CLOUD CODE: Public Space in 4 Dimensions

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The use of situated technologies within buildings is creating a new kind of interface between users and the space they occupy. Sentience, or a state of being self-aware, emerges through technology as a way that individual input can be processed to give back information about performance in real-time. Time, or the 4th dimension, becomes material by being made visible and pliable through digital fields that generate quantitative networks which produce qualitative spatial effects. Through sensing nodes and algorithmic processing buildings can produce a real time assessment of intensity of occupancy and environmental ambient conditions.

"Cloud Code" is a public art commission in the newly built municipal Central Permitting Center that our team was commissioned to conceive, program, fabricate and install. The art work is a conduit and real-time display of the occupancy, activity, and air quality in the building. The interaction of occupants within the physical space of the public areas is measured and displayed as an algorithmically generated animation.

A rear-projection display of animated graphics is generated by a network of meshed microsensors housed in custom fabricated enclosures. The occupants feed data through these to processing software that we coded for the project. The activity creates a cloud-like indication of indoor air quality in the first floor public area of the building. In addition to air quality and occupancy, other qualitative aspects of the building such as movement and ambient sound are graphically represented in an abstracted floor plan within an algorithmic real-time feedback loop.

The project exemplifies a crosscutting approach to the evolving role of art in public buildings, embedded intelligent technologies, custom designed software and interfaces and the integration of time into the design of an apparatus that engages the users

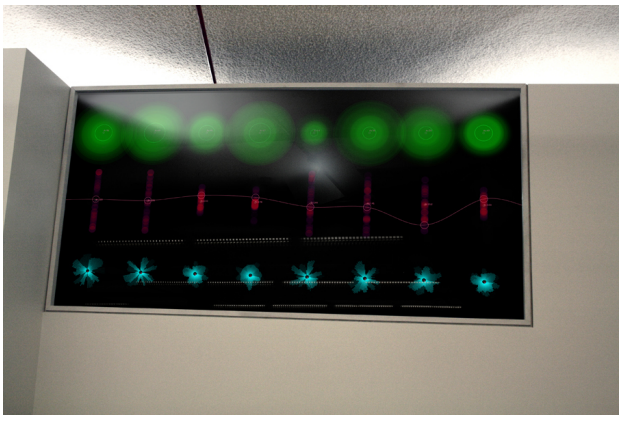

Figure 1: Cloud Code, rear-projected image of animation on glass

with a system of information management and display. Architecture in the 4th dimension in this case is not one of robotic kinetic components but one that tracks precise human movements and environmental activity and then processes it into information that reverberates and influences responsive reactions among the users. Our efforts have created and manifest a new kind of "social network" that is customized for a specific space and produces effects that transcend pure data mining and enters the realm of a public artwork.

SENTIENT PUBLIC SPACE

While surveillance systems and building management platforms have been present in public spaces for many years, their recent expansion and technological advancement has outpaced other innovation in the built environment. From post-9/11 homeland security to the micro-managing of building environmental control systems, the networking of information and imaging of public space has expanded to new depths. Now facial recognition and atomized environmental calibration pulls the level of resolution of these tools down to the individual and allows for one person's individual "fingerprint" to be recorded, tracked and allowed to influence actions farther up the hierarchical chain of command. Flows of occupants, temperature of microclimates and individualized bits of information are accessed and exchanged in real-time with vast quantities.

Our question was how to harness this information quantitatively and reprocess it as a qualitative presence in space and time. How could surveillance become interactive and even a playful presence when it is typically opaque and humorless? This is not a project of subversion but one of immersion and empowerment of the building's users.

ART IN PUBLIC PLACES

Civic art commissions are a compelling way that designers can create interventions in public space that can deviate from the official program of the building. Increasingly we see the rich conceptual ground for thoughtful expression in public buildings being left up to the art program. In our case, our city has a more generous allocation of capital dedicated to the artwork at 1.75% of the overall budget. In a weak economy, this has been a boon for the artists because the funding was dedicated for the work prior to construction and it's immune to cost overruns and value engineering that typically erodes the intention of the architecture.

Typically we operate as facilitators to the artist by working for them in the capacity of architects, fabrication consultants and construction managers. This cross-disciplinary approach allows us to navigate across boundaries that are typically contractual barriers by working on the front of the design process with the artist as we simultaneously engage the project from the vantage point of means and methods of realization.

The work that civic art commissions are now generating is finding ways of integrating with the building rather than just hanging on the wall or existing in a plaza in front in the traditional sense. This requires that the artists understand more about the building process and that the commissioning agencies, building architects, contractors and clients are thoughtful and accommodating to the need for full integration and communication in the process.

Figure 2. Central Permitting Center waiting area, stainless steel sensor enclosure on existing concrete column

CENTRAL PERMITTING CENTER

The Central Permitting Center is the facility that processes all of the permitted activity regulated by the Code of Ordinances from building permits to informal commercial activities. All commercial and residential construction is regulated and certified for occupancy. It also services equally mundane activities like the sign ordinance enforcement, tow

truck permitting and more salacious forms of commerce like firearms and exotic dancing. In a sense it ends up documenting the economic status of the city on any given day. The activity inside is a condensation of the vast and disconnected activities occurring in the urban fabric.

It is also a place where idle waiting and frustration with a bureaucratic process are part of the territory. We felt that art could create a relationship to this by empowering the user to interact with the space in a way that allowed for collective activities to be measured and played back as a series of relationships that indicate the quality of the space. In a sense we sought to take the pulse of the occupancy and rather than count heads or take numbers as the building typically does, we would create a live feed of their actions and invite them to tweak "the system" rather than only be subjugated by it.

The building itself is a beautifully re-purposed rice warehouse near downtown that the city saved from demolition and up-cycled through a careful consideration of its timeless attributes. The architects won over their clients to incorporate a raised floor to delivery mechanical and electrical systems to the offices and public spaces rather than suspend a ceiling which would have covered up the expressive raw concrete mushroom columns. We were invited to intervene in the main lobby space which is long and narrow with various seating situations and visual connection to the plan submission desks for building permitting activities. The concrete columns are on a regular grid throughout the building and repeat down the space of the lobby and modulate the rest of the interior architecture. We were intrigued by the repetition of the columns and their proximity to the public waiting spaces. If these locations could form nodes in system, we could map the activity in different locations in a consistent way with exact separation to distinguish between the sources.

Visiting the space we noticed a variety of sound intensities and zones of movement that differentiated according to the time of day. Numbers are taken by the users who might be architects, contractors or expediters who then wait for their place in the queue to be announced on the intercom. The repetitive sounds and motions associated with that process where augmented with individual conversations and actions. The concept of systematizing the input through multiple nodes emerged as our first reaction to pulling information from the space. We thought that rather than hide the sensors, we would make them part of the architecture and invite occupants to engage them on the local level so that there would be enhanced effects up the chain. The organizing concept of the entire project came into focus in that we were sensing the activity of the building creating a registration of qualities in the space. We additionally became interested in the air quality of the space by measuring levels of CO2 of users breathing near the nodes in addition to human activities that produce sound and movement. The recombination and integration these three quantifiable sources of data could produce a rich "cloud" of dynamic effects when allowed to interact and overlay.

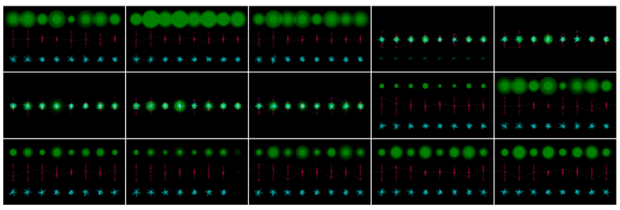

Figure 3. Cloud Code screen shots of animated image based on varing sensor inputs at each column locaton, green bubbles=sound, red waves=motion, blue sonar=CO2

THE CLOUD

We proposed a series of micro-sensors that would produce a field of data in 3D space that we translated into a 4D synchronous moving image as a public art project. Art in its most traditional and conservative sense is static and framed. We sought to create a graphic presence that would never be the same twice, evolving and changing from the point of its inception onward.

"Cloud" is used in contemporary digital parlance as the latest innovation toward erasing unnecessary hardware and distributed software from its presence in information systems through broadband technology and enhanced processing speeds. Collective workspaces have become the standard for collaborative practices and increasingly they operate with local and global networks. We sought to build our small cloud network using wireless controllers employing Zigbee protocols to create a field of sensors that could be placed anywhere and would draw their low-voltage power from solar

cells. This proved to be untested and potentially unreliable so we settled on a hard-wired system for electrical and data transfer. Our version of the cloud became an investment in a entirely ground-up closed loop network that would operate with custom software and hardware.

Our other interpretation of the cloud concept was in the phenomenal qualities of transparency of information and the ephemeral nature of temporal images relaying events in real time. Our efforts focused on an evolving and pulsing cloud of bubbles, sine waves and sonar dials that are images culturally associated with measuring things that are far away or unseen by the naked eye.

THE CODE

It became clear that our programming skills would be required to write custom scripts in order to optimize the processing speeds available to us. In order to produce a "cloud" of effects the communication between sensors and the animation had to be instantaneous and fluid. The need to tweak the code to enhance or change the graphic content was enabled by writing the program from the ground up.

Our code is structured as a series of threaded classes that react to incoming data values. Each class represents a style of geometry that is applied to the each object instance's respective input parameter. Incoming audio values affect the radius for an OpenGL circle in a class we defined as *Bubble*. In the *Wave* class, motion values determine the ycoordinate of a circle for each respective node and then, when laid out sequentially, collectively act as control points for a large moving spline. Finally in the *Sonar* class, CO2 values determine the length from center of a rotating OpenGL line.

All of our classes utilize threading to optimize responsive graphic output. Each object instance computes the necessary math functions in a thread on the main processor, and then draws graphics in a separate function read by the computer's graphics processor.

Threading becomes powerful when it meets a processor of multiple cores. An analogy for threaded vs. unthreaded code would be bottlenecked traffic vs. having all lanes open on a freeway. All graphics pass through arrays and transparencies.

A class, commonly known as an object in Object Oriented Programming, is a userdefined data type that enables a template of custom properties to be used differently in each instance. *i.e. class Human {age, weight, hair, eyes } …new Human Bob{29 years, 183 lbs, brown, green}…new Human John{36 years , 204lbs , blonde , blue}*

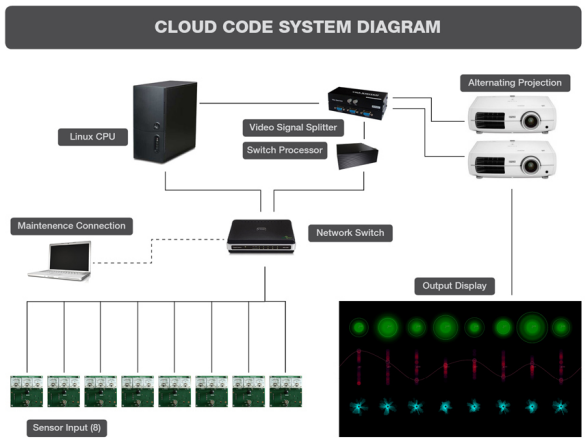

Figure 4. System Diagram

THE FEEDBACK LOOP

Feedback loops in architecture are most commonly associated with environmental control systems and thermostats. A condition is measured and the system reacts automatically to correct the situation to meet a desired state of dynamic equilibrium. Increasingly genetic algorithms are also being used to allow the centralized system to "learn" about patterns of use in time and anticipate conditions. Peak energy pricing and localized occupancy sensing are the new tools of smart grid technologies and micromanaged building control systems. Feedback loops involving human actions structure collective and individual behavior through simple (traffic lights) and complex information systems (air traffic control).

Our agenda was to set up a simple set of inputs and deploy them through the Permitting Center lobby in order to augment the experience and transform it from banal and routine to something more interactive and even playful. The work invites participation and involvement of the public that produces a collective floating image through networked feedback.

THE DISPLAY

The original goal of the Civic Art Ordinance that sets aside 1.75% of construction budget for art sought to find ways to integrate it in to the building. This is usually not the case with schedules set by owners and contractors who are not working with the artists, leaving the art for the end of the project as an afterthought. In our case the artist commissions were awarded early in the process and curated with the intention that they be conceived with the architecture and merged into the critical path schedule in order to find overlaps with the construction trades already working on the project. We installed a custom 5'x10' rear projection 1/4" glass screen embedded in an interior partition wall in the main information desk area. The quality of the projection is enhanced with an enclosure that reduces light pollution from interior and exterior sources. We specified two consumer grade digital projectors with wide angle throw and developed a custom switch on timers that cycles each unit for 2 hrs at a time during hours of operation of the facility in order to preserve lamp life.

THE INTERFACE

It was our intention to allow visitors to engage the sensors with the knowledge that their actions where having real-time effects locally and globally in the network of information and images. The sensors and the custom circuit boards they would be connected had to be protected and all electrical work had to be UL listed and enclosed. We used this opportunity to fabricate robust boxes out of stainless steel sheet metal. Galvanized hard conduit would transfer data and power down to the raised floor system in the building and relay to the central processor at the projection wall. We added three other features to the interfaces that would invite curiosity to the public and invite participation. Three analog needle meters were connected to each sensor to describe levels of input at each location. These engage the user without having the knowledge that their action is being described on the main projection screen. Secondly, we used standard microphone covers to protect the CO2 and sound sensors which invites the user to speak into the unit and simultaneously detect ones exhaled breath. Finally we inscribed a phase on each face plate that was a play on commonly used conversational fragments that might initiate a discussion at the interface about what it is--infrastructure or art? The phrases are:

"is this thing on?"
"breathe some life into it"
"inhale. exhale. repeat."
"permission to speak freely"
"i'll believe it when i see it."
"we're being watched."
"can we talk?"
"so you were saying..."

SOFTWARE

The project was executed on a Linux system using C++ with OpenframeWorks and OpenGL. Originally written in Processing, we moved from the Java based language to C++ to gain speed and efficiency of graphics. Java runs natively on a virtual machine, which makes cross-platform translation simpler, but in turn makes it slower to process than a language that runs on the actual machine. C++ also offers more efficient memory management. Dynamic C was used in the programming of the microcontrollers (sensors). We also utilized bash scripting in the Linux OS to assist with automating tasks such as a routine restarts, application launching, and downtime to optimize system performance and reduce strain. Other considerations in performance were communicating the real time data with UDP (User Datagram Protocol) instead of TCP/IP. TCP/IP is the standard web transfer protocol, it sends a packet to another entity and the entity responds whether it has received the package correctly. UDP directly sends the data streaming without checking if the information was passed correctly. This difference is one of speed and also stability. If data is disconnected or pieces get lost in transmission, then one runs the risk of delayed output. If some data is lost in transfer occasionally, UDP still keeps sending new data to be read expediently.

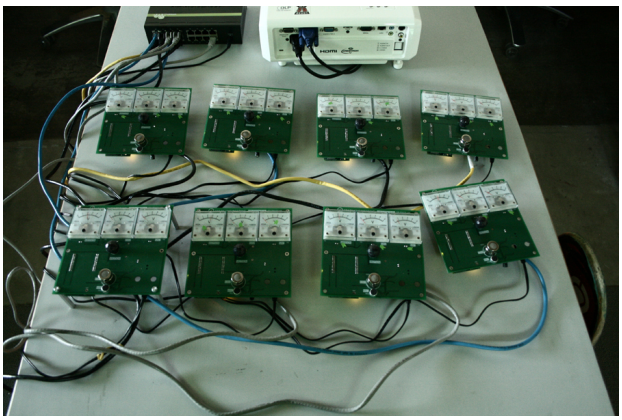

Figure 5. Sensor boards connected to network for testing prior to installation

HARDWARE

The hardware for each input node consists of a custom sensor board that houses a motion sensor, CO2 sensor, microphone, microcontroller, and the 3 analog multimeter displays. The microcontroller reads raw data values from the sensors, remaps them to an appropriate scale of values to work within (1-255). From there the values are concatenated to string format and are relayed to the respective local analog readouts and then sent as UDP packets to the main CPU via Ethernet. The CPU is equipped with a QuadCore Intel i5 chip, Ethernet card, and external network switch to channel data from all 8 nodes.

TIME SPACE CONTINUITY: Designing in 4 Dimensions

As architects we typically defer to the artist for conceptual intuition of a project. Our skill set is better suited to the role of interpreters, facilitators and fabricators. It is this opportunity to work with time as a material that can influence the behavior and tweak the performance of agents in a public space that interested us to shift our focus.

This is ultimately a comment on the relentless presence of enumerating technology in our lives and how it constantly tracks and quantifies without being transparent about the agenda of the operator--if there even is one. In this case it is a perfectly useless apparatus but integrated in such a way that it becomes a seamless presence in a system that lacks purpose for other reasons. It is this continuity with built architecture that we find so intriguing and beautiful to witness as an aesthetic expression of time in space.

Finally the project foresees a point where this type of project will be more interesting as it becomes obsolete. Like the early supercomputer that took up an entire room and provided less processing power than one now has on their mobile device, this over-articulated network that maps a space will have the same odd presence as a phone booth on a street corner has to us now. As surveillance and building system management become even more pervasive and invisible this gesture at making sentient technology a fully transparent and engaging infrastructural presence in a public space will hopefully endure as a continuity of art and architecture of its time.