



**Technical Brief**

# The Role of Avatars in AR/VR Systems

**DISSEMINATION LEVEL PUBLIC**

**PARTNER**

**DFKI**

**AUTHOR**

**Muhammad Zeshan Afzal**



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## 1. The Role of Avatars in AR/VR Systems<sup>1</sup>

Avatars, Augmented Reality and Virtual Reality (AR/VR) systems, and virtual immersive environments are interrelated elements of the digital world that enable engaging and interactive experiences.<sup>2</sup> Users can engage with computer-generated content as if they were physically present in a virtual immersive environment, a digital setting. Complex computer visuals, sound design, and occasionally additional sensory input are used to create these settings to engage people.<sup>3</sup>

Our virtual identity is fundamentally shaped by our avatars, who also improve our experiences in VR and AR environments. These serve as our electronic representatives, giving individuals in the same digital space a visual and interactive entity to relate to. They serve as the user's digital being, enabling social connection, engagement, and individual expression in virtual or augmented reality.

The key element of avatar system is the flexibility to represent our identity in different forms that may resemble ourselves, an abstract concept or even a character that's pure fantasy.<sup>4</sup> This not only allows the users to express themselves but also provides a way to create new identities. Furthermore, avatars are not merely a visual representation; they can help users interact with the digital environment in a way that users imagine themselves as part of the digital world. Moreover, avatars are used to provide social interaction between the different users present in the digital environment. Using a more advanced capture system can render not only the physical movement of users in the digital world but also expressions, voices etc.

Although avatars offer great promise to improve how we interact in simulated environments, their use poses significant issues. For inclusion, it is crucial to make sure that avatars can represent a wide variety of identities. Avatars may possibly communicate private data concerning the user. Therefore, privacy and security issues must also be taken into account. In this technical brief, we discuss the Avatar system and its state-of-the-art along with its sustainability for LEAs. The technical brief ends with shedding light on the challenges and future opportunities of Avatar systems.

## 2. AR/VR Systems

In the modern era, remote collaboration technologies are pivotal in daily life and business communication, especially when keeping a physical distance is essential. However, organisations are facing several challenges in long-distance networking and collaboration, including businesses, research institutes, and people. Overall, these technologies fall in the broad category of the communication system, which is called synchronous remote collaboration. Furthermore, besides video conferencing, other communications tools such as augmented, virtual, and mixed reality collaboration tools are still considered specialised technology. Such systems have three main components: environment, avatars, and interaction.<sup>5</sup> In this brief, we will look at the role of Avatars in AR/VR systems. Nonetheless, we are going to briefly have a look at the immersive environment followed by Avatars.

### 2.1 Virtual Immersive Environment

Industries and researchers are beginning to perceive virtual immersive environments as instruments that could improve the effectiveness of routine computer-based work. With immersive tools and a greater sense of presence, VR and AR have shown promise for distant working settings.<sup>6</sup> Nevertheless, immersive technologies like AR and VR are recognised to have the potential to have adverse or unexpected effects on the user. While primarily utilised for leisure and games, immersive technology has also found utility in the workplace, easing complicated job procedures. Through peripherals, these technologies enable immersion in and engagement with digital content.

### 2.2 Avatar System

An avatar system plays an integral role in AR and VR. It is a key component that encompasses the essentials for promoting interaction, immersion, personalization, and customization. It provides users with a concrete way to express themselves and engage in a digital environment. They perform many roles to bring value to AR/VR systems. The most important of them are Embodiment and Presence. The other functions include communication, interaction, identity, personalization, navigation, control, accessibility, and inclusion. We will look at them individually as follows:

#### 2.2.1 Embodiment

In VR and AR environments, avatars represent the users' embodiments.<sup>7</sup> They are the digital surrogate that serves as a proxy for users' physical presence in the virtual environment. They serve as the basis for user engagement in the virtual world. Therefore, they allow the users to express themselves and control their interactions.<sup>8</sup> However, the embodiment is a broad concept in AR/VR systems that extends beyond simple representation. In a way, it provides a digital self that mimics the users' sense and behaviour. It is to be noted that the realistic representation of users involves motion tracking, gesture recognition in some scenarios, and the rendering of facial expressions, to name a few.

## 2.2.2 Presence

The presence refers to the users' feeling of being part of the virtual environment.<sup>9</sup> Avatars are the tools that help users to develop this sense of presence in the virtual environment. For example, when we move in the real environment or try to grab something, the avatar replicates this movement in the virtual environment so that users feel part of it. It is accomplished by replicating the users' movements and interactions in the virtual environment in a believable way to give the feeling of immersion.

## 2.2.3 Communication

Another important role Avatars play in AR/VR systems is replicating face-to-face communication in the virtual world.<sup>10</sup> In order to accomplish it, the Avatars use speech, text, facial expressions and replication of body movements. This ability is essential for the application where users share virtual spaces.

## 2.2.4 Identity

Identity refers to the ability of Avatars to reflect the actual personality or originality of the users.<sup>11</sup> In the real world, identity is expressed in terms of personality, appearance, beliefs, etc. Avatars provide users with a way to express themselves or an imaginative personality. Users can customize avatars to resemble their physical appearance closely. However, users often choose to represent themselves as highly fictional characters. The Avatar system provides a way for users to express themselves uniquely in a meaningful way.

## 2.2.5 Personalization

While identity refers to the concept of the character we would like to represent, personalization, on the other hand, refers to how the avatars can be customized to achieve the desired representation. However, personalization is a broad term, and it is implemented in the context of AR/VR systems in many distinct directions. Examples are visual customizations, behavioural customization or customization of specific attributes. However, fundamentally personalization enables users to express themselves in a true way or in a way that has a personal significance. Avtar systems provide an effective way of personalization.

## 2.2.6 Navigation

Another role that Avatars play in AR/VR systems is the navigation of the virtual environment. This includes teleporting themselves to different locations in the virtual world and interacting with different objects. Navigation can be performed either by capturing users' movements and replicating them in the virtual world or through specific commands from the user.

## 2.2.7 Control

While navigation refers to the movement of Avatars in AR/VR systems, control is a rather broad category that includes every action that avatars can perform. The control comprises physical actions, pushing buttons, performing gestures etc.

## 2.2.8 Accessibility and Inclusion

Avatar helps to create AR/VR systems that are both accessible and inclusive.<sup>12</sup> For example, users with some physical disability can use Avatars to navigate the virtual world. Also, they can configure Avatars to represent themselves in a way they would like to and improve their interactions through Avatars.

## 3. State of the art in Avatar Systems

The present state of avatar systems today has been considerably affected by advances in technology, with remarkable improvements in their realism, utility, and adaptability. Today's avatar systems go beyond simple visual representation to add intricate behaviours and interactions in order to offer a rich, immersive experience that closely resembles real-world interactions.<sup>13</sup>

There has been a considerable improvement in avatars' visual representation.<sup>14</sup> Avatars may now be created to have highly accurate and more realistic appearances because of the use of advanced modelling rendering technologies. Furthermore, more advanced technologies let users create avatars that closely resemble real people. The technologies used in the creation include realistic facial and emotions rendering and fluid bodily movements.<sup>15</sup> These developments have helped improve the sense of involvement and presence in AR/VR environments, creating a truly immersive experience.

When it comes to the functionality of the avatar, there have been significant improvements. These improvements help modern avatar systems that may imitate many different behaviours, simulating users' bodily actions within the digital environment. The input methods are also multifaceted in modern avatar systems. These methods include voice commands, gesture-based control of avatars,<sup>16</sup> and in some prototypes, even brain-computer interfaces are used.<sup>17</sup> All of these methods offer users a natural and engaging user experience.

The recent developments of Artificial intelligence (AI) have also helped in improving avatar systems. AI can be incorporated in many ways in avatars. One of the most important is mimicking human-like intelligence while interacting with users and other avatars.<sup>18</sup> Furthermore, they can respond to different interactions autonomously, predict the users' commands that may be following and so on. Moreover, the Avatar system can develop emotive responses to the user interaction that further gives rise to an immersive environment.

However, despite having undergone substantial advancement, there are still problems with existing avatar systems. The most important challenge concerns inclusivity and personalisation.<sup>19</sup> Avatar systems that can accommodate an extensive variety of individual identities and preferences are becoming more and more necessary. Customisable avatars that can depict various racial, ethnic, and physical characteristics are becoming increasingly crucial. Additionally, as avatars get more complex and lifelike, an increasing concern for privacy and security deems the consideration even more.<sup>20</sup> Consequently, a significant problem for the future development of avatar systems is striking a balance between the requirement for individualised and immersive avatar experiences and, at the same time necessity to safeguard user data and privacy.

## 4. Sustainable use of Avatars for LEAs

The sustainability of the avatar system for LEAs involves aspects like the long-term usability of avatars and the ability to evolve, according to the investigators from LEAs. Furthermore, the potential impacts on investigators' well-being, privacy and inclusion must also be considered. The literature has specific guidelines about the critical sustainability factors, as described below.

**User Experience:** In order to create a relaxing and exciting user experience, personalisation is essential. The ability to customise one's avatar can significantly increase one's sense of immersion and connection to the AR/VR environment; therefore, users should try to become familiar with these possibilities.<sup>21</sup> Equally crucial is comprehending every aspect of their avatar's actions. Users will get the most fun and satisfaction from their experience if they are skilled at adjusting these settings.<sup>22</sup>

**Social Interaction:** Avatars serve as communication tools in addition to being user representatives. A user's avatar's physical attributes and actions can substantially impact social interactions in AR/VR environments. As a result, users ought to match their avatars' traits to their interactions and the virtual community's setting.<sup>23</sup> It can also improve social interactions to be aware of non-verbal communication in these settings, such as keeping adequate virtual distance or using avatar body language.

**Health Issues:** Long-term use in immersive environments may cause discomfort in the body or additional medical issues.<sup>24</sup> These dangers can be reduced by taking regular breaks from the system. Users should be aware of and make necessary adjustments to avatar control settings that may affect comfort. Users that find it uncomfortable when their avatar moves quickly or abruptly might look into options that allow for smoother, more progressive movements.

**Learning and Skill Development:** The chances for shared and collaborative learning that avatars in AR/VR settings might provide should be taken advantage of by users.

**Psychological Impact:** While avatars can give users a place to experiment with various personas, it's crucial to maintain a healthy balance between one's virtual and physical selves to prevent psychological suffering.<sup>25</sup> Users should be aware of their virtual behaviours as they can have long-lasting effects in the digital environment. A brief guideline is provided in the technical brief "Considerations for sustained AR/VR use by LEAs". These guidelines outline the necessary precautionary measure for the users and organisations that will deploy and use the system in practice.<sup>26</sup>



## 5. Avatar system in INFINITY

Understanding the impact of avatars on the user performance, health and wellness is crucial while creating the avatar system. To promote positive embodiment and sense of presence the INFINITY avatar system is in 3D and offers a range of avatar customisation features so users can customise their avatar as much as possible and make it look just like them. The avatar system customization allows users to change the aspect of different parts of their avatar through the I3CE interface: the gender (figure 1), the face, the body and clothes.



Figure 1: Gender selection feature

The face can be customised by choosing from a wide range of pre-existing faces, on which users can change glasses and haircuts, colour of hairs and colour of the eyes (figure 2).

For the face customization, one feature that had been considered was the creation of 3D avatar faces from 2D photos. However, even though it would provide a more realistic appearance, this feature was abandoned for data privacy reasons.



Figure 2: Face customization feature



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The body can be also modified, by choosing clothes (types and colour), the body shape and height (figure 3).



Figure 3: Body customization feature

Here, it was envisaged to create uniforms based on the style of member states' uniforms, but with the user's member state information displayed above him/her, along with his/her name and organisation, there might have been selection errors and possible misunderstanding between users in the event of a uniform errors. Therefore, the creation of uniforms was not implemented.



Figure 4: Avatar appearance in the I3CE

In the INFINITY environment, the avatars have a realistic appearance (figure 4) and can move using a controller tracking system to link real movement to the avatar.

## 6. Future Challenges and Opportunities

Technological advancements drive the future development of AR/VR systems, and avatar systems is a major component of these systems. This inevitable growth of avatar systems will present both considerable opportunities and challenges.

**Realism and expressiveness:** A challenging task is searching for more realistic and expressive avatars. Despite the enormous strides made, there is still a discrepancy between the sincerity of interactions in the actual world and those made possible by avatars. Enhancing avatar realism, in particular, becomes essential to accurately mimic nuanced human expressions and movements. Further study and innovation in cutting-edge areas, including facial recognition, emotion detection, motion capture, and AI technologies, would be necessary to meet this challenge.<sup>27</sup>

**Privacy and Security:** Security and privacy present yet another set of formidable obstacles.<sup>28</sup> The chances of data misuse or identity theft increase as avatars become more customised and have a greater ability to reflect our real-world personalities. This would require developers and stakeholders to prioritise strong security measures when building avatar systems, ensuring that private information is encrypted and maintained safely. To secure user privacy and guard against potential exploitation, specific policies and strict laws may also need to be implemented.<sup>29</sup>

Apart from these challenges, there are many opportunities:

**AI-Driven Progressively Adaptive Avatar:** The last decade has seen significant progress in AI.<sup>30</sup> Avatars are already using AI to become more innovative and more flexible. In order to offer more realistic and customised experiences, AI has been utilised, for example, to allow avatars to learn from data on how avatars interact with users and modify their behaviour accordingly. This progressive adaptation of behaviour is a milestone and the recent advancements in this area are promising. Consequently, the ability of AI to recognise user preferences, anticipate needs, and imitate emotional responses has also been used to improve the realism of avatars.<sup>31</sup>

**Application Areas:** In addition, fields other than gaming and entertainment are considering expanding avatar systems. Avatars could be used in various industries, including remote work, retail, healthcare, and education. In order to expand the range of potential applications and effects of these technologies, avatars may imitate patient interactions for medical training, direct users through virtual shopping experiences, or imitate a virtual investigation.

**Social Inclusion and Accessibility:** Another significant opportunity is to promote social accessibility and inclusiveness by employing avatar systems. We may work to make sure that all individuals are able to engage in and take advantage of AR/VR environments by creating avatars that can portray a variety of personalities and enabling users with varying physical capacities.<sup>32</sup> This calls for ongoing adherence to inclusive design principles, in-depth user testing, and proactive interaction with a wide range of user communities.<sup>33</sup>

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