Journal of Engineering Sciences
Assiut University
Faculty of Engineering
Vol. 42
No. 3
May 2014
Pages: 816-845

INTERACTIVE MOVEMENT IN KINETIC ARCHITECTURE

Youssef Osama Elkhayat

Faculty of Engineering, Tanta University, E- Mail address: y_elkayat@yahoo.com

Received 27 March 2014; revised 27 April 2014; accepted 4 May 2014

ABSTRACT

In recent years, many interactive concepts have been invented. Some of these concepts have the ability to adapt and interact with the surrounding environment and its variants which include; light, sound, wind, heat or with people. This adaptation and interaction is done by some sort of transformation that does not require human assistance. Moreover, returning to their original state happens without significant deformation at the end of the external influence.

Discovery of such interactive concepts stimulated a number of architects to utilize these concepts in several architectural environmental applications such as; sun shading, sun breakers and windows, in a way which significantly makes use of the concept and technology of interactive movement in architecture. The paper attempts to review the literature and descriptively analyse interactive applications in kinetic architecture and study the role of these applications in the development of this trend in architectural design to be more effective and applicable in the future.

Keywords: Interactive Movement, Kinetic Architecture

1. Introduction

Faced with endless influencing parameters such as time, weather, functions, information, human needs, etc. architecture should be designed with multiple dimensions to face this infinity of forces. Many design techniques and technologies which aim to respond to the constantly changing needs have appeared. The most prominent of these is kinetic architecture, which is considered a development in the theories of architecture and a departure from the static form of architecture to the dynamic form.

This study presents interactive movement as one of the leading factors of contemporary ways of expression in architecture. The evolution of architecture from static and stability to dynamic and movement has been followed by changes in the architectural thought. A new architectural language has been found as some new concepts have emerged, and so modulation vocabulary uses have been introduced, materials and construction methods have evolved and uses of computer and multimedia in architecture have developed.

However, the large cost and their need for high technology in design and manufacturing have made the distribution of this kind of facilities limited to countries either booming economically or own superior technology. However, the lack of resources and knowledge of techniques for these installations led to reluctance among architects to use offeredworking solutions despite the various adaptable properties of different variables [1].

2. The principles of movement

Over the ages, architecture has brought forth a wide-ranging canon of design principles that address how to design good, man-made built environments at all scales. These principles describe the respective, culturally-specific understanding of well-designed architecture. Almost exclusively, however, they concern building structures or building elements that are permanent, fixed or immobile. Little thought is given to the design possibilities afforded by changing individual parts of a building over the course of time. The following examination offers a systematic breakdown of aspects and parameters that inform the good design of movable architecture.

2.1. Time

That's where time is always accompanied movement and material, if the place has three dimensions, the dimension of time is one to forward, and if the place expresses about the spread of things existing together, then time refers to the relay existence of phenomena [2].

2.2. Physics and balance

Mechanics is a science which follows physics, and it is one of extensive sciences dealing with movement of objects and their causes. A branch of Mechanics is “Dynamics”, which deals with objects under effect of forces which often follows statics study [3]. Movement of objects can be divided into One Dimensional Motion, Motion in Two Dimensions, Circular Motion, Periodic Motion, Vibration Motion, and Oscillatory Motion [4].

For each of these kinds of movement- translation and rotation- one can identify three degrees of freedom, depending on how the position or orientation of an object changes with respect to one, two or three coordinate axes. The ability of an object to move around in space is therefore defined by a maximum of six degrees of freedom [2].

2.3. Speed and acceleration

A part of movement is the speed at which movement takes place. Without speed, or a change between two different states there is no movement. Movement results from a change in position from a stationary condition via acceleration and deceleration to a new stationary condition.

Although we are only able to determine the speed of other objects indirectly through percept on our sense of balance, this allows us to directly sense the acceleration of our own body. Acceleration is also relevant for indirect sensory perception. In general, gentle acceleration and deceleration is perceived as being harmonious, or even elegant [2].

2.4. Form and serial repetition

Moving things like all things are characterized by specific forms. But the definition of form is more complex than with static objects as its form changes with movement. The serial repetition of movable building elements is very common in architecture. The way in which elements are coupled in series can have a great effect on the overall appearance[2].

With regard to the external appearance, one can differentiate between two different design strategies: choreographed movement follows a predetermined plan while individual movement means that kinetic element can be moved entirely independently. And when the activity of a single element responds to the movements of neighboring elements, the overall combinatory effect can acquire a swarm-like quality [2].

2.5. Mass and weight

Large masses are more difficult to set in motion as well as to halt once moving. As ever in architecture, the mass of an element needs to be taken into account both in terms of construction as well as design. For architects, the need to consider the implications of mass in the design of moving architectural elements is comparatively new [2].

The perceived weight of an element has important implications for its formal appearance, all the more so when the constructions, or parts thereof, are intended to be movable. By contrast, the slow, ponderous opening sequence of a massive steel door tells of the great effort required to shift its mass.

2.6. Complexity and Scale

Complex temporal and spatial sequences in the transformation of an object can also be used as a means of design. Movement has been and will continue to be integrated into architecture at all scales and orders of magnitude. The scale of the movable element - its order of magnitude in relation to the scale of the human being - has a determining effect on the complexity: the technical realization of movement. This applies equally to small-scale constructions that require high-precision execution as well as to large-scale constructions, which have major implications for the structural framework of rigid building elements, as well as for coordinating construction work on site. Similarly, the combination of individual movements into a kinematic chain increases the geometric complexity of movements. The chain of movements follows a hierarchical pattern in that the movements of a subordinate element (the child) are determined geometrically by the super ordinate element (the parent). The addition of two or more individual movements in a kinematic chain already increases the complexity of the overall movement considerably [2].

2.7. Mystery and interaction

Some movements generate interest precisely because one cannot see where they come from or how they work [2]. Interaction is a kind of action that occurs as two or more objects have an effect upon one another. The idea of a two-way effect is essential in the concept of interaction, as opposed to a one-way causal effect. A closely related term is interconnectivity, which deals with the interactions of interactions within systems: combinations of many simple interactions can lead to surprising emergent phenomena. Interaction has different tailored meanings in various sciences. Changes can also involve interaction.

Interactive Architecture is a processes-oriented guide to creating dynamic spaces and objects capable of performing a range of pragmatic and humanistic functions. These complex physical interactions are made possible by the creative fusion of embedded computation (intelligence) with a physical, tangible counterpart (kinetics). Interactive Architecture includes contributions from the worlds of architecture, industrial design, computer programming, engineering, and physical computing. Interactive Architecture examines this vanguard movement from all sides, including its sociological and psychological implications as well as its potentially beneficial environmental impact [6].

3. Typologies of actual movement in architecture

In architecture, rigid bodies are most common and are usually connected by hinged joints to form movable elements. Elastic bodies are also employed in movable elements at a small scale. At a larger scale, and therefore in a load bearing capacity, the use of elastic bodies is relatively rare, with the exception of flexible membrane structures [2].

Translation describes movement of a component in a consistent planar direction; rotation allows movement of an object around any axis; while scaling describes expansion or contraction in size. These are the basic building blocks of kinetics, which are combined to produce more complex motion, such as a directional twist or roll [7].

Considering that the movement is one of the branches of mechanical physics, the typologies of actual movement in architecture can be divided into five types:

1. The movement of rigid architectural elements.
2. The movement of deformable architectural elements.
3. The movement of soft and flexible architectural elements.
4. The movement of elastic architectural elements.
5. Pneumatic forms.

3.1. The movement of rigid architectural elements

Mechanical movements can always be reduced to basic types of movement: Rotation, Translation and a combination of the two. This classification is used regardless of where the hinge or joint is located and without considering gravity. As we are concerned with movements at an architectural scale, the typologies discussed here always relate to the macro level relevant for their use. Here the function of the movement is considered rather than the precise mechanical or theoretical elaboration of a sequence of movements [Figure-1][2].

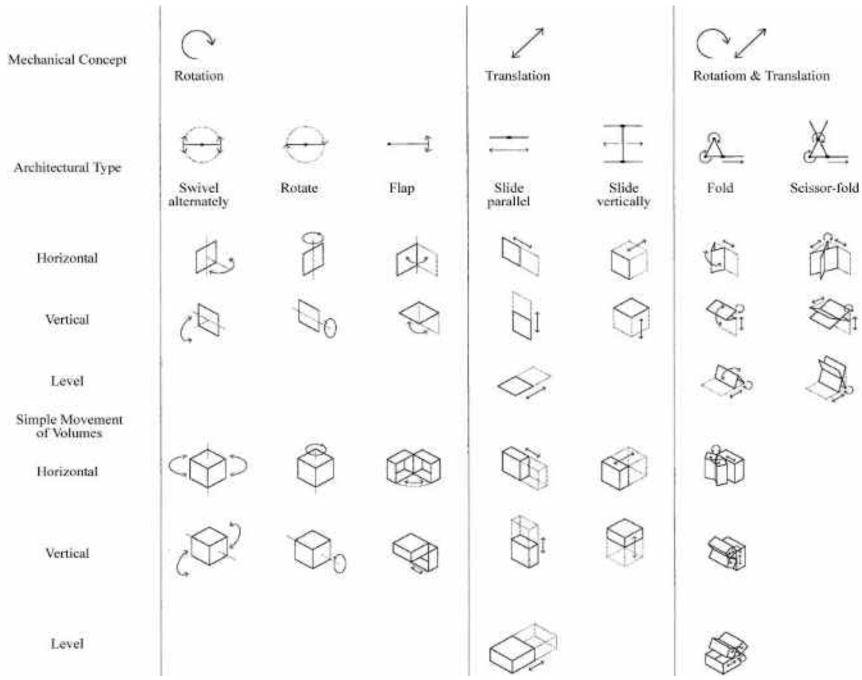

Fig. 1. Movement of rigid architectural elements [2].

3.2. The movement of deformable architectural elements

Deformable architectural elements play an important role in small-scale movements in particular and in the flexible transformation of larger surfaces. In this case, formal and spatial transformations are not the product of different specific and temporal constellations of essentially rigid, unchanging building elements, as discussed above, but instead result from movement within the element or the material itself. Depending on the specific material properties and combinations of the materials used one differentiates between soft and flexible bodies and elastic bodies. Substances and plastic materials that deform irreversibly under force are rarely used in architecture [Figure-2].

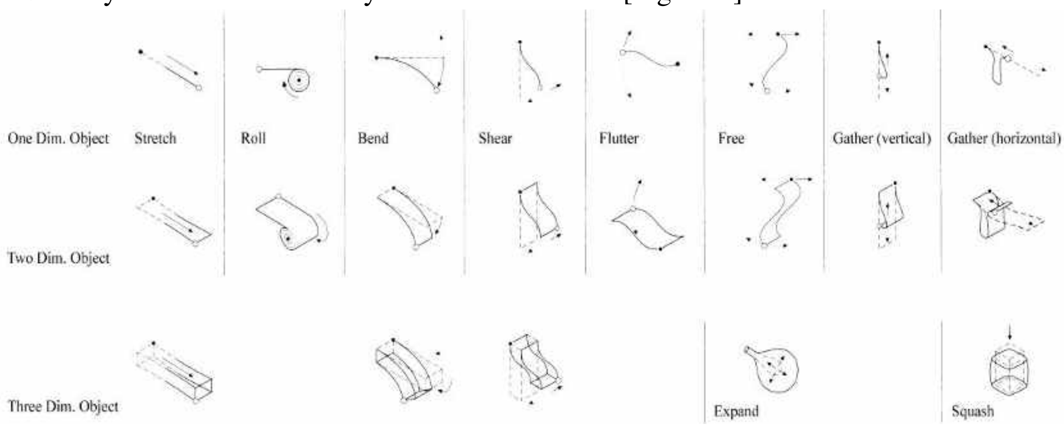

Fig. 2. Types of the movement of deformable architectural elements [2].

3.3. The movement of soft and flexible architectural elements

Flexible architectural elements are able to change shape permanently when external forces are applied without losing their overall formal consistency. Soft and flexible architectural elements can be divided into two types: Linear and Flat elements. Linear examples include fibers, cords or ropes; flat examples include textiles and woven or knitted fabrics. Elastic materials are used extensively in architecture, most commonly in the form of textiles. Textiles and membranes are extremely light and flexible in relation to the surface area they can cover. They are particularly well suited for creating strong visual and spatial divisions with a minimum amount of energy input and are used in combination with a whole vocabulary of hanging, rolling, gathering or pleating systems [5].

3.4. The movement of elastic architectural elements

In contrast to flexible or supple materials, elastic materials are able to regain their original form after deformation without the need for additional external force. In theory, elastic materials offer a variety of architectural applications, however most elastic materials are not available on the market at the necessary size, durability or visual quality. The use of this group of materials is therefore restricted to small-scale elements and less design-related functions, for example steel springs or rubber dampers [2].

3.5. Pneumatic forms

Flat deformable materials can be transformed into three-dimensional objects by inflating them under pressure. As with air balloons, pneumatic constructions are rarely able to oscillate elastically between two different forms of expansion but instead change between two different defined states: inflated and deflated. Deflated pneumatic forms occupy very little volume and can be stored away in a very small space and when sufficiently inflated, they acquire the desired spatial form [5].

4. Actual movable architecture components

Actual movable architecture consists of a number of interrelated elements and dynamic transition structures, and consists of: Structure, Connections, Actuators, Materials and Control systems [Figure-3]. However, it is not required that all items mentioned above to move in movable buildings [8].

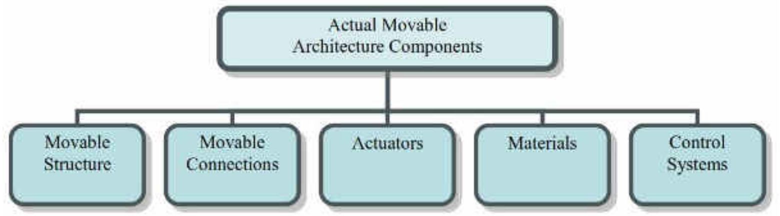

Fig. 3. Actual movable architecture components [Author]

4.1. Movable structure

In the evolution from static to dynamic; movable structures became lighter and became more dynamic, active and less limited. There are six types of movable structures [9]:

- Convertible structures: which are able to change both their form and mode of operation.
- Compact convertible cantilevers: where the transformation of a beam from a compact state to an extended state can be considered as a cantilever.
- Flexible convertible cantilevers: Where systems do not have to be mobile and where their construction may also hinder accessibility, it may be necessary to develop a cantilever system that is itself flexible.
- Flexible and compact cantilevers: A compact and simultaneously flexible construction is achieved by combining the scissor extension principle with telescopic elements, while stabilizing the structural system using a truss like geometric frame. For example, the mobile bridges.
- Movable bridge structures: Moving bridge structures are a further example how the cantilever principle is employed for many different types of construction. This is the case, for example, with swing bridges and bascule bridges [Figure-4].
- Movable roof structures: have been increasingly used since the 1970s as temporary weather protection in the form of roofing for stadiums or swimming pools. An innovative concept for a pneumatically convertible roof was developed as part of a design for an airship hangar in which the hangar was covered with a bivalent load-bearing structure consisting of a three-layer inflatable membrane [Figure-5 A,B].

Fig. 4. Gateshead Millennium Bridge, Newcastle [2].

(A) (B)

Fig. 5. (A) University of Phoenix Stadium, Peter Eiseman, Arizona, 2006. (B) Qi Zhong Tennis Centre, Mitsuru Senda and Environment Design Institute, Shanghai, 2006. [2].

4.2. Movable connections

To facilitate movable connections between two load bearing elements, independent components, bearings or hinges are required. One differentiates between hinged connections that can accommodate rotation or translation, as well as a combination of both movements which can allow up to five degrees of freedom. Depending on the construction of the hinge, the maximum degree of movement can be artificially restricted through the use of constraints [Figure-6][2].

4.3. Actuators

"Actuator" is a device that moves the system which is supplied with a power source that is usually electrical, hydraulic or pneumatic power and turns it into movement. It is the last part in a series of controls and is responsible for the movement of the body in accordance with the orders given by the control system. There are actuators which depend on pressure such as; hydraulic pistons that are pressurized fluid or pneumatic muscles which produce linear movement [Figure-7] [10].

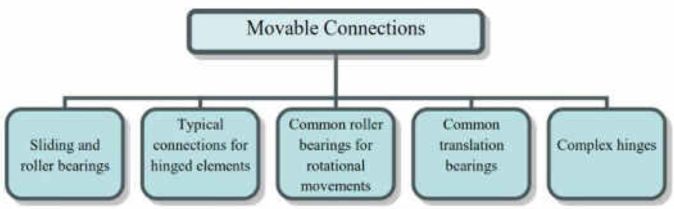

Fig. 6. Movable Connection Types [Author]

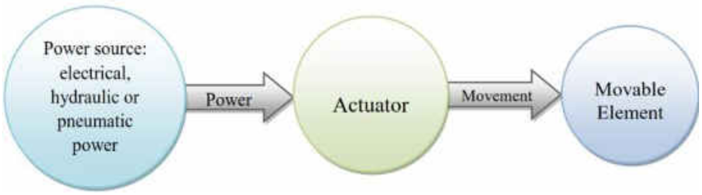

Fig. 7. Actuator role in the movable system [Author]

4.4. Materials

The form of materials and their proportions are used in serving the idea of the movement (Agile materials such as steel or interactive as smart materials), and impact of materials related directly to dynamics of structure system; the more flexible, lightweight materials are used, modulation flexibility increased and the link between the structural elements increases and continues which gives the opportunity to create sophisticated applications for the dynamic equilibrium [11].

The following section provides an overview of the technological possibilities of material development and the available material for lightweight, flexible applications, in particular for movable components.

This classification is according to the nature of the materials' composition [12]:

- <u>Metals</u>: are frequently used in engineering applications because of its multiple mechanical properties, such as; Ductility, High Strength, Hardness [13].It is divided into two types as follows:
  a. <u>Ferrous:</u> such as Steel and Stainless Steel is also appropriate for the purposes of construction in addition to its resistance to rust.
  b. <u>Non Ferrous:</u> such as Aluminum, Copper and Zinc [13].
- <u>Polymers:</u> Plastics are more versatile, lighter, softer, more durable, more colorful and cheaper than any other materials. In terms of their physical constitution, polymers can be divided into three groups:
  c. <u>Thermoplastics: become formable at a particular temperature range.</u>
  d. <u>Elastomers: have a predefined shape but can deform elastically. Under tension or compression they change shape elastically; returning to their original shape after pressure is released.</u>
  e. <u>Thermosetting plastics: once hardened can no longer be shaped. Thermosets are hard, glass-like polymers. Characterized by the presence of chemical bonds between its constituent chains therefore cannot be converted to liquid state and thus cannot be recyclable, such as epoxy resins, which enters in the manufacture of some composite materials.</u>
- <u>Natural Materials:</u> Strips of natural materials such as bamboo, cotton, paper or leather can be woven into fabrics with deferent degrees of transparency and are particular suitable for use in interiors.
- <u>Carbon fiber</u>*:* Carbon in the form of diamonds or lonsdaleite (a stone formed by meteorite impact) is the hardest naturally-occurring material known to man.

4.5. Control systems

A control system is a device, or set of devices, that manages, commands, directs or regulates the behavior of other devices or systems. Control systems are used in industrial production for controlling equipment or a machine [14]. Control system consists of two elements:

- Inputs: are represented in sensors and input different methods, which gives different information about the surrounding environment. There are five modes; Manual Input, Sensors & Detectors, Prior Internal Information, Manual Programming and Internet [14].
  a. Manual Input: Give orders directly from the individual operator without the need for different control methods such as; pressing a key to run or suspension.
  b. Sensors & Detectors**:** They are the methods of collecting information and data in all its forms and types, which is for the operating system. They are just detectors and compilation of information, whether inside or outside the building, some of which is exploring solar radiation, monitoring security, pollution, noise, sensors for facades and the change in color, including what senses and specialized ventilation, energy and lighting systems, through private internal sensors use in achieving the goals of smart architecture.
  c. Prior Internal Information: Where they are provided with the prior system information due to take decisions and could return to it by taking information from the environment, and from that system return to the recorded data to take the necessary decision or to take the necessary decision without the need for sensors such as the decisions that time-related not the surrounding environment.
  d. Manual Programming: Which can be used depending on the operating conditions of the building and modify the drivers according to the convenience of the user or the responsible individual for the operation system so as to conform to all the different circumstances.
  e. Internet: The system can be connected to the Internet to get additional information such as climate and the other or updates regarding this system by the manufacturer.
- Controllers: are represented in the computer that is responsible for the decision to move and therefore receive information from input systems and buffer to actuators that move the structure. There are three modes of Control Systems of dynamic elements, these are as follows [14]:
  a. Internal control: Where the system is divided into smaller systems give the property to the system that makes the decision, such as self-folding ceilings without external controller.
  b. External control: The ability of the system to take action, either by itself or from another source strongly, such as items that can be moved by manual control.
  c. Complex system: a mixture of the two systems where the former system that can take a decision either self or using inputs. It is classified to four types:
     ✓ Direct Control: It means that the movement and control resulting from a direct source or direct order can be controlled electric motor or human

power to move the motorized skylight can run or shut down or in the manual movement of partitions [Figure-8 A].

- ✓ Indirect Control: It means that the movement results from the feedback of sensors that affect the actuator directly to result the desired reaction [Figure-8 B].
- ✓ Indirect Control by Multi-Input: the process and motion control is a result of a number of input devices through a combination of sensors that can receive data from various sources to take the optimum decision to move one element [Figure-8 C].
- ✓ Indirect Control, Intelligent and Heuristic: In this case the system has the learning viability to choose the style of its own motion, where to learn from previous experiences to try to find the best solutions and decisions [Figure-9].

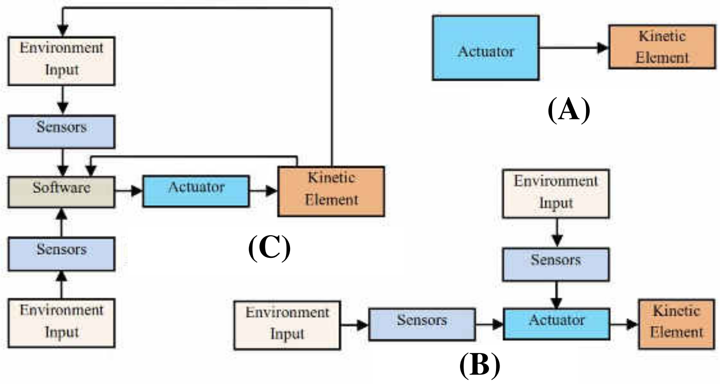

Fig. 8. Complex System
(A) Direct Control. **(B)** Indirect Control**.** **(C)** Indirect Control by Multi-Input. [Author]

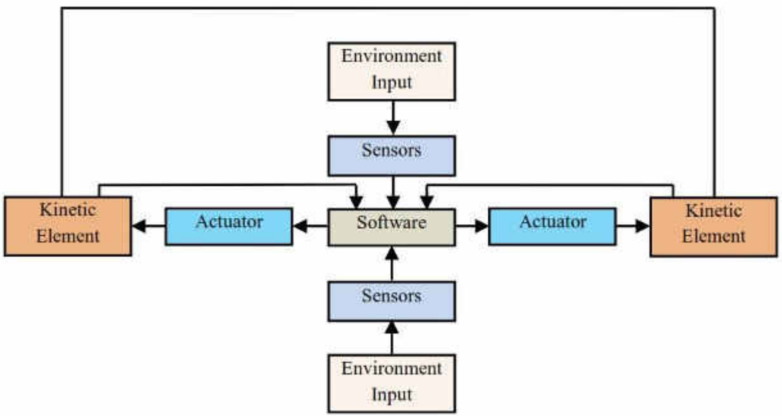

Fig. 9. Complex System(Indirect Control, Intelligent and Heuristic system) [Author]

5. Interactive movement

5.1. Interaction with light

For an architectural project located in a desert climate, Hoberman Associates were asked to design a roof covering for an open-air plaza in Aldar Central Market, Abu Dhabi, UAE. They created a kinetic design that works off an operable grid. In its covered configuration, the shading roof appears similar to a coffered ceiling; yet when retracted, the roof becomes a slender lattice. Each whole unit actually comprises several openings that are driven by a single drive arm, making the system efficient and economic. The grid shade's simple, robust design provides opportunities for custom profiles [15].

Fig. 10. A roof covering for an open-air plaza, Aldar Central Market, Abu Dhabi, UAE. [15]

The new Campus of Justice in Madrid is the largest single site dedicated to law courts in Europe. This building has been designed to minimize unwanted solar gain, while allowing natural daylight inside as a key part of this environmental strategy. Within the Audiencia Provencial, the shading units will occupy the central circular atrium along with the eight peripheral atria. The atrium roof is populated with a unique series of hexagonal shading cells, which, when extended cover the triangulated roof grid. When retracted their profiles 'disappear' into the structural profiles of the roof. During the day, the primary function of the system will be sun shading. An algorithm combining historic solar gain data with real-time sensing of light levels will control the shading units [15].

Fig. 11. A unique series of hexagonal shading cells [15]

As with standard fritted glass, this technology utilizes a graphic pattern in order to control heat gain and modulate light, while allowing sufficient transparency for viewing. Adaptive Fritting builds on the practice of standard fritting with the addition of real-time dynamic motion via motorized control. While conventional fritting relies on a fixed pattern, Adaptive Fritting can control its transparency and modulate between opaque and transparent states. This performance is achieved by shifting a series of fritted glass layers so that the graphic pattern alternately aligns and diverges [15].

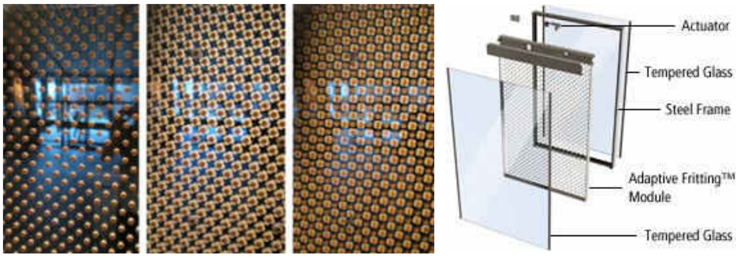

Fig. 12. Adaptive Fritting [15]

SolPix is a patented solar-powered media wall for medium- to large-scale installations in new construction or existing buildings. Developed by Simone Giostra, SolPix is a completely integrated system for power production and sun shading, and also acts as a digital screen. SolPix allows for dynamic content display, including playback videos, interactive performances, and live- and user-generated content. The “intelligent skin” interacts with building interiors and external public spaces using embedded, custom-designed software, transforming a building facade into a responsive environment for entertainment and public engagement. SolPix allows daylight into the building while reducing its exposure to direct sunlight. The sun shading elements provide unobstructed outside views from the building interior, while lending a contemporary texture to the building exterior. The horizontal or vertical panels can be mounted at a preferred angle or can be rotated in order to maximize exposure to direct sunlight [16].

Fig. 13. SolPix[16]

Foiltec’s Texlon foil system offers designers new opportunities in the development of climatic and transparent envelopes. The system can be engineered to virtually any size or shape and can incorporate variable solar and thermal controls, enabling the envelope to be tuned to the ideal climatic or programmatic solution in real time as the sun moves across the sky. However, the air is not part of the structural system, as in the case of air-inflated buildings, where a breakdown in the air supply would cause the entire structure to collapse. With the Texlon system, a breakdown in the air supply would only affect the thermal properties, and the building would remain intact.

The Texlon cladding system offers designers unparalleled opportunities in the development of the climatic envelope. Texlon consists of pneumatic cushions restrained in aluminum extrusions and supported by a lightweight structure. The cushions are inflated with low-pressure air to provide insulation and resist wind loads. The cushions are manufactured from multiple layers of Ethylene-Tetra-Fluoro-Ethylene (ETFE), a modified co-polymer. Originally developed for the space industry, the material is unique in that it does not degrade under ultraviolet light or atmospheric pollution[17].

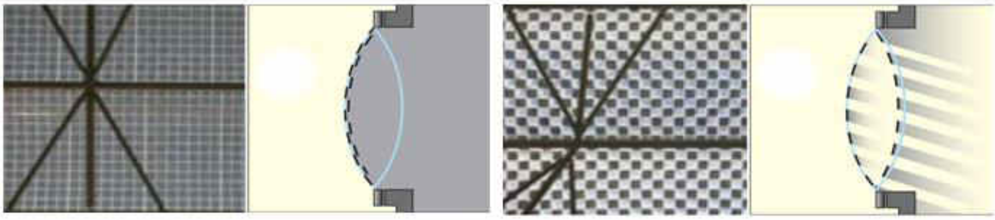

Fig. 14. (A) [Closed] as internal temperatures and solar gains increase the lower air chamber is pressurized reducing the level of light and solar gain penetrating the space.
(B) [Open] Solar and temperature sensors cause the upper air chamber to be pressurized allowing light to penetrate through the gestalt graphics [17]

5.2. Interaction with humans

Hypo Surface Wall designed by Mark Goulthorpe of dECOi Architects, the project consists of an interactive mechanical surface that deforms in real-time based on various environmental stimuli, including the sounds and movements of people, weather, and electronic information. The HypoSurface is comprised by a matrix of actuators, which are given positional information via a highly efficient bus system as well as an array of electronic sensors used to trigger a variety of mathematical deployment programs. The Hypo Surface effectively elevates a highly responsive pneumatic mechanical system to a level of articulate and fluid control through its interception by a highly performative digital control[18].

HypoSurface is a versatile and hyper-effective display medium that is a pure people-magnet: it draws the eyes because no one has seen anything like it before. It captures the digital 'mood' that is in the air, and people are delighted to participate in its intelligent sensuality and they immerse themselves in the wonder of it [18].

Fig. 15. HypoSurface is the World's first display system where the screen surface physically moves! Information and form are linked to give a radical new media technology: an info-form device**.** [18]

The Dune Project projects a vision of a techno-centric nature and its creative application within public space. Viewers look at, walk around, and interact with a large, undulating field of light-emitting tubes. Designed by Studio Roosegaarde, Dune is an interactive landscape which responds to the location and behavior of people. This natural-technological hybrid is represented by large numbers of fibers that are brightened according to the sound and motion of passing visitors. Studio Roosegaarde completed a recent installation of Dune which is 40 meters long and filled with interactive lights and sounds, hundreds of fibers, LEDs, sensors, speakers, interactive software and electronics[19].

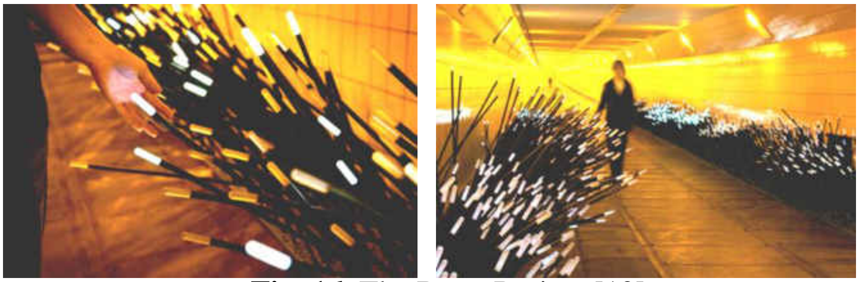

Fig. 16. The Dune Project [19]

Wind 3.0 is an interactive wall feature comprised by hundreds of fibers which respond to a viewer's presence based on a connection between electronic sensors and ventilators. Wind 3.0 moves with the viewer when there is a lot of activity the wall makes large fluid motions, while in other circumstances the fiber animation resembles a soft breeze. In this way, a direct relationship is made between human behavior and sculptural dynamics. Developed by Netherlands-based Studio Roosegaarde, Wind 3.0 plays with the similarities and differences between nature and technology [20].

Fig. 17. Wind 3.0[20]

5.3. Interaction with sound

Inspired by the natural phenomenon of tropism in which a plant actively responds to external stimuli designer NatasaZednik constructed an intelligent kinetic building system entitled Sonomorph that moves in response to changing environmental conditions. A research collaboration with Cornell University, Sljivancanin's sound-responsive wall is comprised of cellular components that react to various stimuli by opening and closing cells that absorb sound and emit light. Other potential stimuli include light, proximity of people, and touch.

Aluminum outer panels and glass-reinforced plastic inner panels are the components of Sonomorph cells. They are mounted to a simple steel wire net with standard hardware and employ various sensory devices, servo motors, and LED lights for interactive functionality. During the day the cells' polished aluminum shells shimmer in the sunlight, and at night they impart a subtle, colored glow. By involving people in new playful interactions, Sonomorph explores various ways in which augmented physical environments can more extensively and specifically engage their dynamic contexts [21].

Fig. 18. Sonomorph that moves in response to the sound [21]

Researchers at the Fraunhofer Institute for Structural Durability and System Reliability LBF and Darmstadt University of Technology have recently developed a new type of soundproof window. When noise waves meet the walls of a building, they can be propagated to the interior by various routes. One is by causing the windows to vibrate, thus carrying the noise into the building. The other is by transmitting sound waves to the interior via the bridges in the structure where the curtain-wall elements are attached to the frame of the building. In both cases, the researchers have found a way to prevent the propagation of sound energy. Acceleration sensors attached to the window panes measure the vibrations generated by the noise. A thin chip of piezoelectric material also attached to the window counteracts the vibration by generating an oscillation at the same pitch but in the opposite sense to that measured by the sensor – causing the pane to move in the opposing direction[22].

Fig. 19. Sound proof window [22]

5.4. Interaction with wind

Super Cilia Skin is a tactile and visual system inspired by the beauty of grass blowing in the wind. It consists of an array of computer-controlled actuators (Cilia) that are anchored to an elastic membrane. These actuators represent information by changing their physical orientation. The current prototype of Super Cilia Skin developed by MIT's Tangible Interfaces functions as an output device capable of visual and tactile expression. Most existing computational tools rely on visual output devices.

Super Cilia Skin is essentially a tactile and visual system. It has ability to replay dynamic gestures over time and to communicate remote gestures; this makes it a potentially valuable tool for education and haptic communication. These cilia move in response to computer-controlled magnetic fields created under the membrane, allowing them to represent information by dynamically changing their physical orientation. The device is designed to sense physical gestures on the cilia and to replay those gestures by wiggling the same cilia that were touched.

On an architectural scale, a facade covered with Super Cilia Skin could represent the "wake" of a local wind pattern billowing up and down the surface during the day generating energy. As a more general display surface, a Super Cilia Skinned floor could trace movement over one's house or weather patterns over the entire state of

Massachusetts. This sensibility is intended to pervade a sense of relationships between local and global conditions [23].

Ned Kahn is an accomplished North California sculptor who deploys materials in order to celebrate and amplify natural forces. His large-scale wind installations, which have names like Wind Portal, Technorama Facade, and Fragmented Sea, utilize vast arrays panels made of aluminum, steel, and other materials to shimmer and dance in the breeze, allowing the natural environment to influence the design. In Articulated Cloud, for example, thousands of 9-inch squares of perforated aluminum are mounted on low friction hinges so that the entire surface of the facade responds to the wind. Each moving panel is perforated with thousands of different sized holes that, when viewed from a distance, create a photographic mosaic of sand dune images. When sunlight passes through the screens, intricate shadow images of the dunes are projected onto the walls and floor of the building lobby. The optical qualities of the skin change dramatically with the weather and the time of day. The articulated skin is supported by an aluminum space frame so it appears to float in front of the building [23].

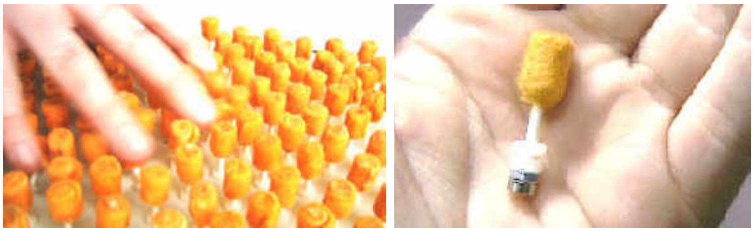

Fig. 20. Super cilia skin [23]

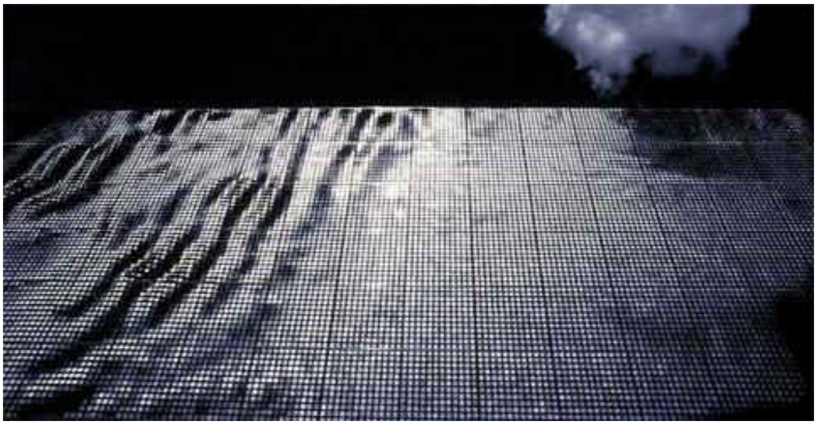

Fig. 21. Articulated Cloud [23]

6. Analysis of the chosen application

The analytical study aims to identify and comprehend the modern architectural applications that will affect the future of movable buildings. Also, the study answers the question; if the interactive concepts are able to cross the restricting borders of the movement in architecture that are faced by designers in the design process of movable buildings in the current time.

6.1. Determinates and standards

The selection of future applications depends on the variety of applications in terms of the technology used to achieve the movement of building through what has been studied previously such as movement resulting from interactive technology with the surrounding environment, whether they are light, human, sound or wind. In the selection of those applications; has taken into account to be modern as much as possible. Also, there has been a focus on applications that have been applied actually in credibility institutions. These institutions must have considerable experience in this field and have proven efficiency projects in the current time.

6.2. Methodology

The research uses the analytic descriptive methodology to identify and comprehend the modern architectural applications that will affect the future of movable buildings. Samples selection is from a range of applications covering various technological aspects utilizing the concept of interactive movement with the external influence such as; light, sound, wind and human.

6.3. Criteria of analysis

In this part the research studies the chosen applications through the following criteria:-

a. *Application definition.* Name, Designer, Location, Type and Date.
b. *Principles of movement.* Time, Physics and balance, Speed and acceleration, Form and serial repetition, Mass and weight, Complexity and scale, Mystery and interaction.
c. *Typology of movement.* Movement of rigid elements, Movement of deformable elements, Movement of soft and flexible elements, Movement of elastic elements, Movement pneumatic forms.
d. *Movable components.* Movable structure, Movable connections, Actuators, Materials, Control systems.

6.4. Descriptive Analysis of applications

a) Interaction with light

✓ *Heliotrope*

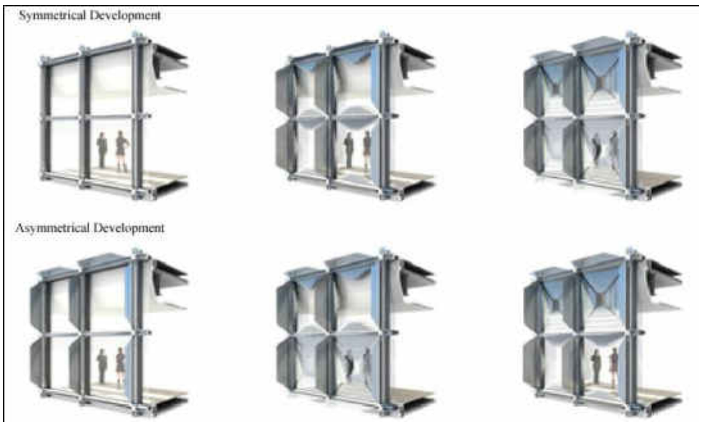

Fig. 22. HelioTrace [15]

Table 1.
Analysis of Helio Trace application

Application definition	**Name**	**Helio Trace**[15]
	Designer	Hoberman
	Location	New York, USA
	Type	Kinetic curtain wall system
	Purpose	Sun-shading
	Date	2010
Principles of movement	**Time**	The HelioTrace Façade System can trace the path of the sun over the course of a day and a year. This process takes 5 seconds for changing the setting of sunshades.
	Physics and balance	Moveable external sunshades have the ability to move in three dimensions with three degrees of freedom and acceptable balance.
	Speed and acceleration	It moves fast with a fixed speed and harmonious acceleration.
	Form and serial repetition	Advantages of HelioTrace include the ability to be designed into non-rectangular shapes, match three-dimensionally curved surfaces when extended, and visually disappear into a building's underlying structure when retracted.
	Mass and weight	It is a lightweight shading unit; could be large or small according to the design requirements.
	Complexity and scale	It is a complicated movable skin with large and small scales.
	Mystery and interaction	Interacting with sunlight, and has a mysterious movement.
Typology of movement		When activated, they extend to form a nearly continuous surface comprised of a series of slats that may be constructed of different materials, including metal, plastic, and wood.
Movable components	**Movable structure**	There is no movable structure.
	Movable connections	The HelioTrace Façade System depends on the typical connections for hinged elements.
	Actuators	It is a rigid surface element extends by electromechanical actuator rotation.
	Materials	flexible with lightweight, high-strength and density aluminum has high rust resistance and tolerance to weather different conditions.
	Control systems	The shades are operated by Indirect Control by Multi-Input. Advanced computer-driven ecological models, which factor in the building's seasonal climates and daily sun paths as well as the building's programmatic use and operating schedules.

✓ *Media Tic*

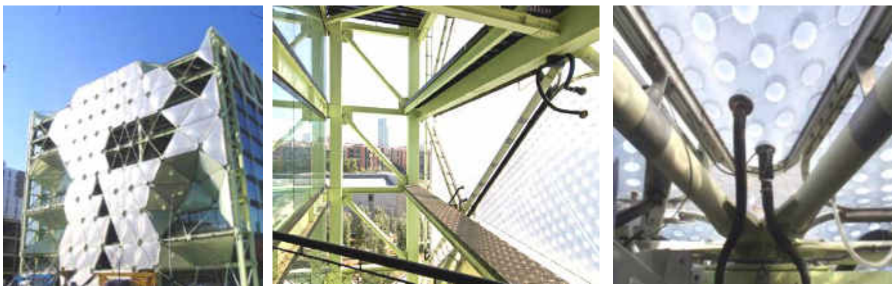

Fig. 23. Media Tic. ETFE cushions view from inside. Bags inflated and deflated by the air pressure system [25]

Table 2.
Analysis of Media Tic application

Application definition	**Name**	**Media Tic** [25]
	Designer	Cloud-9 architect's office
	Location	Barcelona, Spain
	Type	Texlon material
	Purpose	Sun-shading
	Date	2010
Principles of movement	**Time**	The façade made of inflatable ETFE cushions oriented south, act as a variable sunscreen, opening in winter to gain solar energy, and closing in summer to protect and shade. This process takes just 3 minutes.
	Physics and balance	It is a pneumatic material, has the ability to move in one dimension with one degree of freedom and acceptable balance.
	Speed and acceleration	It moves slowly with a fixed speed and harmonious acceleration.
	Form and serial repetition	Its application on the Media-TIC building makes it looks like a gigantic cube padded with plastic bubbles inflated and deflated in series according to the sunlight direction.
	Mass and weight	It is a lightweight material; could be large or small according to the design requirements.
	Complexity and scale	This simple façade thickness is minimized through the use of this light plastic skin (with a total thickness of 0.2 millimeters). Its application on the Media-TIC building makes it look on a vast scale.
	Mystery and interaction	Interacting with light, and has a mysterious movement.
Typology of movement		It is a movement of pneumatic forms.
Movable components	**Movable structure**	There is no movable structure.
	Movable connections	There are no movable connections.
	Actuators	It has ability to change shape without the need for mechanical actuators.
	Materials	The façade, made of inflatable ETFE cushions.
	Control systems	Indirect by input control, both the façades and offices have been equipped with multiple temperature sensors, humidity or pressure that collects information to adjust the interior.

b) Interaction with human

✓ *Hyposurface wall*

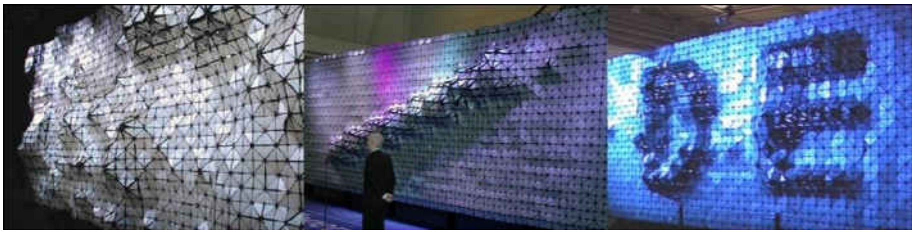

Fig. 24. Hyposurface wall[18]

Table 3.
Analysis of Hyposurface wall application

Application definition	**Name**	**Hyposurface wall** [18]
	Designer	dECOi Architects
	Location	Cambridge, USA
	Type	An interactive kinetic wall
	Purpose	Interacting with human
	Date	2003
Principles of movement	**Time**	The movement takes between (3-10 seconds) according to the customization by the programmer.
	Physics and balance	HypoSurface is a display system where the screen surface physically moves. It has the ability to move in three dimensions with one degree of freedom and acceptable balance.
	Speed and acceleration	The screen surface moves with a high-speed and harmonious acceleration.
	Form and serial repetition	The HypoSurface is like an organism; responsive, stunning and organic in nature. It is a versatile and hyper-effective display medium. It can be used to create customized effects, logos and messaging. Each element moves independently.
	Mass and weight	It could be shipped as many modules as need, and all the necessary equipment. It is a lightweight material; could be large or small according to the design requirements.
	Complexity and scale	It is a complicated surface, it can be large as HypoCeiling, HypoFloor, limitless, or small; it's a Braille reader, or a dynamic mould; it tunes an auditorium, makes waves at a ballgame, sets children screaming with delight.
	Mystery and interaction	Interacting with human, and has a mysterious movement.

JES, Assiut University, Faculty of Engineering, Vol. 42, No. 3, May 2014 , pp. 816– 845

Typology of movement		Actuators convert the electric power to allow rigid screen elements to be pushed or pulled using a bar.
Movable components	**Movable structure**	There is no movable structure, HypoSurface display systems are modular plug-and-play devices, designed for ease of transportation, installation and use.
	Movable connections	There are no movable connections.
	Actuators	HypoSurface uses powerful 'information bus' technology to control many thousands of moving actuators (Pneumatic pistons).
	Materials	aluminum surface could be shipped as many modules as need, and all the necessary equipment. They are lightweight elements have been installed on a steel grid structure.
	Control systems	Direct Control with manual programming, the user interface is easy to use, and allows user to control his own event, like a DJ. Operators can offer enhanced interactivity and effects.

✓ *Dune*

Fig. 25. Dune [19]

Table 4.
Analysis of Hyposurface wall application

Application definition	**Name**	**Dune**[19]
	Designer	Studio Roosegaarde
	Location	Netherlands
	Type	Interactive landscape
	Purpose	Interacting with human
	Date	2011
Principles of movement	**Time**	The movement takes 3 secondsafter the human influence.
	Physics and	the flexible fibers have the ability to move in two dimensions

	balance	with three degrees of freedom and acceptable balance.
	Speed and acceleration	they move slowly with a fixed speed and harmonious acceleration.
	Form and serial repetition	The 60 meter permanent DUNE, situated alongside the Maas River in Rotterdam (NL), utilizes fewer than 60 watts of energy. Within this setting like shrubs, Rotterdam citizens enjoy their daily "walk of light". Each LED fiber moves and lights independently.
	Mass and weight	It is an ultra-lightweight material; could be large or small according to the design requirements.
	Complexity and scale	Corridor of 60 meters in neighborhood 'Esch' Rotterdam, NL. Open for public at night. It is a simple movement in large and small scales.
	Mystery and interaction	Interacting with human, and has a mysterious movement.
Typology of movement		It is a movement of elastic elements; fibers vibrate as a reaction of the human movement and able to resume their original form after vibration without the need for additional external force.
Movable components	**Movable structure**	There is no movable structure.
	Movable connections	There are no movable connections.
	Actuators	It has ability to change shape without the need for mechanical actuators.
	Materials	Hundreds of fibers, sensors, speakers, software and other media.
	Control systems	Dune is made out of recycled polymer and LED lights operated by interactive manual programming software.

c) Interaction with sound

✓ *Sonomorph*

Fig. 26. Sonomorph[21]

Table 5.

Analysis of Sonomorph wall application

Application definition	**Name**	**Sonomorph**[21]
	Designer	NatasaZednik
	Location	Los Angeles, USA
	Type	Sound-responsive wall
	Purpose	Interacting with sound
	Date	2009
Principles of movement	**Time**	Each unit opens and closes in just 5 seconds.
	Physics and balance	It is a flexible material, has the ability to move in one dimension with one degrees of freedom and acceptable

		balance.
	Speed and acceleration	It moves slowly with a fixed speed and harmonious acceleration.
	Form and serial repetition	when the unit opens and closes, it looks like the human eye when opens and close. The repetition in series forms the desired interactive skin.
	Mass and weight	It is an ultra-lightweight material; could be large or small according to the design requirements.
	Complexity and scale	It a simple movable skin could be in small and large scales.
	Mystery and interaction	Interacting with sound by closing or opening with a mysterious movement.
Typology of movement		It is a planar element deforms with bend movement of a deformable element.
Movable components	**Movable structure**	There is no movable structure.
	Movable connections	There are no movable connections.
	Actuators	It has ability to change shape without the need for mechanical actuators.
	Materials	Nickel-titanium alloys (Nitinol) with shape memory properties, interacting with sound by closing or opening.
	Control systems	Interacting with sound by closing or opening without any control systems.

- ✓ *Sound Proof Window*

Fig. 27. Sound proof window [22]

Table 6.
Analysis of Sound Proof Window application

Application definition	**Name**	**Sound Proof Window**[22]
	Designer	Fraunhofer Institute for Structural Durability and System Reliability LBF
	Location	Darmstadt University, Germany
	Type	Sound proof window
	Purpose	Interacting with sound
	Date	2010
Principles of movement	**Time**	Window vibrates in just 1 second.
	Physics and	It is a glazed window, has the ability to move in one dimension

	balance	with one degrees of freedom and acceptable balance.
	Speed and acceleration	It moves rapidly with a fixed speed and harmonious acceleration.
	Form and serial repetition	When the unit vibrates, the pane moves in the opposing direction. The repetition in series forms the desired interactive skin.
	Mass and weight	It is a lightweight glass; could be large or small according to the design requirements.
	Complexity and scale	It a simple movable skin could be in small and large scales.
	Mystery and interaction	Interacting with sound by vibrating with a mysterious movement.
Typology of movement		It is a movement of a planar rigid element.
Movable components	**Movable structure**	There is no movable structure.
	Movable connections	There are no movable connections.
	Actuators	A thin chip of piezoelectric material also attached to the window counteracts the vibration by generating an oscillation at the same pitch but in the opposite sense to that measured by the sensor – causing the pane to move in the opposing direction.
	Materials	Glass with piezoelectric material.
	Control systems	Interacting with sound by vibrating with sound sensor and indirect control system.

d) Interaction with wind

✓ *Wind Arbor*

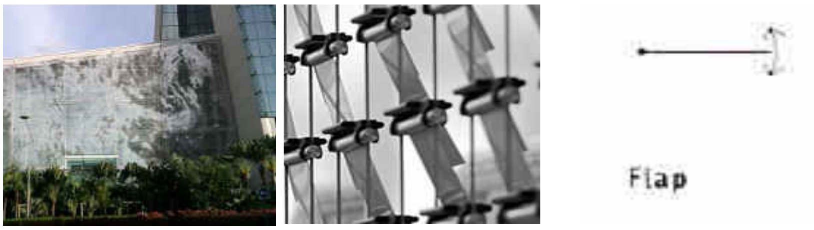

Fig. 28. Wind Arbor[24]

Table 7.
Analysis of Wind Arbor application

Application definition	**Name**	**Wind Arbor** [24]
	Designer	Ned Kahn
	Location	Marina Bay Sands, Singapore
	Type	Hinged elements
	Purpose	Sway in the wind & Sun-shading
	Date	2011
Principles of movement	**Time**	the flappers move in 2 seconds by the movement of the wind.
	Physics and balance	It is a flexible material, has the ability to move in a circular motion with one degree of freedom and acceptable balance.
	Speed and	It moves slow or fast with according to the wind speed and in

JES, Assiut University, Faculty of Engineering, Vol. 42, No. 3, May 2014 , pp. 816– 845

	acceleration	a harmonious acceleration.
	Form and serial repetition	When the flappers move, they reflect light creating a shimmering piece of art. The sculpture consists of 260,000 aluminum metal "flappers" covering the entire western façade. It moves like waves and each flap moves independently.
	Mass and weight	It is an ultra-lightweight material; could be large or small according to the design requirements.
	Complexity and scale	It is a simple movable screen with large scale. Four vertical acres of the glass facade of a hotel lobby was covered with a cable net structure composed of a half a million hinged elements that sway in the wind and reveal the patterns of the wind.
	Mystery and interaction	Small "flappers" are mounted on hinges and can move independently of each other in response to wind movements. The effect is really impressive when there is strong wind and has a mysterious movement.
Typology of movement		It is a rigid surface element rotates (flap) by the force of wind movement.
Movable components	**Movable structure**	There is no movable structure
	Movable connections	The flappers depend on the typical connections for hinged elements. It is turning around its axis. The flappers are mounted on hinges and hung from steel cable so they are free to move independently in reaction to wind movements.
	Actuators	It has ability to change shape without the need for mechanical actuators.
	Materials	Small aluminum flappers are mounted on hinges and can move independently of each other in response to wind movements. The artwork functions as a shade for the lobby, blocking 50% of the sunlight and heat.
	Control systems	Small aluminum flappers interact with wind movements without any control systems.

✓ *Super Cilia Skin*

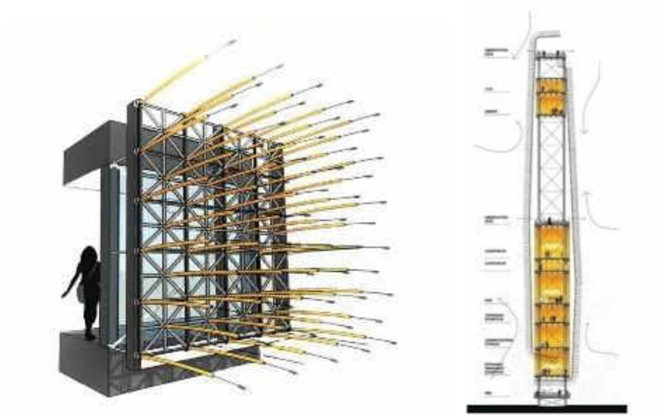

Fig. 29. Super Cilia Skin [23]

Table 8.
Analysis of Super Cilia Skin application

Application definition	**Name**	**Super Cilia Skin**[23]
	Designer	MIT Media Lab
	Location	Cambridge, USA
	Type	A multi-modalinteractive membrane
	Purpose	Harness urban wind energy
	Date	2003
Principles of movement	**Time**	Cilia moves in 3 seconds by the movement of the wind.
	Physics and balance	It is a flexible material, has the ability to move in two dimensions with one degree of freedom and acceptable balance.
	Speed and acceleration	Cilia moves rapidly with harmonious acceleration.
	Form and serial repetition	Super Cilia Skin is a tactile and visual system inspired by the beauty of grass blowing in the wind.Each Cilia moves independently.
	Mass and weight	It is an ultra-lightweight small element.
	Complexity and scale	SCS is simple and could be an exterior skin on skyscrapers that could both visualize information as a billboard size display and harness energy of the wind forces that blow over the building's façade.
	Mystery and interaction	The façade interacting with wind and has a mysterious movement.
Typology of movement		It is a movement of elastic elements; Cilia vibrates as a reaction of the wind movement and able to resume their original form after vibration without the need for additional external force.
Movable components	**Movable structure**	There is no movable structure
	Movable connections	The Cilia depends on complex hinges (ball joint) to vibrate in any direction according to the wind power.
	Actuators	It consists of an array of computer-controlled microactuators (Cilia) that are anchored to an elastic membrane.
	Materials	It is made of an elastic membrane covered with an array of felt actuators (Cilia)
	Control systems	These cilia move directly in response to internal computer-controlled magnetic fields created under the membrane, allowing them to represent information by dynamically changing their physical orientation. Because SCS converts gesture to computer data, multiple Super Cilia Skin devices may communicate over a distance using a standard computer network.

7. Discussion

After reviewing the previous analyses, the study found that there is a clear impact of the scientific progress in the field of interactive movement on the concept and design of kinetic architecture, as the paper has reached to know to which extent of interaction with the environment and people the kinetic architecture will reach in the future. Following is a discussion of the result of the analytical study.

7.1 Time

No longer has movement taken time to be completed; the movement takes place during a short time period ranging from seconds to several minutes at the most, thishelped to achieve better response to the rapid environmental change as a movement of the sun, for example; the interactive movement in HelioTrace. On the other hand;it has increased the human ability to recognize the movement even if it takes only a few moments, for example; the interactive movement in Super Cilia Skin as people can recognize the movement of wind while watching the façade.

7.2 Physics, balance, speed and acceleration

Kinetic architecture takes more freedom than before; and access to levels of movement in three-dimensions such as; Hyposurface wall and the vibratory motion with three degrees of freedom. Despite this freedom of movement, it did not lose any of the required balance to complete the movement. As reviewed in the analytical study above, types of movement varied between relatively slow and fast with the inevitability of having a harmonious acceleration.

7.3 Mass and weight

The actual movement is no longer linked to heavy weight elements; with smart materials movable elements became lightweight and do not require large forces to move.For example, as studied above the inflatable ETFE cushionsin Media Tic building is the lightest interactive shading system. Now there is the ability to design movable elements in large masses without thinking about its weight.

7.4 Mystery and interaction

One of the most important developments in the concept of actual movement in architecture is the mystery, which controls the shape of the movement in all its phases, this increases the mental interaction of the viewer with the movement, as well as increases the aesthetics of the architectural work and adds the thrill factor. Hypo surface Wall has the most mysterious movement as people do not expect what will happen every time they interact with it.

7.5 Typology of movement

The actual movement developed to interact with many of the effects in the environment, such as; the movement of the sun and the wind and with the sound and humans' movement. This has made it easier to observe the typologies of movement that have appeared such as; the movement of the eye when closed and opened such as in the Sonomorphproject and also, the waves stimulated by the wind such as in Wind Arbor. In addition to that, the study found that there are new typologies of movement that have appeared such as; the movement of pneumatic forms in Media Tic building.

7.6Movable components

The design of the movable parts is no longer necessarily as there is no need for movable connections or actuators to exist as the movement is no longer mechanical, examples for this concept were shown in both Wind Arbor and Media Tic building. For the control systems, there is no need to use any control system because of the advantage of smart materials that able to interact with the factors influencing them independently such as Nickel-Titanium alloys in Sonomorph.

8. Conclusion

As thoroughly discussed above, it can be concluded that the overall evolution of interactive movement in kinetic architecture is moving towards interacting with the environmental changes such as; daylight, wind, sound without missing interaction with humans. Many of the presented studies in this paper predicted a change in the design methods of the actual movement in architecture in the future; which calls the designers to take into account the revolutionary changes in the field of interactive architecture.

Another conclusion of the study is that, it is not required to move large parts of the building to be dynamic, but the movement of small parts together can achieve the concept of kinetic architecture. It was also found from the review that the current lack of expansion in the actual movement application in architecture refers to the complexity of the design and the high cost and difficulty of implementation; however the evolution in smart materials makes it easier and simpler. Kinetic architecture is not only an addition in the architectural aesthetics but also play an environmental role in sun shading and improving the functionality of the building.

REFERENCES

[1] M. Asefi, Transformable and Kinetic Architectural Structures, VDM Verlag Dr. Müller, Germany, 2010.
[2] M. Schumacher, O. Schaeffer, M. Vogt, Move: architecture in motion-dynamic components and elements, Birkhauser, Germany, 2010.
[3] J. Meriam, Engineering Mechanics: Dynamics, Wiley & Sons, USA, 1998.
[4] H. Sakeek, Mechanics Principles and Applications, 2006, http://www.hazemsakeek.net/Physics_Lectures(Accessed: 9 6 2012).
[5] R.Kronenburg, Flexible: architecture that responds to change, Laurence King, United Kingdom,2007.
[6] M. Fox, Interactive architecture, 2012, http://www.robotecture.com/showcase/interactive-architecture-book-2009/ (Accessed: 10 23, 2013)
[7] J. Moloney, Designing Kinetics for architectural facades, Routledge, USA, 2011.
[8] J. Sheriden, The engineering of Style, Naval Architecture, Current Thinking on Smart Products and Materials, Jonathan Sheridan Ltd, 2000. http://www.designpartners.co.uk/Smart.html. (Accessed: 10 18 2012).
[9] Kh. Dewidar, A new architectural language, Tasmeem magazine, Issue No.1, Egypt, 2002, p. 75.
[10] D. Grieve, Actuators, 2003, http://www.tech.plym.ac.uk/sme/desnotes/actuators 1.htm. (Accessed: 4 21, 2011).
[11] A. Naseem, The Equilibrium in Architecture, Cairo University, Egypt, 2002.
[12] K. Chai, The Design and Construction of Interactive Architectural Environments: The Digital Mile, Department of Mechanical Engineering, MIT, USA, 2006.
[13] M. Ashby, Material Selection in Mechanical Design, Elsevier Butterworh Heinemann, Oxford, 2005.
[14] Kh. Sherbini, R. Krawczyk, Overview of Intelligent Architecture, 1st ASCAAD International Conference, e-Design in Architecture, Dhahran, Saudi Arabia, 2004.

JES, Assiut University, Faculty of Engineering, Vol. 42, No. 3, May 2014 , pp. 816– 845

[15] Hoberman Associates, Company Profile & Selected Works, www.hoberman.com (Accessed: 14 6, 2013).
[16] Simone Giostra, Solpix, www.sgp-a.com (Accessed: 26 5, 2013).
[17] Vector Foiltec, The TEXLON System, www.vector-foiltec.com (Accessed: 18 4, 2013).
[18] dECOi Architects, HypoSurface, www.hyposurface.org (Accessed: 12 8, 2013).
[19] Studio Roosegaarde, Dune 4.2, www.studioroosegaarde.net (Accessed: 20 6, 2013).
[20] Studio Roosegaarde, Wind 3.0, www.studioroosegaarde.net (Accessed: 20 6, 2013).
[21] Blaine Brownell, Sonomorph, www.materia.nl (Accessed: 15 6, 2013).
[22] Fraunhofer Institute for Structural Durability and System Reliability LBF, Soundproof window, www.moreinspiration.com (Accessed: 13 1, 2013).
[23] Hayes Raffle, M. W. Joachim, J. Tichenor, Super Cilia Skin, www.angible.media.mit.edu (Accessed: 25 8, 2013).
[24] Ned Kahn Studios, Wind Arbor, www.nedkahn.com (Accessed: 28 7, 2013).
[25] Enric Ruiz-Geli, Media-ICT, www.worldbuildingsdirectory.com/project.cfm?id=3752 (Accessed: 25 6, 2013).

الحركة التفاعلية في العمارة الحركية

الملخص العربى:

في السنوات الأخيرة، تم ابتكار العديد من المفاهيم التفاعلية. بعض هذه المفاهيم لديها القدرة على التكيف والتفاعل مع البيئة المحيطة مثل؛ الضوء، والصوت، الرياح أو مع الاشخاص عن طريق تغيير حالتها من دون الحاجة إلى أي تدخل من الإنسان كما يمكنها العودة إلى حالتها الأصلية دون أي تشوه مع انتهاء المؤثر الخارجي. اكتشاف مثل هذه المفاهيم التفاعلية حفز عدد من المهندسين المعماريين إلى التفكير في استخدامها في العديد من التطبيقات البيئية المعمارية مثل؛ التظليل الشمس، الكاسرات الشمسية والنوافذ والتي تؤثر بشكل كبير على مفهوم وتكنولوجيا الحركة الفعلية في العمارة. تحاول هذه الورقة البحثية دراسة وتحليل التطبيقات التفاعلية في العمارة الحركية ودراسة قدرة هذه التطبيقات على تطوير هذا الاتجاه في التصميم المعماري لتكون أكثر فعالية وقابلة للتطبيق في المستقبل.