AUGMENTED REALITY WAYFINDING: A SYSTEMATIC LITERATURE REVIEW

ECE ALPAT

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ABSTRACT

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Alpat, Ece

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The development of emerging technologies of today has brought many innovations. Augmented reality, which is one of the most popular innovations that makes a great contribution to human life, facilitates new opportunities for humans in many areas of life. Augmented reality applications are used in many fields like education, tourism, architecture, food industry, and such. In this study, applications and concepts of augmented reality wayfinding for the interiors are discussed. In this context, the general aim of the study is to comprehensively consider the recent studies in the field of augmented reality research in wayfinding through a systematic literature review and to propose a classification according to the scope and content of the considered studies. Within the scope of the research, 25 studies on navigation with augmented reality are determined and these studies are examined in detail. According to the findings of the study, it has been seen that augmented reality is in the interest of academic research for indoor wayfinding studies, however, only few studies have been dealing with the increase of the accuracy of augmented reality wayfinding and the design of augmented wayfinding systems.

Keywords: Wayfinding, Augmented Reality, Interior Architecture, Interiors, Virtual Reality

ÖZET

ARTIRILMIŞ GERÇEKLİK İLE YÖN BULMA: SİSTEMATİK ALANYAZIN TARAMASI

Alpat, Ece

Tasarım Çalışmaları Yüksek Lisans Programı

Tez Danışmanı: Prof. Dr. Özgen Osman Demirbaş

Ocak, 2022

Çağımızda gelişen teknolojilerin gelişimi birçok yeniliği de beraberinde getirmiştir. İnsan yaşamına büyük katkı sağlayan en popüler yeniliklerden biri olan artırılmış gerçeklik, hayatın birçok alanında insanlar için yeni fırstalar sunarak hayatı kolaylaştırıyor. Artırılmış gerçeklik uygulamaları eğitim, turizm, mimari, gıda endüstrisi ve benzeri birçok alanda kullanılmaktadır. Bu çalışmada iç mekânda artırılmış gerçeklik ile yön bulmayı sağlayan uygulamalar ve kavramlar ele alınmıştır. Bu bağlamda çalışmanın genel amacı, sistematik alanyazın taraması yoluyla yön bulma konusunda artırılmış gerçeklik alanındaki son çalışmaları kapsamlı bir şekilde ele almak ve bu çalışmaların kapsam ve içeriğine göre bir sınıflandırma önermektedir. Araştırma kapsamında artırılmış gerçeklik ile navigasyon konusunda 25 çalışma belirlenmiş ve bu çalışmalar detaylı olarak incelenmiştir. Çalışmanın bulgularına göre, son dönemde artırılmış gerçekliğin iç mekan yön bulma çalışmaları için akademik araştırmaların ilgi alanına girdiği, ancak yön bulmada artırılmış gerçeklik çalışmalarının doğruluğunun arttırılması ve artırılmış yön bulma sistemlerinin tasarımı ile ilgili çok az çalışma olduğu görülmüştür.

Anahtar Kelimeler: Yön Bulma, Artırılmış Gerçeklik, İç Mimarlık, İç Mekân, Sanal Gerçeklik

To my lovely parents, Günseli Alpat and Şenol Alpat

and my dearest friends

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AR	: Augmented reality
CPU	: Central Process Unit
GPS	: Global Positioning System
HMD	: Head-Mounted Displays
HVS	: Human Vision System
QR	: Quick Response
RAM	: Random-Access Memory
RTLS	: Real-Time Locating System
SAR	: Spatial Augmented Reality
TV	: Television
VR	: Virtual Reality

CHAPTER 1: INTRODUCTION

Understanding the users' needs while creating an interior has always been the most important thing throughout the history. For this reason, the need for suitable physical conditions and security has always been essential for interior design since ancient times. Due to the development of civilizations, the needs in various forms of social life related to shopping, health, education, religion, and entertainment arose, and as a direct result of this, some additional requirements for the interior spaces have become inevitable. Throughout these changes, in both the needs of people and altered functions of the spaces, an evolution in spaces has emerged according to the way they are used, which has naturally led interior architects to design interiors to meet the functional, aesthetic, and psychological needs of the individuals who live and work there.

A good interior design must fulfill all physical, safety, and psychological requirements, from the simplest to the most important one. While good ventilation, an excellent acoustic control, sufficient daylight, and direct visual connection with outside etc are some of the physical requirements, being happy, the sense of belonging, feeling safe and secure refer to the emotional relationships established within the interiors, and they are mostly the psychological requirements. In addition, cognitive concepts such as recognition, perception, remembering, easy movement, and wayfinding are also among the psychological needs.

Since individuals are very active creatures, there is always a movement between and within spaces. Therefore, a space is defined according to the possible movements that will take place within it. An individual needs to be able to navigate the space easily and have an idea of where he is because while wayfinding is as easy and a daily process as moving from one place to another, losing your way, and not being sure about your location can turn into a tedious experience. Individuals can feel uncomfortable in case of a lack of security when they cannot manage to find the right direction, which can cause fear and too much distress. Moreover, this situation causes a big loss of time and productivity; accordingly, it might lead the individual to have a poor ability to assess the space. Hence, there are architectural requirements that should not be ignored in designs to prevent losses of time and performance in terms of the wayfinding concept.

The individual observes the environment while in motion. S/he can perceive environmental elements and create a relationship with the whole. Some environments provide the spatial information necessary for wayfinding behavior and allow this information to be comprehended and interpreted, so the individual can find her/his direction properly and move easily. This situation is possible by constructing the environment with specifically defined elements. Thanks to the comprehension of the defined elements, it becomes easier to move and find direction to the target in that environment. Therefore, it is obvious that there is a strong relationship between the wayfinding movement and the formation of environmental images.

Today, technologies that support this relationship are available, and these developing technologies can make a change in many aspects of our lives quite effectively and quickly. This change has an impact on a wide range of areas, from the financial sector to transportation, from health to education as well as the social and business life, and it is widely used in wayfinding. In digital applications that support the wayfinding action, by transferring data to electronic media, more data processing are allowed to be performed simultaneously in a shorter time.

In parallel with all these developments, the rate of the use of information technologies in interior architectural wayfinding increases and becomes indispensable as well. Images simultaneously created by enriching the objects in the existing environment with sound, image, and graphic data, produced by an information processor, are defined as images in an environment of augmented reality. In short, it is the addition of new layers of images on top of the existing reality by the processor. In augmented reality, images are provided by adding virtual objects to existing real images instead of designing everything virtually as in virtual reality.

Augmented reality has been defined as a derivative of virtual reality. Virtual reality technologies surround the user in a completely synthetic environment. In this virtual environment, the user is isolated from the real world and cannot experience the environment he is deprived of (Gold et al., 2005). Conversely, in augmented reality users are allowed to see the real world with which virtual objects are combined or superimposed. After all, it has been found that augmented reality supports, adds, and complements, or in other words it enhances the real world, rather than replacing it completely. From the user's point of view, it is suggested that virtual and real objects exist simultaneously.

Augmented reality has a distinct difference from virtual reality. While the changes created and made in the virtual environment are handled only in the virtual environment, augmented reality users can handle the information and experience they need together with the real world. Augmented reality enables users to directly see the physical properties of objects and experience them without preventing them from perceiving their actions (Khoury, Shen and Shirmohammadi, 2008)

1.1. Aim of the study

Navigation design in an interior is very important and in complex environments, the user is very likely to get lost or confused. Augmented reality, a concept that has entered our lives with the advancement of technology, has affected every area of life as well as interior architecture. Today, it is also a new and popular tool for wayfinding in indoor navigation.

Wayfinding design is critical in case of emergencies. How quick a building evacuation in an emergency such as a fire or earthquake is directly proportional to good navigation design. In addition, being able to easily find a way in public spaces or large-scale interior spaces that we use in our daily lives is also important to sustain our daily life. In this aspect, when it is time to evaluate any design process, it is possible to examine this process in two basic stages. Respectively, first, what to do and next what to use based on the need should be considered.

As a consequence, in this study, technological studies and applications that will contribute to wayfinding design are examined and these studies aim to provide a literature source for future technological studies.

1.2. Research questions

In this study, it is aimed to make a systematic literature review of the technological studies for the improvement of wayfinding design. Wayfinding is one of the most important issues of interior design. Therefore, with the emergence of the development of technology, many new technological applications supporting wayfinding have been developed and these applications are considered to be good contribution to the wayfinding design. However, how these AR and VR applications contribute should be examined and investigated in detail to shed light on future studies. It is presumed that wayfinding design can be developed based on the routing results through augmented or virtual reality. In order to examine the AR and VR applications developed in this direction and to improve the wayfinding design, three research questions are considered:

1. How do AR/VR affect wayfinding?
2. What are the contributions of AR/VR research on wayfinding design?
3. What is the most common method used in augmented reality applications on wayfinding?

1.3. Scope of the thesis

In this study, wayfinding and some digital technologies are discussed and explained. This study aims to assist future augmented reality applications and VR applications to improve wayfinding, by presenting a systematic compilation of studies.

In this study, firstly, wayfinding is discussed in detail, and then digital technologies are explained. The priority of this study among digital technologies is augmented reality because augmented reality systems use some of the same hardware technologies used in the VR system, but there is a very important difference: VR aims to meticulously replace the real world, while augmented reality supports it well (Feiner, 2002). For this reason, it is thought that it is easier to reach augmented reality applications with the widespread use of technology today.

As AR has become more common today, applications that assist wayfinding have been designed and a detailed study has been carried out on the contribution of these applications to the development of wayfinding actions. A systematic literature review has been conducted and through this analysis a matrix has been suggested that provides a classification of the examined studies.

CHAPTER 2: WAYFINDING

2.1. Definition of Wayfinding

Wayfinding is an effective solution based on the problem of interiors, and it is the process that deals with achieving a goal regardless of whether it is a known or an unknown space (Arthur and Passini, 1992). According to a similar definition by Giuliani (2001), people should be permitted to determine their own destination and location in an environment, and a plan should also be made to lead them to go to their destination from their current address. At the same time, the identification, marking, grouping, linking, and organizing of spaces should be included in the designs of wayfinding systems. People need to have the awareness of a place to find their way around. In this regard, wayfinding can be defined as a kind of directing and motivating activity to lead people to find their way (Alan, 1999). When people have little or no knowledge of that environment, navigating in highly complex spaces can cause problems and as a result of this, some orientation disorders might appear. Depending on the structure of the corridors and the number of decision points, it is probable to coincide complex and labyrinth-like large spaces (O'Neill, 1991). For Richter and Klippel (2002) to achieve a goal successfully, not only orientation in an unknown environment is an important factor, but also the requirement for knowledge, which is in particular from external factors. Knowing where people are in complex and unfamiliar spaces is essential to feel safe. Information is required about the interiors where people are, the destination, and the spatial relationship between them during the navigation process. The lack of this information can cause people to change their direction, and it can also cause stress and frustration. People who strive to achieve a set goal may experience distress while experiencing disorientation (Passini, 1984). Inadequate navigation systems reduce efficiency and lead visitors to waste a lot of time when directing them to their destinations (Arthur and Passini, 1992). Wayfinding is very important in the built environment because understanding the built environment is more about how we perceive it than how it is designed. Various theories of perception based on our senses have been developed and gained different dimensions and the Gestalt theory of perception, developed by Köhler, is considered to be one of the first studies on the relationship between human perception and space.

According to the Gestalt theory; mostly perceptions are based on the senses, and it has been discussed and questioned much more than the other theories of perception (Terian and Lang, 1988). Environmental designers, artists, psychologists, interior architects, and even philosophers regard this theory, which leads to links between various disciplines, effective in terms of their fields. The basis of the theory is not based on human behavior, but the learning process of perception and perception of the environment. The focus of this theory, which is integrated with visual perception, is on the explanation of the organizational form of space (Atkinson, 1999). Taking the visual dimension of the environment into consideration, the essential theoretical model for the environment to be organized and perceived is revealed. For this reason, Gestalt theory has to be examined to understand the way the visual perception process works and how the order which forms a physical environment is perceived.

According to Gestalt theory, the whole has a different meaning from the sum of its parts, and the individual does not perceive the whole by separating it into parts but perceiving it as a whole. In short, the principle the whole is greater than the sum of its constituent parts constitutes the basis of the theory. According to this theory, the environment is defined as a meaningful whole formed by parts with dynamic bonds between them (Uzunoglu and Uzunoglu, 2011) As a result of this approach, it is clearly seen that the coexistence and the relationships of these components are of greater importance than the components themselves when it comes to what gives meaning to the environment since people's perceptions are affected by the relationships that environmental components make with them. Depending on the quality and degree of these relationships, environmental perception arises. This theory tries to explain how these values, are associated, brought together, in other words, organized, The purpose of this theory is to explain the organization and relation between these values, which reveal the physical definitions of the elements by addressing the perceptual values of environmental elements such as color, shape, form, and measure (Özbilen, 1983).

Design principles are of great importance in environmental design, and they may account for the connection between forms that define the perceptible aspect of environmental components, and they indicate how these come together to form a whole (Çevik, 1991). These principles, which explain the organizational form of the environment, emerge with design elements such as shape, color, texture, and size, which are the visual qualities of the environment.

2.3. Types of Spatial Knowledge

When people want to explore a new environment, they unconsciously tend to develop mental maps of the environment, called the cognitive map system. The cognitive map helps to find a way in an unknown environment (Sancaktar, 2006). The cognitive map which constantly updates itself to rediscover the environment is a mental representation or set of representations of the spatial order of the environment (Montello and Freundschuh, 2005). These maps consist of five elements: road, edge, sign, region, and nodes (Lynch, 1960). In addition, cognitive maps are sensors for identifying points of roads, streets, or walkways that can move. Edges which include obstacles or boundaries such as walls are line elements that the observer does not use as paths. Landmarks that can be buildings, signs, or shops are visible landmarks which are either large objects in their immediate surroundings or locally vice versa. Regions are large areas that share a common perceived identity, homogeneity, or character that distinguishes them from other areas and introduces the observer mentally. Focal points that can be widely used by people are indicated by nodes (Darken and Sibert, 1993). Cognitive mapping systems constitute a basic component of spatial information that consists of the processes that a person reveals, whether consciously or not, in finding his/her way. Therefore, cognitive maps are vital to improving people’s way-finding, milestone, route, or survey information.

2.3.1. Landmark Knowledge

Information obtained from recognizable objects in an environment is called milestone information. By providing a means to organize, fix, or recall information, milestone information involves the use of highly conspicuous objects to help self-orientation in a new environment (Nash et al., 2000). When it is to contribute to milestone information, landmarks in an environment, or finding objects in the mind permanently, shapes, dimensions, colors and contextual information do a lot (Chen and Stanney, 1999). Likewise, it has a big effect on determining the distance and direction, as it helps to have landmarks along a road, to determine decision points, and to provide the necessary information and it is also a reminder for people to reach their destination successfully (Chen and Stanney, 1999).

2.3.2. Route Knowledge

Route information for Montello, Hegarty, Richardson, and Waller (2004); define it as a representative element that includes the steps necessary to find a way from one place to another. It indicates the potential of an individual to move from his current location to another location (Ruddle and Peruch, 2004). The most important point in terms of connecting important points during a journey is route information (Montello and Freundschuh, 2005). Route information consists of the information about the order of the landmarks and the minimum information in terms of choosing the most appropriate action by making directions such as turn left and continue ahead (Montello, 1998). In addition, route information can be expressed as the direction marking where more known or unknown targets should be pointed while the route information is located between the two target points determined by the participants, or it can be expressed as the measurement and evaluation of the skills of the participants by guiding themselves according to the landmarks or characteristics of the environment (Nash et al., 2000).

2.3.3. Survey Knowledge

Siegel and White (1975) envisioned an information acquisition hierarchy starting with the sign element in the process of obtaining environmental information, in contrast to the theories assuming that routes and only the sign elements associated with these routes are known (Abu-Oibed, 1998). The route information follows the acquisition of the beacon information,

> The information about clue items can be obtained by gaining knowledge of specific environmental properties. It is possible to distinguish a feature as a significant element by being distinctive in terms of appearance (size, shape, color, etc.) and position in the environment. Features that are considered as assigned elements are located at important intersections or points where the direction of movement changes. They are also expected to be more effective when positioned at directional points. In wayfinding experiments, sign elements also play important roles (for example, remembering a specific point in an environment and returning to that point).

Sign elements are also used as fulcrum points. A similar approach to the theory of Siegel and White is the anchor-point theory proposed by Golledge (Abu-Oibed, 1998). Accordingly, important environmental clues (signage) should be based on route information. From this perspective, sign elements must be learned before routes. In the beginning of acquisition of the information, a small number of signal elements are known precisely. However, these few sign elements are the key features at the very first stages of the topological development of the routes. In another work on premise theory, the concept has been redefined. Thus, the fulcrum or reference points do not have to be points. They can also be sections of routes or small areas. For instance, a railway running through a small town, like an individual's home or a local grocery store, can serve as a basis for constructing cognitive representation because this railway was encountered long before the discovery of the place of living or shopping. When the assumptions for the information about sign items and the acquisition of route information are compared, it would be fair to say that the existing experiments are insufficient to indicate which type of spatial learning is more appropriate for adults who experience all stages of the developmental process.

2.4. Components of Wayfinding Design

Finding a way in an unfamiliar place can create a problematic situation. In addition, with a good wayfinding design, designers and interior architects can contribute to the increase of the performance characteristics of the building. A good navigation design can facilitate user access, increase satisfaction and reduce stress by eliminating the confusion that may be in people's minds (Evans and McCoy, 1998). The ability to enter a building and find its way inside and outside the building is a prerequisite for the satisfaction of higher goals (Weisman, 1981). According to Arthur and Passini (1992) whether at regional, urban or architectural scale, wayfinding requirements are an integral part of the design process, from the most general spatial organization of the environment to the articulation of form. Navigation requirements shape the environment, influence the choice of circulation system and contribute to the design of the interior. This is especially true for large building complexes.

In this context, the components that make up the wayfinding designs can be expressed as an architectural and graphical system that offers people the resources that can provide information about the space.

There are two architectural components in terms of wayfinding design in buildings: architectural readability and spatial configuration.

While trying to understand and grasp the space in which a person is, he encounters different dimensions of the space and is under environmental pressure. Although the level of the relationship varies in this process, it can be said that human beings are in a relationship with space in all situations. The level of this relationship varies depending on personal characteristics and spatial qualities. Environmental designers aim to enable people to understand and comprehend that space and to perform their actions in this complex order (Erem, 2003).

Readability is also an environmental quality that provides these opportunities to human beings. As an environmental concept, readability is the quality that enables objects or objects to be noticed by creating a meaningful index of relationships. In other words, it is the environmental variable that provides the opportunity to read, understand and comprehend the environment in options. If people understand what is happening there, depending on the environmental characteristics, they also benefit from the opportunities and advantages offered by that environment. The meaning of readable environments is that people can obtain information from that environment. In this respect, it has been interpreted as the order that forms the environment to be comprehensible (Bentley, 2015).

According to Kaplan and Kaplan (1982), readability is an environmental feature that enables an individual to explore his environment comprehensively without worrying about loss (Nasar, 1987). Lynch (1984) defines readability as the ease of being noticed and organized in a distinct order of parts. In other words, the readability degree of a field is defined as the ease of identifying the parts with each other and being harmoniously organized. Passini (1996) explained the concept of readability by associating it with the characteristics of a space that are suitable for orientation. Similarly, in Fewings (2001), readability is defined as the spatial quality that affects the actions of the user moving and orienting in space (Fewings, 2001). Fussler (1980) argue that a person should be able to read that space to be able to navigate the space comfortably, to perform his actions fluently, and to move without worrying about his environment. Therefore, readable places have many advantages;

- frees you from worrying about disappearance (Wener and Kaminoff, 1983)
- Provides an orientation of facilities for easy and fast movement.
- creates a feeling of trust (Yeung and Savage, 1996)

- reduces psychological disturbances to the environment.
- removes the confusion of the environment (Pollet and Haskell, 1979; Erem, 2003).

It is possible to overcome these problems in today's urban life with readable space designs.

As it can be understood from these definitions made in the literature, readability is considered as an environmental concept that allows one to understand and comprehend the space and guides the user in the space.

When the literature studies are examined, different places in terms of type and scale related to the concept of readability are discussed. In studies on architectural structures, the concept of readability has been questioned, sometimes in a residential area, sometimes in indoor spaces such as a library, hospital, museum, subway stations, where the process of wayfinding gains importance. In the studies conducted on the urban open space scale, it has been approached in terms of obtaining spatial information and solving the problems related to the wayfinding process. These studies aimed at the examination of the interaction between human and space in terms of both human and space and the search for an answer to the question of how a qualified space is supposed to be in terms of readability by investigating how people react to which space. Many researchers have adopted this approach and put forward various theories about the readability of the environment and made the definition of the readable environment with many concepts.

Kaplan (1987) defined readability as a concept that enables people to understand the environment in his study. In the study, it was emphasized that for the space to be readable, it should contain elements that differ in terms of physical properties such as shape, texture, and color in a certain system. He stated that different and prominent elements in this way facilitate the orientation in the space and make the actions more fluent. Readability in architectural environments was first addressed by Lynch (1960). This concept, which is getting more widespread, has started to be discussed based on the relationship between readability and orientation, and this relationship should constitute an input to the spatial design process. The definitions made by Lynch have a guiding quality in this research, as in many studies on both space and city scales. Lynch (1960) mentioned five basic environmental components that make the space more understandable and memorable, guide the human being and make the movements more fluent in the space set up regarding the readability of the space. These components are; roads, edges/borders, regions, intersections, landmarks.

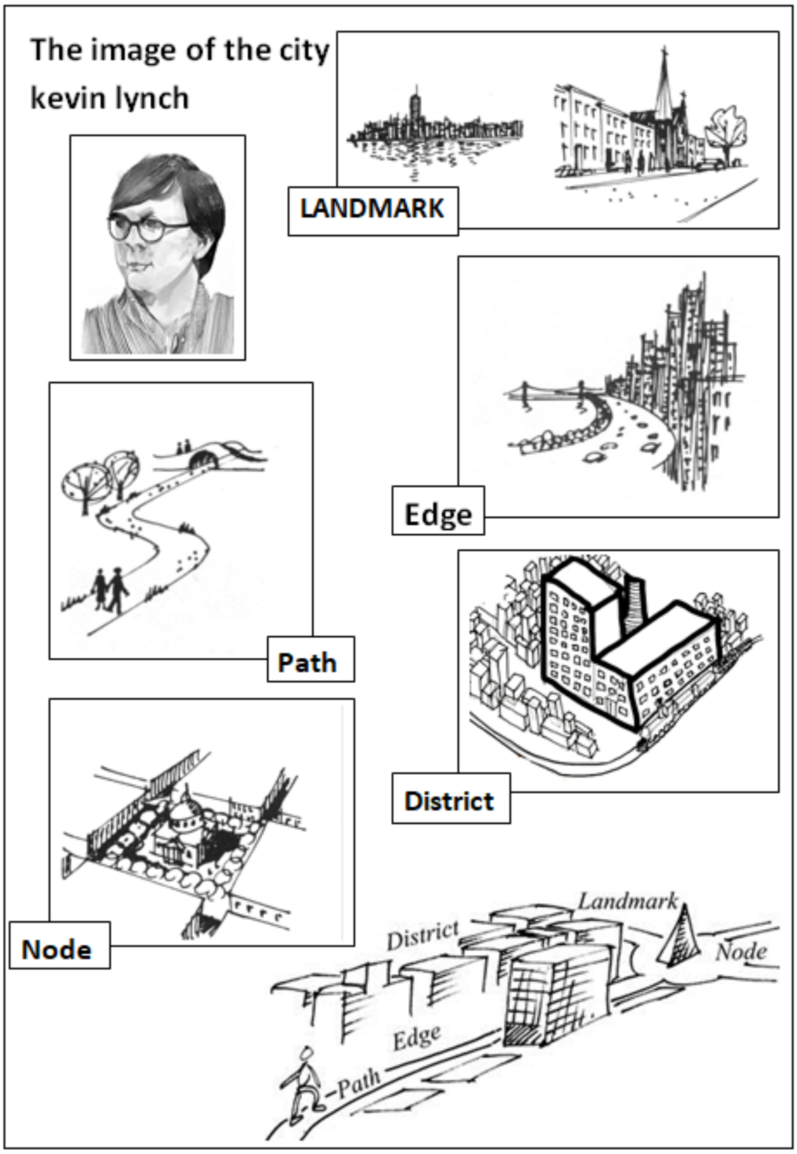

Figure 1. The City Image and its Elements (Source: Abdel-Aziz, 2018)

Paths

Paths are the circulation channels in space. It is the basic component that creates the user's network of movement in space. These components, defined as paths in space, create perceptual values in the user depending on various properties such as width, length, floor covering, and continuity. People perceive, see, associate, integrate, and form a spatial fiction around each spatial component depending on these ways.

Roads with clear starting and ending points create a sense of orientation in humans (Czerkies et al., 1999). However, individuals want to know and understand where their road leads them to. According to Lynch (1960), individuals associate spatial elements with each other in transportation axes where the starting and ending points can be read and create an image against that space. According to Ching (2007), these paths that determine our movement setup are a network that connects activity areas. On these roads where we move along a sequential sequence of activity areas, we roam depending on the questions of where we are and where we are going to. In this context, roads in urban open spaces; are spatial components that circulate, direct, or restrict the users' movements.

Edges / Borders

Edges are like boundaries that separate regions from each other (Lynch, 1960). As it separates two fields or functions from each other, it sometimes has an inclusive and integrative feature. Environmental components such as plant, reinforcement, water element, topography in urban open spaces. Sometimes they are spatial elements that form a border between activity areas, spaces, and roads, and sometimes act as a corridor, which is a part of the transportation network and set up relations between regions. Therefore, these components are considered as environmental components that direct the user regarding how the user will follow and how he will move in the space and allow them to move.

Regions

Regions are areas isolated from their surroundings that can be entered. This abstraction occurs at the points where the continuity in the physical and functional characteristics of the space is interrupted. Areas, where factors such as texture, form, space, symbol, activity, and user profile differ, can be defined as regions (Lynch, 1960). The diversity of activities in urban open spaces enables the space to be divided into zones. Each different activity creates a defined and clear zone. However, it can form the definition of the region not only in activity areas, but also in areas that provide social and cultural interaction. As regions are a part of the space, each region can be divided into sub-regions within its borders.

Node / Intersection Points

Intersection points are the areas where the paths intersect and merge, defined as the focal point of the space. It can also be defined as transition points to functional differences in space. These areas crossed by roads or regions are an important guide for what direction we will go in space. These points, which have collective, unifying, inviting features, are large areas that have the function of squares or squares that transfer the user to the transportation racks or direct the users to the areas we define as activity areas.

Landmarks

Triangulation points are reference points that cannot be entered. They are objects that can be selected and distinguished from almost every point of the space. In general, they are the most prominent and unique points of space that are memorable. Components in urban open spaces create a strong perceptual effect by differentiating at some points and becoming more distinct compared to other spatial components. These components, differentiated according to their surroundings, guide the movement and actions in the space as a reference to the user. These components, which have different dimensions and functions, draw attention and are noticed in spatial scale (Belingrad and Peruch, 2000).

Triangulation points are revealed by elements that create a sense of orientation, are static, and have a high level of clarity (Lynch, 1960). These points, which we frequently refer to while finding our direction in space, are unique components that appear in ineffective positions within the spatial setup and are easier to remember than other spatial components (Özbek, 2007).

All these elements in spatial setup are not alone and independent from each other. Regions consist of intersections defined by boundaries, surrounded by roads and fed by triangulation points (Lynch, 1960). These elements are spatial components that interact with each other and feed each other. Users perceive these elements that make up the space setup. These components put forward by Lync (1960) are auxiliary elements that affect the readability of the space and facilitate the orientation of people in the space.

2.4.1. Spatial Configuration

The concept of organization has been defined as regulation. In other words, it is expressed as saving more than one phenomenon from a complex state and putting them into a certain order. People try to organize everything around them for the continuity of daily life and need a place for this (Allen and Henn, 2006). In other words, every place where human beings interact with the intended use should be organized in a way that facilitates this use. Therefore, the concepts of the human-space organization are closely related to each other. This organization emerges with the systematic arrangement of the space. This is only possible by constructing the spatial elements that make up this organization in a correct relationship during the design process.

Spatial elements form the basis of the organization and direct our movements within the space. These elements determine our orientation in space by assuming the role of limiting, directing, focusing, providing continuity, unifying, and separating in the organization of space (Özdemir, 1994). These elements that form the spatial organization in 3 groups;

- Three-dimensional objects: It determines the boundaries and degree of closure of the space. Spatial character emerges with permeability and voids.
- Two-dimensional texture: The composition, material, and texture features of the floor covering allow the creation of different perceptual ethics in the space.
- Spatial objects: Objects such as plants, water elements, reinforcements, sculptures play a catchier role in the space (Aydemir and Aydemir, 2004).

These elements are the elements that determine the character of the open urban space and form the space organization.

Space is a collection of items that are in close or distant relationships with each other. Each element in this community comes together with its qualities that create perceptual value (line, direction, shape, measure/ratio, value, texture, and color) and form a whole. Individuals, who enter the process of interaction with the space, experience perceptual processes of different values during their actions and movements in that space depending on these elements (Kepes and Giedion, 1944). As a result of this, the elements differentiate and change with these unique qualities (line, direction, shape, measure/ratio, value, texture, and color), become more selectable and perceptible, or these attributes reduce their perceptual values by creating a passive effect in the elements. For this reason, these qualities, which are the physical properties of the elements, and the perceptual values that emerge depending on these qualities gain importance.

Physical properties of items and their relationship with other items on the whole;

- EQUIVALENT: In such relationships, more than one element of close physical qualities came together. Equivalents facilitate visual perception by establishing a strong bond between each other.
- SIMILAR: In terms of their unique qualities, two or more elements tend to integrate by establishing a relationship with each other (Kepes and Giedion, 1944).
- OPPOSITE: Elements that differ qualitatively and create opposite characters lead to an interesting and strong perceptual value (Arnheim, 1954).

It is seen that the elements come together with their unique characters and reveal different perceptual values. For this reason, it is important to make the right decisions in the design process, to establish relationships with a high perceptual value between the elements, to create a simple understandable design product, and to provide unity by saving the space from the complexity of the elements. Nevertheless, each element highlights the other elements as well as itself with its interiors in the whole. The basic condition of the union is to establish sovereignty and balance.

In this relationship that brings the elements together, sovereignty is the situation in which some items or a group of items become more dominant than other items in space. No single element in the design is alone. It is associated with other elements. This relationship takes the form of either a superiority over other elements or a commitment to a dominant element. Balance refers to a certain order. In the composition held together by the sovereignty, the static and settled states of the elements create the balance. Elements become distinct with contrast and transition paths depending on their physically defined characteristics such as line, direction, measure, shape, tone, texture, color, and gain personality and reach unity, and are perceived as a whole (Özbilen, 1983). This perception of space organization is related to the visual perception of the space. In other words, our visual perceptions of the space are a result of the relationship between the elements belonging to that space. Thus, the basis of people's relationship with the environment depends on understanding the relationship between spatial elements. The environment that is best understood is not a uniform, or a plain environment, but rather rich and diverse. However, in addition to diversity, environmental elements must be brought together by following a set of logical principles. The fact that these circles are in an easy and understandable order is not because of their simplicity, but because of the diversity of meaningful connections (Özbilen, 1983).

According to Canter (1974), these principles provide unity in visual perception and make spatial elements more distinct and selectable;

- Proximity
- Similarity
- Continuity
- Closure / Congestion
- Direction- Joint Movements
- Simplicity
- The rule of experience

Elements form a unity in terms of physical properties such as line, direction, measure, shape, tone, texture, and color depending on these principles and increase the tendency to be perceived in groups. These principles, which provide unity by creating a balance in visual perception, are the basic principles that determine the organization of space (Canter, West and Wools, 1974), which defines the order that makes the space perceive more easily. Our perceptions that arise in connection with this disclosure of our attitude towards how we will follow and how we will act in the space.

It has been stated that the principles of proximity, similarity, continuity, closeness/closure are more determinant than other principles in terms of spatial organization and are widely used in spatial arrangements. When it comes to the organization of space, it has been emphasized that it should contain elements that contain basic intimacy, similarity, continuity, and closeness and such elements can be noticed in order (Canter, West and Wools, 1974).

As a result, the basis of space organization is to create unity and composition within a certain system. According to Aydınlı (1986) composition, which means composition in music, is the deliberate arrangement and combination of elements to create a functional and visually satisfying whole in interior architecture.

The spatial design elements (line, direction, shape, size/ratio, value, texture, color) provide a satisfying and happy environment for the people living in it as long as they create space by deliberately arranging them separately (Aydınlı, 1986). The role of environmental designers is related to how these elements come together, that is, how they are arranged. In other words, the environment shaped by the choices made by a designer affects the perceptual and cognitive processes of the users. These results show that users' orientation behaviors are affected by their design decisions (Sürücü, 2015).

The perception of spatial organization allows individuals to obtain meaningful and relevant information from their environment. Therefore, the individual acquires as much environmental information as he needs to get without drowning in the unlimited variables of the space. The individual cognitively defines this meaningful information and transforms it into data suitable for repeated use. The individual who wants to experience the space again does not have to recognize the spatial elements separately but establishes relationships and associations between other elements depending on the reference element or elements about the space in which he/she acquires cognition (Biter, 2008). This perception, which defines the organizational form of space, constitutes the framework of the cognitive map that individuals define, encode, and refer to in terms of reuse (Passine and Arthur, 1992). Depending on this mental pattern, we move and orient. For this reason, the characteristics and criteria that provide spatial organization also shape the wayfinding process of individuals.

2.4.2. Graphical Components in Wayfinding Design

Graphic components can also be effective when navigating an informal environment. Maps and sign systems are the two main graphic components of navigation design.

2.4.2.1 Maps

Schematic expressions and maps are among the information systems that have an important place in routing design.

Schema is a way of describing any subject, object, or phenomenon pictorially. Mathematical expressions and proportions are used extensively in diagrams. Thanks to this feature, the user can simply perceive the given information and have the opportunity to make a comparison (Güler, 2008).

The map is a system in which a certain part of the earth is expressed in a reduced geographical area. In addition to its geographical meaning, maps are a form of visual expression that provides information to the user by shrinking a building or a space at certain rates. Maps can provide information about where the user is at that moment and inform the user about how to navigate to the point he wants to reach. Maps should be positioned where the user needs to decide on where to head (Güler, 2008).

When talking about maps, it is necessary to give information about cognitive maps, which is an abstract concept that people create in their minds, as well as being a concrete form of expression. Cognitive maps manifest as the formation of an image in the mind of a person by experiencing a place he/she comes from. These images formed in the mind help the person find direction in a different place with similar features.

Maps make it easier for the user to reach the point they want to reach by providing a relationship between the place where the person is and the place he/she wants to reach.

2.4.2.2 Signage System

Signs, which take a large place in finding direction, are a way of expressing certain concepts graphically. Signs that can be perceived by all people in different countries have an international language. Signs are among the guiding design elements that can be used indoors or outdoors. Signs are examined under certain headings. Directional signs; identify an object or event with a picture, symbol, or arrow sign. They are the signs that direct the person to the point he is looking for in the interior. Identifying signs; describes a person or object. They are signs that describe a place in any interior. Signs that inspire confidence are expressions that express where the person is.

Signs allow the user to access information accurately. Accordingly, the effects of content, location, lighting, and color elements in signs are important (Helvacıoğlu, 2001).

The content contains the information the sign wants to give. While the user is directed towards the goal he wants to reach, his consciousness also works in this direction. The coincidence of the meaning contained in the sign with the mind of the user enables the perception to occur.

It is an important issue to choose the areas where the signs will be located in the space. There should be a certain ratio of the distance between the location where the sign is located and the user. A sign located in the area where the user's decision-making need arises can achieve its purpose.

The correct and adequate use of illumination is necessary for the sign to be noticed and show its effect.

Colors have important effects on increasing the perceptual effect of signs. Each of the colors used in the signs has specific meanings. For example, the yellow color that evokes the same meaning is used in the signs with the meaning of warning.

Directional signs should be easily perceptible, clean, and clear. It should have qualities that cannot be confused with other signs and should be positioned in the right places. The texts and expressions on the sign should be large enough to be read and be easily understood by everyone (Arthur and Passini, 1992).

2.4.3. Environmental Graphic Design

The public spaces we visit or work in almost every day are complex interiors since a lot of different people for different purposes are using these spaces. very important in terms of design because it is difficult to classify because there is no limit to the use of different groups of people and there are all kinds of people in these spaces. Environmental graphic design is one of the useful design attempts to create a space identity. Environmental Graphic Design is a new design profession that encompasses interior design, landscape design, industrial design, urban planning and behavioral psychology. All architectural and graphic elements such as signs, symbols, maps, sculptures, fixtures, lights, walkways are used in Environmental Graphic Design (Atamaz, 2019).

The environmental graphic design plays an effective role in different urban and public spaces and has a remarkable place from different perspectives. Adding graphical tools and a component to the spaces made to create identity may be the right way, but it should be noted that the relationship between graphical tools and the user is preserved (Eshaghzadeh Torbati, 2018). It provides a layered experience within a spatial experience through environmental graphics, emotional triggers, and touchpoints. It enhances the identity of the place and helps the user to develop the sense of place with strong imagery (Rsmdesign, 2019). Environmental graphic design serves to create a special sense of environment and atmosphere by using two- and three-dimensional forms, graphics and signs. Within the scope of this design, environmental graphic design has various sub-titles and is an interdisciplinary field. Environmental graphic designs have six functions, as; harmony (orientation), information, guidance, definition, instruction and decor, and these functions have been determined according to the classification made by the Environmental Graphic Design Organization (Uyan Dur, 2011).

Wayfinding design is intended to direct the user towards a certain direction, which consists of visual designs. Marking design, on the other hand, are visual signs that show the user the point where he has arrived or will arrive. These signs are images that indicate a name and function of that place. Door letters, floor numbers, building names etc. As such, all of them fall within the scope of environmental graphic design. wayfinding and environmental graphic design give direction to pedestrian or vehicle traffic at main entrances, road junctions, arrival and exit points by combining graphic elements such as typography, symbols and arrows and gives meaning to the space (Gibson, Pullman and Firm, 2009). In the context of environmental graphic design, pictograms are of great importance in routing and signage design in complex spaces because pictographyis a form of expression used in the form of representational and graphical drawings. In other words, it can be explained as signs in writing systems based on meaningful signs (Netvent, 2014). The function of pictograms can be used in airports, train stations, bus stations, shopping malls, business centers, museums, hotels, hospitals, etc. Pictograms help inform and guide people in many public places. For this reason, pictograms should be easily understandable for all who are visiting these public spaces (Wake Up, 2019).

Figure 2. Design elements-Travel and tourism pictograms (Source: Conceptdraw, 2020)

Typography is one of the most essential elements of graphic design since it is one of the visual tools of communication through media. Applying environmental typography to architectural surfaces requires concentrating and thinking on the design aspect from many aspects (Kilic, 2012). As a simple definition typography is the art of writing using letters and symbols (Hannah, 2019). The transfer of all these elements forms the basis of environmental graphic design.

One of the main responsibilities of any designer is to solve the visual problems, independent from the context of the design problem. In this solution process, many different forms of visual expression can be used and there are no exact criterion or rule for these expression methods. However, there are important points to be considered in design, as it is very important that the visual message reflects the content in an original way (Akman, 2017). Not only the way the environmental graphics are designed or composed, it is also very important how individuals can perceive and understand. Not every individual has same perception from the same visual design. In this context individual differences are also an important factor in wayfinding design.

2.5. Individual Differences in Wayfinding

One of the factors affecting wayfinding is individual differences. Studies have revealed that gender differences, spatial familiarity and age differences are factors that affect wayfinding.

Gender, architectural and graphic components are important factors affecting wayfinding. As a result of the research on this subject, it has been revealed that men and women use different strategies in wayfinding and focus on different elements in the environment. Sandstorm et al. (1998) found that men and women used different strategies during self-report measures. While women used topographic elements indicating landmarks, men determined that they the use Euclidean strategy based on distance and directions (Dabbs et al., 1998; Lawton and Kallai, 2002).

2.5.1. Spatial Familiarity

Spatial familiarity has been expressed as the level of recognition of space. Familiarity with space means that one knows the objects that make up that space, what their locations are, and the relationship between objects. As the familiarity with a place increases, the adaptation process of a person to that place accelerates and the process of wayfinding becomes easier accordingly. The space that seems complex in the mind becomes more defined and spatial relationships become understandable (O'Neill, 1992). Familiarity, in other words, refers to cognitive recognition based on acquired experiences. All in all, we go through an intense process from the moment we start using the space. According to Porteous, this process starts with the perception of environmental data.

These perceived data go through a cognitive process. At the end of this process, the meaningful data turn into what the person knows, and cognition occurs (Stea, 1988). This knowledge, which a person has previously acquired, is recognized, remembered, and familiarity occurs depending on the situation of encountering the object or objects.

In other words, this process is summarized as follows:

- In the first stage, there are approaches to the environment in detail to meet the basic needs of human beings, to integrate with the environment, to establish social and cultural relations,
- In the second stage, the information acquired is decomposed in a systematic setup depending on its goals and expectations,
- In the last stage, the individual evaluates the environment in which he/she has gained experience within the possibilities and limits of the environment and puts it in a mold.

At the end of these processes, familiarity with that environment occurs, it is now easier and simpler for a person to remember that environment (Erem, 2003). Therefore, in the spaces we remember and know, how and what choices we will take will involve consciously made definitive decisions.

Although familiar, people may not always remember the places they use frequently. At this point, by conducting various studies on how and in what way spatial information is obtained, individuals have been exposed to the environment and tested. Maps were used as a method, or the person was directly exposed to the environment and gained experience.

Appleyard (1969) drew attention to the differences in the type of familiarity in their study. Mainardi-Peron et al. (1985), on the other hand, mentioned two different criteria: familiarity and functional familiarity. Familiarity speaks of repeated exposure to a place, regardless of any particular purpose. An example of this can be the individual who has to cross the same square to go home every day. Functional familiarity, on the other hand, is a person's relationship with space depending on an action he/she carries out in line with his goals. As an example, the relationship between the vendor who has to open a counter in the same place every day can be shown (Mainardi-Peron et al. 1990).

Gale et al. (1990) mentioned 4 basic criteria that will contribute to the formation of spatial familiarity in theoretical and experimental terms:

- information about location
- visual recognition
- recognition of spatial level
- human-space interaction

These criteria include descriptive and conceptual approaches that shape the process of becoming familiar with a space.

These definitions and results of spatial familiarity studies show that the places people know the most are the places they use and visit most.

Spatial familiarity has also been considered as a concept expressing the degree of domination of individuals over their environment. It has also been stated that it can sometimes be measured by instant recalls or recognition of images explained through photographs, so it is a complex phenomenon, and difficult to define and measure. It has wide boundaries that encompass spatial as well as internal drives. Familiarity includes not only spatial cognition, but also psychological concepts such as trust, belonging, and a sense of intimacy. Some people stated that they were only familiar with a place whose name they knew while others stated that they were familiar with the recognition of photographs of the place. Some have stated that they are familiar with the places they visit frequently and regularly. A different group of users stated that they were familiar with the space if they knew its location and history.

Although these descriptive statements suggest that spatial familiarity is a complex concept, space has a limit. The human mind has a structure that focuses on learning and acquiring knowledge and acquires cognition within the possibilities and limits offered by the place it is in. Evans (1980) put forward two different approaches on this issue; first, the change of mental maps more clearly in a linear direction depending on the formation of spatial familiarity, and the other is the types of spatial components used in this process when obtaining information about a place visited for the first time. In this context, it is stated that as familiarity increases, landmarks become increasingly important, and it is stated that roads play a dominant role in the formation of familiarity. These approaches express the mental and spatial dimensions of spatial familiarity about the circulation setup of the individual moving in space.

As a result, the familiarity that shapes the process of wayfinding in space and the circulation of the user with its different dimensions is a variable that emerges depending on the spatial experience of people and shapes the actions as an individual factor. Regardless of its content and type, multiple visits to a place will reveal a mental pattern related to that space. This pattern includes different features of the space, definable and distinct physical components, reference spatial locations, and objects. For this reason, spatial familiarity concerning the wayfinding process emerges as an important user-oriented variable of our orientations in space.

2.5.2. Age Differences

Another factor affecting wayfinding is age differences, as mentioned above. Çubukcu and Nasar (2005) stated that the age factor has a significant effect on navigation errors and stated that wayfinding performance decreases with increasing age. Galea and Kimura (1993) found that young people are more likely than older people in landmark selection, distance sorting, map placement, and route information. An aging-related decline in navigation and wayfinding performance has been reported about direct measurements of the navigation process in real mazes or virtual mazes (Moffat and Resnick, 2002). Navigation includes the identification of the temporal and spatial sequence of critical route events and route actions of prominent environmental features (Head and Isom, 2010). At this point, according to the environmental learning research conducted by Muffato, Meneghetti and De Beni (2016), it has been seen that the general spatial performance of young adults in environmental learning is better than older adults (Muffato, Meneghetti and De Beni, 2016). Aging appears to impair cognitive abilities in varying degrees, and the most severely affected one can be defined as memory navigation (Harris and Wolbers, 2014). Therefore, after learning a new environment, older adults struggle more than younger adults, for example, to retrace the route they have learned, to remember landmarks in the order in which they are encountered, or to position them appropriately on a map (Carbone, Meneghetti, Borella 2020). They found that they faced difficulties in finding and positioning themselves in unfamiliar environments (Wang et al., 2018). According to research by Wang et al. (2018), elderly participants showed poor ability to remember a planned route, but no matter how age difference affects spatial memory development or wayfinding, personality is also a factor that greatly affects these actions (Schaie et al., 2004). In summary, scientists have observed that age and gender-related factors play important roles in direction finding, but these results vary based on some factors (Wang et al., 2018).

Nowadays, with the development of technology, many VR and AR applications have started to be used in many areas and new applications are designed in the field of wayfinding, considering that technology will help. Wayfinding can create confusion in complex areas, so supporting this direction with new digital technologies will help the user. In this context, in the next chapter, the definition of VR will be discussed to suggest a conceptual foundation for the research.

CHAPTER 3: VIRTUALITY

In this section, VR applications are examined. Firstly, VR, then AR, and then mixed reality are explained in detail. In this study, VR which is mainly examined, is augmented reality. However, augmented reality, since it is thought to be related to other virtual environments, has been examined in detail. At the end of this section, augmented reality is detailed in several different subtitles.

3.1. Virtual reality

The word virtual began to be used in the sense of a computer made visible by software since 1959 when it started to enter our lives in the mid-1400s (Wikipedia, 2019). As a simulated experience virtual reality (VR) can either be similar to or totally different from the real world (Wired, 2019). In 1968 Ivan Sutherland, with the assistance of his understudies, including Bob Sproul, made the primary head-mounted imaging framework, which is broadly acknowledged for use in immersive simulation applications. It was primitive in terms of both user interface and visual realism, and the HMD for the wearer was so heavy that it had to be hung from the ceiling. Then the VR industry provided VR devices from 1970 to 1990 mainly for medical, flight simulation, auto industry design and military training purposes. In 1991, the first immersive VR experiences included headsets and exoskeleton gloves (Şimşek, 2019). In 1992, the first augmented reality experience was produced, which was developed by providing the superposition of 3D virtual objects, enabling vision, sound, and touch. It used an advanced head-mounted display called the Mega Visor Display, developed in conjunction with virtuality in 1994, and was able to monitor head movement in a 360-degree stereoscopic 3D environment. A commercial version was produced in 1999, and the concept, realized as a thin steel mechanism with several computer monitors, was later adapted into the personal computer-based 3D virtual world program called Second Life. VR developed differently after 2010 and Palmer Luckey designed the first prototype of the Oculus Rift. This prototype had a 90-degree field of view previously unseen in the consumer market at the time, and only rotational tracking capability built on the shell of another VR headset. As of 2016, with at least 230 companies developing VR-related products entering the market, VR systems have become available to everyone at lower prices and increased performance (Wikipedia, 2020).

VR technology consists of a head-mounted display and a glove device called the Data Glove. A head-mounted display provides separate images for the user to see, giving it a natural stereo view of a three-dimensional environment. The combination of these two devices allows us to place the user in a three-dimensional environment called VR. This knowledge defines the static geometric structure and behavior of the worlds, that is, the timer aspects of the worlds (Singh et al., 1995). In VR, life-like changes in visual imagery occur in response to the participant's actions. Such realistic feedback often makes them feel that they are somewhere while navigating the computer-simulated world (Hoffman et al., 1995). The purpose of any virtual reality (VR) system is to allow the user to control the environment as naturally as possible (Ghazisaedy et al., 1995). VR is a computer-generated immersive environment in which users have real-time, multi-sensory interactions VR techniques place design in a virtual environment and use an immersive interface to explore it as a wandering (Ahlers et al., 1995). Virtual environments where many users can share information with each other (Wang et al., 1995) and the use of computer-generated 3D environments are VR. Virtual Reality (VR) is a computer-assisted environment for people to explore new worlds, share ideas and experience new experiences in the digital space. A VR experience enables the users to explore a virtual world or computer-generated space by using advanced technology to make their brain feel (immersed) or convinced that they are immersed in a different world, which is not there but should be perceived as real as possible (with our senses). It is a version of reality (such as smell, taste, touch, sight, and hearing) that we perceive and the real or simulated environment in which a sensor lives (Punako, 2018).

People are beginning to understand that VR appeals to a new medium, a new entertainment, a new and very powerful art form (Bates, 1991). VR has four properties. These are:

- Entering, being in: that is mentally leaving the real world and entering the virtual world,
- Interaction: creating perceptual reactions in the user with the reflection of the movements in the real environment to the virtual environment,
- Three-dimensional graphical world: an imaginary or real environment that the person creates and shares with others,

- Emotional feedback: it is affected by the sensory actions of the user in the environment

The historical development of VR technology is generally as follows; The first major discovery in the history of VR began when Charles Wheaton invented the stereoscope in 1838. The stereoscope showed two side-by-side complete photographs that gave the viewer a sense of depth. To spread this illusion, the stereoscope gave the user two identical photographs with slight differences. This revolutionary breakthrough paved the way for other items we use today, such as film, photography, and 3D movies. Inventor Morton Heilig developed the Sensorama, the first machine to give users an immersive feeling through the use of their five senses. Made in the 1960s, the Sensorama gave the user a 4D experience like no other back then. A few years later, computer scientist Ivan Sutherland and his student David Evans combined their efforts to create the first head-mounted display (HMD), dubbed the Damocles Sword. Damocles Sword has become a completely new concept that not only marks a shift in the history of VR but also has an impact on AR. This header allows the user to see a grid-like surface. It has laid the foundations of all VR headsets in the years to come. In 1929, Edward Link invented the first flight simulator called the Link Trainer. The Link Trainer did not have a visual display but had hydraulics actuated by the control wheel. Despite the absence of a visual screen, the trainees felt the same movements as if they were in a real plane. The military used this invention to train World War II pilots. The army did not start using the HMD device for flight simulation until 1979. Thanks to Thomas Furness, father of VR and AR, an HMD has been created for the flight simulator. Without HMD, there would be no such thing as VR, as it lays the foundation for future companies and inventors to produce headsets. In the 1970s and 1980s, optical advances progressed in parallel with projects working in haptic devices and other devices to enable movement in virtual space.

According to the above information, in VR, some devices are required such as headsets, screens, smart glasses, computers, and smart gloves etc. It is a technology that enables the events in the three-dimensional environment to be experienced as if they are real with the help of smart devices and gives a sense of reality in the virtual environment. VR makes people forget the real world by immersing them in virtual environments and pulling them into virtual environments and enables them to act and act as if they were real in the artificial world.

Figure 3. VR headset and associated controllers to control a game (Source: Wikipedia, 2019)

3.2. Augmented Reality

AR is defined as the simultaneous display of the real-world environment, directly or indirectly, by adding virtual images and information developed in the computer environment (Milgram, 1994).

Applications that have started to take place as Augmented Reality (AR) or Augmented Reality (AG) in Turkish informatics terminology aren't a distant technological concept to users and are slowly starting to be taken for granted by brands (Graham, 2013). This term, which is abbreviated as AR in English, is also abbreviated as AG in Turkish usage.

AR provides an environment that can process real and virtual objects together, both interactively and in three dimensions. In the real environment-virtual environment continuum, augmented reality is defined as closer to the real environment and virtual reality (VR) is defined as closer to the virtual environment (Milgram, 1994). This definition is known as Milgram's continuum.

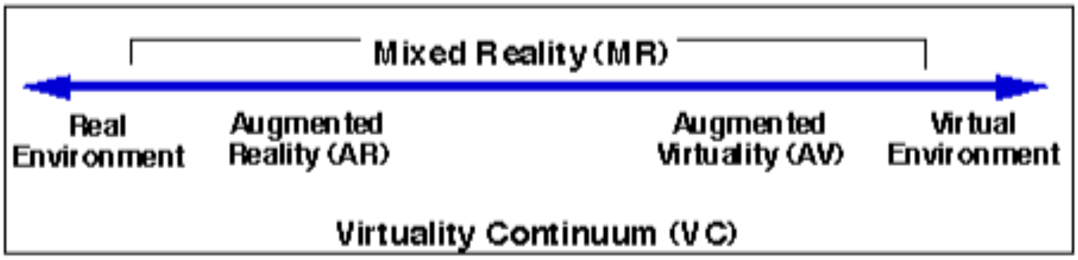

Figure 4. Milgram's VR continuum (Source: Milgram, 1994)

AR appears as a facilitating factor in the daily activities of the user by bringing virtual information into account. AR, apart from the examples that are directly perceived in our current environment, can also be encountered indirectly, for example, in live broadcasts on TVs. It has been determined that virtual reality or virtual environment intervenes between the user and the real world and surrounds the users with a completely synthetic world. It is stated that this situation cuts off the communication of the user with the real world (Milgram, 1994).

By contrast, AR supports the sensations of reality, allowing virtual objects to be superimposed on the real world simultaneously. It has been emphasized that thanks to newly developed tools, AR allows the development of applications for different sensory organs by going beyond the limited display tools such as the head-worn viewer (HMD), which is defined as the only use area (Radianti et al., 2020).

AR aims at enrichment of one's perception of the real world surrounding one's environment, rather than replacing the perception of the real world with a man-made, artificial reality. The new semi-virtual and semi-realistic interface technology of AR has the ability to transfer the instant processed information to the user simultaneously. In this way, it enables the use of AR in many applications such as repair-maintenance, industrial area in production, medicine, military area, supporting education, teaching, games and entertainment areas (Azuma, 2001). Today, QR codes are used to process the real world and the virtual environment simultaneously. The image sensor (camera, optical laser reader, etc.) that detects these codes creates a virtual three-dimensional coordinate system in the real world thanks to AR software and works in three dimensions in the real world by referencing the QR code it detects. It is seen that new detection and recognition methods allow the use of more free and original materials, thanks to algorithms that detect two- and three-dimensional objects independent of QR codes (Graham, 2013).

AR has the potential to appeal to sense organs such as smell, touch and hearing. With applications that support other senses of people with disabilities, vision, hearing, etc. can be supported by auditory and sensory stimuli. While AR can strengthen the presence of an object in a certain environment, the idea of masking and destroying its perception with a virtual object has also been discussed.

The data that the users cannot perceive with their current sense organs can be added to the current real environment observed of virtual objects. When such data is transferred to daily working life, it can help reduce the risk of user error. Reflecting the cable connection sequence of a product moving on an assembly line on an eyeglass, or by means of applications such as Wikitude and Layar, it allows the desired information to be displayed without losing contact with the environment while wandering in any residential area. These and similar AR applications open up countless possibilities in the field of medical imaging, entertainment, advertising, repair and service, conference footnotes, road design for robots, especially in education. In 2013, 670 million USD was invested in the development of AR applications. With this rate of development, this figure was expected to reach 2.5 billion USD for 2018 according to the results of the ABI research institution (Graham, 2013). AR was brought to life in the 1950s when cinematographer Morton Heilig thought that cinema was a medium for the audience to be influenced by all their senses. In 1962, the first prototype of this idea was produced. The name of the prototype was proposed in 1955 as Sensorama, which was described as the future of cinema.

In 1960, it was suggested that we will become more sensitive to our environment thanks to the increasing importance of the role of computers in our lives and the simultaneous access to information.

In 1965, Ivan Sutherland invented the head-worn imaging device. Sutherland (1965) is known as the first person to have succeeded in creating an optical and transparent head-worn AR system.

In 1975, he created the video place (artificial reality space), the room where virtual objects interacted for the first time (The Interaction Design Foundation, 2019).

Later, aircraft manufacturer Boeing engineers brought the augmented reality environment, where they used the words AR for the first time, to the aircraft assembly line. In the early 1990s, employees were able to access the necessary technical information through images projected on their safety glasses because a Boeing 747 aircraft produced at that time was made up of 5 million parts. Thus, a more efficient workflow was created (Caudell and Mizell, 1992).

Figure 5. The first transparent optical imaging device that can be worn on the head (Source: Sutherland, 1965).

This period is also known as the beginning of the time when the advantages of AR over VR were discussed. In these discussions, less energy and pixel requirements of AR are the main topics that stand out.

In 1993, the first working AR system called virtual fixtures was implemented. Simultaneously, the AR system prototype K.A.R.M.A. (Knowledge-based AR for Maintenance Assistance) was produced (Feiner, Macintyre and Seligmann, 1993).

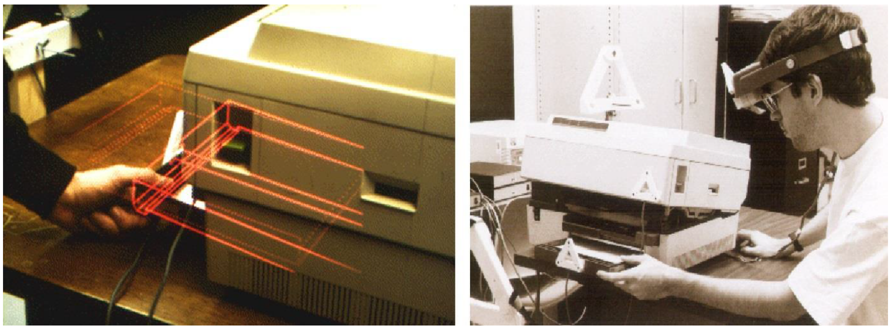

Figure 6. KARMA (Knowledge-based AR for Maintenance Assistance) (Source: Feiner et al., 1993).

While these ideas formed the basic building blocks of today's internet age, they were perceived as inconsistent speeches of mad scientists for that period. However, these views were discussed by a young engineer at NASA at that time, and the ARPA (Advanced Research Project Agency) project was created (Licklider and Taylor, 1968).

In 1964 at MIT, he designed the first image viewer that could be worn on the head. Later, a primitive version of the Graphical User Interface (GUI) was designed with a product called Sketch Pad. Until the 1990s, there was no significant development in this area. A working prototype of the first mobile personal AR device system was designed at Columbia University (Şimşek, 2019).

At the same time, the concept called Milgram Continuity was introduced at the ATR Communication System Lab in Kyoto. With this concept, they examined the definition spectrum ranging from the reality that surrounds us to VR (Milgram, 1994).

In 1997, the first comprehensive review and descriptive article on AR, which works simultaneously and overlaps the interactive, three-dimensional, real and virtual environment, was written (Berryman, 2012).

The first mobile AR application working outdoors was developed in 2000 under the name of ARQuake (Thomas, 2000).

In 2005, Horizon Report predicted that augmented reality technologies would develop further in 4-5 years. In support of this prediction, camera systems that analyze their environment and simultaneously detect their relative positions between objects began to be developed in the same year.

Such camera systems have become the most important basic element that provides the integration of virtual objects with reality in AR systems. By 2008, it was possible to develop dozens of AR applications, mostly mobile applications such as Wikitude AR Travel Guide. Applications in the field of health have also made significant developments by following their mobile applications (Peterson, 2008).

Today, rapidly increasing AR systems and applications have been produced thanks to the advantages of new technologies. The MIT 6th sense prototype paves the way for revolutionary applications thanks to the hardware of retina resolution iPad, iPhone 6, Samsung Galaxy series, tablets and smart mobile devices.

3.3. Mixed Reality

Mixed reality encompasses the whole process from the real environment to the virtual environment, including the other realities called in between, from the initial AR to the final VR. MR covers the continuity between video and enhanced graphics and graphics enhanced video. In line with technological developments, MR systems using VR systems, which continue to be developed for many industries, have many applications from serious games to entertainment, in particular simulation applications, in the field of graphic design application in education, visual arts, architecture, industrial design, publishing, commerce, and video games can be used.

Milgram and Kishino studied the capacity of VR and the limits of MR. The widely accepted view of the VR environment is that it should be an environment where the participant is fully immersed and able to interact with a fully synthetic world. Such a world may imitate features of some real-world environments, either existing or fictional. However, the limits of physical reality can be transcended, creating a world where the laws of physics no longer define the boundaries of space, time, mechanics, and material properties. However, what can be overlooked in this view is that VRis also frequently used with various environments that coincide somewhere along the virtuality process, where it cannot completely meet full immersion and full integration (Milgram and Kishino, 1994). The biggest difference of MR from VR is that physical movement in VR is limited. While the virtual real environment can be experienced in front of the computer in a fixed way or with simulators with limited movements, in the mixed real environment the experiencer is relatively physically free, and his position and movements are simultaneously transferred to the virtual environment by the locators and can be responded to. The experiencer also has augmented data flow in a mixed reality virtual environment.

The transition of mixed reality from a concept to real use has been possible with the transfer of mobile technologies led by mobile phones to VR systems. In July 2012, the American virtual reality company Oculus VR, founded by Palmer Luckey, Brendan Iribe, Nate Mitchell and Michael Antonov, launched Oculus VR DK1 and Oculus VR DK2. In 2015, Valve company, the owner of Steam, exhibited their VR systems at the San Francisco Game Developers Conference. The VR headset produced by Valve in partnership with HTC is called Vive. Vive transfers the movements in a physical area of approximately 25 square meters into the virtual environment by determining the physical location with cross-placed controller base stations (D'Orazio and Savov, 2015). Oculus uses a similar locator system. What Microsoft calls Mixed Reality is software, not hardware, and is more of a VR system than positioned MR systems.

Figure 7. HTC Vive (Source: Gustavo, 2019)

MR is not a mix of AR and VR, but it's inclusive superstructure. The first screening of the world's first mixed reality exhibition titled Thresholds by Mat Collishaw was held in London Somerset House in 2017, and the second screening took place in Istanbul Yapı Kredi Culture and Arts in 2018. The thresholds take the viewer to the world's first photographic print exhibition, opened by British scientist William Henry Fox Talbot at Birmingham King Edward's School in 1839. While navigating the digitally and three-dimensionally built space, viewing the photographs in the digitally built showcases, the audience can touch the objects and surfaces, and they can also feel the smell and heat of the fireplace (İpek, 2019). Although the exhibition specifically stated that it was a mixed reality exhibition which was reported in the media as a VR exhibition.

3.4. Types of Augmented Reality Applications

The concept of AR has been on the agenda of VR for a long time. It has started to take its place not only in the conceptual sense, but also in our daily lives. Nowadays, like GE, Toyota, and LEGO, many international brands have started to use AR as a marketing and interaction tool. Although these applications did not have the chance to reach very large masses, they attracted the attention of the desired target audience and found the interest to create their own dynamic. With the increase in the tools and software required for the development of augmented reality applications, the possibility of reaching more people is increasing.

In current AR applications, the emphasis is on superimposing graphics on video images taken by a webcam. For this, some kind of sensor mark (data code), symbol or picture is required. In any case, the software used (augmented reality plugin) needs these marks for two things. The first is necessary for determining, recording and tracking where content and media will be shown. Secondly, it is necessary to determine what to display. Some AR developers are able to achieve the second method without using the data matrix. In this case, there is no need to use any data matrix. Such applications can be defined as the first level of AR.

Although first-level augmented reality applications are innovative, they have a limited area of use. Eye of Judgment developed by Sony, Kweekies developed by Int13 and AR Toys Concept by Frank Lasorne are among the successful examples of this level of AR applications. When these applications are made mobile instead of desktop, they are subject to the second level of augmented reality.

The best-known of the second-level AR applications is Wikitude-AR, developed by Mobilizy for the Android platform. As soon as we move away from desktop AR applications and pay more attention to where we are and what is happening around us, the mobile device in our hands begins to act like a lens. When we examine our environment with this lens, we can perceive a world that contains information, data and images produced simultaneously and in layers. The IT industry, which has invested in this area, has accelerated the transformation to mobile phones with more powerful processors, mobile internet devices with 3D graphics and GPS function, as they see new opportunities. These new devices have also changed the way we think, the way we interact with communication and the media (Cobzas, 2003).

The third level AR can be defined as Augmented Vision. At this level, the screens in the form of light, portable transparent wearable glasses are moved from the front of the monitors. When AR turns into Augmented Vision, it becomes spiral. All experiences in this medium begin to become more relevant and more personalized to purpose and context.

The third level AR enables massive multi-user access, sharing, dynamic and simultaneous presence in more than one place. For this, a number of technologies and disciplines need to come together.

Some of those are:

- Powerful multi-core mobile internet devices
- Widespread wireless broadband internet network
- Semantic search engines,
- Intelligent pattern and image recognition technology
- Smart agents
- Hybrid service location and client-server architectures
- Interfaces sensitive to human gestures and movements
- Standardized communication protocols, data formats
- They are defined as easy-to-use and intuitive tools for application development and content creation (Cobzas, 2003).

3.4.1. Augmented Reality Imaging Methods

Computer vision is the visual rendering of three-dimensional virtual objects from the viewpoint of the spectator camera. In the creation of augmented reality images, different computer imaging methods are used depending on the camera tracking systems. These methods usually consist of two stages such as Monitoring and identification/creation. Tracking marks, optical images, or points of interest are detected in the images captured by the camera. With tracking, the interpretation of images captured by the camera is provided by using feature detection, edge detection or other image processing methods. In computer vision, the majority of current monitoring techniques can be divided into two classes. These are divided into two as feature-based and model-based (Zhou, 2008).

In feature-based methods, it is aimed to reveal the relationships between the two-dimensional image features of the object and the three-dimensional frame coordinates. Model-based methods, distinctive CAD models or 2D templates of the object to be traced are used.

By establishing relationships with two-dimensional images and three-dimensional frame coordinates, the camera reveals the possibility of posing the three-dimensional coordinates of the object in the two-dimensional environment being viewed. The limitations of camera exposure calculation are directly proportional to the use of point clouds. The rendering/recognition phases are realized by processing the data from the first scene and transferring it to the real-world coordinate system and repeating it continuously.

The point constraint is realized by repeating this constantly. A calibrated camera projected into perspective. Advances in visual tracking have allowed new approaches to how the human brain recognizes objects. With the Human Vision System (HVS), it is aimed to model the Human Vision System, which recognizes infinitely many objects within percent of a second. Thus, the difficulties faced by computer vision will be overcome and very important steps will be taken on the way to progress.

To create an AR environment, screens, data entry tools, monitoring tools, computers and mobile devices are used.

Three different screen types are used based on the AR environment. These are head-mounted-display, HMD, mobile device displays, and spatial-sized displays. Head-mounted displays (HMD) can be worn on the head as well as worn on a helmet. In this case, both the real world and the image projected on the screen can be perceived simultaneously. HMDs can be optical transparent displays or video display vision. Devices with video screen vision are more in demand than transparent screens. Real-world images of the augmented scene are captured with two cameras on your head to get the image. It is blended together with the virtual images coming from the computer and transferred from the real world and the perceived image to the low-resolution screens in front of the eyes. On the other hand, semi-silvered mirror technology allows superimposed graphics to reach the user's eyes directly by being projected onto real-world images in transparent screen devices (Reitmayr, 2003).

Blended scene and real-world images can be perceived more naturally and in higher resolution than devices with video screen vision. In contrast, on screens with video screen vision, the user has more control over the synchronization of the real image with the virtual image, since the image is pre-generated in the computer environment before it is displayed on the screen. On devices with transparent screens, the delay of the real image cannot be interfered with. For this reason, the delays and image shifts that occur during the projection of virtual images onto real-world images are perceived by the user. The virtual images created by the AR system may form an unstable image, or flicker, and may not hold onto the object to be connected in the real image, and may float on the screen (Reitmayr, 2003).

Mobile handsets are defined as devices with screens, cameras and small processors. Using the video screen vision technique, they can create virtual graphics superimposed on the real world. For tracking sensors with six degrees of freedom, they include sensors such as GPS (global positioning system). They recognize tracking signals such as QR codes and can use computer vision methods such as SLAM (simultaneous positioning and mapping) (Wagner, 2006).

In spatial augmented reality (SAR) applications, it allows the projection of graphic information on physical objects by using tracking technologies such as video projections, optical elements, holograms, radio frequency tags (RFID). In such AR applications, the user does not carry an attached or wearable screen. With spatial augmented reality, the user can be separated from technological devices (Bimber, 2007).

It facilitates the interaction and participation of the user with the environment. The AR environment of the communities where the participation is more than one allows interactive participation with each other. Today, its use in museums, laboratories and educational institutions increases the interest in the activity. There are three different approaches based on spatial AR applications; viewed from the video screen, viewed from the transparent screen, and directly perceived according to the interaction with the environment. In spatial augmented reality (SAR), standardized personal computers and screens are used for the system viewed from the video screen. The system is fixed and can be installed with small budgets as long as it does not need to be constantly moved. In SAR systems viewed from a transparent screen, the images are created by aligning them with the existing physical environment (Figure 7). Spatial optical complements such as planar or curved mirror beam splitters (prompter, projection TV, etc.), transparent screens or optical holograms (anaglyph), active and passive three-dimensional glasses are the main elements of such images (Bimber, 2007).

Figure 8. Projection of the VW Toureg framework onto the vehicle (Source: Patrascu, 2010)

The spatial AR viewed from the transparent screen does not support mobile applications, as is the view from the video screen. In directly perceived projection-based spatial images, images are transferred to the surface of the object to be projected uninterruptedly (Mistry, 2009).

There are many types of data entry devices for AR systems. Electronic gloves are used in the mobile AR system of Reitmayr et al. (2003). Wireless wristbands are used in ReachMedia (Feldman, 2005).

The phone itself is used as a pointing device where smartphones are used. In the mobile application called Flightradar24, when the user frames the plane flying in the sky with his phone, he can instantly access the information about the current flight speed of the plane, where it came from and where it is going. With the program called

Google Sky Map, the name of that celestial object is reflected on the screen of the phone, which is pointed at a celestial body in the sky. The data entry tool varies according to the type of application developed for the AR system. If free use of the hands is foreseen in an application, a device without an artificial device in the user's hand or that does not interfere with the natural movements of the hand, for example using the eyes, or wireless wristbands are used.

Monitoring devices, digital cameras, and/or other optical sensors, GPS, accelerometers, accelerometers, gyroscopes, magnetometers, wireless sensors, etc. consists of elements. All these technologies have different sensitivity levels. The obtained precision value also varies according to the application to be developed (Yi-bo, 2008).

Yi-bo et al. (2008) gathered the general tracking technologies to be used for augmented reality under the main headings as mechanical, magnetic sensing, GPS, ultrasonic, inertial and optics.

Papagiannakis et al. (2008) and DiVerdi et al. (2007) added the variables of setup, resolution, time, and environment to these properties.

AR requires the use of powerful processors (CPU) and sufficient random-access memory (RAM) for systems to process computer images. Until a few years ago, portable laptop systems were being installed for mobile AR applications. However, with the advent of smartphone technology and tablets, light and interesting devices are taking the place of transport-dependent systems. Stationed systems continue to use traditional workstation computers with powerful graphics cards (Furht, 2011).

Thanks to the video camera and video imaging features added to portable communication devices, it has enabled the development of an application integrated into the global positioning system. This is known as the ability to see where it is and to notice its surroundings by overlapping the additional data it receives from the global positioning system (GPS). In the 3rd version of the iPhone software development kit, it was allowed to put only informational layers on the image taken from the camera of the mobile device. In the fourth version, these images are allowed to be analyzed. Thanks to the image analysis, it was stated that software developers were allowed to perform live image analysis. Thus, it has been suggested that apart from where the mobile device is and where it is looking, the geometry of the physical objects around it can be analyzed without being tied to a place (Furht, 2011).

3.4.2. Augmented Reality Interfaces

The creation of appropriate techniques is one of the most important aspects of AR that will provide intuitive interaction between the user and the virtual content of AR applications. The four main ways of interaction in AR applications are:

- touchable augmented reality interfaces,
- collaborative augmented reality interfaces,
- hybrid augmented reality interfaces,
- can be defined as developing multiform augmented reality interfaces (Furht, 2011).

There is a direct interaction between the touchable interfaces with the real world, leveraging the use of real, physical objects and gadgets. A method developed by Kato et al. (2000) has been suggested to demonstrate the power of tactile user interaction. In this method, the user can change the layout of the furniture in a living room created in an AR environment with a real physical shovel. The movements of the shovel are intuitively mapped to the hand movements, and the desired furniture object can be selected with the lifting movement with the shovel. The removal of the furniture object is ensured by the striking movement with the shovel.

Another method, a more recent desktop touchable AR interface implementation, uses real physical objects. The physical objects used to play a key role in asking questions related to the map (Kato, 2000).

It digitally projects the information about the searched area on the map onto physical objects. With the use of physical objects, it is aimed to use objects with universal validity instead of user interfaces in different languages. Although the language barrier is overcome here, the use of the objects to be used creates the need for a user manual (White, 2007).

Uncertainties arise because the objects that will be used for people from different countries, different age groups, and cultures may have different meanings for those people. To overcome this uncertainty, it has been suggested that virtual visual cues showing how objects should be moved can be projected onto real physical objects.

In collaborative augmented reality interfaces, using multiple images, remote and in-server activities are supported. It enables the development of a collaborative physical workspace by using three-dimensional interfaces in the same server sharing. In remote sharing, augmented reality can increase the efficiency of teleconferences by enabling the participation of more than one device from different locations without burdening (Gül and Çağdaş, 2012).

It was in the designers' minds that collaborative augmented reality could link multiple user interface dimensions. It has been argued that this requires multiple users, appropriate content, servers, applications, three-dimensional windows, viewing platforms, and operating systems.In the AR project called Studiers tube, it can be seen that there is a collaborative working model in a common server (Schmalstieg, 2000; Schmalstieg, 2002).

It is emphasized that the efficiency of teleconferences for disease diagnosis, surgery and routine care can be increased by using interfaces that can be integrated into medical applications in remote sharing (Barakonyi, 2004).

Hybrid interfaces are defined as a mixture of different but complementary interfaces, and it is argued that a wide range of interaction tools are used (Zhou, 2008).

It provides a flexible infrastructure that is suitable for daily use, does not require preliminary preparation, and which interaction screen or device is unknown beforehand. In the hybrid user interface developed by Sandor et al., both AR images and sound are superimposed on real images on a head-mounted display device with a transparent screen that tracks head movements. With this AR system, it is aimed for end-users to access and reconfigure all controls from physical interactive devices to virtual objects (Sandor, 2005).

Multimodal interfaces combine real objects with speech, touch, natural hand movements, and eye movements to become data input. Such interfaces are still under development. An example of this is MIT's sixth sense wearable gesture-sensitive interface called WUW (Mistry, 2009).

WUW provides feedback to the user by projecting the defined information on the natural movements of the hands and arms onto surfaces, walls, and physical real objects. Another study, which is an example of multimodal interaction, involves interacting with objects with eye and eyelid movements (Lee, 2010).

This is expressed as an interaction tool preferred by the user between the human and the computer. This type of interaction tools has been preferred for future AR applications due to their relatively effective, efficient, easily expressed and easy application in the mobile field, and have found the opportunity to work in a very wide area and have been further developed. These tools have the ability to support the user's skills by disabling or enabling mods, combining them with different mods, depending on the task given. In multi-modal interfaces, the user has the freedom to use the mode he prefers according to the content of the area, such as public space, museum, and library. The freedom to choose the mode of interaction is much more important in systems commonly used in public spaces (Oviatt, 2007).

AR systems can be categorized into five. These are: fixed indoor systems, fixed outdoor systems, mobile indoor systems, mobile outdoor systems, mobile indoor and outdoor systems. Mobile systems are defined as systems where user movements are not limited to a single room but can move with wireless systems. Fixed systems are systems that cannot be moved. The user can only use the system in the place where it is installed. In these systems, user movements are limited, and it is not possible to use the system in another place unless the entire system is moved. The choice of the system to be installed, the people who will develop the application should be decided at the beginning of the installation phase depending on the tracking systems, imaging systems, and possible interface that they will use in the system. For example, while a GPS tracking system is not used in fixed systems, it can be used in outdoor mobile systems. Although the work of application developers on mobile AR systems has been in the minority until today, mobile applications are now being developed more due to the developments in the field of mobile hardware and the potential it holds. A generalization should not be made for AR systems that will be established by looking at these results. Hardware selection can be made according to the application to be preferred in the system likely to be installed. In some cases, although the application preference is not suitable for the selected hardware, it can be preferred by standing out (Rempel, 1995).

In a study, optical tracking systems are preferred more in fixed systems. Hybrid systems are mostly preferred in mobile systems. Although head-mounted display devices are more preferred, they still need to be made more aesthetic and lightweight in terms of usability. Although hands-on interfaces are more preferred today, it is predicted that developing multimodal interfaces will find more use in the coming years (Papagiannakis, 2008).

3.4.3. The Future of Augmented Reality Applications

Data visualization provides more context than information points added to the corkboard. This content can open up new horizons in AR applications (Graham, 2013).

A mirror image of the earth is obtained by point cloud matching, including important statues, buildings, etc. in cities, touristic areas with a high population. The number of people who take photos or videos of places from different angles is high. Point Cloud Model (point cloud models) application is defined as three-dimensional point clouds created by uploading the photos taken by ordinary people for touristic purposes with similar names to online photo archiving sites and then bringing these similarly named photos together. This application, funded by Microsoft, was delivered to the end user under the Photosynth brand (Snavely, 2006).

Developed at Oxford University, PTAM also analyzes elements other than face recognition. Parallel Tracking and Mapping is a video analysis application. It calculates the points of interest in the image as a point cloud by finding the edges, corners, contrast differences. Using this point cloud, the computer maps the three-dimensional map to real-world coordinates (Klein, 2009).

Later, a Mirror World project that could work simultaneously was developed. In this application, eight camera angles and satellite images are used. It was carried out on live recorded video images of the three-dimensional model obtained by combining photographic frames (Hill, 2011).

The connection of these applications with AR emerges when they are used in architecture. In an AR study, they can make the blind spot and invisible areas behind the wall visible by overlapping two different camera images (Barnum, 2009).

When all these are examined together, the GPS receiver on the mobile smart phone can download the point cloud of that region to the smartphone with the mobile data transmission protocol according to the coordinates of your location. Thus, a three-dimensional model of that region is obtained in a near-precise reality. With the camera and PTAM software on the smartphone, the mirror world data that is currently loaded on real buildings can be superposed (Klein, 2009).

In this state, AR, enriched visuality, digital images and/or data in the virtual environment and real-world data are enriched and presented in an integrated manner. Augmented reality adds a new layer on top of real-world data. AR finds application in many environments from education to healthcare today. Architecture is one of them. On the other hand, with the development of AR, infrastructure and devices day by day, these applications seem to attract more attention. Thanks to augmented reality, the technological level we see in science fiction movies is now starting to become real. Webcam-based applications, constantly evolving technological devices and similar technological platforms allow for very different experiences. With the further development of devices and platforms, it is predicted that more useful and much wider applications will be witnessed in the future (Roberts, 2002).

In this context, the possibilities, the point and promises of wayfinding and VR and AR technologies will be discussed in the next chapter through VR and AR discussed in this chapter.

CHAPTER 4: AR AND WAYFINDING

4.1. AR Applications in Wayfinding Strategies

Navigation is a complex cognitive process that is usually required for spaces in complex structures such as museums, hospitals, airports. Individuals have difficulties in determining the location of their wayfinding vehicles, understanding the terms and pictograms on the signs and being sure of the targeted destination by following various signs.

According to Kim (2015), existing wayfinding practices are insufficient to support people's natural navigation behaviors. For this reason, AR applications have a very important role in eliminating this deficiency. In order to meet the wayfinding requirements needed in a complex space or environment, the design should be reviewed for:

1- Current location, direction and target setting

2- Remote recognition of elevators and stairs and room numbers

3- Being sure of the destination while navigating in space

4- Being accessible and portable from mobile devices such as handheld devices.

AR applications improve the experience of a person navigating the space by providing real-time information about targets and features with the help of graphics, text, audio and videos. AR applications also increase the possibilities of visiting experiences when visitors are constantly informed by the interior localization of the physical space and the visualization of this position as individuals move. In this context, two theories have been put forward. These are wireless connection and visual monitoring.

Wireless Connection: Since 2011, the most common solutions for indoor navigation have been realized by means of technological developments that provide wireless connection such as GSM, WLAN, Bluetooth, Infrared, and RFID. However, the low accuracy and low signal speeds of these technological tools have also hindered technological development such as AR. Alnabban (2014) lists the possible techniques in a study as follows:

• Ultrasound

• Optical Marker Based

• Optical Unmarked

• Magnetic

• Inertia

• Ultra-Wideband (Uwb)

• Hybrid, Accelerometer

• Active RFID

• Passive RFID

• Wi-Fi Fingerprint

Many of these technological developments are due to the cost of their infrastructure, complexity of applications, accuracy levels, update rates to applications, operating intervals, portability, etc. is not applicable for any reason. However, Huey (2011) states that it is not possible for these technological approaches to be highly dependent on the presence of a wireless connection in the building to navigate indoors.

On the other hand, Alnabhan (2014) states that many improvements are needed with a significant margin error that provides a reach of up to 7.2 meters by using Wi-Fi fingerprint methods, which is a more accurate result than GPS for I NSAR applications on Android devices stated.

	GPS	GSM	WLAN	Bluetooth	Infrared	RFID
Range	Wide area	Wide area	Micro area	Micro area	Pico area	Pico area
Accuracy	No signal	Low	Low	Low	High	High
Signal Error Rate	No signal	Low	Mid	Low	Lowest	Lowest

Figure 9. Comparison of heterogeneous positioning technologies (Source: Huey, 2011)

Visual Tracking: In terms of the augmented aspects being intuitive, accuracy is considered quite acceptable when superimposing virtual elements in spatial space. Technological realization of point of view, superior tracking ability keeps virtual entanglement stable in real space while also leading to typical image flip or wiggle, which has poor tracking capabilities. Ventura (2014) introduced simultaneous visual placement and mapping by requiring a computer half to triangulate and monitor many points within the scope of the characteristics of the turning points of the surface in physical space with the help of a monoscopic camera. With the advent of this system he introduced, many perspectives predict the perspectives of portable devices directly by exposure. However, among the technology monitoring visual methods;

• Marker tracking

• Unmarked tracking

• Ability of the computer to calibrate spatial positions according to the physical areas of incoming visitors

• There should be expanded monitoring of where the virtual modeling is.

Kim (2015) developed AR applications based on a sign system that needs to be scanned at every turn or decision point of the users of these devices. Although this development facilitates much more accurate results and more precise localization of virtual elements than wireless tracking, a similar experience is required to occur, which requires manual scanning of visual markers to a significant extent. However, it is a matter of debate whether this developed system will help to navigate without problems in the real world, but not in the virtual world. Although it does not have a viable approach, it is obvious that this system made by Kim will turn into a source of inspiration by making improvements in the coming years.

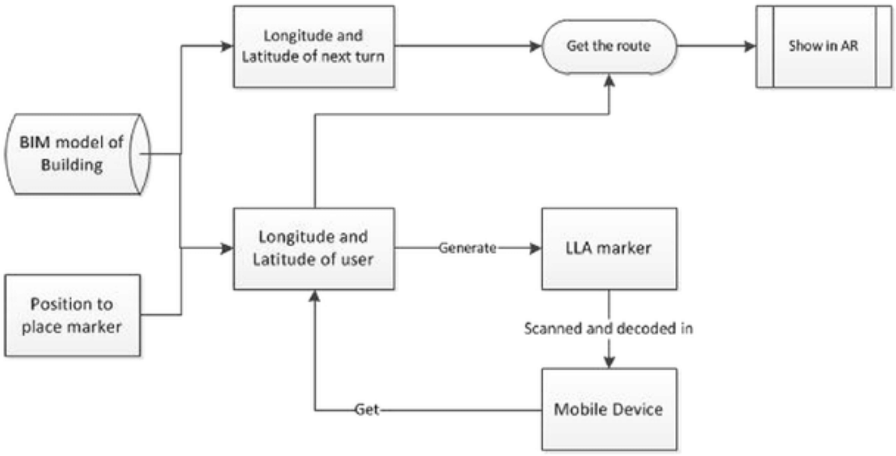

Figure 10. Methodology of AR-based wayfinding mechanism and testbed (Source: Kim, 2015)

Whether augmented reality-based navigation can overcome many of the cognitive processes required in classical navigation is still a matter of debate. In this context, the findings obtained by Shamsuddin (2015) and Kim (2015) revealed that the performance of augmented reality in wayfinding is positive. AR has made it easier for visitors to cover an indoor space, and has corrected the deficiency necessary for reaching the target destination in a short time. Shamsuddin (2015) stated that enhancements such as direction indicators, maps and path restriction can all greatly improve both wayfinding performance and overall user satisfaction. Wayfinding research using augmented reality encourages the development of these methods by analyzing the factors affecting wayfinding behaviors. Augmented reality in the real world is expected to minimize the problems that arise during the determination and interpretation of spatial accuracy among wayfinding applications, thanks to the real world environment. The use of this development in environments like museums also provides benefits in many ways. Some of these benefits are the versatility of outputs and the endless possibilities that content and visualizations provide.

AR is a technology that has been developing for years and is advancing towards today's modern technological structure. The applications of this technology are primarily in the military, industrial and health fields; It is seen that it is used in fields such as education, architecture, marketing, entertainment, tourism, museums and historical sites. In addition to technologies that combine the real world with virtual information, the augmented reality experience has become easy and portable, especially with the production of mobile devices such as smart phones. As a result, the use of AR technology is spreading and researches are being carried out on its use in many different fields (Johnson et al. AR applications in the field of education are used for students to learn more effectively, especially due to technological developments in recent years (Billinghurst et al., 2014). It is seen that such applications are used in classroom environments with augmented reality books and student guides in lessons such as physics, chemistry, biology and mathematics. According to the researches, AR applications used in the field of education are providing a better understanding of the concepts, andmconcretizing abstract concepts. Ensuring the subjects are easier to understand by enriching them with visuals, and increasing the students' motivation for lessons by attracting attention. It has benefits such as enabling students to enjoy the learning phase.

Developments in computer interfaces and hardware have led to the emergence of many augmented reality applications in the field of architecture. Such applications are used to contribute to the visualization, design and construction of an architectural structure (Wang, 2009). However, there are applications that provide content in city visualizations with three-dimensional building models and panoramic images. Figure 14 shows an augmented reality example from the CityViewAR application designed by Lee et al. (2012) for this purpose, showing the old state of a historical building. This app provides information about structures damaged by earthquakes in Christchurch, New Zealand in 2010 and 2011.

Figure 11. Old View of a Historic Building from the CityViewAR Application (Source: Lee et al., 2012)

It is mentioned that augmented reality applications in the field of marketing, apart from traditional marketing forms, attract the attention of consumers and provide more information about products and memorable experiences (Billinghurst et al., 2014). Therefore, AR applications are used by marketers, especially in new product promotions. An example of such applications is the IKEA Place application announced by IKEA in 2017. Thanks to this application, consumers get information about how the products in the IKEA catalog will look in the real environment of their own home (IKEA, 2019).

4.2. Augmented Reality Display Technology and Human Performance

AR applications currently available also reveal an augmentation with visual channels (Berryman, 2012). It is important in many ways to identify different approaches to application screens and to discuss the problems that arise with them. Because the application screens are augmented by revealing a technical area of interest, and together with the evaluation of VR, they make it central to the visualization of direction finding in VR. Carmigniani et al. (2010) provide an overview of AR applications. Two basic approaches on the screens of these applications refer to video or optical transparency. Both approaches allow combining images on two sources. In the video, images of the real world are electronically combined with images generated by computers. In optical transparency, images are combined optically. Both of these approaches have their advantages and disadvantages. The transparency of the video offers a better integration of real-world and electronic images, with little control over recording problems due to their electronic splicing and delays. The graphics created by optical transparency systems in the computer environment move at the same level as the users. For this reason, a way to control the latency while trying to merge with the real world has not been found yet. On the other hand, there is also physical bulkiness in transparent video and optical transparency systems. It is also stated that optical vision performances are generally better than videos, both in resolution and field of view.

Head-up displays provide an optical fusion of electronic images with a real-world scene. Lampropoulos, Keramopoulos and Diamantaras (2020) add provides an important summary of overhead displays by adding symbols to aircraft pilots' front sights. On the other hand, he distinguishes head-on imaging from augmented reality as a point that includes its approach as well as a technical definition. Generally, head-up displays are developed to be used instead of normal gadgets. Augmented reality ensures that instead of changing information, it is preferred to develop and add a real scene. Lampropoulos, Keramopoulos and Diamantaras (2020) states that overhead screens aim to separate the real world quite clearly and do not aim to be perceived as a holistic one.

However, many researchers adopt a different approach in this regard. Among these, Wickens and Hollands (2000) and Carswell and Wickens (1987) state that there should be another more integrated screen type and defiance approach to reduce attention problems. On the other hand, McGee (1999) deals with a perspective of perceptual fusion, while Wickens and Hollands (2000) examine the fusion of objects cognitively. Having a strong sense of duty in applications leads to the conclusion that objects should be connected to each other on an application screen. Establishing these relationships cognitively enables careful evaluations. According to McGee (1999), it only focuses on the spatial and graphical properties of the screens as the enabler of the established connection.

There are many aspects of AR regarding the problems that arise as a result of the performances of people. In this context Lampropoulos, Keramopoulos and Diamantaras (2020) address persistent problems with screens, such as the dynamic range of brightness, limited field of view, and fixed contrast ratio that limits the combination of real and synthetic images. Also, while displays for gaming indicate progress in some of these areas, they are most reasonable for low-cost consumers. Similarly, by adding special LCD panels to the optical path, the occlusion supports of the optical screens are prototyped. The screen sizes of extended screens are decreasing with the use of glass screens.

Monitoring technology is needed for an effective AR to occur. It is necessary to accurately represent the occlusion, communicate with real and virtual elements, and monitor the graphics to support other sensory processes. Indoor monitoring is available today, but the cost is also quite high. Precise outdoor monitoring is a difficult task to perform unless outdoor reference values are prepared with differential GPS or precision maps. Carmigniani et al. (2010) describe prototyping improved user interfaces that allow more mobility and better form factor for a user. On the other hand, other user interfaces include the methods of physical devices that facilitate the manipulation of virtual objects and th interaction between users.

4.3. Human Performance Characteristics in Augmented Reality

In many AR applications, an analogy can be obtained from the designs of control systems, in which people and vehicles are combined with feedback in a closed-loop, by prioritizing human performance. Looking at the literature, it focuses on how the representations of visuals and different representations affect many aspects of human performance.

4.3.1. Display Performance

The performances of the people who use the applications are shaped by both technology and duty consciousness. Wickens and Hollands (2000) put forward a human information processing model in their study. The model in question is the model that creates feedback of sensory processing, perception, cognition, and response. Cognition consists of working memory and attention resources that are in a long process. The presentation of information, on the other hand, affects attention and memory, which affects spatial information. The real world has many variations, between VR and AR, with images and screens that can affect sensor processing.

Looking at the literature shows that there are some sharp views on incorporating many types of visual information while switching to their content without considering the display hardware. While the screen contents affect the attention characteristics of the user, the screen designs must also be careful (Wickens and Hollands, 2000).

Many problems may arise in terms of designing the application screens in the most appropriate way. Among the concepts discussed in this context are the application-appropriate screen design and avoidance of divided attention, the organization of similar features on the screen, the concept of spatial proximity and their compatibility with the task demands of spatial proximity. HUDs can be cited as an example of using spatial proximity.

Congruent symbols are characters that are spatially fused with the real world. The use of harmonious symbols helps reduce the divided attention between symbols and background scene while keeping augmented and real spatial information spatially and perceptively aligned. Lampropoulos, Keramopoulos and Diamantaras (2020) confirms the benefits of cohesive or fused characters in some AR systems.

Lampropoulos, Keramopoulos and Diamantaras (2020) goes a step further to examine and explore the benefits of computer graphics of related objects cognitively fused with real background. He also highlights the importance of seeing Head Up Display as a special case of AR. His work has focused on cognitive tasks. In related studies, Hillebrand, Wahrenberg and Manzey (2012) examined the effect of HUD intervention on the far-field and divided attention between HUD and the far-field. The application environment flew. The authors point to the advantage of the close placement of information for a shorter response time on board. Differences of less than 6.3 degrees and separation of similar information up to 22.5 degrees were recorded, but they did not affect the response time for secondary tasks. However, users tended to focus on a particular image using an effect known as cognitive tunneling or cognitive stabilization. Hillebrand, Wahrenberg and Manzey (2012) point to Weintraub and Ensing's (1992) increase showing that the conformal features of HUD images can reduce divided attention and increase workload.

Compatible features are HUD symbols that act as virtual counterparts to remote area controls. Edgar and Reeves (1997) also point to a study by Fisher (1979) in which symbols do not negatively affect the pilot's far-field focus, but the reverse is not true. This is facilitated by coherent and consistent movement and continuity between coherent images, graphics and true far field. For far-field images, these results can be used as a starting point for further research in AR where range is reduced in many situations, such as navigating a building or maze.

Edgar and Reeves (1997) experimented with different vision conditions (full and zero vision). They investigated response times under various HUD hash conditions by presenting an unexpected discrete event. The HUD used has a field of view (FOV) from 15.4 degrees to 9.4 degrees (this is less than many monocular displays, such as 16 degrees x 20 degrees made by Micro Optical Corporation). Edgar and Reeves (1997) changed the position of the instrument (upside down). Their results show that it is better to be upside down in almost all situations, minimizing divided attention (with the only exception when unexpected events occur). A second experiment by Edgar and Reeves (1997) explores the benefits of compatible displays. For screens superimposed on a background scene, there is an obvious cohesion effect even when the overlay and background are set to the same distance. If the overlay image is not detected as integrated with the background, it will appear closer than the background. Background effects can cause distraction.

Hillebrand, Wahrenberg and Manzey (2012) examined errors in the localization of nearby virtual objects on helmet screens. In this context, they also explain some useful ideas for designing hardware and software for display on a helmet. It has been suggested that embedding may be a useful depth clue. They also propose a concept where the distance of the screen can be adjusted over significant physical distances to provide a possible point where information can ideally be viewed, presenting an integrated display of real and virtual. Three imaging modes were studied: monocular, binocular, and stereoscopic. The binoculars use two precision images to avoid potential visual competition issues. A rotating virtual pyramid was used as a stimulus and placed 58 cm from the user. Users were asked to place their cursors below the lowest point of the pyramid. Experimental results showed that stereo and binoculars have similar properties. Monocular performance was unstable. An interesting result is that the monocular performance seems to fall on the back wall at a distance of 2.2 m from the subject. The second experiment used a rotating checkerboard with similar results. Considering these experimental results of Ellis and Menges (1998), some of the relevant recommendations are:

1. Subjects' head movement may have untested effects. In particular, motion parallax effects can affect results.

2. Weight and cost can support the use of monocular displays. Monocular displays, if used, must provide variable focus to meet the different needs of users.

3. Binocular and stereo displays require the user to see the aperture before use.

4. Binocular computer images or other images should have adapted stereo unevenness.

Research by Edgar and Reeves (1997) also examined visual cohesion when information is visually presented on a HUD or HMD and in real aviation scenes. HMDs with functionality similar to the HUD in aircraft are being introduced. The authors point to the controversy over whether compatibility issues arise with these systems, even if the computer images seem endless. Research results show a wide range of effects depending on environmental conditions, but do not indicate whether appropriate screens are used. These results show that care should be taken in the design and application of overhead or helmet mounted displays. Depending on the task being performed and environmental conditions, there may be some degree of dynamic variation in the content of the screen.

Martin-Emerson and Wickens (1997) investigated the performance of inverted display in HUDs with harmonious symbols, visual attention, and overlay. There is a similar performance-wise relationship between computer maps used in AR and regular paper maps. However, due to the differences in the complexity of the missions and the fact that the participants will travel through space, this thesis requires corrections. In addition, Martin-Emerson and Wickens (1997) used a HUD with image information superimposed on the visual scene. In this thesis, the information content added to the real scene is placed side by side and spatially recorded instead of the background scene. A study by Martin-Emerson and Wickens (1997) compared an overlay HUD with the same screen upside down under different viewing conditions. They found that HUD symbology features promote the division of attention by comparing congruent symbols with traditional ILS symbology. The results showed that the minimum sweep between the flight instruments and the far field contributed significantly to improved performance. Their hypothesis is that if symbols create an object with an erased field, attention can be divided between the overlapping image and its copy in the far field is preserved. In this context, conformal images include perception. The AR approach explored in this thesis will use still images mapped as reinforcements to facilitate task completion.

Furmanski, Azuma, and Daly (2002) review and present Human Factors design guidelines for the spatial representation of augmented scene content in a real-world setting. The authors use a cognitive approach to develop guidelines for manipulating locked objects in AR. The authors are concerned with information storage strategies, which can be complicated not by the cognitive collection of information but by the addition of computer information, allowing the user to identify which information is closer than other information and to keep the information content organized. The authors provide excellent guides for monoculars or binoculars and moving or static images. Recommendations for the use of monocular systems include selective use of transparency, occlusion, scaling, size, texture, shadow gradients, and cross-referenced depth information. An important rule for any AR system is to eliminate unnecessary motion in the image, which can occur, for example, due to flicker in the recording. Pilot studies are being conducted to evaluate some proposals in a static environment. The post-experimental results confirmed most of the suggestions.

4.3.2. Map Configurations

There is a lot of information about map orientation and how it relates to navigation. Modern maps are either egocentric or eccentric, respectively, with users directed upwards (i.e. the map moves under the user's view) or upwards to a fixed position usually north (i.e. the map orientation is fixed and the user's orientation moves). The literature summarized below covers both perspectives and seems a bit mixed in terms of real-world benefits. However, a careful review of the literature shows that the egocentric representation of the map is best when the user is directly represented and involved in the environment. The eccentric view seems to be the best choice when the viewing area is large, or when the user is observing the surroundings or is a more passive participant in the environment. However, the literature says nothing about situations where learning is not an explicit part of the task or there is no particular path specific to the environment. Such situations can arise, for example, during recovery.

Arthur (1996) reported that people tend to construct cognitive domain maps based on how spatial information is received. As Evans and Pezek (1980) a reported, there is an alignment effect when spatial data is obtained from a map. The alignment effect causes the fixed field orientation to be retained in memory. Participants must then mentally rotate their current position to adapt to the recorded performance. Gillner and Mallot (1998) investigated the degree of dissonance and reported that as the discord angles increased, the time taken to align the representations on the map increased. On the other hand, mental representations resulting from navigating did not show an adaptive effect (Evans, 1980).

Arthur (1996) also reported that navigation in a virtual environment includes features of primary and secondary education. Primary learning is the acquisition of knowledge directly from the environment. Secondary learning is the acquisition of information from abstract sources such as paper maps. Using paper maps results in an orientation-dependent view, but this limited view only has an effect when it comes to learning. That is, if the map was learned, it affected performance as measured by travel time from the start point to the endpoint. This thesis argues that AR systems can have similar properties when using a map to zoom in. Interestingly, Arthur (1996) confirmed the multiple representations of Tarr and Pinker in some virtual environment experiments involving three-dimensional spaces but failed to relate the theory to the number of perspectives available when collecting spatial information in a VR. A review by Arthur (1996) identifies issues with scene content embedded in a VR. There is some useful supplementary research that can be done in augmented reality where different kinds of maps can be found in a real-world setting, giving insight into the impact of primary and secondary learning.

In an experiment by Aretz (1991) with 18 male pilots, he compared visual impulse map display to two traditional approaches: tracking and northward finding. The data show that the advantage of tracking the alignment is to align it with egocentric foresight; however, experimental results showed that the inconsistency of the rotating screen hinders the development of a cognitive map. Further work by Aretz and Wickens (1992) addressed issues of reconciliation between the egocentric and the world reference frame (the latter being an example of an eccentric frame of reference) leading to the need for mental rotation as a central operation. Visual impulse (Woods, 1984) is the process of computer screen users integrating data across sequential screens. Visual impulse encodes the integration process with screen design guidelines to effectively distract the user. Wickens and Hollands (2000) report similar results when using egocentric screens that appear to be oriented and rotate in a different direction than self-excited.

Navigation Using Augmented Reality

Navigation or wayfinding is an important application for AR systems (Feiner et al., 1997; Azuma, 1997). Virtual environments should provide a full touchscreen environment for tasks such as wayfinding, while advanced environments can provide the user with maps or directions that can facilitate wayfinding while maintaining the desired touch input. Navigation is a viable field for AR research, as prototype systems supporting mobility are just beginning to be used. As technology is just emerging, it is useful to consider approaches and issues related to navigation in the real or virtual world.

The literature uses various terms to describe navigation, wayfinding, and route learning, but all of them generally describe how people move from one point to another in a real or virtual environment. For example, navigation is defined as the joint task of navigation and movement. Here, navigation is the cognitive element of navigation and movement is the motor element of navigation (Darken and Peterson, 2002). Navigation is cognitive in nature, and a good understanding and use of spatial information can assist in the development of training programs for large-scale system architectures. This thesis includes a special type of navigation called search and rescue operations. Search and rescue navigation involves finding an area to reach a destination, finding a destination, and then exiting a closed route when a destination is reached. Search and rescue operations are typical for a variety of public safety or military applications.

The Landmark-Route-Survey (LRS) model has been a widely used model to collect spatial information during navigation (Colle and Reid, 1998; Siegel and White, 1975). This model defines three different types of spatial information representation. Landmark information can be defined as identifying information about recognizable places in the surrounding area. Route information consists of information about mentally defined routes between locations. Finally, scanning information can be defined as spatial information in the form of a mental map of the environment. These mind maps are believed to be metric representations of surrounding places and objects (Colle and Reid, 1998).

Siegel and White (1975) suggest that different information from the environment emerges sequentially. First, information about visible landmarks is obtained. This information allows people to recognize places, but does not provide them with any information to help them switch between landmarks. Then the bookmarks are placed relative to each other. This relationship between landmarks allows people to develop and learn the ways around them. This route information can be defined topologically and consists of routes that use previously acquired landmarks as decision points and markers to reach specific sites or destinations (Colle and Reid, 1998). Over time, with the support of acquired procedural knowledge, a mental map of the environment can be created.

Although the LRS wayfinding model is common, there are theories that are built on it and contradict Siegel and White's assumption that different types of spatial information are acquired sequentially. Colle and Reed (1998) describe a bimodal model that proposes the idea that research knowledge about local areas can be gained quickly. They assume that a local area is one that is within the user’s immediate field of view and can be separated from other areas. The bimodal model assumes that there are two modes of spatial information collection (Colle and Reid, 1998). There are two modes:eye-tracking mode and route avoidance mode. Unlike the LRS model, in the dual-mode model, the two recommended modes can run simultaneously, and both can work at any user experience level.

Eye tracking is used when people take a spatial view of their current location. A local field can be defined as anything within the spatial range seen from an observer’s point of view. The observer can create an eccentric spatial map of this local area by turning his head or torso. The spatial information obtained in this mode is called direct imaging or reconstruction of three-dimensional perceptual space obtained by viewing objects in a spatial aperture (Colle and Reid, 1998).

Transition mode is activated when the observer moves over a larger area. In this mode, participants do not receive information about the positions of objects obtained in eye tracking mode. Instead, they get topologically encoded information about how to get from one place to another by connecting different decision points (landmarks) and turns. Knowledge gained in this mode is more egocentric and cognitively structured than forward-looking knowledge. Using the route view and route view modes, users can quickly get information about the field survey while also linking this information together to create a cognitive map of the larger region.

Navigating virtual environments is somewhat problematic compared to the real world. For example, learning to navigate computer virtual environments has some properties similar to acquiring macro-spatial information in real space, so it is not easy to see the desired target. There are significant differences in the accuracy of real and virtual environments that can affect wayfinding (Waller, Hunt and Knapp, 1998). They point to a study by Moeser (1988) which states that it can take up to a year to acquire research knowledge about complex spaces in the real world. The authors note that part of the problem of obtaining geodetic information in virtual environments is related to the limited field of view on the screens of virtual objects, which makes it difficult to obtain spatial information.

AR is now defined as a computer-based reality, more like Project Glass. In this context, real images are changed rather than reproduced and as a result of this, our capacity to perceive reality is increased. For example, when Project Glass is worn and looking at the sky, the weather appears in the user's field of view and enriches the view.

Figure 12. Google Project Glass Source: (Source: Hughes Systique Corp, 2013)

However, this example should not mean that AG is such an ordinary technology. The features offered by AG can provide unprecedented benefits and entertainment in the digital world, and it will also be one of the leading technologies in the construction of smart homes, cars and even factories of the future.

Among the services and facilities designed to meet the needs of tourists for cities, countries, regions and continents, AR technology continues to evolve unceasingly. In a region where the application is used, if the user's mobile device is pointed at the buildings/street, information whether hotels and even hotel rooms are empty, a detail from their interior views, etc. can be obtained. In addition, information such as restaurants in that region, cuisine types, menus, comments and ratings can be accessed as well.

Figure 13. Yelp Monocle App (Source: Think, past and present., 2017)

With the increasing diversity of user practices, the individual seeks to make the physical world more livable, convenient and attractive, smart cities are being equipped with smart homes and smart vehicles. In smart cities, besides location, people can also get information such as shopping, routes or historical context. Therefore, this application can be used in many areas such as travel, tourism and the promotion of cultural items. WikiTude, Metro AR Pro, What Was There and Junaio applications are also examples of location-based AR applications. In these applications, various information is given about the region where the camera is kept by using the camera and GPS data of the mobile device.

Measurement of Human Performance in Navigation

Navigation is a well-studied area in terms of human performance in a VR. The literature shows various navigation tasks as well as systemic strategies to improve human performance when performing navigation tasks using a virtual or real environment.

Navigation Performance in Mazes

Waller et al. (1998) create a maze to further explore the acquisition of spatial knowledge in virtual environments. Various conditions were found, including blind (no maze contact), true (one-minute free exploration), map display, tabletop maze VE exposure (2 minutes), VE short exposure (2 minutes), and VE (5 minutes). Subjects were not allowed to fly over the maze or pass through walls. Direction arrows are used to guide the user. Users were supposed to touch certain objects in the maze and not touch the walls.

During some repetitive poses, the expected path was blocked, forcing the user to rely on mental representations of the maze. A distracting task was also introduced in the second exposure. After diagnosis, participants were asked a series of questions, including choosing from different views of different parts of the maze. The user's selection of maze views was used to determine the suitability of the interface or the difference between the user's mental model and the real environment. Real and mental representations of maps are used to show the differences. Another key finding was that the relatively low accuracy of RE allowed people to construct useful representations of large-scale areas, but the short-term effects of RE were generally no better than using a map. There is also evidence that immersive virtual environments do not facilitate survey data acquisition. In conclusion, the authors propose to explore the use of maps in a virtual environment. These results contribute to obtaining useful information for research in AR systems.

4.5.1. Subjective Measures Including Presence

Humans and machines interact in different ways. It is important to understand how machines and people interact in general, but especially when machines are worn by people or are nearby. This is important because the machine is comfortable and does not interfere with one's mobility, perception or performance of secondary tasks. Augmented reality is a technology that can affect these interactions both positively and negatively. Negative results are indicators of where obstacles need to be overcome. For example, AR equipment cannot be used by the public if it is heavy and outdated. While many aspects of interaction can be measured by results, some measures are suitable for surveys or interviews. Many authors have addressed these issues in their various articles.

Clarke (2003) adopts the same view as Hancock (1997) when explaining coevolution. The author points to successful coevolution as an extension of cognitive processing, working memory, or human perceptual systems. For example, a wristwatch can be seen as an extension of the cognitive system because when Do you know what time it is? is asked, most will say yes. The clock is in addition to working memory by recording the time. Hancock (2004) discusses the future of modeling, in part when the Turing test is used. The Turing test is a test in which the participant cannot distinguish between human or computer-generated inputs. In the future, it will not be possible to distinguish between computer generated responses of simulation users and real system responses.

This capability will allow scientists to evaluate concepts and explore aspects of human interactions with machines and other humans outside the real-world interactions before moving on to hardware. Such interactions could be beneficial for the potential use of systems developed in areas such as the co-evolution of AR systems and human evaluation of product prototypes or facilitating human interactions. These discussions are relevant to the current and future capabilities of AR, but a more principled method is needed to understand and manage the dynamics of coevolution. The entity can be a principled method.

Heather (1992) explored presence by identifying three components: self, environment, and social presence. Representing oneself in the environment encompasses self-visualization and sensory responses to a person in the environment. The environmental component encompasses the individual's ability to influence and be affected by the environment. Social aspects include the ability to interact with other creatures in the environment. Heeter's discussion is focused on VR, but the concepts can be applied to augmented reality environments or any environment at Milgram's Continuum.

There are a number of factors believed to affect the asset. These factors are shown in Table 1 (Sadowski, 1999).

Table 1. Factors Affecting Presence

Factor	Guideline	Issue
Ease of Interaction	Provide seamless interaction to simulate the real world.	Poorly designed interaction takes focus away from the experience.
User-initiated control	Provide immediacy of system response, correspondence of user-initiated actions, and a natural mode of control.	Delays, the discordance of users' versus, effectors' actions, and unnatural control devices hinder engagement in the VE.
Pictorial Realism	Provide continuity and consistency in presented stimuli.	Poorly designed visual interaction hinders engagement in the VE.
Length of Exposure	Provide sufficient exposure time to provide VE task proficiency, familiarity with the VE, and sensory adaptation.	Avoid unnecessarily prolonged exposures that could exacerbate cyber sickness.
Social Factors	Provide opportunities to interact with and communicate with others verbally or by gestures.	If one's presence is not acknowledged by others it may hinder the perception that they exist in the VE.
Internal Factors	Identify the types of individuals who will use a VE system and their preferred representational system.	Individual differences can render VE systems differentially effective.
System Factors	Provide multi-modal interaction input/output to facilitate presence.	Poorly designed systems can degrade the users' experience.
User Characteristics	User's perceptual, cognitive and motor abilities and prior experience should be taken into consideration.	It also depends on age, sex and mental health conditions.

In human-computer interaction lies the idea of determining and meeting user expectations. This can only be possible with a clear, well-defined and well-understood system.

First of all, computers, which were produced in limited numbers and can only be used by experts, have become indispensable in our lives in our age. This situation necessitates computer users to use this technological device as effectively as possible. This problem has led to the establishment of the human-computer interaction system. This system aims to make the computer faster and usable in accordance with its nature. This established system consists of four main components. These are user, task, tool, and context respectively. It tries to develop the most efficient interaction technologies by applying human-computer interaction system design practice and ways of evaluation with these main components. Based on the interaction between people, it is seen that interfaces that can provide this level of interaction between the computer and the human have not been created yet. This situation causes people not to be able to use the new technologies they encounter effectively, and therefore the technology cannot become widespread. In this case, the main target that can be followed is to establish the interaction that exists between humans, as well as between humans and computers. Interfaces used in AR technology have also gained importance in achieving this goal.

All in all, a well-designed interface aims to bring the user to their goal in the shortest way. The link established between AR and human computer, more data, comprehensive visual, audio, etc. It can be associated with the pleasure of reaching sensory contents. This extraordinary technology is becoming more and more involved in our lives, making life easier at home, and in the office.

In this context, in the next chapter, the analysis will focus on the recent studies on the subject and create a foundation for the related research topic researchers through a systematic literature review. Accordingly, the research questions will be addressed and answered.

CHAPTER 5: ANALYSIS

5.1. Methodology

In this study, AR and VR applications that will improve direction wayfinding have been examined and a systematic review has been made. In this sense, in the present study, studies on how users complete the wayfinding action with the use of AR and how applications should be developed in line with these tasks were investigated.

The purpose of this study is to conduct a systematic analysis of existing research examining digital technologies used to improve wayfinding. Six keywords were formulated to initiate the review process. These keywords have been chosen in line with the subject examined and have been determined to eliminate the studies that are far from the subject of the researches to be researched. The keywords are; direction finding, AR, VR, digital wayfinding system, cognitive map, and indoor navigation. Wayfinding, VR and AR, digital wayfinding systems are the main keywords, and after the initial literature survey, the terms cognitive map and indoor navigation, which were found to be appropriate for the subject content and considered necessary for the research, were added to the keywords.

Research articles in the Science Direct (Elsevier) database, which is very common today and includes current issues, were used as the target database, and the articles published in the last ten years (since 2010), were taken into account to be used in this field. The reason for examining the articles made after 2010 was the high interest and the rapid developments in the field of VR after this date and since the cost of VR technologies used in the industry was very high before, it became a technology accessible to everyone with the decrease in cost as since it is a technology that has started to spread in every field (Şimşek, 2019).t has also started to become widespread in the field of wayfinding.

As a result of this search, 171 studies were found and the criteria were determined for the elimination of these studies. Studies were analyzed in three stages. As a first step, studies within the identified keywords were found and abstracts of selected articles were reviewed, and articles that were far from the topic content were eliminated and reduced to 82 studies. Then, in the second stage, all of these 82 studies were read again and in more detail. Studies that were thought to not contribute to an application design or wayfinding issue were removed and the number of articles was reduced to 40. In the third and last stage, the studies were separated on the basis of fields. In the third stage, studies not related to interior space were eliminated from the remaining 40 studies, and 24 studies were reviewed and compiled in total.

The contribution of the study is to provide a relevant classification of studies aiming to guide future research.

5.2. Analysis

In this research, studies involving technologies developed for wayfinding have been classified and examined in detail. The 24 studies found have been examined and classified using the table of systematic analysis in the study called *Human Wayfinding Behavior and Metrics in Complex Environments: A Systematic Literature Review* by Iftikhar, Shah and Luximon in 2021. The topics examined within the scope of the analysis are; Authors, Study purpose, Methodology, Analysis techniques, Type and number of subjects studied, and Findings. The studies acquired have been analyzed and discussed in the table below.

Table 2. Systematic review list of research articles

Author	Study purpose	Methodology	Analysis techniques	Type and number of subjects studied	Findings
Wang, Z., Yu, Y., Feeley, C., Herrick, S., Hu, H., and Gong, J. (2021)	Macro-navigation problem for disabled and visually impaired individuals	A systematic orientation optimization model addressing macro navigation for the visually impaired	Optimization modeling, case study, sensitivity analysis		The proposed model establishes a basic model to support navigation decisions for visually impaired pedestrians in complex interiors
Kim, Y.M. and Rhiu, I. (2021)	The effects of navigation interfaces on navigation performance and subjective feelings	Analysis of the performances of 3 navigation interfaces (joystick, WIP, Teleportation) with mixed methods.	Experiment, questionnaires, video recordings	21 participants (11 men, 10 women)	Changes in additional design are required to ensure an enjoyable experience. It is recommended to teleport on a VE where mission performance is not considered important.
Liu, L., Li, B., Zlatanova, S. and van Oosterom, P. (2021)	An overview of the roles of IFC-Based BIM in the world.	Researching the uses of IFC for indoor navigation and issuing guidelines for comprehensive integration into navigation tasks	Literature review, Classification, Survey		IFC data is ideal for visualizing map/location information due to its complete 3D geometry and rich content.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type and number of subjects studied	Findings
Zhu, Y. and Li, N.(2020)	Finding and understanding applications in emergency management	Analysis of the advantages and shortcomings of VR/AR in emergency management	Literature review, Classification,		VR/AR can be used as a visualization tool to vividly convey scenes and information to other users, and is an interaction tool that allows participants to interact with and respond to virtual items.
Dubey, R.K., Khoo, W.P., Morad, M.G., Hölscher, C. and Kapadia, M (2020)	Increasing the efficiency and effectiveness of signage systems	Presenting a multi-objective two-step optimization approach to a complex signage design problem: AUTOSIGN	Modeling, Optimization experiment, System usability test		It provides computational power for rapid visualization with the interaction of O-D pairs and automatically supports user orientation and allows deliberate design iterations
Fu, M. and Liu, R, (2020)	Signage system for building evacuation and indoor navigation in an emergency	Develops an automated control method based on BIM	BIM modeling, case study, checking		The places where the passengers choose their route are not fixed to a certain point; therefore, decision nodes can be changed to decision areas.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type and number of subjects studied	Findings
Hughes, A. and Mee, K (2019)	Exploring how people connect to technological devices in intimate, emotional, and tactile ways	Monitoring and supporting the emotional flow of consciousness between technological devices and the user by experimenting with auto-ethnography	Auto-ethnographic fieldwork, iPhone navigation apps fieldwork stories, review		Emotions are important tools, they affect current mobile performance and are permanently influenced by considering interiors
Gillett,A.J. and Heersmink, R (2019)	Examining GPS navigation with virtual epistemology	Analyzing how GPS-based navigation systems transform some intellectual virtues and making two recommendations	Epistemic tasks, GPS, Smartphone, navigation task		How navigation systems transform epistemic virtues: Knowledge, issues, and solutions
Spagnol,S., Hoffmann, R., Herrera Martínez, M. and Unnthorsson, R (2018)	Electronic travel aid for the visually-impaired	Investigate a new sensory substitution algorithm that transforms a physically-based fluid sound model into its parameters	Experiment, test, analysis, creation of a model, Questionnaires	14 voluntary participants (7F, 7M) Ages ranged from 22 to 46	Fluid flow sounds are clearer to understand and require less time and effort compared to sounds available in terms of intuitiveness, pleasantness and usability.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type and number of subjects studied	Findings
Cœugnet, S., Dommes, A., Panëels, S., Chevalier, A., Vienne, F., Dang, N.-T. and Anastassova, M (2018)	Aging-related wayfinding difficulties	Developing a vibro-tactile guidance system for pedestrians to find their way	Simulator, Navigation task, Questionnaires, Experiment	58 participants (20 young adults, 20 younger-old adults, 18 older-old adults)	Although Vibrotactile has shown positive results regarding the use of haptic feedback during navigation, it has limitations.
Lin, W.Y. and Lin, P.H. (2018)	Indoor networking in location-based indoor routing and 3D building modeling	An approach proposal called i-GIT to generate a graphic-based indoor network containing ground-level and non-level paths from IFC-based building models	principles of Medial Axis Transform (MAT), IFC based Revit model, Experiment, Availability testing		Indoor paths produced by i-GIT can satisfactorily meet indoor routing requirements in terms of road connectivity, and indoor paths created by i-GIT can reach almost any interior.
Rodriguez-Sanchez, M.C. and Martinez-Romo, J (2017)	Wayfinding apps and smart mobility	Providing a universal and accessible solution for managing Direction Finding applications: The Gawa Platform	mobile and wireless Technologies, Apps Development Management profile, case studies	20 participant (11M, 9F)	GAWA supports indoor and outdoor positioning tasks based on accessibility criteria found in the wayfinding application created without knowledge of vehicle programming.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type and number of subjects studied	Findings
Motamedi, A., Wang, Z., Yabuki, N., Fukuda, T. and Michikawa, T (2017)	Investigating parameters that affect signage visibility	Develop a signage visibility and analysis system that uses the as-built BIM model of a building to calculate the area of visibility of the signage and the visibility of the signage	3D building model in BIM, VR simulation,		The efficiency of a layout design can be determined in a virtual reality environment, by analyzing design alternatives and the tool can be used to determine the optimum layout of the signs.
Taneja, S., Akinci, B., Garrett, J.H. and Soibelman, L (2016)	Lack of approach to automatic generation of navigation models for map matching of indoor positioning data	Provide algorithms for automatic generation of centerline-based network, metric-based, and grid-based navigation models.	Experiment, IFC-based BIM model		It shows that the developed algorithms can generate navigation models for dense test environments with regular rectangular spaces as well as for open test beds with irregular and large spaces.
Torrado, J.C., Montoro, G. and Gomez, J (2016)	Navigation problem for people with cognitive disabilities	Develop a mobile tool (Assist-In) to help people with cognitive disabilities perform indoor navigation tasks	Experiment, interviews, (SUS) questionnaire, log analysis, performance analysis, thinking aloud, coaching methods, video, QR code, math algorithms	14 users with various types and degrees of cognitive impairmen	A few shortcomings were observed regarding the route, some for experimental verification, and almost no user had difficulty scanning QR codes.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type and number of subjects studied	Findings
Tsirmpas, C., Rompas, A., Fokou, O., and Koutsouris, D. (2015)	Navigation problems for the elderly and/or visually impaired	To make RFID-based architecture of an indoor navigation system integrated and tested in real time	PERCEPT server, Arduino Microcontroller, RFID Reader Bluetooth chip, Power Regulator, glove, Android-based Smartphone		Considering the time and limitations of human resources, the 99% success rate of the algorithm cannot be considered statistically significant, but different scenarios were simulated multiple times, the smoothness of the algorithm and its predictive behavior were assumed to be safe.
Almeida, A., Rebelo, F., Noriega, P., Vilar, E. and Borges, T. (2015)	Evaluate a virtual environment to examine behavioral compliance against security warnings	Use of VR as a methodological approach to overcome ethical constraints	Experiment, VR equipment, simulation	14 university students (5 females and 9 males) from the University of Beira Interior. Aged between 21 and 38 years old	It has been determined that the virtual environment used needs some adjustments to increase its effectiveness and be more reliable.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type & number of subjects studied	Findings
Kuliga, S.F., Thrash, T., Dalton, R.C. and Hölscher, C. (2015)	Human-environment interaction in the virtual environment	Reinvestigate environmental comparability by comparing how they experience a simulated building and evaluate how users respond to existing redesigns of buildings in VR	3 case studies,a virtual model (video, self-navigation, or interactive large-screen)	23 students of an international spring school in cognitive science	In virtual environment adaptation, not only cognitive results, but also subjective experiences of users should be taken into consideration. VR has strong potential to be used as an empirical research tool in psychological and architectural research.
Rodriguez-Sanchez, M.C., Moreno-Alvarez, M.A., Martin, E., Borromeo, S. and Hernandez-Tamames, J.A. (2014)	Visual navigation systems for disabled users	Designing an adaptive navigation app for smartphones where the design will be accessible to all users regardless of the user's age, blindness or preferences	Experiment, smartphones, usability test, observation, analyze the available screen reading software, vibration feedback, Blind-App Launcher, Talkback,Voice Over	17 participants (11M and 7F)	Users can follow routes without looking at or listening to the phone, providing more mobility and freedom in their movements. App and interfaces are designed, developed and approved by people with limited vision, blind users.

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type & number of subjects studied	Findings
Vanclooster, A., Ooms, K., Viaene, P., Fack, V., Van de Weghe, N. and De Maeyer, P. (2014)	Extending richer cognitive algorithms to three-dimensional interior environments	Applying an improved algorithm to a confined space to minimize the risk of getting lost	Case study (creation and model), Grum (2005) path algorithm		The results of the tests to examine the suitability for indoor navigation showed a slight increase in the road and in length, theoretically less risky roads were calculated.
Rodriguez-Sanchez, M.C., Martinez-Romo, J., Borromeo, S. and Hernandez-Tamames, J.A (2013)	Presenting the GAT platform, a solution for rapid building construction	Creation and updating of context-aware services for tourism for Gat platform wayfinding mobile applications for indoor and outdoor, multi-platform architecture, using technology	3G, GPS, Camera, Sensors, Bluetooth and QR-code acquisition, analyzing modules, comparison of the mobile systems		In GAT, the user can use or manage automated routes for a customized service
Serrão, M., Rodrigues, J.M.F., Rodrigues, J.I. and du Buf, J.M.H. (2012)	Navigation system for the visually impaired and normal users in complex buildings	Presenting a system that integrates indoor GIS of the building with visual cues detected by a normal handheld camera	Maps based on the GIS, handheld camera, visual signs, test, Smartphone		The system complements local navigation with global navigation despite being only indoors. Most routes can be followed even if they are on different floors

Table 2 continued

Author	Study purpose	Methodology	Analysis techniques	Type & number of subjects studied	Findings
Tam, M.L. (2011)	Evaluating direction finding in determining the overall service level of airport terminals	Propose a binary linear program to solve the problem of identifying suitable places to place signposts in airport terminals or other enclosed environments to maximize V	Multi-Level Signage Display Design		The current formulation is limited to one-level-marking information. Multi-level signage indication can facilitate wayfinding. It is recommended to be expanded for further studies.

Research articles have been carefully selected. Thus, in the process of article selection, several articles both included and excluded per phase have been explained in detail in the method section.

The search focused on articles on AR applications studied on wayfinding and examined studies, including complex-structured centers and navigable environments such as hospitals and terminals. The articles were then further refined the specific spatial characteristics of them, and the intended use was organized as the content. The articles used were analyzed according to the conditions of complex locations and wayfinding in the real-world with VR and AR. Six articles were on navigation behavior in VR-based simulations and VE. Articles on computer simulations consisted of on-screen VE, VR, and augmented reality (AR). Four articles on wayfinding aids and cues examined the effects of the design of signage information on wayfinding behavior. These articles studied graphics, studied language accessibility, colors, and the remaining 16 articles were on wayfinding behavior, navigation systems, and navigation interfaces. The articles screened for effective results were critically discussed, and the content, research, methodology to be addressed by further research was elaborated.

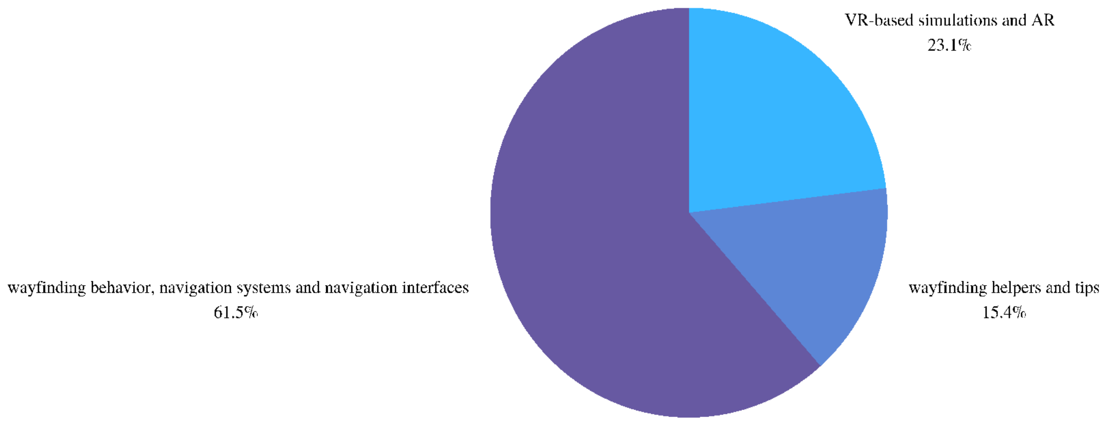

Figure 13. The 24 articles subject content categories

6 articles in analysis are about VR-based simulations, AR and browsing behavior in virtual environment. 4 articles are about wayfinding preferences and tips. All 16 articles deal with wayfinding behavior, navigation systems and navigation interfaces

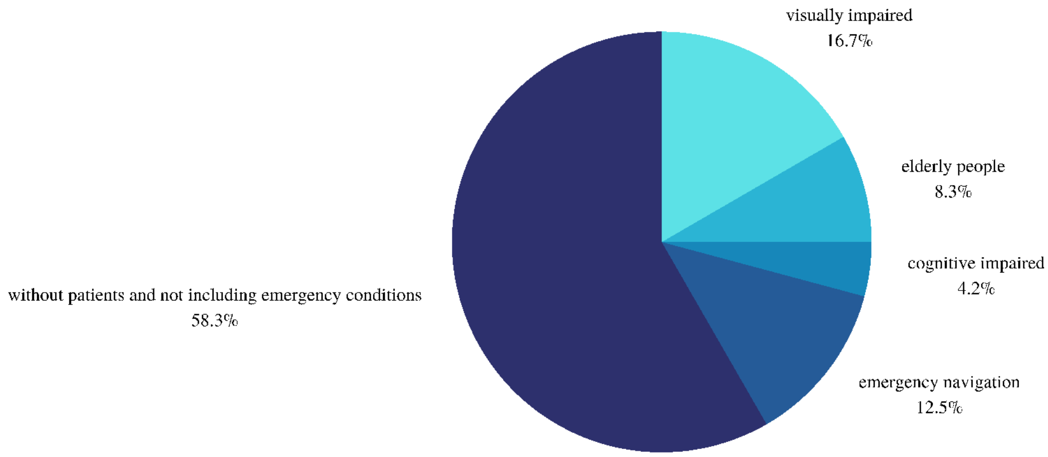

Figure 14. Virtual navigation topic contents of 24 articles reviewed

Of the reviewed articles are 4 articles on the visually impaired, 2 articles on the elderly people, 1 article on the cognitive impaired, and 3 articles on emergency navigation, the remaining 14 studies focused on navigation without patients and not including emergency conditions.

5.3. Findings and Discussion

In the process of navigation, planning and following the route are the essentials, but the movement from one point to another is the result of travel (Kim and Rhiu, 2021). Thus, finding the optimal route is the main purpose of wayfinding (Cheung, 2006; Siegel and White 1975). The user's familiarity with a particular environment shapes the survey information which is obtained from maps or environmental aids. People's interactions with their environment affect their way-finding behavior in various ways (Iftikhar et al., 2021). A series of studies have been carried out and app designs have been made thanks to digital technologies in order to support the wayfinding design and to find an easier way. AR and VR are the most commonly used technologies, and AR supports visualization, animation, and contextual learning.

In the table above, the contents of the studies on digital algorithms and applications for wayfinding, that is, on indoor navigation on a science direct basis, were examined according to the analysis table made by Hassan Iftikhar, Parth Shah and Yan Luximon in 2021, but the location of study was not added to the table in this study since it is not clear. It was observed that BIM modeling was used throughout the studies that were examined (Fu and Liu, 2020; Dubey et al., 2020; Fu and Liu, 2020; Motamedi et al., 2017; Wang et al., 2022). As a system, BIM stands for Building Information Modeling System. In some studies, it has been noticed that it is used with an IFC-based system (Taneja et al., 2016; Lin and Lin, 2018). In general, the semantic definition of building elements, spatial relationships, and quantities and properties of building components are included in the core of IFC for navigation (Liu et al., 2021). In addition, Tsirmpas et al. (2015) use RFID-based architecture in their study. RFID (radio frequency identification technology) is a method of identifying objects individually and automatically using radio frequency (Wikipedia, 2021). Tsirmpas et al. (2015) also designed an antenna circuit suitable for RFID-based architecture and integrated systems. In addition, a wearable module was built and a geolocation server was integrated to develop the proposed module. The application has been developed to support parallel sessions of more than one user, but the algorithm proposed in this study is independent of the topographical features of the building's grid. Equipped with this wearable component, the system user can navigate through the corridors inside the building, following the instructions suggested by the system via the embedded headset. Obstacles inside the building can easily be detected and local surveillance is provided within this system. Furthermore, this ensures the movement safety of the user. Although the result of this study cannot be considered as 99% successful, the smoothness and reliability of the algorithm have been tested by simulating different scenarios plenty of times. With a more detailed research of RFID-based systems, it can spread widely and develop more in the field of both AR and VR.

The unique standard mesh cannot be provided by abstracted navigation models and therefore the path cannot be changed in the shortest distance, but instead, a fine grid model based on ground surfaces provides a unique optimal network that can be closer to reality according to the researches of Lui et al. (2021). It can provide a short distance path. Currently, common navigation models are mostly based on 2D/2.5D surfaces. For navigation, where we define the act of movement as walking hypothetically, the floors we consider are horizontal and vertical (such as elevators and stairs). In such a case, according to Lui et al. (2021) three dimensions may not be needed. At this point, the use of the gridal system may provide convenience to make AR applications more common and less costly, but this may be insufficient when considered by disabled or visually impaired users. When we examine the research of Wang et al. (2021) it is said that one of the most important problems in the system is macro navigation. Generally, it has been observed that micro navigation is used more in studies, but it has been observed that users find their way more easily because a system that has worked with macro navigation gives more information about the place. Lingo 11.0 software was used in the optimization model study by Wang et al. (2021). This system is applied in formulating various optimization problems (Wang et al., 2021). For AR applications, there can be difficult and complex areas in the routes between different activities in the space, and in such cases, some users may experience problems. In spite of the fact that AR is a technology superimposed on the real world, the use of macro navigation can be considered rather than the use of micro navigation when more universal designs are made considering some disabled and visually impaired users. In addition, it should also be taken into account in the applications of VR since the more details there are in a modeled area, the more information the user gets about that space (Wang et al., 2021). In another study, he developed a liquid sound system and produced a model by considering the visually impaired (Spagnol et al., 2018). This system may not appeal to every user, but it can be developed and universalized in terms of AR applications. Overall, strong evidence revealing that people of all ages and different cognitive disabilities respond well to AR-assist glasses, projectors and handheld devices is provided by the literature. (Blattgerste, Renner and Pfeiffer, 2019) A number of systems for the blind have been developed and they are Blind-App Launcher systems such as Talkback and VoiceOver. The sound system which was developed by Spagnol et al. (2018) was designed in order not only to improve the voice algorithm both ergonomically and functionally, but also to reduce the required training time ultimately and provide scale efficiency depending on the available computational resources. An optimization was achieved in real-time blind pathfinding with out-of-the-box hardware technology and minimal delay between data acquisition and sonification. The building block of the fluid flow algorithm is the fluid sound generator. Individual bubbles are considered as atomic units or grains (Roads, 1988) by the algorithm of the generation of liquid sounds according to granular synthesis terminology which were synthesized using the well-known physically-based Minnaert model (Minnaert, 1933). According to the studies reviewed, positive feedback has been observed in users and it is clearly seen in the experiment conducted by Spagnol et al. (2018) that the wayfinding action is facilitated. It can be a good option to use the sound and the vibration in AR systems developed for Wayfinding. However, further investigation is needed for the issue of how this system will work in a complex area due to the fact that route deviations occurred at some points in very noisy environments in the system application by Spagnol et al. (2018). Additionally, the use of QR codes for AR applications can also be a point that can make the system widespread. Today, it will help us find our way in complex areas even when using a QR code to look at a menu, and all kinds of information with the help of Qr codes become easily accessible. Owing to the fact that smartphones are the most common technological tools used, it will be more likely and easier for users to find their way depending on the widespread use of QR codes in AR applications to be made in the future. People with cognitive disabilities have been enabled to perform indoor navigation tasks thanks to a mobile tool (AssisT-In) by Torrado, Montoro and Gomez (2016) and this tool also appeals to all users. We are allowed to use mathematical algorithms to calculate routes with the help of this modeling technique which also let us work with the environment as a graph (Torrado, Montoro and Gomez, 2016). The use of this system in other studies may contribute to Ar applications.

In general, AR systems work over an internet or bluetooth system, so they can update routes and create new routes. Depending on the analysis made on the basis of *Science Direct*, the signage was generally taken into account in the wayfinding design and then systems were built and established on it, and in this advanced system, VR and BIM modeling were generally used. The excessive use of signage to analyze signage systems also creates some confusion. The factors that affect the efficiency of the signage system are as follows; salience, visibility, readability Significance which is subjective cannot be measured consistently, but a general measurement can be made with the salience index. There is a relation between visibility and some physical properties in addition to other factors such as lighting and contrast. Readability, which is the physical properties of a sign on the whole, allows differentiation, such as letters, words, numbers or graphics, and it can be affected by lighting variables as well (Motamedi et al., 2017). Considering all, more effective interface or system designs can be made, but there are always limitations. In the study by Motamedi et al. (2017) it is seen that the current version of Revit does not have an object dedicated to signage, so when exporting the model made, the definitions of regions in Revit get lost, so other types of objects are alternatively used to model the signage. As a result, this most realistic one may not always be provided, some systemic and financial problems may occur, but a general system can be created according to the most common movement as a result of a continuous analysis by considering both movement and behavior. Sometimes, wayfinding cannot cannot be a simple process, especially in complex buildings. It should be considered in the relationships between space and self (Hughes and Mee, 2019) though. It was concluded that not only the behavioral and cognitive results, but also the subjective experiences of the users should be taken into account.

(Kuliga et al., 2015). Regarding the majority of the general results, it is obvious that most of the studies on the base of science directly deal with blind and disabled people. On the other hand, normal users also participated in the experiment of these applications, so these studies can be generalized and may be suitable for the study base. This remains to be proven by future research. Furthermore, the studies reported in the reviewed literature generally used BIM modeling. In addition, some easy-to-access systems were used in these studies due to the widespread use of smartphones.

CHAPTER 6: CONCLUSION

There is an interrelation between navigation and all aspects of the constructed environment and also the intentional circulation of people is regulated with navigation. Various elements range from spatial layouts and circulation-related architectural features to graphic displays, including audio and tactile supports that exist in the features of the design (Passini, 1996). Causing a waste of time, stress and frustration, public buildings, airports and terminals located in city centers within a variety of complex environments such as hospitals and public institutions present multiple navigation problems for visitors (Iftikhar, Shah and Luximon, 2021). Full participation in the environment is required in the wayfinding process (Passini, 1984). Owing to a lack or absence of knowledge of an environment, navigating highly complex areas can lead people to encounter problems, which may cause disorientation. Due to the fact that technologies in AR and VR (Şimşek, 2019), which have become more common after 2010, studies on wayfinding have been carried out as its use in daily life has increased. Both by constantly informing visitors about the indoor localization of the physical space, and the facilities of visual convenience served to individuals while moving, the possibilities of wayfinding experiences have also increased thanks to AR. Two theories which are wireless connection and visual monitoring have been proposed in this context (Kim, 2015). Augmented reality (AR) enables the real environment to be seen, and applies virtual elements that are superimposed on real objects or combined with them. Virtual reality (VR) is a computer-generated immersive environment in which users have real-time, multi-sensory interactions (Gomez et al., 1995). Since AR uses computer-generated information to enhance the physical real-world environment rather than constructing a virtual world on its own, compared to VR, AR is relatively closer to the real environment (Zhu and Li, 2021). Techniques of VR place design in a virtual environment and use an immersive interface to explore it as a navigator.

The purpose of this study is to provide a resource for future studies by examining the augmented and VR applications made to improve wayfinding. Current study is aiming to apply a systematic literature review of the studies in the literature that are discussing AR and VR in wayfinding for the last decade listed in ScienceDirect research engine. Although AR is discussed in the research, VR studies were also included in the study since it is a branch of VR

. Thus, it is desired to provide a more useful resource for future studies. In this context, the reason for examining the studies on technologies in VR after 2010 is that with the development of wearable vision systems, the technology in VR has started to become more ergonomic (Jerdan et al., 2018). Because this has created a big change in the field of VR and these developments have led to the development of various VR glasses such as Oculus Go, Samsung VR, Sony Morpheus, HTC Vive today. At the point where VR technology has reached today, the computer screen has also been eliminated, and since it has become a technology that can be used by anyone with a smartphone via inexpensive solutions such as Oculus Go, Google Cardboard and Microsoft VR kit (Şimşek, 2019), the year limitation has been made in the study. Firstly, wayfinding is discussed in detail, and then digital technologies are explained. In the study, researchers are conducted on how users complete the wayfinding action with the use of AR and how applications should be developed within these tasks. Throughout the review process, six keywords are formulated and determined for the research; Direction Finding, AR, VR, Digital Wayfinding System, Cognitive Map, Indoor Navigation. In this direction, the articles to be examined are determined and 171 studies were reached. Criteria are set for the elimination of these studies and as a first step, only articles related to the following key areas are included: navigation, digital technology, VR, and AR. At the end of the first stage, the contents of the selected articles are scanned, and in the second stage, the studies to be examined are reduced to 40 studies, taking into account the wayfinding, signage systems, AR applications, and virtual simulation studies. In the third and final stages, the studies are separate based on fields. Respectively, studies unrelated to interior space were eliminated, a total of 25 studies are reviewed and compiled in this study.

As a result, it is observed that the studies generally worked on IFC and BIM modeling, in addition, the Revit system is generally used in modeling, but it is found out that not every object could be well-transferred to the virtual environment due to some limitations in these systems. Generally, the designed and developed algorithms are considered in the studies that are examined, and generally a case study is for the systems produced in almost every research that the systems are checked whether they are functional or not. Some studies emphasize that the signage system has an important role in wayfinding design, and signage is detected to be essential in the evacuation of the building in case of an emergency (Fu, and Liu, 2021), and regarding this fact, important points about the signage system are stated in this study. Of the VR and AR applications examined in this articles, 4 were articles for the visually impaired and 1 articles for the mentally disabled, but this was not considered in this study.These technologies also have a lot of potential to help people with visual and auditory and mental disabilities find their way around the built environment or to help them find their way around the built environment.

Many VR applications have been made for the visually impaired, and some of them are Blind-App Launcher and screen reading software such as Talkback and VoiceOver, but in this context, VR and AR applications should be investigated in more detail.

This comprehensive review is considered to be a valuable contribution for future studies, however as a limitation, because of the limited number of studies that are considered, the study doesn't suggest a strong generalization for the subject matter. However**,** it should also be noted that the subject matter is quite recent and most of the studies are in the last decade, so an extended research with additional secondary keywords might be meaningful to find out more related studies. Since the research is limited to the science direct base, it is thought that it should be examined in studies in other databases, and the development of the findings in the study by examining the history of VR technologies is important for the accuracy and functionality of future studies.

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