Flora Dilys Salim :author
Hugo Mulder, Przemyslaw Jaworski
Spatial Information Architecture Laboratory (SIAL), RMIT University, Melbourne :organization
Arup Advanced Technology + Research, London, Foster + Partners, London
Australia :country
United Kingdom

Demonstration of an Open Platform for Tangible and Social Interactions with Responsive Models

:abstract

Information is ubiquitous due to the digitization of our world. There is an unprecedented volume of information in our physical and socially networked world that can be used to inform our design problems and the way we design. To date, designers of parametric models have been using design precedents, archived data, and simulated datasets to inform their modeling process, but live information sources from the environment are rarely considered as direct input to models. The paper discusses novel experiments in which digital parametric design models are extended with live input and parameters from physical environments and online social networks. The paper also presents UbiMash, an open source software platform that was introduced and refined during the development of these experiments.

1 Introduction

Responsive architecture has been envisaged for decades since the introduction of "kinetic architecture" in 1970 by Zuk and Clark *(Zuk & Clark, 1970).* Built examples include the Muscle interactive pavilion (Oosterhuis & Biloria, 2008) that responds to environmental stimuli and the Digital Water Pavilion, an interactive water façade in Zaragoza, Spain (Massachusetts Institute of Technology, 2008). In these examples, physical changes to the building occur in real-time and are driven by physical events, changes in the environment, or user interactions.

Nevertheless, practical and built examples are still uncommon, due to the widespread perception of the high cost of manufacturing these programmable components and the complexity in dealing with physical computing. Only recently, we have seen the increasing development of responsive architectures given the proliferation of affordable hardware (sensors, actuators, and microcontrollers). To non-technical designers, there is still a great deal of complexity to integrate physical computing with 3D modeling software for designing responsive architectures and interactions.

This paper demonstrates a number of responsive prototypes with the potential and direct applicability in various stages of building design. These prototypes were designed and developed just over four days. UbiMash, the open source software used in the experiments, reduced the complexity in dealing with sensors and physical devices.

2 UbiMash

UbiMash (Ubiquitous Mashups) is a generic and open interoperability software platform for designers to connect any physical and hardware devices with the CAD software.

It facilitates physical devices such as the Wiimotes, cameras, Arduino, sensors, and reacTIVision tangible interfaces as well as Web 2.0 data (such as from Twitter) to be connected to various parametric design software, such as Rhinoceros 3D, Grasshopper, Bentley GenerativeComponents (GC), and Processing (see Figure 1).

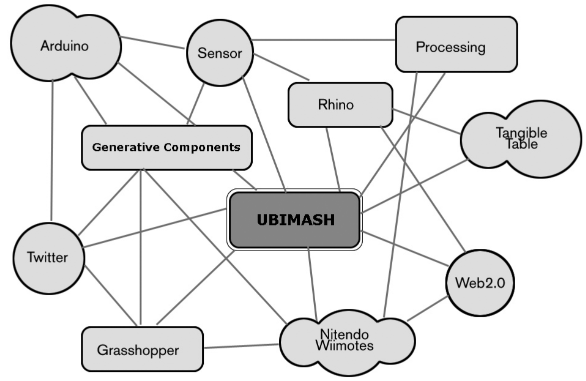

Figure 1. Software and Hardware Connectivity with UbiMash

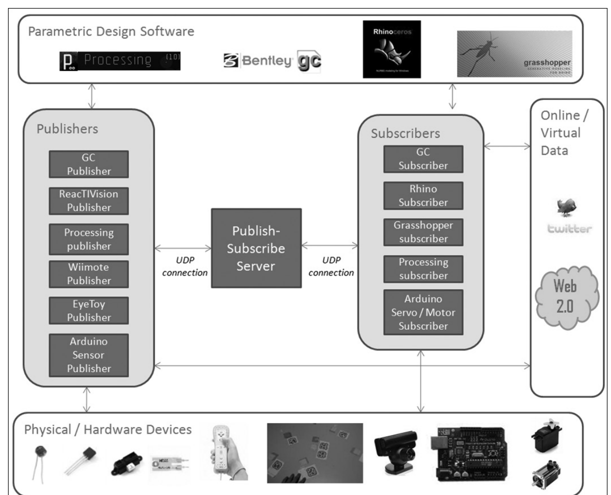

Figure 2. Publisher-Subscriber Architecture of UbiMash

Figure 5. A Wireframe Model Attached with Tangible Markers

UbiMash is built on the concept of publish-subscribe software architecture (Figure 2). It utilizes the User Datagram 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 as well as physical devices can subscribe to the server to obtain specific real-time updates. The UDP connection 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.

The common parametric design approaches associate digital parameters with virtual data sources or simulated data. The presence of parametric design is limited to the 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 (Salim et al., 2010), which integrates form-making and form-finding of the ambient and interactive parametric models, with the aim to support collaborative design.

In the context of responsive architecture, UbiMash opens the way for a new evaluative approach in modeling responsive behaviors. Digital and physical representations of a model can be designed and 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 UbiMash as a bridge.

In modeling a digital representation, real-time sensor input from the environment or Web 2.0 can be integrated into the form finding process to enhance the performative and animative aspects of the model before it is fabricated and evaluated. In modeling a physical representation, the unpredictable behaviors of materials, and the subtlety of assembling the reactive and the mechanical parts, and the ambient data input can improve the accuracy of the digital model. In both scenarios, UbiMash can be used to facilitate a feedback loop between the digital and physical representations.

UbiMash was introduced prior to SmartGeometry 2010 Workshop where all the experiments described in Section 3 took place.

3 Responsive models

The seven projects that were experimented during the workshop can be classified in three groups:

(1) physical responsive prototypes,

(2) design interface, and

(3) parametric design informers.

The physical responsive prototypes are firstly designed in the digital environment. The parametric model can be set up with parameters that are connected and mapped to live data sources, sensors, and actuators to simulate the responsive behaviors of the model. The parametric model is then fabricated and directly attached to the sensors and actuators. As UbiMash enables direct feedback and connectivity between the physical and virtual environment, there is a smoother transition between the design of the digital models and the development of the physical artifacts.

On the interface level, tangible interaction with parametric models has the potential to leverage design collaboration. Traditionally, the process of manipulating parametric models is assigned to a specialist, given the complexity in dealing with a parametric model. With a tangible interface, round-table discussions can involve decision makers handling physical objects which are directly associated to performing variations in the parametric models, giving real-time feedback to the meeting.

Parametric design informers use sensor information from the physical world and online data from the virtual world to update parametric models. The data can be used to inform the design process or to perform collaborative design over a social network.

Each of the projects is discussed in relation to these categories.

3.1 Responsive Bioclimatic Façade

This project, developed by Rafael Urquiza (LEM3A architecture, University of Malaga), Konstanze Grammatikos (Arup Sport), and Filippo Ferraris (Sybarite), is a physical responsive prototype which is designed for energy efficiency and occupant interaction. Sensors are attached to each panel of the façade, with capabilities of sensing light and shade and performing kinetic movement in response to light, shade, and temperature. User interactions will also trigger movements on the panel (Figure 3). The idea, inspired by an origami game, was translated to a GC model and script.

A mesh with 14 triangulated openings and three bio-panels for each opening were fabricated. Each bio-panel consists of two triangles, opaque and transparent, which are joined along one of the sides on a perpendicular angle.

The final kinetic prototype is made up of three different parts: (1) the structure and 42 bio-panels, (2) the mechanical system (servos, plastic arms and nylon tensors), and (3)the electronic system (Arduino boards and codes, sensor devices, and wires). Each bio-panel receives two inputs: the identification of the base triangle and the rotation angle. The light sensors, which are associated with different openings, collect input data that are processed by Arduino to determine the rotation angle of the bio-panels, which are driven by servos (Figure 4).

3.2 Rapid Design and Build Coordination with Tangible Markers

This project, designed by Pierre Cutellic (Gehry Technologies), delivers a proof of concept of an interface that is designed to synchronize the design and construction phasesof building projects. The system allows real-time feedback from a construction site (physical model) to a parametric architectural (virtual) model of the building. Physical models can be compared with the virtual model. Variations which are part of the design environment can be synchronized accordingly.

The prototype consists of a virtual model in GC and a physical representation of that model which is attached with Tangible User Interface Object (TUIO) markers (Figure 5). Using reacTIVision library (reacTIVision 2005), the position and orientation of the markers are monitored in Processing. UbiMash is used to feed the data directly to the parametric model in GC. As the physical wireframe model is modified, the variations of the tangible markers are sensed, and the virtual wireframe model in GC is updated to reflect the changes in the physical model.

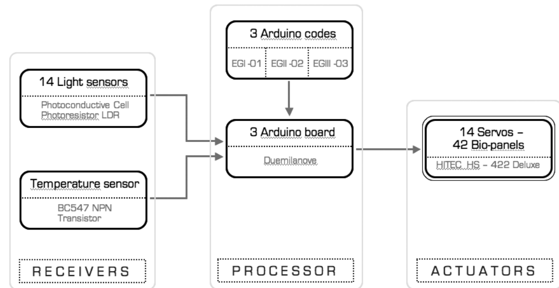

Figure 4. Flow of data in the responsive bioclimatic façade

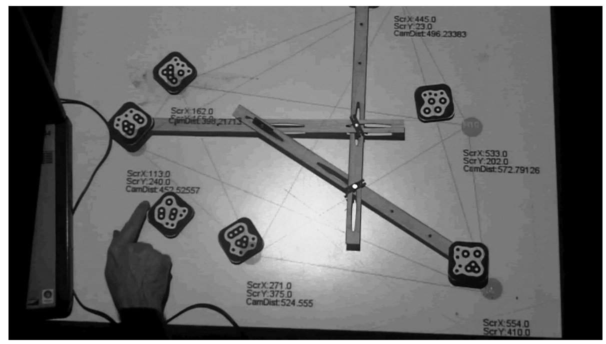

Figure 5. A Wireframe Model Attached with Tangible Markers

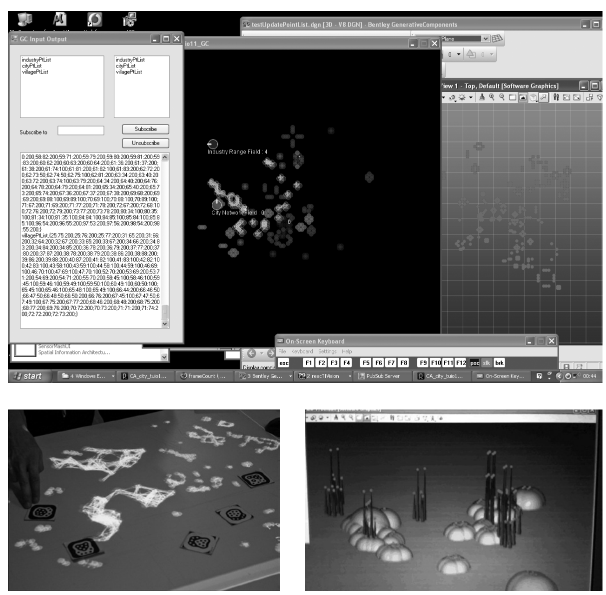

Figure 6. Tangible User Interface for Urban Planning

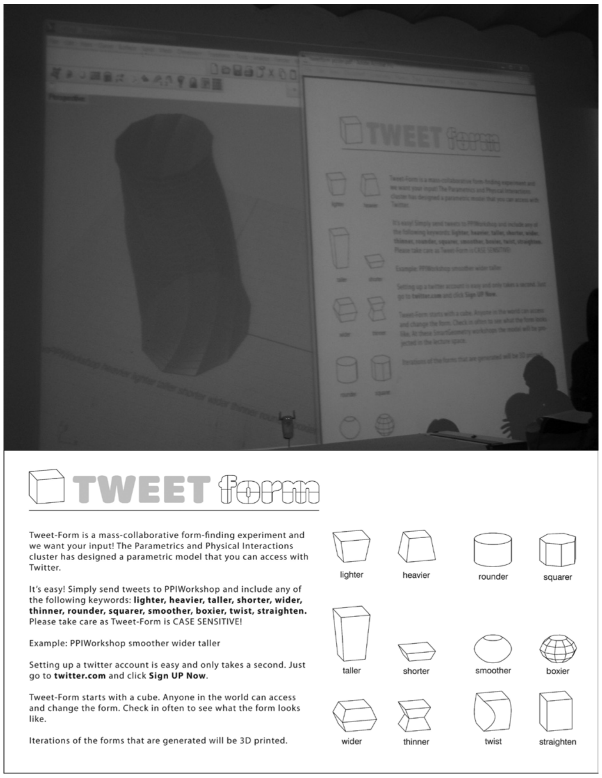

Figure 7. TweetForm

3.3 Tangible User Interface for Urban Planning

The table top design interface for generative urban simulations, a prototype by Takehiko Iseki (Foster + Partners), enhances the versatility of conventional CAD software as a design tool by connecting it with a more interactive and dynamic environment.

The Processing 3D engine is connected to GC to add a timescale to the generative urban simulation. The TUIO *(reacTIVision 2005)* plugin is used to perform visual recognition of the fiducial markers and monitor their positions and rotations on the table. Participants are able to touch, manipulate, and move tangible markers on the table to drive generative processes of growth, where city cells behave differently depending on position of attractors. There are three types of attractors, city, village, or industry, with its own growth pattern. These patterns can be adjusted by rotating side markers to change its properties, like speed and sensitivity towards neighbors.

We use Processing 3D, a programming language and development environment created by Casey Reas and Ben Fry from MIT, for the data visualizations on the table. Processing runs a cellular automata algorithm and organizes cells and their networks before sending that information to GC via UbiMash. GC generates a 3D snapshot of the growing city at the current point in time (Figure 6).

As a result, a responsive design platform is created, where despite complex chains of information exchange, users can access the interface easily and manipulate the urban cells without any technical knowledge.

3.4 Crowd Collaborative Form Finding

TweetForm, a project by James William Ransom (University of Buffalo), utilizes the power of social networks to inform a parametric model in Rhino. This enables crowdsourcing for collaborative form finding. Form finding activity is no longer restricted to individuals, instead, a much larger community can access the form, suggest modifications online, and preview the variations on the fly.

The crowd needs to have an access to a Twitter account, and post keywords to a specific hashtag associated to a particular Twitter account. The keywords, which are associated to particular geometrical manipulation of the model, include: lighter, heavier, taller, shorter, wider, thinner, rounder, squarer, smoother, boxier, twist, and straighten.

Processing reads a Twitter stream and scans for the keywords. If keywords are found, data are sent via UDP directly to Grasshopper. Since the Rhino model is associated with the Grasshopper definition of generative behaviors as described by the keywords, the model gets updated accordingly whenever a keyword is received in the buffer.

The 3D model was streamed online during the system testing, and was projected in one of the public spaces in the workshop venue in order to display live updates from Twitter (Figure 7).

3.5 Subjective Space Scanner

This project by Stefan Di Leo (Rhode Island School of Design) focuses on space, the context, and the boundaries of our occupancy and movement. Architectural design needs to be informed by the understanding of space. The subjective space scanner was developed to inform designers about personal space. The device was made of sonar sensors, GPS, and accelerometers connected to an Arduino board (Figure 8). The scanner can be placed in a backpack and carried around as the subject moves around the space (Figure 9 bottom). The spatial data of the movement of the person in space, such as position, acceleration, maneuvers, and boundaries, are recorded. Using GC script, data are read from the archive to generate the geometry of personal walkway. The model is rendered in GC (Figure 9 top).

3.6 Occupant Motion Tracker

This project, by Yelta Köm (Yildiz Techncal University Istanbul), has a similar focus to Subjective Space Scanner (3.5) but employs a different approach. The main difference is that it uses video camera to track the motion of multiple subjects. The aims are to depict people movements and their relationships and transform this into geometry. The system is used as a design informer to create a parametric model that reflects on the space of occupants.

A camera was installed right above the workshop area to record the motions generated by the occupants. The motions were recorded using frame-differencing technology that is available in Processing. Larger clusters of motions were grouped together, in order to distinguish movements of individuals. This data was fed to GC using UbiMash. In GC, a triangulation algorithm was used to produce a 3D geometry that visualizes the sampling of the data being harvested every 30 minutes (Figure 10).

3.7 Responsive Media Façade

In this project, developed by Hans-Georg Bauer (Barkow Lebinger Architects), motion detection was used to inform the behavior of an illuminated retail façade. The aim of this project was to create a physical screen that allows direct interaction with people passing by. Using visual responses, the installation is trying to attract attention of pedestrians or passersby and engage them in an interactive game (Figure 11).

A prototypical screen consisting of an array of LED-lights was built. The LEDs light up at different positions and with different intensity, depending on movement that is tracked through a camera. Processing is used to find the moving objects within the video data from the camera by comparing sequent frames and displaying the differences as brightness, leaving static areas as black background. The video image is subdivided into areas that correspond to the layout of the LED-screen. The brightness of pixels of each area determines the intensity and duration of each LED light. An Arduino microcontroller is utilized, bridging between digital information and the actual physical screen.

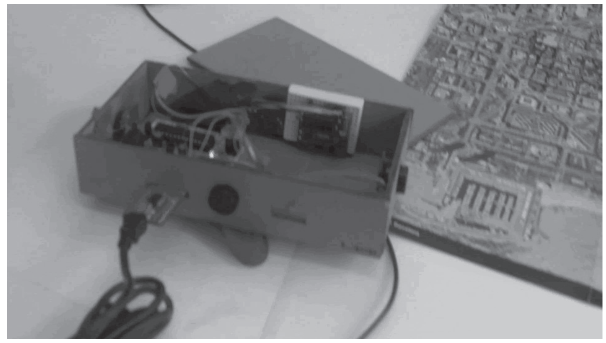

Figure 8. Subjective Space Scanner

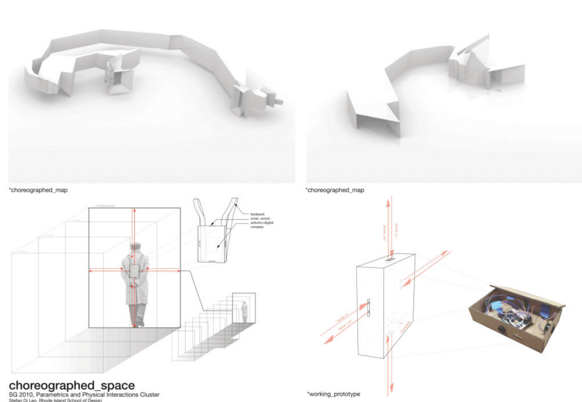

Figure 9. Space Scanning Result

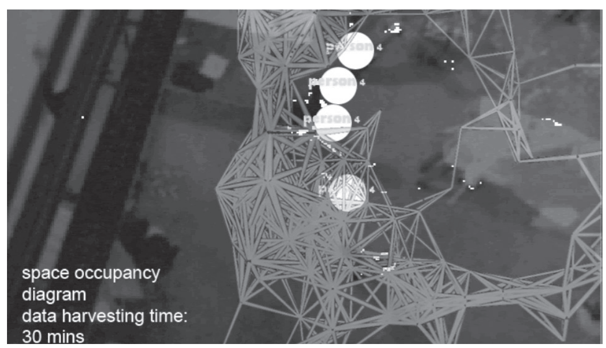

Figure 10. Occupant Motion Tracker

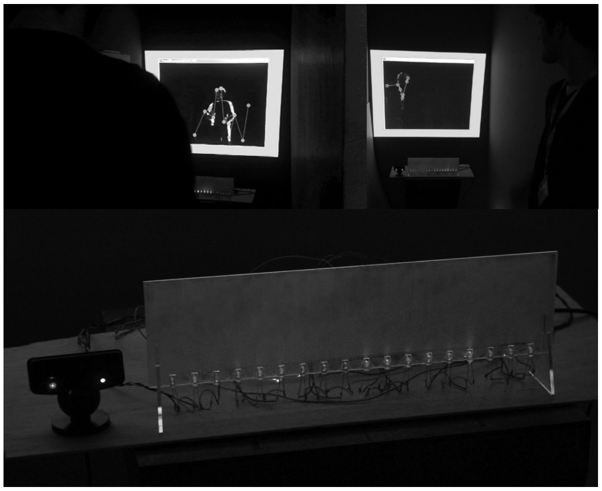

Figure 11. Responsive Media Façade

4 Conclusions and Future Work

This paper has demonstrated that parametric modeling can be further enhanced for design collaboration by integrating social networks, ambient intelligence, and tangible interaction in the design process.

The diverse outcomes of the workshop provide scope for further research. The variety of the projects demonstrates the wide spectrum of applications that can potentially be produced by utilizing UbiMash and the techniques elaborated in this paper. The three categories of models or prototypes presented in this paper—physical responsive prototypes, design interface, and parametric design informers—require further investigations.

The development of UbiMash will continue to add interoperability links with key proprietary CAD as well as with other free and open source software.

In moving the research forward, we are planning to further investigate the use of physical tools and tangible interfaces to support real-world interdisciplinary design conversations and collaboration.

Acknowledgments

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