EDU REKHA INTERNATIONAL JOURNAL OF ARTS, LAW AND SOCIAL SCIENCE

Journal Homepage: https://edurekhapublisher.com/erijalss/

Volume- 2 Issue – 4 (July-August) 2026

ISSN: 3107-5169 (Online)

Frequency: Bimonthly

PAGES: 172-180

ARTICLE TITLE:

The Role of Metavese in Image Segmentation: Recent Contributions and Applications

Basma Mohamed[1*] & Mahmoud Almashad[2]

[1]Department of Information Systems, Giza Higher Institute for Managerial Sciences, Giza, Egypt

[2]Department of Accounting, Giza Higher Institute for Managerial Sciences, Giza, Egypt

ARTICLE HISTORY

RECEIVED
16-07-2026

ACCEPTED
20-07-2026

PUBLISHED
08-08-2026

Corresponding author:

Basma Mohamed

Department of Information Systems, Giza Higher Institute for Managerial Sciences, Giza, Egypt

Abstract

Digital interactions and experiences are undergoing a significant evolution driven by the integration of the metaverse with cutting-edge image segmentation technology. The metaverse serves as a collective, persistent, and real-time virtual environment fusing digital and physical realities. Within this landscape, advanced image segmentation—the process of dividing an image into discrete, meaningful regions—acts as a vital computer vision foundation. By precisely identifying, tracking, and isolating visual elements in real time, segmentation facilitates the seamless overlay of digital objects onto physical environments. This intersection is crucial for driving immersion and intuitive interactions in virtual and augmented reality (VR/AR) platforms, impacting popular sectors such as gaming, education, professional collaboration, and healthcare.

This study comprehensively investigates how the metaverse transforms image analysis and segmentation techniques. The collaborative and immersive 3D workspaces offered by the metaverse enable multiple users to interact directly with segmentation masks, dramatically optimizing data analysis, communication, and workflow efficiency. Furthermore, the metaverse addresses a critical bottleneck in artificial intelligence development; its expansive environments generate vast, rich datasets and realistic synthetic simulations ideal for training and continuous algorithmic refinement, leading to highly robust deep learning models.

Beyond visual enhancement, the integration of image segmentation introduces vital accessibility features, such as gesture recognition and real-time audio descriptions, making immersive spaces more inclusive for individuals with impairments. Despite its notable promise, the progression of this field relies on addressing persistent technological, user experience, and ethical challenges, including cross-platform interoperability, data security, and cultural representation. Ultimately, this convergence establishes a dynamic, scalable platform that pushes the boundaries of computer vision and redefines how human society communicates and collaborates across digital landscapes.

Keywords: Metaverse, Image Segmentation, Augmented Reality, Virtual Reality, Object Recognition

1. Introduction

A complex idea, the metaverse is the fusion of digital and physical worlds, resulting in immersive, interactive areas where users can interact in real time with digital material and one another. Although Neal Stephenson's 1992 novel Snow Crash popularized the word, which has its origins in science fiction, the metaverse has developed into a concrete framework for a variety of technologies and applications [1].

The incorporation of cutting-edge picture segmentation technology is transforming the way users engage with virtual and augmented reality environments as the metaverse develops into a more immersive digital world [2]. By precisely identifying and following items in these areas, image segmentation improves user engagement and makes it possible to seamlessly superimpose digital material on the real environment [3]. In addition to enhancing real-time rendering and scene comprehension, this technology gives developers the ability to produce complex, interactive experiences that appeal to a wide variety of users, including people with impairments [4].

Furthermore, the vast amounts of data generated within the metaverse provide valuable resources for training AI models, driving continuous improvements in segmentation algorithms [5]. Overall, the intersection of the metaverse and image segmentation stands to significantly transform digital interactions, paving the way for a more engaging and inclusive future [6].

The metaverse is rapidly emerging as a transformative digital universe where virtual and augmented realities converge to create rich, interactive experiences for users [7]. At the heart of this evolution lies advanced image segmentation technology, which plays a pivotal role in enhancing user engagement and interaction within these immersive environments [8].

Image segmentation makes it possible to seamlessly integrate digital overlays with the actual world by precisely identifying and separating elements within visual material. This allows for real-time responsiveness and a stronger bond between users and their environment [9].

Image segmentation improves scene understanding in virtual and augmented reality, enabling computers to distinguish between distinct environmental aspects [10]. This feature not only improves the user experience by making virtual interactions seem more intuitive and natural, but it also increases the efficacy of digital information in a variety of contexts, including gaming and education [11]. With the use of this technology, developers may create complex apps that interact with users on several levels and provide engaging, personalized experiences based on context and personal preferences [12].

Moreover, picture segmentation significantly increases the metaverse's accessibility. This technology promotes inclusion by providing accommodations for users with impairments, guaranteeing that a wide range of audiences may participate completely in digital contexts [13]. This focus on accessibility is a basic design philosophy that improves the user experience generally, not just a feature [14]. Significant improvements in picture segmentation algorithms may result from the extensive datasets created in the metaverse, which offer a wealth of resources for machine learning model training and improvement [15]. The quality of interactions and experiences people have in the metaverse will be further improved as these algorithms get more precise and effective [16].

It is more than simply a tool for improving visual representations; it is a catalyst for rethinking how people interact with digital environments, opening up previously unthinkable avenues for creativity, communication, and teamwork [17]. A dynamic and inclusive digital world that revolutionizes user interactions and pushes the limits of our digital experiences is what the metaverse's future, powered by image segmentation technology, promises to be [18]. Additional details may be found in the literature [19–25].

This study investigates how the metaverse is starting to transform picture segmentation. The metaverse provides new methods for this basic computer vision problem by utilizing the immersive and interactive features of virtual and augmented reality. We go over current developments, such as AI-powered segmentation in virtual worlds, collaborative segmentation in shared virtual spaces, and interactive segmentation in virtual settings. Potential uses include a wide range of fields, including improving virtual and augmented reality experiences, remote collaboration, and medical picture analysis. The metaverse has enormous potential to greatly enhance the science of image segmentation, despite ongoing technological, user experience, and ethical problems.

2. Preliminaries Notes:

Definition 2.1 Image analysis is the process of interpreting and analyzing visual data by utilizing a variety of approaches to extract meaningful information from pictures. This can entail a variety of activities, including object identification, pattern recognition, feature measurement, and visual context comprehension. To efficiently interpret and analyze images, image analysis uses a variety of techniques from disciplines including computer vision, machine learning, and mathematics [26].

Definition 2.2 One of the most important aspects of image analysis is image segmentation, which is the act of dividing an image into many parts or areas in order to simplify its representation and increase its analytical significance. Segmentation is the process of grouping distinct areas of an image according to specific standards, such color, texture, intensity, or object boundaries. In order to enable focused analysis and interpretation, segmentation aims to separate particular regions of interest within a picture [27].

Remark 2.3: In order for computers to read and comprehend visual input, image analysis and segmentation are essential elements of contemporary computer vision. These technologies increase the efficiency of data processing, simplify in-depth analysis, and improve object recognition by segmenting complicated photos into digestible chunks [28].

3. Characteristics of the Metaverse:

The term "metaverse" refers to a collective virtual environment that includes the internet, augmented reality, virtual reality, and physical reality. It has a number of important characteristics [29-31]:

3.1 **Persistent:** The metaverse is always present, so even if users log out, its virtual worlds and interactions continue to exist and change. Events in the metaverse or user-made changes have long-term effects.

3.2 **Synchronous and Real-Time:** Metaverse exchanges take place in real time, simulating in-person encounters by fostering a sense of immediacy. Users are able to interact and work together as though they were in person.

3.3 **User-generated content:** The ability for users to produce and contribute material is a key feature of the metaverse. Users have a significant influence on how the environment is shaped, from developing digital materials to building virtual locations.

3.4 **Interoperability:** The metaverse strives for a degree of interoperability, which would allow content and avatars to flow freely between various virtual worlds and platforms, resulting in a cohesive user experience.

3.5 **Economy:** The metaverse has a working economy that frequently uses digital assets and cryptocurrency. Users can participate in a digital economy that emulates actual economic systems by purchasing, selling, and trading virtual products.

4. Technological Foundations:

The creation and operation of the metaverse are supported by a number of technologies:

4.1 **Virtual Reality (VR):** VR immerses users in digitally created worlds where they may interact with three-dimensional surroundings through the use of headgear and sensory gear [32].

4.2 **Augmented Reality (AR):** AR uses digital overlays to improve the actual world. Users may see and interact with virtual items that coexist with their actual environment by using gadgets like smartphones or AR glasses [33].

4.3 **Blockchain Technology:** To ensure security and transparency in the virtual economy, several metaverse platforms use blockchain technology to host decentralized apps (dApps), validate ownership of digital assets, and facilitate transactions [34].

4.4 **Artificial Intelligence (AI):** AI makes it possible for intelligent avatars, tailored suggestions, and automated virtual environment moderation, all of which improve user experiences in the metaverse [35].

4.5 **Cloud Computing:** The metaverse necessitates processing enormous volumes of data, which is made possible by cloud computing technologies that offer scalable resources for virtual experience hosting and delivery [36].

5. Applications of the Metaverse:

The metaverse encompasses a diverse range of applications across various industries:

5.1 **Gaming:** Among the most well-liked sections of the metaverse, this area allows users to make, share, and play games in realistic settings. This is demonstrated by games like Fortnite, Roblox, and Minecraft, which permit social interactions and player-generated content [37].

5.2 **Social Interaction:** Users may interact with communities, go to events, and hang out with pals from anywhere in the world thanks to the metaverse's platform for social experiences. Socializing settings may be found on platforms such as VRChat and Horizon Worlds [38].

5.3 **Training and Education:** To develop interactive learning environments, educational establishments are investigating the metaverse. Through experiential learning, training simulations and virtual classrooms may improve comprehension and engagement [39].

5.4 **Work and Collaboration:** In the metaverse, remote work capabilities are developing, enabling teams to collaborate efficiently regardless of their physical locations through virtual offices and collaboration areas. Virtual conference rooms that mimic face-to-face interactions are being tested by businesses [40].

5.5 **Retail & Commerce:** The metaverse creates new shopping opportunities by enabling users to peruse, try on, and buy both virtual and real goods in immersive settings. In an effort to improve consumer experiences, brands are experimenting with virtual shops [41].

6. Societal Impacts and Considerations:

There are important socioeconomic ramifications to the development of the metaverse:

6.1 **Digital Divide:** Technology and connection will be necessary for access to the metaverse. To prevent the digital gap from growing, it is imperative to guarantee fair access [42].

6.2 **Privacy and Security:** As virtual spaces and data sharing develop, worries about digital identities, privacy, and data security surface. To protect users, strong steps will be required [43].

6.3 **Cultural Representation:** The metaverse may encourage diversity since it is a varied platform. Ongoing conversations around representation and ethics in virtual places are necessary since it also runs the danger of reproducing prejudices and injustices found in the real world [44].

6.4 **Effect on Mental Health:** The metaverse's immersive and occasionally compulsive qualities prompt concerns about its potential effects on mental health. For users' wellbeing, virtual and in-person interactions must be balanced [45].

7. Types of the Metaverse:

The idea of the metaverse, which includes a variety of virtual settings and experiences, is intricate and dynamic. Below is a summary of some of the main categories of the metaverse:

7.1 The Metaverse of Gaming:

- **Description:** Interactive game environments that allow players to explore, compete, and work together [46].
- **Illustrations:**
  - **Roblox:** An online community where users can make and share original games and experiences.
  - **Fortnite:** It blurs the boundaries between social engagement and gaming by hosting concerts and other activities in addition to gameplay.
- Features: User-generated content, multiplayer functionality, and captivating visuals.

7.2 Metaverse Social:

- **Description:** Virtual environments created mainly for communication, social engagement, and community development [47].
- **As an illustration**, consider Facebook's (Meta) Horizon Worlds, an immersive social network where users may interact, explore, and collaborate.
  - **VR Chat:** A social media site that allows users to make avatars and communicate with friends and other people in other worlds.
- **Features:** Emphasis on social interactions, chat capabilities, and avatars.

7.3 Enterprise/Professional Metaverse:

- **Description:** Virtual workspaces designed for corporate training, remote work, and business collaboration [48].

Examples include:

- **Spatial:** A platform for virtual workspaces that allows groups to work together in three-dimensional settings.

- o **Microsoft Mesh:** A mixed-reality platform that facilitates remote collaboration and virtual meetings.
- **Features:** Productivity, virtual meetings, and collaboration tools.

7.4 The Metaverse of Education:

- **Description:** Virtual settings created for training, education, and learning materials [49].
- **As an illustration,** consider Engage, a platform for developing and presenting training simulations and immersive educational experiences.
- o **AltspaceVR:** Holds presentations and educational activities in a virtual reality environment.
- **Features** include immersive educational experiences, simulations, and interactive learning.

7.5 Business/Shopping Metaverse:

- **Synopsis:** Online markets where consumers may peruse, purchase, and sell products and services [50].
- **As an illustration,** consider Decentraland, a virtual marketplace where users may purchase and sell digital assets such as virtual real estate.
- **Sleepium Space:** Within its ecosystem, users may produce and exchange virtual products.
- **Features** include digital asset trading, brand engagement, and virtual shopping experiences.

7.6 Creative Metaverse:

- **Description:** Platforms that enable users to create and share art, music, and other creative content [51].

Examples:

- o **Cryptovoxels:** A user-built virtual world where users can create and showcase their digital art and creations.
- o **Horizon Worlds:** Tools for creators to build immersive content and experiences.
- **Characteristics:** User-generated content, artistic expression, and community showcases.

7.7 Mixed Reality Metaverse:

- **Description:** Environments that blend digital objects with the physical world through augmented reality (AR) and virtual reality (VR) technologies [52].

Examples:

- o Pokémon GO: A mobile game that overlays digital Pokémon onto the real world using AR.
- o Microsoft HoloLens: A mixed-reality headset that allows users to interact with holograms in their physical space.
- **Characteristics:** Combination of real-world elements with virtual overlays, interactive experiences.

7.8 Fitness and Health Metaverse:

- **Description:** Virtual environments focused on fitness, wellness activities, and health-related experiences [53].

Examples:

- o Supernatural: A VR fitness app that offers immersive workouts and virtual environments.
- o Beat Saber: Combines rhythm games with physical activity for an engaging workout experience.
- **Characteristics:** Gamified fitness experiences, community challenges, and health tracking.

7.8 Blockchain-Based Metaverse:

- **Description:** Metaverse environments built on blockchain technology that support decentralized ownership and transactions [54].

Examples:

- o The Sandbox: A virtual world where users can create and monetize their gaming experiences using blockchain.
- o Axie Infinity: A game where players breed, battle, and trade digital pets (Axies) as NFTs.
- **Characteristics:** Ownership of digital assets through NFTs, decentralized economies, and secure transactions.

8. Importance of Image Analysis and Segmentation:

8.1 Improved Object Recognition: More precise object detection and recognition inside pictures is made possible by image segmentation. Machine learning models are better able to distinguish between things by separating distinct components, which enhances performance in applications like medical imaging, autonomous driving, and face recognition [55].

8.2 Enabling Detailed Analysis: Analysts may examine particular aspects, including sizes, colors, and forms, in greater depth by dividing pictures into discrete sections. This is especially crucial in domains like medical diagnostics, where accurate examination of organ borders or tumor forms can guide treatment choices [56].

8.3 Increased Efficiency in Data Processing: By simplifying picture data, image segmentation facilitates processing and analysis. Algorithms can operate more quickly by concentrating on pertinent areas of the image rather than the full one, which is crucial for real-time applications like augmented reality or video monitoring [57].

8.4 Support for Advanced Applications: Applications like object tracking, scene comprehension, and picture classification depend on segmentation. For instance, safe navigation in autonomous cars depends on precisely identifying and segmenting objects, road signs, and pedestrians [58].

8.5 Automation and Machine Learning: Segmentation helps create automated systems that are capable of learning and adapting over time when combined with image analysis. AI models that have been trained on segmented pictures usually perform better in a variety of circumstances due to their increased accuracy and generalization [59].

8.6 Accessibility and Inclusion: By offering contextual information and improving engagement with the surroundings, segmentation aids in customizing experiences for users in applications where visual information is essential, such assistive technology or augmented reality [60].

8.7 Rich Data Insights: From unstructured picture information, rich, structured data may be extracted by image segmentation. Industries including retail (e.g., consumer behavior analysis), agricultural (e.g., crop monitoring), and environmental monitoring (e.g., land use analysis) may all benefit greatly from this structured data [61].

In conclusion, image segmentation and analysis are fundamental technologies that facilitate a multitude of applications in diverse sectors. They are essential in today's data-driven environment because of their capacity to enable sophisticated capabilities and offer insightful information.

9. Examining the Connection Between Image Segmentation Methods and the Metaverse:

Users' interactions with digital surroundings and virtual worlds are greatly influenced by the dynamic and transformational interplay between image segmentation techniques and the metaverse [62]. Image segmentation is becoming more and more important as the metaverse grows, adding aspects of augmented reality (AR) and virtual reality (VR). A deeper look at the intersection of these two domains is provided below:

9.1 Making Immersion Experiences Better

By enabling smooth interactions between digital information and the real world, image segmentation is essential to the creation of immersive experiences in the metaverse. Image segmentation makes it possible for apps that improve user engagement by precisely recognizing and discriminating items in real time, like [63]:

- **Augmented Reality (AR):** Segmentation enables the precise overlaying of digital items onto real-world settings in AR applications. A user may see a virtual couch in their living room, for instance, and the segmentation technology makes sure the digital item interacts with the actual world in a realistic way by obstructing or creating shadows [10].
- **Virtual Reality (VR):** To provide a feeling of presence and immersion, image segmentation tracks user motions and interactions with different objects in VR settings. By offering lifelike interactions, this feature improves training simulations, virtual tours, and gaming [64].

9.2 Object Recognition and Interaction in Real Time

Efficient real-time object detection is crucial for interactive applications in the metaverse. Techniques for image segmentation enable:

- **Gesture Recognition:** Segmentation helps identify hand gestures and movements, allowing users to move naturally when interacting with digital items. This technology is essential for developing user interfaces in virtual environments that are more engaging and intuitive [65].
- **Monitoring User Interaction:** Image segmentation makes it possible to monitor how users interact with different items in virtual worlds, allowing for the creation of tailored experiences depending on user behavior [66].

9.3 Content Development and Creation

Image segmentation is a potent tool for content generation for developers operating in the metaverse. Among its advantages are:

- **Simplified Asset Creation:** By simply separating components inside photos, segmentation enables developers to produce intricate 3D models and environments. This facilitates the creation of more intricate and aesthetically pleasing virtual environments by expediting the design process [67].
- **Improved Scene Understanding:** By assisting systems in comprehending the context of scenes, image segmentation improves user experiences. Developers may construct dynamic interactions based on the unique features of objects by identifying and classifying various aspects in a virtual world [68].

9.4 Features for Accessibility

For users with impairments, the incorporation of picture segmentation in the metaverse can improve accessibility by:

- **Adaptation of User Interfaces [69]:** Segmentation may be used to develop adaptable interfaces that accommodate a range of skills. For example, it can be used to generate gesture recognition for those unable to use conventional controllers or text reading by segmenting visual material.
- **Visual Assistance:** By highlighting significant things in real time and offering audio explanations of their environment, segmentation in augmented reality apps can help visually impaired users [70].

9.5 Training AI Models with Large Datasets

Better AI models for picture segmentation may be trained using the massive volumes of data produced in the metaverse, including user interactions:

- **Deep Learning Improvements:** Developers may train deep learning models to get excellent accuracy in real-time segmentation tasks by utilizing sizable datasets. This development is essential for improving user experiences and making more complex apps possible [71].
- **Continuous Improvement:** As users interact with the metaverse, information gathered about their behavior may be used to continuously enhance segmentation algorithms, which will ultimately increase the quality of immersion and interactions overall [72].

9.6 Potential for Industry Transformation

The metaverse and image segmentation have a link that goes beyond gaming and entertainment; it has the potential to revolutionize a number of industries, including:

- **Education:** By utilizing picture segmentation, AR and VR may provide dynamic, captivating learning environments that offer tailored instructional materials based on real-time analysis and feedback [73].
- **Healthcare:** Image segmentation may be used in simulation training and telemedicine in the metaverse, where accurate visual material is essential for efficient diagnosis and treatment planning [74].
- **Retail:** By enabling customers to see items in their own environments, augmented reality solutions for e-commerce use segmentation to improve the shopping experience and lower returns [75].

10. The importance of metaverse in image segmentation:

The metaverse plays a crucial role in advancing image segmentation through several key aspects:

10.1 Enhanced Interactivity and User Experience:

- o **Intuitive Interaction:** VR/AR allows for more natural and intuitive interaction with images. Users can directly manipulate segmentation masks, point, and gesture within the 3D space, leading to faster and more accurate results [76].

- **Immersive Visualization:** 3D visualizations within the metaverse provide a deeper understanding of the image data, aiding in the identification of subtle features and complex structures [77].

10.2 Collaborative Segmentation:

- **Shared Workspaces:** The metaverse enables multiple users to collaborate on segmentation tasks simultaneously in shared virtual environments. Experts from different domains can work together, share insights, and refine segmentation results [78].
- **Improved Communication:** VR/AR fosters better communication and coordination among collaborators, leading to more efficient and effective workflows [79].

10.3 Advanced Training and Evaluation:

- **Realistic Simulations:** The metaverse can create highly realistic and customizable virtual environments for training and evaluating image segmentation algorithms. This allows for testing in diverse and challenging scenarios, leading to more robust and generalizable models [80].
- **Data Augmentation:** The metaverse can be used to generate synthetic data for augmenting training datasets, improving the performance of AI-powered segmentation models [81].

10.4 Novel Applications:

- **Medical Imaging:** Enables more precise and efficient analysis of medical images, leading to improved diagnosis and treatment planning [82].
- **Industrial Inspection:** Facilitates remote collaboration and quality control in manufacturing and construction [83].
- **Autonomous Systems:** Improves the perception and navigation capabilities of autonomous vehicles and robots [84].

In essence, the metaverse provides a unique platform for pushing the boundaries of image segmentation by offering novel interactive experiences, collaborative tools, and advanced training environments.

11. Conclusion

Because it allows for accurate representations of digital surroundings and immersive interactions, picture segmentation is essential to improving user experiences in the metaverse. Accurately recognizing and isolating items inside virtual worlds enhances gaming and teamwork while encouraging creativity and innovation in content production.

For applications like augmented reality, where accurate identification of various objects is necessary for smooth interaction between the real and virtual worlds, image segmentation is crucial. By enabling improved accessibility, this technology makes the metaverse more accessible to people with different skill levels and enables sophisticated data analysis that can guide user engagement and design tactics.

As the metaverse develops further, the convergence of image segmentation technologies will influence sectors including professional cooperation, education, and gaming in addition to redefining virtual relationships. In the end, picture segmentation plays a critical part in creating a more dynamic and captivating metaverse that optimizes functionality and user happiness.

Abbreviations

AI	**Artificial Intelligence**
AR	**Augmented Reality**
VR	**Virtual Reality**

Author Contributions

Basma Mohamed: Conceptualization, Resources, Methodology, Writing – review & editing

Mohamed Hassouna: Data curation, Methodology, Investigation

Data Availability
No underlying data were collected or produced in this study.

Conflicts of Interest
The authors declare no conflicts of interest.

References

1. Jauhiainen, J. S. (2024). The Metaverse: Innovations and generative AI. *International Journal of Innovation Studies*, *8*(3), 262-272. https://doi.org/10.1016/j.ijis.2024.04.004
2. Uddin, M., Obaidat, M., Manickam, S., Laghari, S. U. A., Dandoush, A., Ullah, H., & Ullah, S. S. (2024). Exploring the convergence of Metaverse, Blockchain, and AI: A comprehensive survey of enabling technologies, applications, challenges, and future directions. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, *14*(6), e1556. https://doi.org/10.1002/widm.1556
3. Poornima, S., Sripriya, N., & Kavitha, M. G. (2024). Development of Augmented Reality Platform Using Image Processing with Deep Learning Techniques. *Journal of Electrical Systems*, *20*(3s), 249-256.
4. Wang, F., Zhang, Z., Li, L., & Long, S. (2024). Virtual Reality and Augmented Reality in Artistic Expression: A Comprehensive Study of Innovative Technologies. *International Journal of Advanced Computer Science & Applications*, *15*(3). https://doi.org/10.14569/IJACSA.2024.0150365
5. Soliman, M. M., Ahmed, E., Darwish, A., & Hassanien, A. E. (2024). Artificial intelligence powered Metaverse: analysis, challenges and future perspectives. *Artificial Intelligence Review*, *57*(2), 36. https://doi.org/10.1007/s10462-023-10641-x
6. Fadhel, M. A., Duhaim, A. M., Albahri, A. S., Al-Qaysi, Z. T., Aktham, M. A., Chyad, M. A.,... & Gu, Y. (2024). Navigating the metaverse: unraveling the impact of artificial intelligence—a comprehensive review and gap analysis. *Artificial Intelligence Review*, *57*(10), 264.
7. Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., & Krogstie, J. (2022). The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures. *Smart Cities*, *5*(3), 771-801.
8. Lian, Y., & Xie, J. (2024). The Evolution of Digital Cultural Heritage Research: Identifying Key Trends, Hotspots, and Challenges through Bibliometric Analysis. *Sustainability*, *16*(16), 7125. https://doi.org/10.3390/su16167125
9. Bhowmik, A. K. (2024). Virtual and augmented reality:

Human sensory-perceptual requirements and trends for immersive spatial computing experiences. *Journal of the Society for Information Display*, *32*(8), 605-646.
10. Dargan, S., Bansal, S., Kumar, M., Mittal, A., & Kumar, K. (2023). Augmented reality: A comprehensive review. *Archives of Computational Methods in Engineering*, *30*(2), 1057-1080. https://doi.org/10.1007/s11831-022-09831-2
11. Putawa, R. A., & Sugianto, D. (2024). Exploring User Experience and Immersion Levels in Virtual Reality: A Comprehensive Analysis of Factors and Trends. *International Journal Research on Metaverese*, *1*(1), 20-39.
12. Sa'ari, H., Sahak, M. D., & Skrzeszewskis, S. (2023). Deep learning algorithms for personalized services and enhanced user experience in libraries: a systematic review. *Mathematical Sciences and Informatics Journal (MIJ)*, *4*(2), 30-47.
13. Dudley, J., Yin, L., Garaj, V., & Kristensson, P. O. (2023). Inclusive Immersion: a review of efforts to improve accessibility in virtual reality, augmented reality and the metaverse. *Virtual Reality*, *27*(4), 2989-3020. https://doi.org/10.1007/s10055-023-00858-z
14. Dincelli, E., & Yayla, A. (2022). Immersive virtual reality in the age of the Metaverse: A hybrid-narrative review based on the technology affordance perspective. *The journal of strategic information systems*, *31*(2), 101717.
15. Rudnicka, Z., Szczepanski, J., & Pregowska, A. (2024). Artificial Intelligence-Based Algorithms in Medical Image Scan Segmentation and Intelligent Visual Content Generation—A Concise Overview. *Electronics*, *13*(4), 746.
16. Xi, N., Chen, J., Gama, F., Riar, M., & Hamari, J. (2023). The challenges of entering the metaverse: An experiment on the effect of extended reality on workload. *Information Systems Frontiers*, *25*(2), 659-680. https://doi.org/10.1007/s10796-022-10244-x
17. Almeida, G. G. F. (2024). The Metaverse Territorial Brand: A Contemporary Concept. *Encyclopedia*, *4*(4), 1472-1481.
18. Dionisio, J. D. N., Iii, W. G. B., & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM computing surveys (CSUR)*, *45*(3), 1-38.
19. Asiri, A., & Mohamed, B. (2024). Binary fruit fly optimization algorithm for counting the number of spanning trees in networks. *Advances and Applications in Discrete Mathematics*, *41*(8), 663-676.
20. Mohamed, B., & Fattah, K. E. A. M. A. (2024). A Comprehensive Survey on the Role of Law in Different Applications in Computer Science. *Social Sciences*, *13*(6), 192-196. https://doi.org/10.11648/j.ss.20241305.17
21. Almotairi, S., Alharbi, O., Alzaid, Z., Hausawi, Y. M., Almutairi, J., & Mohamed, B. (2024). Secure dominant metric dimension of new classes of graphs. *Kongzhi yu Juece/Control and Decision*, *39*(5), 2705-2714.
22. Fattah, K. E. A. M. A., & Mohamed, B. (2024). The Role of Law in Addressing the Risks of Using Artificial Intelligence. *International Journal of Science, Technology and Society*, *12*(4), 151-158. https://doi.org/10.11648/j.ijsts.20241204.13
23. Mohamed, B., Mohaisen, L., & Amin, M. (2023). Binary Archimedes Optimization Algorithm for Computing Dominant Metric Dimension Problem. *Intelligent Automation & Soft Computing*, *38*(1). https://doi.org/10.32604/iasc.2023.041697
24. Mohamed, B., Batiha, I. M., Odeh, M., & El-Meligy, M. Computing the Independent Domination Metric Dimension Problem of Specific Graphs. Journal of Mechanics of Continua and Mathematical Sciences, *19*(12),256-264.
25. Mohamed, B., Mohaisen, L., & Amin, M. (2022). Binary equilibrium optimization algorithm for computing connected domination metric dimension problem. *Scientific Programming*, *2022*(1), 6076369.
26. Alrawahneh, A. A. M., Abdullah, S. N. A. S., Abdullah, S. N. H. S., Kamarudin, N. H., & Taylor, S. K. (2025). Video authentication detection using deep learning: a systematic literature review. *Applied Intelligence*, *55*(3), 239. https://doi.org/10.1007/s10489-024-05886-0
27. Tadesse, D. M., Kebede, S. R., Debele, T. G., & Waldamichae, F. G. (2025). Application of deep reinforcement learning in various image processing tasks: a survey. *Evolving Systems*, *16*(1), 13.
28. Manakitsa, N., Maraslidis, G. S., Moysis, L., & Fragulis, G. F. (2024). A review of machine learning and deep learning for object detection, semantic segmentation, and human action recognition in machine and robotic vision. *Technologies*, *12*(2), 15. https://doi.org/10.3390/technologies12020015
29. Mystakidis, S. (2022). Metaverse. *Encyclopedia*, *2*(1), 486-497.
30. Nevelsteen, K. J. (2018). Virtual world, defined from a technological perspective and applied to video games, mixed reality, and the Metaverse. *Computer animation and virtual worlds*, *29*(1), e1752.
31. Kemec, A. (2022). From reality to virtuality: Re-discussing cities with the concept of the metaverse. *International Journal of Management and Accounting*, *4*(1), 12-20. https://doi.org/10.34218/IJMA.4.1.2022.002
32. Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., & Krogstie, J. (2022). The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures. *Smart Cities*, *5*(3), 771-801.
33. Carbonell Carrera, C., & Bermejo Asensio, L. A. (2017). Augmented reality as a digital teaching environment to develop spatial thinking. *Cartography and geographic information science*, *44*(3), 259-270.
34. Gadekallu, T. R., Wang, W., Yenduri, G., Ranaweera, P., Pham, Q. V., da Costa, D. B., & Liyanage, M. (2023). Blockchain for the metaverse: A review. *Future Generation Computer Systems*, *143*, 401-419. https://doi.org/10.1016/j.future.2023.02.011
35. Fadhel, M. A., Duhaim, A. M., Albahri, A. S., Al-Qaysi, Z. T., Aktham, M. A., Chyad, M. A.,... & Gu, Y. (2024). Navigating the metaverse: unraveling the impact of artificial intelligence—a comprehensive review and gap analysis. *Artificial Intelligence Review*, *57*(10), 264.
36. Lin, L., Chen, Y., Zhou, Z., Li, P., & Xiong, J. (2023). When metaverse meets computing power networking: an energy-efficient framework for service placement. *IEEE Wireless Communications*, *30*(5), 76-85.
37. Sabtu, M. A. S. (2023). Metaverse and soft skills development through video games. In *Metaverse applications for new business models and disruptive innovation* (pp. 120-132). IGI Global. https://doi.org/10.4018/978-1-6684-6097-9.ch008

38. Ortiz, L. (2022). Risks of the metaverse: A vrchat study case. *The Journal of Intelligence, Conflict, and Warfare*, *5*(2), 53-128.
39. Damaševičius, R., & Sidekerskienė, T. (2024). Virtual worlds for learning in metaverse: a narrative review. *Sustainability*, *16*(5), 2032.
40. Popescu, G. H., Ciurlău, C. F., Stan, C. I., Băcănoiu, C., & Tănase, A. (2022). Virtual workplaces in the metaverse: immersive remote collaboration tools, behavioral predictive analytics, and extended reality technologies. *Psychosociological Issues in Human Resource Management*, *10*(1), 21-34. https://doi.org/10.22381/PIHRM10120222
41. Gomes, J., Gain, N., Thakur, R., & Singh, N. (2024). Reimagining Retail: Embracing the Metaverse for a New Shopping Experience. *Library Progress International*, *44*(3), 13439-13448.
42. Othman, A., Chemnad, K., Hassanien, A. E., Tlili, A., Zhang, C. Y., Al-Thani, D.,... & Altınay, Z. (2024). Accessible Metaverse: A Theoretical Framework for Accessibility and Inclusion in the Metaverse. *Multimodal Technologies and Interaction*, *8*(3), 21. https://doi.org/10.3390/mti8030021
43. Wang, Y., Su, Z., Zhang, N., Xing, R., Liu, D., Luan, T. H., & Shen, X. (2022). A survey on metaverse: Fundamentals, security, and privacy. *IEEE Communications Surveys & Tutorials*, *25*(1), 319-352.
44. Zallio, M., & Clarkson, P. J. (2022). Designing the metaverse: A study on inclusion, diversity, equity, accessibility and safety for digital immersive environments. *Telematics and Informatics*, *75*, 101909.
45. Creed, C., Al-Kalbani, M., Theil, A., Sarcar, S., & Williams, I. (2024). Inclusive augmented and virtual reality: A research agenda. *International Journal of Human–Computer Interaction*, *40*(20), 6200-6219. https://doi.org/10.1080/10447318.2023.2244111
46. Nevelsteen, K. J. (2018). Virtual world, defined from a technological perspective and applied to video games, mixed reality, and the Metaverse. *Computer animation and virtual worlds*, *29*(1), e1752.
47. Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., & Krogstie, J. (2022). The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures. *Smart Cities*, *5*(3), 771-801. https://doi.org/10.3390/smartcities5030040
48. Ye, M., Sun, L., & Shen, J. (2022, May). Cultivation of innovative talents with information characteristics for engineering education orientation. In *2022 International Conference on Engineering Education and Information Technology (EEIT)* (pp. 62-65). IEEE.
49. Contreras, G. S., González, A. H., Fernández, M. I. S., Martínez, C. B., Cepa, J., & Escobar, Z. (2022). The importance of the application of the metaverse in education. *Modern Applied Science*, *16*(3), 1-34.
50. Hamurcu, A. U. (2022). The metaverse, online communities, and (real) urban space. *Urbani izziv*, *33*(2), 73-81.
51. Baía Reis, A., & Ashmore, M. (2022). From video streaming to virtual reality worlds: an academic, reflective, and creative study on live theatre and performance in the metaverse. *International Journal of Performance Arts and Digital Media*, *18*(1), 7-28. https://doi.org/10.1080/14794713.2021.2024398
52. Smart, P. (2022). Minds in the metaverse: Extended cognition meets mixed reality. *Philosophy & Technology*, *35*(4), 87.
53. Petrigna, L., & Musumeci, G. (2022). The metaverse: A new challenge for the healthcare system: A scoping review. *Journal of functional morphology and kinesiology*, *7*(3), 63.
54. Ersoy, M., & Gürfidan, R. (2023). Blockchain-based asset storage and service mechanism to metaverse universe: Metarepo. *Transactions on Emerging Telecommunications Technologies*, *34*(1), e4658.
55. Guo, Y., Liu, Y., Georgiou, T., & Lew, M. S. (2018). A review of semantic segmentation using deep neural networks. *International journal of multimedia information retrieval*, *7*, 87-93. https://doi.org/10.1007/s13735-017-0141-z
56. Brauer, M., & Wiersema, M. (2018). Analyzing analyst research: A review of past coverage and recommendations for future research. *Journal of Management*, *44*(1), 218-248.
57. Chouhan, S. S., Kaul, A., & Singh, U. P. (2019). Image segmentation using computational intelligence techniques. *Archives of Computational Methods in Engineering*, *26*, 533-596. https://doi.org/10.1007/s11831-018-9257-2
58. Hoeser, T., Bachofer, F., & Kuenzer, C. (2020). Object detection and image segmentation with deep learning on Earth observation data: A review—Part II: Applications. *Remote Sensing*, *12*(18), 3053.
59. Ghosh, S., Das, N., Das, I., & Maulik, U. (2019). Understanding deep learning techniques for image segmentation. *ACM computing surveys (CSUR)*, *52*(4), 1-35.
60. Khamaj, A., & Ali, A. M. (2024). Adapting user experience with reinforcement learning: Personalizing interfaces based on user behavior analysis in real-time. *Alexandria Engineering Journal*, *95*, 164-173. https://doi.org/10.1016/j.aej.2024.03.045
61. Balducci, B., & Marinova, D. (2018). Unstructured data in marketing. *Journal of the Academy of Marketing Science*, *46*, 557-590.
62. Zhang, L., Anjum, M. A., & Wang, Y. (2024). The impact of trust-building mechanisms on purchase intention towards metaverse shopping: the moderating role of age. *International Journal of Human–Computer Interaction*, *40*(12), 3185-3203.
63. Xu, M., Ng, W. C., Lim, W. Y. B., Kang, J., Xiong, Z., Niyato, D.,... & Miao, C. (2022). A full dive into realizing the edge-enabled metaverse: Visions, enabling technologies, and challenges. *IEEE Communications Surveys & Tutorials*, *25*(1), 656-700.
64. Hudson, S., Matson-Barkat, S., Pallamin, N., & Jegou, G. (2019). With or without you? Interaction and immersion in a virtual reality experience. *Journal of business research*, *100*, 459-468. https://doi.org/10.1016/j.jbusres.2018.10.062
65. Tsai, T. H., Huang, C. C., & Zhang, K. L. (2020). Design of hand gesture recognition system for human-computer interaction. *Multimedia tools and applications*, *79*(9), 5989-6007.
66. Zhao, Y., Jiang, J., Chen, Y., Liu, R., Yang, Y., Xue, X., & Chen, S. (2022). Metaverse: Perspectives from graphics, interactions and visualization. *Visual Informatics*, *6*(1),

56-67.
67. Wang, C., Tinsley, L., & Honarvar Shakibaei Asli, B. (2024). Development of a Virtual Environment for Rapid Generation of Synthetic Training Images for Artificial Intelligence Object Recognition. *Electronics*, *13*(23), 4740. https://doi.org/10.3390/electronics13234740
68. Valipoor, M. M., & De Antonio, A. (2023). Recent trends in computer vision-driven scene understanding for VI/blind users: a systematic mapping. *Universal Access in the Information Society*, *22*(3), 983-1005.
69. Punchoojit, L., & Hongwarittorrn, N. (2017). Usability studies on mobile user interface design patterns: a systematic literature review. *Advances in Human-Computer Interaction*, *2017*(1), 6787504.
70. Khan, M. A., Paul, P., Rashid, M., Hossain, M., & Ahad, M. A. R. (2020). An AI-based visual aid with integrated reading assistant for the completely blind. *IEEE Transactions on Human-Machine Systems*, *50*(6), 507-517.
71. Lateef, F., & Ruichek, Y. (2019). Survey on semantic segmentation using deep learning techniques. *Neurocomputing*, *338*, 321-348. https://doi.org/10.1016/j.neucom.2019.02.003
72. Bhattacharya, P., Saraswat, D., Savaliya, D., Sanghavi, S., Verma, A., Sakariya, V., & Manea, D. L. (2023). Towards future internet: The metaverse perspective for diverse industrial applications. *Mathematics*, *11*(4), 941.
73. Alshammari, A., & Al-Enezi, S. (2024). Role of artificial intelligence in enhancing learning outcomes of pre-service social studies teachers. *Journal of Social Studies Education Research*, *15*(4), 163-196.
74. Tan, T. F., Li, Y., Lim, J. S., Gunasekeran, D. V., Teo, Z. L., Ng, W. Y., & Ting, D. S. (2022). Metaverse and virtual health care in ophthalmology: Opportunities and challenges. *Asia-Pacific Journal of Ophthalmology*, *11*(3), 237-246. https://doi.org/10.1097/APO.0000000000000537
75. Kowalczuk, P., Siepmann, C., & Adler, J. (2021). Cognitive, affective, and behavioral consumer responses to augmented reality in e-commerce: A comparative study. *Journal of Business Research*, *124*, 357-373.
76. Bozzelli, G., Raia, A., Ricciardi, S., De Nino, M., Barile, N., Perrella, M.,... & Palombini, A. (2019). An integrated VR/AR framework for user-centric interactive experience of cultural heritage: The ArkaeVision project. *Digital Applications in Archaeology and Cultural Heritage*, *15*, e00124. https://doi.org/10.1016/j.daach.2019.e00124
77. Chamola, V., Bansal, G., Das, T. K., Hassija, V., Sai, S., Wang, J.,... & Niyato, D. (2024). Beyond reality: The pivotal role of generative ai in the metaverse. *IEEE Internet of Things Magazine*, *7*(4), 126-135.
78. Tu, X., Ala-Laurinaho, R., Yang, C., Autiosalo, J., & Tammi, K. (2024). Architecture for data-centric and semantic-enhanced industrial metaverse: Bridging physical factories and virtual landscape. *Journal of Manufacturing Systems*, *74*, 965-979.
79. Ajiva, O. A., Ejike, O. G., & Abhulimen, A. O. (2024). Advances in communication tools and techniques for enhancing collaboration among creative professionals. *International Journal of Frontiers in Science and Technology Research*, *7*(01), 066-075. https://doi.org/10.53294/ijfstr.2024.7.1.0049
80. Atkinson, D. (2023). Metaverse Decentralized Governance and Networked Immersive Virtual Reality Systems, Machine Learning-based Image Recognition and Predictive Modeling Tools, and Cognitive Automation and Multisensor Fusion Technologies in Digital Hyper-Realistic Worlds. *Review of Contemporary Philosophy*, (22), 68-84.
81. Wu, D., Yang, Z., Zhang, P., Wang, R., Yang, B., & Ma, X. (2023). Virtual-reality interpromotion technology for metaverse: A survey. *IEEE Internet of Things Journal*, *10*(18), 15788-15809.
82. Obuchowicz, R., Strzelecki, M., & Piórkowski, A. (2024). Clinical applications of artificial intelligence in medical imaging and image processing—a review. *Cancers*, *16*(10), 1870. https://doi.org/10.3390/cancers16101870
83. Li, C. Z., Xue, F., Li, X., Hong, J., & Shen, G. Q. (2018). An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction. *Automation in construction*, *89*, 146-161.
84. Tang, Y., Zhao, C., Wang, J., Zhang, C., Sun, Q., Zheng, W. X., & Kurths, J. (2022). Perception and navigation in autonomous systems in the era of learning: A survey. *IEEE Transactions on Neural Networks and Learning Systems*, *34*(12), 9604-9624. https://doi.org/10.1109/TNNLS.2022.3164720