Laboratório VISGRAF

Instituto de Matemática Pura e Aplicada

Metaverse

L. Velho

Technical Report   TR-22-03   Relatório Técnico

March   -   2022   -   Março

The Metaverse

Luiz Velho

The term "Metaverse" was created in 1992 by Neal Stephenson for his science fiction novel *Snow Crash* [7] to designate a three-dimensional virtual space in parallel to the real world. It was a "meta-universe", imagined as the virtual reality successor of the internet.

Since its inception the Metaverse has been associated with applications using virtual and augmented reality technologies, as well as, virtual worlds social platforms like *Second Life* [8]. As a consequence, these initiatives motivated a general perception of a trend towards an integration between virtual and physical spaces with virtual economies. that ultimately would involve the entire industry.

The scenario described above, accelerated by global transformations due to the COVID-19 pandemic, influenced the 5 major Web companies: Google; Apple; Facebook; Amazon and Microsoft, to proactively promote the Metaverse as their "vision of the future". For example, in 2021 Facebook changed the company name to Meta.

Given these facts, it is reasonable to imagine that the "metaverse wave" will gradually reach all sectors of modern society.

Here we consider Metaverse in a very broad sense, encompassing all innovations and technologies related to new media, communications and computing, such as IoT (internet of things), 5G, Cryptocurrencies, and Machine Learning.

In fact, we will not attempt to arrive at a precise definition of Metaverse since we believe it would be misleading given the diversity of points of view of such a phenomenon "in-process".

Nonetheless, it is enlightening to contrast Virtual and Augmented Reality with the notion of Metaverse. While the former (VR / AR) can be considered enabling media technologies, the latter (Metaverse) is a general application context in which they operate, together with many other technological innovations.

• **From Virtuality Continuum to Internet 4.0**

As discussed above, we can think of the Metaverse as a network of 3D virtual worlds focused on social connection, which is related to the real economy and physical spaces. In that sense, the concept of "virtuality continuum" is instrumental.

The Virtuality Continuum is a continuous scale ranging between the completely virtual (i.e., virtuality), and the completely real (i.e., reality). It was first introduced by Paul Milgram [1] and opens up possibilities for variations and compositions of real and virtual objects (See Figure 1).

The area between the two extremes, where both the real and the virtual are mixed, is called mixed reality. This in turn is said to consist of both augmented reality, where the virtual augments the real, and augmented virtuality, where the real augments the virtual.

The concept has been described in the context of new media and computer science, but in fact it could also be considered a matter of anthropology in the Metaverse scenario.
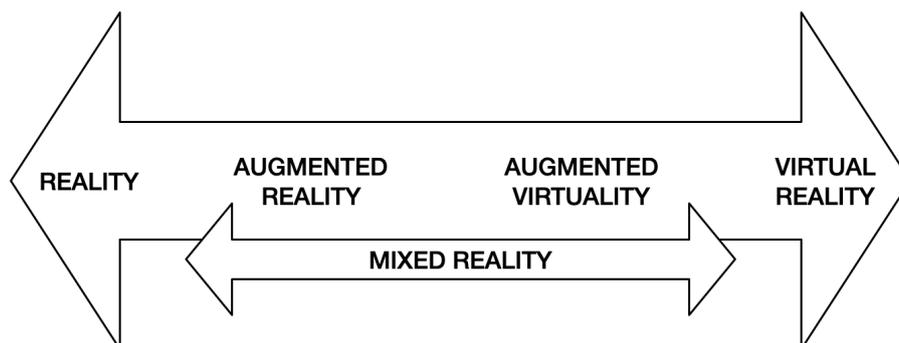

Figure 1 - The Virtuality Continuum. From [1].

Besides the Virtuality Continuum it is enlightening to take into account two other associated continua that also play a role in the unfolding of the Metaverse: the spectrum of technologies ranging from *augmentation* to *simulation*; and the spectrum of applications ranging from *personal* to *social*. The interplay of these two axis is depicted in Figure 2.

The augmentation-simulation axis is akin to AR-VR technologies where augmentation creates a layer onto our perception of the physical environment and simulation models a parallel reality of entire digital environments.

The personal-social axis is linked to a range of applications that focus either on individual users or the world pertaining to a group of users.

The combination of these two axis gives rise to four key components of the Metaverse landscape: Virtual Worlds; Mirror Worlds; Augmented Reality and Life-logging.

To complete the panorama, there are techniques that enable and link these components, such as: Networks and Interfaces; Modeling and Immersion; Sensors and IoT; Interaction and Identity.

This is the scenario proposed by John Smart in the "Metaverse Roadmap: Pathways to the 3D Web" [5].
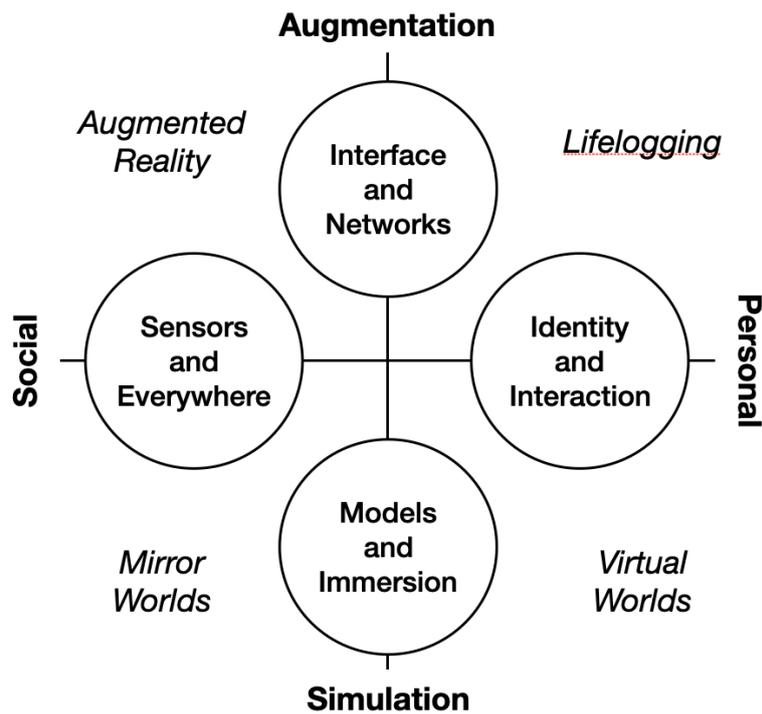

Figure 2 - Metaverse Scenarios. Adapted from [5].

Finally, in order to understand the Metaverse as a complete global context for applications is mister to analyze its relationships with the whole society at different levels. Jon Radoff, in "Measuring the Metaverse" [6], proposes a hierarchy of 7 layers where he moves up the value chain from infrastructure at the bottom to experience at the top, stopping at human interface, decentralization, spatial computing, creator economy, and discovery along the way.

Such conceptual framework employs a standard methodology of computer systems that provides a concrete characterization of the Metaverse as part of our culture, society and information industry.

In summary, as shown in Figure 3, these layers represent:

• Experience - what people engage with, e.g., games, shows, conferences, etc;

• Discovery - how people find out about an experience;

• Creator Economy - content market for the things in the metaverse;

• Spatial Computing - platforms for 3D environments and interaction;

• Decentralization - democratized distribution ecosystem;

• Human Interface - means of access to the metaverse: mobile, headsets, etc;

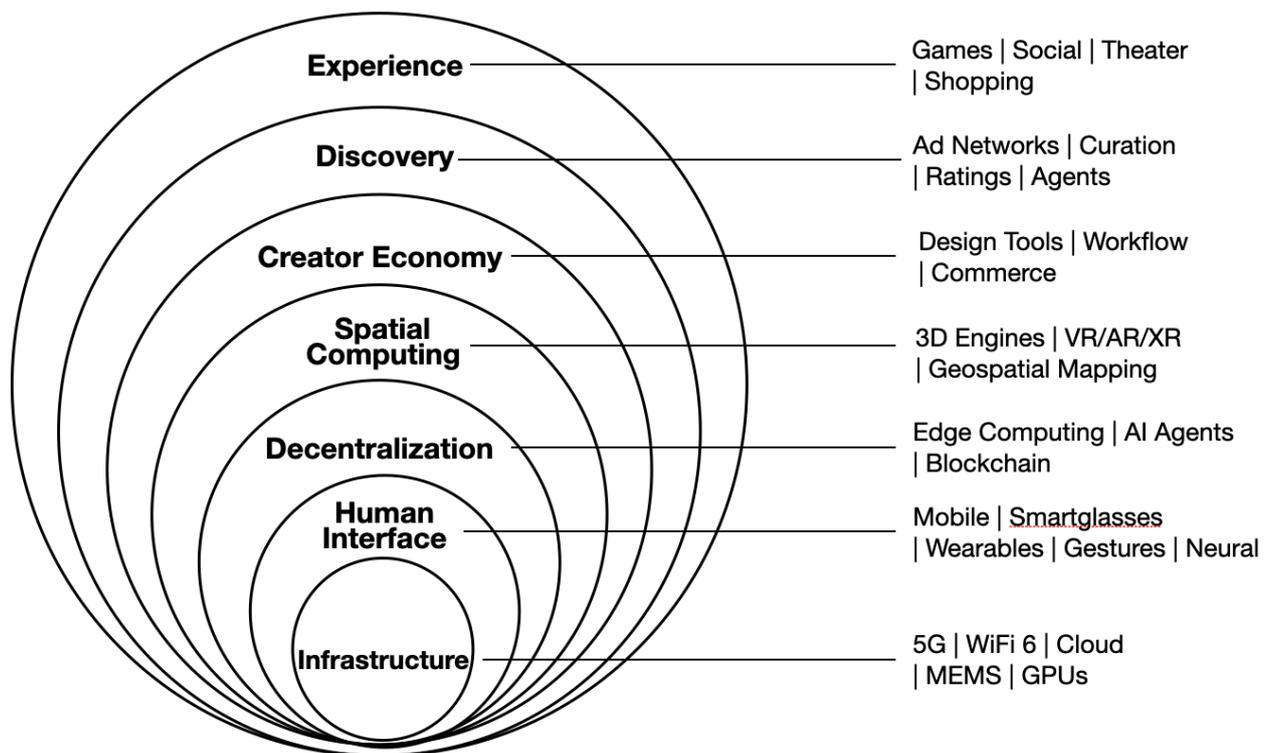• Infrastructure - cloud computing; telecommunication networks.

Figure 3 - The 7 Layers of the Metaverse. From [6].

In a way, the picture rendered above gives a prospective view of what the future Web promises with the Internet 4.0.

- **Expanded Reality for Mediatic Shared Experiences**

As we have seen in the previous section, at the top of the Metaverse pyramid lies "*the experience*". Arguably, from the user's point of view, this is the most relevant element because it is how people relate to the applications context.

It is important to highlight what is novel and unique about metaverse experiences. They are essentially "Mediatic Shared Experiences" within an "Expanded Reality". This scenario involves: mediation; communication and intelligence.

In such experiences the users share content and communicate with each other through an intelligent medium. In this setting we have three levels of abstraction: i) concrete — the metaverse technology; ii) perceptual — the psychophysiological fruition iii) symbolic — the involvement with content and activity. See Figure 4.
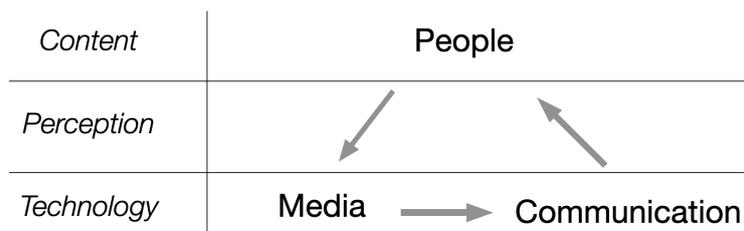

Figure 4 - Mediatic Shared Experience.

The mechanisms behind a metaverse experience belong to the field of study of "Computational Applied Mathematics for Media". This emerging branch of science deals with *mathematical models* that arise from *data sources* and are experienced by *users within an application.* These three entities are mediated by computational processes that enable the fulfillment of the experience.

As can be seen in Figure 5, the users interface with data though sensing and display processes (note that this involves perceptual aspects and this same mechanism allows users to interface with each other through data mediation). The data can be processed in different ways as a signal according to application requirements. Further, it can also go through a process of analysis to in order create a mathematical model that can be used for simulations, as well as in a synthesis process to generate new data [2], [3].

The Data / Model framework is based on many traditional disciplines of Science and Engineering. Recently, it has been enhanced by Artificial Intelligence and Machine Learning techniques.
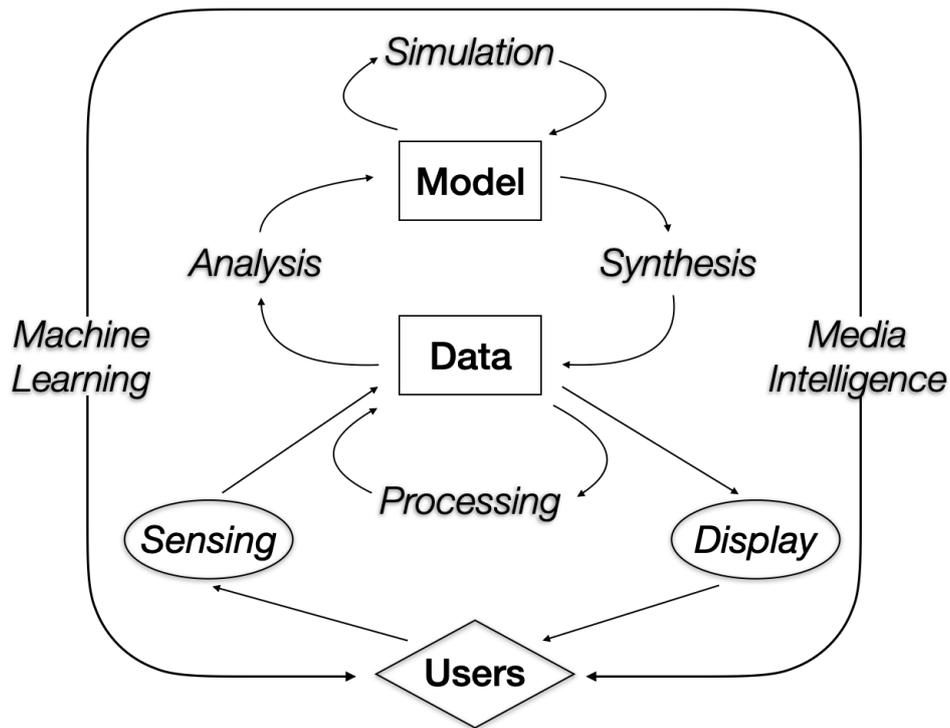
Figure 5 - Data / Model Framework.

References

[1] Paul Milgram; H. Takemura; A. Utsumi; F. Kishino (1994). "Augmented Reality: A class of displays on the reality-virtuality continuum". Proceedings of SPIE - The International Society for Optical Engineering Vol. 2351.

[2] Jonas Gomes and Luiz Velho. (1995) "Abstraction Paradigms for Computer Graphics". The Visual Computer, 11(5):227–239.

[3] Jonas Gomes, Bruno Costa, Lucia Darsa, and Luiz Velho. (1996) "Graphical Objects". The Visual Computer, 12(6):269–282.

[4] Marshall McLuhan, "Understanding Media",(2001) 2nd edition, Routledge.

[5] John Smart, Jamis Cascio, Jerry Paffendorf, (2007) "Metaverse Roadmap: Pathways to the 3D Web", Academia Letters.

[6] Jon Radoff, "The Metaverse Value-Chain", (2021) in Building the Metaverse. https://medium.com/building-the-metaverse

[7] Neal Stephenson (2007), Snow Crash, Rizzoli Eds.

[8] Wikipedia, "Second Life", 2003, https://en.wikipedia.org/wiki/Second_Life