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Interactive-Based Approach for Designing Facades in Digital Era

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Abstract :
No doubt that the digital revolution is widely changing the world, the computer applications have made digital technology as an essential part of our life. The architects and planners invest these technologies to develop the architectural design process. Recently, Interactive Media Facades (IMF) become signs in the city spaces. IMF considers an efficient tool that has electronic surfaces interacting with surrounding users and depends on techniques range from LED surfaces or projection displays to interactive materials with visual properties. Thus, it is important to present the design strategy of interactive facades. The structure of the present paper is divided into: a) introduces IMF, their perception and physical properties; b) presents various types of interaction with IMF; c) explores the interaction design phases; d) analyzes IMF examples by using space explorer model; and finally e) presents a holistic strategy for design IMF that will contribute for enhancing the design process with new approaches in the digital era**.**

Keywords: Design process, IMF, Interaction design, Interactive architecture, LED surfaces

1. Introduction

Architecture throughout history has generated new ways for renewing itself through new concepts and materials. Form using kinetic as seen on Institute du Monde Arabe in Paris, where the shutters automatically open or close to adapt to the lighting levels, to interactive architecture concept [1].

Nowadays the digital revolution impacts observed in several fields of our lives and our world is widely changing due to the applications of information age. As a result, new interactive technologies, materials and networked media have emerged and become devoted tools not only from our everyday life but also from architecture and urban spaces [2]. New interactive proposals and new urban spaces combined these tools that offer more possibilities for the visual programming of the digital surfaces through the interaction design process [3].

Interactive architectural concept has clearly shown and can be defined as the total integration of the specialties of interaction design and architecture [4]. In this concern, buildings become sign images in the urban spaces by using media technologies as architectural elements to enrich urban media (Fig. 1) with other complementary components as art, news, games, advertising, community media and architecture. The buildings emerged with special installations (large electronic screens) that change their characters due to the surrounding interaction, called Interactive Media Facades (IMF) [1, 5-7]. These facades defined through their surfaces or shells, the original term of "facade" is derived from "faces", which indicates the flexibility and responsively to external impacts, similar to the case for human faces [3].

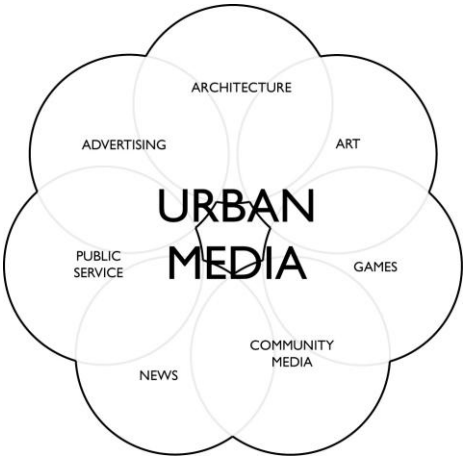

Figure 1: Types of urban media [1].

However, Silva Kalčić [8] thinks that the IMF is a mode of communication between architecture and the environment (the observer/passerby), wherein IMF become intelligent organism developing the traditional buildings using urban technology and building elements

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(Fig. 2) [3]. Therefore, IMF should enlighten people at different scales: eye, car level or to be seen from highways [7]. Hence, the esthetic aspects must be pastured for facade and IMF in parallel (static components and interactive installations) [3]. These installations are often embedded into architectural structures such as dynamic analogue with neon tubes, digital surfaces such as light-emitting diodes (LED) panels, flat screens, projection panels, info-terminals and smart architectural materials, that allow direct interaction with the facades, attract and involve the public audience in the interaction process [3, 9]. Therefore, designing IMF includes designing or modifying building's architecture to change its surfaces into large public screens [10].

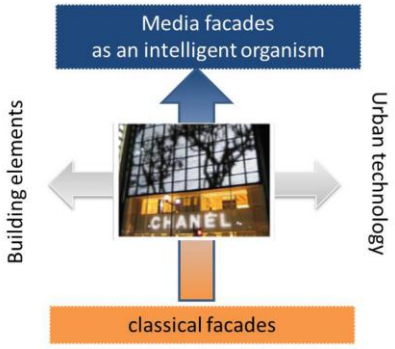


Figure 2: Classical spaces and facades enriched by media elements. Source the authors after [3].

Dalsgaard and Halskov [9] discuss the design process, its prominent arena for information systems design and present a unique set of challenges and potentials for designing systems of IMF and their installations.

The present study focuses on the interaction design of IMF through their perception aspects, categories of exterior spaces front the IMF, types of interaction with the IMF and design phases, and analyses the examples of IMF to present a holistic strategy for the design process of IMF that will contribute to enhancing the design process with new approaches in the digital era.

2. Interactive design of interactive media facades

Undoubtedly the spread of digital technology and new sorts of spatial and surroundings materials, challenges the way designers think about interaction design of IMF at architectural level. They combine materials with dynamic characteristics and interaction forms that allow interactivity at urban spaces [11, 12]. Consequently, buildings become more colorful and dynamic outer surfaces by the integration of digital media [7]. This section discusses related issues in interaction design process of media facades.

2.1. Perceptual aspects of interactive media facades

Perception of IMF is limited through three aspects (Fig. 3): environment, carrier and content.

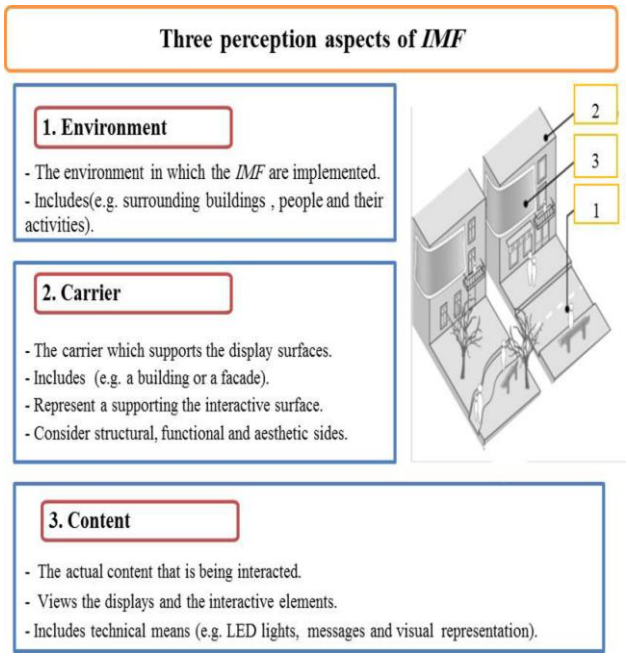


Figure 3: The Perception aspects of IMF. Source the authors after [13].

2.2. Categories of exterior spaces front interactive media facades

According to Fischer and Hornecker [14], there are seven categories of spaces and their relations with the IMF. These spaces change in size and location according to design processes and surroundings (Fig. 4).

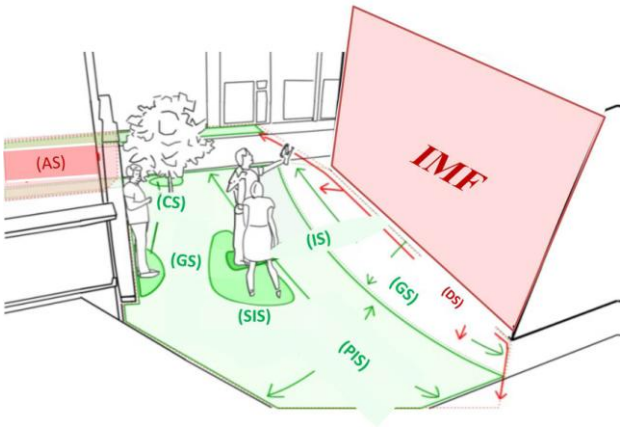


Figure 4: Categories of exterior spaces front the IMF [14].

- **Display Spaces (DS)**: spaces from which the user can see the displays.
- **Interaction Spaces (IS):** the users can interact with the facade form these spaces. They fit single user or many users.

- **Potential Interaction Spaces (PIS):** where the interaction between facades and users can possibly happen.
- **Gap Spaces (GS):** distances between users and facades or between humans.
- **Social Interaction Spaces (SIS):** users attracted by the IMF and take decision to interact with façades.
- **Comfortable Spaces (CS):** spaces that provide protective elements like walls, trees, etc.
- **Activation Spaces (AS):** facade's displays can be seen from [14].

2.3. The relations between space properties and front spaces of interactive media facades

Spaces generally influence on the perception the surrounding buildings. For that, characteristics of spaces are very important aspects and should be securitized through designing IMF. Spaces characteristics determined through their functions, components, shape and proportion. Therefore, the designers should generally realize the space properties and especially their relative to interaction process.

In this context, spaces proportion and inclusion consider the most characteristics connected with interaction process.

- **Spaces proportion**

  Spaces proportion term is defined as the relation between the length, width of spaces and the height of surrounding building (Fig. 5) [15].

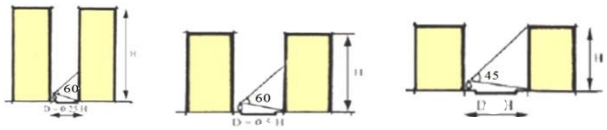


Figure 5: Proportion of main spaces [15].

As a result, when IMF designed, the designers should take mind the proportion of spaces front the IMF and choose the vast space to respect the functions and categories (DS, IS and PIS spaces).

Spaces inclusion

Inclusion degree of spaces is determined by human's visual field as presented in Fig. 6.

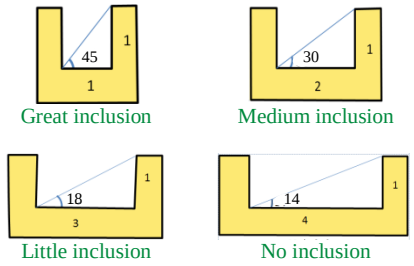


Figure 6: Space's inclusion degree [15].

Finally, when IMF designed, the designers should take in mind the inclusion of spaces front the IMF and choose the little inclusion degree to obtain the best vision to interact with the IMF. Hence, the dimensions of spaces linked to height of interactive objects.

2.4. Potential scenarios for interaction process

Unlimited potential for new forms of interaction between the IMF and users or participations offered due to the growing numbers of IMF in urban spaces, mainly for collaborative multi-user scenarios [16]. Thus, designers play a greater role in social interactions through using new media technologies along with IMF in urban spaces by realizing the following factors [17- 19].

- The users' behavior between attention and motivation (Fig. 7).
- Sequence phases of interaction process between IMF and the users (Fig. 8). They divided into peripheral activities, focal activities and direct interaction.
- F-formation pattern. It considers an effective tool for identifying the different spatial patterns and organizes the social interactions with the IMF. F-formation patterns include different configurations as: L-arrangement; face-to-face; side-by-side; semicircular and rectangular (Fig. 9) [17].

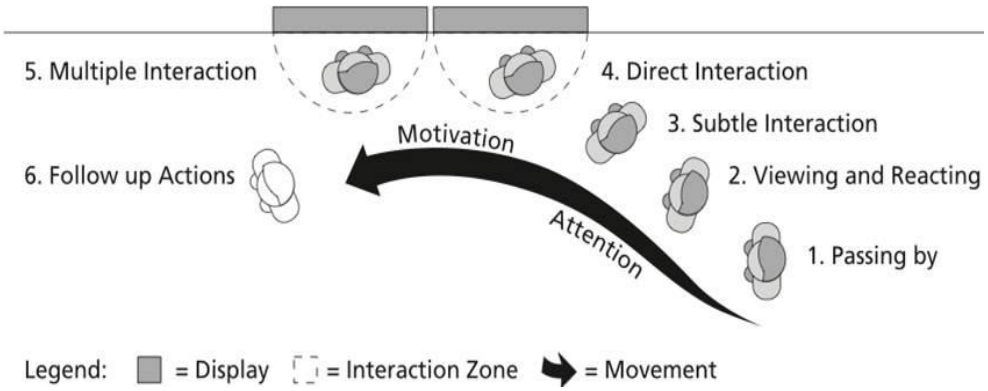


Figure 7: The users' behavior between attention and motivation through the stages of interactions with IMF [17].

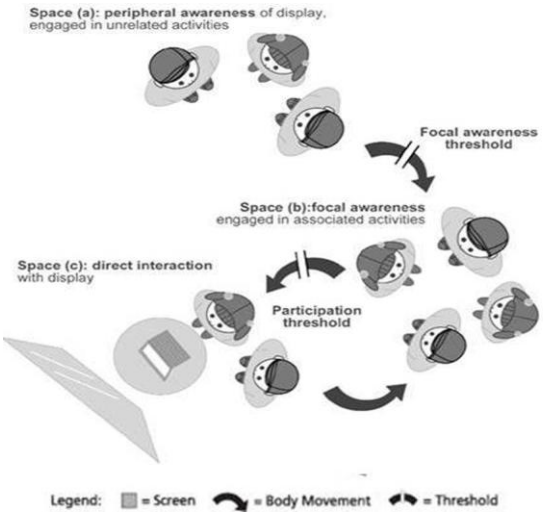


Figure 8: Sequence phases of interaction process between IMF and the users (19).

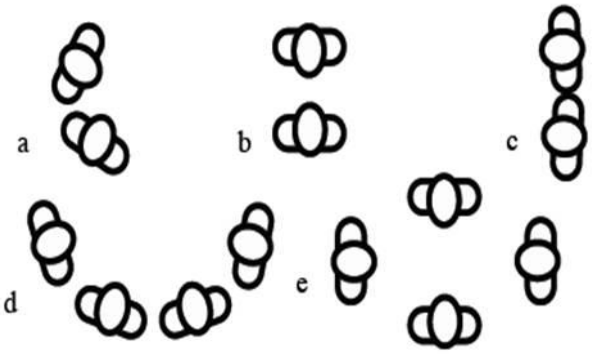


Figure 9: Potential scenarios for spatial patterns different F-formation configurations a. L-arrangement, b. face-to-face, c. side-by-side, d. semicircular, e. rectangular [20].

2.5. Types of interaction with interactive media facades

The users have many styles of interaction with IMF due to the spread development of technologies and technical materials. Hence, the study presents the types of interaction with media facades and classifies these types according to their distances and influences on IMF. Types of interaction are summarized in Fig. 10 and illustrated in the following points.

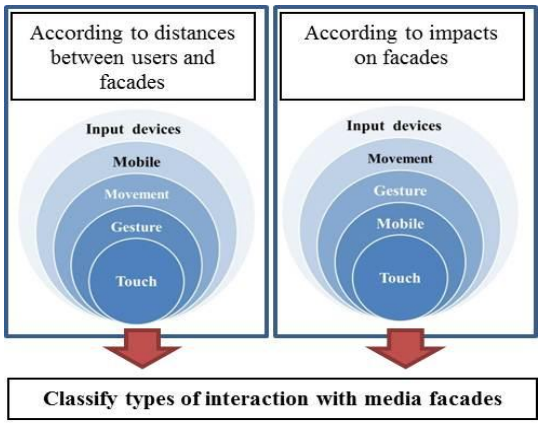


Figure 10: Types of interaction classifications.

2.5.1. Through touch

Any user can interact with IMF without special talents or any previous knowledge. Such as CityWall (Fig. 11), where is mainly appropriate for exploring media in general, and of photos in particular [21].

Figure 11: Example of touch interaction City Wall installation in Helsinki, Finland [21].

2.5.2. Through gesture

Gestures can originate from any bodily motion, however, usually originate from the faces or hands. Users encountered a view of dynamic participations following around the IMF [22]. The best example is Aarhus by Light (Fig. 12) which, emerging users in a new sort of public performance that exploring new possibilities of digital media in urban spaces [9].

Figure 12: Example of gesture interaction by visitors interacting with Aarhus by Light [9].

2.5.3. Through movement

The IMF also responded to the movement of people passing by (Fig. 13). The first example is a Dynamically Transparent Window (DTW) that supported electro-chromatic foil. It can change from solid to transparent when any user pass front it. The second example is The Climate Wall, it is an interactive generator of climate messages. People passing by the facade could hold a word in their body [9].

Figure 13: Examples of interaction by movement: a) Dynamically Transparent Window in shop facade, b) The Climate Wall [9].

2.5.4. Through mobile

Recently, users can interact simultaneously with IMF in other ways through mobile devices (Fig.14). The size, visibility, and large spectators of media facades offer a great potential for interaction participation [16].

On one hand, this type depends on touch projector concept, which transforms the input occurring on the mobile device to facade's server. Thus, interactive controls are shown on the facade surfaces. On the other hand, the live video on the mobile device shows the facade at all times by covering the mobile screen by personal layer on the local live video (Fig.15) [16].

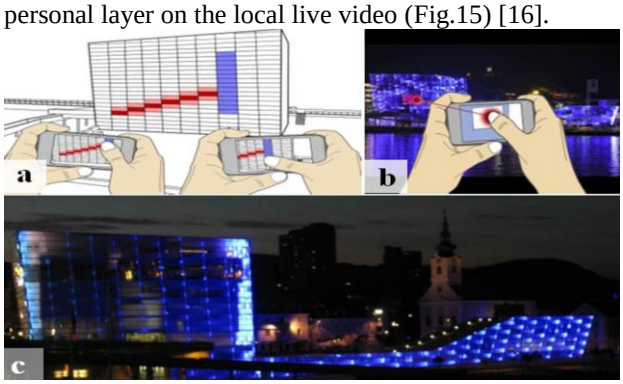


Figure 14: Example of interaction with mobile: a) changes are shown immediately on the facade, b) mobile interactions, c) Ars Electonica Center in Linz, Austria [16].

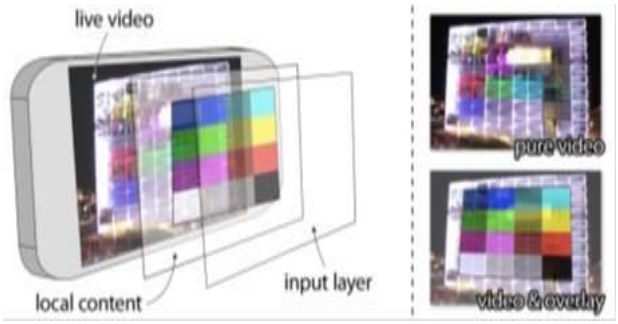


Figure 15: Mobile preparation to interact by mobile [16].

2.5.5. Through input device

Users can interact with IMF through digital devices such as SMSlingshot (Fig. 16) that connecting art, architecture, and technology. The messages could be shot onto the facade through a pinball trigger [14].

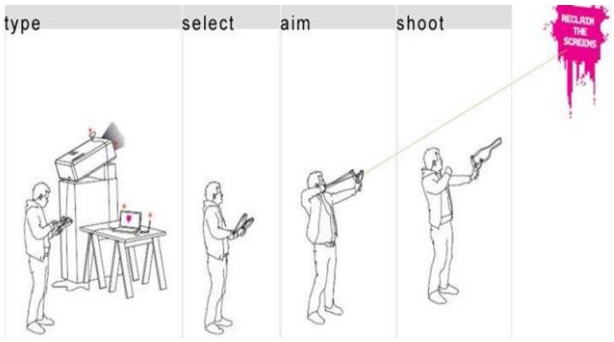


Figure 16: Interaction process with the SMSlingshot [14].

2.6. Physical properties of interactive media facades

The physical properties of IMF differ from regular traditional facades. There are many differences between the purposes of traditional facades and the IMF, the first considers a defensive layer for privacy and climatic influences, it also symbolizes a building's cultural era [15], the second can play a great role in surrounding urban spaces such as: include information, entertainment, art, advertisement [21], gathering the public opinions on certain topics, creating a public playground for participation games or consider attractive landmarks [2]. In this concern, there is another aspect belongs to the presented media and its resolution.

IMF has large dimensions (edges extend more than ten meters). Their resolution is very great and depending on the display technology used. The following presents and regards the different display techniques for IMF according to resolution of displays (Fig.17).

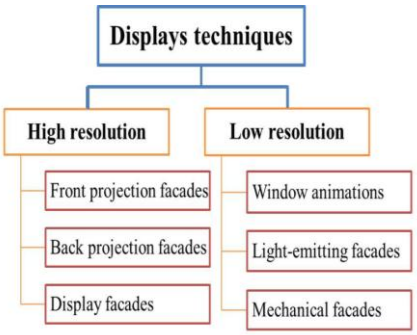


Figure 17: Different displays techniques for IMF according to resolution of displays. Source the authors after [10].

Wiethoff and Gehring [10] discuss these techniques as follow:

- **Front projection facades:** projector device faces directly the facade via one or more video projectors.
- **Back projection facades:** displays generated from behind the facade.
- **Display facades:** contents delivered by combination large screen video displays into the building's surface.
- **Window animations**: windows in a building used by illuminating them, so they are perceived as *pixels*.
- **Light-emitting facades:** facades include LED panels emitting elements into their surfaces.
- **Mechanical facades:** using mechanical kinetic elements to change facade shape [10].

3. Interactive media facades Design Phases

Interactive design process represents world of information systems design and faces group of challenges and possibilities for the interactive design process [9]. Thus, this study discusses and analyzes the interaction design phases including information design, interactive design and sensorial design.

3.1. Information design

This phase considers the start of any interactive project and includes analyzing of the following points:

- **Site tour**: studies the quality of place and the surrounding environment.
- **Interactive users**: recognize the demands of target users, activities and exploring the potential users may perceive.
- **Context**: defines the functions of context, the relevant technologies and interactive environments.
- **Key data collection**: looks at reference projects dealing IMF.
- **Data mapping:** maps out the analyzed data through flowcharts [23-25].

3.2. Interactive design

This phase tracks the path of the user's activities and demands. It includes great steps:

- Convert the flowchart into a storyboard or scenarios, which specifies the participations and the users converting information into user experience. A storyboard is a communication instrument to imagine the sequence of user actions.
- Discover opportunities to obtain experience efficiently and knowledge.
- Put the alternatives of design through scenarios.
- Evaluate the design alternatives to obtain the best design.
- Obtain the best design through evaluation criteria.
- Create a prototype of the chosen design by sketching, manual or digital [23-25].

3.3. Sensorial design

This phase creates the suitable use of several media and technology tools (input/output). The suitable tools have many conditions such as:

- Make the interaction process faster, flexible and efficient.
- Use interactive surfaces easily.
- Be suitable for one or more users,available and accessible for designers and planners.
- Present the interaction design process in various forms [23-25].

4. Selected Projects

This study presents three projects that implement IMF concept. The analysis depends on space explorer model by Dalsgaard et al. [12]. The selected projects are: Aarhus by Light (AbL), Climate on the Wall and ARS Electronica Center.

The selection of these projects depends on their advanced types of interaction used, different purposes or messages, technical installations configured and being designed for significant events worldwide.

4.1. Aarhus by Light (AbL)

Aarhus by Light considers a two-month social experiment with the IMF, that users explore new kinds potentials of digital media in urban spaces (see Figure 18) [20], therefore this study analyzes this project through specific following points [1, 9].

Figure 18: Colored carpets of AbL and interaction by gesture [16].

- **Location:** Concert Hall Aarhus is the second largest city in Denmark towards to the adjacent public park.
- **Interactive Users:** visitors and passersby.
- **Content:** there are two main content elements.
    - Line art skyline of Aarhus landmarks, which slowly appears and disappears freely of other elements (Fig. 19).
    - Silhouettes of users displayed on specific parts of the facade and connected with the user's position in the interaction zones in the park.

Figure 19: Line art skyline of Aarhus landmarks [16].

- **Form:** the form of LED panels in AbL is rectangular, emerged with the facade modules.
- **Interaction concept:** when visitors walk around the park, they pass through three colored interaction carpets. When any user stands on the carpet, a sensor picked up the outlines of his body creating a silhouette on the facade. This silhouette encouraged a playful exploration of the communication between users, while enabling them to interact with the facade by the user's gestures (Fig. 19, 20), where the facade's installations respond automatically.

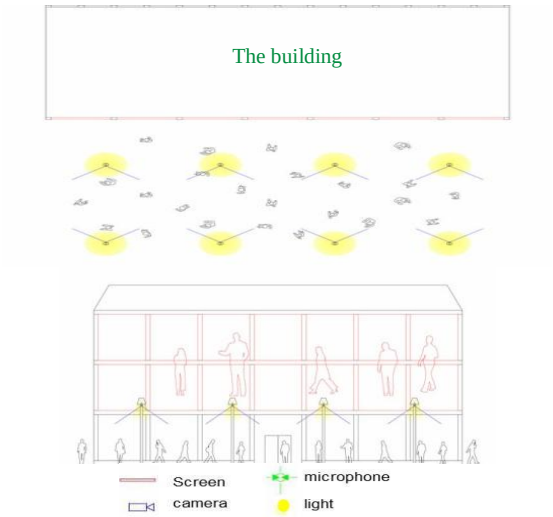


Figure 20: The layout and elevation of Abl project [26].

- **Materials:** they are two different components.
    - Semitransparent LED panels (180 square meters)**:** each panel includes 25x50 pixels that are gathered to a display counting 1250x150 pixels. The panels are semi-transparent and are invisible from a distance.
    - Colored carpets**:** pink, yellow and blue, these carpets are used in the park to attract users to interaction zones.

4.2. Climate on the Wall

This wall considered a large-scale IMF that could be seen from distant during night and generates climate and statements through people's movements on the street (Fig. 21). It considered an event within AARHUSCO2030, an initiative from the 5th to the 8th of March 2009. The event aimed to raise awareness about carbon emissions in Aarhus through: 1) attracting the public to communicate with the climate theme; and 2) raising AARHUSCO2030 concept, regard the dialogue and public contribution about how to treat with the carbon emission facing the city [1, 9]. Thus, this study analyzes this project through these points [10, 14, 16].

- **Location:** these installations were running on the facade of Ridehuset, a central and famous historical building in Aarhus, which located at the corner of two busy streets.
- **Interactive Users:** passersby.
- **Content:** words about climate change, relating to carbon emissions and climate issues float around or above the heads of passersby.
- **Form:** Ridehuset is rectangular facade.
- **Interaction concept:** the installation served as a platform that offered simple conversations about the climate through the following:
    - When people walked or passed by the facade, the words flowed from the facade. These words related to the current climate discussion, like 'more', 'less', 'cars', 'trees', 'people', 'like', 'ice', and 'climate', consequently if a person stopped, the words above him grew and turned into speech bubbles around the word closest to them. These bubble words drop down from above and dragged to a different part of the facade by user's movement.
    - Users could create sentences with these bubble words through picking any word available on the wall and placing it in the sentence.
    - The sentence could be done by one user or multi users that led to spread participation concept.
- **Materials:** the facade's material was the traditional bricks.

Figure 21: Interaction with Climate Wall [10, 14, 16].

4.3. ARS Electronica Center

This building offered anther advanced interaction process between mobile devices of users and their facade (Fig. 22, 23). The interactive process held during the Ars Electronica Festival in September 2010 by interacting through the live video concept. This study analyzes this project through specific points below [9, 12, 21, 27].

- **Location:** the building located at Liz, Austria.
- **Interactive users:** any user had a mobile application that its software allowed to interact with facade through live video (using the camera of an iPhone).
- **Content:** the content of this facade included two applications:
    - Users could solve a 15puzzle on the facade, which looked like eight pixels (i.e., 2 by 4 windows) were representing one tile of the puzzle.
    - Users could paint freely on the facade. Like common drawing applications.

Figure 22: Mobile applications interacting with ARS Electronica Center [27].

- **Form:** ARS Electronica Center is a compound shape consists of three blocks.

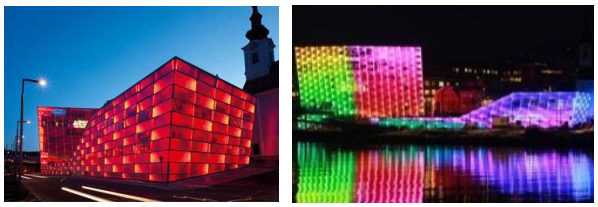


Figure 23: Outer facade of ARS Electronica Center [22].

- **Interaction concept:** interaction with media facade happened by live video on mobile devices, which sent signals to the server; this server applied the interaction to the façade allowing users to (i.e., paint multicolored light on the LED panel) via touch input and technical components (i.e., iPhone, Wi-Fi router, application server, DMX lighting system, and LED lighting elements).
- **Materials:** glass shell that includes a 5,100 square meter LED consisted of 1085 colored windows in size of 3x1 meters. The colors and intensity of the lights can be changed group-by-group (RGB based colors). The size of the building allows a viewing distance of up to 300 meters, with an optimal distance being about 50 meters.

5. Results and Discussions

The IMF design process requires a holistic strategy to obtain good results. Therefore, this study presents general strategy for the design process as illustrated in Table1.

The design process of IMF differs from existing buildings to the building in the design phase, these different influences on the types of interaction with them. Also, the outer surface/material of the building affects in determining the types of interaction and the technical installations of the facade.

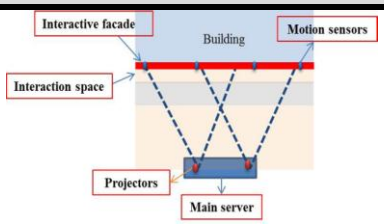
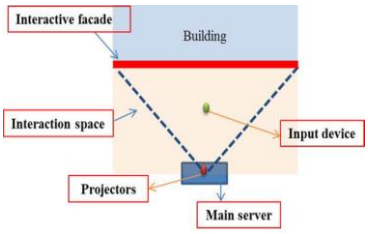
Gestures or movements greatly depend on motion sensors with web cameras that follow and track the interacting users with the IMF. However, Mobiles or input devices depend on the connections between mobile and input devices, and main control unit which interacting with user's actions.

6. Conclusion

This study approaches the IMF concept and the relationship with interactive architecture. Interactive media architecture can evidently contribute to enhance the design process with new approaches in the digital era. As a result, *the* IMF allows new ways of combining media, technology and architecture**.** It presents a successful way to attract consumers, passerby and urban spaces' users or it could show specific events. Recently, IMF increased continually due to their high performance in many aspects and their great potential for new forms of social interaction that attract users rather than the traditional facades.

This paper draws out guidelines phases of designing IMF and presents a holistic strategy for the design process of IMF. No doubt that, interactive process increased by converting the users to participations and by changing the facades' shapes with unexpected way with advanced technology. However, it remains an open question to what degree and how users should balance between fully control the environment and collaborative interactions with social spaces in a positive way. We hope that both the conceptual and practical design process leading to both enjoyable and functional urban spaces.

Table 1: Proposed strategy for IMF.

Facade's surface	Types of interaction	The installations	The illustrations
Existing facade (old) — Traditional or solid surfaces (e.g. bricks , concrete and stones)	Gesture Movement	• Motion sensors with cameras are supported with custom software to transform the gestures or movements of users to the main server. • Main server can contact and send actions of users to projectors. • Projectors convert the gestures or movements to interaction process. **Observation:** streets or paths could be allowed between projectors and the interaction space.	 The range and distance between the motions sensors or projectors determined according to the recent types of technology.
	Input devices	• Input devices with infrared rays and keypads which connecting and transforming actions to main server. • Main server that transforms the signals from input devices to projectors. • Projectors receive signals from server and reproduce them to the facade surface through reactions. **Observation:** the space between projectors and facades consider interaction space (not allowable for any obstacles).	
Facade design phase (new) or existing facade (old) — light-emitting diode (LED) surfaces	Touch	• LED panels can interact automatically with users by tangible.	
	Gesture Movement	• Motion sensors with cameras are supported at LED units. • Main control unit in the building can receive signals from motion sensors and turn back signals, that LED can transform them to shapes interacting with users.	
	Mobile devices Input devices	• Personal mobile devices or input devices provided with special software that send signals to control unit in the building by users. • Main control room in the building can receive signals from mobile devices or input devices and turn back visible signals to the LED surfaces on the facade, where the user can interact with the facade.	
Fluorescent tubes	Gesture Movement	• Motion sensors and cameras fixed with fluorescent tubes, which can send reactions of users (gestures or movements) through signals to control unit. • Main control room in the building can receive signals from motion sensors and turn back signals to the fluorescent tubes interacting with users.	
	Mobile devices	• Personal mobile devices with special software applications send signals to control unit in the building by users. • Main control room in the building can receive signals from mobile devices and turn back visible signals to the fluorescent tubes on the façade.	
Smart materials (Nano technology)	Touch	• These mart materials such as Silver Nanowires respond to tactile inputs through specific software.	
	Gesture Movement	• Web cameras are fixed above the facade, which connecting with computer software. • Software (with control unit) can control at smart materials. • These smart materials such as electro-chromatic foil can transform their characteristics through electronic control.	

7. References

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الملخص العربي:

النهج التفاعلي كمدخل لتصميم الواجهات في عصر الثورة الرقمية

مما لا شك فيه ان الثورة الرقم ية غيرت بشكل كبير العالم ، حيث جعلت تطبيقات الكمبيوتر و تقنيات التكنولوجيا الرقمية جزء رئيسي من عالمنا، و علي هذا السياق المعماريين و المخططين استغلوا ه ذه التكنولوجيا و خاصة التفاعلية في تطوير عملية التصميم المعماري.

حيث أصبحت في الآونة الأخيرة الواجهات التفاعلية علامات مميزة في فراغات المدينة و تعتبر أداة كفؤ ذات أسطح الكترونية تفاعلية تعتمد علي التقنيات المتقدمة التي تتراوح من شاشات الضوء المنبعث أو العرض من خلال أجهزة الاسقاط الي مواد البناء التفاعلية، و لهذا يهدف البحث الى تقديم استراتيجية لتصميم الو اجهات التفاعلية في الفراغات العمرانية المختلفة.

و تنقسم الدراسة الي : 1- مقدمة عن الواجهات التفاعلية و كيفية ادراكها و مواصفاتها، 2- تصنيف الانواع المختلفة للواجهات التفاعلية ، 3- تحليل مراحل تصميم عملية التفاعل، 4- تحليل أمثلة من الواجهات التفاعلية، 5- تقديم استراتيجية عامة لتصميم الواجهات التفاعلية التي تساهم في تعزيز عملية التصميم التفاعلي في ظل الثورة الرقمية.

الكلمات المفتاحية :

الواجهات التفاعلية، عملية التصميم، عملية التفاعل، العمارة التفاعلية، أسطح LED.