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Interactive Architecture: Concepts, Objectives, Applications Review

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ABSTRACT
The concept of interactivearchitecture is one of the modern concepts that emerged with the development of technology and the emergence of environmental, functional and human problems that traditional architecture could not solve because it needs dynamic architecture adapted to internal and external conditions through movement, interaction, flexibility and integration with both the environment and individuals. The paper provides an overview of interactive architecture, its concept, definition, as well as a historical overview, objectives and benefits, and finally the applications of physical and software interactive architecture and how to integrate them.

I. INTRODUCTION:

Architecture aim in general was, and still, to provide a stable, ideal solution, based on the assumption that future conditions in general are fixed and the possibility of change in them is limited. Traditional architecture gives a specific image with certain features such as stability, durability, solidity and other characteristics of traditional architecture, but on the contrary it is more appropriate to assume that there is greater flexibility in the use of buildings and in accordance with the emergence of modern technologies and future development and with unexpected changes in climate patterns and perhaps many studies, hypotheses, and statistics indicated such changes that will occur in the future, which will lead to changes at the level of climate and human behavior, and therefore require new ideas to be addressed and adapted to reach the user's convenience. Here, the role of interactive architecture emerges to change the prevailing situation and gives a better picture of the future, through its ability to adapt and change in order to interact with different circumstances.

II. INTERACTIVE ARCHITECTURE CONCEPT

Interactive architecture is a new direction in design based on the communication between the user and space and the ability of the space to respond in real time and accommodate the different and changing needs of users in a more effective way and create a continuous relationship between society and the built environment (1). It is a building or parts of it that have the ability to make an effective continuous dialogue with its occupants or the surrounding environment (2), it is a building that has spaces and structural elements in which the ability to respond and adapt to human individual, social and environmental requirements and is based on the integration of technology and movement in an architectural formula with the participation of human response and the environment to create an architecture that can be called interactive or responsive (3), which is not just a responsive architecture, but is based on the idea of multi-directional dialogue, which is the art of building a relationship between the parts of the building and its occupants (4).

There are many similar and overlapping names with the idea of interactive architecture, including (kinetic architecture), which refers to a building or part of a building with a variable location, movement or geometry (5). This term focuses on movement without focusing on other aspects such as intelligence and control. As well as the designation (smart architecture), the concept of which has been associated with smart materials, which are materials that have integrated technical functions that have the ability to respond to the climate and work through a change in the properties of the material or through external energy exchange (6, 7)as well as the term (intelligent architecture), which is a higher order than (smart), and it is defined as the buildings that know the environmental condition outside and inside and decide how to provide an appropriate environment for the user's comfort and all of this depends on

responding to the user's desire and is achieved through multiple sensors that connect to the building control system in order to improve the internal conditions (8)and also the name (responsive architecture), which refers to the existence of a dialogue between the users and the building, as well as (adaptive), which refers to adapting to the surroundings and the external conditions affecting it (9).The term (interactive) is more general and comprehensive, as it employs smart systems, moving parts of the building and flexibility in the use of different techniques and methods.

III. HISTORICAL OVERVIEW:

The concept of interactive architecture is a modern concept that has developed in its current form in the twenty-first century, and its development and emergence depended on the merging and fusion of architectural ideas that appeared at different stages and contributed to the formation of this field and gave possibilities for its development (10) where smart architecture began in the sixties and seventies due to the development of computers in the field of science and building technology, and architecture was transformed from a static form to a more kinetic and dynamic form, despite the first kinetic design being conducted in 1908. After that, the convertible architecture was a kinetic design, and the combination of movement and computer science took decades (11)at the beginning of the seventies, a book (kinetic architecture) was written by Roger Clark, where he found that architecture adapts to changes that occur within a set of pressures on which it operates, and technology provides a tool for interpreting and implementing pressures. The book presented the basics of unstable architecture and combined natural creatures and buildings (12) most of the ideas that were put in the book are futuristic and then became real ideas (10) and in the seventies the personal computer was introduced into the work of architects, and in 1987 Jean Nouvel presented (institut du monde arabe in paris) presented a model for kinetic architecture. Nonetheless, the beginning of the twenty-first century marked the real beginning of interactive architecture, where forms and functions are necessary to ensure a good relationship with the new environment. Modern architecture knows no boundaries and virtual and real reality are intertwined in one unlimited space. The lack of clarity of architecture is the new feature of the modern era. Beauty comes from within and is imposed also on the outside, buildings have become complex adaptive systems that communicate with the internal and external environment (1), as a result of advanced technologies and the possibilities available at the present time, the employment of interactive architecture has widely increased. Contemporary trends have been divided into two categories:

- **Pragmatism**: is concerned with solving problems and finding optimal solutions to them
- **Humanity**: is concerned with aesthetical aspects and the psychological and physical impact of changes in the architectural environment on users (3).

Therefore, many contemporary trends of interactive architecture have appeared, including: Space improvement systems, multi-functional design, adaptation to the surroundings, and mobility (13)

IV. OBJECTIVES OF INTERACTIVE ARCHITECTURE:

The main objectives addressed by the interactive architecture can be categorized under three main aspects:

4-1 Environmental aspect: the building may be designed in order to control its internal environment or to control the external variables in the environment around it that try to affect it negatively, as it may act as a regulator the climate changes its state, characteristics and formations in order to control the basic climate elements that secure human comfort, such as thermal energy variables (temperature, air movement, humidity) and lighting variables (visible daylight, ultraviolet rays, infrared rays) in addition to acoustic variables (noise). Vibrations) (14) and this can be achieved by changing the characteristics of the building shell such as closing or opening openings in a physical or visual way in order to allow light or wind currents to pass through, or by changing the volumes to control the variables that enter the building (15).The interactive building has the ability to change its statedynamically to benefit from some energy conservation strategies such as building orientation and opening in the maximum way to take advantage of natural daylighting and the required amount of heat gain and avoid unwanted heat gain and heat loss through air movement in addition to increasing passive solar and passive cooling (16).

4-2 Functional aspect: the interactive building may be designed to achieve a functional goal such as improving the performance of functional spaces and self-operating systems and giving greater flexibility and adaptability to the building to benefit from it better and more effectively. The difference between adaptive space and interactive architecture is the level of interaction, as the previous trends depended on the user to manipulate and change the geometric

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shapes of the parts of the project and manually change the size, color, shape or location of the elements that make up the space. These projects are adaptive, but they were not interactive in terms of ability. On feeling and sensing information from users or the surrounding environment and then adapting itself to changes (3)

4-3 Aesthetical aspect: some interactive buildings are designed with an aesthetic aim to carry aesthetic and psychological qualities that meet the requirements of the user and create a distinct architecture with changing appearance qualities that give a sense of mystery, suspense and dazzle and try to break the boredom that accompanies traditional architecture (17). Interactive architecture does not have the ability to facilitate the lifestyle only, but also, the effect on this method by re-imagining the role played by the physical environment in shaping the environment of the viewer (3)

V. INTERACTIVE ARCHITECTURE APPLICATIONS:

Interactive architecture applications are analyzed according to the following:

5-1 physical components: which include kinetic structural structures and the various elements and parts that generate interaction through their movement of different shapes and types, and can be classified into three main sections (18):

5-1.1 kinetic structures systems: they are buildings or parts of buildings with a changing location, movement or geometry, and the process of developing such systems must take into account kinetic structures, which must be designed as a major part of the overall interactive system and not separate from it to reach more appropriate solutions and efficacy (10). It is divided into three types,Figure (1):

- **Embedded kinetic structures**: they are systems that exist within a larger architectural system in fixed locations, and their main function is to control the larger architectural system or building in response to changing factors (19)
- **Deployable kinetic structures:** they are systems located in temporary and easily transportable stands, characterized by the possibility of being easily created and dismantled (20).
- **Dynamic kinetic structures**: they are structures that exist within a broader architectural entity and operate independently, but in coordination with the larger architectural system, which is the most widespread. Dynamic kinetic structures can be divided into types:

a. Mobile systems: they are systems that can be moved within the architectural space to different locations.

b. transforming systems: they are systems that have the ability to change their shape to take different formations

c. incremental systems: they are systems that can be added or subtracted from buildings in a way that does not affect the overall system (3)

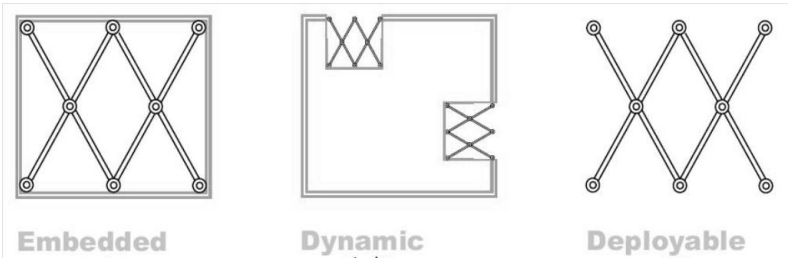

Figure (1) Kinetic structure categories(20)

The systems of kinematic structures can also be organized into different patterns to create different kinematic structures:

- **Linear configuration**: It relies on an axis (straight or curved) that consists of a group of units (motor devices) that are connected by their vertices or edges in oder to transmit movement (21).
- **Central configuration**:It relies on a central point or the focal point of the space, and it has two forms,Figures (2) and (3):

a. Axial configuration: It is arranged using a supporting element (axis) in the center of the model. It is usually dynamic. The devices are arranged in the structure to run back and forth from the center to the periphery.

b. Peripheral configuration: It is arranged in a series of supporting elements placed on the perimeter of the model (11).

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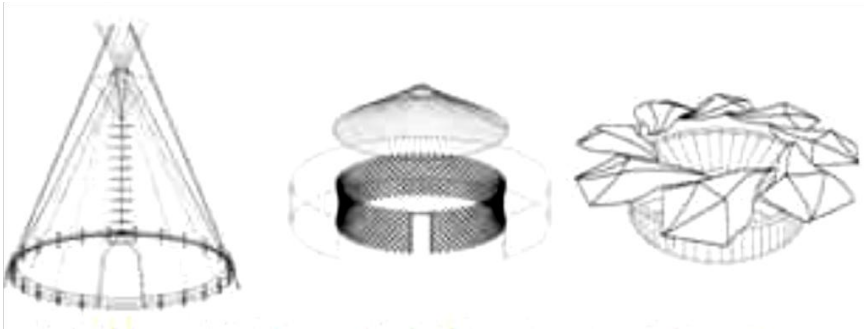

Figure (2)Kinetic architectural structures with centric configuration (21)

Figure (3)The movement of the structurein the Dynamic Tower in Dubai(10)

5-1-2 Internal movement: The applications of internal movement are numerous and can be classified into categories:

- **Transformable Spaces**: provide the ability to transform the changing needs of its residents and be on several levels, such as multiple uses of furniture, flexible spaces.
- **kinetic walls**: movement occurs in the walls, floors, and part of the facades of the building, and we use kinetic walls to leave the impression that it is a response to our actions (22).

5-1-3 kinetic facades: It relies ontransformations in thegeometry to create motion. This motionhas an impact on the facade physical structure, yet it does not cause damage to the structure of the building. Kinetic facades can move in four transitions (23),Figure (4):

- Translation: Motion happens in a vector direction
- Rotation: Motion happens around all axis
- Scaling: Motion takes the form of contraction or expansion.
- Material deformation:Motion relies on material properties changes such as elasticity.

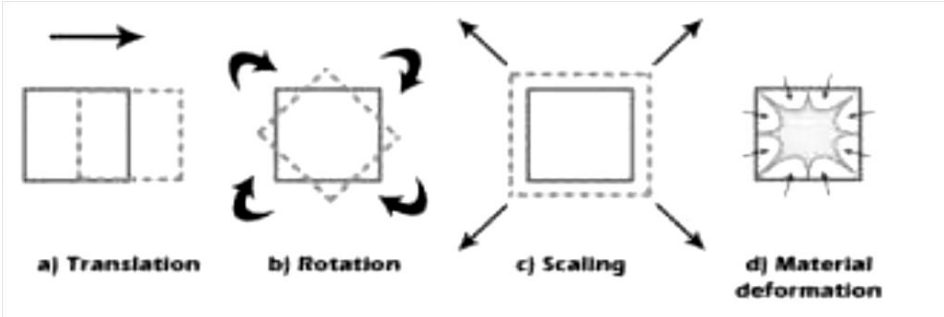

Figure (4)Forms of geometric transitions for kinetic (25)

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5-2 Technological & Programmable Components:

This aspect represents the mind that moves the different physical parts of the interactive system, and it includes embedded computers, which are in the form of an integrated system in the building. In all, the difference between these systems can be divided into two types according to the type of artificial intelligence (22):

- **Central intelligence**: it consists of a central computer that works as a main control unit that controls the different parts. It analyzes the information received from the sensors and is processed and determines the type of response that the system will make. This type needs high-level programming to be able to control the different parts of the building.
- **Swarm intelligence**: in this type, there is no central part, but rather a group of simpler parts that interact with each other and with the surrounding environment. Therefore, a simple type of programming is needed where the parts have their own intelligence, sensors, and engines that respond directly to the information received (24).

Understanding the potential relationship between the intelligent system and the response will help in controlling and choosing the appropriate means to control the required change, and it ranges from simple means to interactive networks, so they differ in their degree of complexity and need and can be classified into the following types:

5.2.1 Direct control: The simplest type of control transforms the input information directly into a response used when the level of information exchanged is on and off.

5.2.2 Indirect control: It is a more complex type that contains a level of intelligence that includes making a decision based on feedback from several sensors, and the control of this system depends on a sensor to sense the change and sends a message to the controller that instructs to turn on or off the energy to control the movement (10).

5.2.3 Indirect responsive control: similar to the previous system, but the teams receive information from multiple sensors and make the best decision among different options.

5.2.4 Ubiquitous Responsive In-Direct Control: It depends on pairs of sensors and motors working together and linked to a single network, the work of the system requires the occurrence of a feedback process between sensors, motors and motor elements, the intelligence of the system has the ability to anticipate various changes and adapt to them automatically.

5.2.5 Heuristic Responsive In-Direct Control: Control of change is either singular or responsive, where the system is characterized by its ability to earn through the system's previous adaptive experiences, and has the ability to choose the best solutions and decisions in order to improve the system's response to various changes (25).

Table. (1) Asummary of the Objectives and applications of interactive architecture(
Source: own preparation by author

Interactive architecture	**Objectives**	Environmental	thermal energy variables (temperature, air movement, humidity)
			lighting variables (visible daylight, ultraviolet rays, infrared rays)
			acoustic variables (noise, Vibrations)
		functional	Optimal use of space
			adaptability strategy
		Aesthetic	Understanding of human behavior
			Architecturalknowledge
	Applications	physical components	kinetic structures systems
			Internal movement
			kinetic facades
		Technological & Programmable Components	Direct control
			Indirect control
			Indirect responsive control
			Ubiquitous Responsive In-Direct Control
			Heuristic Responsive In-Direct Control

VI. CONCLUSION:

Interactive architecture is based on the idea of dialogue between architecture and man on the one hand, and architecture and the environment on the other hand, in order to reach a better state and greater comprehensiveness. It is a modern concept that has emerged and developed with the development of technology and programming, so it is linked to technological innovations. The goal of interactive architecture is to meet the changing requirements and unexpected future conditions that traditional architecture cannot address and adapt to, creating buildings with features that improve the user experience of space and his daily life and have variable aesthetic values that enrich the user experience sensory by exploiting the aesthetic of movement and its changes that add suspense to the building, and the interactive architecture applications based on the merger between two main aspects, the physical aspect represented by the structures, elements and different parts of the building and the technological components represented by computers and automatic control to produce for us an architecture with innovative solutions, low cost and good technology.

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