frontiers | Frontiers in Virtual Reality

TYPE Perspective
PUBLISHED 13 February 2026
DOI 10.3389/frvir.2026.1762601

OPEN ACCESS

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RECEIVED 07 December 2025
REVISED 24 January 2026
ACCEPTED 26 January 2026
PUBLISHED 13 February 2026

CITATION
Girginova K (2026) When XR meets digital twins: redrawing the conceptual map of extended reality.
Front. Virtual Real. 7:1762601.
doi: 10.3389/frvir.2026.1762601

When XR meets digital twins: redrawing the conceptual map of extended reality

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This perspective piece illustrates the synergy between digital twins and extended reality (XR) technologies and calls for their integration in future research. Through a brief example of the latest developments around Pokémon Go, this piece argues that digital twins and XR technologies share fundamental properties and a connected future trajectory. In turn, both stand to benefit from a mutual integration into one another's conceptual repertoire, particularly at a time when digital twins are rapidly expanding, albeit with socio-cultural blind spots, and XR technologies have often not lived up to their corporate hype, leaving the field in search of new, meaningful directions. Furthermore, as this article is part of a special issue that focuses on 'meaningful XR' (interpreted as moving XR research beyond games and gaming), it also reflects briefly upon the very notion of what makes XR 'meaningful', as well as how the synergy between digital twins and XR complicates this concept.

KEYWORDS

AR, augmented reality, digital twins, extended reality, metaverse, Pokémon Go, SLAM, smart glasses

Introduction

This perspective piece illustrates the synergy between digital twins and extended reality (XR) technologies and calls for their integration in future research. Through a brief example of the latest developments around Pokémon Go, this piece argues that digital twins and XR technologies share fundamental properties and a connected future trajectory. In turn, both stand to benefit from a mutual integration into one another's conceptual repertoire, particularly at a time when digital twins are rapidly expanding, albeit with socio-cultural blind spots, and XR technologies have often not lived up to their corporate hype, leaving the field in search of new, meaningful directions. Furthermore, as this article is part of a special issue that focuses on 'meaningful XR' (interpreted as moving XR research beyond games and gaming), it also reflects briefly upon the very notion of what makes XR 'meaningful', as well as how the synergy between digital twins and XR complicates this concept.

Pokémon Go: lessons from the past and directions for XR's future

Pokémon Go is often referenced as the archetypal example of augmented reality (AR) and, as the most successful AR game of all time, it is placed squarely within the range of entertainment. However, when thinking about XR media and how it intertwines with digital twins, Pokémon Go's past and future yet again become an effective illustration for

understanding how the two intersect across multiple levels, including the technical, conceptual, and political-economic. Pokémon Go's history highlights the game's grounding in geospatial intelligence—a past that shares notable similarities with the development of digital twins at NASA (King, 2025). The game was spearheaded by John Hanke[1], who was VP of Google's Geo Product division (including Google Earth, Maps, StreetView, and the internal start-up Ninantic). After splitting from Google in 2015, Hanke remained CEO of Ninantic and launched what we ultimately know as Pokémon Go today (originally developed as 'Ingress' while Hanke was still at Google).

Whereas the game has long been a platform for the production of digital twin content through the millions of scans users have taken on their phones to help map their local spaces (Davis, 2024), the company's overt shift toward a future in digital twin media was only recently publicized. In 2025 Ninantic rebranded to Ninantic Spatial and sold off Pokémon Go, but it had already used the data created by its users to build a visual positioning system to compete with current market offerings (Niantic, 2025). Ninantic Spatial's platform includes the capacity to generate accurate maps of 'anywhere' in the world, to incorporate proprietary data streams, and to update regularly. Their website claims to "deliver semantic understanding at every 3D point. . . even in GPS-denied environments," (website). A key feature that distinguishes Ninantic Spatial's offering is their focus on the localization of digital twins, a socializing of sorts, which is achieved partly through the integration of user-generated data.

Digital twins and XR technologies: the practical convergence

We can see a similar pattern of development across a range of other XR devices and content. Most notably, this occurs in the burgeoning wearables market of smart glasses, which opt for a mixed reality experience bolstered by AI. Most smart glasses use Simultaneous Localization and Mapping (or SLAM for short), which combines sensor input, computer data and estimation, computer vision, AI, and user input to locate and map where an individual is using the glasses in order to provide contextual information to them. In other words, SLAM helps to continuously build and update a street-smart map; a type of digital twin of one's surroundings. There are also products in the works like smart contact lenses which, if successfully released, would lead to even more complex interactions of biospatial and user-generated data. Of course, there are important differences[2] between digital twins and most of the current XR smart glasses or futuristic contact lens experiences but first, let's turn to why the synergy between XR and digital twins matters.

Digital twins are broadly described as virtual, high-fidelity replicas of objects, places, or systems (technical and physiological) that have bi-directional functionality and simulation capacities (VanDerHorn and Mahadevan, 2021). Practically, the close evolution (or co-evolution) of XR media and digital twins matters because digital twins are already adopted globally and at scale across various sectors from event planning to manufacturing. Digital twins are also being hailed as a key component behind the fourth industrial revolution (Borbach et al., 2025; Pires et al., 2019). In other words, digital twins are 'useful'—a label that popular XR technologies have often struggled to receive (Heffernan, 2014; Karpf, 2021; Lawrie, 2020). Thus, in shifting away from gaming (and even the terms augmented or virtual reality), technologies like smart glasses are offering a reimagined societal role for XR that aligns with the social promises and technical and industrial triumph of digital twins.

This co-evolution matters for digital twins, too. At present, most work on digital twins is focused on the physical aspects of places or objects at the expense of their social fabric (Qanazi et al., 2025). While this may be fine in the context of oceanic or manufacturing digital twins, it certainly becomes an important omission when considering digital twins of urban spaces or event venues, for example. Indeed, one can imagine the social layer of digital twins to be an important next development which even further integrates AI, geospatial media, XR devices, and user-generated content. It is precisely here that augmented, mixed, and virtual reality media and scholarship can shed important insights for digital twins' development.

Digital twins and XR technologies: theoretical implications

Given the practical implications listed above, the co-evolution of digital twins and XR technologies matters theoretically, too. Yet, digital twins and XR have rarely been in direct conversation thus far—especially on conceptual matters beyond technical questions and feasibility. Take, for example this journal, a leader in XR research, which itself has published only 10 articles pertaining to digital twins. These articles comprise papers that primarily[3] focus on the mechanics and feasibility of creating and experiencing digital twins for manufacturing using virtual reality (Borro et al., 2022). In these instances, the concept of the digital twin remains largely static and the development occurs in the technology through which it is accessed. On the flip side, a recent special issue in New Media and Society (Borbach et al., 2025) made important strides in offering one of the broadest and most theoretically sophisticated interpretations of the digital twins phenomenon yet, however, it did not explicitly explore the practical and conceptual synergy with XR technologies.

1 Prior to joining Google, John Hanke was co-founder and CEO at Keyhole, a geospatial data visualization firm, that was funded and used by the CIA and US military across a range of operations (Levine, 2018). After a purchase from Google in 2004, Keyhole eventually became Google Earth.

2 It is necessary to acknowledge the diversity and complexity of both, XR technologies and digital twin platforms. The goal of this piece is to make a broader and somewhat theoretical claim about the necessity for a synergy between the two. Further empirical work would then need to be done to establish how this synergy works in specific cases.

3 One article did go further in acknowledging the important social blind spots of digital twins and examined how human avatars may be improved through better haptic experiences (Zhang et al., 2025).

To be sure, there is some research on what is often referred to as "social digital twins"[4] (Qanazi et al., 2025) but it, too, rarely connects to extended reality technologies, foregoing opportunities for critical, conceptual synergies between the two. Thus, what is still missing is a) a conceptual integration of the shared properties, histories, and future trajectories of digital twins and XR technologies, and b) a direct formulation of digital twins as a form of extended reality themselves.

What new questions might such an intervention allow us to ask? For one, it would allow researchers and practitioners to expand and refine the key technical and conceptual features of both digital twins and XR technologies, as well as to promote a more critical and nuanced understanding of their user base and related socio-political and economic issues. While XR technologies and digital twins share the fundamental characteristics of being highly spatial/physical media forms, interactive, with real-time synchronization, and high-fidelity feedback (Bolter et al., 2021; Boyes and Watson, 2022; Ulrich, 2025), a closer look is warranted at the blurred lines where their similarities end and the divergences begin. For instance, part of the power of digital twins lies in their whole-system simulation capacity and bi-directional interaction (many virtual models update based on data from their real-life counterparts *and* can make changes to their real-life counterparts). Whereas XR technologies like VR have a long history of creating successful real-world simulations, their bi-directional functionality is more limited or, at least, more complicated.

Nonetheless, one could argue that a similar limitation applies to digital twin models that claim to replicate a whole system. Critical research denies the claim that it is technically possible to replicate a whole complex system (de Wilde de Ligny et al., 2025). Therefore, any performative and predictive capacity of the resulting digital twin is, by extension, incomplete. Subsequently, turning back to virtual reality simulations or even nascent metaverse research may be a good way to understand the selection of data and social construction that goes into making a digital twin. Likewise, paying closer attention to the (albeit incomplete) performative, predictive, and temporal dimensions of digital twins may push our thinking of XR technologies, like smart glasses, into the realm of digital twins of social potential.

Furthermore, whereas previously digital twin software relied heavily on organizational datasets (traffic patterns, weather conditions, satellite maps, etc.), the synergy between XR and digital twins, as seen, for example in Ninantic Spatial's offering, also adds user-generated and thus, potentially personalized data to this mix. In turn, this new combination presents an extension of what we have traditionally thought of as the data architecture of digital twins/XR and, along with it, poses interesting questions about their user base and political economy.

For instance, as Ninantic Spatial's CEO notes, "existing maps were built for people to read and navigate, but now there is a need for a new kind of map that makes the world intelligible for machines, for everything from smart glasses to humanoid robots, so they can understand and navigate the physical world," (Hanke, 2025). How do we comprehend and ethically align the types of accommodations these multiple users require? What constitutes safe and responsible use of such data and how, in the quest of humanizing digital twins, do we make sure that we do not dehumanize ourselves? In other words, digital twins and XR data and practices need to be approached and handled responsibly from a user and data perspective. Furthermore, as we think about value production in 'social digital twins' we also need to ask critical questions about the commodification of the XR user's body and space, and subsequently, consider the emergent political economy[5] of these new social digital twin models and their stakeholders. We should also ask: is it possible to envision a radically different future for the synergy between XR and digital twins? By turning to philosophy or science fiction, for example, could we transcend the military and market logics embedded in their development in favor of more socially-oriented structures and uses—and what would that look like?

Summary and thoughts on the meaningfulness of XR research

The Ninantic example offered in this perspective piece presents a necessarily limited viewpoint, circumscribed by a corporate, proprietary, and data-extractive model. Nonetheless, as evidenced by the flourishing wearables market, the merging of XR and digital twins is a much broader trend that deserves some timely and focused attention. Indeed, now is a particularly important time to expand the boundaries of XR research, particularly given that many of the consumer VR technologies of the last decade have not fulfilled their widespread social adoption claims, and the field is in need of new directions. Nonetheless, what constitutes meaningful development is not necessarily a straightforward matter.

In the first instance, the synergy between XR and digital twins seems to suggest that meaning is derived from a technology being closely aligned with industry and from being economically productive. More focus on labor and less on play. Nonetheless, examples like the gaming origins of Ninantic Spatial and the growing wearables market highlight the omnipresent forces of 'playbour' in digital technologies (Foxman, 2018; Kücklich, 2005); that is, the strategic blurring of sociality and play with production while retaining, if not exacerbating, a power imbalance between the user/fan and corporation. In turn, as opposed to moving away from gaming toward other, more meaningful XR experiences, this dynamic underscores the need for a deeper engagement with the ways in which games and gaming are embedded and reimagined within the software, hardware, and social cultures of XR and digital twins (Mayer, 2022). This dynamic also opens opportunities to search for other avenues—beyond the economic—of meaning creation and contestation through play, all the while complicating the concept of 'meaningful XR', if meant as a move away from gaming.

In short, we are at a time when placing digital twins squarely within the purview of extended reality media and *vice versa* carries practical and theoretical benefits for practitioners and researchers alike. Given the rapid deployment and merging of both, the implications of their

4 While an argument can be made that social digital twins are quite distinct, there is some fruitful overlap with metaverse and virtual worlds research.

5 For a poignant discussion about an emerging political economy of XR see Steinhoff, 2025.

synergies reverberate across numerous sectors (military, entertainment, urban development, etc.) and extend into real-life ethical and socio-political issues concerning users and data. Furthermore, an exercise in redrawing the boundaries of XR research is fruitful because it shines a light on the limitations of each technology and our current understandings of it, as well as points toward technical and conceptual avenues for future work. After all, what is a digital twin, if not one extension of our realities?

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

KG: Writing – original draft, Writing – review and editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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