Four-dimensional objects, Cellular Automata and Virtual Reality – The Hypercocoon project

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Abstract. This research focuses on the problem of 4D objects generation and its representation. The hypothesis is that through the use of Cellular Automata and contemporary media like Virtual Reality, we can have a new way to generate and experience 4D objects (Hyper-objects). The methodology is to use an interactive generative algorithm to produce the form of a Hyper-object and VR goggles to explore 3D slices of it.

The representation of Cellular Automata systems is usually made by extrapolating one dimension. To exemplify: 1D CA is usually stacked to produce a 2D image. A 2D CA is stacked to produce a 3D Volume. Also, 3D CA systems are somehow represented as a series of 3D cubes because of our inability to imagine a 4D reality and what would be a 4D object, called Hyper-object.

Keywords. Cellular Automata, Virtual Reality, Orthogonal Projection, Hyperobjects

Introduction

Architecture has, in its core, representation tools that are able to reduce 3D objects in 2D drawings. From the Renaissance, especially through the work of Alberti and Dürer, plans and sections were instrumental to reduce one of the dimensions to understand the architectural object and its disciplinary problems: mass x voids, parts x whole, inside x outside.

1. HISTORICAL REFERENCES

1.1. Alberti

The invention of Architectural Design by Alberti separated the builder from the Architect. The Architect became the intellectual author through the use of drawings, specially one very specific kind: Orthogonal representations. Mathematically, it would be a kind of perspective where the observer is located in an infinite distance from the object. One of the first development of this kind of drawing was made by the Italian early Renaissance painter Piero della Francesca in the 15th Century:

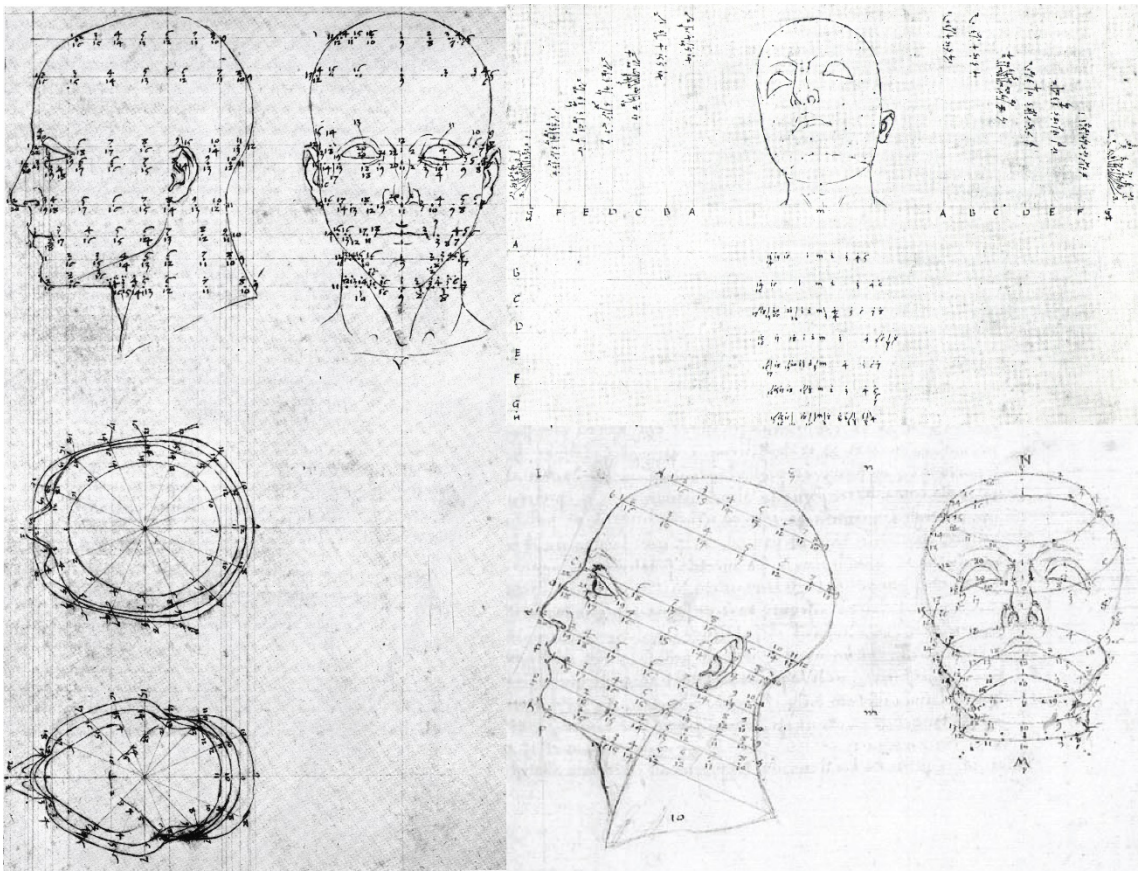

Figure 1: Piero Della Francesca, Elevations and Horizontal Outlines of the Human Head, in De Prospectiva Pingendi (On the Perspective for Painting (1474 – 1482).

Alberti, in his treatise, defended that architects, unlike painters, should not use vanishing point perspectival views because of its lack of "consistent lines", "true angles" and "real measurement, drawn to scale"[1]. Since then, for centuries, Architects were able to design three dimensional objects via two dimensional drawings.

1.2. Dürer

While Alberti avoided any kind of drawing in his treatise in favour of mathematic and algorithmic instructions to reproduce illustrations, Albrecht Dürer made large use of drawings in his treatises. At the beginning of the 16th Century, the artist and theorist born in Nuremberg *"adopted the term* diagram *(*Aufgerissen *or* Aufriss, *"what divides and makes visible," or simply "outline") to refer to the sectioning of reality through perpendicular planes and the translation of objects into series of coordinates in space"*[2]

Also, in his study of human proportion, Dürer developed a geometrical system to represent our bodies that operates through orthogonal drawings:

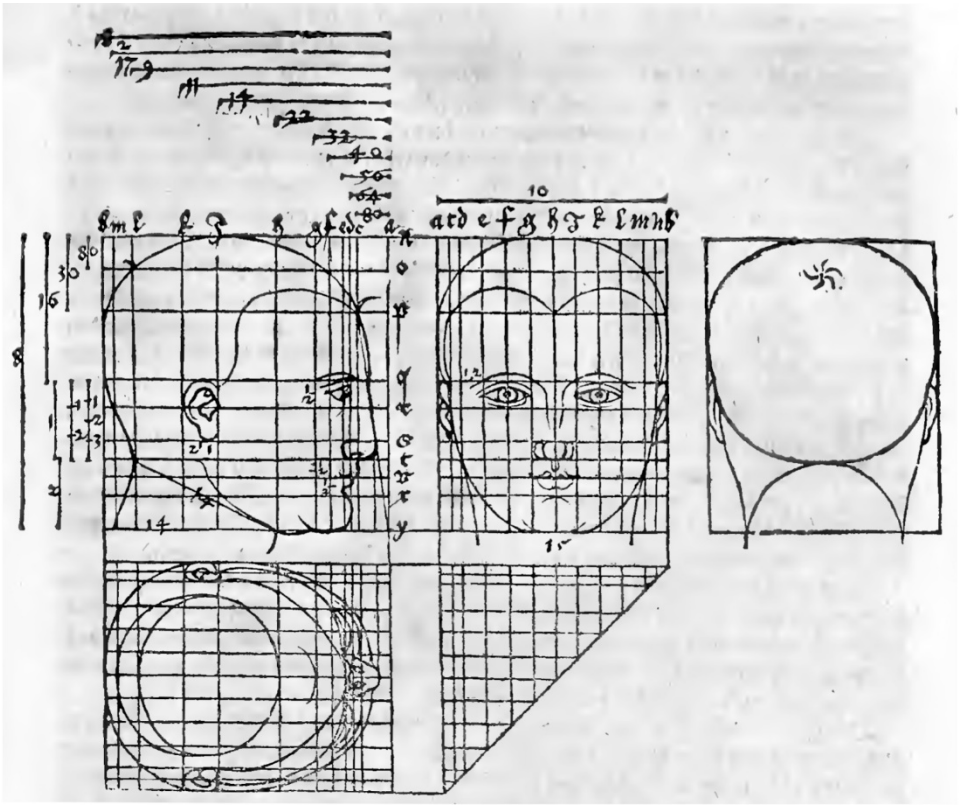

Figure 2: Albrecht Dürer, Four Books on Human Proportion (1532 - 34).

The historical period from the Renaissance until now has been the history of translating spacial objects into orthogonal drawings, or, in other terms, reducing or extrapolating dimensions. Our interest in both Duerer and Alberti lies in how both of them built the cornerstone of techniques to slice reality.

1.3. Duchamp and The Large Glass

The problem of the representation of 4D objects was grasped also by modern artists, mostly identified with the Cubist painters[3]. Duchamp, in an interview[4], declared that he was very interested on this mathematical problem after reading the work of Gaston de Povolowski, and that the bride in the “The Bride Stripped Bare by Her Bachelors, Even” painting, also known as “The Large Glass”, was a projection of a 4D object.

Figure 3: Detail of the figure of the Bride in Duchamp's "The Bride Stripped Bare by Her Bachelors, Even"

2. VIRTUAL REALITY AND THE CONTEMPORARY EXTRAPOLATION OF DIMENSIONS

2.1. Virtual Reality

With the recent advances of graphic cards and pixel density on screens, it's already possible to argue that nowadays we have sufficiently acceptable Virtual Reality experience with customer level solutions like HTC VIVE and Oculus Rift.

According to the philosopher Elizabeth Grosz, *"perhaps the most striking transformation effected by these technologies is the change in our perception of materiality, space, and information, which is bound directly or indirectly to affect how we understand architecture, habitation, and the built environment"*[5]. With the popularization of Virtual Reality goggles as a visualization tool, we have a immersive experience of virtual volumetric objects with one big difference in the way we experience reality: everything that was solid and static in our physical world became variable and malleable in our experience with digital materials.

2.2. Higher Dimensions

The project that culminates from this research produces the phenomenological experience of inhabiting a 4D object. Usually the 4D hyper-object is represented as a succession of cubes that are connected by lines in its vertices as seen in Figure 7**.** This way of representing it is an abstract extrapolation. The problem of imagining and producing the image of realities and objects with more or less than our three dimensional experience of space has been challenging humanity for a long period of time.

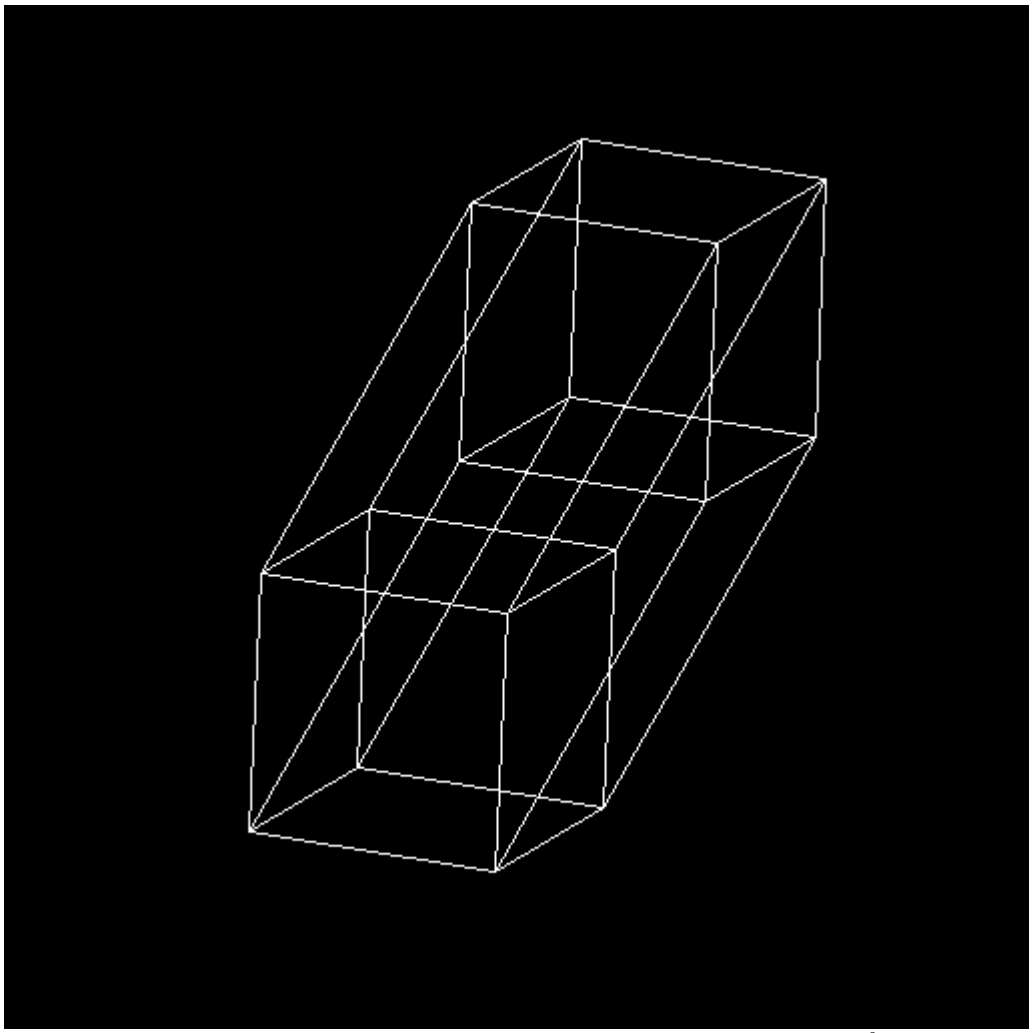

Figure 4: 4D Hypercube presented as cubes connected in the vertices with lines by Alan B. Scrivener[6]

A good example in literature is the book "Flatland" by Edwin Abbott Abbott[7]. First published in 1884, the novel features as a first-person narrator a square that describes, in detail, how is the experience of his two dimensional world and what is the social implications of such reality. The character, in different manners, visits three dimension and single dimensions worlds and, in all of them, for his bad luck, his ideas of worlds with even more dimensions are took as delusions of a mad man, in an indirect reference to Socrates interpretation of Plato's Cave, where he asserts that those who live in the world of shadows (2D) would violently react to the one who come back after seeing the world of objects (3D).

Definitely, it's counterintuitive to imagine objects with four dimensions because it finds no examples in the way we experience our world. So, through the use of CA and Virtual Reality, this project offers the possibility of inhabiting a 3D slice of a hyper-object.

2.3 Cellular Automata Hyper-Object

The representation of Cellular Automata systems is usually made by extrapolating one dimension. To exemplify: 1D CA is usually stacked to produce a 2D image. A 2D CA is stacked to produce a 3D Volume. Also, 3D CA systems are somehow represented as a series of 3D cubes because of our inability to imagine a 4D reality and what would be a 4D object, called Hyper-object.

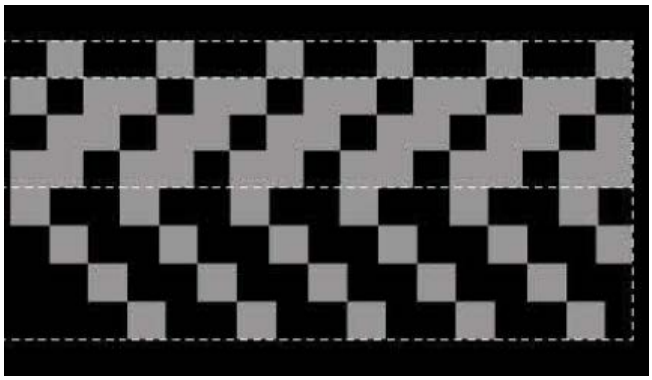

Figure 5. 1D (linear) CA System Stacked.

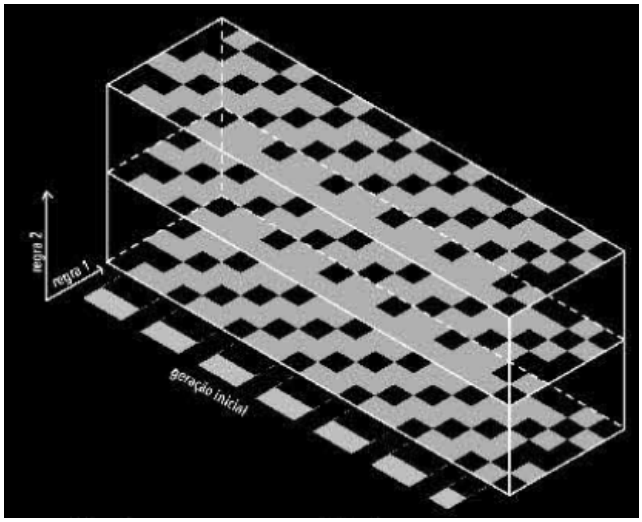

Figure 6. 2D (planar) CA System Stacked.

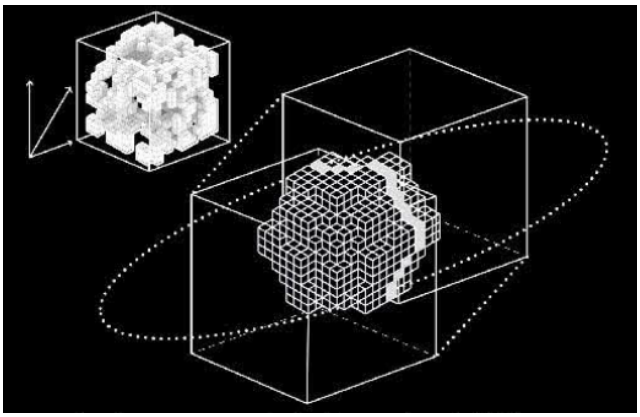

Figure 7. 3D (Volumetric) CA System as a Hyper-object:

The premise of the project is that if a orthographic drawing is a section of a 3D object, a 3D VR experience can be seen as a section of a hyper-object. The forms here created are not merely the development through time of the CA system, but also the result of the interaction between the subject and the system in real time. The project operates in two modes:

A. The user position changes the initial rule of the CA system or;
B. The user position changes the state of nearby cells.

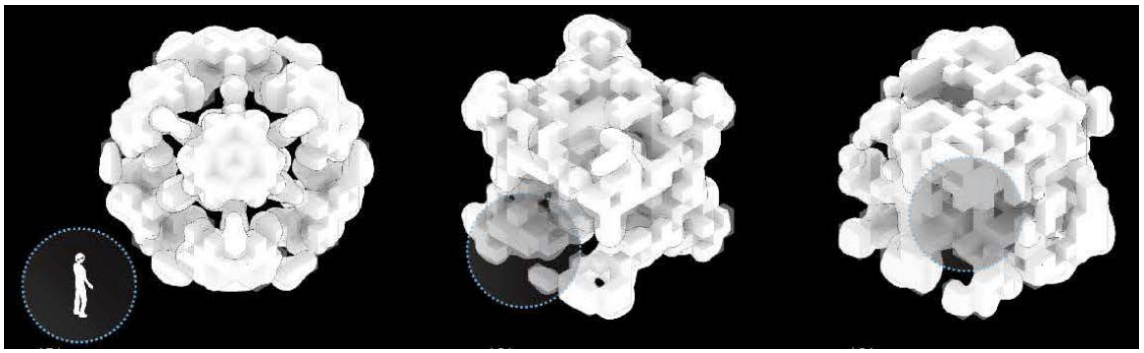
Figure 8. The changes in CA system according to the user's position.

To produce an architectural object, the project creates a virtual cocoon which dimensions are 6m x 6m x 6m. To give form to the system, two methods were developed in parallel: (a) the cell states informs Voxels and (b) the cell states charges a field that generates a Metaball mesh, according to the computational power available. The whole experience was produced using Rhino, Grasshopper, Python, Mindesk VR and a HTC VIVE goggle.

This research was developed during the workshop "Form finding and generative systems" realized by LAMO (Laboratório de Modelos e Fabricação Digital / Laboratory Models and Digital Fabrication) a Lab form the Post Graduation Research PROURB at Rio de Janeiro Federal University that was held from August 28th to September 6th 2017. The workshop goal was to compare different form-finding techniques (CA, GA, L-Systems and Shape Grammar)

3. CONCLUSION

The researchers realized that CA is a valid tool for multidimensional form making, being able to create n-dimensional objects. Also, VR goggles are very intuitive to experience such objects, pushing us to produce images of counter-intuitive worlds, and enabling us to be more comfortable with it.

This speculation becomes relevant for architectural discourse at the moment when we are faced with the popularization of Virtual Reality that introduces the possibility of infinitely adaptable geometries and the constant feedback between user and architectural object. If Architecture is a discipline that operates not only via physical buildings but has as its core drawings – and we believe that is the case and that it's the definition we depart from - , and *"the virtual reality of the computer space is fundamentally no different of writing, reading, drawing or even thinking,"*[8] Virtual Reality seems like an absolutely valid medium for architecture – be it for designing, visualizing and/or inhabiting these spaces.

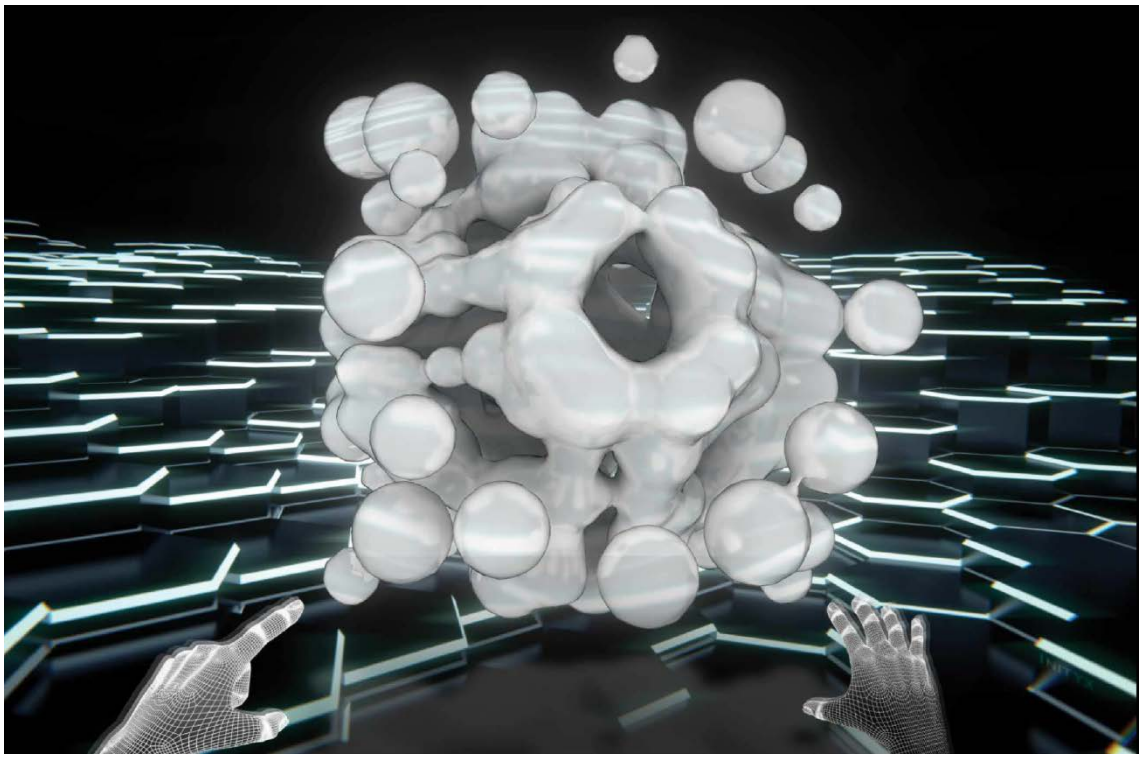
Figure 9. Artistic representation of the Hypercocoon as Metaball mesh in Virtual Reality

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