigations highly speculative in nature; the

students could pursue any combination of digital, wired and/or kinetic models and videos to illustrate their explorations. It became evident early in the studio that the prevailing methodology of illustration would be videos: even in the research, very few case studies were illustrated without use of video technology. This is made necessary by the fact that movement must be illustrated and the most effective way of illustrating movement in today's digital environment is video.
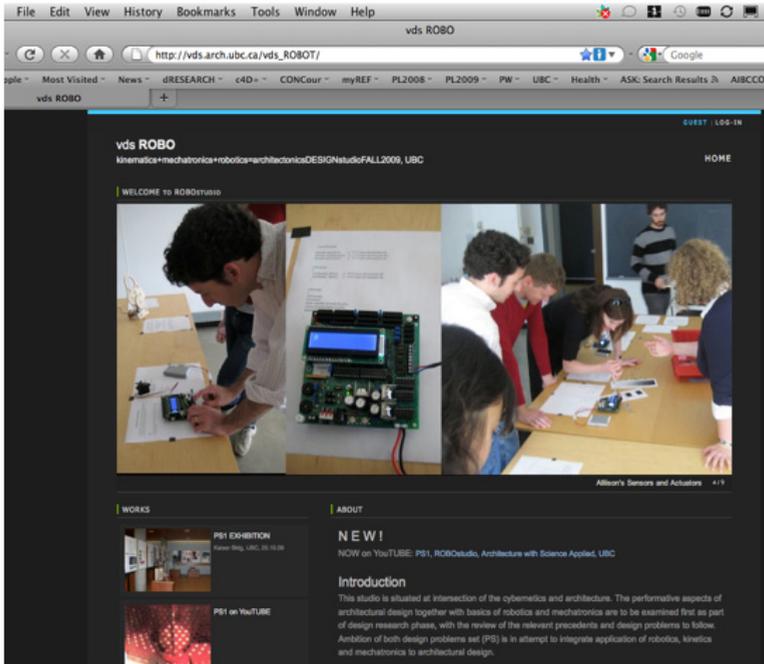

Figure 1. ROBO studio explores sensors and actuators on the front page of VDS portal.

Collaborative work across disciplines in today's context involves exchange of information and drawings virtually. By use of a virtual design studio (VDS) website through which information can be exchanged in a very visual way, a discussion can occur without as much scheduling difficulty. Engineering students' schedules are tight and often require that a collaborative project take place as much virtually as sitting together in studio. This is facilitated by a virtual tool, allowing shorter and more concise discussions when the students meet together in studio. The VDS website is a specialised tool which was developed at UBC for the digital architecture studios. It is formatted to allow images to be immediately seen and synthesised. The website allows publication of research and presentations at each stage of the studio. Research thus

can be easily shared among groups and easily accessed as the studio moves into the problem sets. Although the VDS website was not developed as an application for an interdisciplinary studio, it worked well to facilitate the communication between disciplines and eased the cultural and schedule difficulties which inevitably occurred.

The introduction to micro-controllers was initially given to architecture students, who learned that micro-controllers are like small computers that perform programmed and logical operations. The key realisation that most micro-controllers have only two kinds of input – analog and digital – was important to formulation of future designs. Architecture students realised that the familiar notion of digital means, in effect, that there are only two possible states, whereas analog means there is a scale of infinite levels between on and off. Extending this as a metaphor for two educational systems, engineering students were rather comfortable with binary design thinking, but attitude of architects was amazingly fuzzy and accommodated all shades of grey. It made process of collaboration difficult initially, but quickly the cultural difference was found to be creative and productive.
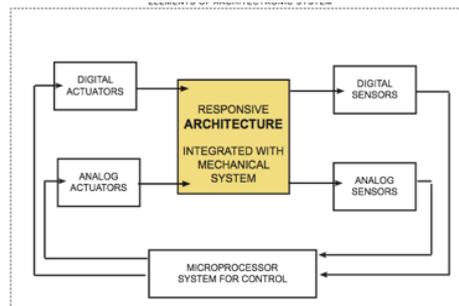

Figure 2. Architectronic control system diagram, 2009.

The engineering and architecture students worked in collaboration to produce drawings, computer simulations, animations, and working scale models of all or part of their designs. Decisions as to what software and what types and scales of wired models would be presented were made on a case by case basis by the students involved in each project. Just as an architecture student must decide which software best represents their project or which material they should model in, similarly judgements must be made on what should be wired and at what scale: sensors and actuators, as with many elements in architecture, do not always scale well. As such, decisions must be made as to what actuators would be used for the models versus what would be used at full scale. Similarly, what sensors would be used for presentation of an idea and how would these compare to the installed, full scale sensors.

Control systems were similarly discussed. A whole new set of judgements were brought to the table for discussion amongst the group.

Organisation of the studio and companion engineering course was undertaken by three faculty members from the school of architecture, two of whom are engineers as well as architects. The students' progress was monitored through formal and informal review sessions. Specific technical assistance with regard to mechatronics issues was provided by a teaching assistant from the engineering field of mechatronics.

The intent of the integrated studio was to bring engineers and architects to work together in a collaborative studio environment, using the expertise of the engineers, but placed within a new cultural and social context with the end goal being a comprehensive design project which addresses cultural and technical issues for a specifically framed project.
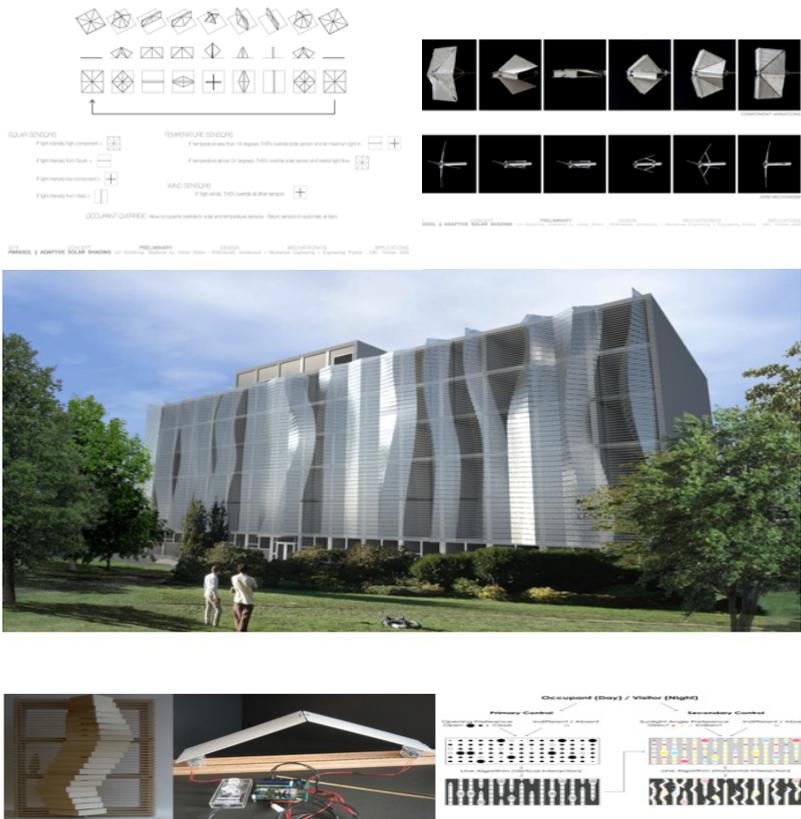

Figure 3. P1: Swarm skin by Patrick Danielson, Brady Del Rosario, and Dylan Gilmore

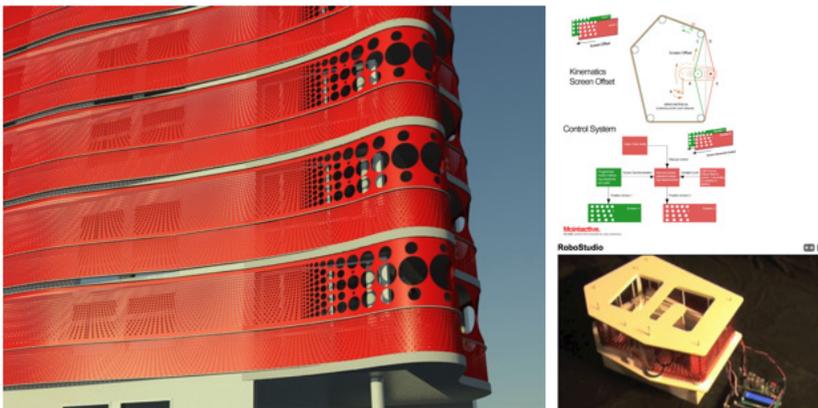*Figure 4. PS1: Parasol by Stephanie Au, Lori McGillivray and Adrian Straka.*

Figure 5. PS1: Moire by Peter Loebel, Esteban Matheus and Sina Sajadian-Mousavi.

3. PS1 skin

The initial design project (PS1 Skin) was a retrofit for buildings on campus whose envelopes had problems with their environmental performance. These problems resulted in poor conditions for the building occupants (i.e., inadequate solar control, uncomfortable interior temperatures or lighting conditions, etc.). The buildings chosen were representative of typical building types on and off campus from the time periods in which they were built. The speculative projects completed by the students proposed mechatronic facade

systems which responded both to occupation and environment. The students were asked to speak to occupants and determine what was problematic about the envelope, and respond with a solution which incorporated technical performance as well as design quality. The responsive building envelope involved design and modeling of a fragment of a building enclosure, sensored to perform. The situated building skin would formatively adjust itself to the dynamic criteria derived from human or environment interactions.

Although the project was situated as a skin retrofit, each building had a specific circumstance that was to be remedied which related to building exposures and orientations as well as problems with the existing enclosure construction, building massing and program. As such, each skin had an individualised and highly customised solution – both customised to the program within, be it offices, classrooms or labs as well as customised to sun orientation and envelope problems. The use of mechatronics in many cases gave an advantage to the designers in their ability to be effective and respond to variations in environment and in variations in user requirements and desires, even varying across a very short distance.

4. PS2 transformers[3]

The second problem set (PS2) dealt with the resolution of contested public space by an infrastructural intervention at any scale, be it building, bridge or seat. This problem set was broadly open to students' initiative but it addressed some aspect of transformation metamorphosis, disambiguation or shapeshifting. These themes are more common in mythology or science fiction than architecture but have a broad capability for engaging us and are therefore particularly suited to architecture. This process takes place when something undergoes a radical transformation. The electronically assisted metamorphosis of form or transfiguration is no longer so mythical.

Figure 6. PS2: Robotic bridge / ferry hybrid by Lori McGillivray and Arta Alagheband.

Figure 7. PS2: Robotic configurable plaza by Dylan Gilmore and Sina Sajavian-Mousavi

The site was a busy public space with multiple modes of transport and contested space due to its popularity as well as its constrained land area. The site has also undergone change over time, from an industrial site to its current multi-use condition. Each project encouraged use of structure to define space as well as consideration of the interaction with the body.

Students' projects ranged from those using acoustic information to shape a music hall in real time to a hybrid robotic bridge / ferry which responded to oat and pedestrian traffic and used the occupants to power the crossing.

5. Conclusion and future research

In running the ROBO studio in the fall of 2009, a clear idea of how the engineering course and architecture studio enhance each other's learning was obtained. The courses, while clearly allowing the students to work in their area of expertise, also allow an environment where a mutual respect and interaction is developed for the completion of the design. Whereby normal studios and courses address issues within their own disciplines, the opportunity to work in a collaborative environment is challenging to arrange in an academic environment. This studio attempted to offer collaborative learning by setting up an academic framework, with the supporting technical web based infrastructure required to support the academic endeavour. In terms of computational tools, geometric modeling software like Rhino or 3Dstudio was used, while motion models were simulated in Inventor or Solid Works. Program-

Figure 8. PS2: Acoustically responsive adaptable performance space, Esteban Matheus.

ming of controllers, incorporating use of sensors and actuators, was required for the development of the working models illustrating the principles of each project.

This investigation highlighted range of possibilities for interactive environments in architecture. The projects demonstrated a breadth in possible applications of control systems which was unforeseen. To narrow the field for further study, it was noted that some of the most beneficial investigations involved applications of mechatronics to sites where more than one program was desired across time, and this transformation of architecture allowed the space to accommodate a variety of uses. Another approach to narrow the study focused on use of only one economical and simple actuation to produce interesting investigations. It was noted by the engineers during the course of the study that sensors were inexpensive and actuators were costly so the more sensing and less actuating that takes place, the more economical the overall system. This type of economic reality applied to architecture could, as shown in other related architectural explorations, result in highly innovative systems and spatial consequences.

Endnotes

1   Mechatronics is the combination of mechanical engineering, electronic engineering, computer engineering, control engineering, and systems design engineering to create useful products (Wikipedia, http://en.wikipedia.org/wiki/Mechatronics, 13 Nov 2009).
2   Robotics, while having a range of definitions, generally is more specifically related to the replacement of the human and providing a tool which does repetitive tasks that a human would previously have performed.
3   Understood not as device that transfers energy. Transformers, Masters of Disguise, originally a toy system popular in 1970's Japan, later theme for cartoons and movies, where alien cars become robots.