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Modern Mashrabiyas with High-tech Daylight Responsive Systems

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Abstract

The environmental and social role of closed oriental balconies (Mashrabiyas) remains a significant vernacular aspect of Middle Eastern architecture. However, nowadays this traditional Islamic window element with its characteristic latticework is used to cover entire buildings as an oriental ornament, providing local identity and a sun-shading device for cooling. In fact, designers have reinvented this vernacular Islamic wooden structure into high-tech responsive daylight systems – often on a massive scale and using computer technology – not only to cover tall buildings as an oriental ornament, but also as a major responsive daylight system.

It is possible to use the traditional architectural Islamic elements of the Middle East for problem-solving design solutions in present-day architecture. The potential for achieving these solutions lies in the effective combination of the design concepts of the traditional elements with new smart materials and technologies. Hence, modern mashrabiyas could be a major responsive daylight system. Contextual information drawn from relevant theory, ethnography and practice is used to form a methodological framework for the modern mashrabiyas with high-tech responsive daylight systems. The main results set boundaries for the viability of computer technology to produce mashrabiyas and promote a sustainable way of reviving their use within Middle Eastern buildings.

1. Introduction

Building facades tend to be more adaptive and responsive with the climate, indoor environments, space functions and occupants as the modern mashrabiyas with high-tech responsive systems. Within the scope of this paper, the type of building facades with high-tech modern mashrabiya is defined by three characteristics as follows: (Wang and Beltrán, 2012)

- To strengthen the relationship between the climate and environment with its connotation of indoor environmental conditions and energy efficiency.
- To integrate the physical motion or behaviors with the architectural aesthetics.
- To imply biological metaphors with the idea of optimal performance and access to the surrounding natural resources.

The main objective of this paper is using mashrabiya as a responsive daylight system by combining the design concepts of the traditional mashrabiya with new smart materials and technologies. Hence, modern mashrabiya with high technology will be a major responsive daylight system.

2. MASHRABIYA CONCEPT

The mashrabiya is a wooden lattice screen which is composed of very small wooden balusters round in section. The name mashrabiya is derived from the word “drink” in Arabic language. The mashrabiya was originally a “drinking place” as the shade and open lattice of a mashrabiya provided a constant current of air which, as the sweating surfaces of porous clay pots evapo rated, cooled the water inside. The mashrabiya has numerous different functions among including controlling the passage of light, regulating air flow, reducing the temperature of the air current, increasing the humidity of the air current and guaranteeing a great amount of privacy, as shown in Figure 1.

Figure 1. Example of a Mashrabiya in exterior shot (on the left) and in interior shot (on the right)

Egypt’s climate is classified as hot desert arid climate according to Köppen‟s climate classification system (Peel et al., 2007). It is characterized by high direct solar radiation and a clear sky which demands specific façade treatments to reduce heat gain while providing suitable daylighting. Double-skin façades (Like Mashrabiyas) are one of the building’s facade treatments that can improve the indoor environment while minimizing the use of energy if designed properly (Poirazis, 2006). The traditional double façade types of buffer, twin face and extract-air, where the exterior layer is glazed, have been evolved for hot arid climate resulted in a hybrid approach which employs a shading screen as the exterior face coupled with a high performance curtain wall system as the interior layer of the façade (Boake, 2014), as shown in Figure 2.

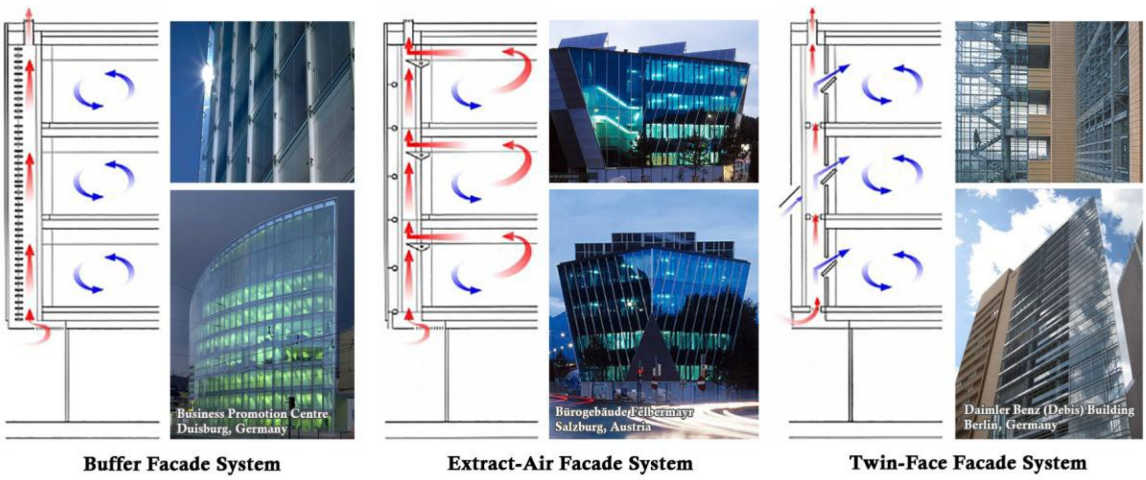


Figure 2. Examples of double façade types of buffer, twin face and extract-air, Source: Author

Daylighting in architecture is a design generation strategy that exploits natural sunlight in indoor spaces, reducing reliance on electric light, maintaining human health and a productive work environment during daytime. The mashrabiya has a major effect on the daylight performance inside the building.

3. CONCEPTS AND USES OF MASHRABIYA THROUGHOUT THE AGES

It is very important to understand the concept of this traditional window screen throughout the ages. Hence, uses of Mashrabiya will be discussed through its past as well as the current and future possible contexts of a possible Mashrabiya revival using current manufacturing technologies as follows:

3.1 Uses of Mashrabiya in the Islamic Era:

The name of the 'Mashrabiya' is related to its function as a passively cooled space for storing clay water pots. Therefore, the name is derived from the Arabic verb "yeshrab" that means "drink". From a structural view, mashrabiya is a wooden lattice screen like a closed balcony, that element is outside the window for around 35cm, as shown in Figure 3.

This shading element plays a crucial role in absorbing daytime humidity and releasing it at night. The mashrabiya has also an important Islamic cultural and social value of privacy as it functions as an architectural veil (Madeo and Schnabel, 2014).

The small openings in the mashrabiya, which is made of fine-turned wood or shading louvers, allow females to view the exterior world from inside without being revealed to the gaze of outside men. Gender segregation and veiling is a core value of the Islamic religion that made the use of mashrabiya quite popular throughout history. Mashrabiyas are known under different names such as Shanashel in Iraq, Mushabak in Iran, Roshan in Saudi Arabia and Aggasi in Bahrain, as noted by Almurahhem (2009) and Ben-Hamoush (2004). (Ragette, 2006)

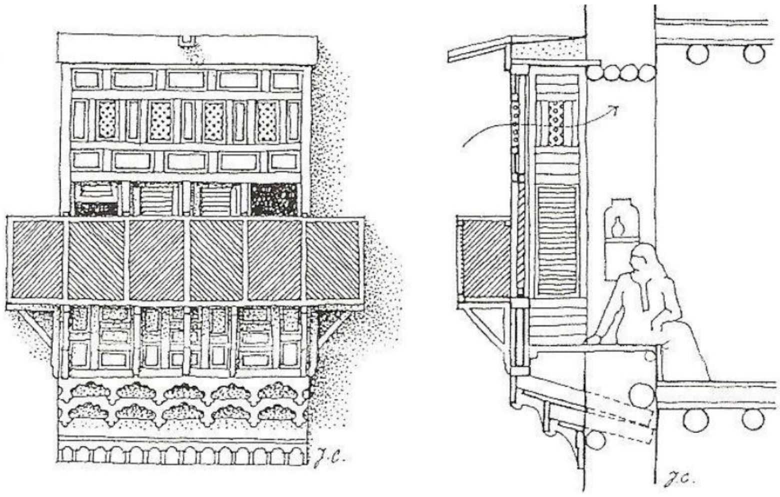


Figure 3. Details of Mashrabiya in elevation and section view (Ragette 2006)

3.2 Uses of Mashrabiya in current era:

3.2.1 Mashrabiya in modern architectural projects:

Mashrabiya, in modern architectural projects, has been used to achieve many things as follows: (Figure 4)

- Mashrabiya as an Adaptive Skin:

In architecture, the environmental value of Mashrabiyas was a defining concept in a lot of applications around the world. Producing an architectural envelope that can respond to sun exposure and changing incidence angles during the different days of the year were the aims of the Al Bahar towers project by Aedas (2012) and the Oxygen Villa (2012) designed by Egyptian studio house. An earlier pioneering invention in the field was Jean Novoul's Arab Cultural Institute design in France (1987). The modern smart adaptive skin of the Al Bahar towers project wins the contest between intelligent technology and the heritage value, as Mashrabiyas uses specialized programming methods and thermal actuators that open up the Mashrabiya like an origami fold.

- Mashrabiya as a Structural Pattern

The verity of opening to provide sun shade was transformed as a structural membrane by 109 Architects in Saint Joseph University (2011) in Lebanon and King Abdulla university for science and Technology (2012). The local brick made Pattern House in Iran (2012) represents the combination of mashrabiya-like structure made of local available materials and craftsman skills.

- Mashrabiya as a Cultural Value

The third interpretation of mashrabiya in the architectural context relies on its shape, which recalls Islamic identity and cultural values. Excellent Applications can be seen in the Masdar sustainable city in Abu Dhabi, UAE (2010) and the Mashrabiya House of Palestine (2011).

3.2.2 Mashrabiya within interior design:

Interior design spaces have also been influenced by Mashrabiyas. Figure 4 displays the different interior effects of the researched element. The basic passive cooling function of the shading device is integrated with the beauty of the play of shade and shadows of its openings.

Different new manufacturing techniques are being utilized, as seen in the CNC project recap 2 screen (2009) or the clay screen, entitled E-cooler (2010), that utilises water to perform a passive cooling effect like an old clay water jar. A distinguishing feature is the incorporation of writing, as introduced by Suzan Hefuna (1997), on artistic Mashrabiyas; this promotes dialogue between languages (Madeo and Schnabel, 2014).

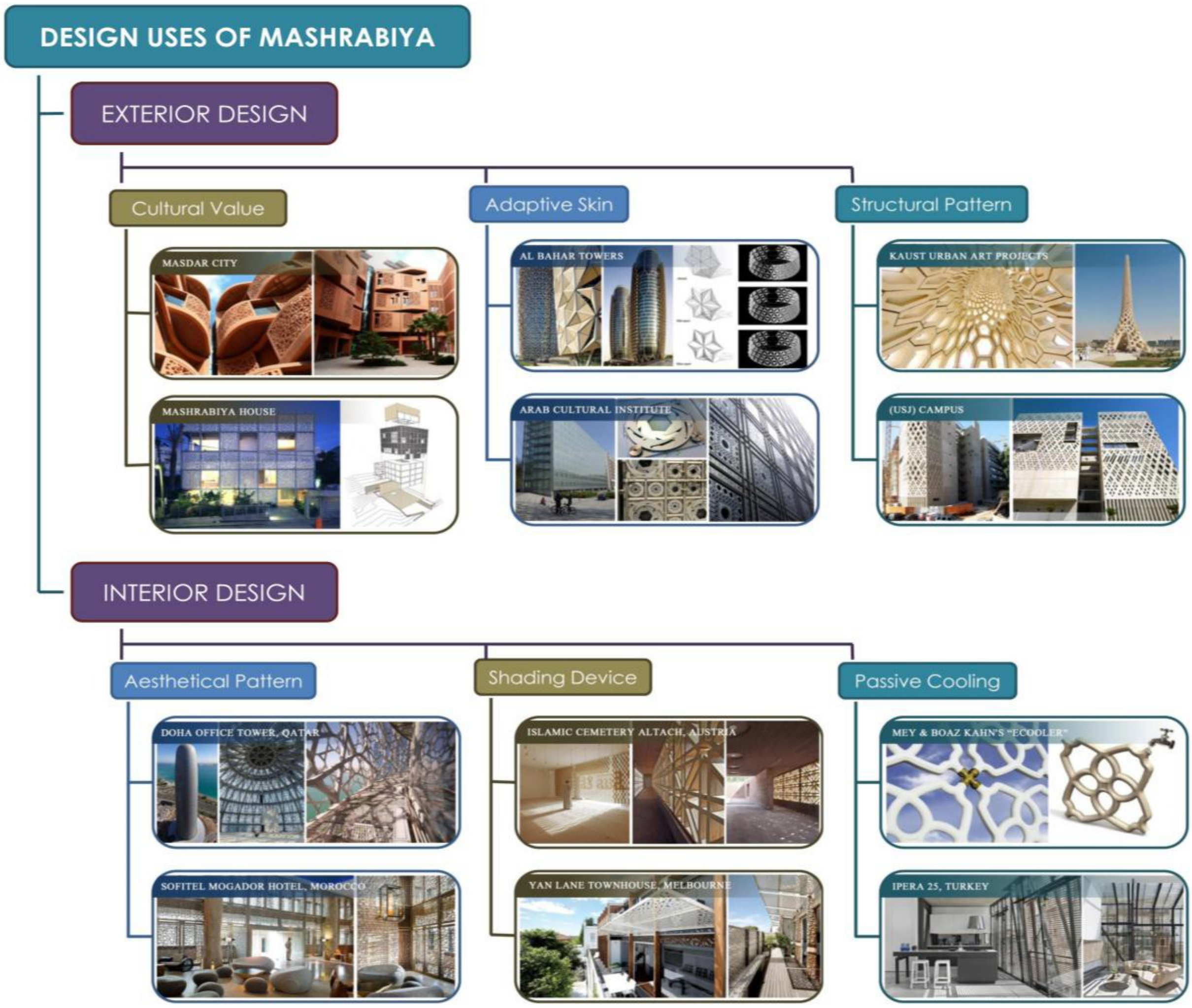


Figure 4. Mashrabiya context within exterior and interior design, Source: Author

4. DAYLIGHTING

Throughout history, natural daylight has been a primary source of lighting in buildings. As we entered the mid-20th-century, electric light replaced natural daylight in buildings in many cases. Fortunately, during the last quarter of the 20th-century and early years of this century, architects and designers have recognized the importance and value of introducing natural light into buildings. Hence, modern mashrabiyas with high-tech daylight responsive systems is a design strategy to get as much natural light as possible deep into the building while controlling heat and surface brightness within the users' fields of vision.

4.1 Intelligent Mashrabiya and Daylighting Performance

The intelligent Modern Mashrabiya behavior enables adaptation to the surrounding environment by allowing the human body to overcome the changing environmental conditions. Buildings are exposed to a wide range of undesirable and varying environmental conditions, which requires the envelope to possess intelligent capabilities like Kinetic and dynamic facade which automatically respond to environmental changes and user demands (El-Sheikh, 2011).

5. DAYLIGHTING SIMULATION

Various software packages were used for generating modern mashrabiyas with high technology Daylight responsive systems. Hence, design generation and application is divided into three phases as follows:

5.1 Input

The input data that is required for the daylight simulation can be concluded into three main points as follows: The Climate data which depends on the building location, information about the location surrounding environment, and the illuminance level demanded for each type of buildings. That Input data is very important during early design stages.

5.2 Process

Digital design tools in a façade configuration simulation process is used to identify the optimal opening and closing patterns for a specific period in a specific location on a specific luminous level.

Daylight simulation is a commonly used strategy for predicting the quality of luminous environments, as a set of results generated through executing numerous simulation runs for different facades configurations. Rhino, Grasshopper and the DIVA plugin are the most common software tools for daylight simulation which were designed to work together to make the simulation clean, quick, and reliable, as shown in Fig- ure 5.

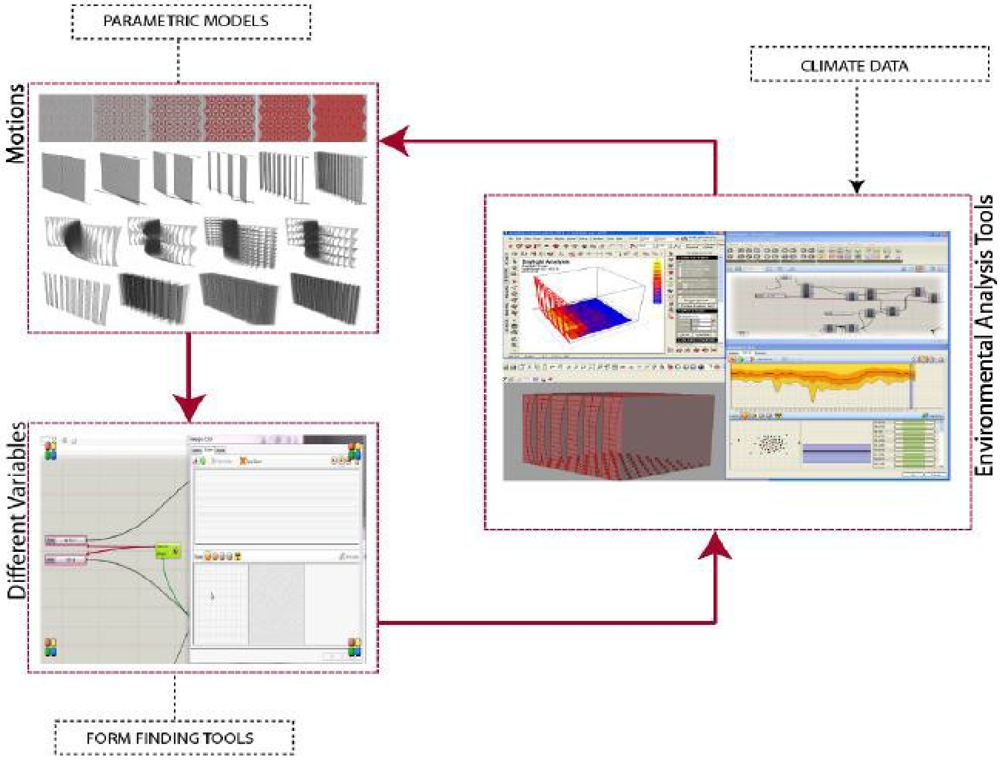


Figure 5. Explains the process of these simulations to find the optimal facades configuration. The variables were represented by sliders with set minimum and maximum values depending on designers‟ requirements (Cheung, 2013)

5.3 Output

The output will be a design feature which responds to the input and gets applied to the façade to moderate solar heat and lighting gains. The façade will essentially modify itself based on the input from light sensors within the interior and get transformed into usable responsive data (Cheung, 2013).

6. DAYLIGHT AUTONOMY

One of the key aspects of building rating systems such as Leadership in Energy and Environmental Design system (LEED) is daylighting design. LEED uses metrics such as Daylight Autonomy (DA), which is the percentage of annual daytime work hours that a given point in a space is above a specified illumination level. There are two metrics in LEED v4 for rating daylight autonomy design: Spatial Daylight Autonomy (sDA) and Annual Sun Exposure (ASE) metrics, which can help architects make good design decisions by forming together a clear picture of daylight performance.

sDA has no maximum limit on luminance levels, therefore, ASE in LEED v4 is used to describe how much of space receives 1000 lux or more of direct sunlight for at least 250 occupied hours per year, which can cause glare and thermal stress.

Within the design framework, the daylighting simulation depends not only on the simulation tool and its numerous calculation capabilities, but also on the pre-defined parameters, based on the demanded daylight performance. The algorithmic components incorporated into the set of parameters force data to flow in certain directions for evaluation purposes. The design processing system ends when there's an optimal facade configuration, as shown in Figure 6.

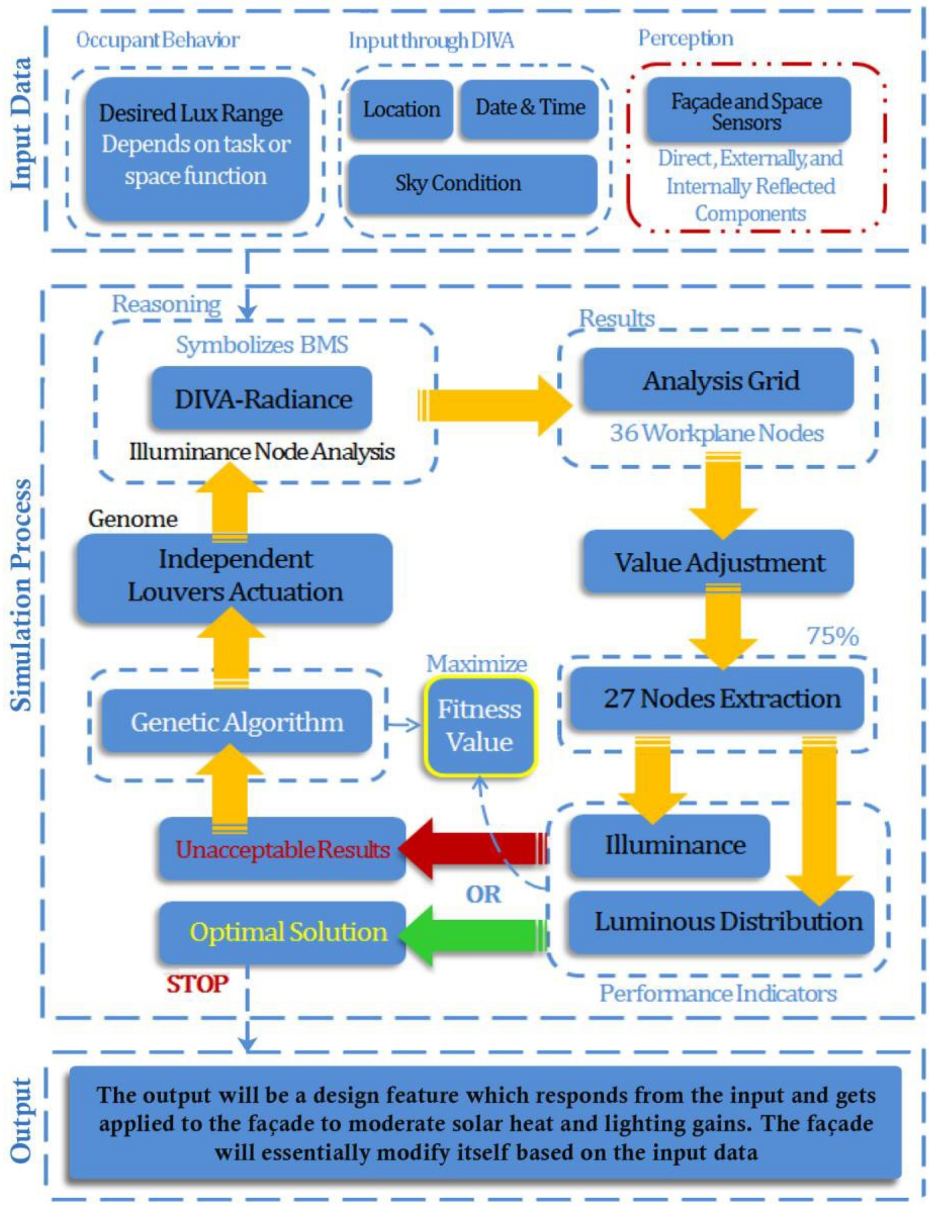


Figure 6. System logic – the path of data exchange between the proposed algorithm and the daylighting simulation tool. (El-Sheikh, 2011)

7. MODERN MASHRABIYAS WITH HIGH-TECH DAYLIGHT RESPONSIVE SYSTEMS APPLICATIONS

Within contemporary architecture, there is a growing interest in modern mashrabiyas with high-tech responsive systems. Hence, there are a lot of applications of modern mashrabiyas in the 21st century. Some of those applications will be displayed below in chronological order as follows:

7.1 Institut Monde Arabe Kinetic Façade

Institut Monde Arabe in Paris is designed by Jean Nouvel and was completed in 1987. The huge 30 by 80 meter South façade acts as a giant “mushrabiya” which perfectly combined high-tech modernity with traditional Arabian architecture form. These façades change continuously each day, each hour, showing a new "face" which adapts to the changing conditions and needs, as shown in Figures (7) (El-Semary, 2014).

The institute features radical high-tech walls emblazoned with mechanical apertures that respond to sunlight by narrowing to reduce solar exposure or dilating to allow daylight to fill the interior, as shown in Figures 7 and 8.

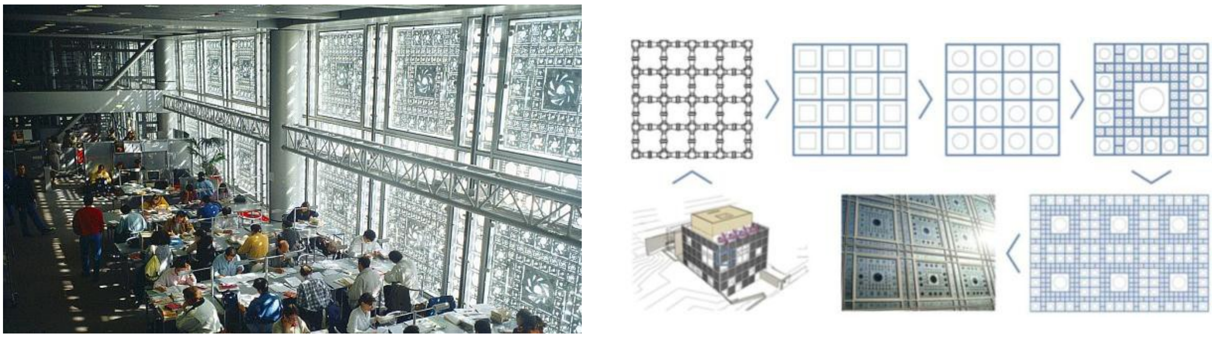


Figure 7: Main concept of Institut du Monde Arabe façade “mushrabiya”, (El-Semary, 2013)

Figure 7. Interior shots of Institut Monde Arabe shows the sensitive diaphragms which regulate the amount of daylight entering the building

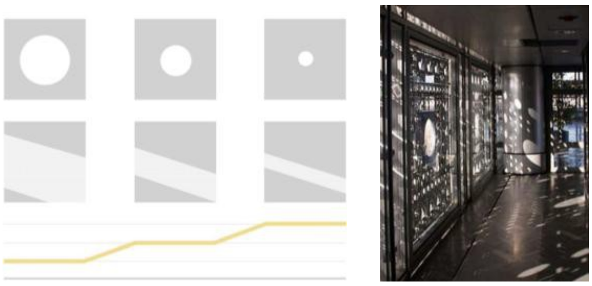


Figure 8. The Daylight and thermal energy con- trolling through the responsive kinetic façade (El-Semary, 2013)

7.2 Kinetic Shading system of Q1 Building:

Q1 Kinetic shading System in ThyssenKrupp Quarter designed by JSWD Architekten is located in Cologne, Germany and was completed in 2010. An innovative, highly efficient sun shading system was developed for large parts of the Q1 façade, as shown in Figure 9.

The highly efficient sun protection system has a key role in the overall appearance of Q1. The circa 400,000 stainless steel lamellas are oriented in response to the location of the sun and enable light redirection without blocking the view, as shown in Figure 10 and 11 (El-Semary, 2014).

Figure 9. Photo of the south and east facades of the Q1 Building

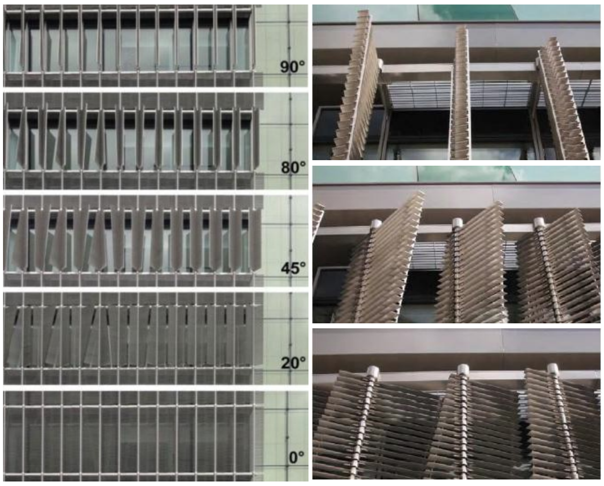


Figure 10. Different states of the sun-shading kinetic system

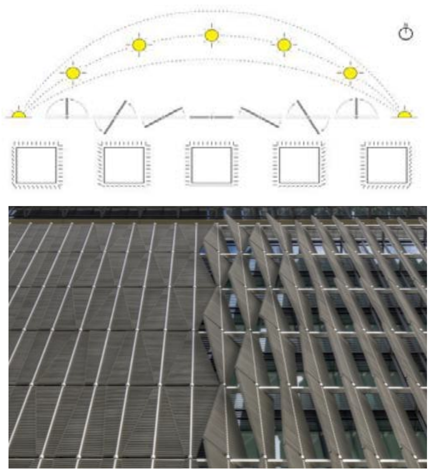


Figure 11. Sunshade Diagram which re- sponse to the location of the sun

7.3 Al Bahar Towers Kinetic Facades:

Al Bahar Towers have been designed by Aedas Architects in Abu Dhabi, UAE, they were completed in June 2012. Al Bahar Towers took inspiration from a traditional Islamic motif to design an innovative and visually interesting external automated shading system for the building. The kinetic façade has been conceived as a contemporary interpretation of the traditional Islamic "mashrabiya"; a popular form of wooden lattice screen found in vernacular Islamic architecture and used as a device for achieving privacy while reducing glare and solar gain, as shown in Figures 12 and 13 (El-Semary, 2014).

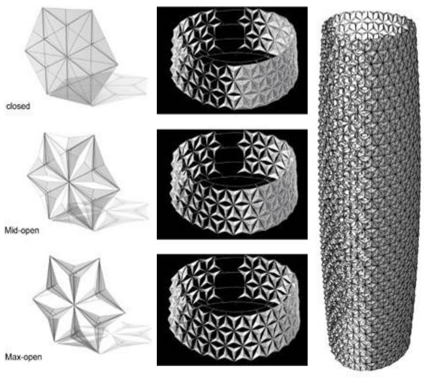


Figure 12. Al Bahar Towers external automated shading system, Abu Dhabi, UAE (El-Semary,2014)

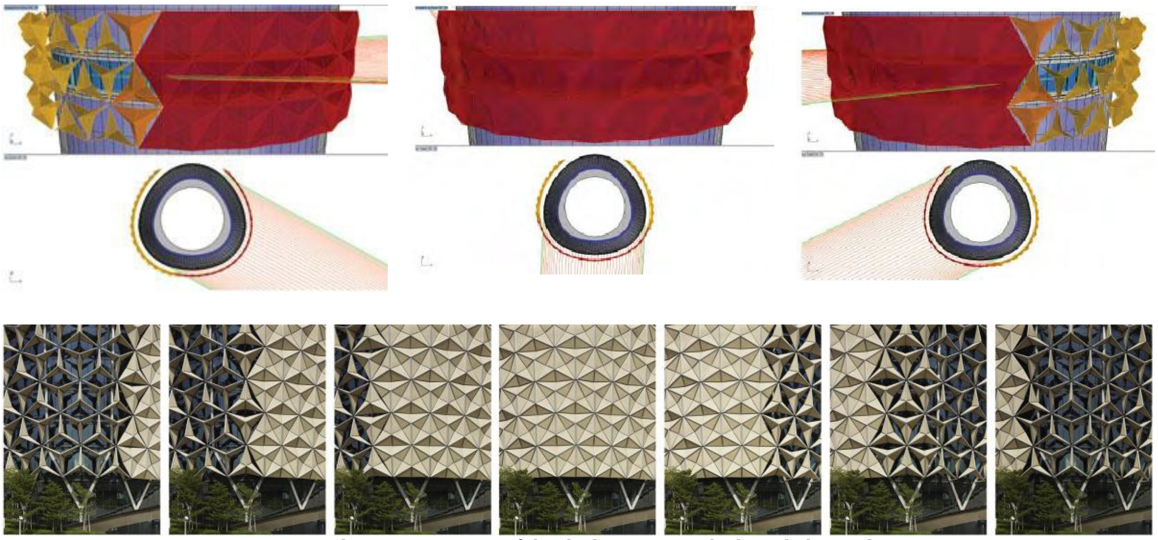


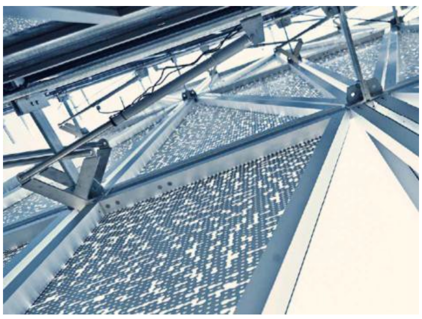
Figure 13. The Kinetic process of the shading system which track the sun location

7.4 SDU Kolding Campus

SDU Kolding Campus is a new central plaza by the Kolding River and will have an interaction with other educational institutions in Denmark. It is designed by Henning Larsen Architects and was completed in 2014.

The daylight changes and varies during the course of the day and year. Thus, the Kolding Campus is fitted with dynamic solar shading, which adjusts to the specific climate conditions and user patterns and provides optimal daylight and comfortable indoor climate spaces along the façade. Because the location of the university is in Denmark, the sun will be on a low angle throughout most of the year. The choice of a vertical kinetic facade is therefore a good one because a horizontal shading system wouldn't

Figure 14. Exterior shot of SDU Kolding Campus



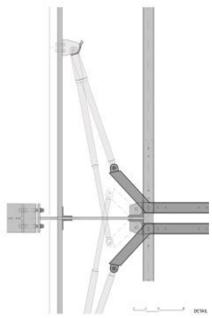


Figure 15. Interior shot of SDU Kolding Campus shows the amount of daylight entering the building block as much sun, as shown in Figure 14, 15

Figure 16. SDU Kolding Campus Kinetic façade detail

7.5 HelioTrace facade system

HelioTrace Façade System can trace the path of the sun over the course of a day and a year to significantly reduce solar heat gain while maximizing daylight and views for building users, this system is under construction (El-Semary, 2014).

In HelioTrace, a high-performance glass curtain wall is shadedusing two exterior devices: opaque panels that project from the mullions, perpendicular to the façade; and 50-percent perforated panels deployed parallel to the building envelope. Both can be programmed to respond to solar movement and interior occupancy. Energy savings are enhanced by integrated interior systems: chilled ceilings and beams, and an underfloor dedicated outside air system, as shown in Figure 17.

Figure 17. Showroom Dynamic façade system with unlimited faces, (El-Semary, 2013)

8. CONCLUSION

This paper presents the mashrabyia as an intelligent building skin and as the flexible adaptability of building façades to respond by motion to changing environmental conditions, taking into account human interaction and behavior.

The paper demonstrates, from the perspective of the mentioned modern mashrabiya with high-tech, that it can help mitigate various environmental problems and decrease the need for mechanical systems such as HVAC systems and artificial lighting, add to the occupants’ comfort, and potentially could be used to generate electricity.

Through this paper and our discussion of modern mashrabiya, some recommendations have been deduced as follows:

- Modern mashrabiya is a valuable tool for Architects, Engineers, Surveyors and Designers, so by proper design of interactive mashrabiya the size of the energy consumption system can be reduced bringing down the initial investment.
- Modern mashrabiya with high-tech daylight responsive systems represent a smart solution for various environmental & aesthetic considerations.
- Future researchers have to start focusing on the modern mashrabiya as it is time to shape future directions of the developing “Facades” in a sustainable manner.
- Mashrabiya wants some guidance outlines in the design phase to make it more useful to the environment and human needs with no omission for the aesthetic element.

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