INTRODUCTION- BUILDING FAÇADES AS COMMUNICATION SURFACES

Building facades have been studied since the 1970’s for their independent properties, and particularly as communicators of symbolic meanings. Drawing influence from theories by Guy Debord’s ‘Society of the Spectacle’ and Postmodern ideas (Imperiale, 2000), architects, such as Bernard Tschumi, Jean Nouvel and Herzog de Meuron, explored transparent surfaces and printed building skins as modes of communication during the 1990’s.

The influential book ‘Learning from Las Vegas’ (Venturi et al., 1972) analyzes the Golden Strip of Las Vegas, emphasizing the use of electrical signage as a communication tool that overlaps generic building facades. In a later book ‘Iconography and Electronics upon a Generic Architecture: A View from the Drafting Room’ (1998) Venturi examines popular culture examples of giant electronic billboard, such as New York’s Times Square, and elaborates on the use of communication technology as a symbolic element in architecture, while space itself remains generic. Venturi traces this approach back to ancient Egyptian hieroglyphs, and promotes the use of digital technology in the creation of the visual facade, a communication surface that is changeable and dynamic.

Digital technology as façades

Digital technology enabled the evolution from static media facades into dynamic and interactive ones. Contemporary examples of merging building skins with electronic media started to appear in the last two decades. For example, Peter Cook’s Art museum in Graz (Figure 1), Austria (Bullivant, 2005) is covered with florescent lighting controlled by a digital interface. The lights in this case are completely integrated in the non-generic curvy skin, and can be used to display low resolution patterns.
Media facade projects around the globe are blurring the borders between architecture, advertisement, art and technology. Explorations of the interaction between digital imagery and space can be found in many recent art installations, like the ‘Facsimile’ by Diller Scofidio + Renfro. This installation interestingly merges the digital image with the physical façade in a dynamic way, where the screen is moving along the building skin, while it also experiments with the content, combining real-time and fictional mediated views. This paper will unfold the evolution of media facades into dynamic moveable building elements.

**KINETIC ARCHITECTURE: FROM MOVING IMAGES TO MOVABLE COMPONENTS**

This chapter explores a variety of definitions of dynamic and kinetic architecture, and points to the potential arising from technology advancement to move from dynamic images on facades into dynamic skins of facades, roofs and partitions.

The term kinetic originates from the Greek word kinesis, indicating motion, movement or the act of moving. ‘Kinetic architecture’ implies the integration of a particular degree of motion within the design of buildings (Stevenson, 2010). Kinetic architecture may be defined as “buildings and/or building components with variable mobility, location and/or geometry” (Fox, 2003).

Some futuristic 60’s concepts of ‘mobile architecture,’ such as those articulated by Yona Friedman, for example, proposed fixed mega-structures that were supporting changeable partitions and enclosure definitions. In contrast to the ideas of modular designs, which are reconfigurable, but basically static, kinetic or dynamic architecture is exploring architecture that embeds movement.

The concept of ‘flexible building’ systems can be traced back to “tent” structures from primordial nomadic civilizations. Although these temporary shelters were derived from simple and rudimentary technologies, they explored the concepts of portability, flexibility, and movement, which have an important role in the field of kinetic architecture today. Many examples of tents, inflatable temporary structure etc. can be found in the book ‘Flexible: Architecture that Responds to Change’ (Kronenburg & King, 2007).

‘Portable building’ or ‘demountable building’ can be defined as structures that can be shipped to a new location, sometimes as a whole, and other times dismantled and rebuilt. Once installed, these buildings do not have a significant dynamic element and are sedentary until their next shipment. Mobile homes, also called ‘trailers,’ can be included in this category. Contemporary Examples of this type are Lot-ek’s MDU –Mobile Dwelling Unit and Shigeru Ban’s Mobile Museum, both assembled from used

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**Figure 1**
Peter Cook’s Art museum in Graz with programmable embedded lightings as part of the building’s skin and Diller+Scofidio + Renfro ‘Facimile’ installation.
shipping containers and travelled around the world as exhibition pavilions.

‘Kinetic structure’ is the concept of an integrally dynamic, adaptable and interactive structure. It has very few built examples, even though recent technological developments in mechanical and electrical engineering, together with the use of innovative materials, offer an immense potential (Marques et al., 2011). In addition, academic research on kinetic architecture as a distinct subject is fairly recent.

This research focuses on ‘kinetic architecture’ as defined by Fox, architecture where physical movement is an integral part of the primary functional and formal nature of the building component.

Advances in embedded computation and cutting edge smart materials have triggered new proposals that were only possible to dream of in the past.

Furthermore, new generations of kinetic facades, where aesthetics and communication are fully integrated with the design and technological realization of the building, are becoming more popular. These facades have the potential to completely transform the urban landscape, by generating a real interface between city inhabitants, the digital world and the architectural space (Stevenson, 2010). This paper focuses on tangible dynamic spatial systems. It combines sustainable principles, performative design processes and parametric modeling for mass customization and variation.

A SHORT SURVEY OF KINETIC BUILDING PRECEDENTS BY CATEGORIES

Some kinetic components in architecture have been developed to become a ubiquitous part of our built environment. Elements, like passenger elevators, automatic doors and escalators, are part of mainstream architecture and will not be included in the short survey of kinetic building elements.

Kinetic structures

‘Embedded kinetic structure’ is characterized by the integration of kinetic systems in the structure of the building, and its main function is the adaptation and control of the architectural system as a whole, in response to various factors and needs. Although scarcely explored, this typology has been used in several successful projects by Chuck Hoberman and Santiago Calatrava (Figure 2). (Marques et al., 2011)

Figure 2
Kuwait Pavilion in 1992 world Expo by Santiago Calatrava: the finger-like structure can be opened and closed.

Figure 3
Montreal Olympic Stadium giant folding roof.
Operable roof
This category contains buildings with roofs that can be opened or closed, offering variable conditions of daylight and ventilation.

The Montreal Olympic Stadium (Figure 3), built in 1976 and renovated continuously ever since, incorporated a giant retractable fabric roof to protect the audience from rain and snow and allow open-air events in the summer. It worked for a short period, but due to multiple failures, the roof was replaced. It demonstrates an attempt to build an extra-large scale dynamic element.

A short examination of additional examples of dynamic roofs over sport facilities raises multiple operational, structural and design challenges, resulting from the scale, materials and technology involved.

Moveable building floor
Since the end of the fifties, several revolving, full-floor platforms have been built around the world, on top of touristic destinations, such as company’s headquarters, restaurants and viewing towers. Using a relatively simple motor rotating around the building core elevators, many of these towers still operate today. A detailed survey of rotating buildings can be found in Chad Randl’s book about Revolving Architecture (2008).

A contemporary precedent for a moving building floor, ascending and descending rather than rotating, can be found in Rem Koolhaas’ Maison Lemoine, France (Figure 4). To allow a handicap homeowner to move through the house, a whole room functions like a platform elevator. In addition, some walls and apertures are also electrically operated. This is a unique example for dynamic spatial change in a domestic environment. An additional example for a moving floor is Norman Foster’s ‘Sperone Westwater Gallery’ in NY. The ‘moving gallery’ is a room size giant elevator that doubles as a freight elevator and a moving gallery; it can extend a floor exhibit or create a smooth passage between the gallery floors [3].
Dynamic apertures and building facades

‘The adaptive Building Initiative,’ a recent collaboration between Chuck Hoberman and Buro Happold yielded some inspiring innovative adaptive surfaces, made out of moving panels and allowing the user to control levels of day lighting, sun exposure, ventilation and visual privacy. One of its systems, Permea, was tested and successfully installed in Abu Dhabi’s historic Central Market. It uses servo motors and custom control and can be installed on vertical and horizontal surfaces [4].

An additional contemporary prototype for a building envelope is Jacob & Mcfarlane’s ‘Breathing Wall’ (Figure 5). It was designed for a house nested in hilly topography, allowing interaction with the environment, to vary sunlight, ventilation, views and privacy. A conceptual prototype was realized in a 2007 installation at the Architectural Association in London.

KINETIC, PERFORMATIVE, SUSTAINABLE AND PARAMETRIC DESIGN

Continuing Venturi and Debord’s theories, architect, professor and philosopher Greg Lynn is promoting the use of animation, parametric software and digital fabrication techniques to produce an ‘architectural Spectacle’. Moving beyond the ‘spectacle’, today disciplinary formal games (unlike in the 80’s and 90’s) need a purpose other than aesthetic experimentation in itself. The architecture discipline – the academy’s legacy of beaux-arts formalism — has become so watered down and vague that it no longer provides a strong armature to work against or within. Without a broader system, the drive for form has become self-referential and meaningless outside the field of architecture itself. Instead, architecture should perform rather than simply form; structurally, environmentally, economically, programatically, contextually, or in multiple arenas. With this new discourse, meaning can be constructed locally and regionally (Meridith, 2008). Performance-oriented design employs advanced simulation and visualization software in a ‘generative’ manner to create architectural form (Grobman and Ron, 2011). Performative approach can be used for all scales; from an urban master-plan, a building’s initial form and up to detailed patterns.

Parametric design is based on totalizing systems of organization with variable relationships. “Parametric design is a process based not on fixed metric quantities but on consistent relationships between objects” (Meridith, 2008). In such systems, a change in every element affects all other elements. While rooted in the past, and can be compared to the relationship between the single to the whole in Renaissance architecture, parametric design is utilizing advanced digital tools and requires different methods of design than those used by most architects today. The advantage of this process is that it allows for variability and gradual transformation through repetition of basic elements (such as a building block, a tile, a window or a structural element), thus it supports customized design. For example, it can respond to specific local demands of lighting, privacy and visibility in a space.

Connecting sustainable design to performative strategies can augment the general performance of a building and promote a more efficient design process, while producing a form that embeds a larger amount of performance-related information.

It promotes minimization of energy consumption and of negative impact on the environment. Because physical architecture consumes a huge percentage of the natural resources of our environment, an emphasis on responsible sustainable design is at highest priory. Sustainable design goals combined with new developments in analysis and modelling techniques can result in more efficient customized design, yet aesthetic and more sophisticated than before.

KINETIC BUILDING SKIN PROTOTYPES

With the use of a performative, sustainable approach and parametric processes we can combine the benefits and efficiency of one with the diverse and complex qualities of the other. The projects described in this chapter wish to bring this theoretical exploration into practical implementation. Their
goal is achieving sustainable design and enhanced user experience in built environments. They explore electronic hardware and software required for the design of responsive building elements, and experiment with the application of the acquired knowledge to generate a built dynamic fabric that is both intelligent and communicative.

An early example for the use of kinetic facade components as both symbolic and performative (although the project may have not been conceived with this goal) is the ‘L’Institute du Monde Arab’ by Jean Nouvel in Paris, France, 1988. “The huge south-facing garden courtyard wall is created by an ocular device of striking originality, made up of numerous and variously dimensioned metallic diaphragms set in pierced metal borders. These diaphragms operate like a camera lens to control the sun’s penetration into the interior of the building. The changes to the irises are dramatically revealed internally while externally a subtle density pattern can be observed” (Sharp, 1991). These motifs are actually 240 motor-controlled apertures. The mechanism controls the light entering the building — an effect often used in a static climate-oriented Islamic architectural element called ‘Mashrabiya.’

Wall_Fold installation (Ron, 2003) is a working prototype for a “smart” architectural partition or an aperture with programmed behavior and changing patterns (Figure 6). The installation generates a subjective, hybrid, flexible, immersive and dynamic personal space. The design process was initiated by theoretical analysis of personal space in contemporary reality of portable computing and wireless communication, in comparison to the standardized, rational Modernist space. The partition is made out of pairs of servomotors, connected by flexible vinyl bands to create a smooth surface. The kinetic elements generate a sensitive and complex environment and ambiguous spatial condition: smooth and flexible folds between the inside and the outside, open and closed. Space thus becomes continuous and dynamic.

The last part explores working prototypes that were developed under the ‘dynamic responsive surfaces’ undergraduate seminar at Shenkar College of Design and engineering, Israel (instructors Ruth Ron and Engineer Tzach Harari). They apply the acquired knowledge to create an interactive dynamic ‘smart skins’ for the ‘Team Israel’ 2013 Solar Decathlon China pavilion.

The ‘Interactive Mashrabiya’ project was created by Lilach Raz, Ady Levi and Yafit Zvulun. Drawing inspiration from regional Islamic ‘Mashrabiya’ shading surfaces and from Jewish symbolic Star of David’s geometry, the students designed a folded triangular module (Figure 7).

Movement and Interaction: using an IR proximity sensor, the surface is programmed to be triggered

Figure 6
when a viewer is approaching. Two servo motors are rotating and unfolding each module, moving it to its opened position (Figure 8).

Performance criteria: the surface will be positioned as an outer skin on the western pavilion’s facade, bordering the main entrance pathway to the site. When closed, it creates maximum shading and privacy, when opened it allows natural ventilation and views between the pathway and the interior, while still blocking low western sun rays in the afternoon, thanks to its morphological depth.

The system is in prototyping phase and is being developed for the September 2013 event. (Figure 9).

A second project developed in the seminar suggests merging shading device, ventilation and display screens into one landscaping element that will be incorporated in the Pavilion’s back yard. It is designed by Liat Greenhot and Mercedes Benarrosh.

Using simulation of local climate, the shading element is carefully calculated to cast shadow during the competition’s opening hours. The interaction scenario is similar to the first project: when a viewer is approaching, a proximity sensor triggers embedded fans and display screens. Combining passive shading, active ventilation and information display is designed to improve thermal comfort in the yard.
and achieving the communication and education goals of the decathlon competition (Figure 10).

After prototype presentations in July 2012, selected projects will be developed to full operational models. The first project of the ‘digital mashrabia’ will be expanded to cover the pavilion’s western façade and the second project will be simulated and tested in the pavilion’s garden. User interaction, performance and digital components will be tested and re-evaluated in order to fulfill their potential.

**Options for future development**

Interaction design and Performance - the Solar Decathlon pavilion is operated on solar energy solely and thus requires the most energy-efficient design. The prototype systems should be optimized to preserve energy by their own activation patterns and by their effect on the site’s microclimate.

In the first stage the projects used proximity sensor to detect approaching people. Adding environmental sensors can allow the systems to optimize themselves even when there are no people around. Temperature, humidity and light level sensors added to the ‘digital mashrabia’, accompanied with a custom programming to evaluate the result can trigger the opening or closing of the modules to achieve best climatic performance. To allow privacy, a ‘manual’ mode could be developed to override the sensors.

The fans and display screens in the second project are energy consuming. The controlling program could be improved with temperature and humidity sensors’ input. While the fans should be activated only when users are approaching during hot and humid conditions, the screens can run promotional information display to attract people to come closer during visiting hours. They can be programmed to have a ‘stand-by’ mode and an ‘active’ mode, depending on the proximity sensor input and a timer.

The materials of both projects should be considered for their durability and sustainability, and integration into the design as a whole.

Practical implementation of sustainable and performance-driven design pushes the boundary of eco-kinetic designs, and I hope it will be a fertile educational experience.

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**Figure 10**

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