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THE FUTURE ENVELOPED IN TECHNOLOGY. IMMERSIVE ARCHITECTURE AND ADDITIVE STRUCTURES IN URBAN FABRIC THROUGH THE EYES OF AR AND AI

PRZYSZŁOŚĆ ZANURZONA W TECHNOLOGII. IMMERSJA ARCHITEKTURY A STRUKTURY ADDYTYWNE W TKANCE MIEJSKIEJ OCZAMI AR I AI

Abstract

New technologies, particularly those related to augmented reality (AR), are increasingly influencing the adaptability, flexibility, and multidimensional perception of urban spaces. Architectural immersion, which enables real-time engagement between the physical and virtual worlds, has become a key tool for the visual and functional personalization of spaces. This paper represents an exploratory experiment by the author, utilizing additive structures within existing urban environments through the application of AR and AI tools. The primary aim of this research is to explore and evaluate the impact of new technologies, especially AR and artificial intelligence (AI), on the perception of architectural spaces. The experiment seeks to analyze the interaction between users and space using AR and AI, and to investigate aspects of cognitive psychology, cognitive science, and the philosophy of architecture in the context of these emerging technologies. The research methods included literature reviews, spatial experiments preceded by 3D modeling and simulation, and preliminary theoretical analysis based on the philosophy of architecture.

Keywords: augmented reality (AR) in architecture, artificial intelligence (AI) in architecture, architectural perception, reversible modular structures, additive structures

Streszczenie

Nowe technologie, szczególnie związane z rozszerzoną rzeczywistością (AR), mają współcześnie coraz większy wpływ na adaptacyjność, elastyczność i wielowymiarowe spojrzenie na przestrzeń zurbanizowaną. Immersja architektury, która w czasie rzeczywistym umożliwia zanurzenie się i trwanie pomiędzy światem rzeczywistym i wirtualnym, jest obecnie jednym z narzędzi personalizacji wizualnej i funkcjonalnej przestrzeni. Artykuł stanowi podróż – eksperyment autorki z zastosowaniem struktur addytywnych w istniejących przestrzeniach miejskich dzięki zastosowaniu narzędzi AR i AI. Celem badań jest eksploracja i ocena wpływu nowych technologii, zwłaszcza rozszerzonej rzeczywistości (AR) oraz sztucznej inteligencji (AI), na postrzeganie przestrzeni architektonicznej. Eksperyment ma na celu analizę interakcji między użytkownikami a przestrzenią przy użyciu AR i AI oraz zbadanie aspektów psychologii poznawczej, kognitywistyki i filozofii architektury w kontekście nowych technologii. Metody badawcze objęły: studia literaturowe, eksperymenty przestrzenne poprzedzone modelowaniem i symulacją 3D oraz wstępną analizą teoretyczną na podstawie filozofii architektury.

Słowa kluczowe: rozszerzona rzeczywistość (AR) w architekturze, sztuczna inteligencja (AI) w architekturze, percepcja architektury, rewersyjne struktury modułowe, struktury addytywne

1. INTRODUCTION

At the beginning of the exploration into a new phase of architectural pursuits, let's imagine conducting a brief cognitive experiment. This experiment requires mental visualization and empathy. We transport ourselves for a moment to one of the medieval cities, where we have the privilege of walking. Suddenly, a cathedral building (in a style that will later be called Gothic) emerges before us. Height, light, audacity? Accustomed to the squat structures of Romanesque architecture, we cannot yet decide whether we are looking at *the sacred* or *the profane* at this moment. The great impression this new style made on its users is illustrated by Leone Battista Alberti in the 15th century, who, when proposing the term Gothic, used it pejoratively, referring to barbaric and pagan solutions. David Watkin, in his *History of Western Architecture*, titles one chapter *The Gothic Experiment*.[1] One can make the bold thesis that every object which became the beginning of a new trend was a kind of architectural experiment (Ill. 1). It might seem that everything in the field of architecture has already been built.

Ill. 1. A fragment of a drawn vision of a Gothic cathedral – a visual impression. Illustration generated using AI graphic generation tool (Midjourney), source: https://www.midjourney.com/home.

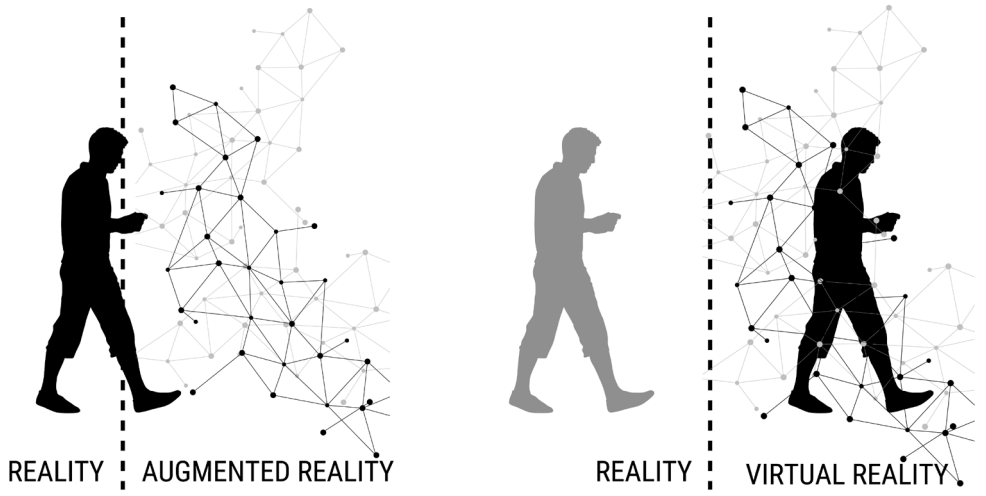
The inhabitants of the medieval French city of *Sens* probably thought the same.[2] Perception in architecture, based on mental models or the haptic and visual perception of architectural fabric, is one of the significant research directions. Juhanni Pallasmaa repeatedly refers to the perception of architectural structures in a haptic and visual manner in his works.[3] The experience of architectural space is gradually entering the realm of neuroscience through increasing technological capabilities. One of the contemporary areas of experimentation is

[1] D. Watkin, *Historia architektury zachodniej*, Arkady, Warszawa 2006 [after:] P. Wróbel, *Eksperyment w Architekturze. Wolny wybór czy konieczność i obowiązek*?, "Państwo i Społeczeństwo" 2017, no. 1.

[2] *Katedra w Sens – Pierwsza gotycka katedra Francji* [in:] Sekulada, https://sekulada.com/katedra-w-sens/ (access: 13.07.2024).

[3] J. Pallasmaa, *The Eyes of the Skin: Architecture and the Senses*, John Willys &Sons, Chichester, Hoboken, NJ 2005, and J. Pallasmaa, *The Thinking Hand: Existential and Embodied Wisdom in Architecture*, John Wiley & Sons, Chichester 2009.

immersive modeling and its integration with augmented and virtual reality. Immersion, from the Latin "immersio," means "to immerse." Architecture that signifies us allows for a literal immersion into the structure. The technological leap we are witnessing has enabled architecture to enter the realm of virtual reality. This was the moment when immersion gained new and deeper meaning. Currently, as architects, we have the ability to operate at the intersection of augmented reality (AR) and virtual reality (VR) (Ill. 2). Introducing architectural design into the immersive realm, bridging the real and virtual worlds, allows for prototyping and experimenting with structures on a completely different plane.



Ill. 2. Diagram showing the visual boundary between Augmented Reality (AR) and Virtual Reality (VR), own elaboration.

2. EXPERIMENT IN ARCHITECTURE

Contemporary architecture requires openness to experimental exploration. We are on the brink of a paradigm shift in architecture, moving towards sustainable and pro-ecological solutions. Material engineering is developing dynamically, with new solutions being sought for lightweight structures that also ensure high insulation and energy efficiency parameters. The potential of engineering in modern construction stands at the threshold of new discoveries and the search for alternative paths in architectural design. New directions in building design are entering the architectural nomenclature. One of the design approaches is the *design for deconstruction* trend.[4] It introduces a new way of interpreting ecology in architectural design. Pro-ecological actions, on the one hand, are understood as the use of natural materials with a low carbon footprint[5]. On the other hand, they can encompass the entire lifecycle

[4] J. Kanters, *Design for Deconstruction in the Design Process: State of the Art*, "Buildings" 2018, no. 8(11), art. no. 150. DOI: 10.3390/buildings8110150 (access: 13.07.2024).

[5] S. Sipahi, N. Kulözü-Uzunboy, *A study on reducing the carbon footprint of architectural buildings*

of buildings, including the potential for construction, deconstruction, relocation, and reassembly. This understanding of ecology introduces a completely new concept of sustainable development, which, over many years of being applied in various, sometimes inadequate parallels, has already become devalued in nomenclature. The phenomenon under discussion can be better illustrated by a concept that is just beginning to appear in architectural considerations, namely: *reversible modular design*.[6] It enables a more complete integration of circular architecture into the design space.

3. REVERSIBLE ARCHITECTURE – EXPERIMENT HERE AND NOW

Contemporary architecture is on the verge of significant changes due to increasingly perceptible climate changes. Global legal regulations are causing our architectural paradigm to undergo substantial transformations. New directions in shaping and experimenting with material engineering and architecture per se are being developed right now. Denmark, in response to planned legislative changes and climate discussions, has taken decisive actions to reduce the carbon footprint of buildings based on a 50-year lifecycle to 12 kg CO_2/m² annually. From 2024, this limit has been further reduced by an additional 1.5 kg annually.[7] Taking a holistic view of the lifecycle of building materials and buildings, along with their usage, new directions in architecture are emerging that will very likely have a significant impact on future urban planning and city design. As part of the UNESCO-UIA cooperation, Denmark was recognized as the World Capital of Architecture 2023.[8] One of the initiatives undertaken as part of this event was the creation of a low-emission, experimental residential complex in collaboration between the Velux group, Effect Architects, and Artelia Engineers. The project, The Living Places, was located in a new district of Copenhagen called Jernbanebyen, also known as the *railway district*.[9] In collaboration with the Copenhagen architectural office COBE, a completely new district is being developed. The concept of the new master plan is based on the implementation of greenery, which is to form the core of the design premise. The reference to "railways" is related to the existing, old railway infrastructure, which will be partially preserved as an artifact of the past. The Living Places project involved designing and constructing a temporary residential complex that could be entirely dismantled and relocated, while maintaining a carbon footprint below 4 kg CO_2/(m²a). This mini-settlement is located in Copenhagen until the end of October, and its future is currently unknown. This housing experiment fits into the trend of design for deconstruction and reversible modular design, serving as a kind of sustainability manifesto where durability takes on a completely different dimension.

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based on their materials under the guidance of eco-design strategies, "Clean Technologies and Environmental Policy" 2021, no. 23, pp. 991–1005.

[6] *Reversible Buildings, Modular Buildings: What's the difference?* [in:] Saint-Gobain, 3.09.2021, https://www.saint-gobain.com/en/news/reversible-building-modular-building-whats-difference (access: 13.07.2024).

[7] J. Schoof, *Living Places Copenhagen by Effect Architects* [in:] Detail, 24.07.2023, https://www.detail.de/de_en/living-places-copenhagen-von-effekt-architects (access: 8.07.2024).

[8] World Capital of Architecture 2023, https://arkitekturhovedstad.kk.dk/en (access: 8.07.2024).

[9] B.J. Bøje-Kovács, A. Eriksson, L. Stenfeldt, S.M. Thestrup, *Applying data for urban neighborhood development, the case of Jernbanebyen*, Institut for Byggeri, By og Miljø, Aalborg Universitet 2023.

4. ARCHITECTURAL ITERATIONS AND SPATIAL EXPERIMENTS

Aaron Betsky, curator of the 11th Venice Architecture Biennale, spoke about the role contemporary architecture should fulfill: "We need architecture beyond buildings. Architecture must go beyond buildings because they are insufficient. They are large, uneconomical collections of natural resources that are difficult to adapt to constantly changing living conditions."[10] The 2008 exhibition, titled "Out There: Architecture Beyond Building," demonstrates how architects and architectural theorists strive to transcend previously defined boundaries. The application of augmented reality (AR) in architectural design is becoming one of the contemporary modeling languages. Currently, tools enabling the use of AR solutions in architectural practice are widely available. Many popular 3D programs have plugins that allow for AR analyses in existing architectural realities. In the simplest hardware configuration, after generating a 3D model, one can integrate the model with a real photo using a mobile device. However, there are more advanced methods for utilizing augmented reality capabilities, such as using AR glasses. Advanced solutions are employed in industry for complex material calculations or operating production equipment. Augmented reality tools also frequently appear in contemporary art. Jenny Holzer, a young contemporary artist, implemented an application on the University of Chicago campus that displays quotes from great writers and thinkers, including Plato, Helen Keller, Audre Lorde, Toni Morrison, Friedrich Nietzsche, Mary Shelley, and Virginia Woolf. The title of the immersive exhibition, YOU BE MY ALLY, is a fragment from "If Not, Winter: Fragments of Sappho" by Anne Carson.[11] Nowadays, multimedia and immersive exhibitions are becoming very popular, allowing users to "immerse" themselves in the content and abstraction of a creatively crafted world. Japanese artist Yayoi Kusama (born in 1929) created the exhibition INFINITY MIRRORED ROOM – LET'S SURVIVE FOREVER. By introducing spheres with mirrored surfaces and reflective walls, she invites the user into her interpretation of the vision of infinity.[12] Thanks to advanced visual technological capabilities, a whole series of exhibitions has been created, inviting users to immerse themselves in the drawings and paintings of numerous artists. The exhibition "Story of the Forest" in Singapore is inspired by the works of William Farquahar, transposing 69 drawings into immersive 3D animations.[13] The international art collective teamLab creates immersive exhibitions worldwide, inviting visitors from around the globe to fully immerse themselves in augmented reality.[14] Contemporary art extensively leverages the technological capabilities of augmented reality, creating immersive exhibitions across the world. Architects, however, take a more conservative approach to the widespread use of AR in design and modeling. In interior design, VR and AR capabilities are being increasingly applied on a larger scale (Ill. 3).

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[10] After: L. Klein, *Poza budowaniem, Relacja z 11. Biennale Architektury Współczesnej w Wenecji*, "Quart" 2009, no.1, p. 108, https://quart.uni.wroc.pl/pdf/11/quart11_Klein.pdf (access: 8.07.2024).

[11] *The Commission* [in:] You be my ally, https://www.jennyholzer.uchicago.edu/project (access: 8.07.2024).

[12] *Yayoi Kusama's INFINITY MIRRORED ROOM – LET'S SURVIVE FOREVER* [in:] Art Gallery of Ontario, https://ago.ca/exhibitions/yayoi-kusamas-infinity-mirrored-room-lets-survive-forever (access: 13.07.2024).

[13] Marcus, *The Story of the Forest* [in:] Medium, 6.05.2024, https://medium.com/tourist-in-my-own-country/the-story-of-the-forest-397c67b9f6a5 (access: 13.07.2024).

[14] TeamLab Borderless Tokyo, https://www.teamlab.art/e/tokyo/ (access: 13.07.2024).

Ill. 3. Iterative representation of a hypothetical art pavilion – visual impression. Illustration generated using the AI graphic generation tool (Midjourney), source: https://www.midjourney.com/home.

5. SUMMARY

Currently, solutions based on augmented and virtual reality are being increasingly applied in architectural design. The immersive approach to shaping architectural objects and the actual implementation of AR in the modeling space can completely change the way architectural solutions are presented. Real-time modeling using AR tools can facilitate design communication among Investors, Users, and Designers. The necessity to develop new directions in architectural design based on pro-ecological principles and circular economy requires the creation of new tools and the posing of fundamental questions about the future of architecture. AR solutions and immersive modeling can be significant tools in supporting the new architectural paradigm.

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Author's Note

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She is currently focusing her scientific and research activities on issues related to innovative residential architecture, with particular emphasis on movement in architecture and mobile structures temporarily stationed in urban and non-urban areas. She is the author of scientific articles on movement in architecture, responsive architecture, and reversible structures. Her involvement in the educational process has led to numerous student awards in various competitions, including the Citation Award for a student project in the international competition "Architecture at Zero" for a zero-emission agricultural center in the USA in 2023, a project carried out as part of the course "Environmentally Friendly Residential Architecture," and 1st place for the student project Co-Living California in 2021. She is an active architect specializing in designing single-family and multi-family houses, adapting existing buildings, and interior design. Additionally, she collaborates with industry in co-creating grant applications in the interdisciplinary area. She is a member of IASS (The International Association for Shell and Spatial Structures) and PZITB (Polish Association of Construction Engineers and Technicians).

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