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Perceptional Boundaries

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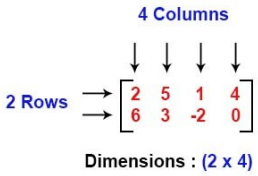
There comes a time when we emerge into a new world with a certain historical, political and social context. The genes we inherited provide us with certain predispositions for a variety of things. Nevertheless, we have to find our way through because there are plenty of pathways that we can choose to explore. These pathways are partially determined by a certain context that contains them. This container can be called a matrix. It has a variety of items attached to its context which can be all sorts of things like numbers, physical people or more metaphysical elements such as emotions or interactions. Basically, it is a defined space containing elements attached to the type of the matrix in question. But wait, there is a lot more to it! Through the means of this essay I will explore the meaning of the word matrix as well as its correlation to the boundaries defined to contain our environment. I will dive into historical and contextual meanings of this word to analyze the sub-matrixes that we as humans are able to observe around us. Defining sub elements of a wider and more complex container should provide us enough matter to be able to speculate on the possibility of ourselves being contained in a matrix. I will use arts as the reason of the exploration of my thoughts and science as a quantifier and analyzer of the subjects discussed. I will attempt to make a bridge between artistic and scientific audiences by balancing their respected counterparts.

First, let's have a chronological overview of its usage to gain a broader perspective of its possible meanings. The "matrix" originates from the Latin word matrix, matrices, which is itself derived from latin *mater*. The latter would mean "mother", which shows that the word "matrix" involves a component or structure that serves as support. This Latin definition can be used in several different contexts. First, this term related to "mother" was introduced as meaning the womb, the female reproductive organ, and was popularized in the sixteenth century. Today, it fell into disuse. Later, it referred to a cause or a place where an event takes its source. It is precisely this idea which is at the origin of the different meanings that we give to this term today. Around 1520, it designated letters of the mold stamping. In 1770, German author Holbach was one of the first to use this term as a common name for a "place where something is born" in his philosophical work *The System of Nature or, the Laws of the Moral and Physical World.* By following this path in 1845, the term was introduced in a completely different way in

botanics. Indeed, it is from that time that it became possible to use it as defining a mature tree with ripe fruit. It is important to emphasize that the name "matrix" also refers to a fundamental concept of mathematics and statistics, which was used later for the first time by James Joseph Sylvester in 1850. Finally, it seems that "matrix" could also be used as an adjective, like "matrix language" or "color matrix", to denote the language or colors from which all the others emerged.

In the following few paragraphs, I will explain one of the matrix more technical applications. Each paragraph will serve as support to its previous by providing fundamental concepts. I think that it is important to have a comprehension of its rather scientifical application studied in *Linear algebra* to understand the underlining beauty of this mathematical concept. It may require some additional time to reflect on this technical application. Therefore, the reader should not be intimidated because a lot of vulgarization will be provided further in this essay. Nevertheless, this few paragraphs will provide an intriguing overview of one of the smallest representations of a matrix to emulate our world.

In mathematics, a matrix is an array with rows and columns. An array has cases which you can picture as boxes that could contain a value : [box 1, box 2, … , box n] where n is some greater number. Once these boxes are put together or associated by an increasing index, their combination would be called an array.

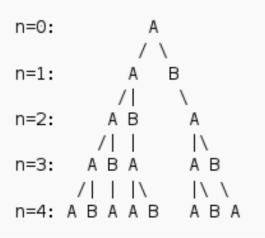


Here is a 2-dimensional matrix of two (rows) by three (columns). It is a way to arrange data and to simplify its manipulation whilst obeying certain rules proper to their matrix structure. It is possible to perform basic arithmetics on them. For example, one can only add two matrices to form a sum if both of them have the same number of rows and columns. There are indeed a lot of different areas where this mathematical structure is used. It is omnipresent in many fields like physics, mathematics and computer graphics. Therefore, we may say that it is a structure used to arrange data that is fundamental to science defined in a mathematical language.

Now that we understand its structure, where do we use it? Let's define what is a *Lindenmayer System*[1]. Also called an L-System, it is a formal grammar that defines a growing organism. Originally, the reason behind this was to use rules to find a pattern in growing plants in order to be able to study them in depth. The Algae is the simplest example of this.

[1] L-Systems, Wikipedia.

In the beginning there is an axiom, a root and from it, based on rules, we generate new elements at each new iteration. We can see that an axiom, root A in combination with these rules: (A → AB), (B → A), will generate the image below for each n iterations.



Let's put everything together by considering a 3-dimensional plant. If we want to generate it, we would have to be able to move at each iteration in three different axes, namely: x for left-right, y for top-bottom and z: deeper or closer. Therefore, we can represent each of the movements x, y, z by their rotation vectors which can be imagined as coordinates with a given direction referred to by a letter with a right arrow on top.

One can imagine a moving turtle that builds our plant using the movements we provide it. As the turtle progresses starting at the root, it takes different directions.

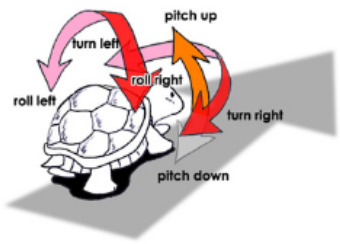


Fig.3 Turtle traveling in 3D space

The orientation of the turtle in space can be represented by three vectors H, L, U, indicating the turtle's heading, the direction to the left (or right), and the direction up (or down). Where R is a 3×3 rotation matrix. Specifically , rotations by angle α about vectors U, L and H are represented by the matrices in Fig.4. – Real-time 3D Plant Structure Modeling.

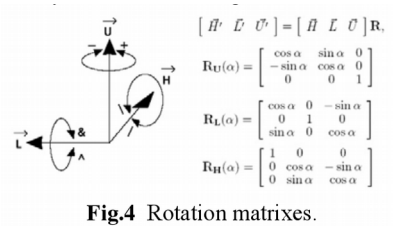


Fig.4 Rotation matrixes.

I think it would be fair to say that this summary of the technical aspect is necessary to understand the importance of the mathematical structure, namely the matrix and its nesting concept. It is clear that a tree contains a certain amount of sub matrixes defining its attributes. As we remember, it obeys its own arithmetic rules. Therefore, we can easily compute a tree to visually represent it in a certain virtual environment.

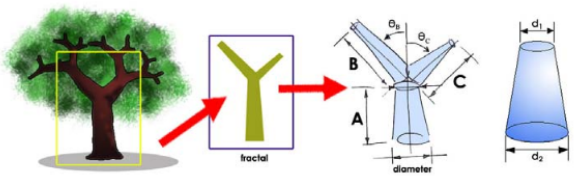


Fig.5 Measurement and plant characteristics extraction

Images source: Real-time 3D Plant Structure Modeling[2].

[2] Real-time 3D Plant Structure Modeling, National Electronics and Computer Technology Center.

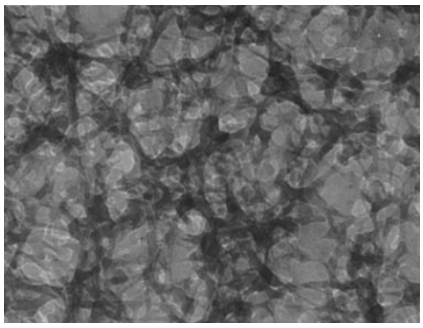
Moving a level higher, we could imagine that a tree is itself contained in a matrix. If we think of this situation using the analogy of Matrioshka, the Russian nested dolls, we can imagine that one matrix can contain another one and so on until the very foundations of the structure we wish to explore. We saw earlier an example of this on a mathematical foundation used to build an growing organism using the *Lindenmayer System* grammar.

As a student of the Computation Arts & Computer Science, I learn the computational paradigms and explore the technological mediums outside of their defined utility to question their function. The exploration of their unimagined applications helps me identify certain patterns of usage and gain a deeper understanding of the possible applications and boundaries. From my perspective, it seems that the technological mediums surrounding us tend to embody an integrated and highly specialized life assistants. We seem to become actors in a world adapted to our needs. As an analogy, we could picture characters in a video game. Usually, gamers tend to understand the boundaries of an open world video game that they play. In these types of games, a player faces different challenges and enemies, but how come an enemy can defeat them if they are performing at their best? Perhaps their reflexes weren't fast enough or their memory didn't have the capacity to store all of the possible strategic moves. It would be fair to say that an Artificial Intelligence has its part in this. We develop algorithms to implement Machine Learning techniques in order to create more challenging opponents that react to our set of actions. As for now, it seems that we haven't created a sufficiently complex virtual world that would not necessitate playing against other human beings that are more challenging to us. What if we created such an AI? Would it manage to become aware of our existence and control one of their own mortal coil by surpassing our capacities? In order for this intellect to understand the boundaries of its matrix (open world), it would first have to understand beyond it. Without going into speculation, let's consider that we are this intellect with a limited reach of our human capacities. We often use scientific tools, machines to reach beyond by seeing further with a microscope or perform more complex calculations by using the computational power. If we are able to push further our human capacities, we should be able to go one level higher in the matrix hierarchy every time an advancement is made. Thus, we can quantify better the different types of matrixes surrounding us.

The famous movie *The Matrix* of 1999 is indeed one of the most popularized associations to meaning of the word. In this scenario, the protagonist Neo finds himself a prisoner of a matrix created by machines to make humans believe they live their normal lives, while in reality they are being wired and exploited for their human energy in a world without sun where they are used as batteries for the machines. The movie's action scenes serve as exciting representations of complex and meaningful ideas. For instance, Neo's mentor and savior Morpheus tells him that he is a prisoner of his mindset which was built to conceal the ugly reality, a reality of which he is a slave, that he is in

a prison that he can not see nor smell. A social matrix as depicted in this case gives us an impression of empowerment over our future while in reality we are only spectators in automated cars driven by a combination of social, geographical and historical aspects. As the virtual world grows exponentially proportional to the technology today, our real world keeps merging more and more with a virtual one. Thus, the distinction between both becomes questionable. In the context of video games, they define their own rules of physics with a structural hierarchy. It is quite interesting to see a resemblance of this, in a more transparent level.

Still, it seems that comparing a virtual world with an organic one is a bit odd. If we're comparing them with the use of matrix, there should be a way to define the living organism in terms of it. Indeed, there is a way! It is possible to explore the concept of the matrix purely in biology :



researchers have named "cytomatrix", or "ground substance" the material in which connective cells and tissue are nested. The use of the word "matrix" in this case refers to its earliest meaning, "mother" : it illustrates how it is a structure that serves as support. This substance is of vital importance for all living creatures, seeing that it allows the proper functioning of biological cells. The Stereo pair of this image taken from Porter's[3] academic publication shows the three-dimensional structure of the cytoplasmic matrix in a cultured NRK (Normal Rat Kidney) cell after rapid freezing and drying from the frozen state.

It shows how the matrix is a key concept in a very wide range of fields, this case being the field of biology. For instance, it is well-known that many artists tried to capture the beauty of biology in their work. An example of this is Ernst Haeckel's *Art Forms in Nature*[4], which is an illustrated book depicting artistic renditions of biological forms he studied. He indeed shows that symmetry and fractals can be seen in nature through biology, and offers a new perspective on it, which can also be done with the concept of cytomatrix.

"*The Matrix is everywhere. It is all around us. Even now, in this very room. You can see it when you look out your window or when you turn on your television. You can feel it when you go to work... when you go to church... when you pay your taxes.*" - Morpheus.[5]

Are we contained in a matrix? All in all, even if we humans beings don't necessarily feel it, we are certainly starting to understand the meaning of surrounding matrixes in their various but related concepts. Perhaps by exploring a broader range of domains, one could identify elements and their surrounding boundaries.

[3] The cytomatrix : A short history of its study, K. R. Porter
[4] Art Forms in Nature, Ernst Haeckel, Wikimedia Commons
[5] Morpheus Quote, The Matrix (1999) movie

Do we actually learn to explore different concepts or are we just learning to become a specialized part of the matrix following a certain scheme? The Computation Arts field is strongly merged with Computer Science since it is depending on the computation performed by computers. It is clear that mathematical concepts are the abstraction and the foundations behind computation, whereas biology studies the living world around us by which is inspired the majority of our thinking to conceptualize technologies. Nevertheless, it seems that various science and arts fields are only starting to merge together on only few branches... In order to gain a broader understanding of the possible matrices, one should understand the correlation between diverse fields, subsystems.

As we have seen, even the living organisms have a matrix that contains its cells and tissues. Then, why wouldn't our world be itself contained in a higher dimensional matrix that we haven't yet been able to perceive?

References

[1] L-Systems, Wikipedia, [online], https://en.wikipedia.org/wiki/L-system

[2] Real-time 3D Plant Structure Modeling by L-System with Actual Measurement Parameters, Rawin Viruchpintu and Noppadon Khiripet, National Electronics and Computer Technology Center, Pathumthani 12120, Thailand, [online], http://www.bioquest.org/products/files/13157_Real-time%203D%20Plant%20Structure%20Modeling%20by%20L-System.pdf

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[5] Morpheus Quote, The Matrix (1999) movie, [online], http://www.imdb.com/title/tt0133093/quotes?item=qt0324255