The Metaverse in Industry 5.0: A Human-Centric Approach towards Personalized Value Creation

Contributor: Dimitris Mourtzis

In the context of Industry 5.0, the concept of the Metaverse aligns with the vision of Web 4.0, representing a digital ecosystem where individuals and organizations collaborate in a human-centric approach to create personalized value. This virtual universe connects multiple interconnected worlds, enabling real-time interactions between users and computer-generated environments. By integrating technologies like artificial intelligence (AI), virtual reality (VR), and the Internet of Things (IoT), the Metaverse within Industry 5.0 aims to foster innovation and enhance productivity, efficiency, and overall well-being through tailored and value-driven solutions. Therefore, this entry explores the concept of the Metaverse in the context of Industry 5.0, highlighting its definition, evolution, advantages, and disadvantages. It also discusses the pillars of technological advancement, challenges, and opportunities, including its integration into manufacturing. The entry concludes with a proposal for a conceptual framework for integrating the human-centric Metaverse into manufacturing.

Keywords: Metaverse ; Industry 5.0 ; Web 4.0 ; human-centricity

---

The Metaverse is another revolution of the Internet [1], which provides users an immersive experience through the support of communication channels between the real and virtual world [2]. It is a multi-dimensional (including the three dimensions of space and the dimension of time, among others) virtual space within which users can interact through their virtual replicas [3]. Consequently, implementation of the Metaverse facilitates the generation of a replica of the real/physical world, which can both interact with and affect certain aspects bidirectionally. Further to that, it facilitates everyday tasks such as trading, socialization, and work [4][5]. As a result, the design of new products will become an indispensable part of the Metaverse. Users will be capable of remotely collaborating with product developers, and knowledge can be transferred in a more robust way.

1.1. World Wide Web (WWW): From Web 1.0 to Web 3.0

Among technological advances and advancements, the creation and evolution of the WWW is of utmost importance. It began as a simple communication tool back in the 90s, and since then it has become a driving force for the communication of the world, the exchange of information and assets, the remote execution of tasks, and the collaboration of groups [6].

Web 3.0, also known as the Semantic Web, was introduced by Tim Berners-Lee et al. in their research [7]. What is worth noting is the vision of the authors for the structure of the Internet (see **Figure 1**), which amplifies the level of comprehension of the machines with the integration of ontology-based frameworks.
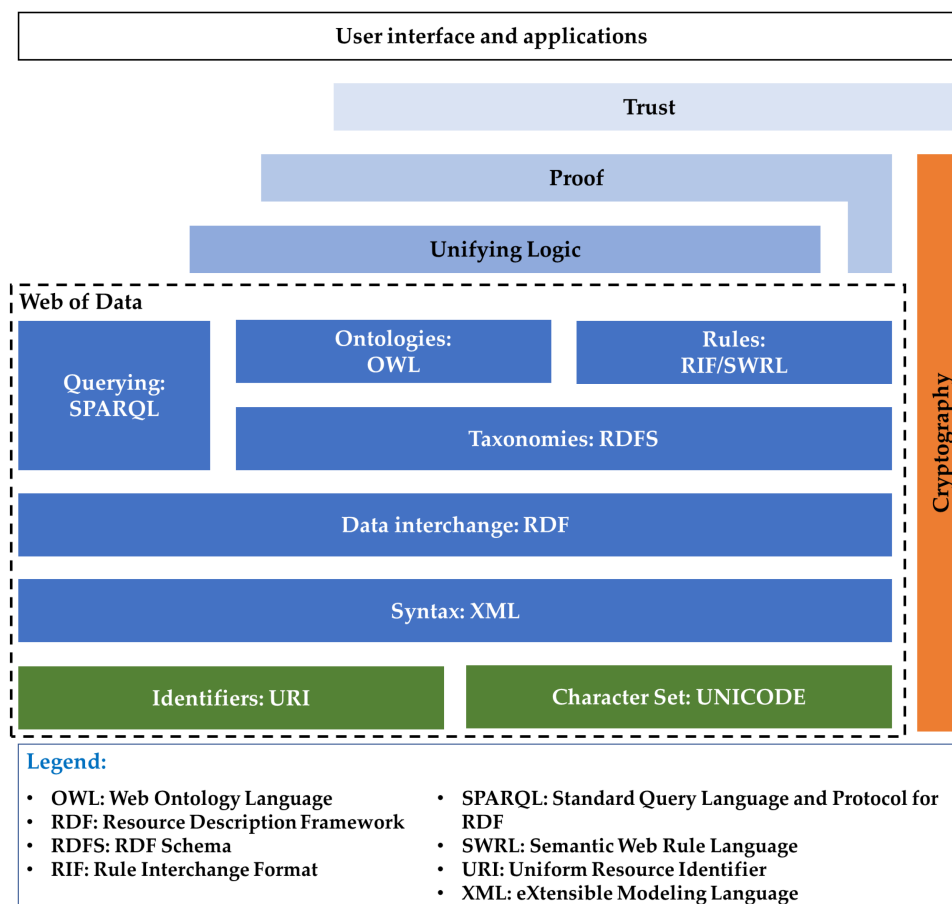
Figure 1. Web 3.0 stacked layer architecture (developed by the author).

1.2. Web 4.0 and the Metaverse

Web 4.0 currently has not been discussed adequately; however, it can be realized as the symbiotic web. Web 4.0, recognized as the fourth generation of the World Wide Web, is envisioned by the European Union executive to integrate artificial and ambient intelligence, Internet of Things devices, trusted blockchain transactions, virtual worlds, and extended reality. Web 4.0 envisions a harmonious interaction between humans and machines, leading to advanced interfaces like brain–computer interfaces (BCIs). It emphasizes efficient web content comprehension and execution for faster, superior website performance. This concept involves achieving a critical mass of network participation for global transparency and collaboration across sectors. Web 4.0, or webOS, resembles an operating system, facilitating highly intelligent interactions similar to the human brain [8]. While the concept of virtual worlds, commonly referred to as the Metaverse, is not novel, recent advancements in technology and improved connectivity infrastructure have prompted significant investments from companies like Meta. However, the outcomes of these investments have been met with uncertainty [9].

The objective of Web 4.0 is to enhance the inclusivity of the internet, specifically targeting individuals with disabilities who will benefit from the utilization of assistive technologies for improved access to web content. Web 4.0 is presently in its nascent phase, yet it has already exerted significant influence on our internet usage patterns. Anticipated advancements in the future are expected to further optimize user-friendliness and interactivity on the web, surpassing current standards. More specifically, in the era of Web 4.0, the convergence of the Metaverse and advanced BCIs promises to seamlessly merge virtual experiences with cognitive capabilities, leading to a new era of interconnected digital landscapes. A technological pillar to achieve that will be BCIs that facilitate human–computer interaction through the utilization of neural signals generated by the user's thoughts. By detecting and translating brain activity into computer-readable commands, BCIs have the potential to revolutionize our interactions with technology. While still at an early stage of development, BCIs exhibit immense promise for diverse applications, ranging from communication and control of prosthetic devices to entertainment. The transformative impact of BCIs extends beyond aiding individuals with disabilities, offering broader advancements in human–computer interaction as a whole [10].

In light of this projection, commissioner Thierry Breton introduced a non-legislative initiative concerning the Metaverse last year. The strategy emphasizes that virtual worlds are persistent and immersive environments, leveraging technologies such as 3D and extended reality (XR) to seamlessly blend the physical and digital realms in real time, serving diverse purposes [11]. In financial terms, the Metaverse is growing, indicating a potential investment opportunity beyond the hype. Concretely, in 2022, worldwide revenue for the Metaverse was rated at 65.51 billion US dollars. The corresponding

projections for 2023 are 82.02 billion US dollars, and, most importantly, it is estimated that by the end of 2030 the market size of the Metaverse will have grown by more than ten times reaching a value of 936.57 billion US dollars [12].

1.3. Web 4.0 and the Metaverse Need

In the rapidly evolving technological landscape, Web 4.0 emerges as the latest trend, necessitating our awareness and adaptation to remain at the forefront [13]. In summary, Web 4.0 is characterized by most of the technological pillars of Industry 4.0 (**Figure 2**) and the following properties [14]:

Figure 2. Web 4.0 and the Metaverse, common technologies (developed by the author).

- The online environment has to be consistently connected, enabling constant interaction. Users can connect with one another;

- The emerging web functions as a unified Web OS, where information seamlessly transfers between various points within the system;

- Background processes involve self-learning AI systems that strive to comprehend users, mimicking human communication patterns;

- It engages users through interpersonal communication methods, much like human interactions;

- It embodies an intelligent, interconnected, and open web structure;

- The speed and dependability of Web 4.0 exceed previous standards;

- It necessitates ubiquity, identity, and connectivity as fundamental prerequisites.

Based on the above, the following summarizing and comparative **Table 1** has been created.

Table 1. From Web 1.0 to Web 4.0—Technical Details (Developed by the Author).

Web Version	Description	Technical Aspects	Application Examples	Reference
Web 1.0	Static, read-only web content	Basic HyperText Markup Language (HTML) and Cascade Styling Sheet (CSS) for layout;	Early websites, online encyclopedias	[15]
Web 2.0	Interactive, user-generated content	Asynchronous JavaScript and XM (AJAX) for real-time interactivity	Social media platforms, Wikipedia, YouTube	[16]

Web Version	Description	Technical Aspects	Application Examples	Reference
Web 3.0	**Semantic web, machine-understandable data**	**Resource Description Framework (RDF), ontologies, metadata for semantic understanding**	**Linked data projects, semantic search engines**	[17]
Web 4.0	**AI-driven, immersive and personalized experiences**	**Artificial intelligence (AI), Internet of Things (IoT) integration, virtual reality, blockchain potential**	**AI virtual assistants, mixed reality applications**	[13]

1.4. Human-Centric Metaverse Challenges

The creation of the Metaverse poses a crucial challenge requiring a solution. As per the literature [6], the development and viability of the Metaverse are fundamentally centered around humans. Consequently, significant consideration must be given to human experience [18]. Furthermore, the Metaverse's operations necessitate the organization and involvement of human agents. Safeguarding human rights and combatting criminal activities within the Metaverse are also critical challenges that require attention [6]. Thus, by the time the conception of the Metaverse originated by humans, the Metaverse has to follow the principle of "placing the human operator/user first".

1.5. Contribution of the Paper

The EU's economic forecast for the period beyond 2030 [19] emphasizes digitalization as a primary driver, with Web 4.0 representing a significant technological shift leading to a seamlessly interconnected, intelligent, and immersive global environment. The virtual worlds market is projected to expand from €27 billion in 2022 to over €800 billion by 2030, indicating substantial growth [20]. Virtual worlds are set to impact societal dynamics, presenting both opportunities and challenges that require attention. The new strategy aims to align Web 4.0 and the Metaverse with EU values and principles, ensuring the full application of individuals' rights and fostering a conducive environment for European businesses. The strategy aligns with the Digital Decade policy's 2030 objectives [21], emphasizing skills, business, and public services in digitalization. Infrastructural aspects are covered through the Commission's connectivity package and broader initiatives, while addressing openness and global governance in virtual worlds and Web 4.0. The key strategy pillars are as follows: (1) empowering people and reinforcing skills; (2) business—supporting a European Web 4.0 industrial ecosystem; (3) government—supporting societal progress and virtual public services; and (4) shaping global standards for open and interoperable virtual worlds and Web 4.0.

Thus, this research explores the key intersection of cutting-edge technology and human-centered innovation, emphasizing how the Web-4.0-based industrial Metaverse can revolutionize Industry 5.0 by empowering individuals to actively shape and personalize value creation within the industrial landscape.

1.6. Manuscript Structure

The rest of the manuscript is structured as follows. In Section 2, an exploration of Cyber-Physical Systems (CPS) and their role in facilitating personalized value creation within the industrial Metaverse is presented. Then, in Section 3, a framework specifically designed for personalized value creation in the Metaverse, providing insights into its implementation and application, is discussed. Section 4 delves into the challenges faced in developing an industrial human-centric Metaverse and its relationship with Web 4.0. Finally, the concluding remarks summarize the key findings and contributions of the paper. The review methodology of this entry is analyzed in a detailed manner in the Supplementary Material, in which Figure S1 is used in order to indicate the most pertinent areas of research as well as their interconnections in the context of Metaverse and personalized value creation.

References

1. Mystakidis, S. Metaverse. Encyclopedia 2022, 2, 486–497.

2. Aloqaily, M.; Bouachir, O.; Karray, F.; Ridhawi, I.A.; Saddik, A.E. Integrating Digital Twin and Advanced Intelligent Technologies to Realize the Metaverse. IEEE Consum. Electron. Mag. 2022, 1–8.

3. Mourtzis, D.; Panopoulos, N.; Angelopoulos, J. Production management guided by industrial internet of things and adaptive scheduling in smart factories. In Design and Operation of Production Networks for Mass Personalization in the Era of Cloud Technology; Elsevier: Amsterdam, The Netherlands, 2022; pp. 117–152.

4. Qin, H.X.; Wang, Y.; Hui, P. Identity, Crimes, and Law Enforcement in the Metaverse. arXiv 2022, arXiv:2210.06134.

5. Wang, F.Y.; Qin, R.; Wang, X.; Hu, B. MetaSocieties in Metaverse: MetaEconomics and MetaManagement for MetaEnterprises and MetaCities. IEEE Trans. Comput. Soc. Syst. 2022, 9, 2–7.

6. Mourtzis, D.; Panopoulos, N.; Angelopoulos, J.; Wang, B.; Wang, L. Human centric platforms for personalized value creation in metaverse. J. Manuf. Syst. 2022, 65, 653–659.

7. Berners-Lee, T.; Hendler, J.; Lassila, O. The semantic web. Sci. Am. 2001, 284, 34–43.

8. Aghaei, S.; Nematbakhsh, M.A.; Farsani, H.K. Evolution of the world wide web: From WEB 1.0 to WEB 4.0. Int. J. Web Semant. Technol. 2012, 3, 1–10.

9. Polona, C.A.R.; André, M.T.; Maria, N. Metaverse: Opportunities, Risks and Policy Implications. 2022. Available online: https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)733557 (accessed on 25 July 2023).

10. Mourtzis, D.; Angelopoulos, J.; Panopoulos, N. The Future of the Human–Machine Interface (HMI) in Society 5.0. Future Internet 2023, 15, 162.

11. Bertuzzi, L. LEAK: EU Commission to Set Out Its Vision on the Metaverse, Web 4.0, EURACTIV. 2023. Available online: https://www.euractiv.com/section/platforms/news/leak-eu-commission-to-set-out-its-vision-on-the-metaverse-web-4-0/ (accessed on 20 July 2023).

12. Metaverse Market by Component, Vertical and Region—Global Forecast to 2027. Market Research Report 2022. Available online: https://www.marketsandmarkets.com/Market-Reports/metaverse-market-166893905.html?gclid=CjwKCAjwoqGnBhAcEiwAwK-OkaLifxbj9JphDw88AoKfBZTkmaFs3l9_XSmstcbHnoKJ3gZCcHqCBRoClKsQAvD_BwE (accessed on 18 July 2023).

13. Almeida, F. Concept and dimensions of web 4.0. Int. J. Comput. Technol. 2017, 16, 7.

14. Zhou, Z.; Li, Z.; Zhang, X.; Sun, Y.; Xu, H. A Review of Gaps between Web 4.0 and Web 3.0 Intelligent Network Infrastructure. arXiv 2023, arXiv:2308.02996.

15. Ibrahim, A.K. Evolution of the Web: From Web 1.0 to 4.0. Qubahan Acad. J. 2023, 1, 20–28.

16. Khanzode, C.A.; Sarode, R.D. Evolution of the world wide web: From web 1.0 to 6.0. Int. J. Digit. Libr. Serv. 2016, 6, 1–11.

17. Nath, K.; Dhar, S.; Basishtha, S. Web 1.0 to Web 3.0-Evolution of the Web and its various challenges. In Proceedings of the 2014 International Conference on Reliability Optimization and Information Technology (ICROIT), Faridabad, India, 6–8 February 2014; pp. 86–89.

18. George, A.S.H.; Maschio, F.; Shaji, G.; Baskar, T.; Digvijay, P. Metaverse: The next stage of human culture and the internet. Int. J. Adv. Res. Trends Eng. Technol. 2021, 8, 1–10.

19. Towards the Next Technological Transition: Commission Presents EU Strategy to Lead on Web 4.0 and Virtual Worlds. 2023. Available online: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3718 (accessed on 25 July 2023).

20. EU Competitiveness beyond 2030: Looking Ahead at the Occasion of the 30th Anniversary of the Single Market. 2023. Available online: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1668 (accessed on 25 July 2023).

21. Europe's Digital Decade. 2023. Available online: https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade#tab_2 (accessed on 18 July 2023).