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# CAN ARCHITECTURE BE 11-DIMENSIONAL? THE NATURE OF SPACE IN THE ARCHITECTURE OF THE DIGITAL WORLD ERA

**Abstract**

This research aims to explore the development of architectural theories about 'architectural dimensions' and look at architecture as a multidimensional space. It is important to understand that with today's development of virtual reality technology and through the combination of theories of physics and architecture, a new possibility of creating space has emerged. The arguments are made through inductive reasoning and grounded theory approach. According to the M-theory (one of the contemporaneous leading physics theories), physics suggests a world with 11 dimensions. A question could be asked in this way that should architecture be perceived whether as subjective or objective? Therefore, the theoretical arguments have been focused on three parameters of 'Subjectivity', 'Time', and 'Reality'. These parameters are the joint integration of the theories in architecture and quantum physics about dimensions. This representation is justified by the demonstration of identical theoretical attributes that are manifested both in the continuum of 'quantum architecture' and 'quantum realm'. On this basis, the dimensions counted for the status quo of architecture would be 1. 'Physical and Virtual Creatress of Space' (Physical/Virtual depth, edge, and ceiling height) or a space of mixed reality (real world merged with virtual reality); 2. 'Active Architecture' (corporation of Relative and External time in the creation of Physical/Virtual Dynamism); and 3. 'Smart Engagement of Experiential Dimensions' (interactive mental, sensorial, and corporeal engagements based on local and non-local realities). These three factors account for 'Reality', 'Time', and 'Subjectivity', respectively. In the end, 'Eleven-Dimensional Architecture' would be introduced. Examples of this kind of architecture could be found in smart architecture with mixed reality settings.

**Keywords:** Architecture Dimensions, Physics Dimensions, Virtual Dimensions, Theory of Architecture, Mixed-Reality.

# CZY ARCHITEKTURA MOŻE BYĆ 11-WYMIAROWA? CHARAKTER PRZESTRZENI W ARCHITEKTURZE CYFROWEGO ŚWIATA

**Streszczenie**

Artykuł ma na celu zbadanie rozwoju teorii architektonicznych na temat „wymiarów architektonicznych" i spojrzenie na architekturę jako wielowymiarową przestrzeń. Wraz z dzisiejszym rozwojem technologii, w tym wirtualnej rzeczywistości oraz poprzez połączenie teorii fizyki i architektury, pojawiła się nowa możliwość

rozumienia przestrzeni. W artykule przedstawiono ciąg myślowy w oparciu o rozumowanie indukcyjne i zastosowanie metodologii teorii ugruntowanej. Zgodnie z teorią M (jedną z współczesnych wiodących teorii fizyki), fizyka sugeruje świat o 11 wymiarach. Można by w ten sposób zadać pytanie, czy architekturę należy postrzegać jako subiektywną czy obiektywną? Na tej podstawie argumenty teoretyczne koncentrowały się na trzech parametrach „Subiektywności", „Czasu" i „Rzeczywistości". Parametry te są wspólne dla teorii architektury i fizyki kwantowej na temat wymiarów. Reprezentację tę uzasadnia wykazanie identycznych atrybutów teoretycznych, które przejawiają się zarówno w kontinuum „architektury kwantowej", jak i „przestrzeni kwantowej". Na tej podstawie, wymiarami liczonymi dla status quo architektury byłyby 1. „Fizyczne i wirtualne tworzenie przestrzeni" (głębokość fizyczna/wirtualna, krawędź i wysokość) lub przestrzeń rzeczywistości mieszanej (świat rzeczywisty połączony z rzeczywistością wirtualną); 2. „Architektura aktywna" (korporacja czasu względnego i zewnętrznego w tworzeniu dynamizmu fizycznego/wirtualnego); oraz 3. „Inteligentne zaangażowanie wymiarów empirycznych" (interaktywne zaangażowanie umysłowe, sensoryczne i cielesne w oparciu o lokalne i nielokalne realia). Te trzy czynniki odpowiadają odpowiednio za „Rzeczywistość", „Czas" i „Subiektywność". Na koniec zostałaby wprowadzona „architektura jedenastowymiarowa". Przykłady tego rodzaju architektury można znaleźć w architekturze inteligentnej z ustawieniami rzeczywistości mieszanej

**Słowa kluczowe:** wymiary architektury, wymiary fizyczne, wymiary wirtualne, architektura jedenastowymiarowa.

## Introduction

Architecture theatricians like Le Corbusier, and Charles Jencks were always seeking another expression to describe architecture to define our new desires according to the status quo of scientific discoveries. Contemporary architecture is gradually becoming a phenomenon that cannot be graspable with just the 4 dimensions explained in modern architecture. By the implementation of virtual reality in architecture to create an architecture of mixed-reality[1], and artificial intelligence sensors employed by smart architecture[2], new dimensions are added to the 4-dimensional architecture. In addition, new inventions have been made to facilitate the use of virtual reality even more than before and towards an ultimate experience of mixed reality[3]. Yet there is a need for identification

[1] Ahn K., Ko D. S., & Gim S. H., *A study on the architecture of mixed reality application for architectural design collaboration*, In International Conference on Applied Computing and Information Technology, Springer Cham pp. 48–61.

[2] Marikyan D., Papagiannidis S., & Alamanos E., *A systematic review of the smart home literature: A user perspective*, " Technological Forecasting and Social Change", 2019, pp. 138, 139–154.

[3] Kress B. C., & Cummings W. J., 11-1: Invited paper: Towards the ultimate mixed reality experience: HoloLens display architecture choices, In SID symposium digest of technical papers, 2007, Vol. 48, No. 1, pp. 127–131.

and justification of these new emerging dimensions in architecture. This worldview has already started in the late 90s with the Jencks' expression that "form follows worldview"[4]. In his book, *The Architecture of the Jumping Universe* Charles Jencks the architectural critic has stated that the new architecture stems from our new worldview and it adequately reflects this worldview based on the self-organizing and open-ended universe[5]. Based on the modern definitions of the universe that were coined by Einstein, Hinesburg, Edward Lorenz, Bennett Mandelbrot in their theories of *Relativity*, *Uncertainty Relation*, *Butterfly Effect*, and *Mathematics of Roughness*, respectively, our new worldview has shaped. They all imply a more degree of uncertainty, subjectivity, and relativity that shares the most with the new architecture defined by smart mixed reality technology.

Even Semiotics analysis, which highly contributes to forming our understanding of the surrounding world, has always had a major impact on architecture. Claude Lévi-Strauss's structuralism theory led to constructivism in architecture. So as Jacques Derrida's deconstructivism approach toward semiotics. Relative to semiotics and quantum visions, Roth[6] in his article entitled *Quantum Vision in three Dimensions* expresses that in conceiving an image, one would correspond to his own interpretation rather than an 'objective unique encryption'. "One can notice that the 'B' letter in the farewell word '|3ye' can be interpreted into a number if we insert it in the series of numbers |3, |4, |5"[7]. Similarly, in the perception of depth, Roth[8] proposes four models using quantum mechanics formalisms that deceive the brain to have the illusion of depth. It is like a 3d object appearing in a mirror reflection.

Physicists have always tried to demonstrate their findings and problems with geometry to clarify them both for themselves and audiences. The relationship between geometry and physics became more necessary and prominent by the introduction of the theory of relativity and explanations of time dimension until today. Physical dimensions, therefore, are the manifestations of geometry in physics. The subject of discussion in this research is this kind of manifestation because it is the point where physics and geometry merge the most with architecture. To some extent, this relationship becomes more artistic as astrophysicist Paul M. Sutter emphasizes: there are artistic and human aspects of the scientific process.

In architectural theory, in an essay about *The Essence of Architectural Creation*, Schmarsow's explanations about 'creatress of space' introduce spatial dimensions in architecture and the axis of depth to measure our free movement. After-

[4] Jencks C., *The architecture of the jumping universe: A polemic: How complexity science is changing architecture and culture*, Academy Editions, London 1997.
[5] Ibidem, p. 14
[6] Roth Y., *Quantum vision in three dimensions. Results in physics*, 2017, *7*, 4101–4103.
[7] Ibidem.
[8] Ibidem.

ward, the influence of the dimension of time on architecture was coined by Van Doesburg via the introduction of 'De Stijl' in 1924[9] which later was practiced in the Cubism movement perfectly. Eventually, we could witness the influence of the theory of relativity on architecture that was perfectly practiced in the Expressionist movement by the work of Erich Mendelsohn. The goal of this research is to explore the above-mentioned relationship whether in theories of physics, geometry, or architecture to set forth theories of physical dimensions in architecture begun from Vitruvius and peaked in the 20th century by the introduction of the dimension of time and relativity theory in architecture. The body of this article is articulated around the subjects of space and architecture to enrich our inner logic of the built space in the era of the digital world.

"Quantum theory, as the most precise explanation of our physical world, has not only triggered a tremendous technical improvement but has also introduced a revolutionary quantum world view that considers the material world as a non-deterministic construct, deciphered with probability and interactivity… From this point of view, true interaction can be envisioned between users and their constructed environments, and between designers and their computational tools[10]."

If an interpretation for the last quotation is to be made, it could be figured out that for a new architecture in the era of quantum physics, both 'architectural representation' (that is the interaction between designer and their tool) and the 'experience of architecture' (that is the interaction of users with their constructed environment) are mixed with an ever-shifting existence or experience. Since the three parameters of 'Subjectivity', 'Time', and 'Reality' are the joint integration of the theories in architecture and quantum physics about dimensions, this ever-shifting existence, and experience of architecture is depicted in Figure 1. Figure 1 is also a timeline to depict the architectural theory backgrounds for defining the new contemporary architecture. Virtual dimensions (synthetic built environment) and subjective dimensions (mental, corporeal, and sensorial engagement with the environment) will endow architecture with an ever-changing quality. It is because these two sets of dimensions are non-deterministic by nature. As it is defined by multiple resources, "the main goal of Mixed Reality is the creation of a big space by merging real and virtual environments wherein real and virtual objects coexist and interact in real-time for user scenarios"[11]. These scenarios are what has been referred to as a subjective attribute of architecture while the existence of the virtual objects is a paradox for this subjectivity. The same paradox also existed between the theory of relativity and quantum theory as it was first introduced. To solve this paradox, research has been done. To fill the gap be-

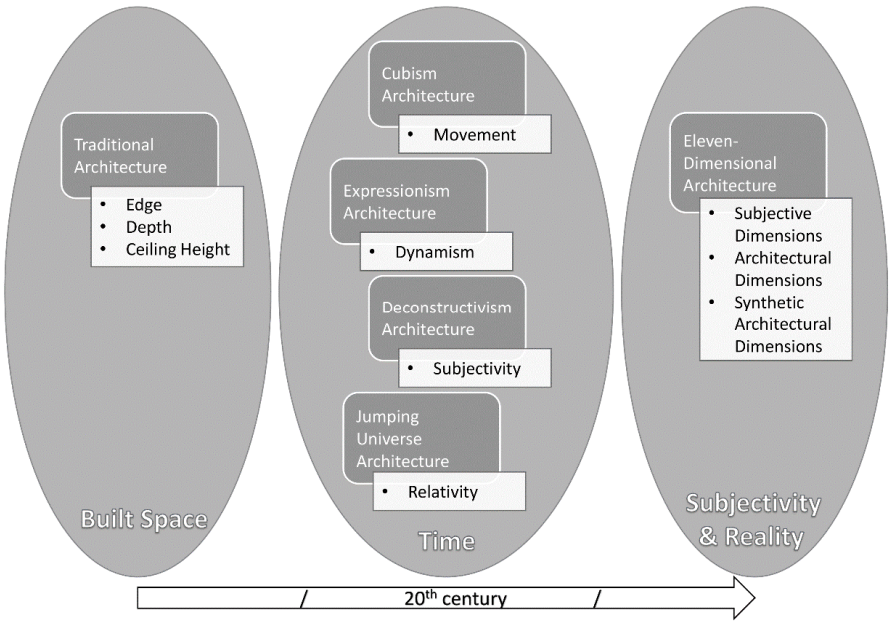
[9] Berrett J., and Marquardt V., *The Fourth Dimension and Non-Euclidean Geometry in Modern Art by Linda Dalrymple Henderson*, "Technology and Culture", 1985, Vol. 26, No. 4, Oct., 1985, pp. 879–882.

[10] Redi I., *Quantum Architecture*, 2010. Retrieved from: http://ivanredi.com/quantum-architecture/ [Access: 12.12.2021].

[11] Rokhsaritalemi, S., Sadeghi-Niaraki, A., & Choi, S. M. (2020). *A review on mixed reality: Current trends, challenges, and prospects*. *Applied Sciences*, 10(2), 636.

tween reality and prediction, microclimates have been proposed to associate the relative atmosphere in the mixed reality setting[12].

**Figure 1.** The hypothesis of the research: application of the notion of dimensions in architecture.




Source: Own study.

In their book 'Disappearing Architecture: From Real to Virtual to Quantum', authors refer to Cyberpunk fiction to account for the relationship between Real, Virtual, and Quantum in architecture[13]. They later make a discussion about 'large scale instruments of displacement' or environments with Mixed reality. An architecture of existence or non-existence, on or off, and real or virtual. A duality that makes the explorer conceive the built space and form as 'quantum objects'. William J. Mitchell points out that these instruments of temporal displacement "embed the virtual in the physical and weave it seamlessly into daily urban life"[14]. Established on these conceptions, in table 1, the relationship of quantum, virtual, and real realms are explained through a grounded theory analysis. The argument in this table is charted based on three factors of subjectivity, time, and reality. The main objective of the table is to metaphorically

[12] Latifi M., Burry J., & Prohasky D., *Make the Invisible Microclimate Visible: Mixed Reality (MR) Applications for Architecture and Built Environment* [In:] *Design Modelling Symposium Berlin,* Springer, Cham 2019, pp. 325–335.
[13] Flachbart G., and Weibel P., *Disappearing Architecture from Real to Virtual to Quantum*, Springer Science & Business Media, Berlin/Heidelberg 2005, p. 15.
[14] Ibidem, p. 20.

integrate the paradigms in the discussed worlds. The reason why these three factors are the main contributors to the argument will be explained in the following sections.

**Table 1.** Primary codes and memos are based on the notions of relativity, reality, and objectivity.

| Row | Data source | Codes | Memos |
|---|---|---|---|
| 1 | Quantum World | **Objective reality**<br>"In quantum mechanics, time is understood as an external concept[15]" | **Quantum dimensions:**<br>• "Quantum world is objective but objectless"[16]<br>• Entanglement allows quantum teleportation[17], time travel, and offers different realities[18]<br>• Based on the String Theory, the universe incorporates spatial compacted dimensions that are dynamic[19]. |
| 2 | Virtual (Digital) World | **Objective reality**<br>Reality is rendered and the passage of time is disturbed. therefore, time is completely subject to the designer's mind and independent of the user. Therefore, it is absolute | **Virtual dimensions:**<br>• Virtual reality is objective and objectless<br>• Simulation of varying and different times is made possible by Virtual Reality, thus time is objective<br>• Dimensions could be altered and are not static |
| 3 | Real (Physical) World | **Subjective reality**<br>The theoretical physicist Carlo Rovelli posits that time is illusionary[20]. Einstein proposes a relative time rather than an absolute one | **Spatial dimensions:**<br>• Real world is subjective to the observer<br>• Subjectivity of the real realm is derived from human mental and sensational engagement while objectivity is an attribution of the physical dimensions of the surrounding in the space-time continuum |

Source: Own Study.

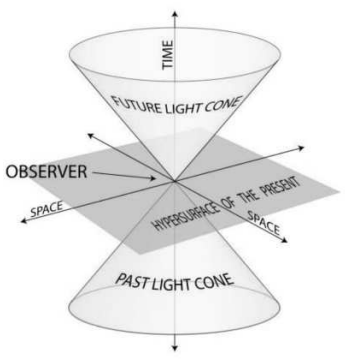
[15] Zeh H.D., Time in Quantum Theory., [in:] Greenberger D., Hentschel K., Weinert F. (eds), Compendium of Quantum Physics, Springer, Berlin/Heidelberg 2009, p. 786.
[16] Herbert N., Quantum Reality: Beyond the New Physics, Anchor Books, Random House, Inc., New York 1985, p.145.
[17] Dunningham J. and Vedral V., Introductory Quantum Physics and Relativity (Second Edition), World Scientific Publishing Company, Singapore; Hackensack, NJ 2018, p. 237.
[18] Arntzenius F., and Maudlin T., Time Travel and Modern Physics, [in:] *The Stanford Encyclopedia of Philosophy* (Winter 2013 Edition), Edward N. Zalta (ed.) 2013. https://plato.stanford.edu/archives/win2013/entries/time-travel-phys/ [Access: 12.12.2021].
[19] Jensen S., An Introduction to String Theory, 2004. Retrieved from: http://www.slimy.com/~steuard/research/StringIntro/index.html#outline [Access: 12.12.2021].
[20] Jaffe A., The Illusion of Time, Mac Millan Publishers Limited, part of Springer Nature, 1985, vol 556, pp. 304-305. Retrieved from: https://media.nature.com/original/magazine-assets/d41586-018-04558-7/d41586-018-04558-7.pdf [Access: 12.12.2021].

After analyzing the codes and memos listed in the table, it would be suggested that to define architecture in the era of quantum mechanics, the real environment should be integrated with a virtual one that shares many attributes with the quantum environment. “The real frontier of integration between real and virtual world is probably in breaking the barrier with physical reality, and with the ambition to also recover sensorial and corporeal dimensions”. In a space mixed with digital dimensions, virtual space is perceived as real, but it is not haptic. This attribute is the most common parameter of correspondence in the nature of quantum and virtual worlds. Other similarities in quantum and virtual worlds, as are addressed in table (1), are the objectivity of time and the dynamic nature of dimensions. Before jumping to conclusions, it seems necessary to explain the notions of dimensions in both physics and architecture contexts.

## 1. The Dimension of Time in Architecture

Humans are molded by the 3 spatial dimensions which define any physical form and space (width, height, and length), and we have measured any object or space using them. Einstein added a fourth dimension to these physical dimensions that are in past and future directions, and Christopher Nolan in the movie ‘Interstellar’ has demonstrated this vector in a virtual environment (Figure 2). The subjectivity of the depicted place (a library) in this scene of the movie, is because the main protagonist has found himself immersed in the 4D environment in terms of all three factors of corporeal, sensorial, and mental dimensions. That is because the place has appeared as the timeline of a memorial place for the explorer (in this case it is a library).

**Figure 2.** (a) The dimension of time as a perpendicular vector on 3D space. (b) Tesseract: 3D demonstration of 4D in the movie ‘Interstellar’.

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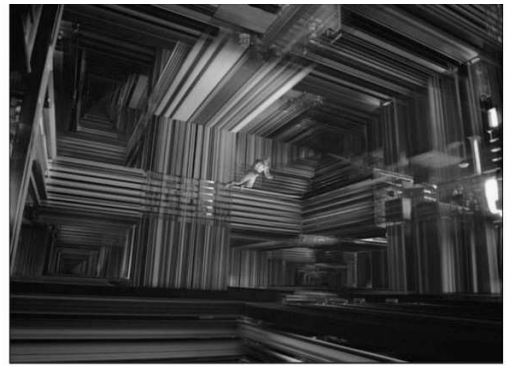

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Source a: https://www.universetoday.com/12563/will-time-be-replaced-by-another-space-dimension/ [Access: 20.12.2021].
Source b: https://interstellarfilm.fandom.com/wiki/Tesseract
[Access: 20.12.2021]

While physics introduced time as the fourth dimension, architects and theoreticians defined notions regarding movement and non-Euclidean geometry to get architectural theory coped with this newly discovered physical reality. "It is clear that in architecture we find the most tangible evidence for the influence of the fourth dimension and non-Euclidean geometry"[21].

Einstein added the vector of 'Time' as the fourth dimension to the three-dimensional space. Based on Bodish's explanations about this vector, in perceiving time, we have only a sense of its presence. Bodish explains that: "Due to our being stuck in three-dimensional space, we cannot visualize a fourth-dimensional coordinate system, or what an object in the fourth-dimension would look like"[22]. As an artistic attempt to visualize the fourth dimension, Cubism then absorbs our attention. "Construction of all the three-dimensional states of the four-dimensional figure"[23] is a method of manifesting time in architecture employed by Cubist artists.

Therefore, one way of considering time and, thus, movement in architecture is by creating different facets in the form that are in contrast with symmetrical facets of form in classical architecture. Besides cubist artists and architects, it was Mendelsohn's work in Einstein's tower that introduced another feature of time vector in architecture: these attributions were 'Dynamic Spirit' or 'Aerodynamic Form' by 'curvilinear non-Euclidean form, curved windows, and lack of frontality'[24]. It further has been referred to as "Immobile Motion" by Arnheim[25]. On this basis, Ahmadi has counted the attribute of architectural dynamism in relation to time under the category of perception[26].

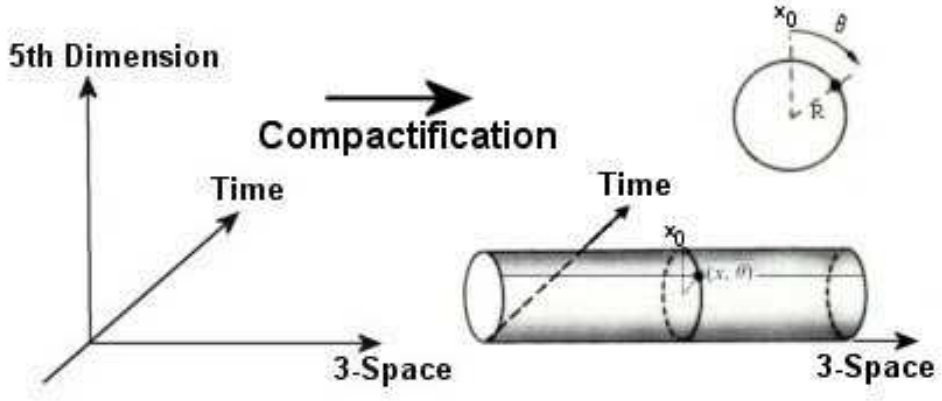
## 2. Superstring theories: Dimensions Beyond Space-Time (3+1)

After recognizing time as a dimension, plenty of scientists tried to answer the questions in quantum mechanics and they concluded that to answer possible questions arising from this realm, the existence of other dimensions is required. The first endeavor in this area was the Kaluza-Klein theory. Kaluza's 5th dimension, which was supposed to explain the possibility of unified gravity with elec-

[21] Berrett J., and Marquardt V., op.cit.
[22] Bodish E., Cubism and the fourth dimension, "The Mathematics Enthusiast", 2009, 6(3), pp 527–560.
[23] Ibidem.
[24] Hart V., *Erich Mendelsohn and the fourth dimension*, "Architectural Research Quarterly", 1995, 1, pp 50–59.
[25] Arnheim R., *Art and visual perception: A psychology of the creative eye. 50th anniversary printing*, Berkeley, CA, University of California Press, California 2004, p. 423.
[26] Ahmadi M., *The experience of movement in the built form and space: A framework for movement evaluation in architecture*, "Cogent Arts & Humanities", 2019, 6: 1588090. https://doi.org/10.1080/23311983.2019.1588090 [Access: 12.12.2021].

tromagnetism, was endorsed by Einstein. This new dimension was illustrated by 'cylindricity' and 'compactification' which are currently obsolete[27] (Figure 3).

**Figure 3**. Kaluza-Klein's model of the fifth dimension.




Source: https://archive.briankoberlein.com/2014/10/19/radion-days/index.html [Access: 12.12.2021].

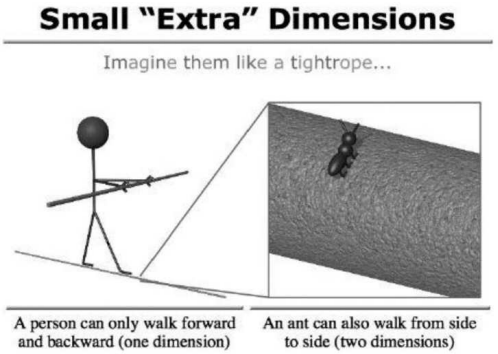
In the next step, rapidly changing Superstring theories were a quest to unify quantum mechanics and general relativity proposed that at the most fundamental level, matter and energy consist of tiny and vibrating strings rather than particles[28]. Therefore, the universe is composed of three spatial dimensions (infinitely large dimensions), time, and extra small dimensions wrapped and compacted (in a manifold or space with unique properties which were supersymmetry and mirror symmetry) (Figure 4b) that makes them invisible to the view[29]. In *An Introduction to String Theory*[30], Jensen explains that given the current experiments, it is possible that even there is an extra dimension within almost one millimeter, and the cause that we cannot perceive it is because it is 'compacted' or 'finite' (Figure 4a). According to Becker et al. (2006), there are five superstring theories that each of which is in 10 dimensions[31].

M-theory unifies the five superstring theories by growing the eleventh dimension[32]. Michio Kaku, a world-renowned American physicist, in M-theory[33] ex-

[27] Wesson Paul S., *Space-time-matter: Modern Kaluza-Klein Theory*, World Scientific Publishing Co. Pte. Ltd., Singapore 1999, p. 28.
[28] Becker K., Becker M., & Schwarz J. H., *String theory and M-theory: A modern introduction*, Cambridge university press 2006, p. 2.
[29] Yau S.T. & Nadis S., *The Shape of a Life: One Mathematician's Search for the Universe's Hidden*, Yale University Press, Connecticut 2019, pp. 186–187.
[30] Jensen, op.cit.
[31] Becker K., Becker M., & Schwarz, J. H., op.cit., p. 9.
[32] Ibidem, p. 11.

plains that the universe has 11th dimensions as a characteristic of space-time, and beyond 11 dimensions a universe could not be stable[34]. Therefore, in this paper, we take M-theory as a reference for a world of 11 dimensions.

**Figure 4.** (a) Small Extra dimensions. (b) Calabi–Yau manifold: 2D demonstration of extra dimensions.

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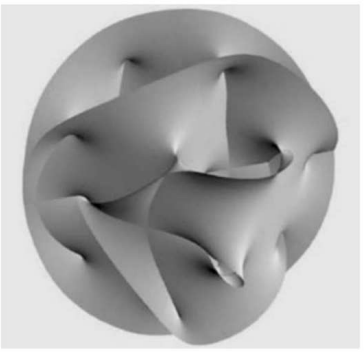

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Source a: http://www.slimy.com/~steuard/research/StringIntro/slide09.html [Access: 20.12.2021].
Source b: https://phys.org/news/2014-12-universe-dimensions.html [Access: 20.12.2021].

There are subtle analogies between 'architecture mediated by virtual reality' and the folded physical dimensions in the realm of quantum physics. The reality in both is subjective to the individual observing them. In another expression, "the quantum world is objective but objectless"[35] like a rainbow. Or as Herbert describes: "No one sees (smells, feels) the same subjective apple, but everyone agrees that there is one objective apple that is the source of these varied sensations."[36]. In quantum reality, the mere act of observation alters reality. For getting a better clarification, take Young's double-slit experiment for example. In every trial, the outcome has been depended on whether the experiment has been observed or not. If the path of the photons of light is observed, then Young's interference pattern would disappear, but if the experiment would not be observed, then the light would create a wave pattern on the detecting

[33] Kaku, M., *Introduction to superstrings and M-theory*. Springer Science & Business Media, 2018.
[34] Big Think *Michio Kaku: The Multiverse Has 11 Dimensions* [Video file], 2011, May 31. Retrieved from: https://www.youtube.com/watch?v=jI50HN0Kshg [Access: 12.12.2021].
[35] Herbert N., *Quantum Reality: Beyond the New Physics*, Anchor Books, Random House, Inc., New York 1985. p. 145.
[36] Ibidem, p. 144.

screen[37]. This worldview is explained by Schrödinger's cat paradox which Schrödinger applied to everyday objects[38]. He later argues that while Einstein introduced locality (4-dimensional space-time-continuum), quantum dynamics by posing non-locality implies that: "besides living in a world in which space and time exist we also at the same time live in some dimensions in which space and time do not exist"[39]. All these facts would direct our mind towards a new definition of architecture that unites two different realms in a single installation.

Movies have always been a good visual example for explaining more tacit and implicatory notions. In the movie 'Inception' (Figure 5), the director of the movie has filmed a setting that depicts a virtual environment with subjective control of the protagonist on their surroundings. In this setting, it has been shown that how human dimension (mental engagement with the virtual environment) has tremendous effects on the form of the subjective reality of the virtual world. In other words, while the virtual world is objective, the presence of the protagonist could alter reality and thus making it a subjective realm.

**Figure 5.** Two cinematic scenes in the movie 'Inception' show the engagement of human dimensions with virtual dimensions in their mind and how this engagement could result in specific subjective effects. These virtual effects could be against the natural laws in the real world.

Source: Captured from the movie 'Inception 2010'.

Holy Trinity in the church of Santa Maria Novella in Florence could be noticed as a classical exemplar of a representation in architecture that masterfully manipulates reality and time by creating a classical virtuality through linear perspective which has been referred to as 'Masaccio's Illusionism'[40]. Not only it gives the

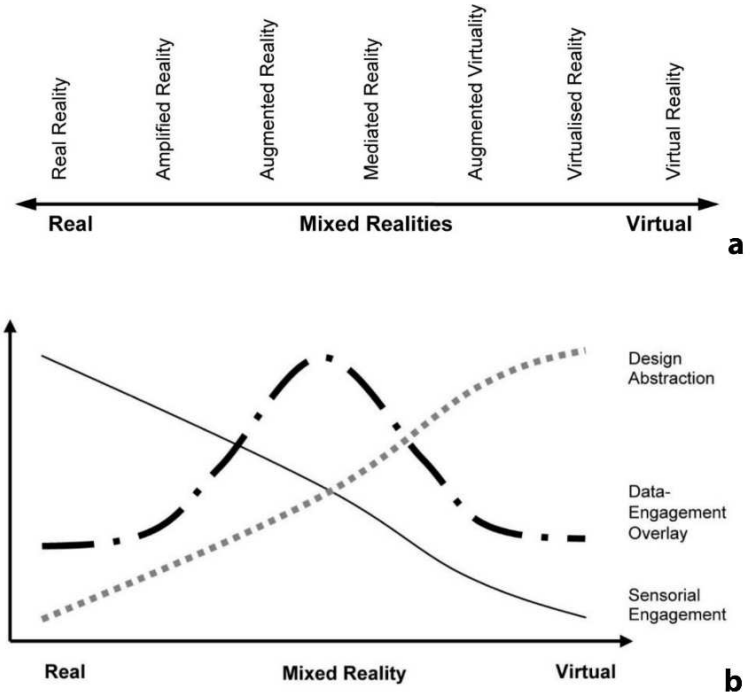
[37] Vallow K., and Micucci J. (Producers), & Druyan A., and Braga B. (Directors), *Cosmos: Possible Worlds* - Episode 9 (Television series), CA: Fuzzy Door Productions, Los Angeles 2020.
[38] Moser F., *Schrödinger's cat paradox and some other nice stories from science – what do they teach us?* "Computers & Chemical Engineering", 1994, volume 18, Supplement 1.
[39] Ibidem.
[40] Cheng S., *Masaccio's Illusionism*, 2012. Retrieved from: https://openlab.citytech.cuny.edu/arth11036415f2012/2012/10/22/masaccios-illusionism/ [Access: 12.12.2021].

spectator the virtue of time travel but also it has represented the illusion of a 3D room that is opposed to the real dimensions of the church.

## 3. Discussion

So far it is clear that the theories in physics have profound impressions on architecture theorists. By any breakthrough in the field of physics, a new work of architecture has got influence from it. In fact, architecture has always served physics as a tool for manifesting physics theories in an artistic way. Based on the explanations made above, metaphorically, the virtual dimensions in the mixed realities accompanied with human dimensions would, in a figural way, account for the quantum dimensions introduced by string theory. In another way, the implications in the continuum of reality in mixed reality (Figure 6) along with subjective presence would imply the inner logics of quantum dynamics.

**Figure 6.** Top: order of realities. Bottom: Depth of real and virtual realms.

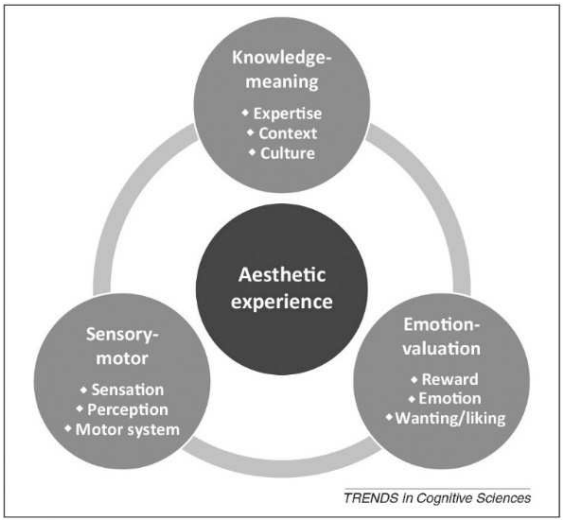



Source (a): Schnabel M.A., Wang X., Seichter H., Kvan T. (2007). *From virtuality to reality and back in*, "Proceedings of the 12th International Association of Societies of Design Research" (IASDR), Hong Kong 2007, pp. 12–15.

Source (b): Wang, X., Schnabel, M.A. (2009). *Mixed Reality in Architecture, Design, and Construction* (1st. ed.). Springer Publishing Company, Incorporated. ISBN: 978-1-4020-9087-5, P. 10.

One of the primary matters of study in quantum physics is light. The general theory of relativity explains that light travels in a curve trajectory around a massive object. In a study exploring space and light, Boyarsky (1992) explains that this is due to one of these causes: first, the beam of light itself bends, or second, the space is curved. The second cause, if true, suggests a completely different definition of space which was formerly supposed to be defined by the shape of other objects. A similar trend goes for architecture, too. In the classical theory of architecture and as explained by D. K. Ching in his book 'Architecture, Form, Space, and Order' the existence of built space is in the wake of creating a form[41]. Meanwhile, in the presented architectural theory in this paper, the environment of mixed reality, being objectless, acts as a space but not as a form. It is the same notion of space that Boyarsky points it. Digital design is objective while objectless and this is just the identical attribute of architecture with the quantum realm. In this metaphor, aesthetic experience (Figure 7) would be mediated by virtual reality and thus a part of small extra dimensions in the 'eleven-dimensional architecture'. The digital design which endows the built space with objectless reality is one way to imbed digital dimensions of architecture to create a virtual built space other than the real form and space. The experience created by this kind of architecture is both subjective and objective since the reality varies with different scenes at the same time.

**Figure 7.** The aesthetic triad.




Source: Chaterjee A. Vartanian O., *Neuroaesthetics*, "Trends in Cognitive Sciences", July 2014, Vol. 18, No. 7.

Based on the previous statements and shared theories, a correspondence between physical dimensions and architectural dimensions could be drawn as

[41] Ching F. D. K., *Architecture, form, space, and order* (4th ed.), John Wiley and sons, Hoboken 2014.

depicted in the table 2 (Table 2). Dimensions in physics are objective and apply to all objects and living things. This may also include living things that unlike us can grasp other dimensions. But architecture always remains human-centric and the subjectivity of dimensions in the realm of architecture has more weight. Lobell[42] explains that as architects, we should instill the reality of our era (which now is quantum reality) into our designs. He later puts it that the way we experience buildings is what we need to consider for quantum architecture:

"Our experience of our buildings, changes reflecting changes on our consciousness even before new materials and methods of construction come into play… and is constantly undergoing change" (Lobell, 2012).

**Table 2.** Dimensions of Architectural Experience in accordance with physical dimensions (The numbers from 1 to 11 are correspondent to the number of dimensions which have been explained throughout this article).

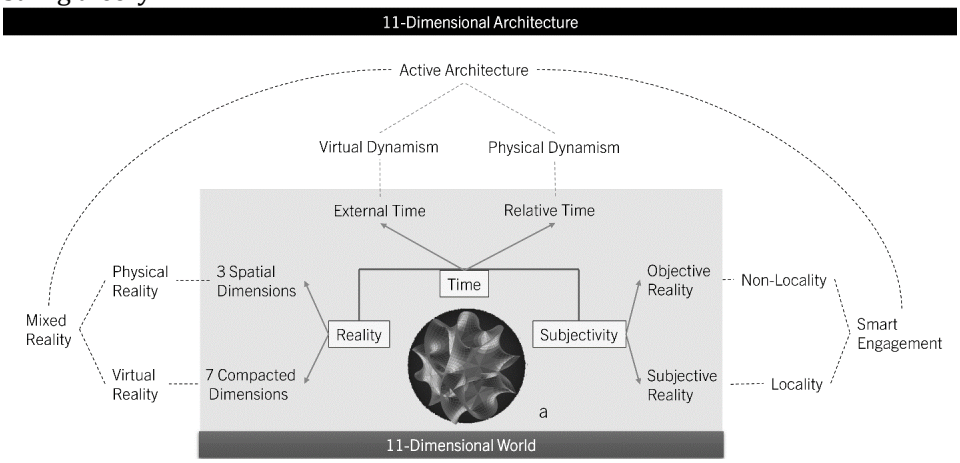
| **Physics Dimensions** | **Spatial Dimensions** | | Experience mediated by technology | **9-11.** Smart Design in the Mixed-Reality | **11-Dimensional Experience** | |
|---|---|---|---|---|---|---|
| **1.** Length | **1.** Depth | | | **9.** Interactive Motion Detecting Dimension | Smart Corporeal Engagement | |
| **2.** Width | **2.** Edge | | | | | |
| **3.** Height | **3.** Ceiling Height | | | | | |
| **4.** Time | **4.** Dynamism | | | | | |
| **5-11.** String Dimensions (7 compacted spatial dimensions) | **5-8.** Quantum Vision (Synthetic Dimensions) | **5.** Virtual Depth | | **10.** Interactive Sense Detecting Dimension | Smart Sensational Engagement (Sensory-Motor Experience) | Aesthetic & Semantic Experience |
| | | **6.** Virtual Edge | | | | |
| | | **7.** Virtual Height | | | (Emotion-Valuation) | |
| | | **8.** Virtual Dynamism | | **11.** Interactive Perceptive Dimension | Smart Mental Engagement (Knowledge-Meaning) | |

Source: Own study.

For further clarification, a graphical abstract has been created based on Table 1 and 2 (Figure 8). In this diagram, it is proposed that according to the metaphorical correspondence between architecture and quantum physics, architecture could be defined with the three attributes of Smart Engagement, Active Architecture, and Mixed Reality. The metaphorical correspondences are based on the philosophical and representational notions both in quantum & string theories and architectural theories. In addition, another graphical abstract depicts the hypothesis explained in Table 2 more clearly (Figure 9).

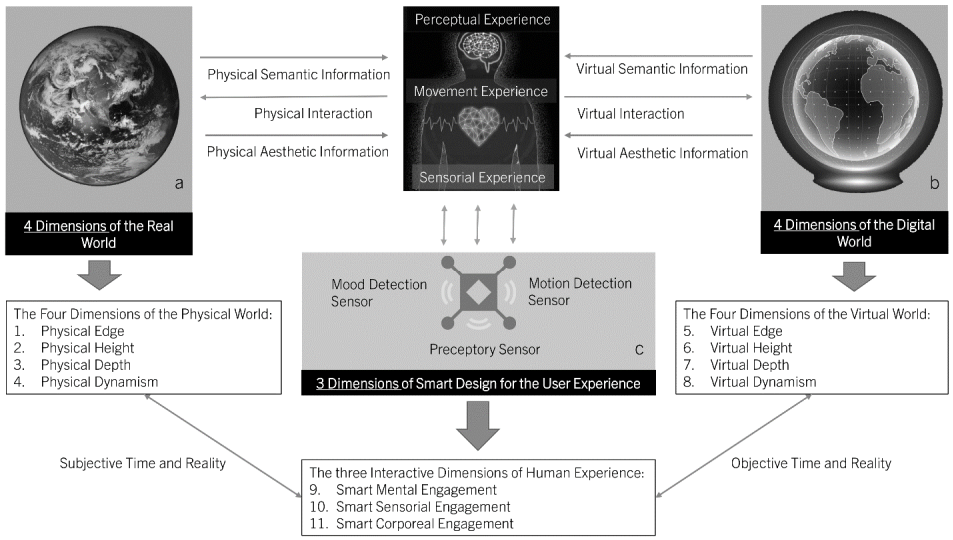
[42] Lobell J., *Quantum Theoretical Issues in Architecture: It's A Lot Stranger Than We Think*, 2012, Retrieved from: https://johnlobell.com/quantum-theoretical-issues-in-architecture-its-a-lot-stranger-than-we-think/ [Access: 12.12.2021].

**Figure 8.** The correspondence between the quantum world and eleven-dimensional architecture. The central shape (a) is the graphical representation of string theory.




Source: Own study.
Source shape a: https://www.physicsmindboggler.co/wp-content/uploads/2019/10/Hidden-Dimensions-e1509124680508.jpg [Access: 20.12.2021]

**Figure 9.** Graphical representation of Eleven-Dimensional Architecture.




Source: Authors
Source shape a: https://www.freevector.com/uploads/vector/preview/17997/FreeVector-FreeVector-Earth-Graphics.jpg [Access: 20.12.2021].
Source shape b: https://cdn5.vectorstock.com/i/1000x1000/37/69/hologra-phic-globe-with-continents-computer-vector-28523769.jpg
[Access: 20.12.2021].

## 4. Examples of Eleven-Dimensional Architecture

'Eleven Dimensional-Architecture' would be defined as an architectural endeavor to introduce 11 dimensions of M-Theory in architecture. To define an architectural typology for this notion at the present time, in this article three ways of creation could be named. First cinematic montage in architectural sets to create more than just a 3d environment and atmosphere; second the use of VR glasses in cultural heritage sites[43] to reconstruct the parts of a ruined historic building as they were before[44]; third cinematic installations to reincarnate or display far objects or built spaces in time or place such as planetarium and museums mixed with virtual realities; and forth VR videogames with a focus on architecture[45]. The degree of virtual and real engagement with each of these four types depends on both the designer of the worlds and the user's subjective control. A primary example of such a museum is the Pergamonmuseum in Berlin (Figure 10). The perfect emanation of the intended architecture could be sought in the design models and practices that not only create virtual dimensions but also by embedding specific sensors to catch the mood, pattern of movement, and emotion of the users they enable the place to function in an interactive and ever-changing pattern[46] and especially adjustable and flexible to the user habits[47]. One of the first designs that considered the incorporation of reality and virtuality, is the Fresh Water Pavilion in Zeeland created by Kas Oosterhuis who proposed the Synthetic dimension in architectural design[48].

Montage is seen as a spatial method of juxtaposition that, whilst originating in the context of images, has the power to transform three-dimensional spaces … Cinematic montage infuses in us not only the recognition of multiple dimensions with regard to the perception of architectural space, but that space itself is presented in more than one dimension, including that of architectural space[49].

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[43] Ahn K., Ko D. S., & Gim S. H., op.cit., pp. 48–61.

[44] Fonnet A., Alves N., Sousa N., Guevara M., & Magalhães L., Heritage BIM integration with mixed reality for building preventive maintenance. In *2017 24º Encontro Português de Computação Gráfica e Interação (EPCGI),* IEEE 2017, pp. 1–7.

[45] Miltiadis C., Virtual Reality, Videogames, *Architecture and Education-From utopian drawings to inconstructible navigable environments*, eCAADe conference 2018, "Computing for a better tomorrow", Lodz 2018.

[46] Oungrinis K. A., Liapi M., Gkologkina E., Kelesidi A., Linaraki D., Paschidi M., ... & Mairopoulos D., *Intelligent spacecraft modules: Employing user-centered architecture with adaptable technology for the design of habitable interiors in long-term missions*. In *64rd International Astronautical Congress,* Beijing, China, IAC-13 E, 2013, Vol. 5, pp. 2–1.

[47] Op.cit. pp. 138, 139–154.

[48] Oosterhuis K., *The synthetic dimension. On the Tectonics of the Rebellion & Aldo Rossi's Plan for the Bonnefanten Museum*, OASE 1991, pp 16–27. Retrieved from https://oasejournal.nl/nl/Issues/31/DeSynthetischeDimensie.

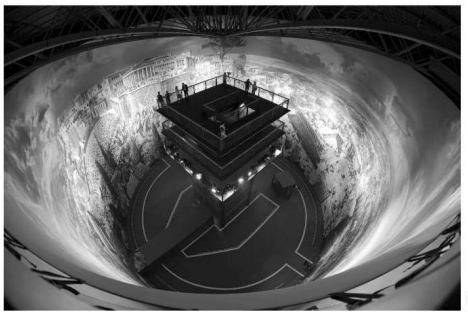
[49] Koeck R., *Cine-scapes: Cinematic Spaces in Architecture and Cities*, Routledge, 2013 pp. 15–16.

Das Panorama is subtly described below:

"The temporary exhibition of the artist Yadegar Asisi at the Das Panorama of the Pergamon Museum Berlin combines the results of years of archaeological and architectural research with the vision of a contemporary artist, through the digital reconstruction of the ancient city of Pergamon during the period of the High Roman Empire. The user is immersed and surrounded by a 360° panorama where palaces, theatres, objects, and settings that take him back to antiquity are depicted. In fact, the artist has reconstructed the ancient city, through the composition of over 40 photos depicting scenes of everyday life through the skillful use of light and sound, cyclically the scene varies from a daytime setting to a nocturnal one. In this scenario, the user, surrounded by images and sounds, goes back in time, and takes part in life in the ancient city… This creates a new form of illusory experience, offered only by visual and acoustic perception, where the user is passively projected into a new context, immersed and surrounded by digital dimensions"[50].

Such settings could be even more developed in sense of their atmosphere and flexibility with the rapid growth of technology in the field of virtual reality. Virtual ancient or future people in flux with their surroundings could be reincarnated. Certain atmospheres accompanied with their specific sensorial inputs would be resurrected and it would be possible to be changed by the simple desire of the users.

**Figure 10.** Das Panorama of the Pergamon museum in Berlin.


a


b

Source a:
https://www.visitberlin.de/system/files/styles/visitberlin_gallery_item_visitberlin_mobile_1x/private/event_images/bo-33-c1994705-789a-ee51-9b21-b314717141db.jpg?itok=Xpe5rRxh. [Access: 20.12.2021].
Source b:
https://upload.wikimedia.org/wikipedia/commons/7/75/Yadegar_Asisi_Panorama_DRESDEN_BAROCK.jpg [Access: 20.12.2021].

[50] Giugliano G., Laudante E., *Design as Collaborative Connection between User,* Technology and Cultural Context, IOP Conf. Ser.: Mater. Sci. Eng. 949 012010, 2020.

## 5. Conclusion

The presented work tried to reintroduce an emerging architecture in an era that architectural experience is mediated by digital technology. For this purpose, the research is aimed to review the extant literature among architecture and modern physics theories to offer an initial framework of an architectural theory. In table 2, it is evident that the first three dimensions are concrete until we import the fourth dimension to the space. The perception of depth, edge, and probably ceiling height will vary for each frame of reference during the observer's movement. The same thing goes for the objectless quality of space in virtual reality, too. In this sense, the architectural environment would be an ever-changing prodigy during the experience of the explorer (mentally, sensory, and corporeal), not to mention the shifting reality of architecture itself with the 'time' that appears to be both subjective and objective. Such attributes have been observed in mixed reality installations. In fact, the status quo of technology in this era offers four types of such architecture. This typology includes cinematic montage in architectural sets, VR glasses in cultural heritage sites, cinematic installations, and VR videogames with a focus on architecture. All in all, smart mixed reality architecture which creates smart engagement with the users (mental, sensorial, and corporeal), active architecture, as well as a mixed reality space, is what this grounded theory tries to imply.

## References


1. Ahmadi M., *The experience of movement in the built form and space: A framework for movement evaluation in architecture*, "Cogent Arts & Humanities", 2019, 6: 1588090. https://doi.org/10.1080/23311983.2019.1588090 [Access: 12.12.2021].
2. Ahn K., Ko D. S., & Gim S. H., *A study on the architecture of mixed reality application for architectural design collaboration*, In International Conference on Applied Computing and Information Technology, Springer.
3. Arnheim R., *Art and visual perception: A psychology of the creative eye. 50th anniversary printing*, Berkeley, CA, University of California Press, California 2004.
4. Arntzenius F., and Maudlin T., *Time Travel and Modern Physics*, [in:] *The Stanford Encyclopedia of Philosophy* (Winter 2013 Edition), Edward N. Zalta (ed.) 2013. https://plato.stanford.edu/archives/win2013/entries/time-travel-phys/ [Access: 12.12.2021].
5. Becker K., Becker M., & Schwarz J. H., *String theory and M-theory: A modern introduction*, Cambridge university press 2006.
6. Berrett J., and Marquardt V. *The Fourth Dimension and Non-Euclidean Geometry in Modern Art by Linda Dalrymple Henderson*, "Technology and Culture", 1985, Vol. 26, No. 4, Oct., 1985.

7. Big Think *Michio Kaku: The Multiverse Has 11 Dimensions* [Video file], 2011, May 31. Retrieved from: https://www.youtube.com/watch?v=jI50HN0Kshg [Access: 12.12.2021].

8. Bodish E., *Cubism and the fourth dimension*, "The Mathematics Enthusiast", 2009, 6(3).

9. Boyarsky, A., *Probing space with the two-slit experiment*, "Physics Letters A" 1992, Volume 170, No. 3.

10. Cecil J., Kanchanapiboon A., *Virtual engineering approaches in product and process design*, "The International Journal of Advanced Manufacturing Technology", 2007, 31: 846–856. DOI 10.1007/s00170-005-0267-7.

11. Chaterjee A. Vartanian O., *Neuroaesthetics*, "Trends in Cognitive Sciences", July 2014, Vol. 18, No. 7.

12. Cheng S., *Masaccio's Illusionism*, 2012. Retrieved from: https://openlab.citytech.cuny.edu/arth11036415f2012/2012/10/22/masaccios-illusionism/ [Access: 12.12.2021].

13. Ching F. D. K., *Architecture, form, space, and order* (4th ed.), John Wiley and sons, Hoboken 2014.

14. Coburn A., Vartanian O., Chatterjee A., *Buildings, Beauty, and the Brain: A Neuroscience of Architectural Experience*, "Journal of Cognitive Neuroscience", 2017.

15. Dunningham, J. and Vedral, V. (2018). Introductory Quantum Physics and Relativity (Second Edition). World Scientific Publishing Company, Singapore; Hackensack, NJ, ISBN 9789813228641.

16. Flachbart G., and Weibel P., *Disappearing Architecture from Real to Virtual to Quantum*, Springer Science & Business Media, Berlin/Heidelberg 2005.

17. Fonnet A., Alves N., Sousa N., Guevara M., & Magalhães L., Heritage BIM integration with mixed reality for building preventive maintenance. In *2017 24º Encontro Português de Computação Gráfica e Interação (EPCGI),* IEEE 2017.

18. Giugliano G., Laudante E., *Design as Collaborative Connection between User, Technology and Cultural Context*, *IOP Conf. Ser.: Mater. Sci. Eng.* 949 012010, 2020.

19. Hart V., *Erich Mendelsohn and the fourth dimension*, "Architectural Research Quarterly", 1995, 1.

20. Herbert N., *Quantum Reality: Beyond the New Physics*, Anchor Books, Random House, Inc., New York, 1985.

21. Jaffe A., *The Illusion of Time*, Mac Millan Publishers Limited, part of Springer Nature, 1985, vol 556. Retrieved from: https://media.nature.com/original/magazine-assets/d41586-018-04558-7/d41586-018-04558-7.pdf [Access: 12.12.2021].

22. Jencks C., *The architecture of the jumping universe: A polemic: How complexity science is changing architecture and culture*, Academy Editions, London 1997.

23. Jensen S., *An Introduction to String Theory*, 2004. Retrieved from: http://www.slimy.com/~steuard/research/StringIntro/index.html#outline [Access: 12.12.2021].

24. Koeck R., *Cine-scapes: Cinematic Spaces in Architecture and Cities*, Routledge 2013.

25. Kaku, M., *Introduction to superstrings and M-theory*. Springer Science & Business Media, 2018.

26. Kress B. C., & Cummings W. J., 11-1: Invited paper: Towards the ultimate mixed reality experience: HoloLens display architecture choices, In SID symposium digest of technical papers, 2007, Vol. 48, No. 1

27. Lobell J., *Quantum Theoretical Issues in Architecture: It's A Lot Stranger Than We Think*, 2012.

28. Latifi M., Burry J., & Prohasky D., *Make the Invisible Microclimate Visible: Mixed Reality (MR) Applications for Architecture and Built Environment* [In:] *Design Modelling Symposium Berlin,* Springer, Cham 2019,

29. Retrieved from: https://johnlobell.com/quantum-theoretical-issues-in-architecture-its-a-lot-stranger-than-we-think/ [Access: 12.12.2021].

30. Marikyan D., Papagiannidis S., & Alamanos E., *A systematic review of the smart home literature: A user perspective*, " Technological Forecasting and Social Change", 2019.

31. Miltiadis C. *Virtual Reality, Videogames, Architecture and Education-From utopian drawings to inconstructible navigable environments*., eCAADe conference 2018, "Computing for a better tomorrow", Lodz 2018.

32. Moser F., *Schrödinger's cat paradox and some other nice stories from science – what do they teach us?* "Computers & Chemical Engineering", 1994, volume 18, Supplement 1.

33. Oosterhuis K., *The synthetic dimension. On the Tectonics of the Rebellion & Aldo Rossi's Plan for the Bonnefanten Museum*, OASE 1991, pp 16–27. Retrieved from https://oasejournal.nl/nl/Issues/31/DeSynthetischeDimensie.

34. Oungrinis K. A., Liapi M., Gkologkina E., Kelesidi A., Linaraki D., Paschidi M., ... & Mairopoulos D., *Intelligent spacecraft modules: Employing user-centered architecture with adaptable technology for the design of habitable interiors in long-term missions*. In *64rd International Astronautical Congress,* Beijing, China*,* IAC-13 E, 2013, Vol. 5.

35. Redi I., *Quantum Architecture*, 2010. Retrieved from: http://ivanredi.com/quantum-architecture/ [Access: 12.12.2021].

36. Rokhsaritalemi, S., Sadeghi-Niaraki, A., & Choi, S. M. (2020). *A review on mixed reality: Current trends, challenges, and prospects*. *Applied Sciences*, 10(2), 636.

37. Roth Y., *Quantum vision in three dimensions*. *Results in physics*, 2017, *7*, 4101–4103.

38. Schnabel M.A., Wang X., Seichter H., Kvan T., *From virtuality to reality and back in*, "Proceedings of the 12th International Association of Societies of Design Research" (IASDR), Hong Kong 2007.

39. Schmarsow A. *The essence of architectural creation*, 1893. Retrieved from: http://designtheory.fiu.edu/readings/mallgrave_schmarsow.pdf [Access: 25.12.2021].

40. Vallow K., and Micucci J. (Producers), & Druyan A., and Braga B. (Directors), *Cosmos: Possible Worlds* – Episode 9 (Television series), CA: Fuzzy Door Productions, Los Angeles 2020.

41. Wang X., Schnabel M.A., *Mixed Reality in Architecture, Design, and Construction* (1st. ed.), Springer Publishing Company, Incorporated 2020.

42. Wesson Paul S., *Space-time-matter: Modern Kaluza-Klein Theory*, World Scientific Publishing Co. Pte. Ltd., Singapore 1999.

43. Yau S.T. & Nadis S., *The Shape of a Life: One Mathematician's Search for the Universe's Hidden*, Yale University Press, Connecticut 2019.

44. Zeh H.D., *Time in Quantum Theory*, [in:] Greenberger D., Hentschel K., Weinert F. (eds), *Compendium of Quantum Physics*, Springer, Berlin/Heidelberg 2009.

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