EMERGENT INACTIVITIES
FROM THE PRIMITIVE HUT TO
THE CEREBRAL HUT

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ABSTRACT
What potential does the rapid development of interactive architecture hold for the future of our environment? Will it lead simply to a "responsive environment", which might introduce a new level of environmental control and comfort? Or might it effect some more profound changes? Might it help to breed, for example, a new form of emergent behavior, whereby humans and interactive devices could combine to generate a pervasive computational intelligence that effectively operates as a form of "brain"?

This paper is an attempt to speculate about the far-reaching implications of interactive devices that not only make the environment more adaptive and flexible, but also serve to engender a new configuration of the built environment itself. It argues that interactive devices promote a bottom-up emergent behavior that constitutes a low-level form of "swarm intelligence". If networked into an overall system, such devices could have the capacity to generate more complex intelligent behaviors. Still further, if this system is linked to the brains of the users, an even more sophisticated form of intelligence will emerge. Through the interactions of human beings and the networking of various interactive devices, each of them invested with their own computational capacity, the built environment might therefore potentially turn into a form of intelligent computational system or "brain".
EMERGING INTERACTIVITY

Interactive design has been one of the fastest developing areas of computational design in recent years, thanks largely to the commercial availability of various devices to either sense human operations or control a response to those operations. Sensors, such as Kinect and Leap Motion, have become readily available on the market place, while micro-control boards, such as Arduino, Raspberry Pi, and Galileo by Intel, and actuators, such as various servos, DC motors, stepper motors, smart materials, and pneumatic devices have also become highly popular. If we add the increasing availability of cheap and readily available lighting systems, such as RGB LED lights in various forms, addressable LED strips, and other similar products, we can see that a whole new field of research and development has opened up, such that any student of architecture can now experiment with these systems. Indeed, arguably tuition about these systems should be readily available in every school of architecture, although it might take some time before expertise in working with these systems has spread from early centers of interactive research, such as the Interaction Design Institute Ivrea, to less technologically advanced educational environments or environments where a skepticism about technology in general may still hold sway.

Nonetheless, it is clear that interactive design is here to stay, whether we are talking about simple responsive systems, such as user-presence-activated lighting systems that preserve energy by switching off lights in the absence of human movement, or more advanced user interface (UI) systems using Kinect, Leap Motion, or other devices now appearing on the market that link the adaptation of buildings to the behavior and gestures of the human body.

One can gauge the popularity of interactive architecture through the exhibition, Interactive Shanghai, held at the Center for Architecture and Urban Planning (CAUP) at Tongji University, Shanghai, China in 2013. The exhibition took place in conjunction with a conference on interactive design that featured not only leading western interactive designers, such as Philip Beesley, but also a new generation of Chinese interactive designers, such as Gang Song, Yu Lei, and Philip Yuan.

What made this exhibition remarkable is that it was the first exhibition to offer a comprehensive overview of interactive design within schools of architecture worldwide. The exhibition gathered together material from a range of architectural schools that have been exploring the potential of this domain, schools such as Harvard Graduate School of Design (GSD), UCL Bartlett School of Architecture, Dessau Institute of Architecture (DIA), TU Delft Hyperbody, Paris Malaquais, Royal Melbourne Institute of Technology (RMIT), Hong Kong Polytechnic University (PolyU), South China University of Technology (SCUT), Tongji University, Tsinghua University, and the University of Southern California (USC). The fact that an exhibition as comprehensive as this could be held is evidence in itself of the growing popularity of this area of research. Moreover, the fact that interactive design is being pursued in so many schools of architecture suggests that it is in academia—rather than practice—that a familiarity with such systems is being fomented most extensively.

INTERACTIVITY AS EMERGENCE

One of the interesting features of interactive operations is the potential development of “emergent” behaviors. For example, as an interactive installation responds to the behavior of the user, the user in turn also responds to the behavior of the installation. This will carry on building up indefinitely in a continual feedback loop based on a mutual response between user and installation. As a result, a continual bottom-up unpredictable overall behavior will develop what we have come to know as “emergence”.

Emergence occurs whenever two or more agents are operating in relation to one another—i.e., other words, wherever there is a multi-agent system that manifest itself in a form of populational behavior or “swarm intelligence”:

An Emergent Interaction System consists of an environment in which a number of individual actors share some experience/phenomenon. Data originating from the actors and their behavior is collected, transformed and fed back into the environment. The defining requirement of emergent interaction is that this feedback has some noticeable and interesting effect on the behavior of the individuals and the collective – that something “emerges” in the interactions between the individuals, the collective, and the shared phenomenon as a result of introducing the feedback mechanism. (Niklas Andersson, et al. 2003)

A common everyday example of this emergent collective behavior is the “swarm intelligence” that can be observed in a flock of birds, such as starlings, when they come in to roost in the evening. The complex aerial gymnastics of these birds is defined not by any top-down logic that is imposed from above, but rather through a bottom-up logic that “emerges” out of the simple interactions between the individual birds. In other words, as the flock swoops, soars or veers in any direction, it is not being directed or controlled by any one particular bird, but rather each individual bird is following a certain set of basic rules to do with cohesion, separation, and alignment – keeping a certain distance from the birds in front and on all sides, while flying at the same speed and traveling in the same basic direction. But importantly, out of these individual behaviors, a certain collective intelligence arises that is not pre-determined but self-regulating and adaptive: “Constantly mutating, emergent systems are intelligent systems, based on
interaction, informational feedback loops, pattern recognition, and indirect control. They challenge the traditional conception of systems as predetermined mechanisms of control and focus instead on their self-regulating adaptive capacity.” (Leach 2004: 72) What makes this theory so relevant is that emergent behaviors may be detected in any multi-agent system, no matter how incommensurable its constituent elements. Thus, as the title of Steven Johnson’s best-selling book, Emergence: The Collective Lives of Ants, Brains, Cities and Software, reveals, we can extend the model from seemingly dumb creatures, such as ants, to the sophistication of the brain itself and on to cities and certain software that operates as a form of multi-agent system (Johnson 2002). Wherever two or more agents interact in a bottom-up manner, emergent behavior can be seen to result. As Manuel DeLanda observes:

“The dynamics of populations of dislocations are very closely related to the population dynamics of very different entities, such as molecules in a rhythmic chemical reaction, termites in a nest-building colony, and perhaps even human agents in a market. In other words, despite the great difference in the nature and behavior of the components, a given population of interacting entities will tend to display similar collective behavior. (DeLanda 2002)”

Importantly, this model suggests that a form of computational intelligence is potentially at work within any multi-agent system—intelligence, most obvious perhaps in the example of slime mold foraging for food. Moreover, their behavior can be compared to that of the brain, since the brain itself—as a neural network—is also a multi-agent system. Furthermore, it should be noted that not only does the model of emergence point towards a direct connection between multi-agent interactions and computer software, but also that the term “computation” implies multi-agent behavior, since it is derived from the Latin “computare”, meaning “to think together”. As such, we can see the potential of the interaction between user and the smart interactive devices in the house to generate a simple form of emergent computational intelligence.
THE HOUSE AS BRAIN

The sophistication of the system will increase as the number of agents and the connectivity between those agents increase. If, then, the smart devices within the house were themselves to be interconnected into a network, we could imagine the possibility of a more sophisticated system where the emergent intelligence would extend beyond the interaction between device and user, to include all other devices, so as to generate a more pervasive form of computation. In other words, the potential of any networked system of interactive devices is that it lends itself to a distributed network of intelligence that effectively constitutes a form of computer.

Computation is the most important factor in interactive design, since it operates as a form of “brain” to the body, although a computer, in and of itself, is not necessarily intelligent. It is simply a tool, and, as with smart materials or any actuators, it must be used in the right way for it to contribute to any form of intelligence. Moreover, it would be naïve to assume that any “intelligence” within any low-level computational system is necessarily useful. The important question, then, is how that computational system is programmed and deployed. As such, there should be some programmable objective—such as energy conservation—behind the use of any computational system.

We can see the clear potential of a multi-agent system as a distributed network of intelligence, if we consider the example of the swarm robots—or “swarmanoids”—developed by Marco Dorigo, “a heterogeneous robotic swarm made up of different types of robots”, which can take on various tasks through the logic of distributed intelligence. These systems can be more adaptable and robust than traditional monolithic systems. As Dorigo comments:

3 Lacescape, interactive installation, Interactive Shanghai, 2013, by students Anqi Yu, James Merriman, Jiahong He, Jie Xiong, Di Meng, Li Li and Tim Duan
Swarm robotics systems are made up of swarms of relatively simple and cooperating devices rather than of a single and powerful robot. The main idea is that a system of many simple devices that exploit distributed control and self-organization to coordinate their activities might be more robust to failures than a monolithic system such as a humanoid robot. In other words, the lack of a central controller—none of the robots is in charge of directing the swarm activity—and the redundancy in the robot swarm—individuals are interchangeable as they all have the same or very similar capabilities—makes a swarm robotics system very robust to failures. In fact, should one or a few individuals fail, the others can take over and the overall system would show only a limited degradation of its performance.

Likewise, we can see the potential of multi-agent logics operating at an urban scale as a means of optimizing traffic systems (Bazzan, Kluegl 2009). Predicting traffic behavior is a challenging task. While there are several systems that offer information on traffic conditions, in order to predict the actual behavior of motorists there must be some form of simulation of drivers’ coordination decisions based on the interdependence of a series of actions operating within a multi-agent system:

One challenge to researchers dealing with traffic management is to find efficient ways to model and predict traffic flow. Due to the social nature of traffic, most of the decisions are not independent. Thus, in traffic systems the inter-dependence of actions leads to a high frequency of implicit co-ordination decisions. Although there are already systems designed to assist drivers in these tasks (broadcast, Internet, etc.), such systems do not consider or even have a model of the way drivers decide. (Bazzan, Kluegl 2004)

As such, multi-agent systems can be used to simulate the complex, bottom-up, self-organizing principles that govern traffic and other systems. But, beyond this, they also hold out the clear potential to simulate behavioral systems within the house, where—likewise—a form of intelligence can emerge based on the interdependence of individual operations, and where bottom-up interactive processes are increasingly at work.

If we are looking for an example of how individual interactive and responsive computational systems in a house might be networked in order to turn them into a broader low-level “computer”, we might look to the example of the Nest thermostat that coordinates various sources of data in order to create a system that can learn progressively from the behavior of the occupants in order to minimize energy consumption. What, then, is being suggested here is the potential extension of this simple principle of “swarm intelligence” found within any multi-agent system to create a genuinely intelligent environment that operates as a bottom-up “computer” or “brain”—the house as “thinking machine”.

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Swarm Bots, part of a self-assembling robotic swarm of robots developed by Marco Dorigo

4 Vince Tang, Interactive Light-Flower, for Alice in Wonderland Installation, Los Angeles, December 2013. For video of full installation see http://vimeo.com/89476130

5 Swarm Bots, part of a self-assembling robotic swarm of robots developed by Marco Dorigo

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Finally—at a further level—we could also see a potential connection between the networked interactive devices within the house—operating as a form of “brain”—and the actual brains of the users themselves. In other words we could imagine the potential for a “neuromorphic architecture”, which could sense behaviors of the brain and respond accordingly. This, then, would extend the distributed intelligence of the house from the low-level intelligence of a networked system of interactive devices—operating as a form of multi-agent system—to a secondary multi-agent system, the brain itself, to generate an even more sophisticated computational network.

It is here that we can recognize the far-reaching implications of this logic. For, according neuroscientists such as Antonio Damasio, the brain should be understood not as a “command control center” but rather as a kind of self-regulating device that—much like a thermostat—regulates the body, and keeps it in a state of equilibrium or “homeostasis” (Damasio 1994, 2010). By definition, then, the brain operates interactively with the body to balance its physiological and psychological condition. If we are to extend the notion of the body to include the “housing” of that body (for the body also interacts with its environment), we can make a connection between the brain and the built environment.

As such, we can immediately recognize the potential for interactive computational devices to facilitate this connectivity and generate a new condition, whereby the house might not only operate as a form of low-level distributed intelligent system, but might also be connected to the higher level activities of the brain itself. The brain and the house, then, would be connected through an interactive logic. In other words, not only could the house serve as a form of “brain”, but the brain could also serve as a form of “house”.

CONCLUSION

Recent developments in interactive architecture have potential implications beyond the straightforward technical interactions between users and their environments. This paper has sought to explore the potential of an emergent behavior that could develop out of the multiple interactions between users and their environment, as the popularity of interactive devices begins to spread.

Already we can discern simple emergent behaviors developing out of the interaction of users and interactive devices within their environment. If networked so that they become part of a larger multi-agent system—these could potentially result in a form of low-level intelligence that could be understood as a kind of distributed computer. Eventually, we might reach the point where such devices—if networked with the brains of the users—could be understood as part of a higher-level intelligence, so that the house becomes a form of “brain”, and the brain a form of “house”.

Famously, Le Corbusier once described the house as a “machine to live in”. His comments have elicited a variety of responses—some positive, some negative. If, however, we were to think through the logic of this paper, his diagnosis did not go far enough.

With the advanced technological devices that populate the contemporary house—from the environmental control systems to music systems and ever more sophisticated entertainment devices—we find that the house has indeed become a form of complex machine. But—more than this—with the advent of remote sensing technologies and other potentially interactive devices, a new configuration can be discerned, whereby beyond their straightforward technical capacities, these new technologies could potentially be ushering in a new form of emergent interactive behavior that if connected to the brain itself might generate a highly intelligent system. As such, the house of the future could also be understood potentially as a distributed network of interactive devices that—collectively—“compute” data, so that the house itself could become a form of “machine to think with”.

6 “The Cerebral Hut”, is an installation designed by Guvenc Ozel, where commercially available devices to record concentration levels and blinking are reprogrammed in order to activate an installation through brain activity.
It is perhaps no coincidence that China is turning into one of the main centers for interactive design, thanks largely to the low cost of components, such as Arduino control boards, nitenol and LED lighting, in that country.

3. A note of caution, however, needs to be sounded here, in that much of the student work on display was based on systems operating at a relatively small scale. It is one thing to use an Arduino control board to operate a Servo motor within an installation little larger than an architectural model, but is quite a different challenge to produce a system capable of operating at the scale of a building, although we are beginning to see larger scale installations within architectural practice, such as the Hyper-Matrix installation (on this see: https://vimeo.com/46857169). Moreover, the reliability of these systems needs to be greatly enhanced if they are to have a lasting impact on architectural design itself. The Interactive Shanghai exhibition was forced to close early due to the failure of some of the exhibits. This is perhaps a salutary lesson that the full potential of interactive systems cannot be realized so long as the durability of the systems used remains in question. Memories of the failure of Jean Nouvel’s responsive façade system for the Institut du Monde Arab in Paris occur only too often in this field.


5. Within the field of architecture, multi-agent systems have become an important field of research. Educators, such as Alisa Andrasek, Jose Sanchez, Karl Chu, Paul Coates, Cecil Balmond, Roland Snooks and Ed Keller have explored the potential of using these systems to generate designs using Processing an other multi-agent systems, although the generation of often static forms is quite different to the operations of interactive systems where form is continually reconfigured in real time. This interest in a distributed model of design is forecast by Stan Allen when he cites Craig Reynolds’s work and suggests that swarm logic offers an insight into emergent methodologies, “Crowds and swarms operate at the edge of control. Aside from the suggestive formal possibilities. I wish to suggest with these two examples that architecture could profitably shift its attention from its traditional top-down forms of control and begin to investigate the possibilities of a more fluid, bottom-up approach.” (Allen, 1997)


8. For other examples of research into traffic behavior using multi-agent systems, see: BURMEISTER, (1997); Dia and Purchase (1999); ROSSETTI, et al. (2000); Fiosina and Fiosins (2013)

9. Research in this field is still in an early stage of development. However, in recent years there have been a series of significant developments that suggest that the field is ready to have a major impact on architectural theory. The publication of Cognitive Architecture: From Bio-Politics to Neo-Politics (Niedich and Hauptmann, 2010) introduced research in this field to a broader audience. Meanwhile, architect Greg Lynn, along with creative designer, Alex McDowell and neuroscientist, Sergei Gepshtein, has recently been awarded a Hay Research Grant to explore the perception of the brain within architectural spaces, with the clear potential of developing a ‘neuromorphic architecture’. The grant was made by the Academy of Neuroscience for Architecture (ANFA) based at the Salk Institute, San Diego, which has also organized a conference on the connection between neuroscience and architecture, with a subsequent publication. (Dougherty and Arbib, 2013). The ANFA is holding a second conference for September 2014: http://www.anfarch.org/wp-content/uploads/2014/03/2014-ANFA-cfp.pdf (accessed 4/12/2014). A symposium on ‘Neuroscience and Architecture’ was also held in Helsinki, Finland, in 2013 with the proceedings published. (Tidwell, 2013). Other advanced research into neuroscience and architecture has been conducted by architect, Pierre Cutellic, and neuroscientist, Fabien Lotte. (Cotellic and Lotte, 2013). Further publications in the field include two books by John Eberhard (Eberhard 2007, 2008), and a book edited by Juhanla Palasama, Harry Malgrave and Michael Arbib. (Palasama, Malgrave and Arbib, 2013) At a larger scale Wolf Prix has been leading a research initiative, ‘Brain Cities’, that seeks to connect neuroscience with urban planning, based on the work of the neuroscientist, Wolf Singer. See http://www.braincitylab.org, accessed 4/12/2014.

REFERENCES


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IMAGE CREDITS

Figure 1. Arusyak Manvelyan
Figure 2. Behnaz Farahi
Figure 3. Anqi Yu
Figure 4. Vincent Tang
Figure 5. Marco Dorigo
Figure 6. Guvenc Ozel

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