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VR-TECHNOLOGY AS A MODERN ARCHITECTURE TOOL

Abstract. *Visualization tools like CAD help architects to develop their projects, but they're not always successful in doing that. For one, the tools are too complex and the digital drawings and models produced are still 2D screen bounded, which makes it difficult – for collaborators and clients as well as the architects – to get a real, accurate sense of how design will look like, function, and take up space in the reality. According to the current way how CAD works for both visualization and prototyping – it has tremendous limitations. Every architect using CAD face problem of limitations resulting in misunderstanding between person who look at the visualization and own architects spatial view. 3D simulation on the 2D screen causes difficulties in experiencing scale, contextual elements and depth. However it is not proved that CAD representation results in wrong perception, since each individual human spatial perception has ability to intuitively compensate scale and depth issues individually that may differ from architects one. Thus, VR has the possibility to avoid pitfalls and provide natural and perception-friendly visualization. The epoch of CAD is ending – Virtual reality (VR) will be next digital visualization standard [1; 2]. This article explore the way and experience how architects will use the new methods of visualization using modern VR approach and expanding from this – investigation of the VR relationship and possibility to integrate into the architectural workflow. Article evaluates how differently CAD and VR affection results in the final space design and proves the CADs insufficiency in spatial visualization.*

Keywords: CAD; VR-technology; virtual reality; design; architecture

Introduction

There is no difference between a blueprint on the flat paper or 3D model on a flat screen. Literally both are bound to 2D space of paper or monitor. Those flat screens were our unique means of interacting with the virtual information depriving us of the spatiality, thing that is vital not only for the quality of the experience but also for organization of personal ideas and perception of the surrounding world. Moreover, it is a fact, that details are the most important containers of information, none of the flat screens can provide us with such spatial cues as proximity, territoriality and privacy.

What is the solution? – Virtual Reality can become one, a new possible drawing medium. Just like the ink whenever one draw the blueprint. It will not make one a better designer or architect but it will give a new tool to become better. It will give the ability to draw in VR in real time without leaving VR space and breaking immersion, it will bring designers and architects closer to having the medium be at the same speed as the one's imagination.

Floor plans, 3D renderings, and models are often used to convey an idea for a particular space within a design, but even these approaches – a staple of architectural design – can fail to effectively communicate ideas with clients.

This is where VR will come into its own. As an immersive technology, it will transport users into a fully interactive 3D environment, giving them the opportunity to explore a virtual representation of a particular room, floor, or building design as a whole.

Main material

There are three main requirements for VR software development:

– Productivity. As mentioned above, there are three main requirements for a VR development system, one of which is performance. High frame rate (100 Hz) and low latency are required to effectively "immerse" in a virtual reality environment. Poor performance is not just an inconvenience for the end user; this can cause unpleasant side effects, including disorientation and motion sickness. Therefore, the VR system must be able to use all available system resources, such as the processor and special graphics equipment. The system itself should have as few "overloads" as possible, allowing the equipment to operate at maximum efficiency.

– Flexibility. The development environment must be able to adapt to many hardware and software configurations. If the environment cannot adapt to the new configurations, applications will be limited in capabilities. The development environment must be embedded because the developer does not have to rewrite the application for each new configuration. In addition, the architecture of the system itself should not limit the use of applications that can be developed with it.

– Easy to use. The development system should be easy to set up, learn and use. The application programming interfaces (APIs) and / or languages used to create applications must be clearly planned and hide as much of the complex internal system of the application as possible.

The ideal development environment must meet each of the above requirements. In fact, they often conflict. The easy-to-use interface of the system can limit the developer's parameters, sacrificing flexibility. A very flexible system can be difficult to optimize for performance due to the number of options presented to the developer.

There is potential for VR in modern architecture and/or designer workflow. Designers and Architects workflow to produce final blueprint or preview is handled in the digital way. For the start, let’s define what goes into architecting and designing, including current visualization toolsets and figure out the different reality providers like VR and CAD. Architects and designers «sell» their work in form of the creation and enhancement of the real world, real environments, real buildings. Since that, basically, they have to think in 3D and then turns that vision into a 2D visualization which is then translated again into a real, 3D space. So, new digital way is not so different from old method when each blueprint or visualization preview was made on the paper, other words – simulation of the spatiality on a flat screen is a method that falls back to the perspectival 2D-drawings. These old-fashioned methods have become common within the patterns of architectural design. Moreover, such technology has been of the greatest drivers of innovations in sphere, forcing architects and designers to switch to CAD or other digital-based development tools. Visualization tools like CAD help architects and designers to develop their projects and ideas; but they’re not always successful in doing that. For one, the tools are too complex; and the digital drawings and models produced are still bound to a 2D screen, which makes it difficult – for collaborators and clients as well as the designers themselves – to get a real, accurate sense of how a design will look like, function, and take up space in the real environment. CAD has certainly technologically enabled designers and architects to manage their projects but the reality is that designers are still viewing blueprints on computer screens as well as paper. They are using pictures and plans just for now, and it is difficult to conceive, revise and execute a project based upon static renderings. Therefore, firstly launched in 1963[3] and more than fifty years later CAD remain most preferred tool for 3D visualization in architecture or design. But the epoch of CAD is about to be over Virtual reality (VR) tends to become next standard for digital visualization. The following article explore the way and experience how architects will use the new methods of visualization using modern VR approach and expanding from this – investigation of the VR relationship and possibility to integrate into the architectural or design workflow. Evaluate how differently CAD and VR affection results in the final space design and prove the CADs insufficiency in spatial visualization.

Arguing that current way how CAD works for both visualization and prototyping/ blueprinting have tremendous limitations. Every architect or designer using CAD face the same problem in these limitations which result in misunderstanding between person who look at the visualization for the first time and own architects or designers spatial view. 3D simulation on the 2D screen causes difficulties in experiencing real scale, contextual elements and depth. It is not yet proved claim that CAD representation can result in wrong perception, since each individual human spatial perception has ability to intuitively compensate issues of scale and depth in own, individual way that may differ from architects one. [4] Thus, VR has the possibility to avoid such pitfalls and provide more natural and perception-friendly visualization.

There are three statements proving that VR architecting and design is more efficient that old fashioned methods.

– Statement #1: No matter how experienced is designer but in 3D visualization through 2D screen they will constantly issue scale misjudges of the objects and their spatial relationship to each other. Therefore, it would be easier to keep track on scale and depth in virtual reality that in CAD.

– Statement #2: CAD derived designer would produce greater packing density of features without straight relationship to the avatar that can result in great open spaces. VR designer will create more rational positioning of features in relation to the avatar.

– Statement #3: VR realistic rendering is more desirable than greater amount of abstract forms in CAD [6].

The only one way to prove those statements was to handle real experiment. So long 10 profound CAD designers took part in the experiment consisting of two stages. First stage was performed using CAD tool. Subjects of the experiment were able to view and manipulate the models and space in simulated 3D within a perspective view. Subject had full control over their camera angles. Thus the subject had ability to replicate 2D viewport or approximate human eye perspectives by manipulating the camera. Task for the first stage was to make final exterior design using given space, objects and textures during 20 minutes. The second part of the experiment was performed in virtual reality. Subject viewed the space they've just designed with the perspective simulates at a standing human vision. Their viewport was binded to the movement of their head, movement was binded to the gamepad controller allowing subject to move in VR environment.

The task for second stage was to observe result in VR and share comments about their expectations of what they've done during stage one and result they've experienced during stage two, observing the actual look of the designed space.

The collected data allowed to make separate provements of the statements above.

Statement #1 is completely about personal perception of the real scale in VT and whether or not people would consider it easier to perceive scale in 2D viewport or in VR. Most of subjects responded with surprise during second stage concerning their faulty sense of scale and depth (see Figure 1). Two out of eight subjects confirmed that scale in was just like they planned it should be during design process. Comparing to post CAD interview none of the subjects were aware about the scale they were designing in. Nine out of ten subjects confirmed that manipulating with objects in VR would be initially more intuitive considering the relation between objects or between object and avatar. Therefore, both the speed and consideration are more efficient in the self-centered perspective of VR in comparison to the perspective in CAD through flat screen. The final conclusion was that experiment proves statement #1: intuitive perception of scale and other spatial perceptions are better in VR than in CAD.

Figure 1 – Dynamic scale representation according to distance

Statement #2 concern that the VR approach spacing of elements (see Figure 2) in relation to the avatar comparing to perspective such as in CAD would promote more cramming of elements [7]. The premise of this statement had to do with the belief that having allocentric spatial processing, or spatial processing relating object to object, would lose the avatar element in relating to a spatial order. In order to test this statement, we looked at the way that subjects interpreted the layout of their designs. In the post CAD interview, one out of ten subject said if he was to take his design further, he would add more elements to his design. During VR stage, we found that ten out of ten subjects complain about emptiness and redundant open space. Thus the VR perspective actually completely proved our statement that VR with its intimate relation to the human scale would actually promote favorable choices for space managing.

Figure 2 – Spacing and mesurement tool

Statement #3 is about to see if there was a preference for certain textures. This statement came from the question of VR's suitability for abstract, non texturing modeling. This formal massing design preference currently exists in CAD where material and texture is a finishing gloss on the overall form of the element instead of an inherent property of the object[8]. Whether it is desirable to have a tool that has options for textures versus non textures, with or without material encoding is a debate in design that has only been enabled by the design tools we use. If the modeling tool we used biases our representation of our models in a certain direction, there are consequences that manifest in our design process and our consideration of form and materiality. Final designs of each subject were taken and the amount of rendered texture and no texture in these designs have been analyzed. Including the sky, trees, water, and sculptures as 'rendered' texture (see Figure 3) and the white ground and walls as 'no texture'. After we showed designs to other designers and asked to define «liked» and «disliked» designs. In comparing the amount of rendered and no texture designs as well as liked and disliked we hoped to find the provement. In average, for designs, there is 61.9% rendered texture and 38.4% no texture in the design. For disliked designs, there is 52% rendered texture and 48% no texture. Just from the designs, there is a slightly higher percentage of rendered textures in liked designs, although the gap is but about 10% [5]. Aside from designs analysis, the design commentary also provided some additional valuable data. As mentioned earlier, we asked subjects about feature density. And most of them messed with density because of non-textured environment. Thus in conclusion, we will say statement #3 is supported by subjects and realistic rendering textures in VR are more desirable for better design results.

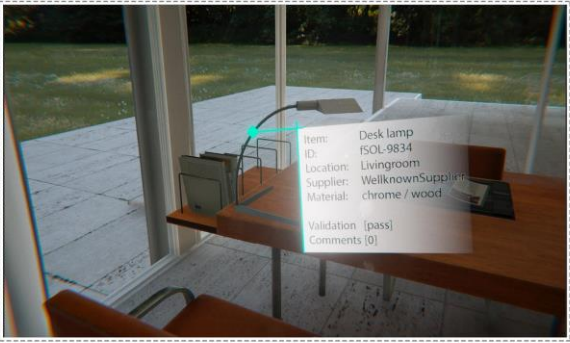

Figure 3 – Object settings tool with ability to change texture preferences

Along with the development of the virtual reality tool sand the experiments to understand its efficiency as a design tool, we were able to get better understanding of the VR environment as approach of critical creation. We believe the demonstrated viability for an architectural/designers VR tools as well as challenged some of the design/architectural practices enabled by CAD-like modeling[9]. The subjects demonstrated the fallibility inherent in different virtual representations, be it CAD or VR, and through examining their design workflows and conclusions, we can better understand how CAD and VR results in perceptions of scale, object relationships, materiality, and spatiality. VR naturally emphasize better intuitive understandings of scale and object spatial relationships, but does so in an experimental manner. CAD provides illusions of real scale, density, and immersion. Both no texture and realistic rendered textures can be deployed in VR, with a slight preference for realistic rendered textures. Finally architects and novices, when self-evaluating their immersive 3D spatial imagination from a plan, perform almost the same, with architects performing slightly better. These conclusions demonstrate a space for VR as a unique and worthwhile new approach for architectural design. The experiment also allowed for some further investigations and possibilities of future VR applications. Different subjects weighed in with the various uses of VR. One particularly interesting proposition was to design from the perspective of those who are not currently considered, such as views for children or for wheelchair users that have different lines of sight. Some found VR as a helpful tool. but not a replacement for traditional CAD modeling and there were many different opinions on its place and role in the design history. On the broader scope, the next step for this project and this research would be to evolve the VR review tool into the VR editor tool. By taking the VR proof of concept and develop it into a full VR editing environment[10], we could make a more comprehensive comparison between designs in CAD and designs in VR. The beginnings of this research was interested in this possibility but the difficulties in creating flexible VR metaphors to edit space proved to be quite the challenge. One example of such a difficulty was how objects could be moved and manipulated far away from the body. The question of whether the user would have to move with the object in order to place it was one out of many object manipulating concerns. The metaphors that enable modeling would have to be reimagined for an immersive virtual reality environment. Doing so would transform design and the act of making and architectural modeling in virtual space.

It is obvious that VR models are useful marketing tools. The customer being able to choose/correct elements of building or interior and easily provide perception unbounded data to the architect or designer for further work in the same VR space. Another function is ability to vote on designs with multiple proposals; as simple as flipping the sofa or chair and you can immediately see a visual difference. Each customer can flip to as they wish and see if it fits from their own point of view. With a modern VR technologies that allow one to use VR on the mobile – customer will be to experience a new interior not only for a few minutes but even a few weeks and choose what they really enjoy.

The process of information model construction is a revolutionary method in comparison with traditional methods of design management and design development in projects. This technology, despite the fact that over the last period its usage in design, architecture and construction has increased considerably, still there are some barriers and limitations in its widespread usage through complexity.

Virtual reality is a technology that over the past years has gained significant improvement in its technical support, which in turn has allowed the distribution of virtual reality helmets at affordable prices and, consequently, made them more widespread. The dive capacity associated with the interactive virtual reality software provides a brand new potential for the design industry because of users' ability to visualize in a scale of 1: 1. This way, it allows better understanding of the space or of the models before they are created in the real world.

A game engine was used to develop a prototype of an program for designers using virtual reality technologies in which interested project parties can interact and evaluate project design with virtual reality and it does not require any kind of technical education (user interface is intuitive) and where the result of work in a virtual reality environment is automatically exported from the virtual reality model to the BIM model.

It is worth nothing that the prototype software using virtual reality technology is an executable file that can be run without the need to install any additional software that facilitates distribution. The use of the software can be individual or group. Using collaboration with stakeholders results in better results because the design or other aspects can be discussed and resolved. Another advantage of the prototype program is that the user interface is intuitive, so it does not require any prior technical knowledge to use, which facilitates integration with all project participants.

Conclusion

In conclusion, the ability to immerse people into virtual worlds – specifically into digital simulations of proposed buildings – will be a game changer for the AEC industry. New realities – augmented, virtual, mixed – offer a new, far superior level of real-world scale, proportion and perspective over current tools. These technologies will empower architects, engineers and designers to become more innovative by freeing them from the limitations of 3D models in 2D formats and bringing their 3D dreams to life.

With advances in Building Information Modeling, Virtual Reality and Augmented Reality technologies have many potential applications in the Architecture, Engineering, and Construction industry. However, the AEC industry, relative to other industries, has been slow in adopting AR/VR technologies, partly due to lack of feasibility studies examining the actual cost of implementation versus an increase in profit. The main objectives of this paper are to understand the industry trends in adopting AR/VR technologies and identifying gaps within the industry. The identified gaps can lead to opportunities for developing new tools and finding new use cases. To achieve these goals, two rounds of a survey at two different time periods (a year apart) were conducted. Responses from 158 industry experts and researchers were analyzed to assess the current state, growth, and saving opportunities for AR/VR technologies for the AEC industry. The findings demonstrate that older generations are significantly more confident about the future of AR/VR technologies and they see more benefits in AR/VR utilization. Furthermore, the research results indicate that Residential and commercial sectors have adopted these tools the most, compared to other sectors and institutional and transportation sectors had the highest growth from 2017 to 2018. Industry experts anticipated a solid growth in the use of AR/VR technologies in 5 to 10 years, with the highest expectations towards healthcare. Ultimately, the findings show a significant increase in AR/VR utilization in the AEC industry from 2017 to 2018. [11]

Virtual Reality has been widely used in games, education etc. But one can imagine its use in construction. A flat representation (even if it is 3d model on a flat screen) can sometimes be misinterpreted, instead, 3D model in VR with animation on how to place a detail or how stuff works can be clarifying. Adding the advantage of a floating grid, digital warning signs, just in time calculations and placing/testing variable things such as paint, accommodations, layouts and other component options can save the project both time of architects/designers and money, so that more effort can be spent on design, not just looking how to make things cheaper.

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VR-ТЕХНОЛОГІЯ ЯК СУЧАСНИЙ ІНСТУМЕНТ АРХІТЕКТУРИ

Анотація. *Засоби візуалізації, такі як CAD, допомагають архітекторам і дизайнерам розвивати власні проєкти та ідеї. Проте часто виявляється, що інструменти надто складні, а цифрові малюнки і моделі досі пов'язані з 2D-екраном. Залежність від 2D-простору ускладнює співпрацю клієнтів та дизайнерів. 2D-залежність не дозволяє отримати реальне, точне розуміння, як дизайн буде виглядати, функціонувати і яке займати місце в реальному середовищі. Враховуючи особливості роботи CAD-середовищ, пов'язаних із завданнями візуалізації та прототипування, очевидними стають їх обмежені можливості. Кожен архітектор чи дизайнер, використовуючи CAD, стикається с цими обмеженими можливостями, що призводить до нерозуміння людиною, яка перший раз бачить візуалізацію, і просторового бачення архітектора. 3D-простір, зображений на 2D-екрані, породжує проблеми у сприйнятті розміру, контекстних елементів та глибини. Однак факт, що CAD-візуалізація завжди веде до хибного сприйняття не доведено. Оскільки просторове сприйняття кожної людини у свій спосіб компенсує відсутність інформації про розмір чи глибину, то воно може різнитися з баченням архітектора. Натомість VR технології можуть допомогти уникнути вищеописаних проблем. Отже, епоха CAD закінчується, а технології віртуальної реальності (VR) стають наступним стандартом цифрової візуалізації. У статті досліджено як архітектори використовуватимуть нові методи візуалізації та досвід використання сучасного підходу VR, а саме дослідження можливості інтегрування VR в архітектурний або проєктний робочий процес. Оцінено наскільки різний ефект мають результати CAD і VR в остаточному дизайні простору, доведено неефективність CAD у просторовій візуалізації.*

Ключові слова: CAD; VR-технологія; віртуальна реальність; дизайн; архітектура

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VR-ТЕХНОЛОГИЯ КАК СОВРЕМЕННЫЙ ИНСТРУМЕНТ АРХИТЕКТУРЫ

Аннотация. *Средства визуализации, подобные CAD, позволяют архитекторам и дизайнерам развивать проекты и идеи. Однако часто оказывается, что инструменты слишком сложны, а цифровые рисунки и модели до сих пор связаны с 2D-экраном, что затрудняет сотрудникам и клиентам, а также самим дизайнерам получить реальное и точное понимание того, как дизайн будет выглядеть, работать и какое занимать место в реальной среде. С учетом особенностей работы среды CAD, связанных с заданиями визуализации и прототипирования, очевидным становиться ограниченность возможностей среды. Каждый архитектор или дизайнер, использующий CAD, сталкивается с этими ограничениями, которые в свою очередь ведут к непониманию человеком, который впервые видит визуализацию пространственного видения архитектора. 3D-пространство, изображенное на 2D-экране, порождает проблемы восприятия размера, контекстных элементов и глубины. Однако факт того, что CAD-визуализация всегда ведет к ложному восприятию не доказан. Поскольку пространственное восприятие каждого отдельного человека способно своим образом компенсировать отсутствие информации о размере или глубине, оно может разниться с виденьем архитектора. В свою очередь VR-технологии позволяют избежать вышеизложенные проблемы. Соответственно, эпоха CAD заканчивается. Вместо этого, виртуальная реальность (VR) становится следующим стандартом цифровой визуализации. В статье показано как архитекторы будут использовать новые методы визуализации и опыт использования современного подхода VR, а именно исследование возможности интегрирования VR в архитектурный или проектный рабочий процесс. Оценено насколько разный эффект имеют результаты CAD и VR в окончательном дизайне пространства, подтверждена неэффективность CAD в пространственной визуализации.*

Ключевые слова: CAD; VR-технология; виртуальная реальность; дизайн; архитектура

Link to the post

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ДСТУ *Цюцюра С.В. VR-технологія як сучасний інстумент архітектури [Текст] / С.В. Цюцюра, Б.Т. Бебешко, К.В. Хорольська // Управління розвитком складних систем. – 2020. – № 42. – С. 69 – 74, dx.doi.org\10.32347/2412-9933.2020.42.69-74.*