The impact of intelligent systems on architectural aesthetics

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Abstract. During its historical development, materials and architecture have always been inextricably linked. More recently, the application of modern materials and new achievements in architecture around the world have actualized the issue of the relation between architectural aesthetics and technology. Technological advancement allows the creation of new forms and a new way of shaping materials. Therefore, smart and nanotechnology have a significant impact not only on modern buildings, but also on the emergence of new architectural expression and style. Using analytical descriptive methodology and research literature, this paper focuses on the analysis of selected case studies in order to determine the impact of new intelligent technologies and modern materials on the ecological and aesthetic needs of today's architecture.

1 Introduction

As today the human beings are still in a critical condition in terms of energy consumption, designing a building that implies energy consumption and building environmental protection, is one of the main responsibilities of architects [1]. The building skin, as both the building's primary protection from the external influences and as the Architect's expression, must be appropriate implemented into design to address increasingly complex sets of requirements [2]. As the solving of an architectural problem always includes a synthesis of aesthetic and engineering capabilities the evolution of technological paradigm has great effect to the architectural practice.

Technology is changing and improving at an extraordinary rate, and is impacting facilities and the building construction industry like never before. Buildings are becoming largely automated, service oriented and efficient. Considering that abundance of technological changes nowadays, it is necessary to establish a balance of intelligent building features to architectural quality, both aesthetic and functional, whose appropriate relationship can help meet the user needs.

There are many definitions of intelligent buildings. It is difficult to formulate a unique conception of intelligent buildings and no single definition is accepted worldwide. Different regions and different disciplines may have diverse preferences and different intelligent buildings concepts may predominate [3]. For Sinopoli (2010) intelligent buildings are not just about installing and operating technology or technology advancements. Technology

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and the systems in buildings allow to operate the building more efficiently; to construct the buildings in a more efficient way, to provide productive and healthy spaces for the occupants and visitors, to provide a safe environment, to provide an energy-efficient and sustainable environment [4].

2 Architectural elements of intelligent buildings

Among the essential elements of intelligent buildings are building envelopes and materials. The building envelopes as adaptive or responsive facades are those that able to adapt to changing climatic conditions on daily, seasonally or yearly basis. They are adaptive because of the ability to respond or benefit from external climatic conditions in order to meet efficiently and, more important, effectively occupants comfort and well-being [5].

2.1 Intelligent Facade Systems as an architectural-aesthetic element

Adaptive facades are multi-parameter high-performance envelopes that, opposite to fixed facades, react mechanically or chemically to external climate to meet internal loads and occupants needs.

Adaptive systems are more suitable than fixed ones since they can be adjusted in relation to the changing of solar radiation, allowing individual control, optimal shading and maximization of daylight use. Two approaches can be distinguished: kinematic approaches to adaptability and elastic kinetic approaches to facade shading [6,7, 11].

Table 1. The adaptive facades systems. Source: Author.

Systems	Approaches to adaptability	Possibilities
Facade shading	Kinematic approaches Elastic kinetic approaches	
Control systems	External - active Internal - passive	Sensors etc. Smart materials
Facade efficiency	Externally applied systems Internally applied systems Integrated in the facade	Double skins Switchable glazing

Also are applied external-active control systems (sensors etc.), and, on the other hand, internal-passive control systems, whose have the ability to self-adjusting in response to environmental stimuli like temperature, relative humidity, solar radiation and so forth without the implication of external electrical sources [8]. Smart materials are examples of internal control systems. According to the building efficiency, the most significant differentiation may be seen in differentiating between internally applied systems, externally applied systems and systems integrated in the facade (double skins and switchable glazing) [9,13,16]. The adaptive facades systems can be summarized as Table 1.

2.2 Contribution of smart materials to architectural aesthetic

Selection of materials for use in architecture is based on appearance and aesthetic, ease of construction with regard to human resource skills, availability of local or regional, as well as materials used which are in the near place.

The capability to property change causes smart materials to have the ability to respond to environmental conditions change. Materials with the energy exchange capability having many applications in architecture can also receive input energy and change to another form of energy used depending on conditions and situations [17].

Table 2. Smart materials and architectural requirements [17].

Architectural requirement	Relevant material characteristic	Smart material application
Control of solar radiation transmitting through the building envelope	Spectral absorptivity/transmission of envelope material Relative position of envelope material	Electrochromics Photochromics Liquid crystal displays Suspended particle panels Louver control systems -exterior radiation sensors (photovoltaics) -interior daylight sensors (photoelectrics) controls (shape-memory alloys)
Control of conductive heat transfer through the build.en.	Thermal conductivity of envelope material	Thermotropics Phase change materials
Control of interior heat generation	Heat capacity of interior material Relative location of heat source Lumen/watt energy conversion ratio	Phase change materials Fiber-optic systems Thermoelectrics Photoluminescents Light-emitting diodes
Secondary energy supply systems	Conversion of ambient energy to electrical energy	Photovoltaics
Optimization of lighting systems	Daylight sensing Illuminance measurements Occupancy sensing Relative location of a source	Photovoltaics Photoelectrics Fiber optics Electroluminescents
Optimization of HVAC systems	Temperature sensing Humidity sensing Occupancy sensing CO2 and chemical detection Relative location of the source and/or sink	Pyroelectrics Hygrometers Photoelectrics Biosensors Thermoelectrics Phase change materials
Control of structural vibration	Euler buckling Inertial damping Strain sensing	Piezoelectric Magnetorheological Electrorheological Shape-memory alloys Fiber optics

3 Architectural-aesthetic characteristics of intelligent buildings

The intelligent buildings have some characteristics from the viewpoint of aesthetics. Movement, changing and adjusting with the environmental condition are the new technological-aesthetic characteristics of contemporary buildings [10,12]. Vaisi (2012) considered that the most important characteristics of technological aesthetics can be summarized as following Table 2:

Table 2. The most important characteristics of the technological aesthetics [10].

Characteristics	Use in buildings
Remote control	Remote control doors Remote control air conditioners
Adjustability and changeability	Temperature control Portable structures Intelligent security systems
Movement	Mobile structures Portable cabins Retractable roofs
Excitement	Suspension bridges Wheels Elevators
Adjustable with Environment	Photovoltaic cells Aerogel materials Smart glasses Solar lights
Unprecedented	Reinforced concrete Curtain walls Skyscrapers High ways, Nanomaterials

4 Contemporary practice in intelligent building production

In the following sections of this article are analyzed the examples from practice with the aim of emphasizing the significance of the intelligent strategies used in architectural design.

4.1 University of Southern Denmark – Campus Kolding

The building by Henning Larsen Architects represents distinguishing, modern and innovative architecture [19]. Its triangular shape was generated by the site. The facade is an integrated part of the building, vital to its unique and varied expression.

The energy consumption of the campus is so low that the building is classified in Energy Class 1. This makes Campus Kolding the first to meet the demanding energy targets of Denmark's 2015 building codes and one of the world's first low-energy universities. The energy demand is reduced by 50 percent compared to similar buildings of the same typology in Denmark through passive design and the implementation of efficient and intelligent systems.

The shape and structure of the building alone replace some of the solutions that would otherwise require energy-intensive technology (see Fig. 1.). The striking solar screening consists of around 1,600 triangular shutters of perforated steel, adjustable to match the amount of daylight and desired inflow of light at any time. The perforation of the shutters is a light, organic pattern of round holes. The facade design strikes the optimum balance between the amount of light and energy allowed to flow in and out.

Sensors monitor heat and light levels around the building, allowing the facade panels to shift from open to half-open to fully open. Concrete slabs are left exposed to take advantage of thermal heat gain. The ventilation system is integrated into the ceiling planes, rather than through traditional ducts, which cut both energy and construction costs. Efficient LED lighting is used throughout, while photovoltaics and solar-heating panels dramatically reduce the amount of energy taken from the grid [20]. All of that leads to energy consumption of just 48 kWh/m^2/year.

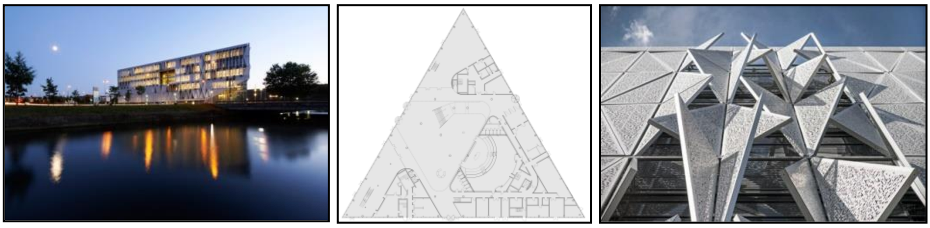

Fig. 1. Climate-responsive kinetic facade and a triangular form of Campus Kolding (Source: www.archdaily.com).

4.2 Italy Pavilion – Milan Expo 2015

The Italian Pavilion is an innovative, contemporary building designed as a white tree made of concrete by the Nemesi Studio. It is a 13,000-square meter "smog-eater" [21]. The Pavilion consists of the permanent building Palazzo Italia and an adjacent series of temporary structures [22]. Palazzo Italia manifests an architectural and constructive challenge for the experimentation and innovation in design, materials and technologies used (See Fig. 2.). The building is designed to be sustainable and innovative. Photovoltaic glass is used in the roof and the new concrete with photocatalytic properties for the branched facade.

The concept of the building is an "urban forest" with the branched outer envelope. For the design of this "skin" Nemesi has created a unique and original geometric texture that evokes the intertwining random branches. Architects used over seven hundred panels of Biodynamic concrete to capture air pollutants. When this material comes into contact with light, it can capture pollution in the air, transforming it into inert salts and reducing smog levels. The mortar used is 80% recycled aggregates, including scrap material from marble quarries in Carrara that helps add more luster than in traditional white cement. This new material is also very dynamic, enabling the creation of fluid designs like the complex shapes used for the panels that are part of the construction of Palazzo Italia.

The roof represents an innovative "sail". It’s an interpretation of a forest canopy, with photovoltaic glass and flat and curved geometric shapes. Together with the building's envelope of branches, it represents a manifest expression of innovation in design and technology. The roof reaches its architectural height above the inner piazza, where a massive glazed conical skylight hangs over the square and the central steps, radiating natural light [23].

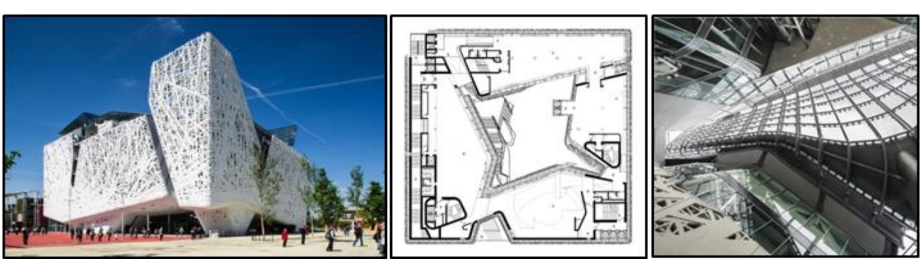

Fig. 2. Experimentation and innovation in design, materials and technologies used (Source: www.architizer.com).

4.3 The Crystal

The Crystal, a Sustainable Cities Initiative by Siemens, was designed by Wilkinson Eyre Architects. The 6,300 sq m building, housing exhibition spaces, conference facilities and a technology and innovation centre, has been designed to achieve the highest international sustainability credentials for a building (BREEAM Outstanding and LEED Platinum). The building represents innovative and bold architecture that can harness the benefits of the latest 'green' technology.

The form of the structure draws inspiration from the many sides of the crystal. The crystalline geometry of the architecture forms a series of angular shapes (See Fig. 3.). Architects used types of highly insulated glass with varying levels of transparency, allowing spaces to be naturally lit whilst controlling solar gain. This careful use of translucent and mainly opaque glazing has been designed to minimise the running costs of the building [23]. The exterior comprises three types of double-glazed units. Transparent panels make up 39 per cent of the envelope. Translucent panels are used where light is desirable but solar gain must be controlled and opaque insulated panels make up the remainder. Further efficiencies are achieved by raking the facade to reflect solar gain and self-shade parts of the building. Parallel-opening panels - 1m x 3m - are the most unusual element of the mixed-mode ventilation system. This was considered optimal because it allows the maximum amount of air volume per opening. Full natural ventilation is possible when outdoor temperatures permit.

The overall effect is a building which reflects varying weather conditions, though the dark palette of the glazing lend. On the inside, the combination of rooflights and carefully positioned vision glass results in well-lit interiors [24]. This project shows how new technologies can help create a highly sustainable building without relying solely on passive systems.

Fig. 3. The crystalline geometry of the architecture (Source: www.archdaily.com).

4 Conclusion

Technology and architecture have a long symbiotic relationship, in which advances in one field enable or demand changes in the other. The new generation of contemporary architecture is completely different from the architecture in the past. Intelligent building has a technological identity, and technology has an important role in creation of its form, volume, façade, and materials. Technological aesthetics is the most important exclusivity of present buildings [10].

The building skin perform the role of an environmental filter between interior and exterior conditions, while addressing and resolving a wide spectrum of issues such as technical performance, visual appearance, ventilation, assembly, etc. Adaptive facades are building envelopes that are able to adapt to changing climatic conditions on daily, seasonally or yearly basis. By adaptive we mean the ability to respond or benefit from external climatic conditions to meet efficiently and more important effectively occupant comfort and well-being requirements. Adaptive facades are multi-parameter high performance envelopes that, opposite to fixed facades, react mechanically or chemically to external climate to meet internal loads and occupant needs.

Finally, we can conclude that:

- intelligent buildings have a significant impact on the life of their occupants.
- the intelligent buildings can offer an excellent environment to live in [18].

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