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SCALING DATA VISUALIZATIONS IN STRATEGIC EXTENDED REALITY MAPS AND OPTIMIZING COGNITIVE JUMPS BETWEEN VISUALIZATIONS FOR BETTER SITUATIONAL AWARENESS

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ABSTRACT

This thesis seeks to point out different graphical methods for creating an immersive extended reality map with minimal loss in situational awareness during scene transitions. Virtual maps are often required to work swiftly and accurately but also to depict the actual environment as detailed as possible. These requirements may result in a cluttered three dimensional (3D) view where a person is able to see too many unwanted objects obstructing the view. In order for the person to solve this, they need to relocate in the scene. Relocating in the scene, through multiple objects on different levels of the map may result in the loss of situational awareness. To regain the situational awareness a person needs to take their time to observe and identify the environment. This may take a while depending on the complexity of the view, but nonetheless it will take time from the person, resulting in an unwanted user experience.

To get an insight on how to solve the problem described above, multiple research papers were gathered. The gathered material covered graphical issues and human behavior within the virtual environment. While many of the papers focused heavily on the technical implementation of the related tests, it was possible to use Endsley's theory on situational awareness as a reference to reflect on the possible solutions for reducing the loss of situational awareness during cognitive jumps.

To form an estimation on if the graphical implementations mentioned in the gathered material would be beneficial for maintaining situational awareness during cognitive jumps, a hypothetical application was designed. The demonstration application was inspired by Google Maps and Street View and was using the vicinity of the Empire State building as demonstration location, as it is highly obstructed by massive infrastructure. While the logical usage of the graphical features was simple to determine in a way that the user would avoid any direct obstructions in the map view, it is hard to tell however, if the situational awareness can be maintained when using the application by moving around. In order to determine if the graphical features have positive effect on the situational awareness, a test application with multiple test distances for graphical effects and multiple test users would be required. However, the effectiveness of these features is based on the mapping study into literature and still need to be validated.

Keywords: Situational awareness, virtual environment, cognitive jump, graphical implementation, map application, extended reality

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TIIVISTELMÄ

Tämä opinnäytetyö pyrkii kartoittamaan erilaisia graafisen toteutuksen metodeja, joilla voidaan toteuttaa immersiivinen laajennetun todellisuuden kartta, jossa käyttäjä ei menetä tilannetietoisuutta näkymän siirtymien aikana. Virtuaalikarttojen on usein toimittava nopeasti ja tarkasti mutta silti kuvattava vastaava ympäristö niin tarkasti kuin mahdollista. Nämä vaatimukset saattavat johtaa sekavaan kolmiulotteiseen (3D) näkymään, jossa henkilö näkee liian monta ei-haluttua objektia, jotka peittävät näkymää. Jotta henkilö pystyy välttämään tämän, hänen on siirryttävä näkymässä. Näkymässä siirtyminen useiden objektien ja kartan tasojen läpi voi johtaa tilannetietoisuuden menettämiseen. Jotta tilannetietoisuus voidaan jälleen saavuttaa, henkilön täytyy havainnoida ja tunnistaa ympäristö. Tämä saattaa viedä hetken riippuen näkymän kompleksisuudesta, mutta joka tapauksessa vieden aikaa henkilöltä johtaen ei-haluttuun käyttäjäkokemukseen.

Jotta voitiin saada käsitys, miten yllä mainittu ongelma voidaan ratkaista, koottiin useita tutkimuspapereita. Kerätty materiaali käsitteli graafisia ongelmia ja ihmisen käyttäytymistä virtuaaliympäristössä. Vaikka monet paperit keskittyivät voimakkaasti niihin liittyvien testien tekniseen toteutukseen, oli mahdollista käyttää Endsleyn teoriaa tilannetietoisuudesta referenssinä pohdittaessa mahdollisia ratkaisuja vähentämään tilannetietoisuuden menettämistä kognitiivisten hyppyjen aikana.

Jotta voitiin luoda arvio, ovatko kerätyssä materiaalissa mainitut graafiset toteutukset hyödyksi tilannetietoisuuden ylläpitämisessä kognitiivisten hyppyjen aikana, suunniteltiin hypoteettinen prototyyppisovellus. Prototyyppisovellus sai vaikutteita Google Maps- ja Street view -sovelluksista ja käytti Empire State Buildingin lähiympäristöä demonstraatiosijaintina. Sillä sijainto on erittäin katettu massiivisella infrastruktuurilla. Vaikka looginen graafisten ominaisuuksien käyttötapa oli yksinkertainen määrittää siten että käyttäjä välttäisi suorat esteet karttanäkymässä, on kuitenkin vaikea määrittää voiko tilannetietoisuuden ylläpitää, kun applikaatiota käytetään liikkumalla. Jotta voitaisiin määrittää, onko graafisilla ominaisuuksilla positiivinen vaikutus tilannetietoisuuteen, tarvittaisiin testisovellus useilla testietäisyyksillä graafisille efekteille, ja useita testikäyttäjiä. Nyt kuitenkin näiden ominaisuuksien tehokkuus nojaa kirjallisuuskatsaukseen ja ne vaativat edelleen testausta.

However, the effectiveness of these features is based on the mapping study into literature and still need to be validated.

Avainsanat: Tilannetietoisuus, virtuaaliympäristö, kognitiivinen hyppy, graafinen toteutus, karttasovellus, laajennettu todellisuus

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FOREWORD

This thesis was written for my Bachelor's degree in Computer Science and Engineering at the University of Oulu in Finland. The subject of this literature review type thesis is to define and evaluate the methods for implementing optimized strategic extended reality maps with focus on achieving a better situational awareness. This is an intriguing subject to delve into, as virtual maps and holographic user interfaces have mainly been visualized in movies and other fictional media, but are now becoming a part real-life. First, I would like to thank my active and encouraging thesis instructors. I am grateful to my instructors Dr. Paula Alavesa and Mikko Korkiakoski for providing me with continuous support and possibility for asking for help with the thesis anytime I might need it. It has been an intense few months working with the thesis and every time when the work has felt overwhelming, my instructors have been able push me forward with their positive attitude. Secondly, I would like to thank my family for supporting me year after year, always encouraging me to reach yet another way-point in my life.

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Minttu Ukkola

LIST OF ABBREVIATIONS AND SYMBOLS

ACM	Association for Computing Machinery
AR	augmented reality
FOV	field of view
IEEE	Institute of Electrical and Electronics Engineers
POI	point of interest
SA	situational awareness
VE	virtual environment
VR	virtual reality
XR	extended reality

1. INTRODUCTION

1.1. Motivation

Over the past decades the interest over virtual environments (VE) and their possible use cases have been studied by various researchers and developers. The technical possibilities as well as the difficulties for the new implementations have been a major interest for many of these studies. However, when finding and developing new VE implementations and use cases, the user experience in VE should be observed in order define the most beneficial and usable solutions. One major aspect of user experience is to develop an environment where a person is able to maintain their situational awareness (SA) while using the application. In this literature review we use Endsley[1] research which describes the level-based structure of SA. In VE the user frequently moves from scene to scene, during these transitions between the scenes the cognitive jumps may cause the user to lose their SA. Other material used in this review were focusing on multiple technical implementations in VE involving controls and display methods. The VE focused papers used to in this review were published between years 2006 and 2021. While many of the used material were dated from technical point of view the user experience data which was gathered was still usable considering human senses and behavior and it was possible to form a connection between the user experience and SA.

1.2. Method

The method used in this study is a review, but not a systematic review as the approach was not thoroughly systematic. For brevity in this thesis the method is described as a review, however this is a mapping study [2] in literature.

1.2.1. Publishers

The publishers for the chosen material used in this review were selected independently but generally accepted by the instructors for this thesis. The publishers included were Institute of Electrical and Electronics Engineers (IEEE), Association for Computing Machinery (ACM), Taylor&Francis and Elsevier. The publishers were mainly selected after considering the subject and the research to be high quality.

1.2.2. Search Terms and the Search Engine

The material used in this review was gathered by using Google Scholar as search engine. The searches for the material were executed between October to November 2021. The key search terms shifted from XR to VR and AR, as XR as a term is still new and is not commonly used in papers. The XR, AR, VR abbreviations or the related word combinations were combined with search terms such as: (“3d map”, ”immersive map”, ”immersive holographic map”, “depth perception”, “shading”, “cognitive jump", "prism map", "map", "environment", "virtual space", "data visualization", "scaling", "zooming"). The searches resulted from around nine thousand to two million search results. The large number of results indicates that some of the term combinations could have been narrower. However, it was possible to arrange the received results by their date and relevance which ruled out irrelevant articles from the results.

1.2.3. Selection of the Papers

The papers were chosen by taking the publishing date into account as VE technology is advancing at a fast pace. As mentioned earlier, the technical level of the used equipment in the chosen material is not necessarily a major problem as this thesis focuses more on user experience rather than the technical implementation of the used VEs. However, the lack of graphical features and accuracy of the used controls may hinder the user experience and therefore affect the results. The usefulness of the papers was mainly evaluated by observing the abstract, to see if the subject and the test environment matches the scenarios encountered when using immersive virtual maps. The discussion and result sections were used to evaluate if the papers support the user experience assumptions for different features discussed in this thesis. The number of times the papers were referred was used to loosely evaluate the quality and usefulness of the papers. However, only the newest papers seemed to lack reference times which is logical as the papers have been out only few months.

2. RELATED WORK

Over the past few years extended reality (XR) has become increasingly popular in educational and entertainment applications. The VEs strive to become as immersive as possible creating an artificial real world or an imaginary world for a user to experience. Along with the graphical implementation of the environment, the usability of the applications has proven to be a challenge. XR accessible VEs frequently suffer from being unclear to the user or the controls of the application are not intuitive. This may cause the person using the VE to become confused, spending their time on figuring out how to use it [3]. While it is common that it is required for a user to adapt to the application and any transition in the environment requires the users' attention, it is clear that the VEs still suffer from the user losing their SA when using the application [4]. Different graphical indicators and controlling methods can be used to maintain the SA, which we would like to present in this section.

The material for this thesis is gathered in Table 1 which summarizes the relevant aspects such as: the author(s), publishing date, interaction method, and scaling. The emphasis is on the graphical field of interest the material represents, the technology emphasis as well as whether the paper focuses more on the applications with real or virtual environment in addition to their virtual enhancements. The papers were selected based on their date, if the related tests match the immersive virtual maps usage scenario and have emphasis on user experience and are referred as much as possible considering the publishing date. Detailed description of the process can be found from the Introduction section. All key papers are in the list of references, quite obviously the excluded papers are not referred in this thesis.

Table 1. Key papers

Reference	**AR VR XR**	**Visual point of interest indicators**	**Interaction method: Sight/Touch**	**Scaling: Real World/ Altered**
Kapler, Thomas and King, Robert and Segura, Dario 2019 [5]	AR/VR	Color, Mark	Sight	Real World
Satriadi, Kadek Ananta and Ens, Barrett and Cordeil, Maxime and Czauderna, Tobias and Jenny, Bernhard 2020 [6]	VR	Color, Size, Spherical view	Touch	Altered
Yang, Yalong and Dwyer, Tim and Marriott, Kimbal and Jenny, Bernhard and Goodwin, Sarah 2020 [7]	VR	Color, Size	Touch	Altered
Quach, Quang and Jenny, Bernhard 2020 [8]	AR/VR	Color, Size, Mark, Spherical view	Touch	Real World/ Altered
Newbury, Rhys and Satriadi, Kadek Ananta and Bolton, Jesse and Liu, Jiazhou and Cordeil, Maxime and Prouzeau, Arnaud and Jenny, Bernhard 2021 [9]	VR	Color, Size	Touch	Altered
Interrante, Victoria and Ries, Brian and Anderson, Lee 2006 [10]	VR	Mark	Sight	Real World
Steinicke, Frank and Bruder, Gerd and Hinrichs, Klaus and Lappe, Markus and Ries, Brian and Interrante, Victoria 2009 [4]	VR	Mark	Sight	Real World

Reference	AR VR XR	Visual point of interest indicators	Interaction method: Sight/Touch	Scaling: Real World/ Altered
Bach, Benjamin and Sicat, Ronell and Beyer, Johanna and Cordeil, Maxime and Pfister, Hanspeter 2018 [11]	AR/VR	Color	Touch	Real World
Cidota, Marina A and Clifford, Rory MS and Lukosch, Stephan G and Billinghurst, Mark 2016 [12]	AR/VR	Color, Focus	Touch	Real World
Swan, J Edward and Livingston, Mark A and Smallman, Harvey S and Brown, Dennis and Baillot, Yohan and Gabbard, Joseph L and Hix, Deborah 2006 [13]	AR	Color, Transparency, Size	Sight	Real World
Singh, Gurjot and Swan, J Edward and Jones, J Adam and Ellis, Stephen R 2010 [14]	AR	Mark	Sight	Real World
Rahimi, Kasra and Banigan, Colin and Ragan, Eric D 2018 [15]	VR	Mark, Color	Sight	Altered

2.1. Key Elements for Maintaining Situational Awareness While Observing the View, and during Cognitive Jumps

SA can be considered as a person's ability to identify an environment and act accordingly. In this thesis the concept of SA is mainly based on Endsley's theory which presents three levels of SA. A person's perception over present elements within the VE is the first key factor for forming and preserving level 1 SA during an event [1]. At this level, a person is only noticing and identifying objects within the space during an event. Subsequently, the next level (level 2) of SA is reached if the person can form a logical relationship between observed elements and evaluate the significance of these elements. Multiple gathered research related tests in different VE concepts seek to enhance the usability of the VE with graphical indicators. The purpose of these indicators is to highlight the points of interest (POI) within the space and ensure the logical usage of the application tested. SA levels 1 and 2 will be the main interest for this thesis, as the gathered material does not directly demonstrate level 3 SA, in which the person is able to predict upcoming events based on the knowledge of the present elements and their relationships within the space [1]. For observing the effect of cognitive jumps on SA, level 1 information alone is not sufficient enough, as the cognitive jumps include the logical relationship between at least two elements or views. Therefore, for this thesis, we will assume, that any test situation which includes a person losing their SA while using the test application, level 2 SA will include level 1 SA without separately dissecting these two levels from each other. This is because level 2 requires level 1, but level 1 is not able to demonstrate cognitive jump on its own.

2.2. Visual Point of Interest Indicators

The implementation of visual indicators and interaction methods in VE are key elements for achieving a good user experience. In this section the visual POI indicators and interaction methods for XR map applications are presented and evaluated.

2.2.1. Focus

Focus as a visual POI indicator resembles a typical camera focus feature, where the background view is either blurred or faded out compared to the object in the foreground. This will logically highlight the object of interest and reduce the visibility of other objects, while still keeping them within the view to prevent losing the perception of relationship between the objects. Citoda et al. research suggests that the blurring and fading effects mainly have a negative effect on a person's depth perception. While in virtual reality (VR) the visual effects described above have a slightly less negative effect than in augmented reality (AR), both of these visual effects may have unwanted results when moving objects within the view [12]. However, as the object of interest is heavily highlighted within the view and the visibility of other objects is demoted, blurring and fading could be considered as a viable visual indication method for selecting objects.

2.2.2. Transparency

Partial transparency of any object can be used to display other objects behind the one at the front. While this may seem obvious as people constantly encounter this phenomenon in their everyday lives when, for example looking through a window, it is an important aspect to take into consideration with VEs. With transparent objects, a person in a VE is able to see objects that are obstructed by the closest object in their field of view (FOV). This may help the person to observe potential POIs from a distance and select a new location in the virtual map for example. This kind of visual effect can be utilized in a view where the person is on the same level as the objects or there is a major obstruction in the view. However, an experiment from Swan et al. shows that after a certain distance, the person in the environment starts to misevaluate the true distance of the objects. This becomes even more challenging of a task when there is a transparent object in the view.[13]

2.2.3. Map Markers

Markers, also known as "map pins", are usually symbols that are used to pinpoint certain POIs. These symbols are often colored differently from the background and used for example in maps to point out the current location of the person. In a similar manner, these markers can be used in VEs. In VR and AR maps, markers are used in a similar manner as in common map applications such as Google Maps. The markers are either icons or clear color differences between POIs. These indicators can be used to either highlight POIs or as selection markers. The virtual space can also be visualized more clearly with markers by placing them at different distances, for example in the corners of a room to enhance the depth perception capability.

2.2.4. Color

Color is one of the most basic methods to differentiate objects from each other. For example, it can be used to separate countries on a world map. Color can be used as an indicator in multiple ways which overlap with many other depicted graphical indicator implementations. Color difference can be used to separate objects from other items in the view via a completely different color or simply by changing the borders for example. The impression of depth can be simulated with a different hue indicator color by creating a shadow-like visual effect.

2.2.5. Size

In the real world, landmarks such as skyscrapers are clearly visible even in highly obstructed city views. It is clear that the size of these buildings is an attribute which makes them stand out from the scenery and makes it possible to for example navigate based on their location. Size can be used to pop-up a POI from the scene. In a VE, this can be achieved by enlarging an object or minimizing the surroundings when the user is focusing on or selecting the POI. Size can also be used to separate other indicators, such as marker type graphical indicators, from each other.

2.2.6. Spherical View

The use of a fisheye lens is a well-known method in photography for achieving a wide-angle view of the direction the lens is pointing at. While fisheye lenses distort the image heavily, it is easy to keep track of a POI within the view. In a VE, similar benefit can be achieved by placing the objects in a spherical manner, with an advantage of not having a distorted image. Spherical view as a graphical indicator slightly differs from the other methods, as it does not directly relate to one object nor alter its visual attributes, but instead it affects the whole scene. In a spherical view the objects in the view are arranged so that the POIs are arranged around the user, in a sense, highlighting the objects from each other by not suppressing other objects.

2.3. Interaction Methods in Virtual Environment

In most VEs, the basic interaction methods are moving one's head while wearing a VR headset, or by moving the controller attached to the one's hand. Other methods such as controlling the application with voice or even by tracking the eye movement can also be implemented. However, in this thesis we simplify these detailed methods for controlling the VE, into concepts of sight and touch, also excluding the voice control as the focus of the thesis is mainly on the visual interaction.

2.3.1. Sight

The mental effort in a situation can be reduced by placing objects within the FOV, thus reducing the need for head movement. The requirement for moving one's head can be detrimental for concentration and increase the cognitive burden if used as an interaction or a selection method. In a paper by Kapler et al. [5] this is mainly depicted to happen in a navigation situation. While driving for example, any major distraction is more problematic than when a person remains stationary and is not subjected to outside distractions.[5] According to Interrante, Ries and Anderson [10], elements such as limited FOV, graphical inaccuracies, or the sheer knowledge of being in a virtual space may hinder a person's capability of judging distances within the space, even if the space was accurately scaled to match the real environment the person is in.[10] This indicates that any common elements depicted above may also have a negative impact on a person's perception while in an XR environment especially during cognitive jumps. While observing a virtual map for example, a person within the space might get distracted by the common problems of an XR environment, especially if the person does not have previous experience with a VE and is not capable of passively ignoring the possibly distracting features. Steinicke et al. [4] suggest that it is easier for a user to estimate the distance in a VE when a gradual transition from the real world to the VE is being used. By using a gradual transition, the person is convinced that the VE really correlates with the real world, has no obstacles, or different distances for example. [4] This supports the assumption that usability and capability of maintaining the SA can be enhanced by designing the virtual space in a manner where moving between the scenes or views happens gradually, e.g. avoiding teleportation as described in Rahimi et al.'s paper [15]. The paper also corroborates the theory that it is easier to adapt to the VE if there is a clear visual connection to the real world. In a virtual map application this could be achieved by using an XR type of an implementation, where the real-world components are also present to a certain extent. As described in the transparency section, transparent objects may have a negative effect on depth perception. However, if distance is not relevant or as long as one would expect in a virtual map environment, the transparency might allow the user to better keep track of what other elements are within the view and occluded by the map on the foreground, therefore possibly providing situational benefit for the map design.

2.3.2. Touch

Another common method to navigate and interact within the virtual space is to use the relative position of the user's hands or handheld controllers to point out which objects the person is "touching". The word touching being in quotes, because the person is not usually touching anything physical, but rather seemingly touching the object. In the case of accuracy, it is clear that using hands is a more precise maneuvering method and more feasible to implement with current technology than controlling the objects using head orientation for example. In Satriadi et al.'s [6] paper the group used a spherical layout to display multiple maps for the user to interact with. While the main interest of the research was on the usability of the spherical 3D space, using direct point- and select-action with common VR controllers was also discussed. The controlling method was successful during the tests, but it was assumed that accurate freehand gesture controls might prove to be either difficult to implement or might cause unnecessary fatigue for the user.[6] In Quach et al.'s [8] research, a person was placed in a virtual town view which used bars around the user to pinpoint the matching locations on the surrounding area. The tests were focusing on comparing different immersive implementations of a spherical map with bar indicators, and had generally favorable results. The interaction method with the map suggests that spherical map view where a person can rotate and look around may be beneficial for the immersion. Therefore, we can assume that the more the map resembles a real-world situation, the more the person is familiar with the VE by default, resulting in improved SA.[8] Whether the insight described fits the virtual maps in general, depends heavily on the purpose and design of the virtual map. Larger scale observation of different locations or maps can greatly differ from a single POI real-time navigation map, where the user usually needs a narrow view of a single scene. Let us assume that there is only a single map within the view that only exceeds the FOV borders when the view is zoomed in close enough. In this scenario there is no need for a spherical view, but if the map has any height differences for example, it may require the user to tilt the map to see behind certain objects or to enhance depth perception as demonstrated out in Yang et al.'s research [7]. Point-and-click, and angle detection -controls work in this type of a scenario, but a more precise and immersive interaction with the map can be achieved if the control mechanism resembles grabbing of a physical map, either via controller finger tracking and/or hand position detection. The closest mechanism to this that I found, was implemented in a paper by Newbury et al. [9], where the maps are moved by using gestures which resemble real world body movements, for example pulling something towards you. While in Newbury's [9] demonstration the controller is still technically point-and-click, the arm movement dictates the action. This type of interaction can be exhausting for the user and not doable in all virtual map environments, but serves as a good example of a more physical interaction with the map.[9]

3. DISCUSSION AND SUMMARY

In this thesis a mapping study into literature was conducted to find the optimal visualization styles for AR maps. Based on the selected 12 key papers, an ideal map visualization is presented and discussed here. While the related work and the key papers list various types of visualization, I will be presenting and discussing the ones that I found the most relevant when implementing a map application. Many of the listed methods for visualization did not result in direct benefits when moving from scene to scene such as the transparency, which was heavily situation dependent.

Overall, markers for the objects in a VE can be considered beneficial to make the view clearer for the user as the wide usage of markers especially in map applications suggests. However, as with any object, the markers should be used only with a certain view distance as multiple markers may obstruct the view. In order to prevent view obstruction with marker objects, changing the color of the objects in the scene may itself act as a marker. By changing the color to for example red, one is able make the object into a marker. This helps in maintaining the object or any adjacent objects unobstructed. However, if every object is colored with bright colors the main POIs may be lost in the view. Therefore, this method should only be used with certain distances, in order to avoid confusion due to the various highlighted objects in the view at the same time.

While the object selection methods and POI separation overlap with each other, the emphasis of this analysis is mainly on the POI separation, as the selection usually requires a person to already recognize the POI in order to select it. During cognitive jumps within the scene, a person is rarely aware of their next movement or the POI they are trying to reach. Therefore, the selection method is not as relevant as the indicators for objects.

It falls under speculation how the objects should be displayed in the view, because not a single method can universally be considered as the most effective method. Based on Google Maps and Street View, possible set-ups for a map application could utilize features such as:

- Limitations of how much can be seen within the FOV.
- Partial transparency.
- The color difference between the background and the foreground.
- Holographic nature.
- Stretching the view when moving.
- Top-down angle.
- Limited distance for the markers.

3.1. Demonstration Use Case and Prototype Description

To demonstrate the features listed above, I will present the use case of an example city map application. When starting the suggested prototype, the user is placed above a city view 30 meters higher than the top of the tallest building within range of 500 meters. The height and the range are approximations, defined based on the needs of a user moving on foot and after observing the vicinity of the Empire State Building and the Bryant Park in Manhattan in New York City, United States. The purpose for selecting these distances is to give the user a top-down city view, which seeks to avoid the view obstruction by the nearby buildings. The user's location above the buildings would naturally be higher if the user wants to observe a larger, less detailed city view. However, in this demonstration the main focus is on the closer city view as it covers the key elements of the map implementation methods and related problems more efficiently. In the set-up described above, a problem is already encountered when a building in close range is much higher than the buildings in vicinity.

3.1.1. Obstruction Avoidance

The Empire State Building is almost twice as tall as most of the buildings within the range of 500 meters from the building. While 30 meters from the top of the building appears to be a usable height in most cases, a problem arises when a building is much taller than the nearby buildings and the user is placed next to that tall building. The tall building will obstruct the buildings behind it. One possible solution to avoid this kind of obstruction is to remove any buildings close to the user completely. In this demonstration, a sphere is imagined, with radius of the altitude of the user, and with the user at the center of this sphere. Any part of a building which overlaps with the sphere, will be removed from the view. Method of removing the buildings completely when in range, might cause unwanted "popping" of objects when the building leaves the sphere and appears again. Therefore, the building object is cut and/or is added a transparency effect in order to smoothly add the objects back to the view while user is moving. In addition, of removing the obstructing parts of the objects, partial transparency of the objects is used within range of 100 meters to make the streets visible for the user, since the routes and the buildings are the main POIs in city map application. However, as mentioned earlier in this thesis, the transparency of the objects may cause unclear and confusing view for the user. To avoid needlessly detailed and unclear view, a simplified color scheme is implemented.

3.1.2. Color Selection

Typical holograms seen in science fiction are well known to have blue hue and appear partially transparent. Generally speaking, the blue color may not provide any known advantage over other colors for attention [16], except for yellow and red hues as they are often used as eye catchers in warnings for example. The hue of the chosen color is the key element when choosing the overall color scheme. Light hues have tendency to be less irritating watch and offer a monotonous landscape from which the actual POIs are easy to highlight. For this demonstration, light blue hue was chosen for the buildings and terrain of the city and light yellow hue for the streets, so that the destination of a person walking the streets is able to identify the routes to the target more efficiently. To implement partial transparency, the streets are displayed so that they can be seen through the buildings for 200 meters from the user with color and visibility gradually fading to the scenery. The distance for this effect is chosen by observing the vicinity of the Empire State Building. A person moving from city block to city block with walking speed, does not require information of all the other streets unless the route is selected, which would display the whole path to the destination.

3.1.3. Marker Specifications

For separating the buildings from each other, markers were used. Icons with descriptive graphics such as a camera icon for tourist attraction, can be used to mark the POIs on the map. With a large number of sights and restaurants etc. in a large city, the range for displaying POI markers should also be defined. When in the closer view of the application, the markers are displayed within 300 meter range, additionally, the POIs close to the destination and next to the chosen route would be displayed. This way, a person exploring the area would have an image of possible targets within a walking distance while avoiding overwhelming number of POIs. When the user selects a target POI in the demonstration application, the target marker and the building will be highlighted. For the target highlighting, a more vibrant blue hue will be used for the building as well as a yellow hue for the icon of the selected POI. By using stronger colors, the user can quickly see where the target is in the view. The route to the target should also be highlighted by using a more vibrant yellow hue, for the same reason as with the buildings and markers.

3.1.4. Visual Effects

In this subsection, a concept of sense of location is used. In this case, sense of location means a person's ability to tell where they are from their current position. For the surrounding areas in the application, when outside the 500 meter range the buildings would gradually receive a less vibrant light blue hue and lose any detail except for the height of the buildings. With this feature the user will not lose the sense of location on a larger scale but additionally will not be confused by the distracting details. To further enhance the user's possibility for maintaining the sense of location, a weak fisheye lens effect was chosen for bringing more objects within the FOV. This effect however, should not be strong as it distorts the scenery and may cause extremely confusing and undetailed view. Finally, in addition for making the objects in the view gradually fade and appear, a stretch effect similar to Street View was added when moving long distances from area to area. With this effect the user can maintain the SA while moving and the details of the target location would smoothly appear to the view. The effect is not added when moving short distances as there is no long distance transition or a huge difference in detail of the objects.

3.1.5. Summary

Many of the features described are heavily dependent on the optimal distance for displaying objects in the view. As the application features described are only hypothetically useful in maintaining the SA, to confirm the true usability of these features, the actual test application should be implemented and tested.

3.2. Future Research

It is hard to determine, how the features described would affect the SA during cognitive jumps. To validate these technical and design solutions, a real test application should be implemented. A group of people would be required to test the application in a user test and provide feedback on the usability and user experience. The test scenario should have multiple versions of the application with different distances for the graphical features in order to compare the test results with different parameters.

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