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DIGITAL EMPATHY IN ARCHITECTURE – BETWEEN TECHNOLOGY AND SPATIAL EXPERIENCE

CYFROWA EMPATIA W ARCHITEKTURZE – MIĘDZY TECHNOLOGIĄ A DOŚWIADCZENIEM PRZESTRZENI

Abstract

The article discusses the influence of digital technologies on architectural design focused on users' emotions and spatial experience. It attempts to answer the question of how technology, contemporary digital tools and environmental simulations support the creation of atmosphere, sense of safety, comfort, and perception of space. The study examines the limitations of digital processes, which may lead to the standardization of design and the selection of more economical solutions at the expense of aesthetic quality and the individual character of architecture. The article is based on an analysis of the literature concerning the perception of architecture and the relationship between humans, space, and technology, as well as a review of selected contemporary design tools.

Keywords: *architecture, digital technology, empathy, spatial perception*

Streszczenie

Artykuł porusza problem wpływu technologii cyfrowych na projektowanie architektury ukierunkowanej na emocje i doświadczenia użytkownika. Stanowi próbę odpowiedzi na pytanie, w jaki sposób technologie cyfrowe oraz symulacje środowiskowe wspierają kształtowanie atmosfery miejsca, poczucia bezpieczeństwa, komfortu i percepcji przestrzeni. Rozważania dotyczą również ograniczeń procesów cyfrowych, które mogą prowadzić do standaryzacji projektowania i wyboru rozwiązań ekonomicznych kosztem jakości estetycznej oraz indywidualnego charakteru architektury. Podstawę artykułu stanowi analiza literatury dotyczącej percepcji architektury oraz relacji człowiek–przestrzeń–technologia, a także przegląd wybranych współczesnych narzędzi projektowych.

Słowa kluczowe: *architektura, empatia, percepcja przestrzeni, technologia cyfrowa*

1. INTRODUCTION

Contemporary architecture is undergoing a phase of intensive digital transformation. Technologies such as Building Information Modeling (BIM), parametric design, and Virtual Reality (VR) have come to dominate the architectural design process, offering unprecedented levels of precision and efficiency. Nevertheless, alongside these technological advancements, a fundamental question emerges regarding the role of the human being within this increasingly digitized design environment. To what extent are algorithms capable of accounting for the 'soft' dimensions of spatial experience, including emotions, sensory perception, and psychological comfort?

The concept of 'digital empathy' in architecture can be defined as the capacity of technological tools (and of the designers who have a command of them) to simulate, anticipate, and respond to the emotional and sensory needs of future users. This article aims to analyze this phenomenon by highlighting both the potential of digital technologies to enhance the quality of spatial experience and the inherent risks associated with the excessive quantification of the built environment.

2. PHENOMENOLOGY OF SPACE: THE BODY, THE SENSES

Any discussion of the contemporary digitalization of architectural design practice requires a prior and fundamental redefinition of architecture itself, which, within a technocratic perspective, is often mistakenly reduced to the visual-spatial domain of geometry or to technical and functional parameters. From the perspective of phenomenology – represented in classical philosophy by thinkers such as Maurice Merleau-Ponty[1] – human beings are not merely external, Cartesian observers of the world around them but profoundly embodied subjects who perceive, interpret, and co-create space through the physical presence of their bodies. The body thus constitutes the primary frame of reference, a biological filter, and a cognitive instrument through which physical stimuli are pre-reflectively translated into emotional and psychological states.

In its deepest existential dimension, architecture does not manifest itself as a collection of plans, cross-sections, or idealized three-dimensional renderings, but rather as a dynamic somatic process. The experience of space occurs at a pre-conceptual and intuitive level, preceding any attempt by the human mind to rationally categorize a given environment in aesthetic or functional terms. The affective response evoked by the volume of an interior is deeply rooted in the evolutionary mechanisms governing the search for shelter, the need for safety, and kinesthetic orientation within the three-dimensional world.

3. THE ALGORITHM TRAP: LIMITATIONS AND THREATS

Despite the immense potential of contemporary digital technologies, any attempt to translate the rich and multisensory nature of human spatial experience into the language of digital data entails significant risks. By their very nature, algorithms are capable of processing only those aspects of reality that can be measured and quantified. Consequently, they can efficiently

[1] M. Merleau-Ponty, *Fenomenologia percepcji*, trans. M. Kowalska, J. Migasiński, Fundacja Aletheia, Warszawa 2001, pp. 83–116.

optimize parameters such as energy consumption, daylight availability, or corridor dimensions, yet remain largely incapable of addressing qualitative phenomena that resist numerical representation, including the sense of coziness, the atmosphere of a particular place, or the emotional comfort that a space may evoke. As reliance on computational analysis increases, these intangible yet fundamentally human dimensions of architectural experience risk becoming marginalized. Moreover, within market-driven design processes, optimization frequently evolves into a mechanism for minimizing costs and maximizing usable floor area. Rather than fostering empathetic environments that respond to the psychological and emotional needs of their occupants, such an approach risks producing spaces that are technically efficient and economically profitable, yet sterile, repetitive, and ultimately devoid of character and human warmth.

- Standardization and the loss of *Genius Loci*

Digital processes, by facilitating the replication of design patterns, may contribute to the homogenization of architecture. When the optimization of building form is delegated to evolutionary algorithms (whose primary objectives are, for example, the maximization of usable floor area or the minimization of energy consumption and construction costs), architectural values that resist quantification inevitably become marginalized. These include local identity (*genius loci*), proportions defined through human visual judgment, and the craftsmanship embodied in architectural detail. As a consequence, digitally optimized environments may achieve high levels of technical performance while simultaneously losing the cultural specificity and experiential richness that distinguish meaningful places.

- Hyper-rationality vs. aesthetics

Architecture conceived exclusively through the lens of performance (performance-driven design[2]) frequently exhibits a deficit in both aesthetic and humanistic qualities. Feelings of safety, comfort, and intimacy cannot be reduced solely to objectively optimized environmental parameters, such as illuminance measured in lux. On the contrary, subtle imperfections, asymmetry, material weathering, and the tactile qualities of natural materials often foster a profound emotional attachment between the user and the place. Although contemporary digital technologies are increasingly capable of simulating the appearance and behavior of natural environments, they continue to struggle with generating the authentic haptic dimension of architecture – that quality which Juhani Pallasmaa famously describes through the metaphor of the 'eyes of the skin'[3].

4. TECHNOLOGY IN THE SERVICE OF HUMAN EXPERIENCE

Traditionally, empathy in architectural design has been grounded in a triad consisting of the designer's subjective intuition, accumulated professional experience, and the established principles of environmental psychology. For decades, architectural practice required the unique ability to mentally translate two-dimensional technical drawings into multidimensional, multisensory spatial experiences. Architects were expected to anticipate how the human

[2] R. Oxman *Performance-Based Design: Current Practices and Research Issues*, "International Journal of Architectural Computing" 2008, no. 6(1), pp. 1–17.

[3] J. Pallasmaa, *The Eyes of the Skin. Architecture and the Senses* (3rd ed.), Wiley, Chichester 2012.

body would respond to volumetric form, how light would interact with the texture of a wall, and how the configuration of spatial boundaries would influence occupants' perceptions of privacy, intimacy, and safety. Although this process often produced works of remarkable poetic and architectural value, it inevitably remained susceptible to cognitive bias, while its validity could only be verified after the building had been completed and occupied.

The contemporary technological paradigm does not invalidate this humanistic foundation; rather, it fundamentally redefines and extends it. Intuitive assumptions are increasingly replaced – or substantially supported – by advanced computational simulations that enable comprehensive and dynamic analyses of the interactions between humans, space, and the environment during the pre-construction phase, long before the first foundations are laid or construction capital is committed.

This new phase of architectural design shifts the emphasis from the geometry of the building itself toward its sensory and behavioral performance. Digital technologies function as a form of 'prosthetic empathy', providing architects with access to physical phenomena and cognitive processes that remain imperceptible to direct human observation. Such tools make it possible to translate abstract and difficult-to-measure concepts – including the atmosphere of a place, coziness, and psychophysical comfort – into rigorously parameterized datasets. Paradoxically, the mathematical precision of computational modeling begins to serve the objective assessment and preservation of those architectural qualities that fundamentally determine human well-being and foster emotional attachment to the built environment.

4.1. MODELING ATMOSPHERE AND HUMAN COMFORT

Contemporary digital technologies enable the precise modeling of physical factors that directly influence human well-being. Advanced simulation tools facilitate the optimization of the following aspects:

- Daylight and shading: computational daylight simulations enable precise analysis of solar movement, luminance distribution, and glare within interior spaces. These factors play a fundamental role in regulating circadian rhythms, melatonin production, and the overall psychological well-being of occupants[4]. Advanced metrics such as Spatial Daylight Autonomy (SDA)[5] and Annual Sunlight Exposure (ASE) [6] support the design of interiors that maximize access to natural daylight while minimizing the risks of overheating and visual discomfort.
- Acoustics: acoustic ray-tracing simulations facilitate the reduction of noise and the deliberate shaping of the desired soundscape[7]. This is particularly critical in office buildings, educational facilities, and healthcare environments, where reverberation time has a direct impact on concentration, fatigue, communication efficiency, and patient recovery.

[4] M. Andersen, *Unweaving the human response in daylighting design*, "Building and Environment" 2015, no. 91, pp. 101–117.

[5] S.V. Ershov et al., *Effective Simulation of Spatial Daylight Autonomy and Annual Sunlight Exposure*, [in:] *Conference: 32nd International Conference on Computer Graphics and Vision*, Ryazan 2022, pp. 64–72.

[6] B. Abboushi, *The Case for Multicriteria Annual Sunlight Exposure Guidelines*, [in:] *Building Performance Analysis Conference and SimBuild*, Chicago 2020, pp. 358–365.

[7] S. Bernat, *Wokół pojęcia soundscape. Dyskusja terminologiczna* [*Around the term soundscape. Terminological discussion*], "Prace Komisji Krajobrazu Kulturowego" 2015, no. 30, pp. 45–57.

- Microclimate and building services: the modeling of Mechanical, Electrical, and Plumbing (MEP) systems together with Heating, Ventilation, and Air Conditioning (HVAC) systems enables the creation of environments that are physiologically and sensorially comfortable. Such analyses contribute to preventing Sick Building Syndrome (SBS)[8] by optimizing indoor temperature, humidity, air quality, and ventilation performance.
- Pedestrian Wind Comfort[9]: urban-scale computational fluid dynamics (CFD) simulations evaluate wind behavior around buildings, supporting the design of safe and comfortable public spaces. These analyses help eliminate hazardous downdrafts, wind tunnels, and other aerodynamic phenomena that discourage outdoor activity.
- Visibility analyses (Isovists[10] and Visual Comfort): digital mapping of visual fields, compositional axes, and degrees of spatial openness from the human perspective facilitates the optimal placement of glazing and viewpoints, thereby strengthening visual connections with the surrounding landscape and vegetation in accordance with the principles of biophilic design.
- Behavioral and evacuation simulations (Crowd Simulation[11]): algorithmic modeling of pedestrian movement under both everyday and emergency conditions enables the optimization of circulation systems, the reduction of congestion, and the enhancement of users' intuitive perception of spatial safety.
- Life Cycle Assessment (LCA): databases integrated with BIM models enable the automatic calculation of the environmental impacts associated with construction materials throughout their entire life cycle. Such analyses support environmentally responsible design decisions and may be regarded as an expression of empathy on a macro scale – toward future generations and the global environment.

At this point, digital optimization reveals another dimension of its operation – one governed primarily by economic rationality. In seeking an optimal balance between environmental performance and investment costs, algorithms increasingly become instruments of rigorous cost minimization. Structural and material simulations may demonstrate that a particular architectural component – for example, an ornamental arcade, a structural cantilever, or a purely expressive architectural detail – generates unnecessary construction costs due to increased material consumption. As a consequence, such elements are frequently eliminated during the digital optimization process solely on the basis of quantitative calculations.

A similar process of reduction may affect the sensory qualities of architecture. Cost analyses integrated within BIM environments facilitate the substitution of high-quality finishing materials with less expensive alternatives. Durable, textured, and tactile materials such as clinker brick – which significantly contribute to haptic perception and strengthen the user's sense of place – are often replaced with standardized thin-coat plaster systems. From the perspective of computational optimization, such substitutions produce immediate

[8] T. Wittczak, J. Walusiak-Skorupa, C. Pałczyński, *„Sick building sydrome" – nowy problem w medycynie pracy*, "Medycyna Pracy" 2001, no. 52(5), pp. 369–373.

[9] R. Gnatowska, *Dobór kryteriów oceny komfortu wiatrowego pieszych*, "Budownictwo i Architektura" 2011, no. 8(1), pp. 5–13.

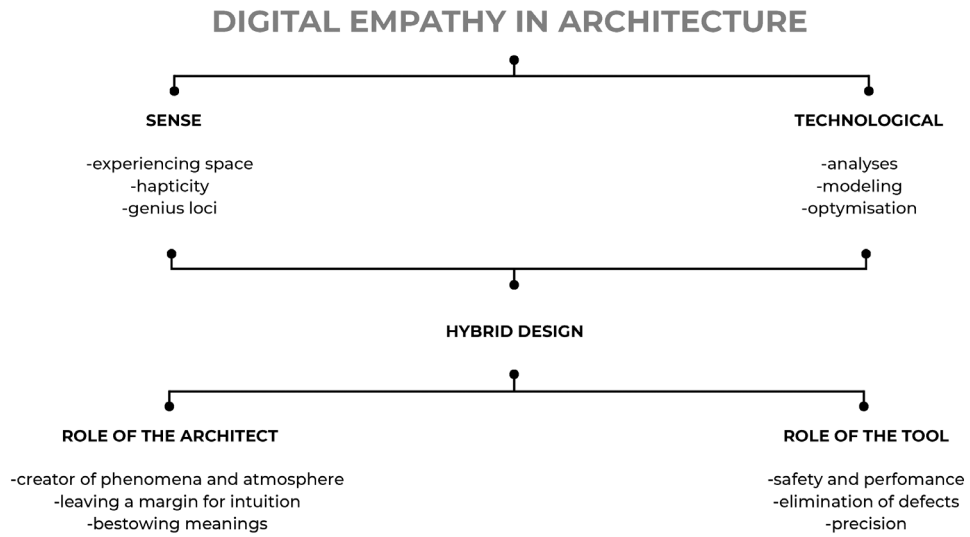
[10] M.L. Benedikt, *To Take Hold of Space: Isovists and Isovist Fields*, "Environment and Planning B" 1979, no. 6(1) pp. 47–65.

[11] M.-L. Xu et al., *Crowd Simulation and Its Applications: Recent Advances*, "Journal of Computer Science and Technology" 2014, no. 29(5), pp. 799–811.

and measurable financial savings. From the perspective of architectural experience, however, they substantially diminish aesthetic quality, erode the individuality of the building, and impoverish the multisensory experience of space.

5. TOWARD HYBRID DESIGN

A response to the profound dichotomy between mathematically driven, rational technologies and the subjective, multisensory nature of human experience is offered by the paradigm of hybrid design. Rather than rejecting advanced digital tools, this approach seeks their dialectical integration with a humanistic understanding of architecture. Such a paradigm, however, requires a fundamental redefinition of the architect's role. It calls for a departure from the position of a passive software operator or an unquestioning executor of algorithmic instructions. Instead, the architect must once again assume the role of a creator of spatial phenomena and a curator of human experience. Within this framework, parametric scripts, numerical simulations, and predictive models regain their proper status as analytical instruments and intellectual resources rather than autonomous decision-making mechanisms determining the form of the built environment.



Ill. 1. The diagram above structures the concepts in the form of a logical tree. It illustrates how the intersection of technology and humanism engenders a new quality

The implementation of digital empathy in everyday architectural practice therefore requires the conscious and critical application of data-driven design[12] methodologies. Information derived from environmental simulations, behavioral analyses, and neuroarchitectural

[12] J.C. Quiñones-Gómez, E. Mor, J. Chacón, *Data-Driven Design in the Design Process: A Systematic Literature Review on Challenges and Opportunities*, "International Journal of Human-Computer Interaction" 2024, no. 41(9), pp. 1–26.

research should serve as a precise representation of human needs and enable architects to identify and eliminate functional deficiencies, lighting-related shortcomings, and spatial pathologies at the earliest conceptual stages of the design process.

The true identity of architecture emerges precisely where the mathematical predictability of computational models reaches its limits. The hybrid approach therefore assumes that a deliberate space must be preserved for those dimensions of architecture that cannot be quantified: creative intuition, the poetics of space, the expressive value of imperfection, and the inherent unpredictability of human behavior and emotion. While algorithms are capable of optimizing structural performance and environmental efficiency, they remain incapable of designing nostalgia, melancholy, or the sense of transcendent wonder that architecture can evoke. Hybrid design should therefore be understood as an alliance between technology and humanism, in which digital tools ensure safety, environmental performance, and technical efficiency, while the architect – through the exercise of creative empathy – imbues the built environment with meaning, cultural identity, and emotional depth.

6. CONCLUSION

Digital technologies have fundamentally transformed the ways in which the built environment is designed, evaluated, and experienced. Simulation tools and immersive digital environments provide unprecedented opportunities for shaping architectural atmosphere and enhancing the psychophysical well-being of occupants. In this context, they may be understood as instruments of *digital empathy*, enabling designers to anticipate and engage with the perceptual experience of future users.

Nevertheless, reducing architectural design to purely algorithmic processes entails the risk of producing environments that are technically efficient yet devoid of emotional depth, cultural identity, and experiential richness. The true quality of architecture emerges at the intersection of technological precision and humanistic sensitivity. Ultimately, the future of architectural practice will depend not only on the continued advancement of digital technologies but also on our ability to develop and employ them in ways that respond to human beings not merely as physical organisms but as embodied, emotional, and meaning-making individuals.

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