RIO 2019
GRAPHICA
XIII International Conference on Graphics
Engineering for Arts and Design

EXPLORING THE POTENTIAL OF THE FOURTH DIMENSION AS A SPECULATIVE DESIGN ELEMENT: REFLECTIONS AND APPLICATIONS

WANICK, Vanissa[1],

Resumo

O desenvolvimento de futuros conceptuais e imaginários é crucial para os designers, uma vez que abre possibilidades para pensar em aplicações de novas tecnologias. Com os avanços da Realidade Virtual (VR) e Realidade Aumentada (AR), há uma necessidade constante de integrar elementos 3D no design de interação. Com isso, é possível imaginar novos mundos que poderiam eventualmente ir além da terceira dimensão. Este artigo discute as implicações da quarta dimensão como um elemento de design especulativo. Através da discussão da pesquisa interdisciplinar e pela mistura de disciplinas como matemática, física, design e arquitetura, este artigo descreve o potencial de olhar para dimensões “invisíveis”.

Palavras-chave: 4D; 3D; Realidade Virtual, Design Especulativo, Arquitetura, Futurismo

Abstract

The development of conceptual and imaginary futures is crucial for designers since it opens possibilities to think about applications of new technologies. With advances of Virtual Reality (VR) and Augmented Reality (AR), there is a constant need to integrate 3D elements in interaction design. With this, it is possible to imagine new worlds that could eventually go beyond the third dimension. This paper discusses the implications of the fourth dimension as a speculative design element. Through the discussion of interdisciplinary research and by mixing disciplines like mathematics, physics, design and architecture, it describes the potential of looking at “unseen” dimensions.

Keywords: 4D; 3D; Virtual Reality, Speculative Design, Architecture, Futurism.

[1] University of Southampton / v.w.vieira@soton.ac.uk

1 Introduction

In the classic romance of many dimensions, Edwin Abbott (1992) imagined how the third dimension looked like for 2-dimensional (2D) beings (the "flatlanders"). In the "flatland", a square received the visit from a sphere that looks like a circle. When invited to see the world from the point of view of the sphere, the square sees three dimensions, looking beyond its current two-dimensional world. It is the beginning of the discussion around "other" dimensions and speculations around them.

Thinking about "other" dimensions has been in the agenda of many artists and in particular Cubists and mathematicians (e.g. *Esprit Jouffret* (1903), mathematician who influenced Picasso and others) reinforcing the idea that graphical projections can aid the manifestation of the fourth dimension (HENDERSON, 2013). The fascination about other dimensions (that go beyond our 3D world) has influenced the development of speculations on how can we design real-world experiences.

Speculations within the Design disciplines are not new and overlap with activities such as critical design, design probes and design fictions, which can be used for the purpose of creating new worlds (AUGER, 2013). For designers, the development of "futures" is crucial since it is possible to think about applications of new technologies. The "what if" question is a constant variable that speculative design cares about (TONKINWISE, 2015). Science fiction is one way to express this narrative and films such as *Blade Runner* or *Minority Report*, try to portray how people would interact with "futuristic" technologies. For example, *Steampunk*, a science fiction movement that merges aspects from Victorian days with modern computing, has been used to explore design fictions, particularly through the Do-It-Yourself (DIY) movement and the influence of cultural aspects in design (TANENBAUM; TANENBAUM; WAKKARY, 2012). Speculations have also appeared in the field of geometry. In an article published in 2016, Colman (COLMAN, 2016) discusses the work of Robert Smithson[2], American artist who was extremely inspired by the temporal dynamics of decay and entropy in modern aesthetic structures, as mentioned by Colman in the following citation:

> Smithson thus mixes the categories of Euclidean and quantum physics as they were known in the mid twentieth century – where the Euclidean infers an homogenous time; whereas Quantum structures (including quantum geometries) allow for complexity and uncertainty (COLMAN, 2016)

This suggests that geometry allows possible futures and with technology in our hands it might be also possible to expand them. With advances in Virtual Reality (VR) and Augmented Reality (AR), being three-dimensional is a requirement and it is why perhaps rethinking "dimensions" and geometries is also part of the design process, which also includes thinking about "impossible" geometries.

Why are we talking about the fourth dimension today? In the contemporary world, we are surrounded by uncertainties (PINK; AKAMA; SUMARTOJO, 2018); these can be a reflection of global politics, environmental concerns and the dissemination of fake news all over the world. Thus, by looking at uncertainties it might be a way to look towards possibilities. The conjecture that this paper conveys is that if either or not the fourth dimension has been

[2] http://www.robertsmithson.com/index_.htm

used as a speculative design element and what would be the possible applications that the fourth dimension can communicate, particularly in contexts such as product design, interface design, interactive media, architecture and experience design.

The aim of this paper is to demonstrate the application of the "speculative" fourth dimension in design disciplines as a design fiction element, looking at aspects like temporality and space in design. First, this paper reviews the concept of the fourth dimension, considering its interdisciplinary field. Then, the review is expanded towards the use of current technologies to interact and build artefacts in the fourth dimension. This review is followed by a list of possible applications of the fourth dimension as a speculative design element.

2 The interdisciplinary nature of the fourth dimension

In this section, the characteristics of the fourth dimension are discussed through a review of applications that consider the fourth dimension as an element of speculative design.

It is possible to see the fourth dimension through the lenses of mathematics and art as other types of geometric shapes (HENDERSON, 2013). Also, in mathematics, 4D has been mentioned as "dynamic". The *4D Julia set* and the *Mandelbrot set* are two examples of fractals that work through iterative function that repeats to infinite. Mandelbrot, for instance, has looked at the intricacies of nature and forms, describing irregular patterns and shapes as fractals (BURN; MANDELBROT, 2007); it shows the power of imagination through maths and the visualization of a maximum of iterations in a specific graph. Scientists can also use 4D as a visualisation resource. For example, whilst looking for keywords on "4D" and "data", it was possible to find tags[3] used by programmers and data scientists through *MatLab*, a software that helps data scientists to calculate large sets of data.

From the perspective of science, however, the fourth dimension is mostly related with time (ELBERT; KEIL, 2000). This is why space-time becomes the fourth dimension altogether, with the "fabric" of the universe (MUSSER, 2018) and most of our experiences depending on our perception in a specific time and space. For design disciplines, this aspect can sound quite speculative and perhaps far from real applications. For example, can 4D make our daily experiences better? And what is the relationship between 4D and design? How can the fourth dimension can be used a speculative design element?

Considering this, in order to understand the fourth dimension in this context, the next subsections are divided into parts that emerged from the literature review, considering the perspectives of architecture, product design and interactive media (e.g. games, VR, AR) through examples.

Interactive media

In 2017, *Miegakure* studio have produced two pieces of interactive media; one as a Virtual Reality (VR) interactive objects in 4D called "4D objects[4]", in which it is possible to play with 4D geometric solids and a game. In both examples, the shapes "shift" along the user's field of view. Particularly in the VR example, there is also the possibility to utilise depth to understand how the shapes move (see Figure 1 with a visual list of 4D toys).

[3] https://uk.mathworks.com/matlabcentral/fileexchange/?term=tag:%224d%22
[4] https://store.steampowered.com/app/619210/4D_Toys/

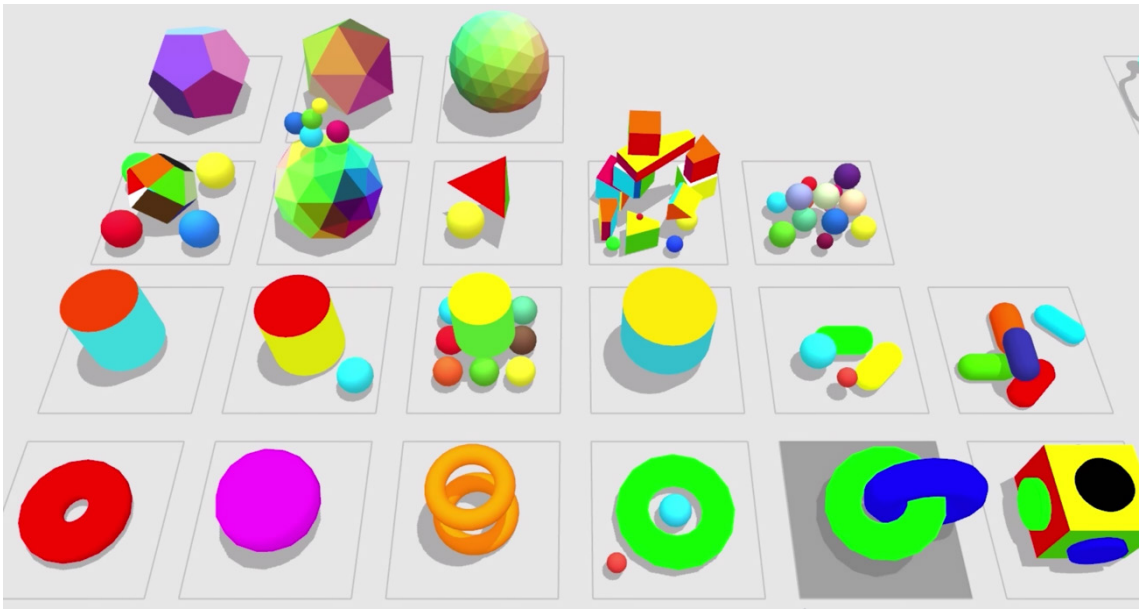

Figure 1 - Screenshot of the game 4D Toys, created by Marc ten Bosh (http://4dtoys.com/).
Source:

This aspect only highlights the nature of the fourth dimension as a design element, which is something that is "there", yet hidden to our eyes. The game *Fez*[5], from the designer Phil Fish, also touches the possibilities of merging dimensions and uses that as a mechanic in the game. Similar associations with geometry have been found in many 3D games. Another example is the mobile game *Monument Valley*[6], created by the design agency *ustwo*, in which the player needs to solve puzzles using the third dimension as a strategy. Similar strategies can be found in the work of M C Esher[7], showing paradoxical architecture schemes based on impossible (and infinite) geometries and tessellations. This approximation of other dimensions has been explored as a design element in different situations. By early 2000's, websites started adopting the *Parallax effect* for scrolling ("30 Great Websites with Parallax Scrolling", 2001), creating an illusion of depth in a 2D environment (the computer screen). Therefore, in the interactive media context, 4D is a mix of visual illusions, limited by the technology used (3D interfaces in VR or 2D interfaces in websites, for example). Brands are also being transformed from 2D to 3D. With advances on VR and AR technologies there is a constant need for 3D user interfaces and typography to be transformed into 3D (WILSON, 2018). Although this example does not explore the potential for the fourth dimension it shows that design elements can be transformed by technology. By adding another dimension to brand design, movement and depth also become part of the brand identity. This means that a "4D brand" would possibly include other layers not yet considered today, but could be enhanced by multisensorial design (HULTÉN, 2011).

Multisensorial design

The fourth dimension can also be a representation of multisensory elements, such as in 4D movies and 4D museums. For example, for movies and films, the 4D is presented in the

[5] https://store.steampowered.com/app/224760/FEZ/
[6] https://www.monumentvalleygame.com/mv2
[7] https://www.mcescher.com/

environment of the cinema, with motion control, vibration, air emission, tickler, water, smell or fragrance and light effects (OH; LEE; LEE, 2011). Thus, the fourth dimension becomes more than a mathematical term for a dimension that we cannot "see", but a dimension that is all about multisensorial perception and experiences. The artistic group *teamLab*[8] has many examples of applications of multisensorial experiences in spaces, using projections, sound and animations (see Figure 2). With projections all over the space in different areas, there is a recreation of the space using visual illusions and sound to provoke a sense of presence. A theme park using VR ("4D virtual reality theme park", 2013) is another example of the multisensorial layers of technology applied in order to promote immersive experiences.

Multisensory design is not new and has been employed as an approach in design and marketing (HULTÉN, 2011). For example, in 2011 Schifferstein presented a model for multisensory design, looking at methods required by designers to develop experiences and more interesting products for people. Thus, in multisensorial environments, technology plays a huge role on the development of the sense of illusion. Other aspects that are included in this scenario are not just visuals but related to sound effects (and acoustics).

Figure 2 - teamLab, 2018, Interactive Digital Installation, Sound (Hideaki Takahashi https://borderless.teamlab.art/ew/iwa-waterparticles/).
Source: teamLabBordeless.

Product design and architecture

Another example is active origami applied and product design. This technique utilises computational origami and responds to external non-mechanical stimuli (e.g. heat, chemistry, electromagnetism) (GE et al., 2014; PERAZA HERNANDEZ; HARTL; LAGOUDAS, 2019). These 4D objects can be printed, making use of kinematic geometry. This shows that in product design "movement" or kinematics is a key concept of the application of the fourth dimension idea, which may evoke aspects like personalisation. For example, in the website "Nervous System" (see Figure 3), users can create their own jewellery online, transforming the tessellations and using 3D visualisations to test their own prototypes online. This idea is very similar to tessellations and fractals that can be used in projects in architecture.

There is a strong relationship between form (the geometric form), movement and space

[8] https://borderless.teamlab.art/

in architecture. Movement in architecture can be understood through the lens of kinetic architecture (BAROZZI et al., 2016). In kinetic architecture, buildings are adaptive and have moving components. Elements such as time, physics, balance, speed, acceleration, form, serial repetition, mass, weight, complexity, scale, mystery and interaction are part of this interactive feature of kinetic architecture (ELKHAYAT, 2014). One example is the development of intelligent buildings such as the *Bionic Tower* in Abu Dhabi. The *Bionic Tower* created by architects at LAVA[9] is an adaptive building, composed by adaptive components that mimics natural shapes. Another example is the *Hypo Surface Wall*[10]. This wall is the first surface design that moves, interacting directly with human input. With new technologies, it is possible to prototype and design such buildings by the use of parametric architecture, through algorithms. For example, computational elements have aided architects to explore fractal geometry, kinematics, topological space, metamorphic architectures and genetic algorithms (STAVRIC; OGNEN MARINA, 2011). What is more, the way adaptive buildings are designed can also reflect cultural patterns. For instance, *Lideta Mercato*, a building in Ethiopia follows fractal shapes from dresses from Ethiopian women, showing how geometry can also reflect cultural elements (MAY, 2013). However, fractals and visible shapes are not the only way to build "spaces". Artist Bernard Leitner[11] looked at sound as a "building component", creating spaces using sound waves. Thus, building materials do not have to be visible all the time and that fits the idea of the fourth dimension. Speculations using architectural shapes can be used to imagine the future of cities. For example, artist *Tomas Massareno* created imaginary worlds using "air" as element. In this work Cloud Cities[12], the artist invites the public to a reflection about sustainable futures, in which cities would "fly" in the sky, but people would get a feeling of "buoyancy" or floating.

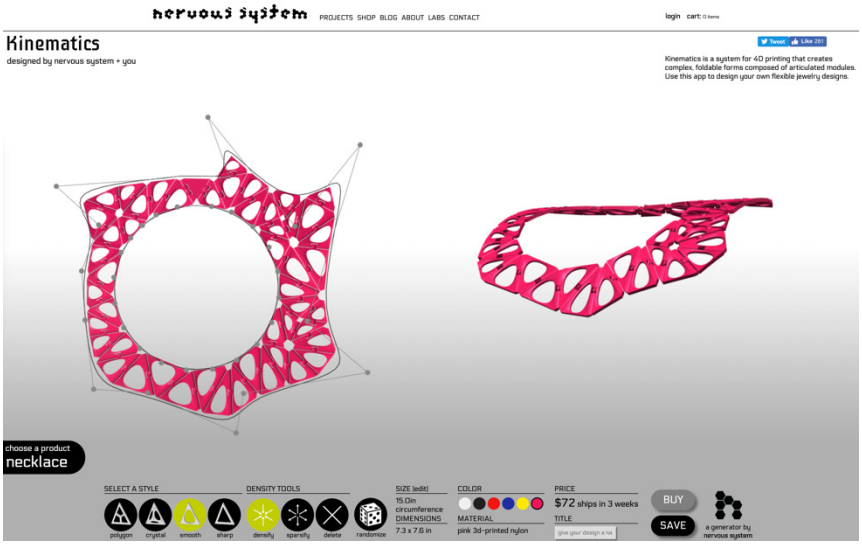

Figure 3 - Screenshot
Source: Nervous System https://n-e-r-v-o-u-s.com/

[9] https://www.arch2o.com/bionic-tower-lava/
[10] http://www.decoi-architects.org/2011/10/hyposurface/
[11] https://www.bernhardleitner.at/works
[12] https://studiotomassaraceno.org/stillness-in-motion-cloud-cities/

3 Speculative Design elements and applications

Speculative design is about thinking of new possibilities for the Design discipline (DUNNE; RABY, 2013) and because of that, time itself becomes a "design" element. If considering the aspects discussed about the nature of the fourth dimension, speculations in this case would have past, present and future existing simultaneously. The applications mentioned in the previous section showed most examples that had both physical and digital elements that were experienced by the "observer" or "observers". As for example, in 4D museums and 4D films, social presence is also a dimension (OH; LEE; LEE, 2011). As highlighted in the review in the previous section, the way the 4D is portrayed in design are through movement, space and time, but also form and function. And with that, materials might differ. For instance, sound could be a component from the fourth dimension since it is not "seen", but only experienced. From the review, adaptation is a key strategy. For example, buildings can adapt to thermal stimulus or visuals can be adapted to convey certain illusions to our senses (and provide a sense of immersion). At times, humans can interact with these stimuli; for example, an interactive wall or a game would have consequences based on our input. Thus, what is missing in the fourth dimension is the application and the rationale for the use of this dimension. What about human values? What can we make with that and why? In this section, two scenarios are discussed using the fourth dimension as a design element. For that, characteristics are considered: spatial interaction, movement (e.g. kinematics), time, geometry, senses (including sound) and technological artefacts (e.g. VR, algorithms).

Scenario 1) Living memories

In this scenario people would be able to record their experiences using multisensorial data. For example, sensors would record smells, tactile information and visuals using cameras and other types of technology. After capturing the whole experience, people could revisit it, playing memories through multisensory VR equipment and immersive technologies. In an imaginary future, people could also change these memories and explore new choices. Questions related to this scenario are: *What if we could revisit a memory from a long time ago? What if we could change this memory? What if we could live this memory again? What would be the other possible choices we could have made? How can that affect the future?*

Once people change their "recorded" memories and make different choices, the "virtual" space (*spatial interaction*) could be transformed according to their choices. This would change the whole environment and the experience (*kinematics*). Since people would be able to record, revisit and change (virtually) their memories, then time would be a "constant" element, in which past, present and future coexist. The sensorial elements of this experience are related to the five senses captured by the "recorder", with possibly an addition of other senses that could include feelings and emotions. The geometry of this scenario lies on the design of the space (could be a living room, or outdoors environment). It would be required that in this case the "memory" is captured in fragments that can be combined into a full experience. Thus, geometric elements would include a full 360º degree view that could be fragmented in order to be recomposed in the virtual environment (see Figure 4). Technological artefacts that could be used are a recorder (camera with sound) and a way to record smells, tactile information and taste.

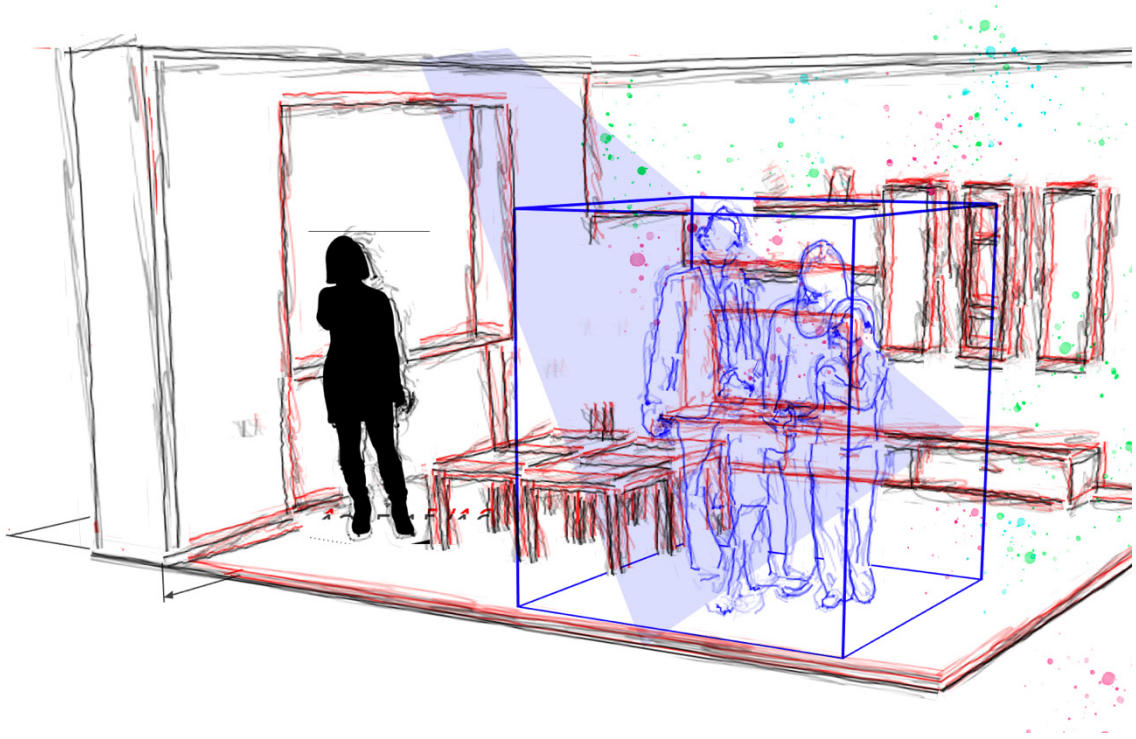

Figure 4 - Living memories scenario.
Source: sketch elaborated by the author

Scenario 2) Embodiment of nature

In this scenario people would be able to experience nature in a more "organic" way in their daily lives, being able to connect with all nature elements (plants, animals, etc.). The idea behind this is to bring back nature to human beings as everything as a living "being", which would include the embodiment of all senses. Questions related to this scenario are: *What if we could visualise (and feel) our own sound and the sound of everything near us, from radio waves and plants? How could that change our own choices and perspectives towards the environment? Can this connection with nature heal us?* Although this scenario could overwhelm people with the number of stimuli, the idea is that by using "invisible" elements, it would be possible to connect with nature in a more sustainable way and perhaps influence aspects such as mental health issues or even accessibility. For example, people with disabilities could be able to explore nature in other ways. In this case, by connecting with the environment (*spatial interaction*), which in this case it is more related to "outdoor" environment, people would be able to feel nature through different lenses (*senses*). In this case, the kinematic nature of the scenario is through biomorphic interactions (similar to adaptive buildings). This would be also reflected on the geometry of the space (which could include fractal geometry based on natural shapes). Time would depend on natural interactions and would make use of thermodynamics. Technological artefacts in this scenario are the use of intelligent materials and algorithms that could connect data from sensors and adapt the experience for each individual or group dynamically (see Figure 5).

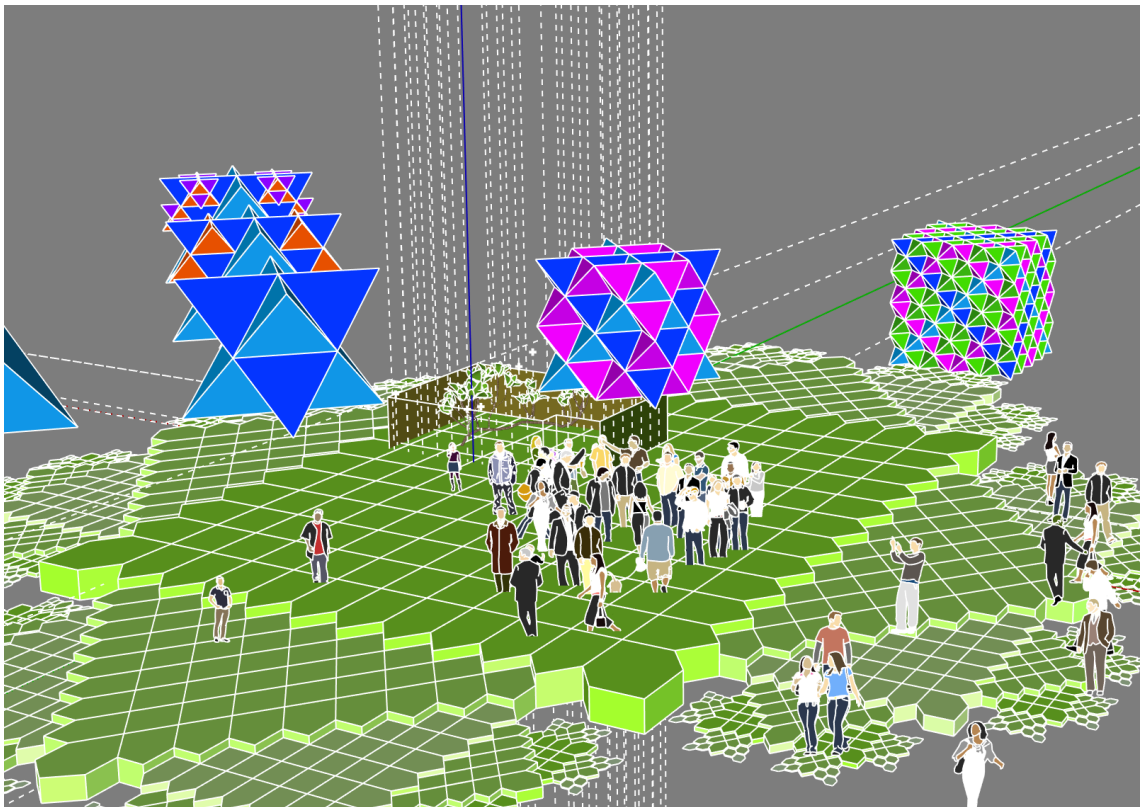

Figure 5 - Embodiment of nature in an outdoor environment.
Source: sketch elaborated by the author

4 Conclusion and final remarks

This paper aimed at exploring the fourth dimension as a speculative design element. The fourth dimension by nature is a speculative element, but it has been discussed in the literature in architecture and design as possibilities to improve individual or group experiences. That is, the fourth dimension might not be “seen” but “experienced” through different senses (or more). With the discussion of examples, it was possible to categorise the nature of 4D as an element that contains spatial interaction, movement (or kinematics), time, geometry, senses (including sound) and technological artefacts, such as VR, AR and algorithms. Through the development of two scenarios, it was possible to identify many opportunities for research in the area and the expansion of the fourth dimension as a speculative design element. This paper is a starting point on the discussion of speculative dimensions and it is expected that this paper can be of use for architects and designers willing to go beyond our three-dimensional world.

Image usage permission

Permission to use the screenshot of pages (Figure 1 and Figure 3) were granted by the original authors via email. Figure 2 is part of the media material published by teamLabBordeless in their website. Figures 4 and 5 were elaborated by the author using the software SketchUp.

References

30 Great Websites with Parallax Scrolling. Disponível em: <https://www.awwwards.com/30-great-websites-with-parallax-scrolling.html>. Acesso em: 19 maio. 2019.

4D virtual reality theme park. Disponível em: <https://www.designboom.com/technology/4d-virtual-reality-theme-park/>. Acesso em: 19 maio. 2019.

ABBOTT, E.A. ***Flatland: a romance of many dimensions***. Dover Publications Inc.; New Ed edition. 1992.

AUGER, J. Speculative design: crafting the speculation. **Digital Creativity**, v. 24, n. 1, p. 11–35, 28 mar. 2013.

BAROZZI, M. *et al.* The Sustainability of Adaptive Envelopes: Developments of Kinetic Architecture. **Procedia Engineering**, v. 155, p. 275–284, 2016.

BURN, R. P.; MANDELBROT, B. B. The Fractal Geometry of Nature. **The Mathematical Gazette**, 2007.

COLMAN, F. Speculative Geometry: Robert Smithson's glass jars, satellites and material aesthetics. **Journal of Visual Art Practice**, 2016.

DUNNE, A.; RABY, F. **Speculative Everything: Design, Fiction and Social Dreaming**. Cambridge MA: MIT press, 2013.

ELBERT, T.; KEIL, A. **Imaging in the fourth dimensionNature**, 2000.

ELKHAYAT, Y. O. Interactive movement in kinetic architecture. **Journal of Engineering Sciences**, 2014.

GE, Q. *et al.* Active origami by 4D printing. **Smart Materials and Structures**, 2014.

HENDERSON, L. D. **The Fourth Dimension and Non-Euclidean Geometry in Modern Art**. Cambridge, MA, U.S.A.: MIT Press, 2013.

HULTÉN, B. Sensory marketing: the multi-sensory brand-experience concept. **European Business Review**, v. 23, n. 3, p. 256–273, 17 maio 2011.

JOUFFRET, E. **Traité élémentaire de géométrie à quatre dimensions et introduction à la géométrie à n dimensions**. Gauthier-Villars, 1903.

MAY, K. T. **Architecture infused with fractals | TED Blog**. Disponível em: <https://blog.ted.com/architecture-infused-with-fractals-ron-eglash-and-xavier-vilalta/>. Acesso em: 19 maio. 2019.

MUSSER, G. What Is Spacetime? **Scientific American**, v. 318, n. 6, p. 55–58, 15 maio 2018.

OH, E.; LEE, M.; LEE, S. **How 4D effects cause different types of presence experience?** Proceedings of the 10th International Conference on Virtual Reality Continuum and Its Applications in Industry - VRCAI '11. **Anais**...New York, New York, USA: ACM Press, 2011Disponível em: <http://dl.acm.org/citation.cfm?doid=2087756.2087819>. Acesso em: 19 maio. 2019

PERAZA HERNANDEZ, E. A.; HARTL, D. J.; LAGOUDAS, D. C. Introduction to Active Origami Structures. In: **Active Origami**. Cham: Springer International Publishing, 2019. p. 1–53.

PINK, S.; AKAMA, Y.; SUMARTOJO, S. **Uncertainty and Possibility : New Approaches to Future Making in Design Anthropology**. London: Bloomsbury Academic, 2018.

SCHIFFERSTEIN, H. N. J. **Multi sensory design**. Procedings of the Second Conference on Creativity and Innovation in Design - DESIRE '11. **Anais**...New York, New York, USA: ACM Press, 2011Disponível em: <http://dl.acm.org/citation.cfm?doid=2079216.2079270>. Acesso em: 11 mar. 2018

STAVRIC, M.; OGNEN MARINA. Parametric Modeling for Advanced Architecture. **International Journal of Applied Mathematics and Informatics**, 2011.

TANENBAUM, J.; TANENBAUM, K.; WAKKARY, R. **Steampunk as design fiction**. Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12. **Anais**...New York, New York, USA: ACM Press, 5 maio 2012Disponível em: <http://dl.acm.org/citation.cfm?id=2207676.2208279>. Acesso em: 27 mar. 2016

TONKINWISE, C. How We Intend to Future: Review of Anthony Dunne and Fiona Raby, Speculative Everything: Design, Fiction, and Social Dreaming. **Design Philosophy Papers**, 29 abr. 2015.

WILSON, M. **The future of branding? The third dimension**. Disponível em: <https://www.fastcompany.com/90172325/the-future-of-branding-the-third-dimension?utm_source=twitter.com&utm_medium=social>. Acesso em: 19 maio. 2019.