Moving Images – Static Spaces: Architectures, Art, Media, Film, Digital Art and Design

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New Ways of Design Presentation: Interactive Projection Mapping as a Presentation Tool in Architectural Design Process

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INTRODUCTION

In parallel to the developments in computer technology, it has become inevitable to use new representation mediums and forms of representation production in order to increase production and efficiency in the field of architecture. In this developmental process, Virtual Reality and Augmented Reality representation mediums have come into sight and become used in architecture. The forms of representation production in these medium types offer experiences beyond the ability of users to observe photo-realistic images or computer-aided animations via computer monitors.

While the Virtual Reality presents the 3D and immersive medium to the user through the head-mounted display, the virtual world is integrated with the physical space in Augmented Reality types in which equipment head-attached and hand-held are used. Among all these types, Spatial Augmented Reality type, in which the projectors are used, is entirely different from others regarding the spectators' way of using the medium. In the Spatial Augmented Reality medium, no equipment connected to the body of the user is used, and the user with the naked eye can monitor the integration of the virtual object with the physical space. Because of these features that Spatial Augmented Reality environment has; it is used in a lot of fields such as installations and theatrical shows.

During the historical process of architecture, a variety of 3D techniques have continually being developed in the use of perspective drawings and models, and nowadays in digital representations. This historical process shows how important that the use of 3D representation is for architecture. Spatial Augmented Reality medium which is used in many fields give the impression that powerful of 3D sensation that can be seen with the naked eye, and it is the essential factor for the use of this representation in architecture.

In this study, the presentation mediums in architecture were examined and then the use of Projection Mapping as a representation medium was compared in terms of interaction with other multimedia representation types. In the implementation discussed, the use potentials of the Projection Mapping technique with an interaction type in the architectural field were investigated by using the types of analysis and the alternatives of the design in urban fabric.

REPRESENTATIONS IN ARCHITECTURE

Goodman refers to the concept of representation in his book; "The most naive view of representation might perhaps be put somewhat like this: "A represents B if and only if A appreciably resembles B", or "A represents B to the extent that A resembles B". Vestiges of this view, with assorted refinements,

persist in most writing on representation. Some of the faults are obvious enough. An object resembles itself to the maximum degree but rarely represents itself; resemblance, unlike representation, is reflexive".[1]

Since the qualities of the represented in its essence are transformed, when representer represents something. For this reason, the state of representation includes a qualification beyond resemblance.

Zettl indicates that the person who performs the representation transfers this characteristic by being clarified, intensified and interpreted after perceiving certain aspects of the representation. [2]

It is important to classify representations in order to understand the representations used in architecture and to distinguish between these representations.

These representations used in architecture classify as: [3]

-Iconic representations: Perspectives, models

-Analytical representations: Various graphics, contour lines, painting

-Symbolic representations: Languages used in cultural differences and made up of words.

Today, in addition to these three representations in architecture, digital representations are considerably being used. The most important feature of these digital representations is that they have the power to present the whole of iconic, analytical and symbolic representations together and in a practical way.

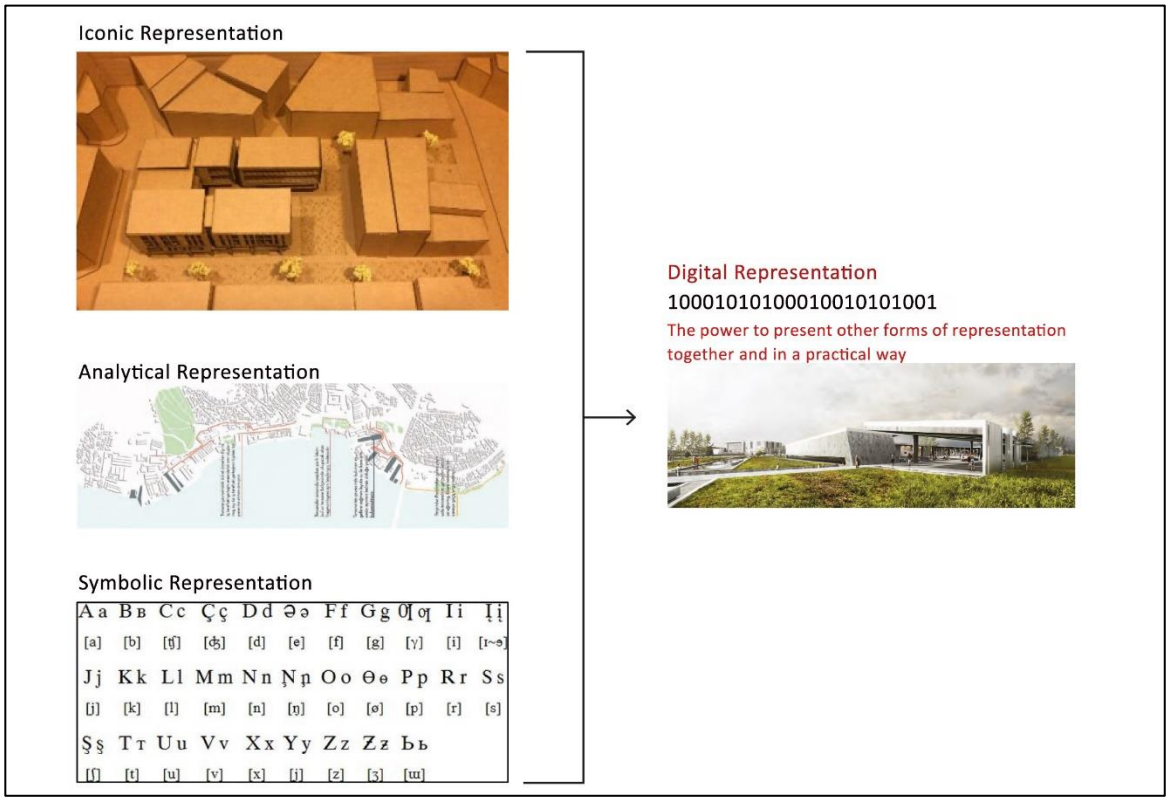


Fig 1. Digital representations can include the entirety of other types

As it is in many design areas, architecture as a production area needs various representation mediums to present the designed space. These representation mediums in architecture are used in the design process, at the end of the design process and the end of the construction of the final product.

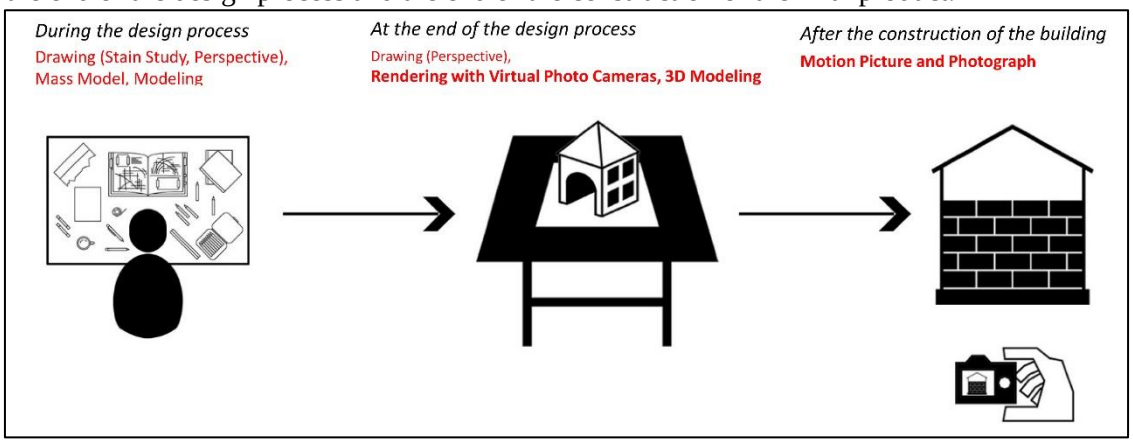


Fig 2. Usage phases of representations in architecture

Smeltzer and team classify representation mediums as:
- Computer screens,
- Printed images
- Photos, slides
- Visual animations
- Virtual Reality systems.[4]

Aydin classifies representation mediums in his doctoral thesis as;[5]
- Traditional Architectural Representations
Line
Perspective
Models
-Multimedia Architectural Representations
Architectural Representation in Cinema
Architectural Representation in Computer Medium[6]
Architectural Representation in the Virtual Reality Medium.
It is very important to add the Augmented Reality environment which is used in architecture today to Aydin' classification.

TRADITIONAL ARCHITECTURAL REPRESENTATIONS

The use of traditional representation based on the production process in which the crafts production activities were maintained became technic representation having rules after the Enlightenment Revolution because of the architecture that became a professional occupation. These types of representations are also used today; free-hand drawings, perspectives and models.
Scale hand-drawn drawings (plan-section-view-scale perspectives) had continued to exist as a strong representation in architecture till the prevalence process of digital representation in addition to freehand drawings, sketches in another name.[7]

Another traditional representation type, perspective, is basically the expression of a 3D object in a 2D medium. Today, producing scaled perspective by hand have lost the prevalence of architectural use due to the ability of computer-aided digital representation to produce this representation effectively.
The architectural model is one of the representations used in architecture to express a design as 3D and to transmit these 3D relationships to the spectator.[8] In this type of representation, the scale is chosen by its unique state of design. Due to the vocational education of the architect in the school; this means of scale representation shows what the actual building will be, and effectively expresses the context of the building with its surroundings.[9]

ARCHITECTURAL REPRESENTATIONS IN MULTIMEDIA

Multimedia mean that the medium which appeals to multiple senses of the spectators and therefore the multiple media are used together. The production of architectural representation in multimedia arouse as the heritage of traditional representations which is old-traditional cultural forms and languages, depending on the historical process of architecture. The necessity of using *multimedia* naming instead of *digital representation* of these types of representation is due to the fact that the history of new media tools precedes the development of digital tools in parallel with the history of cinema and that these take from cinema as features of multimedia.[10]

Architectural Representation in Cinema Medium

The relation of the cinema to architectural representation is based on the necessity of using space or space representation to create a moving image in cinema environment. Space which is the main component of the architecture is used in 3 forms as real, decor and virtually created spaces in the cinema.[11] In the use of space as real and decor, it is necessary to create a recording with the camera and then to edit the images by conventional or computer-aided techniques.

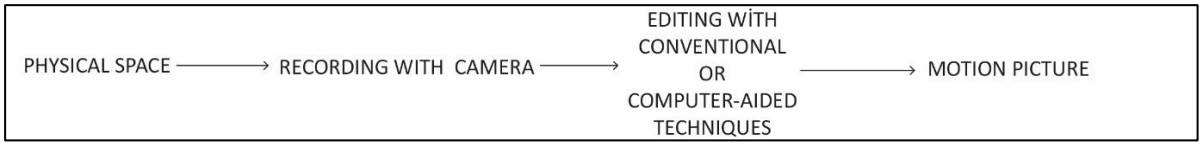


Fig 3. The production process of real space or decor in cinema

The producing representation of the virtual space in the cinema can only be realized by computer-aided methods.



Fig 4. The production process of virtual space in cinema

Architectural Representation in Virtual Reality Medium

Virtual Reality (VR) refers to the medium in which a user can experience a 3D world that does not exist in reality through various simulation tools and has the opportunity to travel here. In the process of using VR as a medium of representation in architecture, virtual space is created through software that computer-aided representations are produced, after which the user can navigate in a virtual world with computer connected devices and experience 3D effect. The most important device among the devices used by the user to experience VR technology is the head-mounted display.

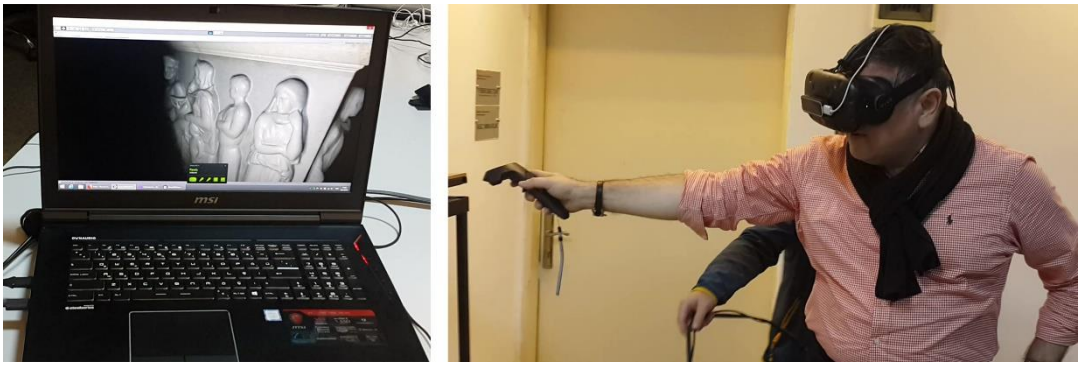


Fig 5. Experiencing VR through head-mounted display

Architectural Representation in Augmented Reality Medium

Contrary to the VR, production of representation in Augmented Reality medium, it includes the ways in which a virtual world intertwines with the real world. In order to create an architectural representation in Augmented Reality (AR), a more complex process involving the entire process of producing representation in Virtual Reality and computer is required. In the use of AR systems, a variety of digital tools and equipment are requirement for visual representation in real space.[12]

Bimber and Raskar indicate that "*Augmented reality displays are image-forming systems that use a set of optical, electronic, and mechanical components to generate images somewhere on the optical path in between the observer's eyes and the physical object to be augmented.*" [13]

Bimber and Raskar deal with the Augmented Reality systems under three titles as the **head attached, hand-held and spatial**.[14]

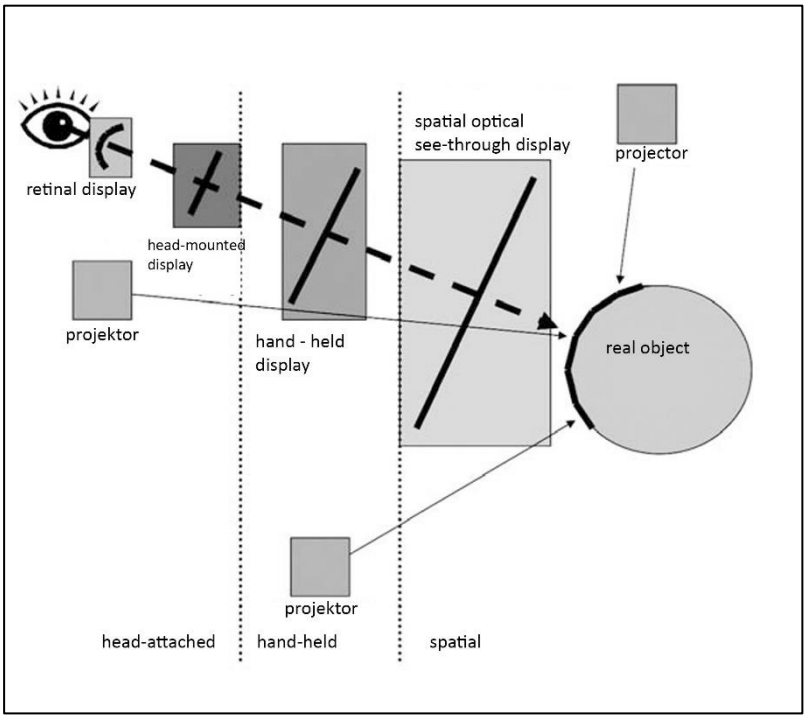


Fig 6. According to Bimber and Raskar, AR types

According to Dalsgaard and Halskov, *3D projection is best defined as Augmented Reality (AR), since it consists of digital information that is projected onto physico-spatial structures.* [15]
Representment in the Spatial Augmented Reality has again transformed into presentation of representation from other multimedia types.[16] **Because Spatial Augmented Reality can integrate with physical and spatial objects; the representation gives the opportunity to integrate with another type of representation or even with the represented object.**[17]

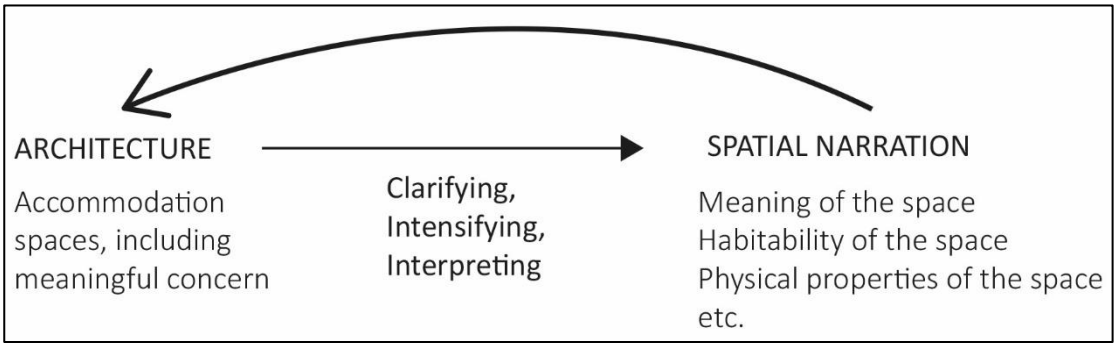


Fig 7. Architectural representation in Spatial Augmented Reality

THE RELATION BETWEEN INTERACTION DESIGN AND ARCHITECTURAL REPRESENTATION MEDIUM

The design is an activity where the architect interacts with various tools and stakeholders in different types. In this activity, the interaction with digital devices is constantly being renewed, which also enhances the interaction with the stakeholders. In order to understand the interaction of the architect with the digital tools, it is necessary to understand in which points the architecture intersects with the interaction design.
When the historical process of the interaction design is examined, it is observed that the interaction types are very strong relation with space. Interaction systems controlled by tangible, freehand gesture movements and many more need space or a space element.
In the researches about the digital tools used in architecture, the relations between the architects and the design tools and the way of interaction is at the forefront. For this reason, the intersection of these two fields is the issue for which digital tools the architect uses and how the architect interacts these tools.

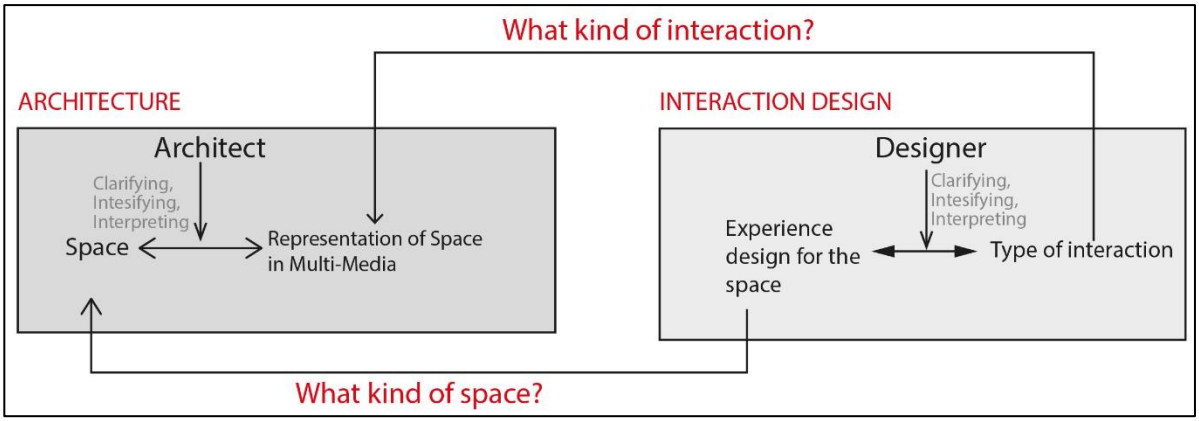


Fig 8. Relation between architecture and interaction design

According to Wiberg and others; From the earliest 2D graphical user interfaces to 3D representations, emerging into mobile computing, context-aware computing, urban computing, public displays, ambient computing, tangible computing, and ubiquitous computing, our awareness of space and its role in the interaction process is becoming more distinct. [18]
It is important to examine the tools used to better understand the physical relations between architecture and interaction design, based on today's interaction types. Karray and others deal with today's human-machine interaction in two main themes as single mode and multimodal, regarding their technical usage types. [19]

Visual-Based Interaction	Audio-Based Interaction	Sensor-Based Interaction
• Facial Expression Analysis • Body Movement Tracking (Large-scale) • Gesture Recognition • Gaze Detection (Eyes Movement Tracking)	• Speech Recognition • Speaker Recognition • Auditory Emotion Analysis • Human-Made Noise/Sign Detections (Gasp, Sigh, Laugh, Cry, etc.) • Musical Interaction	• Pen-Based Interaction • Mouse & Keyboard • Joysticks • Motion Tracking Sensors and Digitizers • Haptic Sensors • Pressure Sensors • Taste/Smell Sensors

Fig 9. According to Karray and others, single mode interaction types

VR is a multi-modal representation medium with a variety of visual-based and sensor-based interactions from interaction types. The Augmented Reality types of hand-held and head-attached devices used show features similar to the multi-mode. However, the interaction types of Spatial Increased Reality is based on the preference of the practitioner. The interaction types of these are examined in Table 1.

Table 1. Interaction Levels of multimedia representation mediums

Representation Medium	Virtual Reality	Augmented Reality		
Imaging Device:	Head-mounted Display	Projector - Projection Mapping	Hand-held	Head-Attached
	T Y P E S	O F I N	T E R A C	T I O N
Visual-based Interaction:	Body Movement Tracking	Body Movement Tracking (Optional)	Body Movement Tracking	Body Movement Tracking
Audio-based Interaction:	1-Human-Made Noise/-Sign Detections (Gasp, Sigh, Laugh, Cry, etc.) (Optional) 2- Musical Interaction (Optional)	Human-Made Noise/Sign Detections (Gasp, Sigh, Laugh, Cry, etc.) (Optional)	Audio-based Interaction (Optional)	Audio-based Interaction (Optional)
Sensor-based Interaction:	1-Joysticks 2- Motion Tracking Sensors and Digitizers 3-Haptic Sensors (Optional)	1-Mouse & Keyboard 2-Motion Tracking Sensors and Digitizers(Optional) 3-Haptic Sensors (Optional)	1-Haptic Sensors 2- Pen-based Interaction	1-Joysticks(Optional) 2-Motion Tracking Sensors and Digitizers
Level of Interac-tion in Today's Usage:	VERY HIGH	LOW	HIGH	HIGH

Among these types, VR moves away the user from the real world while having a volumetric 3D effect on the user in the virtual world. The head-attached type is similar to the VR, while the use of hand-held equipment in AR is similar to the usage of the monitor (Table 2).

Table 2. General comparison of multimedia representation mediums

Representation Medium	Virtual Reality	Augmented Reality		
Imaging Device:	Virtual Reality Simulation Headset	Projector - Projection Mapping	Hand-held	Head-Attached
Purpose:	Experiencing the user in a 3D virtual world	Offering a virtual image experience on a real-physical object with the naked eye	Displaying the created virtual object through the cameras on the mobile devices.	Displaying of the virtual object with retinal and head mounted simulation device.
Advantages:	1- Volumetric 3D virtual medium 2- Immersive effect	1- Group viewing opportunity 2-Attaching to virtual and real object 3-High resolution 4-High number of FPS 5- Angular imaging without head rotation tracking	Devices are quite portable	Offering a volumetric 3D opportunity to the user
Disadvantages:	1- Side effects for the user due to the use of simulation headset 2-FPS in under optimal level 3-Allowing individual use only 4-Taking the user out of the real world	1- Poor volumetric effect 2-Influencing of brightness of real environment and material reflection level	In these systems, since the monitoring is done via a monitor, the effects are very close to the presentation of the representations in the computer-aided motion picture medium	These systems are similar to Virtual Reality systems in regard to disadvantages.
Level of Interaction in Today's Usage	Very High	Low	High	High

Although the Spatial Augmented Reality (Projection Mapping) allows for a poor interaction with the spectator, it differs from all other mediums because of its ability to integrate the virtual object in physical space (nature) in a way that seen by the naked eye.

ARCHITECTURAL REPRESENTATION IN PROJECTION MAPPING

The methods used in the implementation process of the Projection Mapping (PM) include the ways developed by combining the techniques used in the fields of cinema and visual effect (VFX). This process includes a series of stages. These stages are that beginning with the projectors and surface selection, followed by the creation of the images for reflection in the computer with various software, the completion of transmission the images generated to PM software.

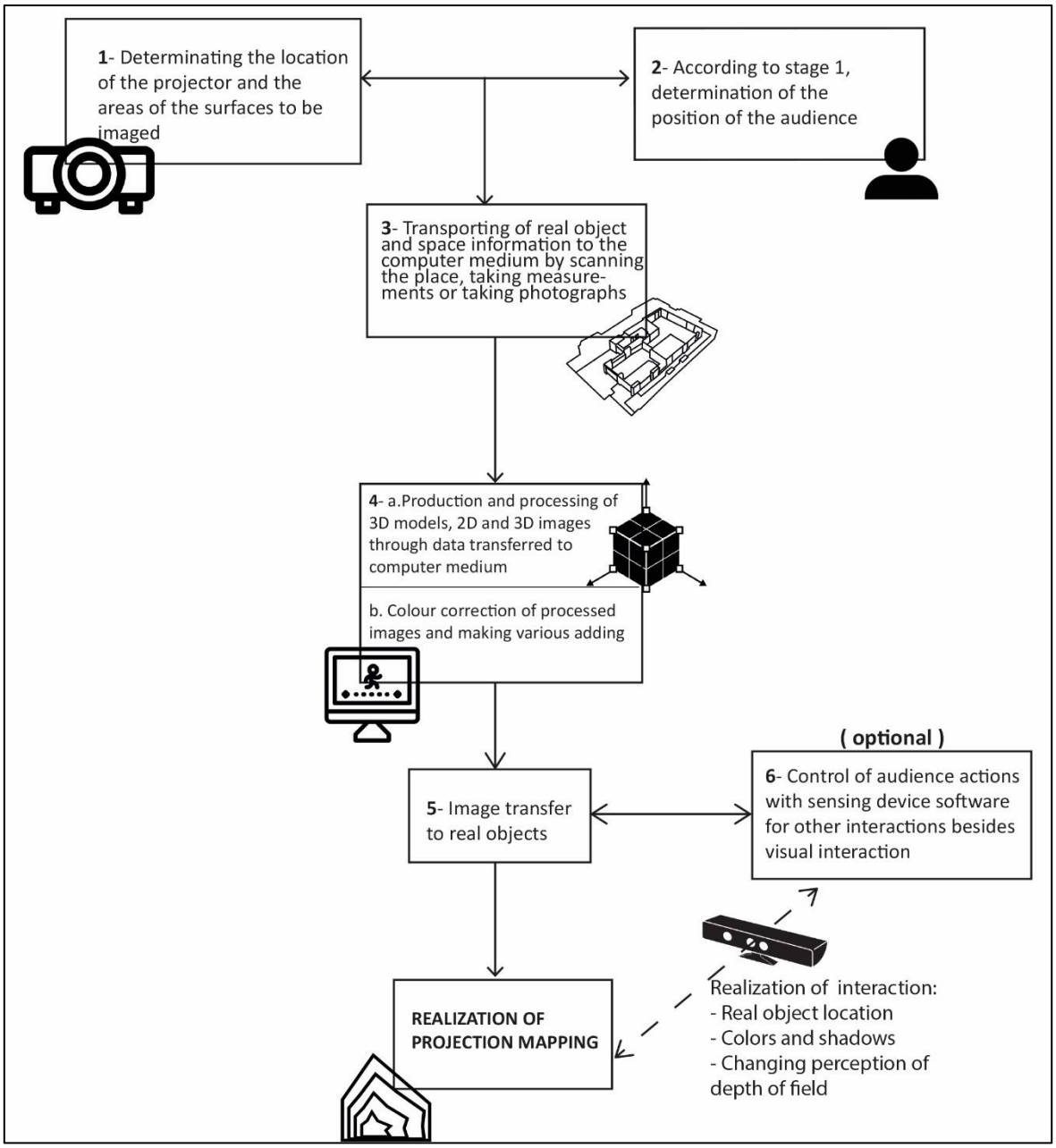


Fig 10. The Implementation Process of PM

Faults made at different stages of the implementation process of the PM technique can weaken or eliminate the illusion of spectator perception. The first and second phases of the implementation process are significantly related to each other. This issue is related to accurately transfer of real object-space information into the digital environment at the third stage. In the implementation of the PM, it is necessary to integrate the physical objects (nature) and the virtual objects in the direction of certain components which will provide the illusion of the spectator's perception.

These components which will provide the illusion determine the conditions under which the virtual object can exist within the effect of reality.

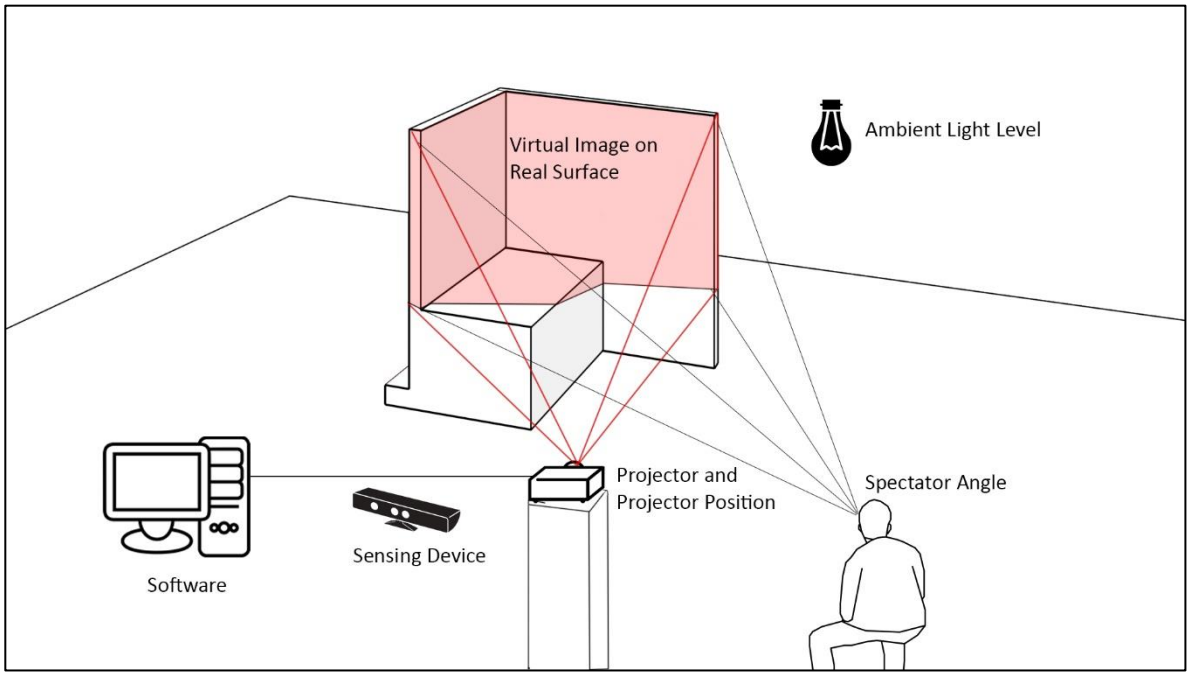


Fig 11. Components of PM

While the image can be used as surface painting to create only 2D effect for the spectator, using the virtual object on the front or back side of the reflection surface, a strong depth and 3D effect can also be created for the spectator.

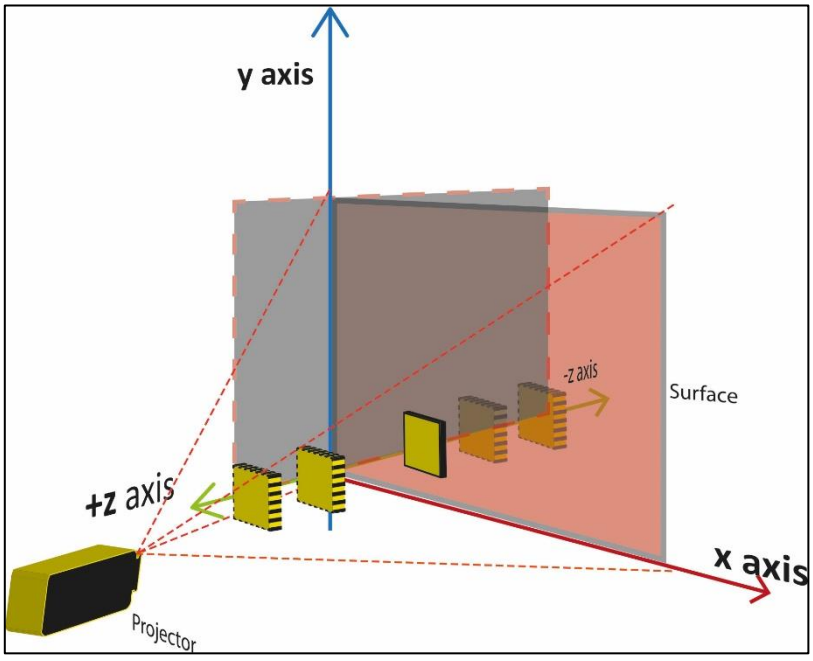


Fig 12 Axes on the reflection surface

Examples of Use of Projection Mapping in Architecture

Since Projection Mapping has the power to transform any simple surface into a 3D and complex virtual environment, this technique is used in many areas from industrial design to theatrical performances. Various studies related to the use of PM have been carried out in the field of architecture.

In a study conducted by Chen and his team, a wall projection of 1:1 scale was performed. In this reflection, the 2D environment was created in which the students could interact with the surface in order to understand the real surface material and material dimensions and the surface painting technique was used. [20] However, the use of the programming language in the whole process to achieve the interaction in this work creates a negative situation in order to find the usage area in architecture and to be widespread. According to Dourish's historical classification of human-computer interaction, it means that this method is not very suitable for today's levels of human-computer interaction.[21]



Fig 13. Chen and his team' surface painting PM project

In the study of Narahara and Kobayashi, PM was applied with reflection on the architectural model. With this projection, a circulation situation of the space and different facade alternatives were showed. [22] However, circulation analysis related to urban fabric and context is presented in a very limited area in this project.

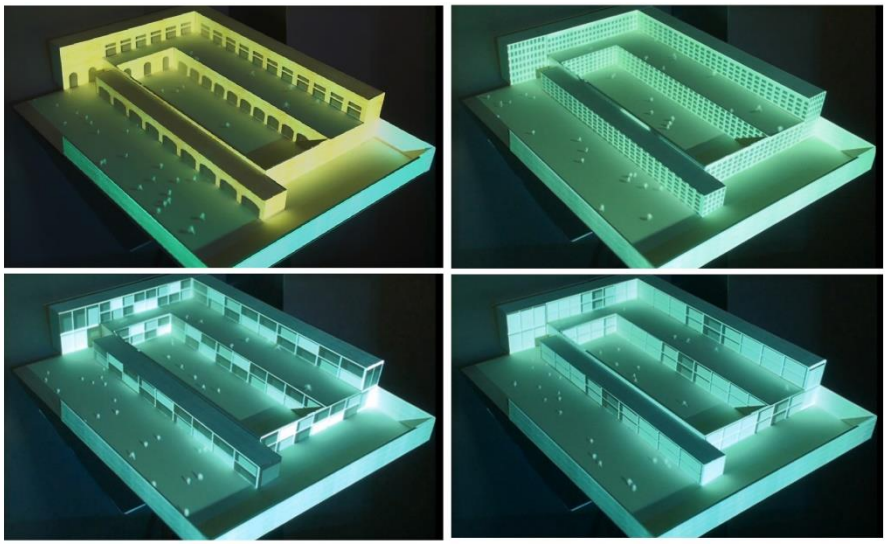


Fig 14. Narahara and Kobayashi' CrowdMapper project

In the work of the CAVI Research Group at Aarhus University, reflection was carried out for the urban design project designed by an architectural firm. This study is important because it involves strong urban context and influential 3D effect.[23] However, various perspective distortions are observed in this study for the case of 3D perception because the spectator's angle is not clearly defined. The angle of the spectator and the projector is the same point.

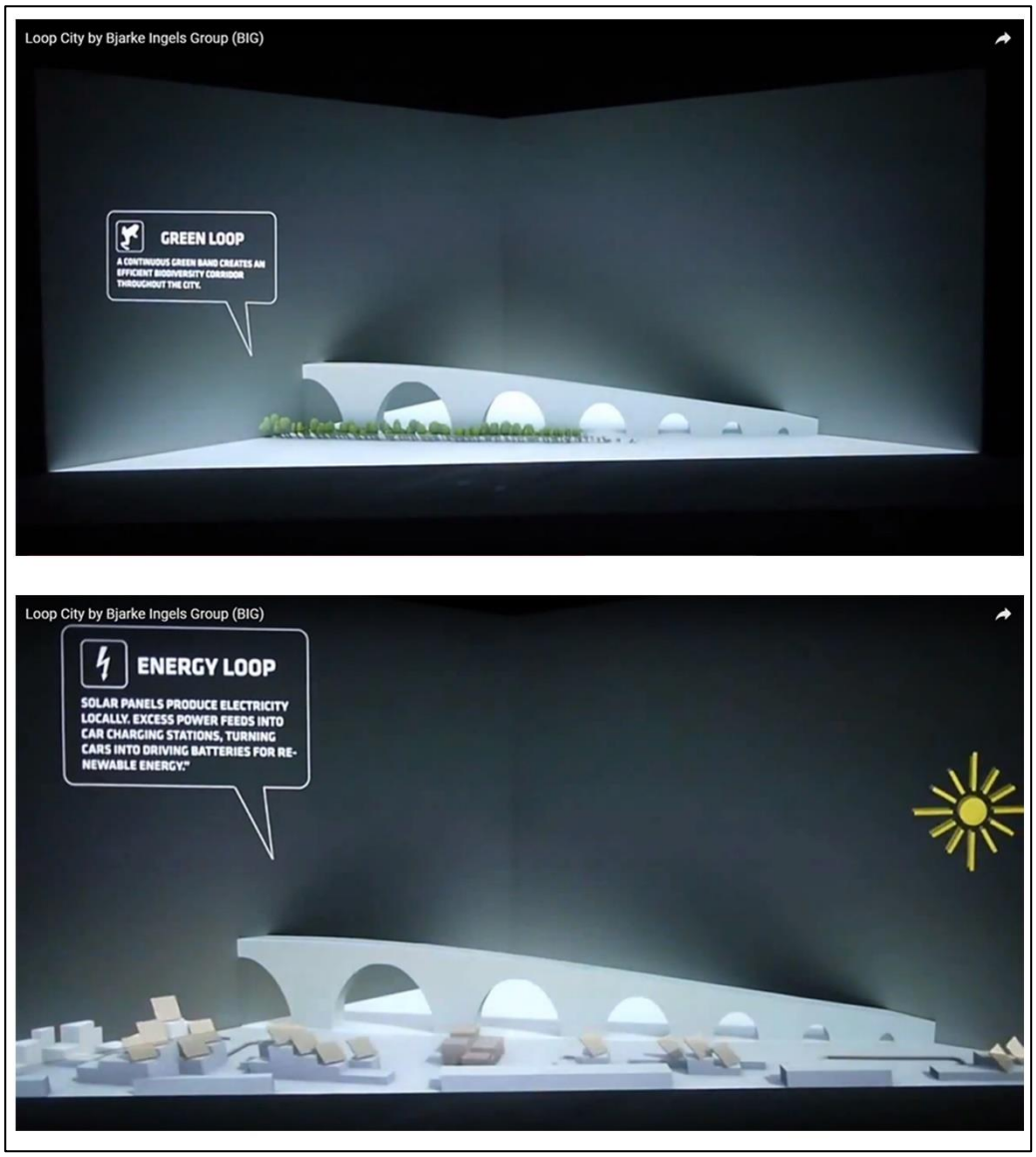


Fig 15. CAVI Research Group' Loop City project

ARCHITECTURAL PRESENTATION OF 3D INTERACTIVE PROJECTION MAPPING

This study is composed of two separate animations. While the content of the first animation is composed of various analyzes including the urban context and these analyses are supported by the architectural plans, the second is composed of two design mass alternatives.

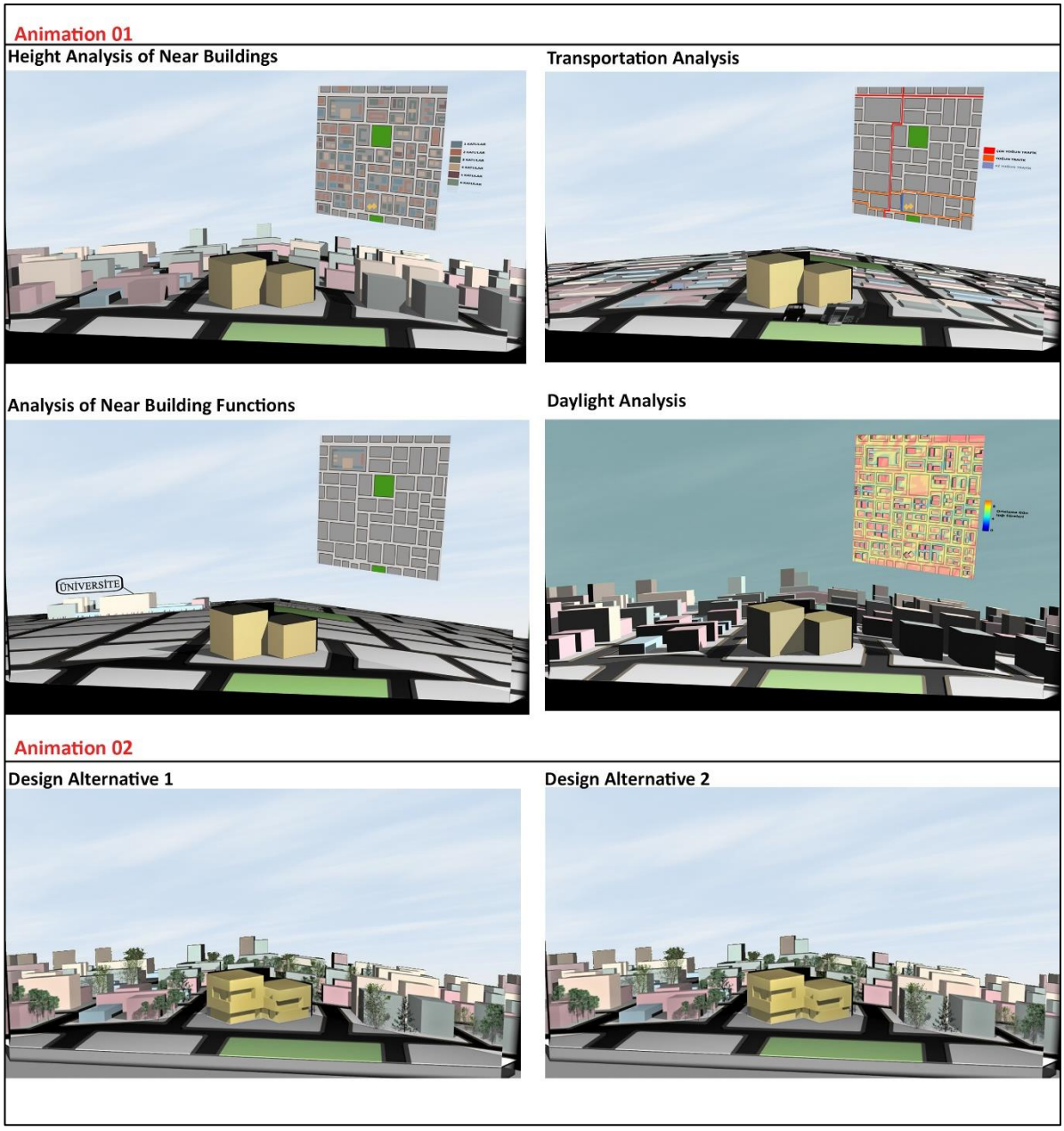


Fig 15. Contents of animations

The user can switch between these two videos on surfaces with the Leap Motion controller which provides free-hand gesture control. In this way, two videos can be experienced in relation to each other.



Fig 16. Interaction between virtual image and spectator

The potential of this work to be provided to architects can be listed as:
-Using of this technique in combination with 1:1 and multi-scale object
-Creating a medium where direct eye contact can be established without using a head-mounted display
-Integration with other traditional representations such as conventional scaled model
-Differing from today's usage in this field, working on Z-depth rather than surface painting
-Enhancing the interaction with representation which means enhancing the interaction with represented space

CONCLUSION

This study emphasizes the developmental possibilities of PM technique, including the use of the interaction between spectator and medium, and the creation of 3D perception beyond the use of the surface painting technique which is frequently used for usage of PM in architecture. This study also revealed the potential for presenting the context of a designed building and the city and using the PM technique as a dynamic medium.

The concepts of *time and motion* that can't be addressed in traditional representation in architecture should be considered as a deficiency for this experiential and applied oriented field.

In addition to being a medium that can be used within the field of professional architecture producing and presentation has also strong potential for use in architectural education with the benefits provided by the use of *time, motion, interaction, and descriptive geometry knowledge*. The use of PM in architectural education provides the theoretical knowledge to be acquired by the analysis of urban fabric; it also enables the acquisition of applied knowledge for the creation of the representation environment.

Interactive use of this technique in architecture gives an opportunity to the student for integrating design problems and designed product in a single representation medium. The various analysis of the design environment and the design alternatives together usage with the 3D perception has created an example of how to use Projection Mapping technique in the face of a design problem of the architectural education.

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[2] Herbert Zettl, Sight, Sound, Motion: Applied Media Aesthetics (Boston: Cengage Learning, 2011).4-5.
[3] Representations among these classifications can be used separately or in a complex way. But within architecture, the symbolic and analytical representations are most often used among them, depending on the mode of production of architecture
[4] Geert Smeltzer, Walther Roelen and H. Wagter, "Design Model Image Presentation", (paper presented at the annual meeting for Education and research in Computer Aided Architectural Design in Europe Conference, Munich, 1991)
[5] Erdal Devrim Aydin, "Enhancing Architectural Representations in 3D Virtual Reality: Building Denotative and Connotative Meanings" (PhD diss, Yildiz Technical University, 2012), 23-38.
[6] What Aydın refers to as "Architectural Representation in Computer Medium" is the practical production of other types of representations through the use of digital representations.

See Erdal Devrim Aydin, Togan Tong and Suleyman Emre Pusat, "Computer Aided Photo-Real Modeling: Art or What?", (paper presented at the annual meeting for Proceedings of International Conference on Computer Graphics, Imaging and Visualisation, 26-28 July 2006, Sydney): By the help of the computer-aided 3D modeling software, which are increasing numerically and getting complicated, the computers started to imitate the appearance of reality (nature) close to perfect and because of its this feature, it is started to be used intensely, in architecture, in the design of industry products, ***especially in cinema***, shortly almost in everywhere visual designs are made.

For this reason, it is necessary to convert from Representation in Computer Medium into Representation in Computer-Aided Cinema environment thereby making classification more clear and widened. It is also important to add an Architectural Representation in the Augmented Reality Medium, which is now used as a representation medium in architecture.

[7] Although sketches continue to exist today as representation substantionally used in architecture, scale hand drawings are not used much because the scale drawings can be produced in a more practical and powerful way via computer-aided.

[8] Models are often used in the field of architecture today because of its strong 3D effect.

[9] Nick Dunn, Architectural Modelmaking (London: Laurence King, 2014), 1.

[10] In his work, Manovich studied and demonstrated the strong ties between cinema and new media.
See Lev Manovich, The Language of New Media (Cambridge: MIT Press, 2001), 9:

- *the parallels between cinema history and the history of new media;*
- *the identity of digital cinema*
- *the relations between the language of multimedia and nineteenth century pro-cinematic cultural forms;*
- *the functions of screen, mobile camera, and montage in new media as compared to cinema;.*
- *the historical ties between new media and avant-garde film.*

[11]Gul Kacmaz, "Architecture and Cinema: A Relation of Representation Based on Cinema" (Master diss, Middle East Technical University, 1996), 13-16.

[12] In this process, the virtual image is produced using software that computer aided representations can be produced. This virtual image is then integrated into the real world through the use of various digital tools and methods.
See Dieter Schmalstieg and Tobias Hollerer, Augmented Reality: Principles and Practice (Boston: Addison-Wesley Professional, 2016), chap. 3, https://arbook.icg.tugraz.at/Schmalstieg-2016-AW.

[13] Oliver Bimber,and Ramesh Raskar, Spatial Augmented Reality: Merging Real and Virtual Worlds (Wellesley: CRC Press, 2015), 71, http://pages.cs.wisc.edu/~dyer/cs534/papers/SAR.pdf.

[14] Bimber,and Raskar, Merging Real and Virtual Worlds, 72.

[15] Peter Dalsgaard and Kim Halskov, "3d Projection on Physical Objects: Design Insights from Five Real Life Cases." (paper presented at the Proceedings of the SIGCHI conference on human factors in computing systems, Vancouver, May 07–12, 2011).

[16] Spatial Augmented Reality is also commonly named as Projection Mapping in a lot of scientific research.

[17] While the Spatial Augmented Reality system as an architectural representation tool can be used with a model that is a traditional representation. In addition to that, when a building facade is represented, it is used in combination with the representation,represented by a reflection on the facade.

[18] See Sheep Dalton, Holger Schnädelbach, Tasos Varoudis, and Mikael Wiberg "Architects of Information." Interactions 23 (2016): 62, accessed February 10, 2018, doi: https://doi.org/10.1145/2933266.

[19] See Fakhreddine Karray, Milad Alemzadeh, Jamil Abou Saleh, and Mo Nours Arab. "Human-Computer Interaction: Overview on State of the Art." International Journal on Smart Sensing and Intelligent Systems 1 (2008): 137-45, accessed February 20, 2018, doi:10.21307/ijssis-2017-283 .

[20]See Chien-Tung Chen and Teng-Wen Chang. "1: 1 Spatially Augmented Reality Design Environment." In Innovations in Design & Decision Support Systems in Architecture and Urban Planning, ed. Jos P. Van Leeuwen et al. (New York: Springer Press, 2006), 487-499.

[21] According to Dourish, *There are four separate phases of developmental process. These are characterized as electrical, symbolic, textual, and graphical forms of interaction.*
See Paul Dourish, Where the Action Is: The Foundations of Embodied Interaction (Cambridge: MIT Press, 2004), 5-11.

[22] Taro Narahara and Yoshihiro Kobayashi. "Crowd Mapper: Projection-Based Interactive Pedestrian Agents for Collective Design in Architecture" (paper presented at the annual meeting for Education and research in Computer Aided Architectural Design in Europe Conference, Vienna, September 16-18, 2015)

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