RESEARCH ON HYBRID TECTONIC METHODOLOGIES FOR RESPONSIVE ARCHITECTURE

HAO-HSIU CHIU
Department of Architecture, Tunghai University
181 ChungKung Rd., Taichung, Taiwan
hchiu@thu.edu.tw

Abstract. This research intends to provide a comprehensive understanding and tectonic patterns of responsive architecture. By qualitatively analyzing a series of critical responsive buildings from Ito's early Wind Tower through Diller and Scofidio's Blur Building to Cloud 9's recent Habitat Hotel, tectonic themes of "lightness", "morphing", "improvisation", and "networking" are set to the elucidate methodological relationships between their tectonic expressions and design concepts. Based on these designated themes, manipulation of materiality, techniques of construction, and mechanism of responsiveness in the studied cases are comparatively discussed and demonstrated with visualization of their tectonic design patterns. The objective of this research is to stress on the importance of tectonic consistency and offer evidences in combining physical components with digital configurations in order to achieve poetic expressions of structure, function, as well as aesthetics so that genuine spatial quality for digital era can be truly revealed.

1. Introduction

As human beings today live with the environments of ubiquitous computation and communication, architectural space can no longer simply be a functional "machine for living" (Corbusier, 2008) but an "interface for information exchange and interaction" or "incentive of senses, a communication machine"(Moccia, 2006). With the ongoing development of digital and information technologies, the focus of architectural design will lie not only on the construction of space and volume, but also on that of interface and software systems underlying emerging hybrid spaces. Architects are more and more confronting the design challenges to properly manipulate both physical (material, object, surface, space, etc.) and digital (image, sound, network, information flow, etc.) elements and systems while remaining consistent in

integrating technology, functionality, as well as aesthetics for hybrid design. It is important to understand the patterns of hybrid tectonics in order to keep this consistency. Many avant-garde architects have been experimenting on merging bricks and bits with advanced technologies to explore the frontiers of responsiveness in architecture. Dynamic surfaces and structures are created to manifest more sensitive, intelligent, interactive, and improvisational nature of space. This research intends to discuss and explore the tectonic themes and patterns of hybrid architecture from selected 18 built cases and prototypes based on their consistency from design concepts to realization. As a result, we found four tectonic themes among these cases by analyzing their formal expressions and interactive mechanism. They are themes of "Lightness", "Morphing", "Activating", as well as "Networking", each representing crucial properties and meaning of the emerging architecture breed.

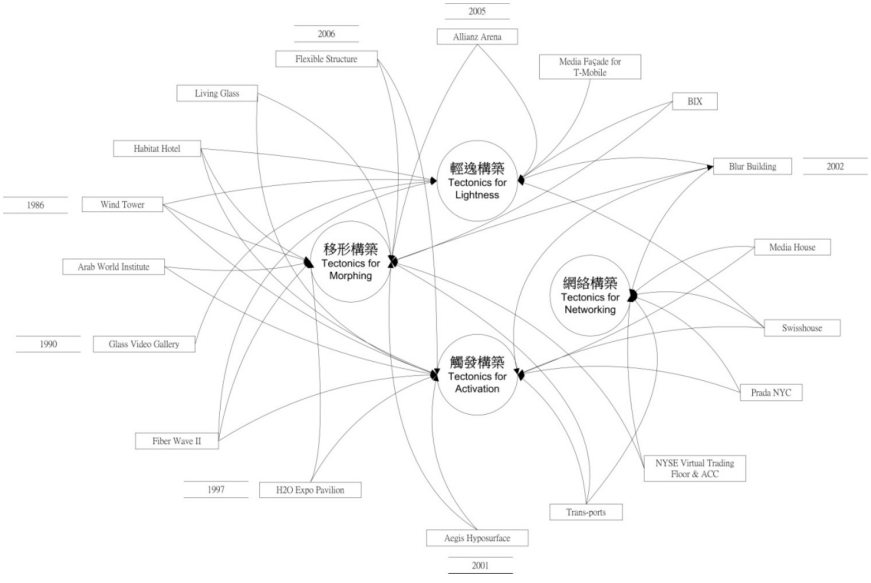

Figure 1 Tectonic Themes and Related Cases of Hybrid Architecture

2. Tectonics for Lightness

The transient and fluid nature of digital media makes the visual "lightness" as first theme of hybrid tectonics. Compared with the fact that modern architecture pursued lightness through spatial transparency and continuity, responsive architecture makes itself look weightless by constantly changing its own formal

configuration. Instantaneity and re-configurability become fundamental to such hybrid tectonics. There are several ways to achieve the goal of being visually light:

2.1 BEING EPHEMERAL – BLURRING OF VOLUME

Utilizing immaterial and variant elements such as water and lighting can blur the boundary of design shapes and incur instability of volumes. Toyo Ito's early project "The Tower of Wind" (Figure 2) may well demonstrate this concept of ever-changing architectural composition to reflect its kinetic urban contexts. Ito inserted a programmable neon-light layer into the space between the existing concrete ventilation tower and cylindrical aluminum meshes with punched holes. The lighting patterns and colors vary constantly to respond to intensity of wind blows and surrounding sounds through sensor detection. The profile of the tower becomes indeterminate due to its visual temporality and ephemerality. The formal uncertainty further lightened volumetric intensity.

Figure 2 The Tower of Wind

Figure 3 T-Mobile Media Facade

2.2 BEING SEAMLESS – SHEER AND SLIM SKINS.

Many hybrid architectures are designed with double skins including a structure layer and a display layer. Although the volume of a building of such kind remains stable and complete, the tectonic techniques of superficial and transparent overlays make it skinny, borderless and invisible. AG4's T-Mobile Bonn Headquarter established a sheer LED "Media Facade" (Figure 3) to merge media presentation with building structure. The low-res but ultra-bright LED display layer is seamlessly integrated into its glass cladding and panel system. Passersby can still see through the glass box when the media facade is presenting commercial video or images so that the physical activities inside the building will be dissolved into the electronic imagery. The seamless visual transition between virtual and real surfaces, to a degree, reduces the certainty of architectural archetype.

2.3 BING FLUID – SIMULATION OF NATURAL VARIATIONS.

Diller and Scofidio's "Blur Building" for Swiss Expo 2002, on the other hand, intensifies the concept of lightness with foggy cloud caused by spraying tiny drops of lake water form 31400 jets. The changing speed of wind and temperature are continuously converted to density and velocity of the blurry cloud. The immateriality of fluid fog results in formal mutability, fuzziness, and fading nature so that the long-lasting rationale of tectonic expressions from stable walls, columns, floors is subdued. Dynamic interaction between humans and nature overrules the articulation of space.

TABLE 1. Tectonic Strategies for Lightness

Methods for Lightness	***Project***	***Tectonic Pattern***	***Function***
Ephemerality (Blurring of Volume)	The Tower of Wind (Ito)	Changing patterns, brightness and colors of neon lighting to respond to wind speed and ambient sounds	Convert urban noises into a dynamic and responsive sculpture
Seamlessness (Sheer and Slim Skins)	T-Mobile Bonn Heasquarter (AG4)	Merge low-res and ultra-bright LED overlay with physical façade layer	Urban branding
	Habitat Hotel (Cloud 9)	Sheer meshes with LED and sensor nodes as an architectural overlay to reflect solar energy and movements	Urban branding
Fluidity (Simulation of Natural Variations)	Blur Building (Diller+Scofidio)	Changing density and velocity of water fog to respond to wind speed, humidity, and temperature	Remove visual spatiality with fog to enhance bodily senses with electronic gadgets

3. Tectonics for Morphing

The kinetic morphing of tangible or analog surfaces and structures is another tectonic strategy for communicating information or supporting interaction. Physical formal transformation gives multi-faceted functional possibilities and environmental adaptability. It also goes beyond the aesthetics of merely visual representation with its tactile materiality and structural authenticity. There are three different tectonic compositions for morphing based on cases:

3.1 TANGIBLE PIXELS

The concept of "pixel" for architecture is undoubtedly not new. Bricks and tiles are physical pixels used for structural composition and tectonic articulation. However, dynamically interconnecting tangible pixels with hybrid techniques makes it possible for indeterminate forms. Aegis Hyposurface (Figure 4) designed by dECOi may best demonstrate a 3D morphing structure with the tangible pixel idea. Connected triangular metal petals are driven by 896 pneumatic pistons to form a live wall so as to continuously animate the waving topological surface. The physical morphing becomes feasible through "folds and unfolds" between connected pixels.

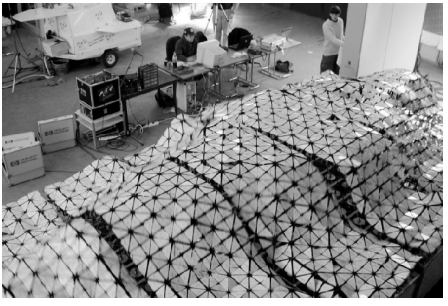

Figure 4 Hyposurface by dECOi

Figure 5 Flexible Srtucture by oframBFRA

3.2 FLEXIBLE STRUCTURE

Besides the morphing technique of pixilated surface, shape-changing three-dimensional structure opens up the possibility of design optimization with "dynamic equilibrium" in architecture. Natural creatures change forms or postures according to constantly changing environments in order for high efficiency and situational functionality. For instance, a caterpillar may curl up in defense. A giraffe drinks water with its front legs splayed and its head down for balance. oframBFRA argues architecture should be as responsive as animals for the same purpose. It's "Flexible Structure" (Figure 5) made up of SMA (shape memory alloy) and metal components and wires can react to ambient variations with different sensors. The SMA components contract when heated up with electricity and at the same time open up the space underneath as sensors detect an addition of use population. Compared with rigid structure systems of most buildings, such a soft structure system may be highly applicable with its potentials for structural adaptability, on-demand performance, and kinetic aesthetics.

3.3 PLIABLE SURFACE

Responsiveness and interactivity can also be achieved in another way of morphing by applying pliable or flexible materiality to architectural surface or structure. "Living Glass" developed by The Living combines the characteristics of silicon surfaces with SMA wires to create a responsive wall. In contrast to mechanical actuators, material actuators (SMA) are used to organically twist and morph the transparent surfaces when infrared sensors detect indoor human activities. The linear cuts on its surface therefore open and close in real-time and allow air to go through to adjust humidity and temperature, just as if the living skin is breathing. Such formal and functional metaphor of biological mechanism further emphasizes the potentials of physical morphing techniques for more intelligent and android spaces.

4. Tectonics for Activating

Followed by the first two tectonic themes in formal transformations, "activating" strategy concentrates more on mechanisms behind spatial interactivity. As a responsive architecture should still resonate to its habitual contexts (constant flux of people, goods, resources, knowledge, weather conditions, etc.), the interplays and processes of its input/output, sensing/actuating need be designed for optimal improvisation. Interactive or responsive scenarios therefore surpass static formal creation. There are basically two kinds of activation strategies:

4.1 PARTICIPATORY ACTIVATION

Participatory activation involves "autonomous" control or actions. Participants or users may consciously and actively decide when (activation time), how (activation methods), or to what degree (activation level) to take actions during an interactive process. Although most participatory activation mechanisms have been seen as an automation strategy for so-called intelligent buildings (automatic doors, motion-sensitive lighting system, and so on), recent applications are to facilitate more scenario-based interactive experience. The interactive dressing rooms in PRADA New York flagship store, for instance, can demonstrate how participation activates situational experiences for corporate branding. As a collaborative project of OMA/AMO and IDEO, one wall of a dressing room forms the door, which the customer can "make opaque for privacy during changing or clear to show off a garment to someone outside the booth. Another wall inside holds a camera and display and works as a "magic mirror" adding a four-second delay so the customer can spin around and view all sides of the garment. The opposite wall has two interactive closets, one for hanging clothes

and one with shelves. Sensors in the closets detect the electronic tags on the chosen store items and trigger a touch screen that displays the item and its related information, from availability to permutations of color, fabric, and size." A typical process of participatory activation takes place in order with customer action, sensor detection, and actuator reaction based on habitual and situational contexts. "Human participation" becomes a required task to collect effective user inputs by identifying, interrelating and interpreting user "spatial information" (distance, position, posture, etc.) and "identity information" (interest, gender, height/weight, etc.).

4.2 ADAPTIVE ACTIVATION

Different from participatory activation, adaptive activation involves "non-human" and "dependent" reactions, and is sensitive to changing "ambient information". With the help of emerging sensing and actuating technologies, responsive architecture nowadays can make an instant presentation or formation by being fed with translated real-time and continuous data flow from environments. Like sunflowers reacting to direction and intensity of ever-changing daylights for photosynthesis, architectural surfaces, spaces, and structures may automatically and constantly adjust themselves to improve functional amenity, environmental sustainability, and communicational effectiveness. The "Habitat Hotel" designed by Could 9 Architecture consists of a building with an "energy mesh" wrapped around it. The energy mesh has individual nodes with solar cells, light sensors, and LEDs which collect sun's energy during the daytime and give off different colors at night according to the amount of energy collected. The appearance of the building adapts to the cycles of ecological essence without human triggers.

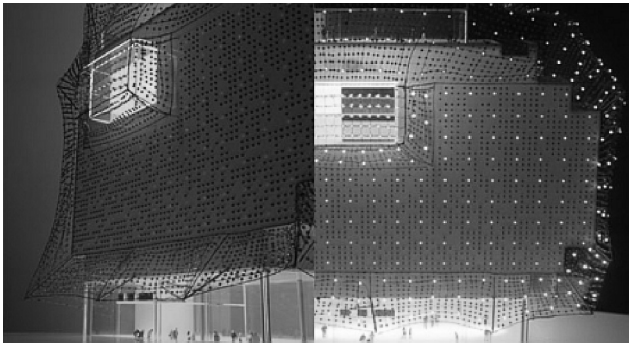

Figure 6 Habitat Hotel by Cloud 9 Architecture

4.3 ACCIDENTAL, PERIODICAL, AND CONTINUOUS ACTIVATION.

As we considered the temporal dimension of activation mechanisms, we found three activation patterns suitable for different responsive situations:

(1) **Accidental activation** – sensing a sudden change and responding promptly for drawing attentions
(2) **Periodical activation** – sensing and responding to cyclical changes of the surroundings for informing contextual knowledge or optimizing performances.
(3) **Continuous activation** – sensing and responding to continuous flow for synchronous adaptation.

5. Tectonics for Networking

The last critical tectonic strategy is networking. When interactions and responsiveness take place at two different remote locations or between virtual and real places through internet, walls could not only be divisions but extensions; Objects could not only be functional instances but nodes of connection. Places and spaces become an event container for instant plug and play. We discovered three hybrid patterns to construct such a networked reality:

5.1 REPRESENTED/DATA-DRIVEN HYBRIDIZATION

While detection (input) and reaction (output) to data/dataflow is the core of designing interactive and responsive architecture, the "datascape" from dynamically representing and correlating meaningful information of either real or virtual worlds can be a new kind of hybrid space. Asymptote's NYSE Virtual Trading Floor and MVRDV's Datatown are two interesting cases for visualizing data as space. The former converts fluctuating financial data into a three-dimensional waving object in the Virtual Trading Floor while the latter reconstructs a mega virtual town from visualizing pure data of urban statistics. Both projects argue that the mapping or visualization of data is no longer a design representation but space itself to experience and inhabit. The merge of data and space blurs the boundary of digital and physical.

5.2 CONNECTED HYBRIDIZATION

The distance between local and remote does not really exist today. The web and video conferencing technology allow not only people but places to be connected. Synchronous and asynchronous interactions may occur by means of architectural elements. Walls, furniture, objects in space can turn into visual

and behavioral interfaces to mediate remote interactions. The Swisshouse project (Swiss Consulate in Boston) by Jeffrey Huang (Figure 7) employed this concept of connection and was designed as an information hub and web node (Huang and Waldvogel, 2004). Swiss scientists and scholars around the world are able to share and exchange their knowledge and experiences anytime when the "spatial connection mode" is on. Its back-projection digital wall seamlessly extends the space to that on the other side in Zurich. Therefore, it is not only people but also activities and events to be mediated through networked connection. The digital/physical hybrid space becomes inhabitable interface.

Figure 7 The Spatial Connection Mode of Swisshouse

5.3 AUGMENTED HYBRIDIZATION

Another hybrid pattern of networking for responsive architecture is to bridge the virtual and physical realms to augment space. "Trans-ports", for instance, is an augmented space prototype designed by Delft University-based Hyperbody Group. It has a data-driven virtual pavilion and a physical counterpart connected to each other. The active structures and pneumatic muscle skins allow the shape of physical or virtual pavilion to change in response to the user activities

TABLE 2. Patterns of Hybrid Tectonics for Networking

	Data-driven Hybridization	***Connected Hybridization***	***Augmented Hybridization***
Relationship between virtuality and reality	Physical → Virtual or Virtual → Physical	Physical ↑ Virtual ↓ Physical	Physical ↑ ↓ Virtual
Hybrid Mode	Representation	Connection	Augmentation
Tectonic Strategy	Visual Interpretation	Event Interface	Real-virtual Intertwine

(movement, proximity, and touch, etc.) on its counterpart. Architecture becomes programmable and augmented system similar to a human body. Messages can be dynamically exchanged and reacted between the virtual and the real to form an organic "hyperbody".

6. Conclusion

The primary drive of architectural innovation today is undoubtedly technological development. The fact that materials become lighter, forms freer, functions more complicated, and reactions more humane is the outcome of applying hybrid tectonic methodologies from design conception to construction. The four tectonic themes (lightness, morphing, activating, and networking) and their related strategies are those been initially explored by successful precedents and become good references for future studies. More issues and great potentials of responsiveness and interactivity in architecture still need to be surveyed as the technology keeps on progressing.

References

Betsky, A., Hays, M., Anderson, L., Crandall, J., Dimendberg, E., Goldberg, R., Schafer, A.: 2003, *Scanning: the Aberrant Architecture of Diller + Scofidio*, Witney Museum of Art, NY, USA.

Bullivant, L.: 2005, 4dspace: Interactive Architecture, in *Architectural Design (AD)*, Academy Press.

Le Corbusier: 2008, *Towards a New Architecture*, BN Publishing.

Frampton, K.: 1995, *Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture*, MIT Press, MA, USA.

Guallart, V.: 2005, *Media House Project : The House is the Computer, the Structure is the Network,* Actar.

Huang, J., and Waldvogel, M.: 2004, Inhabitable Interfaces for Connecting Nations, in *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, Cambridge, MA, USA, ACM 2004, pp. 195-204.

McCullough, M.: 2005, *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing,* MIT Press, MA, USA.

Moccia, M.: 2006, Tele-contiguity and Interaction: Architecture as Communication Interface, *IET Conference Publications 2006*, v2-161.

Oosterhuis, K.: 2003, *Hyperbodies: Towards an E-motive Architecture*, Birkhauser, Basel.

Schmitt, G. N.: 1999, *Information Architecture Basis and Future of CAAD*, Birkhauser, Basel.

Vandemoere. A.: 2005, Form Follows Data: The Symbiosis between Design & Visualization, in *Proceedings of CAAD Futures 2005*, pp. 31-40.