Investigations in Robotic Urbanism

"Rediscovering Urban Space through Interactive, Data Driven Installations"

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Abstract

This paper examines the redefinition of public urban space through the evaluation and implementation of a series of globally interconnected interactive & robotic kiosks. Through the utilization and deciphering of relevant urban data, "Public Sphere" creates a new tangible layer within the urban fabric accessed through local and global reactive interfaces that engage the "contemporary" urban dweller with a network of urban ecologies that had previously remained hidden or overlooked. Through a series of studies examining the relationship between "Users, Robot & Global Network", this paper outlines the processes and inquiries that inform the current location of this ongoing research.

Keywords: Big Data, Internet of Things, Urbanism, Interactive environments, Robotics

Introduction

The harnessing and utilization of big data within the various scales of architecture and the urban environment are finding itself evermore relevant with recent advances in parametric methods of data extraction within the design of the built environment (Hess, T. and Sauda, E. 2014, Chiu, M. and Peng, C. 2005, Webb, A. 2014, Beirao, J and Arrobas, P. 2013). With vast amounts of continuously updated environmental and user-driven/crowd-sourced data at our fingertips, designers have the ability to create installations, buildings and other spatial artifacts/networks that are not only extremely user-specific, but also gain the capacity to adapt to ever-changing internal and external conditions in real-time.

How though can designers decipher these vast fields of data to determine which is relevant and which is not? And when taking on interactive projects such as these that harnesses harvested urban data, how can we gauge short and long term project success, as well as the potential impact on the future urban context?

Currently, such data driven projects remain limited as a result of existing rigid infrastructures, the use of dated design and fabrication methodologies, high costs of implementation as well as the use of inefficient materials and systems that do not allow for a high level of immediate visual and physical adaptability & interactivity. Created within this limited and fixed framework, such projects quickly find themselves out of date or underutilized, only to fall into an early obsolescence or removal.

Through the utilization of big data, interactive systems, robotic installations and innovative fabrication methodologies, the authors argue for a new smart-city based public interface or kiosk typology which not only redefines a given public space through information and interaction, but also re-centers the city as a whole around a publicly-accessible and globally interconnected network. This new urban lens allows the city's users to not only experience the city, but also redefine it's context in unique, personal and innovative ways.

This research also highlights the effects of interconnected and interactive artifacts on both the user and the surrounding urban conditions through an exploration in object and systems-level thinking within metacognition. Through this lens, the paper highlights a critical position on data-driven installations raised through the research, design and implementation of a network of interactive and interconnected "Public Spheres" proposed to be initially deployed within the dense urban fabric of Chicago (Figure 1). Building upon analyses and critiques, the paper advances the interpretation of smart cities artifacts through the initial design of an autonomous interactive public interface along Chicago's contemporary Lakefront with the potential to spread further, integrating them into other global cities of varying scales.

Figure 1: The "Public Sphere" dispersed on the landscape.

The "Public Sphere" inserts a new dynamic layer of information and interaction within the city that was previously nonexistent. Through the revealing of inconspicuous urban and ecological information and by fostering social exchange and interactivity, this project breaks down the typical typology of urban kiosk into fun and flexible urban furniture with the ability to connect individual nodes globally rather than functioning as a purely visual singular artifact. In addition, the authors highlight metacognitive and historiographical foundations to problematize common over-simplifications of current interactive projects, while revealing key cultural and ecological elements to the users situated within the broader issues of urban place making.

"Public Sphere" explores the creation of adaptable, kinetic and intelligent architectural networks and forms through the development and implementation of intelligent interfaces, innovative/low-cost materials and methodologies for urban, intelligent networks. Rather than attempting to make previous technologies, material and fabrication processes "smarter", this the "Public Sphere" investigates design intelligence as a process, which goes far beyond the creation of so called "smart" artifacts which only react to localized users, while also reevaluating the entire process of such scales of design.

The intelligence embodied within interactive projects must manifest through the surrounding urban context and become more deeply integrated into all aspects of how we conceive the design process. This may manifest in how information is disseminated both digitally and physically on the global scale, how users interact with the kiosk, how the interfaces can evolve over time through human interaction, how the project dissipates throughout the cityscape spawning new urban artifacts, through novel design processes and fabrication and finally though innovative funding pipelines. By completely rethinking the role of the typical urban "kiosk", the authors will in turn question the shifting facility of contemporary urban space, and how designers can better integrate adaptability directly into both the processes of design and within the artifacts itself.

Utilizing robotic/on-site manufacturing, smart reconfigurable skins and intelligent embedded robotic systems, the authors argue for a globally interconnected network of urban kiosks that not only learn and adapt to their surrounding environments, but also begin to redefine them through their integration into the cities social, economic, technological and cultural frameworks.

The prototypical city

Cities are in continuous competition for younger and more diverse populations. Growth demands are enormous - not only in the development of new places to live and work, but also in the creation of new places for social and environmental engagement. Amidst that growing density and pressure, cities more than ever before require humane, attractive space for people to gather together. Cities need to grow in productivity while retaining residents and businesses, and attracting local and travel commerce by offering more unique and specific experiences for both groups and individuals.

The creation of permanent/monumental spaces though limits the potential for variations in long-term activities within a given space. Cities remain evolving ecologies under a constant state of change potentially spanning hundreds or thousands of years. Although the fabric and culture of the city develops over these prolonged periods of time, current trends and technologies evolve at a pace far beyond what is currently possible using common materials and methods of construction. Can we not create physical artifacts within the slowly evolving fabric of cities with the ability to adapt and evolve at the speed of everyday life?

To test this hypothesis, the "Public Sphere" will be examined within the fabric of Chicago. In an internationally renowned hub for both design and commerce, Chicago's urban condition currently exists due to more than two centuries of rapid growth in industry, commercial and technological advances as well as immigration. Along with its vast transportation and social services infrastructure, Chicago situates itself as an ideal platform for the testing of a new typology of smart, adaptable infrastructural insertions.

The digital disconnect

Although people remain digitally connected throughout the day in such a place, the city perhaps more than ever before remains a series of disconnected nodes. People, despite being networked more broadly through mobile devices to ever-larger amounts of growing information, become further disconnected from their tangible surroundings. For example, following the map on your phone disconnects you from a variety of conditions within your immediate context by forcing you to bypass potential points of interest or interaction for the shortest time or distance possible. These tangential points of interest that fall outside of the guided view now merely become noise, overlooked both digitally and physically.

Big data & "smart" cities

Cities are also experimenting with new architectural and infrastructural forms and systems to meet the changing needs of its residents and commercial partners due evolving trends. These trends include the use of digital information and communication technologies as a means to improve the performance and quality of urban facilities and amenities. The so-called "smart" city also aims to reduce resource consumption and overall cost for services while attempting to universally engage and effectively communicate with its residents. With our current reliance on physically "wired" infrastructures, cities face considerable hurdles in their attempts to create a fully connected yet resilient smart infrastructure. The high costs and time required to create a smart city from ground up or within an existing city generates conditions where the implemented technology becomes obsolete before the project is even completed.

In contrast, "Public Sphere" focuses on creating the greatest physical effect through the smallest amount of permanent infrastructure. By remaining as stand alone artifacts not tied into the existing physical infrastructure, the kiosks avoid the constraints associated with typical constructions.

Methods for Adaptive Urban Ecologies

Through a series of explorations in urban kiosk prototypes, this paper investigates the potential of interactive objects combined with integrated robotic systems to create a new typology of adaptable, rapidly constructed, high quality, low-cost and intelligent urban spaces. These explorations push a series of four design strategies:

a. The re-evaluation of current spatial needs within the prototypical city.

b. The development of a formal design process and language that allows for maximum adaptability and interactivity.

c. The evaluation and testing of temporary, onsite robotics for rapid fabrication and customization.

d. The embedding of intelligent robotics within the facade, creating a skin with the ability to adapt visually and physically to it's ever changing internal and external conditions.

Through this research, the authors highlight critical factors concerning the feasibility, design and implementation of adaptable, interactive, and networked kiosks as key public amenities that may potentially redefine how physical artifacts are regarded within smart cities.

Expanding on current research and analysis on the "Public Sphere" in Chicago, this research moves current design studies towards full scale working prototypes that pave the way for a new typology of "Smart" urban intervention. The "Public Sphere" questions often over-simplified formal practices and rather focuses on how form can be generated and responsively modified within the built environment, to absorb and distribute changing information within the current urban environment. Through rigorous small scale and full-scale prototypes, this paper will attempt to invalidate both typical cost, complexity and hardware obsolesce problems typically associated with interactive urban installations.

Evolving spatial/social needs

Rapidly evolving technologies and digital interconnectedness call for a much-deserved social evolution of the urban environment. Thomas Goetz wrote in a 2012 WIRED Magazine article, that there are several key indicators that help the design community predict evolving spatial and social needs. He claimed among many interesting points, that "It's no secret that the best ideas—the ones with the most impact and longevity—are transferable; an innovation in one industry can be exported to transform another. But even more resonant are those ideas that are cross-disciplinary not just in their application but in their origin." (Goetz. 2012) In that way, a robotic urbanism can be viewed as a nexus that brings together fields of design, technology and the broader economy. Goetz also goes beyond an indication to look for what he calls "cross-pollinators" to discuss the need for good "deep design", meaning strong rigorously networked information and tenacious users who demand unique experiential qualities in the services and products they choose to interact with. He further clarifies: "Thankfully, we are on the verge of a golden age of design, where the necessary tools and skills—once such limited resources—are becoming automated and available to all of us. This timing is critical. "Too much information" has become the chorus of complaint from all quarters, and the cure is not more design but deeper design, design that filters complexity into accessible units of comprehension and utility."

Form

With a smooth and glossy finish, the "Public Sphere" is aptly named for its rich well-defined spherical form as much as for its ability to engage and connect with its surrounding public audience. Form though falls secondary to function in the case of this urban artifact. The simplistic, spherical form allows for the highest level of usable surface area for both imbedded visual interfaces as well as for removable urban furniture. Each module can be individually programmed for unique functionality while retaining a consistent exterior curvature for their use as interchangeable street furniture.

To keep the formal system as free to modification as possible, a set of simplistic interchangeable materials, fabrication methods as well as a series of unique polyhedral based parametric facade subdivision networks were

derived. These systems allow for the exploration and creation of a large variety of unique, site-specific kiosks typologies and modules. The system of skin subdivisions not only defines the size, form and function of the individual modules but also defines the aluminum structural frame and infrastructural pathways. As the form is modular and similar on all sides (Figure 2), kiosks can reconfigure their orientation based on optimal siting conditions. Based on plug-and-play methodologies, simular modules can also be swapped between various installations around the city based on localized user preferences and changing tendencies.

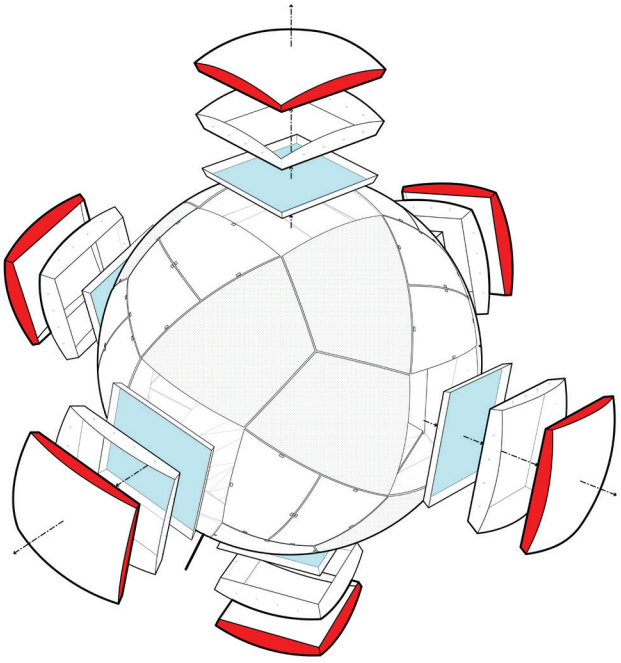

Figure 2: Module typologies.

Materials + Fabrication

Fabrication of the "Public Sphere" was intentionally designed to be as simplistic as possible (Figure 3). The "Public Sphere" consists of four simple layers:

a. Lightweight robotically fabricated (material cutting & welding) aluminum frame.

b. Thickened aluminum and wood clad infrastructural platform housing electronic components, energy storage as well as physical storage compartments.

c. Vacuum formed reinforced polypropylene interchangeable skin modules.

d. Hinged visual/interactive interface lying between the skin and interior.

Initial prototypes examined the potential for the use of on-site robots as a means of fabrication that are currently under further development. Two specific methods were examined and remain in the process of testing.

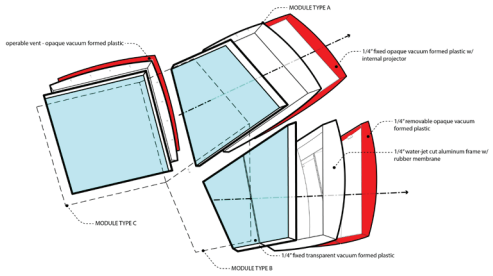

Figure 3: Module elements.

First was the use of industrial robots (specifically a KUKA KR60) to wrap a series of aggregating carbon fiber structural modules. These modules could be optimized for a high strength to weight ratio but have led to a series of larger questions that need to be solved. First is the cost of carbon fiber. In these case studies high strength 12k pre-impregnated carbon fiber tow was tested for its ease of use. Although the amount of materials used and waste produced have been dramatically reduced through the utilization of carbon fiber, the creating of a structurally robust module became increasingly expensive. The next issue was the materials need to baked at a temperature of 240°F for a period of 6 hours. Although this is a fairly low temperature, the additional curing process requires the use of an on-site oven that overly complicates the fabrication process. Finally was the problem of accuracy and repeatability through our current methods of carbon fiber winding. Our current tests did not provide the high levels of accuracy needed for the seamless insertion of electronics infrastructures as well as for the creation of a true plug-and-play system.

Because of these issues, a more simplistic system was tested using robotic milling and welding of large-scale aluminum panels. Although this system requires further development, the simplistic means of fabrication allows for an extremely high level of accuracy and formal flexibility, while also minimizing cost and construction waste. Enclosure is simply achieved though heat forming of reinforced polypropylene panels. As the subdivisions are derived from variations on polyhedral patterns, the number of module variations in this current prototype was limited to three which made replication of the skin modules extremely simplistic. When assembled or being dissolved by the users, each of these individual systems can remain functioning seamlessly as a whole or as individual autonomous urban artifacts.

Systems for rapid reconfiguration

The design communities desire for permanent/monumental buildings and public spaces hinders the long-term viability of current interactive installations as our preferences and

computing technologies are in a constant state of change. In contrast to this, the "Public Sphere" looks not to the permanence of itself, but rather uses flexible systems that allow for adaptability in the near and long terms.

In addition, recent innovations in low-cost computing platforms such as "Arduino Uno and Raspberry Pi" used in conjunction with simplistic robotic systems has allowed for the easy implementation of interactive elements directly into the initial design process of the "Public Sphere". Through the direct linking of robotic elements into the Rhino 3D design environment through Grasshopper plug-in's such as Ladybug, Honeybee and Firefly, designers can now not only design static physical artifacts and material interfaces but now also tie environmental, global and or sensor data directly into the project for immediate simulation. This demystifying of both data and robotic programming through visual coding also allows for the easy swapping of data input types throughout the design process or even in the future of the installed artifact.

To deal with this rapidly changing digital environment, it was necessary for the "Public Sphere" to be extremely agile in form and interface. The creation of highly flexible systems took place in several investigations:

a. A highly flexible form allowing for a multiplicity of orientations.

b. The maximizing of usable surface area for both interchangeable interactive and physically usable.

c. A simplistic structural system with a high level of potential embedded variations.

Adaptable form + function

Adaptive systems within architecture have typically been associated with high levels of complexity as can be found in projects such as "HypoSurface" created by dECOI architects. Although projects such as these are able to interact with their surrounding environment, these projects remain extremely expensive because of their extensive infrastructures and complex fabrication processes. The projects can also become constrained by the vast numbers of parts; redundancies as well as the complexities involved in the future modification of their initial infrastructure. Rather than creating interaction purely through complex robotic systems, the "Public Sphere" focuses on simplistic interactions thorough visual interfaces and interchangeable/removable urban street furniture.

The Public Sphere rests in a closed state in the sand. Prodigious and clean in form, sitting organically in the landscape; they draw people in and invite closer scrutiny, and come to life as potential users begin to approach. They react to sound and touch, when closed off, acting as a reflexive surface for the cities little known ecologies; through user inquiries, real-time projections of the lake's inner ecology may emerge. Or perhaps a periscope into the din of Millennium Park. When open for use: they slowly disintegrate into tailored yet unrecognizable forms as they accommodate key urban programing for the urban dwellers. Through adaptive paneled surfaces, Beach Balls open via hinges and surface extrusions to allow access and activation, unique to each purpose in the network. Encouraging interaction, each module communicates it proximity back to the core, creating a visual and audible dialog between the two. The now removed panels open the visual screen up for touch interaction. Although beginning as a single contained object within the urban fabric, the "Public Sphere has now broken down creating physical and digital interactions over the scale of a city block.

The Public Sphere (Results)

Although still in the early stages of development and prototyping, this research looks to redefine the typology of urban kiosk, not as a lonely static object; another box in the public realm, but rather a network of public interfaces which redefine the city. Public Sphere reimagines the public lakefront as the dynamic, dramatic and current recreational frontline that the city of Chicago deserves – where urban social animals can find magic while redefining how public space is used and created within the city. The Public Sphere enhances the lakefront to make everyday life a spectacle through public interaction and through the exposing of both obscure data and places of interest.

A traditional kiosk might act as a dispensary, for food; maybe for something fun, but at most, a kiosk will be a place for basic information. Providing the sort of knowledge that any local person, or Siri or Google for that matter would know if you only asked - coming to your eyes and ears with no mystery or explanation to it, and hardly ever from anything deeper than its own skin. Kiosks struggle to do more, as some recent examples will show, trying to push a technology, or a fashionable aesthetic, but still remaining for better or worse in the same place as before.

What if the Kiosk could be more? Could a kiosk be more synthetic? Could it be a portal to somewhere, something of use rather than simply dispensing goods? Is it too much to ask a kiosk to inspire human emotion? Could a kiosk uncover and illuminate hidden elements of the city? Could the kiosk create a dialog between social and environmental forces? The "Public Sphere" looks to answer these questions.

Exposing hidden ecologies

Countless ecological processes are ostensibly hidden from view beneath the surface of the lake. Countless more social exchanges and interactions throughout the city remain personal and intimate, essentially dislocated from one another. This is the result of the aforementioned technological disconnect, but is also more obviously due to issues of scale and complexity. The underwater disconnect is mostly visual, but both cases represent an opportunity to better utilize

digital sensor-based technology. Why not attempt to reveal activities taking place real-time elsewhere in the city? If done properly, could projections on civic infrastructure better enhance connections between individuals and communities?

Conclusion

More work is needed to determine a range of factors from site-specific feasibility to establishing criteria for pre- and post-occupancy performance. However, the limited potential of existing urban architectural typologies to connect communities through emerging digital and architectural technologies is highly motivating. Students and practitioners involved with the advancement of built environment will find opportunities collecting, organizing and utilizing data to propel their imagination and inform their design processes.

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