Responsive Systems and Electronic Spatial Interfaces

Outcomes in Architectural Design Studios

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Abstract: This conference paper is the first of two papers that discuss the outcomes of a long-term pedagogical research project into the integration of interdisciplinary design-research, and making practices into the content of second-year architecture studios. This paper focuses specifically upon one studio involved in the design of responsive systems and electronic spatial interfaces. The studio introduces students to technologies associated with “The Internet of Things” and encourages them to consider how their use in design might impact a range of different social and spatial systems. Through the design, prototyping, and testing of these systems students are encouraged to learn through practice, developing their projects iteratively while being critical of the implications of their actions. Through a discussion of the studio aims, structure, project examples, and outcomes, this paper outlines an initial approach to the teaching of programming and electronics within a design studio context. Along with the paper on Biological Systems these works highlight the importance of critical engagement with materials and processes and of opening up future architectural pedagogy to new fields of exploration.

Keywords: Architectural education, critical design, responsive systems, spatial computing

1. Introduction

The architecture that I have studied, that I have practiced with other architects, with my professors... It is over. Eduardo Souto de Moura (2016)

Architecture consumes earth’s limited resources, it is long lasting and expensive, and it can significantly alter the quality of living of its users. We live in a fully explored, finite, over populated world and so it is imperative that we do not think of and produce architecture in the same ways that we have in the past. It is essential that we understand humans, non-humans, objects, buildings, cities and regions not as isolated entities, but as parts of systems of increasing complexity and uncertainty. As humans, it is important that we understand our place in these systems, not an overwhelmingly important position but only as part of it. Climate related natural disasters, over population, uncontrolled consumption, disregard
for non-humans and non-humans environments, food and water supply constraints, artificial intelligence, massive migrations, cultural tensions, raising inequalities, extremist groups and unannounced acts of random violence are unprecedented challenges that are all connected. It is important to recognize that actions have consequences and that there is no such thing as designing an isolated entity. As a part of this system, architects need to understand the world that they live in, in order to raise awareness about the consequences of their designs.

Starting from these foundations, a long-term pedagogical and research project was implemented at the University of Western Australia under the Integrated Design ethos. During their second year, architecture students are given the opportunity to take a 13 week studio called Making. As a part of the school’s design stream, students are invited to develop solutions to design problems that may or may not include architecture. During the semester, students are required to submit both prototypes and finished products at their real scale as opposed to drawings and models. This encourages design development through experimentation, and the production of multiple prototypes that are critically examined and iteratively improved. Through this process, students are expected to develop a better understanding of the difficulties faced in producing built objects, and to consider the relations between projects that only exist in print, on screen, as models and those that exist in the built environment, leading to careful and thoughtful future designs.

The majority of studio coordinators of Making are not architects, and those that are have specific skills that are unusual within architectural practice. Some of the most recent specialized skills ranged from: ceramics, eco-activism, responsive electronic interfaces, biological systems, ecological systems, traditional carpentry, graphic design and conceptual art. By opening the design studios to coordinators with diverse backgrounds, students can focus on different underlying design systems. By offering the opportunity for students to work with diverse specialists, we are expanding their fields of action. By opening up the discipline to new fields of action – biological, electronic, multispecies, conceptual arts, we enable students to collaborate in trans-disciplinary approaches and complex environments where outputs are unpredictable, through design. We empower students to become independent thinkers, to have the desire to run their own practices. We accept unexpected, ambitious, and unfinished projects that can be more interesting than expected, finished, and predictable outcomes. To do that, we ask students to redefine what success means, to seek alternative uses for design knowledge other than in the production of commodities. To use making as a means of interrogating the world to better appreciate and understand the impacts of design decisions and to allow students to pose their own questions instead of reacting to defined problems. It is important to assume that by doing this we are no longer in an expert/apprentice position; we are together with our students in an experimental research journey with unpredictable outcomes. We do not know exactly what students will produce and we do not know how it will be applied in future architecture. It is precisely this, the acceptance of uncertainty, the program’s greatest strength. Together we lay the foundations for a future that we cannot foresee. Our world is rapidly changing. Architecture education and practice have to adapt, to open up new fields of exploration and to prepare students for uncertainty.

This conference paper is first in a series of conference papers from our long term pedagogical and research project.

2. Responsive Systems and Electronic Spatial Interfaces

In architectural discourse the idea of a responsive environment has its roots in the 1960’s with the Cybernetics movement and scientists, engineers and mathematicians such as Norbert Weiner, Gordon
Pask, and Ross Ashby. The field was concerned with how processes of self-regulation and feedback could underpin an understanding of systems within the natural world, which could then be applied to the creation of adaptive computational systems (Yiannoudes, 2016). The concept of a ‘responsive architecture’ was first explored by Cedric Price and Nicholas Negroponte (among others) who were interested in applying ideas that were emerging in the field of Cybernetics to architectural design (Mathews, 2006; Negroponte, 1975). Since this time these ideas have evolved in a number of directions, with the concept of responsive spatial systems seeing growing prevalence within a number of fields such as art, architecture, urban design, computer science, and interaction design.

Over the last decade, the increased availability of cheap, programmable microcontrollers, sensors, and actuators, as well as free access to programming platforms and information about their use has provided an opportunity for designers to engage with the production of digital systems and interfaces, not just on a conceptual level, but through engagement with the technology itself. Technologies of these kinds, sometimes referred to as “The Internet of Things”, are changing the ways that we understand and operate within the physical world as spatial computing is increasingly becoming (for better or worse) a part of our everyday lives. While the increased volume of data available to us presents the dystopian possibility of authoritative control of our actions, it also opens up new possibilities for how we interact with and perceive the world around us. For students of architecture, the accessibility of electronics and programming technologies provides an exciting opportunity to complement their practice with interdisciplinary skills.

3. The Studio Format

In the design of responsive systems, interactions and interfaces are of central importance. In relation to the understanding of ‘interaction’, the architect Norbert-Schulz (2000) suggests that qualitative teaching demands that a manual grasp - hands on training - should contribute to qualitative comprehension. This is a sentiment echoed by Kreuger (2011) who suggests that it is cognitively economical to use the ability to recognize the possibility within something rather than to invent those possibilities oneself. In this design studio, this kind of ‘hands-on’ training was necessary for the students to be able to engage with a range of unknown quantities within a limited space of time.

In the Making studio, the intent was not to teach students the practice of interaction design, which as Lane and Tegtmeyer (2014) identify is a field that is more concerned with the practical and pragmatic application of digital technologies in the creation of products and services. The pedagogical technique employed shares more similarity with Meta-design, which is a design process focused on the lessons learned by making mistakes (Fischer and Giaccardi, 2006) and Critical Making (Ratto, 2011). Critical Making consists of three main processes: research into existing literature to establish themes and provoke questions, prototype development to develop skills and establish design parameters, and a third stage of communication, critical reflection, and revision. Production of designs in collaborative groups of teachers, students, and stakeholders is also emphasized in order to provide greater feedback within the making process.

The question posed to students at the outset of the studio was “How can electronic hardware and software be incorporated into the design of a responsive spatial system?” Students were expected to be able to identify and engage with a system (spatial, social, physical, imagined etc.) within a chosen site, identified through self-directed processes of mapping and research, and then propose design interventions that they would later prototype and test. Before beginning the studio, students were given access to a small amount of reference material. Each reading was focused on a different topic; mapping,
cybernetics, interactive art, and responsive architecture (Corner, 1999; Jones, 2006; Krueger, 2011; Mathews, 2006). The first stage of the studio was an individual assignment worth 30% of the overall grade which lasted two weeks. Students were asked to identify a potential site within the campus, document their spatial experience, and begin to imagine possibilities for intervention. Through various processes of mapping, some of which were introduced in studio presentations and readings (Corner, 1999), students identified existing systems within their site that they could engage with (Figure 1). They were also asked to complement these investigations with research into literature and precedents. The outcomes of this initial research were then presented and discussed within the studio to direct and develop ideas for the second part of the assignment, and identify technical skills that needed to be learned.

![Figure 11: Lighting study, Atusa Haddad.](image)

The second assignment was also an individual exercise worth 50% of the overall grade. From a developed conceptual standpoint students were given four weeks to imagine, design, and prototype an artifact that responded to their identified system. The submitted artifact could be considered as a modular component of a larger assemblage, or as a single agent in a network of distributed agents. In producing their designs, students were encouraged to experiment and develop multiple prototypes. The process of experimentation and prototyping was also to be documented in a short film to communicate the intent of the project and the process of design experimentation.

Students were expected to develop technical skills independently and as required to be able to produce their responsive system. The basics of electronics and programming were established in a couple of workshops and after this, direction was given to students only in response to particular problems that emerged in each project. In this case, validating or developing a design intervention could not simply be a formal or speculative exercise – development necessarily had to occur through a continual process of design, testing, evaluation and revision to identify the scope of potentials in their project and also to refine and direct the behaviour of their responsive system. This could not just be done through traditional methods of speculation and representation through drawing. Instead, making was encouraged as the primary means of design development.
4. Outcomes

Given the relative openness of the brief there were a large number of different approaches to the idea of a responsive system. The following is a list of projects and their identified typologies. This framework is based on Schwartzman’s categories for design and art that involve technology and embodiment (2011) with the addition of the category of ‘Reactors’ to describe projects that were concerned with patterns of motion in the animated reactions of objects and how they can evoke an emotional response within a viewer.

4.1. Reframers

Challenging the relationship of the body to space/ recasting the role of objects in spatial rituals

- *Periscopes*, transmitting light from larger context within an enclosed external site
- *A ‘Functional’ Intervention*, collapsing chair - reframing the expected role of furniture through détournement
- *Claustrophobia Module*, inflatable wall in corridor triggered by presence (Figure 2)
- *Remote Viewer*, viewfinders that switch user perspectives through telepresence
- *A Priori*, lit wireframe sculpture connected to users heartbeat
- *Vibro Chair*, chair that invites user to sit by vibrating when in proximity

![Figure 12: Claustrophobia Module, Chelsea Smith, An inflatable wall that restricts corridor movement.](image)

4.2. Environments

Altering or generating spaces through sensory effects.

- *Soundmites*, sonic responsive network
- *Synthesis*, sound feedback loops in spaces
- *Lightbox*, interior space with light sculpture that changes colour based on external activity
- *Chromosaturation*, reactive generation of spatial volumes through primary colours (Figure 3)
- *Atmo-Sphere*, sonic telepresence module for your head
• *Reflective Traces*, patterns of motion represented through reflecting light from vibrating pools of water onto building

![Image](image.png)

Figure 13: *Chromosaturation*, Haley Harrison, Colour volumes that shift based on nearby activity

### 4.3. Tools

Extending or augmenting spatial systems through the representation of quantitative information

- *Windcopy Machine*, representing external wind conditions using interior kinetic sculpture
- *Heatmap Chair*, Public benches that react to patterns of use through changing colours
- *Flow Counter*, counter system for stair and ramp
- *Mood Lamp*, representing user mood on building columns through patterns of colour derived through skin temperature
- *Level Representation*, communicating activity levels on different floors of building through light sculpture

### 4.4. Mediators

Interacting with the threshold between systems natural/physical

- *Leaf Catcher*, net sculpture that changes form as it collects tree leaves (Figure 4)
- *Coloured Shadows*, prismatic glass installation in stairwell that changes patterns of light and colour in reaction to changing interior light conditions
- Skylophone, ambient installation that converts sky colour into xylophone melodies
Figure 14: Leaf Catcher, Riley Omelczuk, A series of nets that intervene with natural processes of decay.

4.4. Reactors

Generating object behaviours through patterns of motion

- **ALVA Pets**, small machines with reactive ‘personalities’
- **Systema Medusozoa**, mimicking undulating Jellyfish motion through reactive, inflatable sculpture (Figure 5)
- **Japanese Fans**, mechanical fans in corridor that actuate based on direction of motion

Figure 15: Systema Medusozoa, Nadya Haryanto, A study of systems of motion in jellyfish.

From the prototypes that were produced in this stage, the students were asked to decide on a single project to develop further as a group for the final assignment (worth 20% of the final grade and assessed as an entire class). The entire studio was asked to work together to produce the final product with smaller groups being assigned to specific tasks (ie. design team, project management, construction detailing, system design, programming, electronics, filming, drawing etc.). Soundmites was the project that was
chosen for the final assignment. The concept of the project was for a system of reactive machines to be attached to the metal downpipes around the architecture campus (Figure 6). These units would respond to the movement of people around the space by striking the downpipes with various intensities and tempos. Each module consisted of an internal enclosure made of 3d printed ABS plastic that would contain an ultrasonic proximity sensor, a battery pack, a small motor and striking armature, and an Arduino microcontroller. This internal enclosure was designed to sit within a timber case that would waterproof the electronics and provide a clamping mechanism, enabling the Soundmite to be attached to a range of different downpipes. The aim of the project was to generate an altered sonic environment outside the architecture school through a network of these units – programmed with a simple reactive logic to strike the downpipes when they detected a person moving within a certain proximity. While the behaviour of each object was simple, the combination of a dozen units created a chaotic and unpredictable soundscape that changed in response to the activity within the monitored space.

Figure 16: Soundmite building pipes, map of system installation, Emiline Elangovan
5. Conclusion

In the 1990’s Mark Weiser (1991) predicted that invisible and ubiquitous computing would produce a state of “embodied virtuality” enabled by the development and integration of wireless networks, sensors, and actuators into the built environment”. For design students, the accessibility of contextual information derived from technology is now taken for granted as a natural part of everyday rituals. Davies and Thrift (2015; 2004) have both noted that this naturalisation of technologically mediated experience comes for most at a price; in order to benefit from the increased efficiencies provided by quantitative organisation of spatial activity we have to be willing to submit a degree of agency to the control of these new organising systems. Just as in the use of a computer operating system, an understanding of the underlying structure is not required for the efficient use of the system (and in the case of commercial systems it is often not desired). However, knowledge of the inner workings of the program provides a much greater scope for interaction and control of that system. As computational logics become applied to the design of everyday objects we are faced with the same dilemma – we can operate within the parameters set out by the original programmer, or we can open ourselves to the possibilities inherent in the technology through a deeper knowledge of the design of its underlying systems. Marc Tuters (2004) has noted that as computation becomes an increasingly prevalent component of the physical environment “the imagination of programmer, with her coded control of the virtual's interface with the real” will increasingly determine the shared, consensual reality of digitally mediated existence. For design students, being able to engage with electronics and programming provides them with the opportunity to navigate an interdisciplinary field that is rapidly transitioning from a specialisation to a core component of the design of environments and everyday objects. As such, it will be important for future architecture students to understand how these systems operate. In the case of this studio, engaging students in experimentation with an unknown
quantity forced them to negotiate the balance between conceptualisation and pragmatic application. The use of Critical Making as a design methodology enabled students to develop research and technical skills through their application in specific projects. Moving from individual work to group work during the progression of assignments allowed the complexity of the project to scale alongside the development of their skills, and provided a forum for critical reflection through discussion with the whole class. However, this also introduced a number of issues with relation to the fairness of applying a single grade to the final assessment and the impact of this upon overall grades which could be improved by reducing groups to smaller teams of 4-6 students.

In the imminent future, responsive systems will become (for better or worse) a part of our everyday lives. As the internet of things develops, the design of responsive spatial systems will become increasingly important, not just in the way that it can control spatial effects and the actuation of objects and buildings, but also in the way that blockchain and other emerging technologies (such as Ethereum and IOTA) will connect spatial activities to economic systems of exchange. In this context the design of responsive systems will have major impacts upon social, economic, and political spheres and not just the aesthetics of the built environment. Teaching at least some degree of literacy in electronics and programming will prepare students of architecture for future uncertainty and enable them to engage in an increasingly mediated world.

References