COLLECTIVE INTELLIGENCE: AN ANALYTICAL SIMULATION OF SOCIAL INTERACTION WITH ARCHITECTURAL SYSTEM

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Abstract. This paper proposes an architectural system interactive to both users and the environmental condition in real-time. While nature acts as a global control for the system, the user can alter it locally. Due to the increasing digitization of our contemporary culture, there is an unprecedented capacity for information to flow in our physical and socially networked world that can be used to inform design problems and processes. Live and real-time information sources, like Twitter, could be virtually scanned for specific data input associated to a particular geometrical manipulation. This process enables a collective group of users to inform the system. As the number of users increases there is collaboration for defining the form which is different from single user interaction. Since the model is associated with a specific definition of generative behaviours as described by the words, these definitions could be used as the keywords to manipulate its form. In this research these keywords act as data input from Twitter account and the model reacts in real-time and its form changes according to that specific keyword. An analytical simulation runs over the digital model which has been conceived by users to show how it is performing according to environmental conditions.

Keywords. Real-time data streaming; crowd-sourcing; interactive architectural system.

1. Introduction

With continual shifting of the technology implementations into architecture, an understanding that building by nature is dynamic in character and is therefore necessary to develop more sustainable and environmentally oriented architecture. In this line of research, there is a growing interest to construct physical systems which have the ability to actively respond to local climatic conditions and social settings, allowing inhabitants to continuously inform and adjust local climates and
their enclosures from both phenomenological and functional perspectives calls for new design approaches that place spatial performance and perceptual issues at the core of design methods and models. In order to make architecture more efficiently responsive to both users and natural environment, architecture should be understood as an ecology, involving dynamic and varied relations and mutual modulation between material systems, macro- and micro-environmental conditions, and individual and collective inhabitation (Hensel and Menges, 2006).

Many visionary architects have urged for a radically new way of approaching architecture that would allow it to embrace the new opportunities of our time: “Until now architecture was a discipline of intractability. Buildings were always meant to be as steady as a rock and give shape to the flow (of people, energy and matter) and, more importantly resist that flow. Let’s imagine that buildings and built environments are becoming programmable. Form and substance can both be driven. An interactive relationship will effortlessly grow between the users and smart appliances are beginning to communicate now. Buildings will develop into a smart swarm of building parts in contact with each other and with their users” (Oosterhuis, 2001; Jaskiewicz, 2010).

Some of the more recent efforts link such approaches to the idea of architectural systems being an integral part of their surrounding environment with the proclaimed need of upholding a constant exchange with the same. The Blur Pavilion by Diller + Scofidio is an example of this approach, rather than being a closed system trying to separate itself from it. However, most of these researches consider architecture as a responsive system either to its users or nature. While the former gives control to the user to adapt the system, it fails to be compatible with environmental factor. Therefore, the system does not benefit from natural element such as day-lighting and natural ventilation among others; by the same token, the latter is not a fully efficient system because it does not take into account the needs/intentions of the users. In this system users’ variable does not affect the process of form finding. So the result form, although compatible with environmental factors, may not be desirable for the users because there are many unpredictable user-related variables which may influence the efficiency of the system.

This paper outlines new experiments, in which physical prototype models are driven by live input from local weather data and online social networks. This design framework integrates user intentions, computational techniques and environmental conditions leading to a performative prototype which aims at providing optimization and compatibility. The outcomes of the research show promise of structural integrity and responsive reaction of the prototype model to live information input by online crowdsourcing and climatic condition.
2. Interactive Architecture (IA)

Responsive architecture is any kind of architecture that has the ability to respond to users’ needs (Sherbini and Krawczyk, 2004) and environmental conditions. While responsive architecture means architecture that just reacts to users’ actions, interactive architecture strictly implies a reciprocal relationship between architecture and its inhabitants and an inherent learning process of both. An adobe wall, for example, responds to outdoor temperature where it keeps cold air in the house when it is hot outside. It is a material property; it is not out of an intelligent processes. However, interactivity in synchrony with its definitions (e.g., Haque, 2006; Oosterhuis et Xia, 2007), interactive architecture can be defined as architecture that exhibits autonomous behaviour, in which that behaviour evolves through inter-actions with its users and environment (Jaskiewicz, 2010).

2.1. RESEARCH APPROACH TO IA

This paper therefore illustrates a research agenda aiming at understanding the morphodynamics of architecture through both communication with the natural surrounding and interaction with users in real-time (Hensel and Menges, 2006). Therefore, it combines both functional and phenomenological aspects of interactive systems by exploring physical prototypes and pro-cessing adaptive behaviours that respond to climatic conditions as well as social parameters. In doing so, the intention is to set up a time based adaptive domain, applied through learning algorithms classified as ‘intelligent’ system which meets these criteria:

- Input system that receives information by means of information receiver
- Processing and information analysis
- Output system that reacts to the input in form of a response
- Time consideration that makes the response happen within the needed time
- Learning ability (Sherbini et Krawczyk, 2004)

3. Collective Interaction (Intelligence)

One of the key questions to be answered when conceptualizing interactive urban space is how information flows in to be organized? One aspect is the flow of information within the interactive system itself. The other, more significant, aspect is the flow of information between Interactive system and its users. Culturally, we are accustomed to the idea of humans controlling all artificial systems. The notion of control, however, refers to a one-directional mode of communication, which stands in opposition to the idea of interactivity that entails an inherently reciprocal relationship. Nevertheless, the following models of control in architecture are
by analogy also applicable to interactive architecture, assuming that the relationship of control can be substituted by the relationship of the mutual affect.

Two elementary models for user control of participatory of architecture (both presented at the same conference in 1971) belong to Yona Friedman, the “Participatory Architecture” (Friedman, 1972) model, and Charles Eastman, the “Adaptive-Conditional Architecture” (Eastman, 1972) model. Friedman’s model puts building users in direct control of architectural adaptations, through one, centralized interface and control system, which coordinates all architectural adaptations within the given context. Conversely, Eastman’s model proposes a distributed system of installations and devices that operate autonomously and are individually controlled by building users through local (negative) feedback loops. Tristan d’Estree Sterk reintroduced models of Eastman and Friedman to the contemporary discourse and proposed another model combining the two, which he calls the “hybridized model of control” (d’Estree Sterk, 2006), where both local and global (top-down and bottom-up) control is possible (enforced either by users or by “intelligent processes”). By generalizing this classification, interactive system models can be ordered along the line of their increasing distribution and flexibility and decreasing centralization (shift from global, through local, to no coordination).

Any kind of such models requires communication between at least some of its autonomous components, and thus can be treated as a multi-agent system (MAS). MAS are typically developed in software, but can also be found in robotic applications (e.g. swarm-bots (Mondada et al, 2004)) and are often associated with development of artificial intelligence (Russel et Norving, 2009) (e.g. swarm intelligence). MAS can consist of simple-reflex or learning (intelligent) agents. Many of the existing MAS models include coordination or control mechanisms operating in parallel to distributed agent processes. There are numerous established models of such ‘hybridization’ with varying degrees of importance of coordination or control, listing of which is beyond the scope of this paper. Generic MAS models are thus an obvious foundation for development of more specific models for interactive architecture with multiple users (Jaskiewicz, 2010).

4. Interactive Model

The experimented prototype is a canopy designed for an open public space which has been developed through a workflow with these three parts:

- Part one: provides a user interface through a web-based interface, Twitter account and Processing, which enables users to communicate with a parametric model of the canopy in grasshopper and manipulate that.
Part two: Connection between a physical model, identical to the virtual model, through Arduino and Servos that alters based on changes made by users accordingly.

Part three: links between the parametric model in grasshopper, and an analytical simulation in Vasari through Revit Python Shell to evaluate the performance of the model (Figure 1).

4.1. USER-INTERFACE

Processing is an open source which is a java-based programming language and development environment created by Casey Reas and Ben Fry from MIT, for designers who want to create images, animations, and interactions; processing initially developed to serve as a software sketchbook and to reach fundamentals of computer programming within a visual context (pro-cessing.org). In addition, it facilitates physical devices such as Wiimotes, cameras, Arduino, sensors as well as Web 2.0 data (such as from Twitter) to be connected to various parametric design software, such as Rhinoceros 3D, Grasshopper and 3ds Max, Maya and other modelling programs.

Through the Processing a script has been developed which is built on the concept of publish-subscribe software architecture. It utilizes the User Data-gram Protocol (UDP) and a central server. The server publishes information from various sources, such as sensors, the web, Arduino, or other physical interfaces. Parametric software, grasshopper, as well as Web 2.0 data can get connected through the server to obtain real-time updates. The UDP connection has been
developed through processing and Grasshopper for this project can be programmed as custom features, plug-ins, or scripts of the associated software or hardware interfaces. The software architecture is extensible, flexible, and allows integration with any platform that supports UDP network protocol.

This script enables users to inform a parametric model in Rhino, Grasshopper, utilizing the power of social networks. This enables crowdsourcing for collaborative form finding. Through this process, form finding and control of the system is no longer restricted to individuals and it enables a crowd of people in a public space to have control of the form of the physical realm.

The crowd needs to have an access to a Twitter account, and post keywords to a specific “hashtag” associated to a particular Twitter account. (Salim et al., 2010a) The keywords, which are associated to particular geometrical manipulation of the physical model, in this example: Shady and Sunny which are defined and simplified based on the function of the element to be user friendly.

Processing reads a Twitter stream and scans for these keywords, shady or sunny. If keywords are found, data are sent via UDP directly to Grasshopper. Since the Rhino model is associated with the Grasshopper definition of generative behaviours as described by the keywords, the model gets updated accordingly whenever a keyword received in the buffer (Salim et al., 2010a) (Figure 2 and 3). It takes five seconds for processing to filter the account and every five seconds it updates the result.

The similar process is devised for the geo-location of user. User can also tweet its location (the longitude and latitude,) this coordination is associated with an

![Figure 2. Processing scans the twitter for keywords (Sunny and Shady).](image)
attractor point in grasshopper to the virtual model which affects a certain number of modules in its proximity (Figure 4). The location of the user affects a 6x6 grid of modules centred to the location of point. Using the specific location of each user the system makes a distinction between users and associates their location in the real world in coordination with the virtual model.

4.2. VIRTUAL TO PHYSICAL

The common parametric design approaches associate digital parameters with virtual data sources or simulated data. The presence of parametric design is limited to virtual world and the parameters are not usually exposed to the physical world. In order to support collaborative design, a parametric model can be extended with ambient computing, physical parameterization, and interaction. It supports an activity that we refer to as form fostering which integrates form-making and form finding of the ambient and interactive parametric models, with the aim to support collaborative design (Salim et al., 2010b).
Processing multimedia programming is powerful platform in order to model responsive behaviours. Digital representation of the model could be done in both in processing itself or in the programs specially design for that purpose such as grasshopper. Likewise, the physical representation is through the Arduino micro controller connected to processing. Thus, physical and virtual models are developed in parallel and evaluated in a different scale, given that the data source can be simultaneously linked to various representations in both worlds by using Processing, Grasshopper, Arduino as a bridge.

Grasshopper is connected to the Arduino through firefly plug-in. Firefly is a set of software tools which allows near real-time data flow between Grass-hopper and the Arduino micro-controller. In this respect the keywords found in the twitter account, sunny and shady, are associated with a binary value (True_False) in grasshopper. The binary values are the translation of a mechanical system which opens and closes the shading device. This mechanism is based on the rotation of some electrical motors which rotate from 0 to 180 angles. This also control the angle of servos from (0 to 180) which opens and closes the hexagonal shaped modules for example once the user tweets the sunny keyword, the binary key sets on the true value and that changes the angle of servos to zero which closes the hexagonal shading modules. Likewise, when the user tweets shady, that sets the binary key on the false value and rotates servos 180 degree which closes the associated module.

4.3. ANALYTICAL SIMULATION-FEEDBACK LOOP

Focusing on the setup of a responsive system that relies on its own internal feedback processes to trigger a formal change in its components- in accordance with the climatic information received from the external environment- allows a more refined approach to the information transfer between a specific system and its influencing environment.

Through a similar process, using Revit Python Shell, Grasshopper is linked to Vasari in real-time. Project Vasari provides a series of analytical simulations of the parametric 3d model taken from grasshopper and based on the local climate data. The communication between these two platforms benefits from the rapid generative of a parametric model and analytical simulations to examine the performance of the system. Vasari puts the model in a wind tunnel (Figure 5) to simulate how the model reacts to the fluid dynamics and also gives a simulation of solar radiation on the canopy. Since the modules are dynamic and the form of the canopy changes over time, this simulation analysis gives a thorough understanding of how model is responding to the environmental conditions based on the user interaction. The feedback to the system occurs at this point as users
monitor this analytical simulation and will understand how their data input is affecting the form of the canopy and how these changes relate to the wind and solar energy. Thus its design could be considered as an experimental and educational platform to aware users of how architecture should react to weather conditions.

5. Conclusion

The paper demonstrates that architectural system can act as a medium be-tween user intentions and environmental conditions. The collective intelligence of the users can manipulate the form of the canopy which finally will be optimized based on their own needs. Therefore, there is no pre-anticipation of how the form might be optimized, instead it is the users who decide. This project is an example of that shows parametric modelling can be further enhanced for design collaboration by integrating social networks and ambient information. The synthetic system of architecture, informed by users and environmental conditions supports performance for continuously improved spatial conditions through regulation of daylight, radiation exposure, the enclosure of spaces and a diverse visual expression achieved through interaction of the canopy with users and local climate data input.

The continuous research thus attempts to construct simpler, even more de-fined performative methods and prototypes, whose objectives remain to explore structural, phenomenological, social and environmental aspects.

In doing so, future prototypes and models are developed within a described operational framework for response architectural typologies, with focus on ‘Coupled Direct Response’. This approach is based upon integration of data flow from users and environmental condition into one platform.
References


Oosterhuis, K. and Xia, X: 2007, iA #1, Episode, Rotterdam, The Netherlands.


