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BEYOND 3D: DESIGNING POSSIBLE FUTURES THROUGH THE POWER OF THE FOURTH DIMENSION

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Resumo: Com os avanços de tecnologias como Realidade Virtual (VR) e Realidade Aumentada (AR), há uma necessidade constante de integrar elementos 3D no design de interação. Este artigo[2] discute as implicações do design da quarta dimensão (4D), como elemento especulativo do design para o desenvolvimento de experiências interativas. Através da discussão de disciplinas mistas, como matemática, física, design e arquitetura, este artigo descreve o potencial de olhar dimensões que vão além do 3D, a fim de aumentar as futuras aplicações do design interativo e re-imaginar a maneira como construímos novos espaços e interações.

Palavras-chave: 4D, 3D, geometria, futurismo, design especulativo.

Abstract: With advances of technologies such as Virtual Reality (VR) and Augmented Reality (AR), there is a constant need to integrate 3D elements in interaction design. This paper[2] discusses the implications of the design of the fourth dimension (4D) as a speculative design element for the development of interactive experiences. Through the discussion of mixed disciplines like mathematics, physics, design and architecture, the current paper describes the potential of looking dimensions that go beyond 3D in order to augment the future applications of interactive design and reimagine the way we build new spaces and interactions.

Keywords: 4D, 3D, geometry, futurism, speculative design.

1 Introduction

Uncertainties surround our contemporary world; these can reflect the current situation of global politics, environmental concerns and the dissemination of fake news all over the world. As Pink et al. (2018) mention, although uncertainty can be condemned by reinforcing indecision and vulnerability, it can also harness disruptive innovations. 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 used as a speculative design element and what would be the possible applications that

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[2] The current paper contains sentences from the previous paper published at Graphica 2019.

the fourth dimension can communicate, particularly in contexts such as product design, interface design, interactive media, architecture and experience design. This paper is an extension of a paper presented at the *Graphica 2019 conference*, held in Rio de Janeiro in September 2019. The initial paper had the objective to explore the fourth dimension as a speculative design element. Based on that, the current paper builds on the concepts discussed on the previous research. The previous paper demonstrated the application of the "speculative" fourth dimension in design disciplines as a design fiction element, looking at aspects like temporality and space in design. It also looked at contexts such as product design, interface design, interactive media, architecture and experience design.

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. But how would that look like to 3D beings like us? What would the fourth dimension look like and how can we perceive it? Questions like these populated the area of science and art for over 100 years.

Why are we talking about the fourth dimension today? And why is this important for graphics Thinking about "other" dimensions has been in the agenda of many artists and in particular Cubists and mathematicians 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 and virtual experiences.

Speculations within the Design discipline 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 based on new scientific experiments. However, it is important to mention that both science and design fictions overlap. 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). Therefore, it is not just technology that guides innovation and adoption, but also values and how people interact with them. This is why that if people could imagine themselves interacting with this new futuristic scenarios and new products from this future world, we could understand how new values would emerge.

Today, we have been living in a world that is each time more connected through multi-sensory and immersive technologies. With Virtual Reality (VR) and Augmented Reality (AR), Artificial Intelligence (AI) and new high-speed connections like 5G, we are connected everywhere, all the time, with digital devices that generate and collect data from each point of interaction (with us, with the environment and with objects) (WANICK; XAVIER; EKMEKCIOGLU, 2018). Particularly with VR and AR environments, most of these interactions and visual resources are 3D. Therefore, being three-dimensional is a requirement and it is why rethinking "dimensions" and geometries is also part of the design process, which also includes thinking about "impossible" geometries. What is more, speculations around "other dimensions" appear across disciplines. Speculations have also appeared in the field of geometry. In an article published in 2016, Colman (COLMAN, 2016) discusses the work of Robert Smithson[3], 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. Thus, the main question that arises is *How can we design with the fourth dimension, if it is becoming each time more imperative to understand the dynamics of the use of new technologies?* How can we revisit the speculations around the fourth dimension and think about the use of new technologies through the perspective of this dimension? How can the fourth dimension help designers and architects to think about new possibilities and applications?

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3 http://www.robertsmithson.com/index_.htm

The aim of this paper is to continue the discussion about the applications of the "speculative" fourth dimension in design disciplines as a design fiction element, looking at aspects like temporality, geometry and space in design. First, this paper reviews the concept of the fourth dimension, considering its interdisciplinary nature. Then, the review is expanded towards the use of current technologies to interact and build artefacts with the fourth dimension. This review is followed by a list of possible applications of the fourth dimension as a speculative design element through a discussion of three scenarios: 1) revisiting living memories, 2) healing through natural resources and 3) building "invisible" spaces.

2 The fourth dimension across disciplines

Art and mathematics have been always overlapping. For instance, Picasso has been influenced by the work of mathematician *Esprit Jouffret* (1903). In his work *Traité élémentaire de géométrie à quatre dimensions et introduction à la géométrie à n dimensions* (1903), Jouffret mentions that due to the nature of the geometrical conception of equation it was crucial to understand the geometrical forms that could emerge from such variables; these would be represented by hypersurfaces which would become popularized by the use of the hypercube or tesseract (the 4D cube). The difference now is that in the 4D-world, 3D objectives have an extra degree of freedom. Therefore, it is natural to address the fourth dimension through the lens of geometry and mathematics.

2.1 The fourth dimension in geometry, science and art

The work of *Jouffret* not only influenced Cubists but it also opened the discussions around the existence of the fourth dimension, opening it towards a more philosophical debate. This is because *Jouffret* believed that the fourth dimension could only (or possibly) exist geometrically. With this, the fourth dimension offers possibilities that go beyond our vision and might be attached to other senses. The four-dimensional approach worked in line with Cubists, in particular for *Picasso*. His first lines and drawings for *Les Demoiselles d'Avignon*[4], for instance show the intricacies of applying space and time in a two-dimensional canvas.

It is also 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

[4] https://www.moma.org/collection/works/79766

Mandelbrot set are two examples of fractals that work through iterative function that repeats to infinite. The *4D Julia set* is named after mathematician *Gaston Julia* and it basically contains two complex numbers that have two components, making it a fourth dimensional formula. These two components are both a real and an imaginary value. 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 (Figure 1). For example, Figure 1 shows the visualisation of the *Mandelbrot* set; the space outside the main "blob" in the middle represent infinity. The *Julia* sets are part of the main central figure, but represented by particles that remind us of "dust"; this is because the Julia set depends on a constant that varies across each iteration. The key takeaway from both Mandelbrot and Julia sets is that their constants contain two elements that are real and imaginary. This puts the fourth dimension into another perspective.

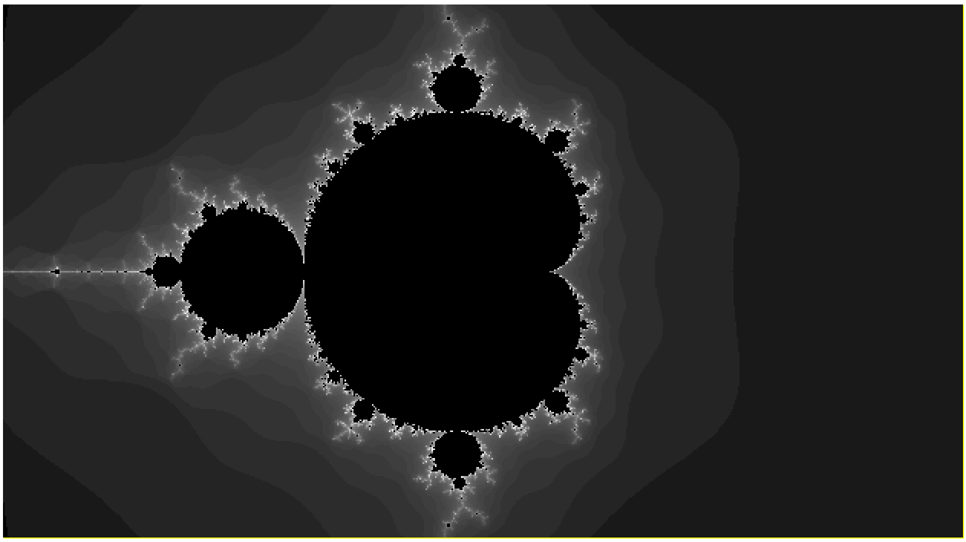

Figure 1 – Mandelbrot set visualisation (designed by the author using *Processing*)

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[5] used by programmers and data scientists through *MatLab*, a software that helps data scientists to calculate large sets of data. This is because datasets can contain different "dimensions" and mathematically speaking, a fourth dimensional space in mathematics means that you have a space with four variables or points. For instance, Zhivomirov (2015) developed

[5] https://uk.mathworks.com/matlabcentral/fileexchange/?term=tag:%224d%22

a code to aid scientists to visualise 4D elements in a graph. Figure 2 shows the example of this graph, with X, Y and Z coordinates and the fourth dimension as a coloured coded dimension.

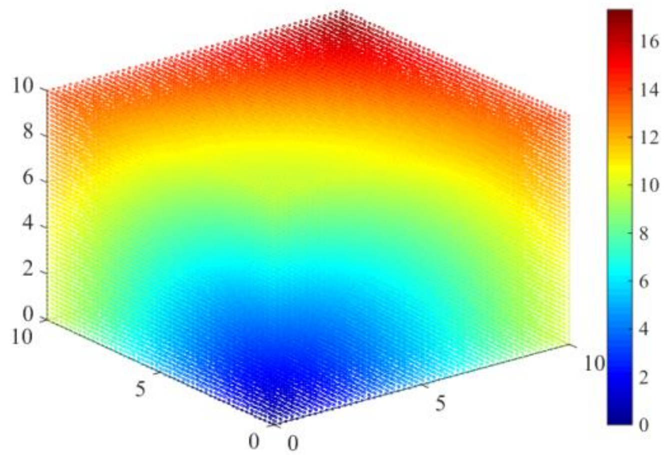

Figure 2 – 4D Data visualisation with Matlab implementation screenshot (ZHIVOMIROV, 2015)

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.

2.2 The fourth dimension in 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 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*[6] has many examples of applications of multisensorial experiences in spaces, using projections, sound and animations (Figure 3). 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 3 – TeamLab, 2018, Interactive Digital Installation, Sound (Hideaki Takahashi https://borderless.teamlab.art/ew/iwa-waterparticles/)

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;

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

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 4), 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.

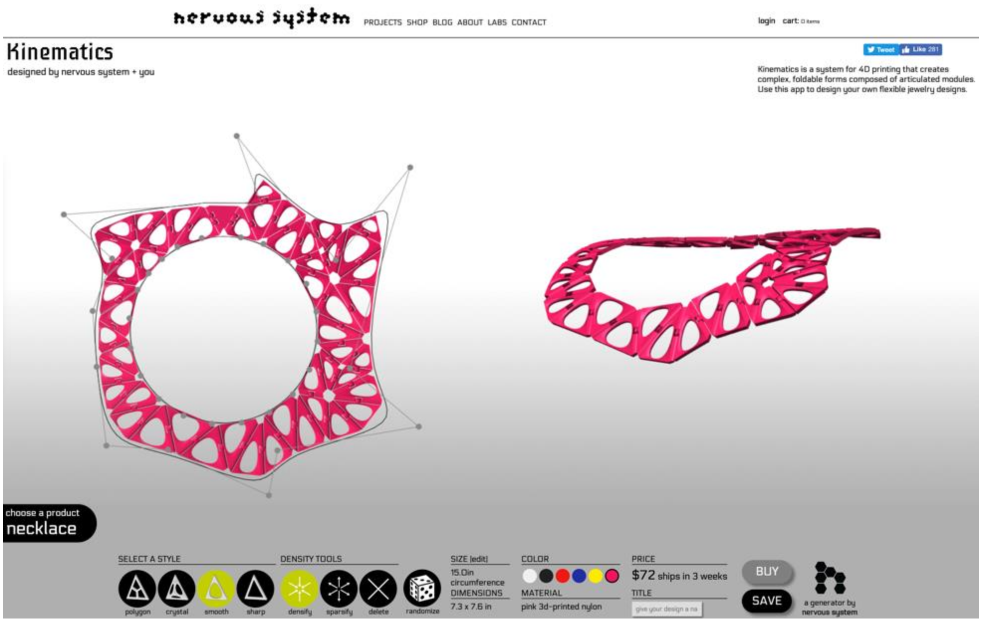

Figure 4 – Screenshot (Nervous System https://n-e-r-v-o-u-s.com/)

2.3 The fourth dimension in architecture

There is a strong relationship between form (the geometric form), movement and space 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[7] is an adaptive building, composed by adaptive components that mimics natural shapes. Another example is

[7] https://www.arch2o.com/bionic-tower-lava/

the *Hypo Surface Wall*[8]. 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[9] 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*[10], 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.

2.4 The fourth dimension in virtual reality and interactive media

The term “Virtual Reality” was first coined by Jaron Lanier[11] who designed the first VR “goggles”, at this time a very experimental head-mounted device that used stereoscopic imagery. The device had the same principles as today’s *Oculus Quest* (developed recently by Facebook) or *HTC Vive*; that is, all VR goggles have a stereoscopic display, which provides a separated image for each eye. A similar exercise can be done by the use of *anaglyphs* (with one lens in red and another in cyan). However, stereoscopy can be challenging if it is not well designed. For example Banks et al. (2012) mention that geometry needs to be designed in the right way, mostly related to the alignment of images to the viewer’s retina. On the other hand, the focus on the 3D nature of VR puts human vision as the main sense to be considered in this experience. This suggests that 3D becomes a vision-related characteristic, leaving space for the fourth dimension to explore multisensorial environments. It is also important to remember that VR technologies not only bring a sense of depth, but it

[8] http://www.decoi-architects.org/2011/10/hyposurface/
[9] https://www.bernhardleitner.at/works
[10] https://studiotomassaraceno.org/stillness-in-motion-cloud-cities/
[11] http://www.jaronlanier.com/

allows users to explore the possibilities to walk in a 360º space (WANICK; XAVIER; EKMEKCIOGLU, 2018). In fact, the main elements of VR are visualisation, immersion, interactivity (e.g. based on sensors) (YUNG; KHOO-LATTIMORE, 2019). Therefore, there is scope to consider other elements that go beyond human vision and include space exploration and interaction as core components.

On the side of applications, there is a great opportunity to expand the use of the foirth dimension, particularly in virtual environments that consider "fantasy" as main elements. For example, in 2017, *Miegakure* studio have produced two pieces of interactive media; one as a Virtual Reality (VR) interactive objects in 4D called "4D objects[12]", 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 5 with a visual list of 4D toys).

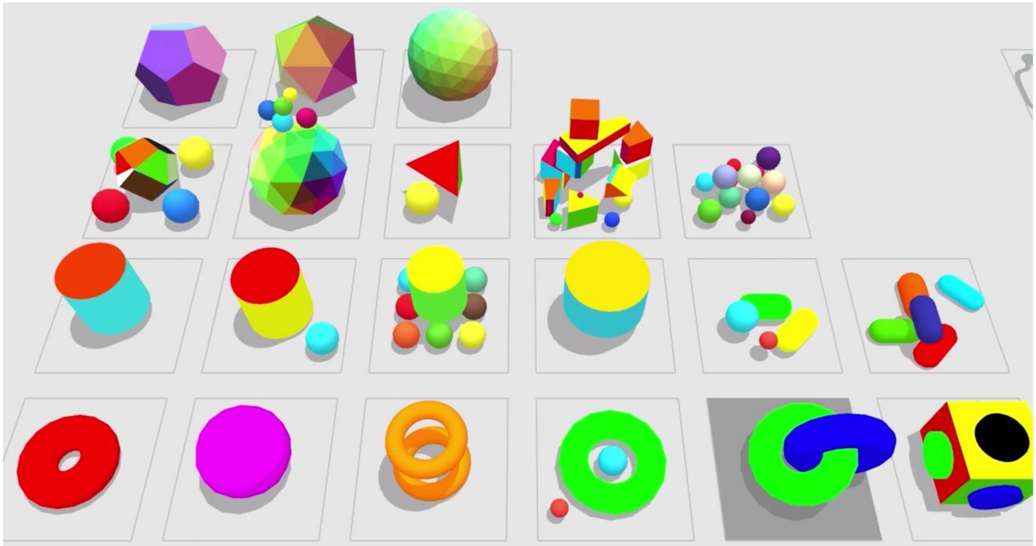

Figure 5 – Screenshot of the game 4D Toys, created by Marc ten Bosh (http://4dtoys.com/)

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*[13], 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*[14], created by

[12] https://store.steampowered.com/app/619210/4D_Toys/
[13] https://store.steampowered.com/app/224760/FEZ/
[14] https://www.monumentvalleygame.com/mv2

the design agency *ustwo*, in which the player needs to solve puzzles using the third dimension as a strategy. These games require a lot of spatial thinking from the player. Similar strategies can be found in the work of M C Esher[15], 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).

3 Moving towards the fourth dimension as a speculative design element

Speculative design is a discipline that addresses the new possibilities of design (DUNNE; RABY, 2013); one of these possibilities is using the discipline of *Design* as a speculative element itself. For example, it is possible to develop scenarios, fictions and thought experiments that encompass imaginative worlds through the creation of new products, prototypes and fictions. Design fictions are similar to science fiction, but with *Design* as the main subject. Speculative Design embraces the imagination of futures of products, services and systems but also their context of application and societal values (AUGER, 2013). Dunne and Raby (2013) discuss the differences between different levels of imagination of "possible" futures. In the diagram composed by five cones (Figure 6), Dunne and Raby show that designers tend to operate in the "probable" cone area, whereas the area of "preferable" futures requires more discussion. This is because speculative design is not about predicting the future; it is about giving opportunities to discuss possibilities within the space of "preferable" futures. Therefore, it is all about designing for scenarios about how things "could be" and how people would react to them.

[15] https://www.mcescher.com/

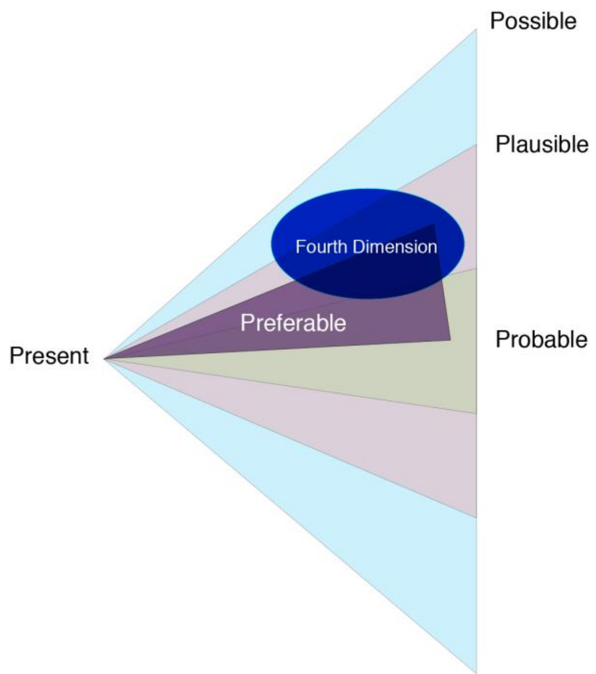

Figure 6 – Situating the fourth dimension as a speculative element (adapted from (DUNNE; RABY, 2013)

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, three 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). The methodological approach of this paper considers the design of scenarios, built through the concept of the fourth dimension such as spatial interaction, movement (or kinematics), time, geometry, senses (including sound) and technological artefacts, such as VR, AR and algorithms. Table 1 shows the elements gathered together. However, some questions remain. Since we cannot see the fourth dimension how might we experience it? In the next section, three scenarios are discussed in order to address these questions.

Table 1 – Elements of the fourth dimension as a speculative design element

Elements	Description
Virtual	These are technological artefacts, mostly with VR/AR/MR environments that consider 3D imagery; it should also contain AI algorithms It may also include the environment and objects from the physical world.
Invisibility	The use of other elements (in particular sound) as a material/resource
Values	Values that emerge from the interaction of humans with the world; cultural and social elements
People	Human input in the system; could involve more than one person in the interactive space
Visible	Optical illusions, interactions that depend on the observer
Geometry	Narratives that contain real-time interactions; the way invisible and visible elements are organised in the space
Senses	Multisensorial outputs and inputs (e.g. sensors)
Spatial interaction	Types of interactions that happen in this space. It can involve 360º visualisations and haptics
Time	Past, present and future existing simultaneously
Movement	Kinematics and dynamics. Here algorithms and mechanical artefacts should be considered

3.1 Scenario 1: Revisiting 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.

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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 7). Technological artefacts that could be used are a recorder (camera with sound) and a way to record smells, tactile information and taste.

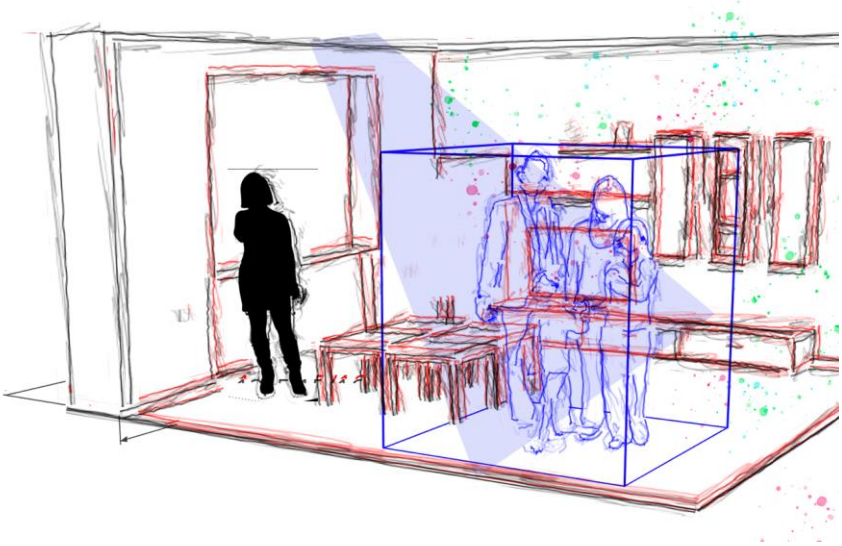

Figure 7 – Living memories scenario (sketch elaborated by the author)

3.2 Scenario 2: Healing through natural sounds

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.). This could be done in a way to be able to “heal” ourselves from the interactions with nature. 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 8).

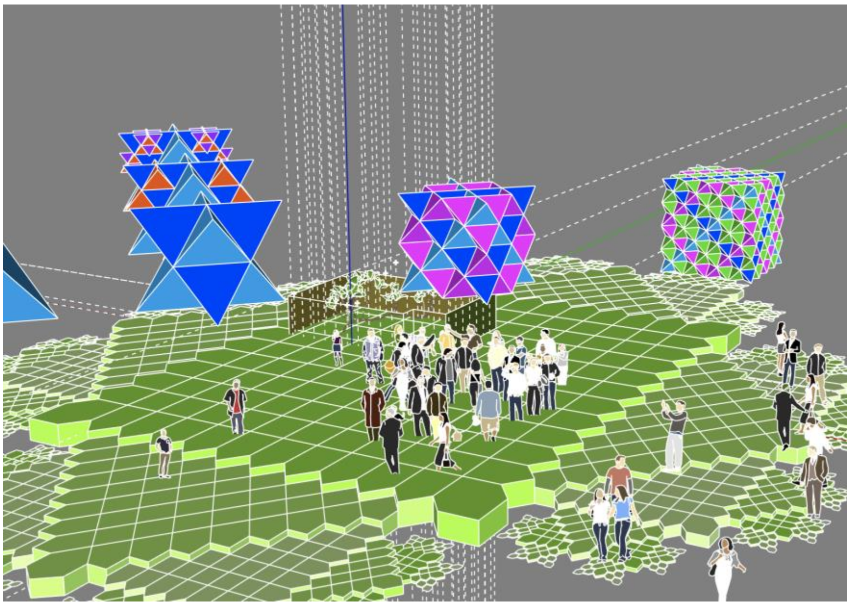

Figure 8 – Embodiment of nature in an outdoor environment (sketched by the author)

3.3 Scenario 3: Building “invisible” spaces

In this scenario, it would be possible to craft spaces using sensorial information, algorithms and mixed reality technologies (MR/VR/AR). People involved in this would be designers, mathematicians and scientists, working together to design spaces for people. Through sound, algorithms and even elements from virtual reality (or mixed reality by using lenses of goggles), “creators” would be able to design these spaces by a constant and dynamic interaction with computers and AI. These creators would collaborate with AI agents, who would then provide guidance and advice to creators.

This could be applied through and advancement in parametric algorithms in architecture, for example.

Questions related to this scenario are: *What if we could use the sounds we hear and other senses we perceive in order to build better worlds and systems? How could that change the way we work? What would be the role of the public in this context? How can we foster collaboration in this context and how to manage large amounts of data towards creativity?* Although this scenario would require a lot of collaboration (not just with AI agents, but with others), it would also include a vast amount of materials to be used to create such spaces. For example, by connecting with the environment through different outputs (*spatial interaction*), the “creators” would be able to access a library of senses that go beyond human vision, which could include brain waves as well (*senses*). In this case, the kinematic nature of the scenario is through the dynamic interactions and creative outputs (similar to geometric tessellations). This would be also reflected on the geometry of the space (which could include fractal geometry and adaptive shapes with movement). Time would be included as a design element and decay would be considered in the creation of such spaces. For example, can sound waves decay? In this case people would be able to experience different spaces just by using brain waves and sound. This would change tourism dramatically. Technological artefacts in this scenario are the use of intelligent materials and algorithms that could connect data from sensors, haptics, brand waves and sound waves (see Figure 9).

Figure 9 – Building invisible spaces through sound waves, brain waves and AI agents (sketch elaborated by the author)

4 Discussion and conclusion

This paper aimed at exploring the fourth dimension as a speculative design element. Inspired by the *Romance of many dimensions* from Abbott and his “flatlanders” and the current developments of technologies (in particular for the design of virtual worlds), this paper discussed the many possible applications of the fourth dimension.

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). This puts the fourth dimension as an “unseen” dimension, not just attached to human vision as its main sense. Therefore, questions that emerged were *How can we design with the fourth dimension? How can we project and draw for the fourth dimension?*

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 three 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.

Scenario 1 discussed the possibility to revisit one’s memory, by recording it through different types of sensors around the space. People could have the element of “time” happening in the same scenario, being even able to change these memories or looking for other possible choices during a decision-making process. This scenario is similar to a scenario created by the *Netflix* series *Black Mirror* (*The Entire History of You*[16]). Different from the episode, though, in the scenario proposed in this paper it is possible to revisit the memories through different points of view.

Scenario 2 showed the importance to utilise the fourth dimension as a connector between humans and the environment. This is not completely impossible. For example, existing technologies such as PlantWave[17] allow people to listen to the music of the plants through a device that “reads” sound waves from the plants.

Scenario 3 showed the possibility for a constant and dynamic collaboration between “creators”, including AI agents and people (general public and experts) in order to design new and “invisible” spaces. With the possibilities to include sound and

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[16] Note: "Black Mirror" is a contemporary series of speculative scenarios created around new technologies. https://www.imdb.com/title/tt2089050/?ref_=ttep_ep3
[17] https://www.midisprout.com/

brain waves into the creative process, the scenario 3 shows the idea that multisensorial data could aid "creators" to not just build such spaces but for other people to experience them. This would change the way we deal with tourism, since people could experience new spaces without having to travel. It is important to remember that questions emerged from scenario 3 are not limited to that application. The management of large amounts of datasets is a challenge that should be addressed, particularly because datasets can have more than 3D dimensions (and could go even beyond 4D). It might be possible that quantum computing enters into a stage that this type of question could answered by the use of quantum elements.

Future research in this area may consider the way we design and develop projects considering the fourth dimension. This could include new forms of geometric drawing and parametric algorithms that could aid the development of such spaces. Other possible applications of the fourth dimension are the consideration of this element within the Design discipline and its applications for educational purposes. Workshops considering the elements shown in this paper could be conducted with students or clients in order to enhance creative thinking.

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.

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