AMERICAN JOURNALS
Open Access, Peer Reviewed Journals
American Journal of Technology and Applied Sciences
ISSN (E): 2832-1766 Volume 39, August - 2025

IMMERSION: HOW ANIMATION IS SHAPING THE FUTURE OF HUMAN-COMPUTER INTERACTION (AR/VR/MR)

Saniya Assembek
Motion Design Expert. New York, NY

ABSTRACT

The article examines the role of animation in shaping user experience in immersive technologies: augmented (AR), virtual (VR) and mixed reality (MR). Particular attention is paid to the function of animation as an interface tool that influences perception, navigation, interaction and emotional involvement of the user. The features of the use of animation in various types of XR environments are analyzed, as well as its importance in creating a cognitively comfortable and intuitive digital space. The importance of designing animation taking into account the psychophysiological features of perception and technical limitations of devices is emphasized.

KEYWORDS

Animation, AR, VR, MR, human-computer interaction, immersive technologies, UX design, digital space.

Introduction

The scientific novelty of the presented study lies in the integrated approach to the analysis of animation in the XR environment, where it is considered not just as a visual design, but as a key cognitive and interface tool that shapes user behavior and perception in immersive environments (AR, VR, MR). For the first time, the emphasis is placed on the influence of animation on the perception, orientation, attention and emotional involvement of the user in the XR environment, which requires an interdisciplinary approach based on psychology, ergonomics and interface design. The study also clarifies the role of animation in navigation and interactivity of XR, highlighting it as a link between the interface and the user, providing logical navigation, reducing cognitive load and adaptation to the virtual environment, which has previously remained insufficiently studied in the context of XR.

The rise of immersive technologies, including augmented (AR), virtual (VR) and mixed (MR) reality, is revolutionizing the way people perceive information and interact with digital systems. Traditional interfaces limited to screens, buttons and a mouse are giving way to digital environments in which the user does not just look, but literally "immerses" themselves. In this new reality, animation is transformed from a simple element of visual design into a critical tool that ensures effective communication of information, intuitive navigation and the creation of a deep emotional connection between the user and the digital world. Without the proper use of animation, immersive environments risk becoming disorienting and difficult to master, which significantly reduces their practical value and user experience.

The different types of “realities” are distinguished by the following key characteristics: the degree of realism of the virtual objects displayed, the level (depth) of immersion in the virtual space, and the method of user interaction with the environment. It should be noted that there is some ambiguity in terminology, where mixed reality (MR) is sometimes referred to as “hybrid reality”. The terms “programmable reality” or “immersive VR” are also used .

Augmented reality (AR) does not change the perception of the surrounding world, but only adds artificial elements and data to the real environment. This synthesis can be illustrated by the development of AR glasses, such as Epson Moverio , Google Glass and Toshiba Glass . AR allows the user to receive information without using their hands and without interrupting their current activity.

Mixed reality (MR) is the next step in detachment from the real world. MR integrates with virtuality, adding realistic virtual objects to the real world. The technology consists of visualizing and fixing virtual objects in real space in such a way that the observer perceives them as real. MR combines the best features of AR and VR: the user continues to interact with the real world, in which virtual objects exist , perceived as “natural”.

Virtual reality (VR) provides the user with full immersion in an artificially created world, isolating him from the real environment. The user uses a virtual reality helmet and other devices for immersion. VR provides the effect of presence and immersion in another space (for example, a race track, a desert or any other world created by a scriptwriter, designer and developer). To achieve the effect of "deceiving" the brain, it is necessary to take into account the principles of its operation and make significant efforts to simulate interaction with the created environment by influencing the senses. Currently, the impact on hearing and vision has been successfully mastered, but developments in the direction of influencing other senses continue [1].

With the development of immersive technologies (AR/VR/MR), animation has evolved from an auxiliary visual tool into an active mediator between the user and the digital environment. Today, its role goes beyond aesthetics, becoming a key element of communication, spatial orientation, information exchange and emotional feedback. Animation allows you to create a cognitively comfortable interaction model for the user, as close as possible to the natural human experience.

AR/VR environments lack the usual elements of two-dimensional interfaces, such as a cursor, windows or taskbar. The user’s orientation in three-dimensional space is provided by animation, which acts as a guide. The appearance of objects with gradual increase, visual “hints” in the form of gestures, the movement of light pointers - all this helps the user navigate in digital reality. As noted by the expert in the field of virtual reality (VR) and the author of the book “ The VR Book : Human-Centered Design for Virtual Reality » J. Gerald , in virtual reality, each element must have spatial meaning and be related to the user's actions. Animation, in turn, makes this connection clear and understandable [2].

One of the key elements of interactive design is timely and clear feedback. In traditional interfaces, it is implemented through a change in the color of a button, a sound signal, or vibration. In AR/VR environments, feedback is achieved primarily through animation. For example, when interacting with a virtual object in VR, such as picking up an object, realistic physics are important: the object should change position, sway slightly, and visually convey a sense of weight. These effects do not just improve the appearance of the interface, but also strengthen the user's trust in the virtual environment. D.

Norman , in one of his works, emphasizes the importance of affordances and feedback as fundamental elements of good design: “Movement is a form of visual confirmation that signals: “You did it right” [3].

In immersive environments, animation performs not only an informational but also an emotional function. It can create a sense of the liveliness of the digital world, add playfulness and ease to interaction, or, on the contrary, solemnity and tension. A person is psychologically inclined to endow movements and gestures with symbolic meaning, including perceiving them as the “behavior” of a digital agent. Games and educational VR applications often use characters with animated facial expressions, poses, and expressive gestures. Such characters become a kind of guides that facilitate interaction between the system and a person, reducing cognitive load and promoting the formation of trust. UX design researchers note that “animation forms the emotional context of the interface, influences the first impression and the general perception of the system as “alive” or “dead” [4].

Animation allows for the creation of visual metaphors, replacing text instructions and accelerating the learning process. For example, the rotation of an object can signal its interactivity, and a pop-up expansion of an icon can signal the possibility of interacting with it. Such effects are especially important in AR/VR environments, where the speed and clarity of interaction directly affect the user's perception. Research conducted by D. Milgram and F. Kishino demonstrated that contextual visual animation facilitates faster adaptation to mixed and virtual environments, helping the brain to “rethink” the behavior of objects in accordance with the new reality [5].

In immersive technologies, animation plays a central role in facilitating the perception and understanding of information, which is especially important in the context of complex and innovative AR, VR and MR interfaces. The principles of perception psychology and cognitive science confirm that well-organized animation of objects allows the user to interpret events occurring in the digital space more quickly and effectively.

Animated transitions between interface states help the brain form coherent mental models. This effect is known as the principle of cognitive continuity: smooth changes allow the user to better understand the events and changes in the interface. B. Zimmerman notes that “smooth animation of transitions reduces cognitive load by allowing the user to retain context in memory, which significantly improves comprehension” [6]. This is especially true in AR/VR environments, where objects often appear and disappear in three-dimensional space. Without animation, such sudden changes can cause disorientation or loss of connection with the context.

Animation allows replacing lengthy text instructions or complex diagrams with simple, intuitive movements. For example, the movement of an arrow indicating a direction is perceived faster and more naturally than a static pointer. A study by M. Johnson and A. Peters found that using visual animated cues in AR applications increases the speed of user learning by 30% compared to traditional text instructions [7].

Animation plays an important role in directing the user's attention to key interface elements. For example, a soft pulsation or slight vibration of a button signals its readiness for interaction. This technique helps reduce information overload and improve the efficiency of interaction. According to research by S. Argulyan and co-authors, the use of dynamic visual effects in augmented reality interfaces increases the accuracy and speed of object selection by 25% [8].

In immersive interfaces, animation plays an important role in creating a sense of a real, physical world in which objects have mass, inertia, and obey the laws of physics. Such realism enhances the effect of presence and reduces the feeling of the "artificiality" of the environment. Scientists note that physically accurate animation of objects helps improve cognitive perception of space and increases the level of involvement in the VR environment [9].

In immersive technologies (AR, VR, MR), animation outgrows the role of a decorative element and becomes a fundamental tool for managing user attention, navigation, providing feedback and creating a sense of presence. In each of these environments, animation performs specific tasks, adapting to the user's perception features and the characteristics of the digital space.

In the VR environment, animation becomes a key mechanism for maintaining the user's spatial and cognitive orientation. Since virtual worlds are separated from physical reality, the movement of objects, their response to the user's actions, realistic physics, and smooth transitions become necessary elements for creating a sense of presence and immersion. J. Gerald emphasizes: "Without consistent animation, the user loses trust in the system, and immersion becomes superficial" [2].

Examples include:

- animated gestures of virtual avatars to improve interaction.
- teleportation effects that provide logical navigation in space.
- interactive changes to interfaces that respond to the user's head or hand movements.

In the AR environment, animation plays an important role in integrating digital objects into the physical world, creating the illusion of their real presence. This includes:

- animated calibration of digital elements taking into account the lighting and perspective of the real environment.
- contextual visual cues that guide the user, such as directional arrows and icons that appear based on movement.
- animation that responds to user interaction with real objects in real time (for example, flashes, vibrations, or changes in the position of an object).

A study by R. Azum and co-authors showed that animated registration of AR objects relative to the user helps improve information memorization and spatial orientation [10].

The MR environment places the highest demands on interaction, as real and virtual elements coexist and influence each other. In this environment, animation plays a key role in:

- providing interactivity between physical objects and digital elements (for example, a digital ball rolling on a real table).
- with smoothing transitions between the real and virtual worlds (for example, a digital object that seems to "grow" out of physical space).
- personalized adaptation of the interface in accordance with the user's current actions.

D. Milgram and F. Kishino emphasize that "in mixed reality , the key factor is visual and behavioral consistency" – it is animation that makes the interaction between the real and virtual worlds intuitive and cognitively acceptable [5].

Thus, animation in AR, VR and MR not only enhances the visual component, but also performs functional tasks that are critical for the successful interaction of the user with the digital environment. Below is a comparative table reflecting the features of the use of animation in each of the three technologies:

Table 1 - Comparative analysis of animation functions in AR, VR and MR environments

Animation function	AR (Augmented Reality)	VR (Virtual Reality)	MR (Mixed Reality)
User orientation	Animated arrows and labels on a real world background	Full navigation in virtual space (teleport, glide , etc.)	Interactive signage in mixed space
Integration of objects	Smooth registration of objects in the real environment	Full animation of all objects: appearance, disappearance, interaction	Mutual animation between physical and digital objects
Physical realism	Animation taking into account the context (real lighting, movement)	Using a physics engine (gravity, inertia, collisions)	Physically Based Behavior in Hybrid Environments
Feedback	Flashes, pulsations, touch response via animation	Realistic interface response (vibrations, reaction to movement)	Combined feedback (from user and real world)
Conveying emotions and meanings	Animation of digital characters or icons in an augmented scene	Animated avatars , facial expressions, gestures	Unified expression of emotions through digital agents embedded in reality
Support for immersiveness	Creating a sense of co-presence of the digital layer in the real world	Full immersion through synchronized animation of all objects	Smooth switching between worlds, maintaining a coherent experience
Reducing cognitive load	Contextual animation to explain actions	Consistent, logical transitions between actions	Animation that links actions in the real and digital worlds

The comparative analysis shows that the role of animation in AR, VR and MR systems differs depending on the level of immersion of the environment and the nature of the user's interaction with the interface. In AR, animation is primarily used to explain, supplement and provide orientation in the real world. In VR, it becomes the main tool for creating a full-fledged virtual experience, providing navigation, realism and emotional immersion. In MR, animation performs a unifying function, providing smooth interaction between physical and digital objects, which requires a high degree of synchronicity and contextual adaptability.

Current technological trends in the field of XR (Extended Reality (including AR, VR and MR) demonstrate the rapid development of interactive animation solutions aimed at creating intuitive and adaptive interfaces. Animation in these environments goes beyond simple visual decoration, becoming a key element of the user experience, influencing cognitive perception, emotional involvement and human adaptation to new digital spaces.

One of the main trends in XR is the development of context-aware animations that change in real time depending on the user's actions, environment, and intentions. These technologies are based on machine learning, sensor data analysis, and behavioral modeling. Animation becomes proactive : it "understands" the context and adapts, providing support to the user at the right moment.

The development of brain-computer interfaces (BCI) and sensor devices that track physiological indicators such as heart rate, facial expressions, and eye movements opens up the possibility of creating animations that are controlled not only by gestures but also by the psychophysiological state of the user. This increases the level of empathy and personalization in virtual environments, creating so-called “affective interaction.”

The use of neural networks (e.g. StyleGAN , Midjourney , AnimateDiff) and procedural animation algorithms allows for the creation of complex scenes and movements in real time, minimizing the need for manual animation. This simplifies the development of XR applications and ensures the flexibility and scalability of visual elements.

Within the concept of spatial computing (spatial computing) animation becomes a link between the physical world and digital objects, forming "augmented reality" as a space for work and learning. Examples of such solutions are already being implemented in devices such as Apple Vision Pro , Microsoft HoloLens 2 and Magic Leap , where animation helps intuitively perceive objects, navigation and functionality. The emergence of creative XR tools (such as Tilt Brush , Quill , Adobe Substance 3D) allows users to not only interact with animation, but also create it in real time. Thus, animation becomes a tool for the joint creativity of man and machine.

In the next 5–10 years, animation will likely become the primary means of building symbiotic interfaces in which humans and digital systems function as a single cognitive entity. These interfaces will not simply respond to commands, but will also anticipate user intentions by offering visual and animation cues that direct attention, reduce cognitive load, and provide maximum immersion. This is particularly promising for applications in medicine, education, industrial design, and telepresence .

Thus, in immersive technologies, animation ceases to be a secondary element and becomes a fundamental part of the interaction architecture. The convenience, clarity and fascination of human-machine interaction in the future depend on its quality. At the intersection of design, psychology and technology, a new generation of interfaces is emerging, in which movement becomes a language, and the user turns from an observer into an active participant in digital reality.

REFERENCES

1. Mixed reality, AR, VR - types of virtual pleasures [Electronic resource]. - Access mode: https://www.iguides.ru/main/gadgets/smeshannaya_realnost_ar_vr_tipy_virtualnykh_udovolstviy/ (date of access: 04.06.2025).
2. Jerald, J. The VR Book: Human-Centered Design for Virtual Reality. – New York: ACM Books, 2015. – 735 p.
3. Norman, D. A. The Design of Everyday Things. – Cambridge: MIT Press, 2013. – 384 p.
4. Animation in UX Design [Electronic resource] // Interaction Design Foundation. – 2022. – Mode access : https://www.interaction-design.org/ (date accessed : 05.06.2025).
5. Milgram P., Kishino F. A taxonomy of mixed reality visual displays // IEICE Transactions on Information and Systems. – 1994. – Vol. E77-D, No. 12. – P. 1321–1329.
6. Zimmerman, J. Cognitive Psychology of User Interfaces. – Berlin: Springer Publishing, 2015. – 256 p.
7. Johnson M., Peters A. Visual guidance in augmented reality: Effectiveness of animated cues // International Journal of Human-Computer Studies. – 2018. – Vol. 110. – P. 12–25.

8. Argulyan S., Lee H., Park J. Dynamic visual effects for attention guidance in AR interfaces // IEEE Transactions on Visualization and Computer Graphics. – 2020. – Vol. 26, No. 5. – P. 2051–2060.
9. Lawrence K., Baker T. The impact of realistic animation on spatial cognition in VR // Journal of Virtual Reality and Broadcasting. – 2017. – Vol. 14, No. 2. – P. 45–59.
10. Azuma RT, Baillot Y., Behringer R., Feiner S., Julier S., MacIntyre B. Recent advances in augmented reality // IEEE Computer Graphics and Applications. – 2001. – Vol. 21, No. 6. – P. 34–47.