Rethinking Smart Architecture: Some Strategic Design Frameworks
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The paper is an attempt to provide a comprehensive re-definition and a complex-adaptive framework for strategic understanding of smart architecture. The paper rethinks smart architecture's strategic and conceptual frameworks. A complex-adaptive and systems approach has been forwarded as an alternative. Comprehensive definition of smart architecture has been provided. Disparate yet related camps of responsive architecture, adaptive architecture, intelligent buildings, kinetic architecture have been brought under the umbrella of smart architecture. The role of users in smart architectural schemata has been explored. Examples of a few recent architectural projects have been used to illustrate the emerging directions in smart architecture.
1 INTRODUCTION

Smart architecture is fast becoming a buzzword in architecture and related fields. While the discipline of architecture was busy debating the issues of double-coding and architectural semantics during the eighties [1], a spirited circle of researchers in engineering and architecture were actively exploring the notion of intelligent buildings [2]. AT&T toyed with “intelligent buildings” in 1982 [3,4]. A number of books were published under that rubric espousing great hope [5-10]. However, the notion of intelligence has almost always been limited to building system automation, entertainment and appliance integration through computational agencies.

Significant amount of current research on smart architecture is focused on the area of “smart homes.” Scalability, portability, and conceptual clarity have been the limiting factors in extending that research to larger building applications. Interestingly, the research and scholarship in the area of smart environments is finding primary patronage in the technical disciplines such as computer science, electrical engineering and mechanical engineering. For instance, dozens of conferences have been conducted and hundreds of papers have been written on the topic of smart architecture in such forums as IEEE. However, the number of architects or architectural researchers directly involved or interested in this area can be counted on fingers. The number of conferences dedicated to this topic within the discipline of architecture can also be counted on fingers. There is a paucity of work within the discipline of architecture on this important and potentially transformative subject. This paper attempts to outline a complex-adaptive systems framework for smart architecture, outline an agenda, and connect the dots of some significant conceptual, technological and architectural developments in this direction. The title of the paper is double-coded to read in two different ways. One way of reading it is “rethinking the discourse about smart architecture,” and the other way of looking at it is “smart architecture that rethinks its own raison d’être.”

2 DEFINITIONS: SMART ARCHITECTURE, SMART ENVIRONMENTS AND SMART BUILDINGS

One of the goals of this paper is to begin to define the scope and challenges of smart architecture. This task involves defining the attribute of smartness, questioning the purpose of smartness in architecture, and identifying the revolutionary possibilities that are bound to transform architecture as a profession and the building industry as a trade.

What does it mean for architecture to be smart? How smart is too smart? How is smartness measured? How does it differ from the previous attempts at making architecture mechanically and/or computationally intelligent? How does it relate to or embrace design computing, computer aided architectural design and sustainable design? Is there a possible architectural framework that can be used to provide the necessary
direction to the myriad academic and professional pursuits currently underway? What are the formal and spatial implications of smart technologies in architecture? The author will attempt to find answers to some of these questions within the limited real estate of the few pages that follow.

Currently the notion of smart architecture is wrought with unintended vagueness. There has been no fundamental discourse about what constitutes smart architecture and its principles. Is anything with a microchip smart? Is anything that is networked worthy of attribution of intelligence? What are the benchmarks for smartness in architecture? As an architect and a systems theorist with a particular interest in complex-adaptive systems, I find a number of basic systems concepts to be of great help in accomplishing the present task of framing smart architecture.

What is the meaning of smart architecture? Smart architecture maybe comprehensively defined as a blend of passive and active technological and architectural strategies that harness computationally networked, globally connected, complex-adaptive and real-time responsiveness so as to form a co-evolutionary whole with the inhabitants.

The notion of smart environment differs significantly from discipline to discipline. Diane Cook and Sajal Das offer a different definition of smart environment [11]: “A definition of smart or intelligent is the ability to autonomously acquire and apply knowledge, while environment refers to our surroundings. We therefore define a smart environment as one that is able to acquire and apply knowledge about an environment and also to adapt to its inhabitants in order to improve their experience in that environment.”

Within the discipline of architecture, smart architecture is a notion that is currently popular in the sustainable design and smart home circles, where smartness often refers to the ability to passively or actively regulate a variety of environmental parameters including energy efficiency [12-14]. Other terms have been used by various people to mean more or less the same set of architectural attributes and functionality as smart architecture. The term responsive architecture puts emphasis on increasing the interactive nature of building elements in response to environmental or social or commercial needs in real-time [15]. Responsive architecture may involve any form of computationally-mediated responsiveness. Kinetic architecture, a term once popular in the 1960s, is preferred by those who see architecture as a literally more mechanical, kinetic and moving organism [16] where spatial, mechanical movements are essential to its definition. However, all the terms represent directions in architecture that involve active, instantaneous response to internal or external conditions through computational agency.

It is important to understand the subtle yet important distinctions between smart architecture, smart environments and smart buildings. If we set aside the attribute of smartness, we have three terms representing three distinct, albeit overlapping notions: architecture, environment, and building. For the purposes of this paper and the context of the current discourse,
architecture maybe defined as the sum total of the bodies of knowledge, representational systems, artifacts (such as buildings), underlying ordering and configuration systems, practices, philosophies, and the discourses about the culture of building. Architecture involves comprehensive and critical design of institutions.

Environment maybe defined as that which provides the overarching field of frameworks, systems, principles, protocols, infrastructure and platforms within which tools, devices, users and activities can be supported, nourished and nurtured.

A building maybe defined as a physical artifact that is the result of certain architectural processes. A building is a sum total of materials, human activities, HVAC systems, and metabolism.

If we add the attribute of smartness, then it implies that these processes, things and notions are mediated by intelligence, learning, and autonomous decision making in architecture, environments and buildings.

3 COMPLEX VERSUS COMPLICATED

Complexity is not an oft talked about concept in architecture. Robert Venturi’s Complexity and Contradiction in Architecture does venture to some extent in connecting with the notions of complexity in other disciplines while focusing almost exclusively on mannerist complexity of meaning, surface, iconography and historic references. [17]

What is complexity? The word complexity is a derivative of the Latin root complexus, which means totality and embrace. Complexity refers to systemic totality and to the interrelationships between various subsystems. This differs from the common parlance that complexity is opposed to simplicity. The word simplicity descends from Latin roots sim+plec, which literally means single fold. The true opposite of simplicity is complication, which means to fold together. While there is a synonymous relationship between complexity and complication, they are distinctly different notions. Complex systems can be simple or complicated. Complicated systems are not necessarily complex. Complex systems, as they are understood today and defined in no fewer than millions of words of cross-disciplinary discourse, are closely related to such phenomena as adaptive systems, non-linear systems and living systems. In complex systems there is an element of learning and adaptation. There is also an element of self-awareness, which differs significantly from automation. Paul Cilliers, a leading proponent of complex systems theory sums it up thus:

The concept ‘complexity’ is not univocal either. Firstly it is useful to distinguish between the notions ‘complex’ and ‘complicated’. If a system - despite the fact that it may consist of a huge number of components - can be given a complete description in terms of its individual constituents, such a system is merely complicated. Things like jumbo jets or computers are complicated. In a complex system, on
the other hand, the interactions among constituents of the system, and the interaction between the system and its environment, are of such a nature that the system as a whole cannot be fully understood simply by analyzing its components. Moreover, these relationships are not fixed, but shift and change, often as a result of self-organization. This can result in novel features, usually referred to in terms of emergent properties. The brain, natural language and social systems are complex. [18]

Why should we consider complexity in the discussion about smart architecture? Complexity is the essence of architecture. In architecture we find a coming together of the poetics of technology, space, life style issues, idiosyncrasies of individual metabolism, and familial particularities. Smart architecture is no more complicated than smart cars. But smart architecture does pose challenges that are truly complex, cultural, and require creative design solutions. A complex-adaptive approach to smart architecture strategically fosters a more meaningful and connected whole. In the sections that follow, the author will discuss a number of strategies to handle intrinsic or extrinsic complexity in smart architecture.

4 IP VERSUS XP: CONNECTION VS CONTAINMENT AND NETWORK VS ROOM

A building is a network for living in [19]. While all complex-adaptive systems have a sense of autonomy, they are part of a larger system. Just as a human individual has a clear-cut identity as a complex-adaptive system, every human being is an integral part of a large life-world system. Likewise, smart systems would be very dumb if conceived as self-contained systems that are disconnected from the larger world systems. A network as a whole is always a more capable, adaptive and complex system than any of its components. However, it would be a fallacy to think that a network of computers and devices in and of itself is smart. It is the human participation in the network and the networking of human beings that make a network complex, smart and adaptive. Human beings are integral parts of any given intelligent network.

A network is an interconnected system with a certain structure of relationships. Kevin Kelly, the executive editor of WIRED magazine summed up the essence of the current paradigmatic shift thus: “the central act of coming era is to connect everything to everything. All matter, big and small, will be linked into vast webs of networks at many levels. Without grand meshes there is no life, intelligence, and evolution; with networks there are all of these and more” [20]. Derrick de Kerckhove noted that the “architecture of intelligence is the architecture of connectivity. It is the architecture that brings together the three main spatial environments that we live in and with today: mind, world and networks.” [21]

A number of networks are either already in use or being developed that
will radically alter our perception and use of our buildings. Wide area networks (WAN), personal area networks (PAN), body area networks (BAN), and their wireless counterparts WWAN, WPAN, WBAN are at various stages of development and implementation around the world. Intel’s new WiMAX technology buoys these possibilities by preparing to introduce cell-phone-like ubiquitous and wide-ranging network coverage for laptops and other computational devices (www.intel.com/netcomms/technologies/wimax). A WiMAX-equipped laptop or computational device can stay connected to the Internet all the time without any wires. Such a technological network would be a crucial turning point in the journey toward the emerging noosphere. At a time when even the toasters and refrigerators are being hooked up to the Internet, architecture is not going to be left too far behind, despite the best efforts to resist the evolution by the profession’s conservative core. Connection is the keyword, the buzzword and the overarching concept of how buildings could become networked computer systems. A computer as a box that is not connected to the larger networks is very limited in its role and outreach. Similarly, buildings conceived as isolated boxes, albeit internally computationally sophisticated are also very limited in their smartness from a complex-adaptive viewpoint.

4.1 ONSTAR@HOME

General Motors’ OnStar® vehicle security system has already transformed our automobiles, which are now controlled by dozens of embedded computers and networked via satellites, into GPS-powered real-time network nodes. An OnStar operator can access most of the critical systems of an automobile remotely and suggest or coordinate a course of action at the touch of a remote button. The biggest evolutionary jump for automobiles is not in their growing engine size or seductive body shape; it is in the pervasive computerization and wireless digital networking. According to some sources, nearly 80% of all innovations within automobiles today are derivatives of electronic systems [22]. That is a far cry from the pre-nineties automobile industry where manufacturing and fabrication issues took the center stage of innovation. The mobile space of the automobile has been transformed into an interactive real-time network node capable of keeping us connected to the rest of the world, for better or for worse. Automobiles are already a part of the emerging noosphere. The OnStar system can access all the critical vehicular systems, diagnose any problems even before the symptoms show up. It can email the user the system details and diagnostics at anytime. Architecture is also becoming a part of such a post-spatial digital ecosystem.

The Internet Home Alliance (internethomealliance.com), a cross-industry collaboration between GM’s OnStar, Invensys, ADT Security Systems, HP, Panasonic, and many other corporate partners have launched, in early 2002, a post-spatial initiative to integrate OnStar’s Virtual Advisor® service with
home security control, telecommunications control, and climate control from any Internet enabled appliance located anywhere in the world. This system also gives the customer visual access to his or her house at any time. Garage doors, access doors, windows, all the major home appliances, HVAC system, security system, and telecommunication systems are networked using the HP Application Server 8.0 framework as gateway. The participating customer would be able to access any and all of these aspects in real-time from any computational device such as a cell phone or a PDA or a laptop. The customer would be able to remotely turn on or off the appliances such as kitchen stove or refrigerator. Panasonic’s smart doorbell would notify the customer anywhere, through audiovisual access, whenever his or her doorbell is rung. Thus, appliances, HVAC systems, security systems, and a host of other building systems are computationally networked and connected to the global nomads - the home owners.

Many other initiatives and projects are moving in a similar direction. MavHome (University of Texas at Arlington), Adaptive House (University of Colorado at Boulder), House_n (MIT), Aware Home (Georgia Tech), Gloucester Smart House (UK), Microsoft Easy Living, Philips Smart Home and many other ongoing projects are exploring a myriad technological and technical challenges of smart homes.

The repercussions of these initiatives are revolutionary. With OnStar automobile technologies, GE gets to access, assess, and market a variety of products and services to their “target demographic.” The invisible strings of communication and data streams connect GE and its vendors to the various automobiles as they move in space-time. With smart homes, the strings connect to the “sitting targets” of real estate. The marketing and sales possibilities spawned by the data streams generated by smart homes are virtually unlimited and ominously far-reaching. Today, we do see many instances where the computers, cell phones and other devices are thrown-in for free for a subscription service. At some point in the future, it may even be possible to give the house for free for subscribing to a smart home vendor.

5 THE ROLE OF HUMAN(S) IN COMPLEX-ADAPTIVE SMART ARCHITECTURAL SCHEMA

Many of the current models of smart architecture are based on certain assumptions about human behavior and aspirations. In general, these models assume that physiological comfort is the goal of smart environments. They also assume that the HCI (Human Computer Interface) has to become as transparent as possible [23] so as to avoid a steep user learning curve. Yet another assumption is that the humans want more and more hands-off comfort. The flip side of such an approach is that as architecture gets smarter with more and more “sensors,” human senses become more and more numb, anesthetized and potentially atrophied. As more of the “non-
“critical” decision-making is transferred from the users to the smart systems, the users stand the danger of losing their visceral connection to the building and its surroundings.

Few if any of the smart homes are really based on well-developed theories and philosophies about domestic life. Vivian Loftness and Victor Harkoff, et al. had raised this point nearly two decades ago: “The present intelligent building approach basically represents a technologically-centered idea, not a human-centered one, extending the notion that building occupants detrimentally affect environmental performance” [24]. Wisneski, Ishii, el al have taken a similar stance. Their “ambient display” projects are geared toward turning architecture into a comprehensive interface where buildings connect people to the world via the Internet [25]. Most models of smart architecture pit humans on one side and architecture on the other side in a guessing game: movement and behavior prediction algorithms try to guess and learn from certain observations of human actions [26]. Computer vision software try to figure out the human intent [27]. But, is this what we want and need? How much of architecture’s smartness is contributed by the users? What types of non-critical decisions are left for human action? What kind of ecosystem do we want to promote that involves the local landscape, flora, fauna and human beings? What are the ethical and cultural issues of buildings becoming networks for living?

Is there a way to integrate human intelligence and agency into the scheme of things in smart architecture? While we do explore intelligent agents’ learning, it should be equally interesting to study how human beings learn and adapt to or react to smart environments. These are the questions for further exploration beyond the scope of this paper.

6 SMARTER ARCHITECTURE

The Latent Utopias exhibition curated by Zaha Hadid and Patrick Schumacher featured a pioneering kinetic responsive prototype named Topotransegrity. It was a curious mix of topological manipulation through pneumatic space frame structure. The project, designed by 5Subzero, a group of architects from London, featured surfaces that can be manipulated through either an automated control mechanism or a real-time feedback system or a pre-programmable system. The system, if developed as illustrated here, could become a self-organizing system that approaches spatio-temporal smartness with a high smartness quotient.

The system consists of a kinetic space frame driven by three sets of Festo pneumatic pistons. The original prototype was designed to sense the audience movements through pressure sensitive mat and translate the impulses into valve operations controlled via the computer. The scenario depicted in Figure 2 envisages some dramatic architectural possibilities. Topotransegrity proposes to program the walls and floors along with people and events in an all enthralling four-dimensional framework for smart architecture.
Figure 1: Topotransegrity by 5
Subzero

Figure 2: Topotransegrity
Scenario
More and more architects are beginning to explore the form and format of such smart and supple architecture. The Muscle, a prototype featured at the Non-standard Architecture exhibition held at Centre Georges Pompidou from December 10th, 2003-March 1st, 2004. The Muscle was designed by the Dutch design firm Oosterhuis_Lénard and dons a pneumatic structure that behaves like a gigantic, digitally mediated muscle. The building would flex, contract, expand and mold itself to suit changing programmatic conditions over time and in real-time. The architects propose that the place be used for a variety of activities such as a disco or a television studio or a meeting place. The synthetic muscles of the Muscle react as people move near the sensor points. Another way to manipulate the structure is by moving the sliders on a remote computer screen. Thus, the building becomes spatially interactive and can be plugged into the Internet. This alien-looking blob is not necessarily how buildings might look as a whole in the future. Some buildings might look that way. However, the Muscle, as ONL proposes, can literally be used as a series of muscles in a building to control any environmental or other parameters in real-time thereby leading to truly complex, kinetic, performative, and supple architecture. To sum up, as William Mitchell said, “we become true inhabitants of electronically mediated environments rather than mere users of computational devices.” [28]

7 CONCLUSIONS
Smart architecture presents us with a combination of opportunities, challenges and dilemmas. Many of the challenges are to do with the
“architecture of the system” and the viability of conceptual frameworks that form the basis for such an architecture. The paper rethinks smart architecture’s strategic and conceptual frameworks. A complex-adaptive and systems approach has been forwarded as an alternative. While architecture is no more complicated than an automobile, it is arguably far more “complex.”

There has been a convergence of a number of factors that are enabling the emergence of smart architecture as the next frontier: sensor-actuator technologies that have become widely and economically available; ubiquitous computing; and machine intelligence. Intelligent buildings of the eighties (that were heavily building systems-oriented) and the amateur-focused home automation technologies of the nineties are giving way to systemically integrated and globally networked smart architectures that are increasingly human-centric. However, too many approaches to smart architecture are focused purely on the notions of comfort. We must realize that the human needs go beyond the physical comfort. Instead, the emphasis could be laid on globally connecting, informing and empowering the user.

Just as a single computer or a series of isolated computers, no matter how powerful, could not have brought about such a global cultural revolution as the Internet, a smart home or a smart building cannot lead us toward a cultural tipping point. As a number of thinkers have pointed out, connecting the buildings and their systems to the global networks holds more architectural and business potential. Solutions to problems do not always lie in technology alone. Strategic, architectural, cultural, entrepreneurial and other approaches need to be considered together with the technological solutions.

Much work needs to be done in terms of architectural integration and conceptual models of making architecture smarter. At present, the participation of architectural researchers and designers in the development of smart architectural schemata is woefully inadequate. More architects need to recognize the potential of smart architecture and begin to embark on pertinent technical, architectural and market research. The paper has illustrated few of the cutting edge architectural projects that do present various explorations of facets of smart architecture.

References