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Foundations and Trends® in Human–Computer Interaction

Published, sold and distributed by:
now Publishers Inc.
PO Box 1024
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The preferred citation for this publication is

L.-H. Lee *et al.*. *All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda*. Foundations and Trends® in Human–Computer Interaction, vol. 18, no. 2–3, pp. 100–337, 2024.

ISBN: 978-1-63828-445-1

Full text available at: http://dx.doi.org/10.1561/1100000095

Foundations and Trends® in Human–Computer Interaction
Volume 18, Issue 2–3, 2024

Editorial Scope

Foundations and Trends® in Human–Computer Interaction publishes survey and tutorial articles in the following topics:

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Foundations and Trends® in Human–Computer Interaction, 2024, Volume 18, 4 issues. ISSN paper version 1551-3955. ISSN online version 1551-3963. Also available as a combined paper and online subscription.

Contents

All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda

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ABSTRACT

Since the popularisation of the Internet in the 1990s, the cyberspace has kept evolving. We have created various computer-mediated virtual environments, including social networks, video conferencing, virtual 3D worlds (e.g., VR Chat), augmented reality applications (e.g., Pokémon Go), and Non-Fungible Token Games (e.g., Upland). Such virtual environments, albeit non-perpetual and unconnected, have

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brought us various degrees of digital transformation. The term "metaverse" has been coined to facilitate further digital transformation in every aspect of our physical lives. At the core of the metaverse stands the vision of an immersive Internet as a gigantic, unified, persistent, and shared realm. While the metaverse may seem futuristic, catalyzed by emerging technologies such as Extended Reality, 5G, and Artificial Intelligence, the digital "big bang" of our cyberspace is not far away.

This survey presents the first effort to offer a comprehensive framework that examines the latest metaverse development under the dimensions of state-of-the-art technologies and metaverse ecosystems and illustrates the possibility of the digital "big bang". It is essential to highlight that the metaverse encompasses diverse technologies and ecosystems, calling it an interdisciplinary and emerging field. Its primary objective is to provide users with satisfactory and interactive experiences. First, technologies are the enablers that drive the transition from the current Internet to the metaverse. We thus examine eight enabling technologies rigorously – Extended Reality, User Interactivity (Human-Computer Interaction), Artificial Intelligence, Blockchain, Computer Vision, IoT and Robotics, Edge and Cloud computing, and Future Mobile Networks. In terms of applications, the metaverse ecosystem allows human users to live and play within a self-sustaining, persistent, and shared realm. Therefore, we discuss six user-centric factors – Avatar, Content Creation, Virtual Economy, Social Acceptability, Security and Privacy, and Trust and Accountability. Finally, we propose a concrete research agenda for developing the metaverse.

1

Introduction

Metaverse, a combination of the prefix "meta" (implying transcending) with the word "universe", describes a hypothetical synthetic environment linked to the physical world. The word "metaverse" was first coined in a piece of speculative fiction named *Snow Crash*, written by Neal Stephenson in 1992 [239]. In this novel, Stephenson defines the metaverse as a massive virtual environment parallel to the physical world, in which users interact through digital avatars. Since this first appearance, the metaverse as a computer-generated universe has been defined through vastly diversified concepts, such as *lifelogging* [72], *collective space in virtuality* [73], *embodied Internet/ spatial Internet* [94], *a mirror world* [626], *an omniverse*: a venue of simulation and collaboration [428]. In this monograph, we consider the metaverse as a virtual environment blending physical and digital, facilitated by the convergence between Web technologies and Extended Reality (XR). According to the *Milgram and Kishino's Reality-Virtuality Continuum* [383], XR integrates digital and physical to various degrees, e.g., augmented reality (AR), mixed reality (MR), and virtual reality (VR). Similarly, the metaverse scene in *Snow Crash* projects the duality of the real world and a copy of digital environments. In the metaverse, all individual users own their respective avatars, in analogy to the user's physical self, to experience an alternate life in virtuality that is a metaphor for the user's real worlds.

We propose a "**digital twins-native continuum**", on the basis of duality. This metaverse vision reflects three stages of development. We consider the *digital twins* as a starting point, where our physical environments are digitized and thus own the capability to periodically reflect changes to their virtual counterparts. According to the physical world, digital twins create digital copies of the physical environments as multiple virtual worlds, and human users with their avatars work on new creations in such virtual worlds, as *digital natives*. It is important to note that such virtual worlds will initially suffer from limited connectivity with each other and the physical world, i.e., information silo. They will then gradually connect within a massive landscape. Finally, the digitized physical and virtual worlds will eventually merge, representing the final stage of the co-existence of physical-virtual reality similar to surreality). Such a connected physical-virtual world gives rise to the unprecedented demands of perpetual and 3D virtual cyberspace as the metaverse.

To achieve such duality, the development of the metaverse has to go through three sequential stages, namely (I) *digital twins*, (II) *digital natives*, and eventually (III) *co-existence of physical-virtual reality* or namely the surreality. Figure 1.1 depicts the relationship among the three stages. *Digital twins* refer to large-scale and high-fidelity digital models and entities duplicated in virtual environments. *Digital twins* reflect the properties of their physical counterparts [387], including the object motions, temperature, and even function. The connection between the virtual and physical twins is tied by their data [187]. The existing

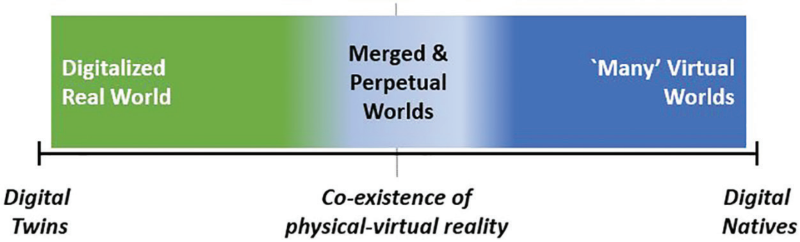

Figure 1.1: An illustration of "**digital twins-native continuum**".

applications are multitudinous such as computer-aided design (CAD) for product design and building architectures, smart urban planning, AI-assisted industrial systems, robot-supported risky operations [46], [118], [289], [439], [459]. After establishing a digital copy of the physical reality, the second stage focuses on *native content creation*. Content creators, perhaps represented by the avatars, are involved in digital creations inside the digital world. Such digital creations can be linked to their physical counterparts, or even only exist in the digital world. Meanwhile, connected ecosystems, including culture, economy, laws, and regulations (e.g., data ownership), social norms, can support these digital creations [74]. Such ecosystems are analogous to real-world society's existing norms and regulations, supporting the production of physical goods and intangible contents [592]. However, research on such applications is still in a nascent stage, focusing on the first-contact point with users, such as input techniques and authoring system for content creation [236], [394], [409], [573].

In the third and final stage, the metaverse could become a self-sustaining and persistent virtual world that *co-exists and interoperates* with the physical world with a high level of independence. As such, the avatars, representing human users in the physical world, can experience heterogeneous activities in real-time characterized by unlimited numbers of concurrent users theoretically in multiple virtual worlds [187]. Remarkably, the metaverse can afford interoperability between platforms representing different virtual worlds, i.e., enabling users to create content and widely distribute the content across virtual worlds. For instance, a user can create contents in a game, e.g., *Minecraft*,[1] and transfer such contents into another platform or game, e.g., *Roblox*,[2] with a continued identity and experience. To a further extent, the platform can connect and interact with our physical world through various channels, e.g., head-mounted wearable displays or mobile headsets (e.g., Microsoft Hololens[3]), showing diversified content, avatars, and computer agents in the metaverse interacting with smart devices and robots, to name but a few.

[1] https://www.minecraft.net/en-us.
[2] https://www.roblox.com/.
[3] https://www.microsoft.com/en-us/hololens.

According to the diversified concepts of the computer-mediated universe(s) mentioned above, one may argue that we are already situated in the metaverse. Nonetheless, this is only partially correct, and we examine several examples to justify our statement with the consideration of the three-stage metaverse development roadmap. The *Earth 3D map*[4] offers picture frames of the real world but lacks physical properties other than GPS information, while social networks allow users to create contents but are limited to texts, photos, and videos with limited options for user engagement (e.g., liking a post). Video games are getting more and more realistic and impressive. Users can experience outstanding graphics with in-game physics, e.g., *Call of Duty: Black Ops Cold War*, that deliver a sense of realism that resembles the real world in great detail. A remarkable example of an 18-year-old virtual world, *Second Life*,[5] is regarded as the largest user-created 3D Universe. Users can build and shape their 3D environments and live in such a virtual world extravagantly.

However, video games still lack interoperability between each other. The emerging platforms leveraging virtual environments (e.g., VRChat[6] and Microsoft Mesh[7]) offer enriched environments that emulate virtual spaces for social gatherings and online meetings. However, these virtual spaces are not perpetual and vanish after the gatherings and meetings. Virtual objects in AR games (e.g., Pokémon Go[8]) have also been attached to the physical reality without reflecting any principles of the digital twins. Figure 1.2 further demonstrates the significant gap that remains between the current cyberspace and the metaverse. Both x- and y-axes demonstrate superseding relationships: Left-to-Right (e.g., Text $<$ Image) and Bottom-to-Top (e.g., Read and Write (RW) $<$ Personalisation). The x-axis depicts various media in order of information richness [124] from text, image, audio, video, gaming, virtual 3D worlds, virtuality (AR/MR/AR, following *Milgram and Kishino's Reality-Virtuality Continuum* [383]) and eventually, the physical world.

[4] https://earth3dmap.com/.
[5] https://id.secondlife.com.
[6] https://hello.vrchat.com/.
[7] https://www.microsoft.com/en-us/mesh?activetab=pivot%3aprimaryr7.
[8] https://pokemongolive.com/en/.

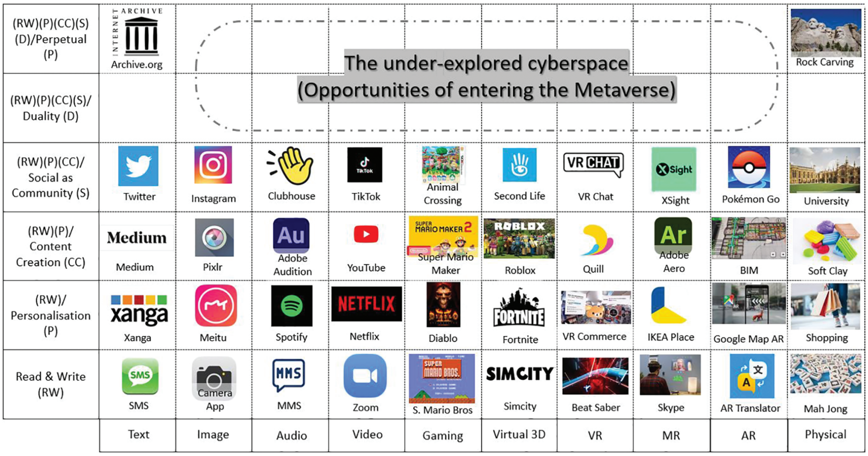

Figure 1.2: The cyberspace landscape of real-life applications, where superseding relationships exist in the information richness theory [124] (left-to-right) as well as transience-permanence dimension (bottom-to-top).

The y-axis indicates user experience under a spectrum between transience (Read and Write, RW) and permanence (Perpetual, P). We highlight several examples to show this superseding relationship in the y-axis. At the *Read & Write* level, the user experience does not evolve with the user. Every time a user sends an SMS or has a call on Zoom, their experience is similar to their previous experiences, as well as those of all the other users. With *personalization*, users can leverage their preferences to explore cyberspaces like Spotify and Netflix. Moving upward to the next level, users can proactively participate in *content creation*, e.g., Super Mario Marker allows gamers to create their tailor-made game level(s). Once a significant amount of user interaction records remain in cyberspace, under the contexts of personalization and content creation, cyberspace evolves into a social community. However, to the best of our knowledge, we rarely find real-life applications reaching the top levels of duality and perpetual (according to the concepts mentioned above in Figure 1.1). Many applications do not have duality because the user experiences in the physical and virtual worlds are not smoothly coupled. Additionally, the perpetual feature is not achieved since most virtual worlds are terminated after a certain time, such as at the end of a session.

To realise the metaverse, technologies other than the Internet, social networks, gaming, and virtual environments, should be considered holistically. The advent of AR and VR, high-speed networks and edge computing, artificial intelligence, and hyperledgers (or blockchain), serve as the building blocks of the metaverse. From a technical point of view, we identify the fundamentals of the metaverse and its technological singularity. This work reviews the existing technologies and technological infrastructures to offer a critical lens for building up the metaverse characterized by **perpetual, shared, concurrent, and 3D virtual spaces concatenating into a perceived virtual universe**. Therefore, the contribution of the work is threefold.

1. We propose a technological framework for the metaverse, which paves the way to realize the metaverse in which users are willing to engage in many virtual worlds.

2. This work examines how cutting-edge technologies like edge computing, XR, and artificial intelligence can contribute to developing a user-centric metaverse. It highlights the disparity between these advanced technologies and the current requirements for achieving a satisfactory metaverse experience as perceived by users.

3. Based on our review, we propose research challenges and opportunities from a user-centric perspective, paving a path toward the ultimate stages of the metaverse.

This survey serves as the first effort to offer a comprehensive view of the metaverse with both the technology and ecosystem dimensions. Figure 1.3 provides an overview of the survey – among the focused topics under the contexts of technology and ecosystem, the keywords of the corresponding topics reflect the key themes discussed in the survey. In the next section, we first state our motivation by examining the existing survey(s) as well as relevant studies, and accordingly position our review in Section 2. Accordingly, we describe our framework for the metaverse considering both technological and ecosystem aspects (Section 3).

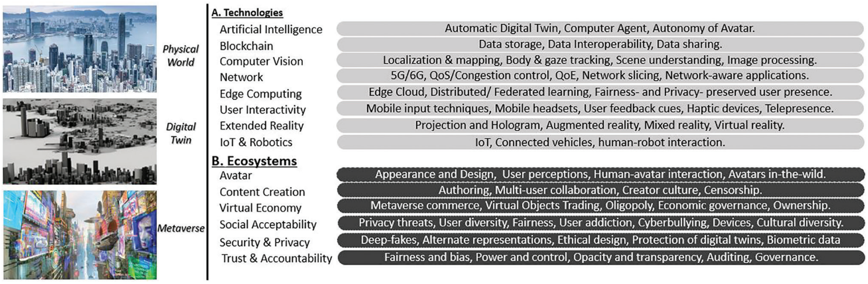

Figure 1.3: Connecting the physical world with its digital twins, and further shifting towards the metaverse: (A) the key technologies (e.g., blockchain, computer vision, distributed network, pervasive computing, scene understanding, ubiquitous interfaces), and; (B) considerations in ecosystems, in terms of avatar, content creation, data interoperability, social acceptability, security/privacy, as well as trust/accountability.

References

[1] 3GPP, "Study on scenarios and requirements for next generation access technologies," Technical report, 2018.

[2] S. Abdallah, E. Benetos, N. Gold, S. Hargreaves, T. Weyde, and D. Wolff, "The digital music lab: A big data infrastructure for digital musicology," *J. Comput. Cult. Herit.*, vol. 10, no. 1, 2017.

[3] J. Achiam, S. Adler, S. Agarwal, L. Ahmad, I. Akkaya, F. L. Aleman, D. Almeida, J. Altenschmidt, S. Altman, S. Anadkat, *et al.*, "Gpt-4 technical report," *arXiv preprint arXiv:2303.08774*, 2023.

[4] E. Ackerman, Femtosecond lasers create 3-D midair plasma displays you can touch, 2021.

[5] A. Acquisti, L. Brandimarte, and G. Loewenstein, "Privacy and human behavior in the age of information," *Science*, vol. 347, no. 6221, pp. 509–514, 2015.

[6] A. Acquisti, R. Gross, and F. Stutzman, "Faces of facebook: Privacy in the age of augmented reality," *BlackHat USA*, vol. 2, pp. 1–20, 2011.

[7] A. Acquisti, R. Gross, and F. D. Stutzman, "Face recognition and privacy in the age of augmented reality," *Journal of Privacy and Confidentiality*, vol. 6, no. 2, p. 1, 2014.

[8] A. Acquisti, C. Taylor, and L. Wagman, "The economics of privacy," *Journal of Economic Literature*, vol. 54, no. 2, pp. 442–92, 2016.

[9] P. Aditya, R. Sen, P. Druschel, S. Joon Oh, R. Benenson, M. Fritz, B. Schiele, B. Bhattacharjee, and T. T. Wu, "I-pic: A platform for privacy-compliant image capture," in *Proceedings of the 14th Annual International Conference on Mobile Systems, Applications, and Services*, pp. 235–248, 2016.

[10] J. Adolf, P. Kán, B. Outram, H. Kaufmann, J. Doležal, and L. Lhotská, "Juggling in VR: Advantages of immersive virtual reality in juggling learning," in *25th ACM Symposium on Virtual Reality Software and Technology,* VRST '19, New York, NY, USA: Association for Computing Machinery, 2019.

[11] G. P. Agnusdei, V. Elia, and M. G. Gnoni, "A classification proposal of digital twin applications in the safety domain," *Computers & Industrial Engineering*, p. 107 137, 2021.

[12] H. S. Ahn, J. Choi, H. Moon, and Y. Lim, "Social human-robot interaction of human-care service robots," in *Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction,* HRI '18, New York, NY, USA: Association for Computing Machinery, pp. 385–386, 2018.

[13] H. Ai, Z. Cao, J. Zhu, H. Bai, Y. Chen, and L. Wang, "Deep learning for omnidirectional vision: A survey and new perspectives," *arXiv preprint arXiv:2205.10468*, 2022.

[14] A. Aijaz, M. Dohler, A. H. Aghvami, V. Friderikos, and M. Frodigh, "Realizing the tactile internet: Haptic communications over next generation 5G cellular networks," *IEEE Wireless Communications*, pp. 1–8, 2016.

[15] G. A. Akerlof, "The market for 'lemons': Quality uncertainty and the market mechanism," in *Uncertainty in Economics*, pp. 235–251, Elsevier, 1978.

[16] A. Alam and A. Mohanty, "Facial analytics or virtual avatars: Competencies and design considerations for student-teacher interaction in AI-powered online education for effective classroom engagement," in *International Conference on Communication, Networks and Computing*, Springer, pp. 252–265, 2022.

[17] G. Alce, M. Roszko, H. Edlund, S. Olsson, J. Svedberg, and M. Wallergård, "[poster] ar as a user interface for the internet of things–comparing three interaction models," in *2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct)*, IEEE, pp. 81–86, 2017.

[18] H. A. Alhaija, S. K. Mustikovela, L. Mescheder, A. Geiger, and C. Rother, "Augmented reality meets deep learning for car instance segmentation in urban scenes," in *British Machine Vision Conference*, vol. 1, p. 2, 2017.

[19] A. Y. Alhilal, T. Braud, and P. Hui, "A roadmap toward a unified space communication architecture," *IEEE Access*, vol. 9, pp. 99 633–99 650, 2021.

[20] F. Alqubaisi, A. S. Wazan, L. Ahmad, and D. W. Chadwick, "Should we rush to implement password-less single factor FIDO2 based authentication?" In *2020 12th Annual Undergraduate Research Conference on Applied Computing (URC)*, IEEE, pp. 1–6, 2020.

[21] F. M. Ametrano, "Hayek money: The cryptocurrency price stability solution," *SSRN 2425270*, 2016.

[22] M. Ammar, E. Zegura, and Y. Zhao, "A vision for zero-hop networking (zen)," in *2017 IEEE 37th International Conference on Distributed Computing Systems (ICDCS)*, IEEE, pp. 1765–1770, 2017.

[23] M. Andriluka, U. Iqbal, E. Insafutdinov, L. Pishchulin, A. Milan, J. Gall, and B. Schiele, "Posetrack: A benchmark for human pose estimation and tracking," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 5167–5176, 2018.

[24] Apple, *View 360° video in a vr headset in motion*, 2021. URL: https://www.qualcomm.com/news/onq/2020/10/29/oculus-quest-2-how-snapdragon-xr2-powers-next-generation-vr.

[25] F. Arafsha, L. Zhang, H. Dong, and A. E. Saddik, "Contactless haptic feedback: State of the art," *2015 IEEE International Symposium on Haptic, Audio and Visual Environments and Games, HAVE 2015—Proceedings*, 2015.

[26] S. Arevalo Arboleda, F. Rücker, T. Dierks, and J. Gerken, "Assisting manipulation and grasping in robot teleoperation with augmented reality visual cues," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems,* CHI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[27] K. Arthur, "Effects of field of view on task performance with head-mounted displays," *Conference Companion on Human Factors in Computing Systems*, 1996.

[28] S. Aryan, H. Aryan, and J. A. Halderman, "Internet censorship in Iran: A first look," in *3rd USENIX Workshop on Free and Open Communications on the Internet (FOCI 13)*, Washington, D.C.: USENIX Association, 2013.

[29] Z. Ashktorab, E. Haber, J. Golbeck, and J. Vitak, "Beyond cyberbullying: Self-disclosure, harm and social support on askfm," in *Proceedings of the 2017 ACM on Web Science Conference,* WebSci '17, New York, NY, USA: Association for Computing Machinery, pp. 3–12, 2017.

[30] Z. Ashktorab and J. Vitak, "Designing cyberbullying mitigation and prevention solutions through participatory design with teenagers," in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems,* CHI '16, New York, NY, USA: Association for Computing Machinery, pp. 3895–3905, 2016.

[31] N. Ashtari, A. Bunt, J. McGrenere, M. Nebeling, and P. K. Chilana, "Creating augmented and virtual reality applications: Current practices, challenges, and opportunities," *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 2020.

[32] M. B. Attia, K.-K. Nguyen, and M. Cheriet, "Dynamic qoe/qos-aware queuing for heterogeneous traffic in smart home," *IEEE Access*, vol. 7, pp. 58 990–59 001, 2019.

[33] E. Ayiter, "Further dimensions: Text, typography and play in the metaverse," in *2012 International Conference on Cyberworlds*, pp. 296–303, 2012.

[34] E. Ayiter, "Azimuth to Cypher: The transformation of a tiny (virtual) cosmogony," in *2015 International Conference on Cyberworlds (CW)*, pp. 247–250, 2015.

[35] A. Azaria, A. Ekblaw, T. Vieira, and A. Lippman, "Medrec: Using blockchain for medical data access and permission management," in *2016 2nd International Conference on Open and Big Data (OBD)*, IEEE, pp. 25–30, 2016.

[36] C. Bachhuber and E. Steinbach, "Are today's video communication solutions ready for the tactile internet?" In *2017 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*, IEEE, pp. 1–6, 2017.

[37] A. Badias, D. Gonzalez, I. Alfaro, F. Chinesta, and E. Cueto, "Real-time interaction of virtual and physical objects in mixed reality applications," *International Journal for Numerical Methods in Engineering*, vol. 121, no. 17, pp. 3849–3868, 2020.

[38] P. Bahirat, Y. He, A. Menon, and B. Knijnenburg, "A data-driven approach to developing iot privacy-setting interfaces," in *23rd International Conference on Intelligent User Interfaces,* IUI '18, New York, NY, USA: Association for Computing Machinery, pp. 165–176, 2018.

[39] H. Bahri, D. Krčmařik, and J. Koči, "Accurate object detection system on hololens using yolo algorithm," in *2019 International Conference on Control, Artificial Intelligence, Robotics & Optimization (ICCAIRO)*, IEEE, pp. 219–224, 2019.

[40] R. Bajireanu, J. A. R. Pereira, R. J. M. Veiga, J. D. P. Sardo, P. J. S. Cardoso, R. Lam, and J. M. F. Rodrigues, "Mobile human shape superimposition: An initial approach using openpose," *International Journal of Computers*, vol. 4, 2019.

[41] S. Baraković, J. Baraković, and H. Bajrić, "QoE dimensions and QoE measurement of NGN services," in *Proceedings of the 18th Telecommunications Forum, TELFOR 2010*, 2010.

[42] N. Barbuti, "From digital cultural heritage to digital culture: Evolution in digital humanities," in *Proceedings of the 1st International Conference on Digital Tools & Uses Congress,* DTUC '18, New York, NY, USA: Association for Computing Machinery, 2018.

[43] A. Barin, I. Dolgov, and Z. O. Toups, "Understanding dangerous play: A grounded theory analysis of high-performance drone racing crashes," in *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, New York, NY, USA: Association for Computing Machinery, pp. 485–496, 2017.
[44] R. R. Barioni, L. Figueiredo, K. Cunha, and V. Teichrieb, "Human pose tracking from rgb inputs," in *2018 20th Symposium on Virtual and Augmented Reality (SVR)*, IEEE, pp. 176–182, 2018.
[45] A. Bauer, D. R. Neog, A.-H. Dicko, D. K. Pai, F. Faure, O. Palombi, and J. Troccaz, "Anatomical augmented reality with 3d commodity tracking and image-space alignment," *Computers & Graphics*, vol. 69, pp. 140–153, 2017.
[46] T. Bauer, P. O. Antonino, and T. Kuhn, "Towards architecting digital twin-pervaded systems," in *Proceedings of the 7th International Workshop on Software Engineering for Systems-of-Systems and 13th Workshop on Distributed Software Development, Software Ecosystems and Systems-of-Systems,* SESoS-WDES '19, IEEE Press, pp. 66–69, 2019.
[47] V. Bazarevsky, I. Grishchenko, K. Raveendran, T. Zhu, F. Zhang, and M. Grundmann, "Blazepose: On-device real-time body pose tracking," *CVPR Workshop*, 2020.
[48] V. Becker, F. Rauchenstein, and G. Sörös, "Connecting and controlling appliances through wearable augmented reality," 2020.
[49] S. Beer, "Virtual Museums: An innovative kind of museum survey," in *Proceedings of the 2015 Virtual Reality International Conference,* VRIC '15, New York, NY, USA: Association for Computing Machinery, pp. 1–6, 2015.
[50] R. Belk, "Extended self and the digital world," *Current Opinion in Psychology*, vol. 10, pp. 50–54, 2016.
[51] S. Bell and K. Bala, "Learning visual similarity for product design with convolutional neural networks," *ACM Transactions on Graphics (TOG)*, vol. 34, no. 4, pp. 1–10, 2015.

[52] G. Bello-Orgaz and D. Camacho, "Comparative study of text clustering techniques in virtual worlds," in *Proceedings of the 3rd International Conference on Web Intelligence, Mining and Semantics,* WIMS '13, New York, NY, USA: Association for Computing Machinery, pp. 1–8, 2013.

[53] M. Bennis, M. Debbah, and H. V. Poor, "Ultrareliable and low-latency wireless communication: Tail, risk, and scale," *Proceedings of the IEEE*, vol. 106, no. 10, pp. 1834–1853, 2018.

[54] C. Berg, S. Davidson, and J. Potts, "Blockchain technology as economic infrastructure: Revisiting the electronic markets hypothesis," *Frontiers in Blockchain*, vol. 2, p. 22, 2019.

[55] C. Bermejo Fernandez, L.-H. Lee, P. Nurmi, and P. Hui, "PARA: Privacy management and control in emerging IoT ecosystems using augmented reality," English, in *ACM International Conference on Multimodal Interaction*, United States: Association for Computing Machinery (ACM), 2021.

[56] C. Bermejo, L. H. Lee, P. Chojecki, D. Przewozny, and P. Hui, "Exploring button designs for mid-air interaction in virtual reality: A hexa-metric evaluation of key representations and multi-modal cues," *Proc. ACM Hum.-Comput. Interact.*, vol. 5, no. EICS, 2021.

[57] J. Biswas and M. Veloso, "Depth camera based indoor mobile robot localization and navigation," in *2012 IEEE International Conference on Robotics and Automation*, IEEE, pp. 1697–1702, 2012.

[58] A. Bochkovskiy, C.-Y. Wang, and H.-Y. M. Liao, "Yolov4: Optimal speed and accuracy of object detection," *arXiv preprint arXiv:2004.10934*, 2020.

[59] G. Boddington, "The internet of bodies—alive, connected and collective: The virtual physical future of our bodies and our senses," *Ai & Society*, pp. 1–17, 2021.

[60] J. Bolliger and T. Gross, "A framework based approach to the development of network aware applications," *IEEE transactions on Software Engineering*, vol. 24, no. 5, pp. 376–390, 1998.

[61] K. Bonawitz, H. Eichner, W. Grieskamp, D. Huba, A. Ingerman, V. Ivanov, C. Kiddon, J. Konečnỳ, S. Mazzocchi, H. B. McMahan, *et al.*, "Towards federated learning at scale: System design," *arXiv preprint arXiv:1902.01046*, 2019.

[62] M. Bouzit, G. Burdea, G. Popescu, and R. Boian, "The rutgers master ii-new design force-feedback glove," *IEEE/ASME Transactions on Mechatronics*, vol. 7, no. 2, pp. 256–263, 2002.

[63] D. Boyarski, C. Neuwirth, J. Forlizzi, and S. H. Regli, "A study of fonts designed for screen display," *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1998.

[64] T. Braud, F. H. Bijarbooneh, D. Chatzopoulos, and P. Hui, "Future networking challenges: The case of mobile augmented reality," in *2017 IEEE 37th International Conference on Distributed Computing Systems (ICDCS)*, IEEE, pp. 1796–1807, 2017.

[65] T. Braud, D. Chatzopoulos, and P. Hui, "Machine type communications in 6g," in *6G Mobile Wireless Networks*, Springer, 2021, pp. 207–231.

[66] T. Braud, C. B. Fernández, and P. Hui, "Scaling-up ar: University campus as a physical-digital metaverse," in *2022 IEEE Conference on Virtual Reality and 3d User Interfaces Abstracts and Workshops (VRW)*, IEEE, pp. 169–175, 2022.

[67] T. Braud, T. Kämäräinen, M. Siekkinen, and P. Hui, "Multi-carrier measurement study of mobile network latency: The tale of hong kong and helsinki," in *2019 15th International Conference on Mobile Ad-Hoc and Sensor Networks (MSN)*, pp. 1–6, 2019.

[68] T. Braud, Z. Pengyuan, J. Kangasharju, and H. Pan, "Multipath computation offloading for mobile augmented reality," in *2020 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, IEEE, pp. 1–10, 2020.

[69] H. Brock, S. Nishina, and K. Nakadai, "To animate or anime-Te? Investigating sign avatar comprehensibility," in *Proceedings of the 18th International Conference on Intelligent Virtual Agents,* IVA '18, New York, NY, USA: Association for Computing Machinery, pp. 331–332, 2018.

[70] G. Brown and M. Prilla, "The effects of consultant avatar size and dynamics on customer trust in online consultations," in *Proceedings of the Conference on Mensch Und Computer,* MuC '20, New York, NY, USA: Association for Computing Machinery, pp. 239–249, 2020.

[71] K. Brunnström, S. A. Beker, K. De Moor, A. Dooms, S. Egger, M.-N. Garcia, T. Hossfeld, S. Jumisko-Pyykkö, C. Keimel, M.-C. Larabi, *et al.*, "Qualinet white paper on definitions of quality of experience," 2013.

[72] A. Bruun and M. L. Stentoft, "Lifelogging in the wild: Participant experiences of using lifelogging as a research tool," in *INTERACT*, 2019.

[73] W. Burns III, *Everything you know about the metaverse is wrong?* 2018.

[74] A. Bush, *Into the void: Where crypto meets the metaverse.* 2021.

[75] C. Cadena, L. Carlone, H. Carrillo, Y. Latif, D. Scaramuzza, J. Neira, I. Reid, and J. J. Leonard, "Past, present, and future of simultaneous localization and mapping: Toward the robust-perception age," *IEEE Transactions on Robotics*, vol. 32, no. 6, pp. 1309–1332, 2016.

[76] W. Cai, Z. Wang, J. B. Ernst, Z. Hong, C. Feng, and V. C. M. Leung, "Decentralized applications: The blockchain-empowered software system," *IEEE Access*, vol. 6, pp. 53 019–53 033, 2018.

[77] C. Campolo, A. Molinaro, A. Iera, and F. Menichella, "5G network slicing for vehicle-to-everything services," *IEEE Wireless Communications*, vol. 24, no. 6, pp. 38–45, 2017.

[78] J. Cao, K. M. McNeill, D. Zhang, and J. Nunamaker, "An overview of network-aware applications for mobile multimedia delivery," in *37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the*, p. 10, 2004.

[79] Y. Cao, Z. Xu, F. Li, W. Zhong, K. Huo, and K. Ramani, "V. Ra: An in-situ visual authoring system for robot-IoT task planning with augmented reality," in *Proceedings of the 2019 on Designing Interactive Systems Conference*, pp. 1059–1070, 2019.

[80] Z. Cao, G. Hidalgo, T. Simon, S.-E. Wei, and Y. Sheikh, "Openpose: Realtime multi-person 2D pose estimation using part affinity fields," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 43, no. 1, pp. 172–186, 2019.

[81] Z. Cao, H. Ai, Y.-P. Cao, Y. Shan, X. Qie, and L. Wang, "Omnizoomer: Learning to move and zoom in on sphere at high-resolution," in *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 12 897–12 907, 2023.

[82] L. Carnevale, A. Celesti, A. Galletta, S. Dustdar, and M. Villari, "From the cloud to edge and IoT: A smart orchestration architecture for enabling osmotic computing," in *2018 32nd International Conference on Advanced Information Networking and Applications Workshops (WAINA)*, IEEE, pp. 419–424, 2018.

[83] T. Carter, S. A. Seah, B. Long, B. Drinkwater, and S. Subramanian, "UltraHaptics: Multi-point mid-air haptic feedback for touch surfaces," 2013.

[84] J. R. Cauchard, J. L. E, K. Y. Zhai, and J. A. Landay, "Drone & me: An exploration into natural human-drone interaction," in *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing,* UbiComp '15, New York, NY, USA: Association for Computing Machinery, pp. 361–365, 2015.

[85] A. Chaabane, T. Chen, M. Cunche, E. De Cristofaro, A. Friedman, and M. A. Kaafar, "Censorship in the wild: Analyzing internet filtering in Syria," in *Proceedings of the 2014 Conference on Internet Measurement Conference,* IMC '14, New York, NY, USA: Association for Computing Machinery, pp. 285–298, 2014.

[86] S. M. Chacko and V. Kapila, "Augmented reality as a medium for human-robot collaborative tasks," in *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pp. 1–8, 2019.

[87] M. Chai, T. Shao, H. Wu, Y. Weng, and K. Zhou, "Autohair: Fully automatic hair modeling from a single image," *ACM Transactions on Graphics*, vol. 35, no. 4, 2016.

[88] I. Chalás, P. Urbanová, V. Juřik, Z. Ferková, M. Jandová, J. Sochor, and B. Kozliková, "Generating various composite human faces from real 3D facial images," *The Visual Computer*, vol. 33, no. 4, pp. 443–458, 2017.

[89] B. J. Challacombe, L. R. Kavoussi, and P. Dasgupta, "Transoceanic telerobotic surgery," *BJU International (Papier)*, vol. 92, no. 7, pp. 678–680, 2003.

[90] C.-C. Chang, R. A. Grier, J. Maynard, J. Shutko, M. Blommer, R. Swaminathan, and R. Curry, "Using a situational awareness display to improve rider trust and comfort with an AV taxi," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Los Angeles, CA: SAGE Publications, vol. 63, pp. 2083–2087, 2019.

[91] I. Chaturvedi, F. H. Bijarbooneh, T. Braud, and P. Hui, "Peripheral vision: A new killer app for smart glasses," in *Proceedings of the 24th International Conference on Intelligent User Interfaces,* IUI '19, New York, NY, USA: Association for Computing Machinery, pp. 625–636, 2019.

[92] D. Chatzakou, I. Leontiadis, J. Blackburn, E. D. Cristofaro, G. Stringhini, A. Vakali, and N. Kourtellis, "Detecting cyberbullying and cyberaggression in social media," *ACM Trans. Web*, vol. 13, no. 3, 2019.

[93] G. Chaurasia, A. Nieuwoudt, A.-E. Ichim, R. Szeliski, and A. Sorkine-Hornung, "Passthrough+ real-time stereoscopic view synthesis for mobile mixed reality," *Proceedings of the ACM on Computer Graphics and Interactive Techniques*, vol. 3, no. 1, pp. 1–17, 2020.

[94] K. Chayka, *Facebook wants us to live in the metaverse.* 2021.

[95] H.-Y. Chen, R.-T. Hsu, Y.-C. Chen, W.-C. Hsu, and P. Huang, "Ar game traffic characterization: A case of pokémon go in a flash crowd event," in *Proceedings of the 19th Annual International Conference on Mobile Systems, Applications, and Services*, pp. 493–494, 2021.

[96] L. Chen, W.-K. Lee, C.-C. Chang, K.-K. R. Choo, and N. Zhang, "Blockchain based searchable encryption for electronic health record sharing," *Future Generation Computer Systems*, vol. 95, pp. 420–429, 2019.

[97] L.-C. Chen, Y. Zhu, G. Papandreou, F. Schroff, and H. Adam, "Encoder-decoder with atrous separable convolution for semantic image segmentation," in *Proceedings of the European Conference on Computer Vision (ECCV)*, pp. 801–818, 2018.

[98] L. Chen, A. Ebi, K. Takashima, K. Fujita, and Y. Kitamura, "Pinpointfly: An egocentric position-pointing drone interface using mobile AR," in *SIGGRAPH Asia 2019 Emerging Technologies,* SA '19, New York, NY, USA: Association for Computing Machinery, pp. 34–35, 2019.

[99] L. Chen, W. Tang, N. W. John, T. R. Wan, and J. J. Zhang, "Context-aware mixed reality: A learning-based framework for semantic-level interaction," in *Computer Graphics Forum*, Wiley Online Library, vol. 39, pp. 484–496, 2020.

[100] Y. Chen, K. Wu, and Q. Zhang, "From QoS to QoE: A tutorial on video quality assessment," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 2, pp. 1126–1165, 2014.

[101] Z. Chen, W. Hu, J. Wang, S. Zhao, B. Amos, G. Wu, K. Ha, K. Elgazzar, P. Pillai, R. Klatzky, D. Siewiorek, and M. Satyanarayanan, "An empirical study of latency in an emerging class of edge computing applications for wearable cognitive assistance," in *Proceedings of the Second ACM/IEEE Symposium on Edge Computing,* SEC '17, New York, NY, USA: Association for Computing Machinery, 2017.

[102] S. Chidambaram, H. Huang, F. He, X. Qian, A. M. Villanueva, T. Redick, W. Stuerzlinger, and K. Ramani, "Processar: An augmented reality-based tool to create in-situ procedural 2D/3D AR instructions," *Designing Interactive Systems Conference 2021*, 2021.

[103] H. Chishiro, Y. Tsuchiya, Y. Chubachi, M. S. Abu Bakar, and L. C. De Silva, "Global PBL for environmental IoT," in *Proceedings of the 2017 International Conference on E-commerce, E-Business and E-Government,* ICEEG 2017, New York, NY, USA: Association for Computing Machinery, pp. 65–71, 2017.

[104] C. Choi, J. Jun, J. Heo, and K. Kim (Kenny), "Effects of virtual-avatar motion-synchrony levels on full-body interaction," in *Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing,* SAC '19, New York, NY, USA: Association for Computing Machinery, pp. 701–708, 2019.

[105] S. Chung, J. Lim, K. J. Noh, G. Kim, and H. Jeong, "Sensor data acquisition and multimodal sensor fusion for human activity recognition using deep learning," *Sensors*, vol. 19, no. 7, p. 1716, 2019.

[106] E. F. Churchill and S. Bly, "Culture vultures: Considering culture and communication in virtual environments," *SIGGROUP Bull.*, vol. 21, no. 1, pp. 6–11, 2000.

[107] V. Clay, P. König, and S. Koenig, "Eye tracking in virtual reality," *Journal of Eye Movement Research*, vol. 12, no. 1, 2019.

[108] P. Clini, E. Frontoni, R. Quattrini, and R. Pierdicca, "Augmented reality experience: From high-resolution acquisition to real time augmented contents," *Advances in Multimedia*, vol. 2014, 2014.

[109] R. Cloete, C. Norval, and J. Singh, "A call for auditable virtual, augmented and mixed reality," in *26th ACM Symposium on Virtual Reality Software and Technology*, pp. 1–6, 2020.

[110] A. Cockburn and S. Brewster, "Multimodal feedback for the acquisition of small targets," *Ergonomics*, vol. 48, no. 9, pp. 1129–1150, 2005.

[111] A. Colley, J. Thebault-Spieker, A. Y. Lin, D. Degraen, B. Fischman, J. Häkkilä, K. Kuehl, V. Nisi, N. J. Nunes, N. Wenig, D. Wenig, B. Hecht, and J. Schöning, "The geography of pokémon go: Beneficial and problematic effects on places and movement," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems,* CHI '17, New York, NY, USA: Association for Computing Machinery, pp. 1179–1192, 2017.

[112] M. Colley, S. Krauss, M. Lanzer, and E. Rukzio, "How should automated vehicles communicate critical situations? A comparative analysis of visualization concepts," *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 5, no. 3, 2021.

[113] M. Colley, S. Li, and E. Rukzio, "Increasing pedestrian safety using external communication of autonomous vehicles for signalling hazards," in *Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction,* MobileHCI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[114] R. Collobert and J. Weston, "A unified architecture for natural language processing: Deep neural networks with multitask learning," in *Proceedings of the 25th International Conference on Machine Learning*, ACM, pp. 160–167, 2008.

[115] L. Corneo, M. Eder, N. Mohan, A. Zavodovski, S. Bayhan, W. Wong, P. Gunningberg, J. Kangasharju, and J. Ott, "Surrounded by the clouds: A comprehensive cloud reachability study," in *Proceedings of the Web Conference 2021*, New York, NY, USA: Association for Computing Machinery. 295–304, 2021.

[116] L. Corneo, M. Eder, N. Mohan, A. Zavodovski, S. Bayhan, W. Wong, P. Gunningberg, J. Kangasharju, and J. Ott, "Surrounded by the clouds: A comprehensive cloud reachability study," in *Proceedings of the Web Conference 2021,* WWW '21, pp. 295–304, New York, NY, USA: Association for Computing Machinery, 2021.

[117] L. Corneo, N. Mohan, A. Zavodovski, W. Wong, C. Rohner, P. Gunningberg, and J. Kangasharju, "(how much) can edge computing change network latency?" In *2021 IFIP Networking Conference (IFIP Networking)*, pp. 1–9, 2021.

[118] P. Cureton and N. Dunn, *Digital twins of cities and evasive futures*, 2020.

[119] A. Cuthbertson, "Google admits giving hundreds of firms to your gmail inbox," *The Independent*, 2018.

[120] L. Cutler, A. Tucker, R. Schiewe, J. Fischer, N. Dirksen, and E. Darnell, "Authoring interactive VR narratives on Baba Yaga and Bonfire," *Special Interest Group on Computer Graphics and Interactive Techniques Conference Talks*, 2020.

[121] A. Cuzzocrea, "Privacy and security of big data: Current challenges and future research perspectives," in *Proceedings of the First International Workshop on Privacy and Secuirty of Big Data*, pp. 45–47, 2014.

[122] CyberGlove Systems, *CyberTouch*, http://www.cyberglovesystems.com/cybertouch, 2020.

[123] K. Czesak, R. Mohedano, P. Carballeira, J. Cabrera, and N. Garcia, "Fusion of pose and head tracking data for immersive mixed-reality application development," in *2016 3DTV-Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON)*, IEEE, pp. 1–4, 2016.

[124] R. L. Daft and R. H. Lengel, "Organizational information requirements, media richness and structural design," *Management Science*, vol. 32, pp. 554–571, 1986.

[125] J. Dai, Z. Zhang, S. Mao, and D. Liu, "A view synthesis-based 360° vr caching system over mec-enabled c-ran," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 30, no. 10, pp. 3843–3855, 2019.

[126] J. Dalek, B. Haselton, H. Noman, A. Senft, M. Crete-Nishihata, P. Gill, and R. J. Deibert, "A method for identifying and confirming the use of url filtering products for censorship," in *Proceedings of the 2013 Conference on Internet Measurement Conference,* IMC '13, New York, NY, USA: Association for Computing Machinery, pp. 23–30, 2013.

[127] Q. Dang, J. Yin, B. Wang, and W. Zheng, "Deep learning based 2d human pose estimation: A survey," *Tsinghua Science and Technology*, vol. 24, no. 6, pp. 663–676, 2019.

[128] T. K. Dang, M. Nitinder, C. Lorenzo, Z. Aleksandr, O. Jörg, and J. Kangasharju, "Cloudy with a chance of short RTTs: Analyzing cloud connectivity in the internet," in *ACM Internet Measurements Conference*, ACM, 2021.

[129] E. D'Antonio, J. Taborri, E. Palermo, S. Rossi, and F. Patanè, "A markerless system for gait analysis based on openpose library," in *2020 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, IEEE, pp. 1–6, 2020.

[130] E. Dao, A. Muresan, K. Hornbæk, and J. Knibbe, "Bad breakdowns, useful seams, and face slapping: Analysis of VR fails on youtube," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, 2021.

[131] A. Dash, A. Shandilya, A. Biswas, K. Ghosh, S. Ghosh, and A. Chakraborty, "Summarizing user-generated textual content: Motivation and methods for fairness in algorithmic summaries," *Proc. ACM Hum.-Comput. Interact.*, vol. 3, no. CSCW, 2019.

[132] A. Davis, J. D. Murphy, D. Owens, D. Khazanchi, and I. Zigurs, "Avatars, people, and virtual worlds: Foundations for research in metaverses," *Journal of the Association for Information Systems*, vol. 10, no. 2, p. 90, 2009.

[133] J. Dean and L. A. Barroso, "The tail at scale," *Communications of the ACM*, vol. 56, pp. 74–80, 2013.

[134] C. Denis-Rémis, O. Codou, and J.-F. Lebraty, "Relation of green it and affective attitude within the technology acceptance model: The cases of france and china," *Management & Avenir*, vol. 39, pp. 371–385, 2010.

[135] K. Diab and M. Hefeeda, "Joint content distribution and traffic engineering of adaptive videos in telco-cdns," in *IEEE INFOCOM 2019—IEEE Conference on Computer Communications*, pp. 1342–1350, 2019.

[136] M. Dianatfar, J. Latokartano, and M. Lanz, "Review on existing VR/AR solutions in human–robot collaboration," *Procedia CIRP*, vol. 97, pp. 407–411, 2021.

[137] E. Dick, "How to address privacy questions raised by the expansion of augmented reality in public spaces," Information Technology and Innovation Foundation, Technical Report, 2020.

[138] S. Dick, "Artificial intelligence," Harvard Data Science Review, 2019.

[139] X. Ding, J. Xu, G. Chen, and C. Xu, "Beyond smartphone overuse: Identifying addictive mobile apps," in *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems,* CHI EA '16, New York, NY, USA: Association for Computing Machinery, pp. 2821–2828, 2016.

[140] J. D. N. Dionisio, W. G. Burns III, and R. Gilbert, “3D virtual worlds and the metaverse: Current status and future possibilities,” *ACM Computing Surveys*, vol. 45, no. 3, pp. 34:1–34:38, 2013.

[141] D. Dobbelstein, C. Winkler, G. Haas, and E. Rukzio, “Pocketthumb: A wearable dual-sided touch interface for cursor-based control of smart-eyewear,” *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 1, 9:1–9:17, 2017.

[142] C. Doerrer and R. Werthschuetzky, “Simulating push-buttons using a haptic display: Requirements on force resolution and force-displacement curve,” in *Proc. EuroHaptics*, pp. 41–46, 2002.

[143] J. Dong, Z. Tang, and Q. Zhao, “Gesture recognition in augmented reality assisted assembly training,” in *Journal of Physics: Conference Series*, IOP Publishing, vol. 1176, p. 032 030, 2019.

[144] M. Dragoni, S. Tonelli, and G. Moretti, “A knowledge management architecture for digital cultural heritage,” *J. Comput. Cult. Herit.*, vol. 10, no. 3, 2017.

[145] H. Duan, J. Li, S. Fan, Z. Lin, X. Wu, and W. Cai, “Metaverse for social good: A university campus prototype,” *arXiv preprint arXiv:2108.08985*, 2021.

[146] H. Duan, J. Li, S. Fan, Z. Lin, X. Wu, and W. Cai, “Metaverse for social good: A university campus prototype,” *ACM Multimedia 2021*, vol. abs/2108.08985, 2021.

[147] B. Dym and C. Fiesler, “Social norm vulnerability and its consequences for privacy and safety in an online community,” *Proc. ACM Hum.-Comput. Interact.*, vol. 4, no. CSCW2, 2020.

[148] F. El Jamiy and R. Marsh, “Distance estimation in virtual reality and augmented reality: A survey,” in *2019 IEEE International Conference on Electro Information Technology (EIT)*, IEEE, pp. 063–068, 2019.

[149] M. S. Elbamby, C. Perfecto, M. Bennis, and K. Doppler, “Edge computing meets millimeter-wave enabled VR: Paving the way to cutting the cord,” in *2018 IEEE Wireless Communications and Networking Conference (WCNC)*, IEEE, pp. 1–6, 2018.

[150] A. Elgammal, Y. Kang, and M. Den Leeuw, “Picasso, matisse, or a fake? Automated analysis of drawings at the stroke level for attribution and authentication,” in *Thirty-Second AAAI Conference on Artificial Intelligence*, 2018.
[151] M. Erel-Özçevik and B. Canberk, “Road to 5G reduced-latency: A software defined handover model for eMBB services,” *IEEE Transactions on Vehicular Technology*, vol. 68, no. 8, pp. 8133–8144, 2019.
[152] R. Ertel, O. Karakaş, and Y. Doğru, “A qualitative research on the supportive components of pokemon go addiction,” *AJIT-e: Online Academic Journal of Information Technology*, vol. 8, pp. 271–289, 2017.
[153] Facebook, *Introducing oculus air link, a wireless way to play pc vr games on oculus quest 2, plus infinite office updates, support for 120 hz on quest 2, and more.* 2021.
[154] A. Faeth and C. Harding, “Emergent effects in multimodal feedback from virtual buttons,” *ACM Transactions on Computer-Human Interaction (TOCHI)*, vol. 21, no. 1, p. 3, 2014.
[155] B. Falchuk, S. Loeb, and R. Neff, “The social Metaverse: Battle for privacy,” *IEEE Technology and Society Magazine*, vol. 37, no. 2, pp. 52–61, 2018.
[156] H.-S. Fang, S. Xie, Y.-W. Tai, and C. Lu, “Rmpe: Regional multi-person pose estimation,” in *Proceedings of the IEEE International Conference on Computer Vision*, pp. 2334–2343, 2017.
[157] M. H. Farhat, X. Chiementin, F. Chaari, F. Bolaers, and M. Haddar, “Digital twin-driven machine learning: Ball bearings fault severity classification,” *Measurement Science and Technology*, vol. 32, no. 4, p. 044 006, 2021.
[158] S. K. Feiner, B. MacIntyre, M. Haupt, and E. Solomon, “Windows on the world: 2d windows for 3d augmented reality,” in *UIST '93*, 1993.
[159] S. K. Feiner, B. MacIntyre, T. Höllerer, and A. Webster, “A touring machine: Prototyping 3d mobile augmented reality systems for exploring the urban environment,” in *SEMWEB*, 1997.

[160] C.-H. Feng, Y.-H. Hung, C.-K. Yang, L.-C. Chen, W.-C. Hsu, and S.-H. Lin, "Applying Holo360 video and image super-resolution generative adversarial networks to virtual reality immersion," in *International Conference on Human-Computer Interaction*, Springer, pp. 569–584, 2020.

[161] G. Fettweis and S. Alamouti, "5G: Personal mobile internet beyond what cellular did to telephony," *IEEE Communications Magazine*, vol. 52, no. 2, pp. 140–145, 2014.

[162] K. J. Fietkiewicz, E. Lins, K. S. Baran, and W. G. Stock, "Inter-generational comparison of social media use: Investigating the online behavior of different generational cohorts," in *2016 49th Hawaii International Conference on System Sciences (HICSS)*, Los Alamitos, CA, USA: IEEE Computer Society, pp. 3829–3838, 2016.

[163] J. Fischer and D. Bartz, "Handling photographic imperfections and aliasing in augmented reality," 2006.

[164] S. Foley, J. R. Karlsen, and T. J. Putniņš, "Sex, drugs, and bitcoin: How much illegal activity is financed through cryptocurrencies?" *The Review of Financial Studies*, vol. 32, no. 5, pp. 1798–1853, 2019.

[165] E. Fosch-Villaronga and A. Poulsen, "Sex robots in care: Setting the stage for a discussion on the potential use of sexual robot technologies for persons with disabilities," in *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction,* HRI '21 Companion, New York, NY, USA: Association for Computing Machinery, pp. 1–9, 2021.

[166] J. A. Frank, M. Moorhead, and V. Kapila, "Mobile mixed-reality interfaces that enhance human–robot interaction in shared spaces," *Frontiers in Robotics and AI*, vol. 4, p. 20, 2017.

[167] G. Freeman and D. Maloney, "Body, Avatar, and me: The presentation and perception of self in social virtual reality," *Proc. ACM Hum.-Comput. Interact.*, vol. 4, no. CSCW3, 2021.

[168] G. Freitas, M. Pinho, M. Silveira, and F. Maurer, "A systematic review of rapid prototyping tools for augmented reality," *2020 22nd Symposium on Virtual and Augmented Reality (SVR)*, pp. 199–209, 2020.

[169] S. Frish, M. Druchok, and H. Shchur, "Molecular MR multiplayer: A cross-platform collaborative interactive game for scientists," in *26th ACM Symposium on Virtual Reality Software and Technology,* VRST '20, New York, NY, USA: Association for Computing Machinery, 2020.

[170] H. Fuchs, M. A. Livingston, R. Raskar, K. Keller, J. R. Crawford, P. Rademacher, S. H. Drake, A. A. Meyer, *et al.*, "Augmented reality visualization for laparoscopic surgery," in *International Conference on Medical Image Computing and Computer-Assisted Intervention*, Springer, pp. 934–943, 1998.

[171] K. Fuchs, D. Meusburger, M. Haldimann, and A. Ilic, "Nutrition-avatar: Designing a future-self avatar for promotion of balanced, low-sodium diet intention: Framework design and user study," in *Proceedings of the 13th Biannual Conference of the Italian SIGCHI Chapter: Designing the next Interaction,* CHItaly '19, New York, NY, USA: Association for Computing Machinery, 2019.

[172] A. Fuller, Z. Fan, C. Day, and C. Barlow, "Digital twin: Enabling technologies, challenges and open research," *IEEE Access*, vol. 8, pp. 108 952–108 971, 2020.

[173] A. G. Martin, A. Fernandez-Isabel, I. Martin de Diego, and M. Beltran, "A survey for user behavior analysis based on machine learning techniques: Current models and applications," *Applied Intelligence*, vol. 51, no. 8, pp. 6029–6055, 2021.

[174] M. Gabardi, M. Solazzi, D. Leonardis, and A. Frisoli, "A new wearable fingertip haptic interface for the rendering of virtual shapes and surface features," *IEEE Haptics Symposium, HAPTICS*, vol. 2016-April, pp. 140–146, 2016.

[175] A. Gajic, E. Gonzalez-Sosa, D. Gonzalez-Morin, M. Escudero-Vinolo, and A. Villegas, "Egocentric human segmentation for mixed reality," *arXiv preprint arXiv:2005.12074*, 2020.

[176] R. Gallagher, "No sex please, we are finite state machines: On the melancholy sexlessness of the video game," *Games and Culture*, vol. 7, no. 6, pp. 399–418, 2012.

[177] A. L. Gardony, R. W. Lindeman, and T. T. Brunyé, "Eye-tracking for human-centered mixed reality: Promises and challenges," in *Optical Architectures for Displays and Sensing in Augmented, Virtual, and Mixed Reality (AR, VR, MR)*, International Society for Optics and Photonics, vol. 11310, 113100T, 2020.

[178] D. Gasques, J. G. Johnson, T. Sharkey, and N. Weibel, "Pintar: Sketching spatial experiences in augmented reality," *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion*, 2019.

[179] M. Gattullo, A. E. Uva, M. Fiorentino, and J. L. Gabbard, "Legibility in industrial ar: Text style, color coding, and illuminance," *IEEE Computer Graphics and Applications*, vol. 35, pp. 52–61, 2015.

[180] B. Geisler, "An empirical study of machine learning algorithms applied to modeling player behavior in a 'first person shooter' video game," Ph.D thesis, 2002.

[181] F. G. Glavin and M. G. Madden, "Skilled experience catalogue: A skill-balancing mechanism for non-player characters using reinforcement learning," in *2018 IEEE Conference on Computational Intelligence and Games (CIG)*, IEEE, pp. 1–8, 2018.

[182] A. Goel, W. A. Rivera, P. J. Kincaid, W. Karwowski, M. M. Montgomery, and N. Finkelstein, "A research framework for exascale simulations of distributed virtual world environments on high performance computing (HPC) clusters," in *Proceedings of the Symposium on High Performance Computing,* HPC '15, San Diego, CA, USA: Society for Computer Simulation International, pp. 25–32, 2015.

[183] A. Golnari, H. Khosravi, and S. Sanei, "Deepfacear: Deep face recognition and displaying personal information via augmented reality," in *2020 International Conference on Machine Vision and Image Processing (MVIP)*, IEEE, pp. 1–7, 2020.

[184] J. Gong, Y. Zhang, X. Zhou, and X. D. Yang, "Pyro: Thumb-tip gesture recognition using pyroelectric infrared sensing," in *Proc. of the 30th Annual ACM Symp. on User Interface Soft. and Tech. (UIST '17)*, pp. 553–563, 2017.

[185] M. L. Gordon and S. Zhai, "Touchscreen haptic augmentation effects on tapping, drag and drop, and path following," in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pp. 1–12, 2019.

[186] D. Grabovičkić, P. Benitez, J. C. Miñano, P. Zamora, M. Buljan, B. Narasimhan, M. I. Nikolic, J. Lopez, J. Gorospe, E. Sanchez, *et al.*, "Super-resolution optics for virtual reality," in *Digital Optical Technologies 2017*, International Society for Optics and Photonics, vol. 10335, 103350G, 2017.

[187] M. W. Grieves and J. Vickers, *Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems*, 2017.

[188] J. Grubert, T. Langlotz, S. Zollmann, and H. Regenbrecht, "Towards pervasive augmented reality: Context-awareness in augmented reality," *IEEE Transactions on Visualization and Computer Graphics*, vol. 23, no. 6, pp. 1706–1724, 2017.

[189] GSMA, *Cloud AR/VR whitepaper*, 2019. URL: https://www.gsma.com/futurenetworks/wiki/cloud-ar-vr-whitepape.

[190] Y. Gu, C. Yu, Z. Li, W. Li, S. Xu, X. Wei, and Y. Shi, "Accurate and low-latency sensing of touch contact on any surface with Finger-Worn IMU sensor," *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*, 2019.

[191] Z. Gu, H. Lu, P. Hong, and Y. Zhang, "Reliability enhancement for VR delivery in mobile-edge empowered dual-connectivity sub-6 GHz and mmwave hetnets," *IEEE Transactions on Wireless Communications*, 2021.

[192] A. Gupta and R. Balakrishnan, "Dualkey: Miniature screen text entry via finger identification," *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2016.

[193] S. Gupta, J. Chakareski, and P. Popovski, "Millimeter wave meets edge computing for mobile VR with high-fidelity 8K scalable 360° video," in *2019 IEEE 21st International Workshop on Multimedia Signal Processing (MMSP)*, IEEE, pp. 1–6, 2019.

[194] K. Ha, Z. Chen, W. Hu, W. Richter, P. Pillai, and M. Satyanarayanan, "Towards wearable cognitive assistance," in *Proceedings of the 12th Annual International Conference on Mobile Systems, Applications, and Services*, pp. 68–81, 2014.

[195] M. J. Haber, "Passwordless authentication," in *Privileged Attack Vectors*, Springer, 2020, pp. 87–98.

[196] T. Hachisu, B. Bourreau, and K. Suzuki, "Enhancedtouchx: Smart bracelets for augmenting interpersonal touch interactions," *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 2019.

[197] I. Hadžić, Y. Abe, and H. C. Woithe, "Edge computing in the epc: A reality check," in *Proceedings of the Second ACM/IEEE Symposium on Edge Computing*, pp. 1–10, 2017.

[198] A. Haffegee and R. Barrow, "Eye tracking and gaze based interaction within immersive virtual environments," in *International Conference on Computational Science*, Springer, pp. 729–736, 2009.

[199] K. Hamada, K. Tachibana, T. Li, H. Honda, and Y. Uchida, "Full-body high-resolution anime generation with progressive structure-conditional generative adversarial networks," in *Proceedings of the European Conference on Computer Vision (ECCV) Workshops*, 2018.

[200] E. u. Haq, T. Braud, Y. D. Kwon, and P. Hui, "Enemy at the gate: Evolution of twitter user's polarization during national crisis," in *2020 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM)*, pp. 212–216, 2020.

[201] J. Hartmann, Y.-T. Yeh, and D. Vogel, "Aar: Augmenting a wearable augmented reality display with an actuated head-mounted projector," in *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology,* UIST '20, New York, NY, USA: Association for Computing Machinery, pp. 445–458, 2020.

[202] C. Harwick, "Cryptocurrency and the problem of intermediation," *The Independent Review*, vol. 20, no. 4, pp. 569–588, 2016.

[203] Y. Hbali, L. Ballihi, M. Sadgal, and A. El Fazziki, "Face detection for augmented reality application using boosting-based techniques," *Int. J. Interact. Multim. Artif. Intell.*, vol. 4, no. 2, pp. 22–28, 2016.

[204] Z. He, R. Du, and K. Perlin, "Collabovr: A reconfigurable framework for creative collaboration in virtual reality," *2020 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 542–554, 2020.

[205] J. Heinonen, P. Korja, T. Partti, H. Flinck, and P. Pöyhönen, "Mobility management enhancements for 5G low latency services," in *2016 IEEE International Conference on Communications Workshops (ICC)*, IEEE, pp. 68–73, 2016.

[206] J. Henderson, J. Avery, L. Grisoni, and E. Lank, "Leveraging distal vibrotactile feedback for target acquisition," in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pp. 1–11, 2019.

[207] R. Herbrich, *Drivatars and forza motorsport*, URL: http://www.vagamelabs.com/drivatars-trade-and-forza-motorsport.htm, 2010.

[208] V. Herdel, L. J. Yamin, E. Ginosar, and J. R. Cauchard, "Public drone: Attitude towards drone capabilities in various contexts," in *Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction,* MobileHCI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[209] J. Hestness, S. W. Keckler, and D. A. Wood, "GPU computing pipeline inefficiencies and optimization opportunities in heterogeneous CPU-GPU processors," in *2015 IEEE International Symposium on Workload Characterization*, IEEE, pp. 87–97, 2015.

[210] W. Hofmann and F. Branding, "Implementation of an iot-and cloud-based digital twin for real-time decision support in port operations," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 2104–2109, 2019.

[211] E. Hoggan, S. A. Brewster, and J. Johnston, "Investigating the effectiveness of tactile feedback for mobile touchscreens," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* CHI '08, New York, NY, USA: Association for Computing Machinery, pp. 1573–1582, 2008.

[212] K. Holländer, M. Colley, E. Rukzio, and A. Butz, "A taxonomy of vulnerable road users for HCI based on a systematic literature review," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems,* CHI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[213] R. L. Holloway, "Registration error analysis for augmented reality," *Presence: Teleoperators & Virtual Environments*, vol. 6, no. 4, pp. 413–432, 1997.

[214] C. W. Holsapple and J. Wu, "User acceptance of virtual worlds: The hedonic framework," *SIGMIS Database*, vol. 38, no. 4, pp. 86–89, 2007.

[215] M. A. Hoque, A. Rao, A. Kumar, M. Ammar, P. Hui, and S. Tarkoma, "Sensing multimedia contexts on mobile devices," in *Proceedings of the 30th ACM Workshop on Network and Operating Systems Support for Digital Audio and Video,* NOSSDAV '20, New York, NY, USA: Association for Computing Machinery, pp. 40–46, 2020.

[216] R. Horst and R. Dörner, "Virtual reality forge: Pattern-oriented authoring of virtual reality nuggets," *25th ACM Symposium on Virtual Reality Software and Technology*, 2019.

[217] W. Hou, H. Han, L. Hong, and W. Yin, "Chci: A crowdsourcing human-computer interaction framework for cultural heritage knowledge," in *Proceedings of the ACM/IEEE Joint Conference on Digital Libraries in 2020,* JCDL '20, New York, NY, USA: Association for Computing Machinery, pp. 551–552, 2020.

[218] M. Höyhtyä, K. Lähetkangas, J. Suomalainen, M. Hoppari, K. Kujanpää, K. Trung Ngo, T. Kippola, M. Heikkilä, H. Posti, J. Mäki, T. Savunen, A. Hulkkonen, and H. Kokkinen, "Critical communications over mobile operators' networks: 5G use cases enabled by licensed spectrum sharing, network slicing and qos control," *IEEE Access*, vol. 6, pp. 73 572–73 582, 2018.

[219] F. Hu, P. He, S. Xu, Y. Li, and C. Zhang, "Fingertrak: Continuous 3d hand pose tracking by deep learning hand silhouettes captured by miniature thermal cameras on wrist," *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, vol. 4, no. 2, pp. 1–24, 2020.

[220] Y. C. Hu, M. Patel, D. Sabella, N. Sprecher, and V. Young, "Mobile edge computing–A key technology towards 5G," *ETSI White Paper*, vol. 11, no. 11, pp. 1–16, 2015.

[221] T. Hua and L. Wang, "Benchmarking implicit neural representation and geometric rendering in real-time RGB-D SLAM," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 21 346–21 356, 2024.

[222] D. Huang, C. Wang, Y. Ding, and W. Tang, "Virtual throwing action recognition based on time series data mining in an augmented reality system," in *2010 International Conference on Audio, Language and Image Processing*, IEEE, pp. 955–959, 2010.

[223] X.-Y. Huang, M.-S. Tsai, and C.-C. Huang, "3D virtual-reality interaction system," in *2019 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW)*, IEEE, pp. 1–2, 2019.

[224] D.-Y. Huang, L. Chan, S. Yang, F. Wang, R.-H. Liang, D.-N. Yang, Y.-P. Hung, and B.-Y. Chen, "Digitspace: Designing thumb-to-fingers touch interfaces for one-handed and eyes-free interactions," *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2016.

[225] T. Hulin, A. Albu-Schaffer, and G. Hirzinger, "Passivity and stability boundaries for haptic systems with time delay," *IEEE Transactions on Control Systems Technology*, vol. 22, no. 4, pp. 1297–1309, 2014.

[226] T. S. Ianchulev, D. S. Minckler, H. D. Hoskins, M. Packer, R. L. Stamper, R. D. Pamnani, and E. Koo, "Wearable technology with head-mounted displays and visual function," *JAMA*, vol. 312 17, pp. 1799–1801, 2014.

[227] L. A. Ib'ñez and V. Barneche Naya, "Cyberarchitecture: A Vitruvian Approach," in *2012 International Conference on Cyberworlds*, pp. 283–289, 2012.

[228] H. In, K.-J. Cho, K. Kim, and B. Lee, "Jointless structure and under-actuation mechanism for compact hand exoskeleton," in *2011 IEEE International Conference on Rehabilitation Robotics (ICORR)*, IEEE, pp. 1–6, 2011.

[229] Y. Ishii, T. Watanabe, and Y. Sejima, "Development of an embodied avatar system using avatar-shadow's color expressions with an interaction-activated communication model," in *Proceedings of the Fourth International Conference on Human Agent Interaction,* HAI '16, New York, NY, USA: Association for Computing Machinery, pp. 337–340, 2016.

[230] Y. Itoh, T. Langlotz, J. Sutton, and A. Plopski, "Towards indistinguishable augmented reality: A survey on optical see-through head-mounted displays," *ACM Comput. Surv.*, vol. 54, no. 6, 2021.

[231] Z. Ivkovic, I. Stavness, C. Gutwin, and S. Sutcliffe, "Quantifying and mitigating the negative effects of local latencies on aiming in 3d shooter games," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems,* CHI '15, New York, NY, USA: Association for Computing Machinery, pp. 135–144, 2015.

[232] E. J. Jeong, D. J. Kim, and D. M. Lee, "Game addiction from psychosocial health perspective," in *Proceedings of the 17th International Conference on Electronic Commerce 2015,* ICEC '15, New York, NY, USA: Association for Computing Machinery, 2015.

[233] M. Jia and W. Liang, "Delay-sensitive multiplayer augmented reality game planning in mobile edge computing," in *Proceedings of the 21st ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems*, pp. 147–154, 2018.

[234] F. Jiang, C. Castillo, and S. Ahalt, "Cachalot: A network-aware, cooperative cache network for geo-distributed, data-intensive applications," in *NOMS 2018-2018 IEEE/IFIP Network Operations and Management Symposium*, IEEE, pp. 1–9, 2018.

[235] F. Jiang, J. Ma, C. J. Webster, A. J. Chiaradia, Y. Zhou, Z. Zhao, and X. Zhang, "Generative urban design: A systematic review on problem formulation, design generation, and decision-making," *Progress in Planning*, vol. 180, p. 100 795, 2024.

[236] Y. Jiang, C. Zhang, H. Fu, A. Cannavò, F. Lamberti, H. Y. K. Lau, and W. Wang, "Handpainter – 3D sketching in vr with hand-based physical proxy," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, 2021.
[237] Y. Jin, J. Zhang, M. Li, Y. Tian, H. Zhu, and Z. Fang, "Towards the automatic anime characters creation with generative adversarial networks," *arXiv preprint arXiv:1708.05509*, 2017.
[238] D. Jo and G. J. Kim, "Ariot: Scalable augmented reality framework for interacting with internet of things appliances everywhere," *IEEE Transactions on Consumer Electronics*, vol. 62, no. 3, pp. 334–340, 2016.
[239] J. Joshua, "Information bodies: Computational anxiety in Neal Stephenson's Snow Crash," *Interdisciplinary Literary Studies*, vol. 19, no. 1, pp. 17–47, 2017.
[240] N. Kaklanis, J. G. Calleros, J. Vanderdonckt, and D. Tzovaras, "A haptic rendering engine of web pages for blind users," in *Proceedings of the Working Conference on Advanced Visual Interfaces*, pp. 437–440, 2008.
[241] T. Kämäräinen, M. Siekkinen, A. Ylä-Jääski, W. Zhang, and P. Hui, "A measurement study on achieving imperceptible latency in mobile cloud gaming," in *Proceedings of the 8th ACM on Multimedia Systems Conference,* MMSys'17, New York, NY, USA: Association for Computing Machinery, pp. 88–99, 2017.
[242] M. Kanbara, T. Okuma, H. Takemura, and N. Yokoya, "A stereoscopic video see-through augmented reality system based on real-time vision-based registration," in *Proceedings IEEE Virtual Reality 2000 (Cat. No. 00CB37048)*, IEEE, pp. 255–262, 2000.
[243] D. Kao and D. F. Harrell, "Exploring the impact of avatar color on game experience in educational games," in *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems,* CHI EA '16, New York, NY, USA: Association for Computing Machinery, pp. 1896–1905, 2016.
[244] S. Kapp, M. Barz, S. Mukhametov, D. Sonntag, and J. Kuhn, "Arett: Augmented reality eye tracking toolkit for head mounted displays," *Sensors*, vol. 21, no. 6, p. 2234, 2021.

[245] V. Kasapakis and D. Gavalas, "User-Generated Content in Pervasive Games," *Computers in Entertainment*, vol. 16, no. 1, pp. 3:1–3:23, 2017.

[246] B. Kelley and C. Tornatzky, "The artistic approach to virtual reality," in *The 17th International Conference on Virtual-Reality Continuum and its Applications in Industry,* VRCAI '19, New York, NY, USA: Association for Computing Machinery, pp. 1–5, 2019.

[247] J. W. Kelly, L. A. Cherep, A. Lim, T. A. Doty, and S. B. Gilbert, "Who are virtual reality headset owners? a survey and comparison of headset owners and non-owners," *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*, pp. 687–694, 2021.

[248] C. Kervegant, F. Raymond, D. Graeff, and J. Castet, "Touch hologram in mid-air," in *ACM SIGGRAPH 2017 Emerging Technologies*, ACM, p. 23, 2017.

[249] D. Kido, T. Fukuda, and N. Yabuki, Mobile Mixed Reality for Environmental Design Using Real-Time Semantic Segmentation and Video Communication-Dynamic Occlusion Handling and Green View Index Estimation, 2020.

[250] D. Kido, T. Fukuda, and N. Yabuki, "Assessing future landscapes using enhanced mixed reality with semantic segmentation by deep learning," *Advanced Engineering Informatics*, vol. 48, p. 101 281, 2021.

[251] H. Kim, M. Kim, and W. Lee, "HapThimble: A wearable haptic device towards usable virtual touch screen," *Chi '16*, pp. 3694–3705, 2016.

[252] H. Y. Kim, B. Kim, and J. Kim, "The naughty drone: A qualitative research on drone as companion device," in *Proceedings of the 10th International Conference on Ubiquitous Information Management and Communication,* IMCOM '16, New York, NY, USA: Association for Computing Machinery, 2016.

[253] J. C. Kim, T. H. Laine, and C. Åhlund, "Multimodal interaction systems based on internet of things and augmented reality: A systematic literature review," *Applied Sciences*, vol. 11, no. 4, p. 1738, 2021.

[254] K. Kim, G. Bruder, and G. Welch, "Exploring the effects of observed physicality conflicts on real-virtual human interaction in augmented reality," in *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*, VRST '17, New York, NY, USA: Association for Computing Machinery, 2017.

[255] K. Klamka and R. Dachselt, "Arcord: Visually augmented interactive cords for mobile interaction," *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*, 2018.

[256] B. Klein, A. V. Lerner, and K. M. Murphy, "The economics of copyright 'fair use' in a networked world," *American Economic Review*, vol. 92, no. 2, pp. 205–208, 2002.

[257] M. L. Knapp, *Nonverbal communication in human interaction*, 1972.

[258] T.-Y. Ko and S.-H. Lee, "Novel method of semantic segmentation applicable to augmented reality," *Sensors*, vol. 20, no. 6, p. 1737, 2020.

[259] A. Kobayashi, R. Aoki, N. Kitagawa, T. Kimura, Y. Takashima, and T. Yamada, "Towards enhancing force-input interaction by visual-auditory feedback as an introduction of first use," in *International Conference on Human-Computer Interaction*, Springer, pp. 180–191, 2016.

[260] M. Kocur, S. Graf, and V. Schwind, "The impact of missing fingers in virtual reality," in *26th ACM Symposium on Virtual Reality Software and Technology, VRST '20*, New York, NY, USA: Association for Computing Machinery, 2020.

[261] T. Kojić, D. Ali, R. Greinacher, S. Möller, and J.-N. Voigt-Antons, "User experience of reading in virtual reality–finding values for text distance, size and contrast," in *2020 Twelth International Conference on Quality of Multimedia Experience (QoMEX)*, IEEE, pp. 1–6, 2020.

[262] A. Kolesnichenko, J. McVeigh-Schultz, and K. Isbister, "Understanding emerging design practices for Avatar systems in the commercial social VR ecology," in *Proceedings of the 2019 on Designing Interactive Systems Conference,* DIS '19, New York, NY, USA: Association for Computing Machinery, pp. 241–252, 2019.

[263] A. Korinevskaya and I. Makarov, "Fast depth map super-resolution using deep neural network," in *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, IEEE, pp. 117–122, 2018.

[264] M. J. L. Kors, G. Ferri, E. D. van der Spek, C. Ketel, and B. A. M. Schouten, "A breathtaking journey. On the design of an empathy-arousing mixed-reality game," in *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play,* CHI PLAY '16, New York, NY, USA: Association for Computing Machinery, pp. 91–104, 2016.

[265] D. Kostenko, N. Kudryashov, M. Maystrishin, V. Onufriev, V. Potekhin, and A. Vasiliev, "Digital twin applications: Diagnostics, optimisation and prediction," *Annals of DAAAM & Proceedings*, vol. 29, 2018.

[266] P. Koutsabasis, S. Vosinakis, K. Malisova, and N. Paparounas, "On the value of virtual worlds for collaborative design," *Design Studies*, vol. 33, no. 4, pp. 357–390, 2012.

[267] K. Krafka, A. Khosla, P. Kellnhofer, H. Kannan, S. Bhandarkar, W. Matusik, and A. Torralba, "Eye tracking for everyone," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 2176–2184, 2016.

[268] V. Krauß, A. Boden, L. Oppermann, and R. Reiners, "Current practices, challenges, and design implications for collaborative ar/vr application development," *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 2021.

[269] T. Kubota, "Creating a more attractive hologram," *Leonardo*, vol. 25, pp. 503–506, 1992.

[270] H. Kukka, J. Ylipulli, J. Goncalves, T. Ojala, M. Kukka, and M. Syrjälä, "Creator-centric study of digital art exhibitions on interactive public displays," in *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia,* MUM '17, New York, NY, USA: Association for Computing Machinery, pp. 37–48, 2017.

[271] A. Kumar, T. Braud, Y. D. Kwon, and P. Hui, "Aquilis: Using contextual integrity for privacy protection on mobile devices," *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 4, no. 4, 2020.

[272] A. Kumar, T. Braud, L.-H. Lee, and P. Hui, "Theophany: Multimodal speech augmentation in instantaneous privacy channels," in *Proceedings of the 29th ACM International Conference on Multimedia (MM '21),* October 20–24, 2021, Virtual Event, China, Association for Computing Machinery (ACM), 2021.

[273] A. Kumar, T. Braud, S. Tarkoma, and P. Hui, "Trustworthy ai in the age of pervasive computing and big data," in *2020 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, pp. 1–6, 2020.

[274] A. Kumar, B. Finley, T. Braud, S. Tarkoma, and P. Hui, "Sketching an ai marketplace: Tech, economic, and regulatory aspects," *IEEE Access*, vol. 9, pp. 13 761–13 774, 2021.

[275] A. Kumar, P. Grover, A. K. Kar, and A. K. Pani, "It consulting: A systematic literature review," in *Digital Nations – Smart Cities, Innovation, and Sustainability*, A. K. Kar, P. V. Ilavarasan, M. Gupta, Y. K. Dwivedi, M. Mäntymäki, M. Janssen, A. Simintiras, and S. Al-Sharhan, Eds., pp. 474–484, Cham: Springer International Publishing, 2017.

[276] H. Kwak, J. Blackburn, and S. Han, "Exploring cyberbullying and other toxic behavior in team competition online games," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems,* CHI '15, New York, NY, USA: Association for Computing Machinery, pp. 3739–3748, 2015.

[277] Y. D. Kwon, J. Chauhan, A. Kumar, P. Hui, and C. Mascolo, "Exploring system performance of continual learning for mobile and embedded sensing applications," in *ACM/IEEE Symposium on Edge Computing*, Association for Computing Machinery (ACM), San Jose, USA, 2021.

[278] Y. D. Kwon, K. A. Shatilov, L.-H. Lee, S. Kumyol, K.-Y. Lam, Y.-P. Yau, and P. Hui, "Myokey: Surface electromyography and inertial motion sensing-based text entry in ar," in *2020 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, pp. 1–4, 2020.

[279] J. La Delfa, M. A. Baytaş, E. Luke, B. Koder, and F. F. Mueller, "Designing drone chi: Unpacking the thinking and making of somaesthetic human-drone interaction," in *Proceedings of the 2020 ACM Designing Interactive Systems Conference,* DIS '20, New York, NY, USA: Association for Computing Machinery, pp. 575–586, 2020.

[280] J. La Delfa, M. A. Baytas, R. Patibanda, H. Ngari, R. A. Khot, and F. F. Mueller, "Drone chi: Somaesthetic human-drone interaction," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* CHI '20, New York, NY, USA: Association for Computing Machinery, pp. 1–13, 2020.

[281] H. Laaki, Y. Miche, and K. Tammi, "Prototyping a digital twin for real time remote control over mobile networks: Application of remote surgery," *IEEE Access*, vol. 7, pp. 20 325–20 336, 2019.

[282] C. Lacey and C. Caudwell, "Cuteness as a 'dark pattern' in home robots," in *Proceedings of the 14th ACM/IEEE International Conference on Human-Robot Interaction,* HRI '19, Daegu, Republic of Korea: IEEE Press, pp. 374–381, 2019.

[283] P. K. Lai, S. Xie, J. Lang, and R. Laganière, "Real-time panoramic depth maps from omni-directional stereo images for 6 dof videos in virtual reality," in *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, IEEE, pp. 405–412, 2019.

[284] K. Y. Lam, L. Hang Lee, T. Braud, and P. Hui, "M2a: A framework for visualizing information from mobile web to mobile augmented reality," in *2019 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, pp. 1–10, 2019.

[285] K. Y. Lam, L.-H. Lee, and P. Hui, "A2w: Context-aware recommendation system for mobile augmented reality web browser," in *ACM International Conference on Multimedia*, United States: Association for Computing Machinery (ACM), 2021.

[286] U. Lampe, Q. Wu, S. Dargutev, R. Hans, A. Miede, and R. Steinmetz, "Assessing latency in cloud gaming," in *International Conference on Cloud Computing and Services Science*, Springer, pp. 52–68, 2013.

[287] D. R. Lampton, D. P. McDonald, M. Singer, and J. P. Bliss, "Distance estimation in virtual environments," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Los Angeles, CA: SAGE Publications, vol. 39, pp. 1268–1272, 1995.

[288] S. Lanette, P. K. Chua, G. Hayes, and M. Mazmanian, "How much is 'too much'? The role of a smartphone addiction narrative in individuals' experience of use," *Proc. ACM Hum.-Comput. Interact.*, vol. 2, no. CSCW, 2018.

[289] F. V. Langen, *Concept for a virtual learning factory*, 2017.

[290] T. Langlotz, C. Degendorfer, A. Mulloni, G. Schall, G. Reitmayr, and D. Schmalstieg, "Robust detection and tracking of annotations for outdoor augmented reality browsing," *Computers & Graphics*, vol. 35, pp. 831–840, 2011.

[291] T. Langlotz, S. Mooslechner, S. Zollmann, C. Degendorfer, G. Reitmayr, and D. Schmalstieg, "Sketching up the world: In situ authoring for mobile augmented reality," *Personal and Ubiquitous Computing*, vol. 16, pp. 623–630, 2011.

[292] A. Lassagne, A. Kemeny, J. Posselt, and F. Merienne, "Performance evaluation of passive haptic feedback for tactile HMI design in CAVEs," *IEEE Transactions on Haptics*, vol. 11, no. 1, pp. 119–127, 2018.

[293] M. E. Latoschik, D. Roth, D. Gall, J. Achenbach, T. Waltemate, and M. Botsch, "The effect of Avatar realism in immersive social virtual realities," in *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology,* VRST '17, New York, NY, USA: Association for Computing Machinery, 2017.

[294] J. LaViola *et al.*, *3D User Interfaces: Theory and Practice*. Addison Wesley, 2017.

[295] A. Lécuyer, J.-M. Burkhardt, S. Coquillart, and P. Coiffet, "'boundary of illusion': An experiment of sensory integration with a pseudo-haptic system," in *Proceedings IEEE Virtual Reality 2001*, IEEE, pp. 115–122, 2001.

[296] B. Lee, G. Han, J. Park, and D. Saakes, *Consumer to Creator: How Households Buy Furniture to Inform Design and Fabrication Interfaces*. New York, NY, USA: Association for Computing Machinery, pp. 484–496, 2017.

[297] C. Lee, G. A. Rincon, G. Meyer, T. Höllerer, and D. A. Bowman, "The effects of visual realism on search tasks in mixed reality simulation," *IEEE Transactions on Visualization and Computer Graphics*, vol. 19, no. 4, pp. 547–556, 2013.

[298] C. Lee, H. Joo, and S. Jun, "Social VR as the new normal? Understanding user interactions for the business arena," in *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems,* CHI EA '21, New York, NY, USA: Association for Computing Machinery, 2021.

[299] D. Lee and S. Lee, "Vision-based finger action recognition by angle detection and contour analysis," *ETRI Journal*, vol. 33, no. 3, pp. 415–422, 2011.

[300] H. Lee, H. Cha, J. Park, S. Choi, H.-S. Kim, and S.-C. Chung, "LaserStroke," *Proceedings of the 29th Annual Symposium on User Interface Software and Technology - UIST '16 Adjunct*, pp. 73–74, 2016.

[301] J.-H. Lee and C. Spence, "Assessing the benefits of multimodal feedback on dual-task performance under demanding conditions," in *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction-Volume 1*, British Computer Society, pp. 185–192, 2008.

[302] J. Lee, M. Lee, G. J. Kim, and J.-I. Hwang, “Effects of synchronized leg motion in walk-in-place utilizing deep neural networks for enhanced body ownership and sense of presence in VR,” in *26th ACM Symposium on Virtual Reality Software and Technology,* VRST ’20, New York, NY, USA: Association for Computing Machinery, 2020.
[303] L. H. Lee, T. N. Wong, and Z. Sun, “An agent-based framework for partner selection with sustainability considerations,” *IFAC Proceedings Volumes*, vol. 46, no. 9, pp. 168–173, 2013.
[304] L.-H. Lee, T. Braud, F. H. Bijarbooneh, and P. Hui, “Tipoint: Detecting fingertip for mid-air interaction on computational resource constrained smartglasses,” *Proceedings of the 23rd International Symposium on Wearable Computers*, 2019.
[305] L.-H. Lee, T. Braud, F. H. Bijarbooneh, and P. Hui, “Ubipoint: Towards non-intrusive mid-air interaction for hardware constrained smart glasses,” *Proceedings of the 11th ACM Multimedia Systems Conference*, 2020.
[306] L.-H. Lee, T. Braud, S. Hosio, and P. Hui, “Towards augmented reality-driven human-city interaction: Current research and future challenges,” *ArXiv*, vol. abs/2007.09207, 2020.
[307] L.-H. Lee, T. Braud, K.-Y. Lam, Y.-P. Yau, and P. Hui, “From seen to unseen: Designing keyboard-less interfaces for text entry on the constrained screen real estate of augmented reality headsets,” *Pervasive Mob. Comput.*, vol. 64, p. 101 148, 2020.
[308] L.-H. Lee and P. Hui, “Interaction methods for smart glasses: A survey,” *IEEE Access*, vol. 6, pp. 28 712–28 732, 2018.
[309] L.-H. Lee, A. Kumar, S. Pirttikangas, and T. Ojala, “When augmented reality meets edge AI: A vision of collective urban interfaces,” in *Interdisciplinary Urban AI: DIS Workshop*, 2020.
[310] L.-H. Lee, K.-Y. Lam, Y.-P. Yau, T. Braud, and P. Hui, “Hibey: Hide the keyboard in augmented reality,” *2019 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, pp. 1–10, 2019.

[311] M. K. Lee, A. Jain, H. J. Cha, S. Ojha, and D. Kusbit, "Procedural justice in algorithmic fairness: Leveraging transparency and outcome control for fair algorithmic mediation," *Proc. ACM Hum.-Comput. Interact.*, vol. 3, no. CSCW, 2019.

[312] Y. Lee, I. Jang, and D. Lee, "Enlarging just noticeable differences of visual-proprioceptive conflict in VR using haptic feedback," *IEEE World Haptics Conference, WHC 2015*, pp. 19–24, 2015.

[313] R. Leenes, "Privacy in the metaverse," in *IFIP International Summer School on the Future of Identity in the Information Society*, Springer, pp. 95–112, 2007.

[314] G. Leiva, C. Nguyen, R. Kazi, and P. Asente, "Pronto: Rapid augmented reality video prototyping using sketches and enaction," *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 2020.

[315] R. Lewis and M. Taylor-Poleskey, "Hidden town in 3d: Teaching and reinterpreting slavery virtually at a living history museum," *J. Comput. Cult. Herit.*, vol. 14, no. 2, 2021.

[316] A. Li, X. Yang, S. Kandula, and M. Zhang, "Cloudcmp: Comparing public cloud providers," in *Proceedings of the 10th ACM SIGCOMM Conference on Internet Measurement,* IMC '10, New York, NY, USA: Association for Computing Machinery, pp. 1–14, 2010.

[317] D. Li, R. Du, Y. Fu, and M. H. Au, "Meta-key: A secure data-sharing protocol under blockchain-based decentralized storage architecture," *IEEE Networking Letters*, vol. 1, no. 1, pp. 30–33, 2019.

[318] H. Li and T. Han, "Towards diverse anime face generation: Active label completion and style feature network," in *Eurographics (Short Papers)*, pp. 65–68, 2019.

[319] L. Li, X. Li, S. Yang, S. Ding, A. Jolfaei, and X. Zheng, "Unsupervised-learning-based continuous depth and motion estimation with monocular endoscopy for virtual reality minimally invasive surgery," *IEEE Transactions on Industrial Informatics*, vol. 17, no. 6, pp. 3920–3928, 2020.

[320] L. Li and J. Zhou, “Virtual reality technology based developmental designs of multiplayer-interaction-supporting exhibits of science museums: Taking the exhibit of virtual experience on an aircraft carrier’ in china science and technology museum as an example,” in *Proceedings of the 15th ACM SIGGRAPH Conference on Virtual-Reality Continuum and Its Applications in Industry*-Volume 1, pp. 409–412, 2016.

[321] N. Li and Y. Liu, “Applying vertexshuffle toward 360-degree video super-resolution on focused-icosahedral-mesh,” *arXiv preprint arXiv:2106.11253*, 2021.

[322] R. Li, T. Song, B. Mei, H. Li, X. Cheng, and L. Sun, “Blockchain for large-scale internet of things data storage and protection,” *IEEE Transactions on Services Computing*, vol. 12, no. 5, pp. 762–771, 2018.

[323] X. Li, Y. Tian, F. Zhang, S. Quan, and Y. Xu, “Object detection in the context of mobile augmented reality,” in *2020 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, IEEE, pp. 156–163, 2020.

[324] Y. Li, N. Vishwamitra, B. P. Knijnenburg, H. Hu, and K. Caine, “Effectiveness and users’ experience of obfuscation as a privacy-enhancing technology for sharing photos,” *Proc. ACM Hum.-Comput. Interact.*, vol. 1, no. CSCW, 2017.

[325] Z. H. Lim and P. O. Kristensson, “An evaluation of discrete and continuous mid-air loop and marking menu selection in optical see-through hmds,” *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services*, 2019.

[326] Y.-C. Lin, L. Hsu, and M. Y. Chen, “PeriTextAR: Utilizing peripheral vision for reading text on augmented reality smart glasses,” *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*, 2018.

[327] C.-e. Lin, T. Y. Cheng, and X. Ma, “Architect: Building interactive virtual experiences from physical affordances by bringing human-in-the-loop,” in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* CHI ’20, New York, NY, USA: Association for Computing Machinery, pp. 1–13, 2020.

[328] J. Lin, X. Guo, J. Shao, C. Jiang, Y. Zhu, and S.-C. Zhu, "A virtual reality platform for dynamic human-scene interaction," in *SIGGRAPH ASIA 2016 Virtual Reality Meets Physical Reality: Modelling and Simulating Virtual Humans and Environments*, 2016, pp. 1–4.

[329] J. Lin and M. E. Latoschik, "Digital body, identity and privacy in social virtual reality: A systematic review," *Frontiers in Virtual Reality*, vol. 3, p. 974 652, 2022.

[330] P. Lin, Q. Song, D. Wang, R. Yu, L. Guo, and V. Leung, "Resource management for pervasive edge computing-assisted wireless vr streaming in industrial internet of things," *IEEE Transactions on Industrial Informatics*, 2021.

[331] P. Lincoln, A. Blate, M. Singh, T. Whitted, A. State, A. Lastra, and H. Fuchs, "From motion to photons in 80 microseconds: Towards minimal latency for virtual and augmented reality," *IEEE Transactions on Visualization and Computer Graphics*, vol. 22, no. 4, pp. 1367–1376, 2016.

[332] D. Lindlbauer and A. D. Wilson, "Remixed reality: Manipulating space and time in augmented reality," in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pp. 1–13, New York, NY, USA: Association for Computing Machinery, 2018.

[333] A. Lingley, M. U. Ali, Y. Liao, R. Mirjalili, M. Klonner, M. Sopanen, S. Suihkonen, T. Shen, B. P. Otis, H. Lipsanen, and B. A. Parviz, "A single-pixel wireless contact lens display," *Journal of Micromechanics and Microengineering*, vol. 21, p. 125 014, 2011.

[334] E. Liotou, K. Samdanis, E. Pateromichelakis, N. Passas, and L. Merakos, "QoE-SDN APP: A rate-guided QoE-aware SDN-APP for HTTP adaptive video streaming," *IEEE Journal on Selected Areas in Communications*, vol. 36, no. 3, pp. 598–615, 2018.

[335] E. Liotou, D. Tsolkas, N. Passas, and L. Merakos, "Quality of experience management in mobile cellular networks: Key issues and design challenges," *IEEE Communications Magazine*, vol. 53, no. 7, pp. 145–153, 2015.

[336] H. Liu, M. Bowman, and F. Chang, "Survey of state melding in virtual worlds," *ACM Comput. Surv.*, vol. 44, no. 4, 2012.

[337] L. Liu, H. Li, and M. Gruteser, "Edge assisted real-time object detection for mobile augmented reality," in *The 25th Annual International Conference on Mobile Computing and Networking*, pp. 1–16, 2019.

[338] P. T. S. Liu, "Medical record system using blockchain, big data and tokenization," in *International Conference on Information and Communications Security*, Springer, pp. 254–261, 2016.

[339] W. Liu, D. Anguelov, D. Erhan, C. Szegedy, S. Reed, C.-Y. Fu, and A. C. Berg, "Ssd: Single shot multibox detector," in *European Conference on Computer Vision*, Springer, pp. 21–37, 2016.

[340] Y. Liu, J. Liu, A. Argyriou, and S. Ci, "Mec-assisted panoramic vr video streaming over millimeter wave mobile networks," *IEEE Transactions on Multimedia*, vol. 21, no. 5, pp. 1302–1316, 2018.

[341] Y. Liu, K. Chen, C. Liu, Z. Qin, Z. Luo, and J. Wang, "Structured knowledge distillation for semantic segmentation," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 2604–2613, 2019.

[342] Y. Liu, L. Zhang, Y. Yang, L. Zhou, L. Ren, F. Wang, R. Liu, Z. Pang, and M. J. Deen, "A novel cloud-based framework for the elderly healthcare services using digital twin," *IEEE Access*, vol. 7, pp. 49 088–49 101, 2019.

[343] Y. Liu, Y. L. Sun, J. Ryoo, S. Rizvi, and A. V. Vasilakos, "A survey of security and privacy challenges in cloud computing: Solutions and future directions," *Journal of Computing Science and Engineering*, vol. 9, no. 3, pp. 119–133, 2015.

[344] J. Lodge, "Nameless and faceless: The role of biometrics in realising quantum (In) security and (Un) accountability," in *Security and Privacy in Biometrics*, Springer, 2013, pp. 311–337.

[345] J. M. Loomis, J. M. Knapp, *et al.*, "Visual perception of egocentric distance in real and virtual environments," *Virtual and Adaptive Environments*, vol. 11, pp. 21–46, 2003.

[346] P. Lopes, S. You, A. Ion, and P. Baudisch, "Adding force feedback to mixed reality experiences and games using electrical muscle stimulation," in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, pp. 1–13, 2018.

[347] C. López Garcia, M. C. Sánchez Gómez, and A. Garcia-Valcárcel Muñoz-Repiso, "Scales for measuring internet addiction in covid-19 times: Is the time variable still a key factor in measuring this addiction?" In *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality,* TEEM'20, New York, NY, USA: Association for Computing Machinery, pp. 600–604, 2020.

[348] D. G. Lowe, "Distinctive image features from scale-invariant keypoints," *International Journal of Computer Vision*, vol. 60, no. 2, pp. 91–110, 2004.

[349] S. Lu, Y. Yao, and W. Shi, "Collaborative learning on the edges: A case study on connected vehicles," in *2nd {USENIX} Workshop on Hot Topics in Edge Computing (HotEdge 19)*, 2019.

[350] X. Lu, D. Yu, H.-N. Liang, W. Xu, Y. Chen, X. Li, and K. Hasan, "Exploration of hands-free text entry techniques for virtual reality," in *2020 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, IEEE, pp. 344–349, 2020.

[351] J.-L. Lugrin, I. Polyschev, D. Roth, and M. E. Latoschik, "Avatar anthropomorphism and acrophobia," in *Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology,* VRST '16, New York, NY, USA: Association for Computing Machinery, pp. 315–316, 2016.

[352] J. Y. Luke and L. W. Evelina, "Exploring indonesian young females online social networks (OSNs) addictions: A case study of mass communication female undergraduate students," in *Proceedings of the 3rd International Conference on Communication and Information Processing,* ICCIP '17, New York, NY, USA: Association for Computing Machinery, pp. 400–404, 2017.

[353] R. K. Lyons and G. Viswanath-Natraj, "What keeps stablecoins stable?" National Bureau of Economic Research, Technical Report, 2020.

[354] Z. Ma, D. Edge, L. Findlater, and H. Z. Tan, "Haptic keyclick feedback improves typing speed and reduces typing errors on a flat keyboard," *IEEE World Haptics Conference, WHC 2015*, pp. 220–227, 2015.

[355] B. MacIntyre and E. M. Coelho, "Adapting to dynamic registration errors using level of error (LOE) filtering," *Proceedings IEEE and ACM International Symposium on Augmented Reality (ISAR 2000)*, pp. 85–88, 2000.

[356] B. MacIntyre, E. M. Coelho, and S. J. Julier, "Estimating and adapting to registration errors in augmented reality systems," *Proceedings IEEE Virtual Reality 2002*, pp. 73–80, 2002.

[357] B. A. Mackey, P. A. Bremner, and M. Giuliani, "Immersive control of a robot surrogate for users in palliative care," in *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction,* HRI '20, New York, NY, USA: Association for Computing Machinery, pp. 585–587, 2020.

[358] H. D. Macleod, *The Elements of Political Economy.* Longman, Brown, Green, Lonqmaus and Roberts, 1858.

[359] N. H. Mahmood, S. Böcker, A. Munari, F. Clazzer, I. Moerman, K. Mikhaylov, O. Lopez, O.-S. Park, E. Mercier, H. Bartz, *et al.*, "White paper on critical and massive machine type communication towards 6g," *arXiv preprint arXiv:2004.14146*, 2020.

[360] S. Mahurkar, "Integrating YOLO object detection with augmented reality for ios apps," in *2018 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, IEEE, pp. 585–589, 2018.

[361] M. Maier, M. Chowdhury, B. P. Rimal, and D. P. Van, "The tactile internet: vision, recent progress, and open challenges," *IEEE Communications Magazine*, vol. 54, no. 5, pp. 138–145, 2016. arXiv: 1602.06925.

[362] L. Malinverni, J. Maya, M.-M. Schaper, and N. Pares, "The world-as-support: Embodied exploration, understanding and meaning-making of the augmented world," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, pp. 5132–5144, 2017.

[363] D. Maloney, "Mitigating negative effects of immersive virtual avatars on racial bias," in *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts,* CHI PLAY '18 Extended Abstracts, New York, NY, USA: Association for Computing Machinery, pp. 39–43, 2018.

[364] D. Maloney, G. Freeman, and D. Y. Wohn, "'talking without a voice': Understanding non-verbal communication in social virtual reality," *Proc. ACM Hum.-Comput. Interact.*, vol. 4, no. CSCW2, 2020.

[365] N. A. Mangiarua, J. S. Ierache, and M. J. Abásolo, "Scalable integration of image and face based augmented reality," in *International Conference on Augmented Reality, Virtual Reality and Computer Graphics*, Springer, pp. 232–242, 2020.

[366] K. Mania, B. D. Adelstein, S. R. Ellis, and M. I. Hill, "Perceptual sensitivity to head tracking latency in virtual environments with varying degrees of scene complexity," in *Proceedings of the 1st Symposium on Applied Perception in Graphics and Visualization,* APGV '04, New York, NY, USA: Association for Computing Machinery, pp. 39–47, 2004.

[367] E. Marchand, H. Uchiyama, and F. Spindler, "Pose estimation for augmented reality: A hands-on survey," *IEEE Transactions on Visualization and Computer Graphics*, vol. 22, no. 12, pp. 2633–2651, 2015.

[368] J. Marin-Morales, C. Llinares, J. Guixeres, and M. Alcañiz, "Emotion recognition in immersive virtual reality: From statistics to affective computing," *Sensors*, vol. 20, no. 18, p. 5163, 2020.

[369] A. Marquardt, C. Trepkowski, T. D. Eibich, J. Maiero, and E. Kruijff, "Non-visual cues for view management in narrow field of view augmented reality displays," *2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 190–201, 2019.

[370] B. Marques, P. Dias, J. Alves, and B. S. Santos, "Adaptive augmented reality user interfaces using face recognition for smart home control," in *International Conference on Human Systems Engineering and Design: Future Trends and Applications*, Springer, pp. 15–19, 2019.

[371] M. Marzolla, S. Ferretti, and G. D'Angelo, "Dynamic resource provisioning for cloud-based gaming infrastructures," *Computers in Entertainment*, vol. 10, no. 1, pp. 4:1–4:20, 2012.

[372] F. Mathis, K. Vaniea, and M. Khamis, "Observing virtual avatars: The impact of avatars' fidelity on identifying interactions," in *Academic Mindtrek 2021,* Mindtrek 2021, New York, NY, USA: Association for Computing Machinery, pp. 154–164, 2021.

[373] Y. Matsuura, T. Terada, T. Aoki, S. Sonoda, N. Isoyama, and M. Tsukamoto, "Readability and legibility of fonts considering shakiness of head mounted displays," *Proceedings of the 23rd International Symposium on Wearable Computers*, 2019.

[374] J. McCarthy, "What is artificial intelligence?," 1998.

[375] S. A. McGlynn and W. A. Rogers, "Provisions of human-robot friendship," in *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts,* HRI'15 Extended Abstracts, New York, NY, USA: Association for Computing Machinery, pp. 115–116, 2015.

[376] A. Mehrabi, M. Siekkinen, T. Kämäräinen, and A. yl Jski, "Multi-tier cloudvr: Leveraging edge computing in remote rendered virtual reality," *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, vol. 17, no. 2, pp. 1–24, 2021.

[377] D. Mehta, S. Sridhar, O. Sotnychenko, H. Rhodin, M. Shafiei, H.-P. Seidel, W. Xu, D. Casas, and C. Theobalt, "Vnect: Real-time 3d human pose estimation with a single rgb camera," *ACM Transactions on Graphics (TOG)*, vol. 36, no. 4, pp. 1–14, 2017.

[378] S. Mehta, M. Rastegari, A. Caspi, L. Shapiro, and H. Hajishirzi, "Espnet: Efficient spatial pyramid of dilated convolutions for semantic segmentation," in *Proceedings of the European Conference on Computer Vision (ECCV)*, pp. 552–568, 2018.

[379] A. Meissner, A. Trubswetter, A. S. Conti-Kufner, and J. Schmidtler, "Friend or foe? Understanding assembly workers' acceptance of human-robot collaboration," *J. Hum.-Robot Interact.*, vol. 10, no. 1, 2020.

[380] M. R. F. Mendonça, H. S. Bernardino, and R. F. Neto, "Simulating human behavior in fighting games using reinforcement learning and artificial neural networks," in *2015 14th Brazilian Symposium on Computer Games and Digital Entertainment (SBGames)*, IEEE, pp. 152–159, 2015.

[381] A. H. Mhaidli and F. Schaub, "Identifying manipulative advertising techniques in xr through scenario construction," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[382] P. Milgram and F. Kishino, "A taxonomy of mixed reality visual displays," *IEICE Transactions on Information and Systems*, vol. 77, pp. 1321–1329, 1994.

[383] P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented reality: A class of displays on the reality-virtuality continuum," in *Telemanipulator and Telepresence Technologies*, H. Das, International Society for Optics and Photonics, SPIE, vol. 2351, pp. 282–292, 1995.

[384] N. Miller and P. Steenkiste, "Collecting network status information for network-aware applications," in *Proceedings IEEE INFOCOM 2000. Conference on Computer Communications. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies (Cat. No. 00CH37064)*, IEEE, vol. 2, pp. 641–650, 2000.

[385] S. Milz, G. Arbeiter, C. Witt, B. Abdallah, and S. Yogamani, "Visual slam for automated driving: Exploring the applications of deep learning," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*, pp. 247–257, 2018.

[386] Q. Min, Y. Lu, Z. Liu, C. Su, and B. Wang, "Machine learning based digital twin framework for production optimization in petrochemical industry," *International Journal of Information Management*, vol. 49, pp. 502–519, 2019.

[387] N. Mohammadi and J. E. Taylor, "Smart city digital twins," *2017 IEEE Symposium Series on Computational Intelligence (SSCI)*, pp. 1–5, 2017.

[388] N. Mohan, A. Zavodovski, P. Zhou, and J. Kangasharju, "Anveshak: Placing edge servers in the wild," in *Proceedings of the 2018 Workshop on Mobile Edge Communications*, pp. 7–12, 2018.

[389] T. Moi, A. Cibicik, and T. Rølvåg, "Digital twin based condition monitoring of a knuckle boom crane: An experimental study," *Engineering Failure Analysis*, vol. 112, p. 104 517, 2020.

[390] M. B. Mollah, M. A. K. Azad, and A. Vasilakos, "Security and privacy challenges in mobile cloud computing: Survey and way ahead," *Journal of Network and Computer Applications*, vol. 84, pp. 38–54, 2017.

[391] R. J. Moore, E. C. H. Gathman, N. Ducheneaut, and E. Nickell, "Coordinating joint activity in avatar-mediated interaction," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, pp. 21–30, 2007.

[392] S. Mori, S. Ikeda, and H. Saito, "A survey of diminished reality: Techniques for visually concealing, eliminating, and seeing through real objects," *IPSJ Transactions on Computer Vision and Applications*, vol. 9, no. 1, pp. 1–14, 2017.

[393] I. D. Motsi-Omoijiade, "Financial intermediation in cryptocurrency markets–regulation, gaps and bridges," in *Handbook of Blockchain, Digital Finance, and Inclusion, Volume 1*, Elsevier, pp. 207–223, 2018.

[394] J. Müller, R. Rädle, and H. Reiterer, *Virtual Objects as Spatial Cues in Collaborative Mixed Reality Environments: How They Shape Communication Behavior and User Task Load*. New York, NY, USA: Association for Computing Machinery, pp. 1245–1249, 2016.

[395] L. Müller, K. Pfeuffer, J. Gugenheimer, B. Pfleging, S. Prange, and F. Alt, "Spatialproto: Exploring real-world motion captures for rapid prototyping of interactive mixed reality," *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 2021.

[396] R. Mur-Artal and J. D. Tardós, "Orb-slam2: An open-source slam system for monocular, stereo, and rgb-d cameras," *IEEE Transactions on Robotics*, vol. 33, no. 5, pp. 1255–1262, 2017.

[397] D. Murphy, "Building a hybrid virtual agent for testing user empathy and arousal in response to avatar (micro-)expressions," in *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*, VRST '17, New York, NY, USA: Association for Computing Machinery, 2017.

[398] N. Murray, D. Roberts, A. Steed, P. Sharkey, P. Dickerson, and J. Rae, "An assessment of eye-gaze potential within immersive virtual environments," *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, vol. 3, no. 4, pp. 1–17, 2007.

[399] Z. Nabi, "The anatomy of web censorship in Pakistan," in *3rd USENIX Workshop on Free and Open Communications on the Internet (FOCI 13)*, Washington, D.C.: USENIX Association, 2013.

[400] K. Nagano, J. Seo, K. San, A. Hong, M. Goldwhite, J. Xing, S. Rastogi, J. Kuang, A. Agarwal, H. Kung, *et al.*, "Deep learning-based photoreal avatars for online virtual worlds in iOS," in *ACM SIGGRAPH 2018 Real-Time Live!* 2018.

[401] A. Nagendran, R. Pillat, C. Hughes, and G. Welch, "Continuum of virtual-human space: Towards improved interaction strategies for physical-virtual avatars," in *Proceedings of the 11th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry*, VRCAI '12, New York, NY, USA: Association for Computing Machinery, pp. 135–142, 2012.

[402] P. Nagpal and P. Prasad, "Pose estimation and 3D model overlay in real time for applications in augmented reality," in *Intelligent Systems*, Springer, 2021, pp. 201–208.

[403] M. Nakao, T. Terada, and M. Tsukamoto, "An information presentation method for head mounted display considering surrounding environments," *Proceedings of the 5th Augmented Human International Conference*, 2014.

[404] Y. Nam, M. Park, and R. Yamane, "Smart glove: Hand master using magnetorheological fluid actuators," in *Proc. SPIE*, vol. 6794, pp. 679 434–1, 2007.

[405] B. A. Narasimhan, "Ultra-compact pancake optics based on thineyes super-resolution technology for virtual reality headsets," in *Digital Optics for Immersive Displays*, International Society for Optics and Photonics, vol. 10676, 106761G, 2018.

[406] A. Narayanan and J. Clark, "Bitcoin's academic pedigree," *Communications of the ACM*, vol. 60, no. 12, pp. 36–45, 2017.

[407] T. Narumi, S. Nishizaka, T. Kajinami, T. Tanikawa, and M. Hirose, "Augmented reality flavors: Gustatory display based on edible marker and cross-modal interaction," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 93–102, New York, NY, USA: Association for Computing Machinery, 2011.

[408] E. Natalizio and V. Loscri, "Controlled mobility in mobile sensor networks: Advantages, issues and challenges," *Telecommunication Systems*, vol. 52, no. 4, pp. 2411–2418, 2013.

[409] M. Nebeling, K. Lewis, Y.-C. Chang, L. Zhu, M. Chung, P. Wang, and J. Nebeling, "Xrdirector: A role-based collaborative immersive authoring system," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, pp. 1–12, 2020.

[410] M. Nebeling and K. Madier, "360proto: Making interactive virtual reality & augmented reality prototypes from paper," *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 2019.

[411] M. Nebeling, J. Nebeling, A. Yu, and R. Rumble, "Protoar: Rapid physical-digital prototyping of mobile augmented reality applications," *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 2018.

[412] M. Nebeling, S. Rajaram, L. Wu, Y. Cheng, and J. Herskovitz, "Xrstudio: A virtual production and live streaming system for immersive instructional experiences," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems,* CHI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[413] E. L. Neely, "No player is ideal: Why video game designers cannot ethically ignore players' real-world identities," *New York, NY, USA*, vol. 47, no. 3, pp. 98–111, 2017.

[414] E. Nerurkar, S. Lynen, and S. Zhao, *System and method for concurrent odometry and mapping*, US Patent 10,802,147, 2020.

[415] K. Nevelsteen and M. Wehlou, "IPSME- Idempotent publish/subscribe messaging environment," in *Proceedings of the International Workshop on Immersive Mixed and Virtual Environment Systems (MMVE '21),* MMVE '21, New York, NY, USA: Association for Computing Machinery, pp. 30–36, 2021.

[416] Business Standard, *Users shun WhatsApp to join Telegram, Signal amid rising data concerns*, URL: https://www.business-standard.com/article/companies/users-shun-whatsapp-to-join-telegram-signal-amid-rising-data-concerns-121010900271_1.html, 2021.

[417] D. Wakabayashi, *Self-Driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam*, URL: https://www.nytimes.com/2018/03/19/technology/uber-driverless-fatality.html, 2018.

[418] NGMN Alliance, "5g white paper," *Next Generation Mobile Networks, White Paper*, vol. 1, 2015.

[419] NGMN Alliance, "Description of network slicing concept," *NGMN 5G P*, vol. 1, no. 1, 2016.

[420] B. V. D. Nguyen, A. L. Simeone, and A. Vande Moere, "Exploring an architectural framework for human-building interaction via a semi-immersive cross-reality methodology," in *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction,* HRI '21, New York, NY, USA: Association for Computing Machinery, pp. 252–261, 2021.

[421] Niantic, *Niantic planet-scale AR alliance accelerates social AR future in codename: Urban legends*, 2021.

[422] A. Nijholt, "Humans as avatars in smart and playable cities," in *2017 International Conference on Cyberworlds (CW)*, IEEE, pp. 190–193, 2017.

[423] T. Niki and T. Komuro, "Semi-automatic creation of an anime-like 3d face model from a single illustration," in *2019 International Conference on Cyberworlds (CW)*, IEEE, pp. 53–56, 2019.

[424] W. S. Noble, "What is a support vector machine?" *Nature Biotechnology*, vol. 24, no. 12, pp. 1565–1567, 2006.

[425] M. Nofer, P. Gomber, O. Hinz, and D. Schiereck, "Blockchain," *Business & Information Systems Engineering*, vol. 59, no. 3, pp. 183–187, 2017.

[426] J. C. Núñez, R. Cabido, A. S. Montemayor, and J. J. Pantrigo, "Real-time human body tracking based on data fusion from multiple rgb-d sensors," *Multimedia Tools and Applications*, vol. 76, no. 3, pp. 4249–4271, 2017.

[427] C. Nuzzi, S. Ghidini, R. Pagani, S. Pasinetti, G. Coffetti, and G. Sansoni, "Hands-free: A robot augmented reality teleoperation system," in *2020 17th International Conference on Ubiquitous Robots (UR)*, IEEE, pp. 617–624, 2020.

[428] *Nvidia omniverse platform*, 2021. URL: https://developer.nvidia.com/nvidia-omniverse-platform.

[429] Y. Ochiai, K. Kumagai, T. Hoshi, S. Hasegawa, and Y. Hayasaki, "Cross-Field Aerial Haptics: Rendering Haptic Feedback in Air with Light and Acoustic Fields," *Chi '16*, pp. 3238–3247, 2016.

[430] M. Ohta, S. Nagano, H. Niwa, and K. Yamashita, "[poster] mixed-reality store on the other side of a tablet," in *Proceedings of the 2015 IEEE International Symposium on Mixed and Augmented Reality,* ISMAR '15, USA: IEEE Computer Society, pp. 192–193, 2015.

[431] B. Okumura, M. Kanbara, and N. Yokoya, "Augmented reality based on estimation of defocusing and motion blurring from captured images," in *2006 IEEE/ACM International Symposium on Mixed and Augmented Reality*, IEEE, pp. 219–225, 2006.

[432] B. Okumura, M. Kanbara, and N. Yokoya, "Image composition based on blur estimation from captured image for augmented reality," in *Proc. of IEEE Virtual Reality*, pp. 128–134, 2006.

[433] I. Oliver, A. Miller, and C. Allison, "Mongoose: Throughput Redistributing Virtual World," in *2012 21st International Conference on Computer Communications and Networks (ICCCN)*, pp. 1–9, 2012.

[434] G. B. Orgaz, M. D. R-Moreno, D. Camacho, and D. F. Barrero, "Clustering avatars behaviours from virtual worlds interactions," in *Proceedings of the 4th International Workshop on Web Intelligence & Communities,* WIC '12, New York, NY, USA: Association for Computing Machinery, pp. 1–7, 2012.

[435] A. Osseiran, J. F. Monserrat, and P. Marsch, *5G Mobile and Wireless Communications Technology.* Cambridge University Press, 2016.

[436] O. Ouda, N. Tsumura, and T. Nakaguchi, "Bioencoding: A reliable tokenless cancelable biometrics scheme for protecting iriscodes," *IEICE Transactions on Information and Systems*, vol. 93, no. 7, pp. 1878–1888, 2010.

[437] S. Ouerghi, N. Ragot, R. Boutteau, and X. Savatier, "Comparative study of a commercial tracking camera and orb-slam2 for person localization," in *15th International Conference on Computer Vision Theory and Applications*, SCITEPRESS-Science and Technology Publications, pp. 357–364, 2020.

[438] C. Pacchierotti, S. Sinclair, M. Solazzi, A. Frisoli, V. Hayward, and D. Prattichizzo, "Wearable haptic systems for the fingertip and the hand: Taxonomy, review, and perspectives," *IEEE Transactions on Haptics*, vol. 10, no. 4, pp. 580–600, 2017.

[439] È. Pairet, P. Ardón, X. Liu, J. Lopes, H. Hastie, and K. S. Lohan, "A digital twin for human-robot interaction," in *Proceedings of the 14th ACM/IEEE International Conference on Human-Robot Interaction,* HRI '19, IEEE Press, p. 372, 2019.

[440] A. Paiva, I. Leite, H. Boukricha, and I. Wachsmuth, "Empathy in virtual agents and robots: A survey," *ACM Trans. Interact. Intell. Syst.*, vol. 7, no. 3, 2017.

[441] M. Pakanen, P. Alavesa, N. van Berkel, T. Koskela, and T. Ojala, "'Nice to see you virtually': Thoughtful design and evaluation of virtual avatar of the other user in AR and VR based telexistence systems," *Entertainment Computing*, vol. 40, p. 100 457, 2022.

[442] R. Pal, J. Crowcroft, A. Kumar, P. Hui, H. Haddadi, S. De, I. Ng, S. Tarkoma, and R. Mortier, "Privacy markets in the Apps and IoT age," University of Cambridge, Computer Laboratory, Tech. Rep. UCAM-CL-TR-925, 2018.

[443] R. Pal, J. Crowcroft, Y. Wang, Y. Li, S. De, S. Tarkoma, M. Liu, B. Nag, A. Kumar, and P. Hui, "Preference-based privacy markets," *IEEE Access*, vol. 8, pp. 146 006–146 026, 2020.

[444] F. S. Parizi, E. Whitmire, and S. N. Patel, "Auraring: Precise electromagnetic finger tracking," *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, vol. 3, 150:1–150:28, 2019.

[445] J. C. Park and J. R. Crandall, "Empirical study of a national-scale distributed intrusion detection system: Backbone-level filtering of html responses in china," in *Proceedings of the 2010 IEEE 30th International Conference on Distributed Computing Systems,* ICDCS '10, USA: IEEE Computer Society, pp. 315–326, 2010.

[446] Y. Park, S. Yun, and K.-H. Kim, "When iot met augmented reality: Visualizing the source of the wireless signal in ar view," in *Proceedings of the 17th Annual International Conference on Mobile Systems, Applications, and Services,* MobiSys '19, pp. 117–129, New York, NY, USA: Association for Computing Machinery, 2019.

[447] R. Pascoal, A. D. Almeida, and R. C. Sofia, "Mobile pervasive augmented reality systems–mpars: The role of user preferences in the perceived quality of experience in outdoor applications," *ACM Transactions on Internet Technology (TOIT)*, vol. 20, no. 1, pp. 1–17, 2020.

[448] M. K. Paul, K. Wu, J. A. Hesch, E. D. Nerurkar, and S. I. Roumeliotis, "A comparative analysis of tightly-coupled monocular, binocular, and stereo vins," in *2017 IEEE International Conference on Robotics and Automation (ICRA)*, IEEE, pp. 165–172, 2017.

[449] S. Peißl, C. D. Wickens, and R. Baruah, "Eye-tracking measures in aviation: A selective literature review," *The International Journal of Aerospace Psychology*, vol. 28, no. 3–4, pp. 98–112, 2018.

[450] E. Pezent, A. Israr, M. Samad, S. Robinson, P. Agarwal, H. Benko, and N. Colonnese, "Tasbi: Multisensory squeeze and vibrotactile wrist haptics for augmented and virtual reality," in *2019 IEEE World Haptics Conference (WHC)*, IEEE, pp. 1–6, 2019.

[451] T. Pfeiffer and P. Renner, "EyeSee3D: A low-cost approach for analyzing mobile 3D eye tracking data using computer vision and augmented reality technology," in *Proceedings of the Symposium on Eye Tracking Research and Applications*, pp. 195–202, 2014.

[452] J. S. Pierce and R. Pausch, "Comparing voodoo dolls and homer: Exploring the importance of feedback in virtual environments," *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2002.

[453] J. S. Pierce, B. C. Stearns, and R. Pausch, "Voodoo dolls: Seamless interaction at multiple scales in virtual environments," in *SI3D*, 1999.

[454] F. Piltan and J.-M. Kim, "Bearing anomaly recognition using an intelligent digital twin integrated with machine learning," *Applied Sciences*, vol. 11, no. 10, p. 4602, 2021.

[455] J. Pilz, M. Mehlhose, T. Wirth, D. Wieruch, B. Holfeld, and T. Haustein, "A Tactile Internet demonstration: 1 ms ultra low delay for wireless communications towards 5G," *Proceedings - IEEE INFOCOM*, vol. 2016-Septe, no. Keystone I, pp. 862–863, 2016.

[456] J. Ping, B. H. Thomas, J. Baumeister, J. Guo, D. Weng, and Y. Liu, "Effects of shading model and opacity on depth perception in optical see-through augmented reality," *Journal of the Society for Information Display*, vol. 28, no. 11, pp. 892–904, 2020.

[457] D. M. Plasencia, "One step beyond virtual reality: Connecting past and future developments," *XRDS: Crossroads, The ACM Magazine for Students*, vol. 22, no. 1, pp. 18–23, 2015.

[458] H. Pohl, T.-S. Dalsgaard, V. Krasniqi, and K. Hornbæk, “Body layars: A toolkit for body-based augmented reality,” in *26th ACM Symposium on Virtual Reality Software and Technology*, 2020.

[459] A. Pokhrel, V. Katta, and R. Colomo-Palacios, “Digital twin for cybersecurity incident prediction: A multivocal literature review,” in *Proceedings of the IEEE/ACM 42nd International Conference on Software Engineering Workshops,* ICSEW’20, pp. 671–678, New York, NY, USA: Association for Computing Machinery, 2020.

[460] R. S. Portnoff, S. Afroz, G. Durrett, J. K. Kummerfeld, T. Berg-Kirkpatrick, D. McCoy, K. Levchenko, and V. Paxson, “Tools for automated analysis of cybercriminal markets,” in *Proceedings of the 26th International Conference on World Wide Web,* WWW ’17, Republic and Canton of Geneva, CHE: International World Wide Web Conferences Steering Committee, pp. 657–666, 2017.

[461] G. J. Pottie, “Wireless sensor networks,” in *1998 Information Theory Workshop (Cat. No. 98EX131)*, IEEE, pp. 139–140, 1998.

[462] I. Poupyrev, N.-W. Gong, S. Fukuhara, M. E. Karagozler, C. Schwesig, and K. E. Robinson, “Project jacquard: Interactive digital textiles at scale,” *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2016.

[463] R. Prada, H. Prendinger, P. Yongyuth, A. Nakasoneb, and A. Kawtrakulc, “AgriVillage: A game to foster awareness of the environmental impact of agriculture,” *Computers in Entertainment*, vol. 12, no. 2, pp. 3:1–3:18, 2015.

[464] A. S. Praetorius and D. Görlich, “How avatars influence user behavior: A review on the proteus effect in virtual environments and video games,” in *International Conference on the Foundations of Digital Games*, New York, NY, USA: Association for Computing Machinery, 2020.

[465] A. S. Praetorius, L. Krautmacher, G. Tullius, and C. Curio, “User-avatar relationships in various contexts: Does context influence a users’ perception and choice of an avatar?” In *Mensch Und Computer 2021,* MuC ’21, New York, NY, USA: Association for Computing Machinery, pp. 275–280, 2021.

[466] K. Prokopetc and R. Dupont, "Towards dense 3D reconstruction for mixed reality in healthcare: Classical multi-view stereo vs deep learning," in *Proceedings of the IEEE/CVF International Conference on Computer Vision Workshops*, 2019.

[467] A. Prouzeau, Y. Wang, B. Ens, W. Willett, and T. Dwyer, "Corsican twin: Authoring in situ augmented reality visualisations in virtual reality," *Proceedings of the International Conference on Advanced Visual Interfaces*, 2020.

[468] Q. Qi and F. Tao, "Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison," *IEEE Access*, vol. 6, pp. 3585–3593, 2018.

[469] L. Qian, A. Plopski, N. Navab, and P. Kazanzides, "Restoring the awareness in the occluded visual field for optical see-through head-mounted displays," *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, pp. 2936–2946, 2018.

[470] C. Qiao, W. Zhang, D. Gong, and Y. Gong, "In situ virtual restoration of artifacts by imaging technology," *Heritage Science*, vol. 8, no. 1, pp. 1–13, 2020.

[471] Y. Qin, S. Hao, K. R. Pattipati, F. Qian, S. Sen, B. Wang, and C. Yue, "Quality-aware strategies for optimizing abr video streaming qoe and reducing data usage," in *Proceedings of the 10th ACM Multimedia Systems Conference,* MMSys '19, New York, NY, USA: Association for Computing Machinery, pp. 189–200, 2019.

[472] Qualcomm, *Oculus quest 2: How snapdragon XR2 powers the next generation of VR*, 2020.

[473] A. V. Rajan, N. Nassiri, V. Akre, R. Ravikumar, A. Nabeel, M. Buti, and F. Salah, "Virtual reality gaming addiction," *2018 Fifth HCT Information Technology Trends (ITT)*, pp. 358–363, 2018.

[474] E. Ramadan, A. Narayanan, U. K. Dayalan, R. A. Fezeu, F. Qian, and Z.-L. Zhang, "Case for 5G-aware video streaming applications," in *Proceedings of the 1st Workshop on 5G Measurements, Modeling, and Use Cases*, pp. 27–34, 2021.

[475] S. Randhawa and S. Jain, "Data aggregation in wireless sensor networks: Previous research, current status and future directions," *Wireless Personal Communications*, vol. 97, no. 3, pp. 3355–3425, 2017.

[476] C. Rao and M. Shah, "View-invariance in action recognition," in *Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001*, IEEE, vol. 2, 2001.

[477] A. Rasheed, O. San, and T. Kvamsdal, "Digital twin: Values, challenges and enablers from a modeling perspective," *IEEE Access*, vol. 8, pp. 21 980–22 012, 2020.

[478] R. Ratan and B. S. Hasler, "Playing well with virtual classmates: Relating avatar design to group satisfaction," in *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work &; Social Computing,* CSCW '14, New York, NY, USA: Association for Computing Machinery, pp. 564–573, 2014.

[479] N. Ratha, J. Connell, R. M. Bolle, and S. Chikkerur, "Cancelable biometrics: A case study in fingerprints," in *18th International Conference on Pattern Recognition (ICPR'06)*, IEEE, vol. 4, pp. 370–373, 2006.

[480] P. Ravindra, A. Khochare, S. P. Reddy, S. Sharma, P. Varshney, and Y. Simmhan, "Echo: An adaptive orchestration platform for hybrid dataflows across cloud and edge," in *International Conference on Service-Oriented Computing*, Springer, pp. 395–410, 2017.

[481] J. Redmon and A. Farhadi, "Yolov3: An incremental improvement," *arXiv preprint arXiv:1804.02767*, 2018.

[482] D. Reilly, A. Echenique, A. Wu, A. Tang, and W. K. Edwards, *Mapping out Work in a Mixed Reality Project Room.* New York, NY, USA: Association for Computing Machinery, pp. 887–896, 2015.

[483] G. Reitmayr, T. Langlotz, D. Wagner, A. Mulloni, G. Schall, D. Schmalstieg, and Q. Pan, "Simultaneous localization and mapping for augmented reality," in *2010 International Symposium on Ubiquitous Virtual Reality*, IEEE, pp. 5–8, 2010.

[484] P. Ren, X. Qiao, Y. Huang, L. Liu, C. Pu, S. Dustdar, and J.-L. Chen, "Edge AR X5: An edge-assisted multi-user collaborative framework for mobile web augmented reality in 5G and beyond," *IEEE Transactions on Cloud Computing*, 2020.

[485] S. Ren, K. He, R. Girshick, and J. Sun, "Faster r-cnn: Towards real-time object detection with region proposal networks," *Advances in Neural Information Processing Systems*, vol. 28, pp. 91–99, 2015.

[486] Y. Ren, Y. Leng, Y. Cheng, and J. Wang, "Secure data storage based on blockchain and coding in edge computing," *Math. Biosci. Eng*, vol. 16, no. 4, pp. 1874–1892, 2019.

[487] A. Reyna, C. Martín, J. Chen, E. Soler, and M. Díaz, "On blockchain and its integration with IoT. Challenges and opportunities," *Future Generation Computer Systems*, vol. 88, pp. 173–190, 2018.

[488] P. Rhienmora, K. Gajananan, P. Haddawy, M. N. Dailey, and S. Suebnukarn, "Augmented reality haptics system for dental surgical skills training," in *Proceedings of the 17th ACM Symposium on Virtual Reality Software and Technology*, pp. 97–98, 2010.

[489] A. Riegler, A. Riener, and C. Holzmann, "A systematic review of virtual reality applications for automated driving: 2009–2020," *Frontiers in Human Dynamics*, p. 48, 2021.

[490] A. Riegler, P. Wintersberger, A. Riener, and C. Holzmann, "Augmented reality windshield displays and their potential to enhance user experience in automated driving," *i-com*, vol. 18, no. 2, pp. 127–149, 2019.

[491] W. Rogers and D. Smalley, "Simulating virtual images in optical trap displays," *Scientific Reports*, vol. 11, 2021.

[492] J. S. Roo, R. Gervais, J. Frey, and M. Hachet, "Inner garden: Connecting inner states to a mixed reality sandbox for mindfulness," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, pp. 1459–1470, 2017.

[493] J. S. Roo, R. Gervais, J. Frey, and M. Hachet, "Inner garden: Connecting inner states to a mixed reality sandbox for mindfulness," *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 2017.

[494] N. J. Rothstein, D. H. Connolly, E. J. de Visser, and E. Phillips, "Perceptions of infidelity with sex robots," in *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction,* HRI '21, New York, NY, USA: Association for Computing Machinery, pp. 129–139, 2021.

[495] M. Roxas, T. Hori, T. Fukiage, Y. Okamoto, and T. Oishi, "Occlusion handling using semantic segmentation and visibility-based rendering for mixed reality," in *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*, pp. 1–8, 2018.

[496] E. Rublee, V. Rabaud, K. Konolige, and G. Bradski, "Orb: An efficient alternative to sift or surf," in *2011 International Conference on Computer Vision*, IEEE, pp. 2564–2571, 2011.

[497] S. Russell and P. Norvig, "Artificial intelligence: A modern approach," 2002.

[498] M. D. Ryan, "Cloud computing privacy concerns on our doorstep," *Communications of the ACM*, vol. 54, no. 1, pp. 36–38, 2011.

[499] M. Sabet, M. Orand, and D. W. McDonald, "Designing telepresence drones to support synchronous, mid-air remote collaboration: An exploratory study," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems,* CHI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[500] S. Saeidi, G. Rentala, T. Rizzuto, T. Hong, N. Johannsen, and Y. Zhu, "Exploring thermal state in mixed immersive virtual environments," *Journal of Building Engineering*, vol. 44, p. 102 918, 2021.

[501] K. Sakaguchi, T. Haustein, S. Barbarossa, E. C. Strinati, A. Clemente, G. Destino, A. Pärssinen, I. Kim, H. Chung, J. Kim, *et al.*, "Where, when, and how mmwave is used in 5G and beyond," *IEICE Transactions on Electronics*, vol. 100, no. 10, pp. 790–808, 2017.

[502] D. Salanitri, G. Lawson, and B. Waterfield, “The relationship between presence and trust in virtual reality,” in *Proceedings of the European Conference on Cognitive Ergonomics,* ECCE ’16, New York, NY, USA: Association for Computing Machinery, 2016.

[503] M. Samad, E. Gatti, A. Hermes, H. Benko, and C. Parise, “Pseudo-haptic weight: Changing the perceived weight of virtual objects by manipulating control-display ratio,” in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems,* CHI ’19, New York, NY, USA: Association for Computing Machinery, pp. 1–13, 2019.

[504] J. Santos, T. Wauters, B. Volckaert, and F. De Turck, “Towards network-aware resource provisioning in kubernetes for fog computing applications,” in *2019 IEEE Conference on Network Softwarization (NetSoft)*, IEEE, pp. 351–359, 2019.

[505] D. Sarkady, L. Neuburger, and R. Egger, “Virtual reality as a travel substitution tool during covid-19,” *Information and Communication Technologies in Tourism 2021*, pp. 452–463, 2020.

[506] M. Satyanarayanan, P. Bahl, R. Caceres, and N. Davies, “The case for vm-based cloudlets in mobile computing,” *IEEE Pervasive Computing*, vol. 8, no. 4, pp. 14–23, 2009.

[507] F. M. Schaf, S. Paladini, and C. E. Pereira, “3D AutoSysLab prototype,” in *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON)*, pp. 1–9, 2012.

[508] D. Scharstein and R. Szeliski, “A taxonomy and evaluation of dense two-frame stereo correspondence algorithms,” *International Journal of Computer Vision*, vol. 47, no. 1, pp. 7–42, 2002.

[509] L. C. Schaupp and M. Festa, “Cryptocurrency adoption and the road to regulation,” in *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*, pp. 1–9, 2018.

[510] L. Schelenz, "Diversity-aware recommendations for social justice? exploring user diversity and fairness in recommender systems," in *Adjunct Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization,* UMAP '21, New York, NY, USA: Association for Computing Machinery, pp. 404–410, 2021.

[511] D. Schmalstieg and T. Hollerer, *Augmented Reality - Principles and Practice.* Addison-Wesley Professional, 2016.

[512] J. L. Schönberger, M. Pollefeys, A. Geiger, and T. Sattler, "Semantic visual localization," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 6896–6906, 2018.

[513] M. Schröder and H. Ritter, "Deep learning for action recognition in augmented reality assistance systems," in *ACM SIGGRAPH 2017 Posters*, 2017, pp. 1–2.

[514] P. Schütt, M. Schwarz, and S. Behnke, "Semantic interaction in augmented reality environments for microsoft hololens," in *2019 European Conference on Mobile Robots (ECMR)*, IEEE, pp. 1–6, 2019.

[515] V. Schwind, J. Reinhardt, R. Rzayev, N. Henze, and K. Wolf, "Virtual reality on the go? a study on social acceptance of vr glasses," in *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct,* MobileHCI '18, New York, NY, USA: Association for Computing Machinery, pp. 111–118, 2018.

[516] D. Sebastien, O. Sebastien, and N. Conruyt, "Providing services through online immersive real-time mirror-worlds: The Immex Program for delivering services in another way at university," in *Proceedings of the Virtual Reality International Conference - Laval Virtual,* VRIC '18, New York, NY, USA: Association for Computing Machinery, pp. 1–7, 2018.

[517] T. Segawa, T. Baudry, A. Bourla, J.-V. Blanc, C. S. Peretti, S. Mouchabac, and F. Ferreri, "Virtual reality (vr) in assessment and treatment of addictive disorders: A systematic review," *Frontiers in Neuroscience*, vol. 13, 2019.

[518] S. Sen, C. Joe-Wong, S. Ha, and M. Chiang, "A survey of smart data pricing: Past proposals, current plans, and future trends," *ACM Comput. Surv.*, vol. 46, no. 2, 2013.

[519] L. Sevcik, M. Voznak, and J. Frnda, "Qoe prediction model for multimedia services in ip network applying queuing policy," in *International Symposium on Performance Evaluation of Computer and Telecommunication Systems (SPECTS 2014)*, pp. 593–598, 2014.

[520] V. F. Sevom, E. Guldogan, and J. Kämäräinen, "360 panorama super-resolution using deep convolutional networks," in *VISIGRAPP*, 2018.

[521] A. Sghaier Omar and O. Basir, "Capability-based non-fungible tokens approach for a decentralized AAA framework in IoT," in *Blockchain Cybersecurity, Trust and Privacy*, Springer, 2020, pp. 7–31.

[522] D. A. Shamma and D. Bryne, "An introduction to arts and digital culture inside multimedia," in *Proceedings of the 23rd ACM International Conference on Multimedia,* MM '15, New York, NY, USA: Association for Computing Machinery, pp. 1329–1330, 2015.

[523] L. Shao, J. Han, D. Xu, and J. Shotton, "Computer vision for rgb-d sensors: Kinect and its applications [special issue intro.]," *IEEE Transactions on Cybernetics*, vol. 43, no. 5, pp. 1314–1317, 2013.

[524] K. A. Shatilov, D. Chatzopoulos, L.-H. Lee, and P. Hui, "Emerging exg-based nui inputs in extended realities: A bottom-up survey," *ACM Trans. Interact. Intell. Syst.*, vol. 11, no. 2, 2021.

[525] S. Shi, V. Gupta, M. Hwang, and R. Jana, "Mobile VR on edge cloud: A latency-driven design," in *Proceedings of the 10th ACM Multimedia Systems Conference*, pp. 222–231, 2019.

[526] T. Shi, Y. Yuan, C. Fan, Z. Zou, Z. Shi, and Y. Liu, "Face-to-parameter translation for game character auto-creation," in *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 161–170, 2019.

[527] Y.-j. Shin, H.-j. Lee, J.-h. Kim, D.-y. Kwon, S.-a. Lee, Y.-j. Choo, J.-h. Park, J.-h. Jung, H.-s. Lee, and J.-h. Kim, "Non-face-to-face online home training application study using deep learning-based image processing technique and standard exercise program," *The Journal of the Convergence on Culture Technology*, vol. 7, no. 3, pp. 577–582, 2021.

[528] A. Shrier, A. Chang, N. Diakun-thibault, L. Forni, F. Landa, J. Mayo, and R. van Riezen, "Blockchain and health it: Algorithms," *Privacy, and Data, Office of the National Coordinator for Health Information Technology US Department of Health and Human Services*, 2016.

[529] J. Shu, R. Zheng, and P. Hui, "Cardea: Context-aware visual privacy protection for photo taking and sharing," in *Proceedings of the 9th ACM Multimedia Systems Conference*, pp. 304–315, 2018.

[530] M. Siam, M. Gamal, M. Abdel-Razek, S. Yogamani, and M. Jagersand, "Rtseg: Real-time semantic segmentation comparative study," in *2018 25th IEEE International Conference on Image Processing (ICIP)*, IEEE, pp. 1603–1607, 2018.

[531] C. Sieluzycki, P. Kaczmarczyk, J. Sobecki, K. Witkowski, J. Maśliński, and W. Cieśliński, "Microsoft kinect as a tool to support training in professional sports: Augmented reality application to tachi-waza techniques in judo," in *2016 Third European Network Intelligence Conference (ENIC)*, IEEE, pp. 153–158, 2016.

[532] L. J. S. Silva, D. L. S. da Silva, A. B. Raposo, L. Velho, and H. C. V. Lopes, "Tensorpose: Real-time pose estimation for interactive applications," *Computers & Graphics*, vol. 85, pp. 1–14, 2019.

[533] M. Simony, S. Milzy, K. Amendey, and H.-M. Gross, "Complex-yolo: An euler-region-proposal for real-time 3d object detection on point clouds," in *Proceedings of the European Conference on Computer Vision (ECCV) Workshops*, 2018.

[534] M. Simsek, A. Aijaz, M. Dohler, J. Sachs, and G. Fettweis, "5G-Enabled Tactile Internet," *IEEE Journal on Selected Areas in Communications*, vol. 34, no. 3, pp. 460–473, 2016.

[535] K. Singh, N. Singh, and D. S. Kushwaha, "An interoperable and secure e-wallet architecture based on digital ledger technology using blockchain," in *2018 International Conference on Computing, Power and Communication Technologies (GUCON)*, IEEE, pp. 165–169, 2018.

[536] V. K. Singh and C. Hofenbitzer, "Fairness across network positions in cyberbullying detection algorithms," in *Proceedings of the 2019 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining,* ASONAM '19, New York, NY, USA: Association for Computing Machinery, pp. 557–559, 2019.

[537] S. Singhal and M. Zyda, *Networked virtual environments - design and implementation*, 1999.

[538] Y. Siriwardhana, P. Porambage, M. Liyanage, and M. Ylianttila, "A survey on mobile augmented reality with 5G mobile edge computing: Architectures, applications, and technical aspects," *IEEE Communications Surveys & Tutorials*, vol. 23, no. 2, pp. 1160–1192, 2021.

[539] R. Skarbez, M. Smith, and M. C. Whitton, "Revisiting milgram and kishino's reality-virtuality continuum," *Frontiers in Virtual Reality*, vol. 2, p. 27, 2021.

[540] M. Slater, C. Gonzalez-Liencres, P. Haggard, C. Vinkers, R. Gregory-Clarke, S. Jelley, Z. Watson, G. Breen, R. Schwartz, W. Steptoe, D. Szostak, S. Halan, D. Fox, and J. Silver, "The ethics of realism in virtual and augmented reality," in *Frontiers in Virtual Reality*, 2020.

[541] R. Sodhi, I. Poupyrev, M. Glisson, and A. Israr, "Aireal: Interactive tactile experiences in free air," *ACM Transactions on Graphics (TOG)*, vol. 32, no. 4, p. 134, 2013.

[542] L. Soler, S. Nicolau, J. Schmid, C. Koehl, J. Marescaux, X. Pennec, and N. Ayache, "Virtual reality and augmented reality in digestive surgery," in *Third IEEE and ACM International Symposium on Mixed and Augmented Reality*, IEEE, pp. 278–279, 2004.

[543] M. Soliman, F. Mueller, L. Hegemann, J. S. Roo, C. Theobalt, and J. Steimle, "Fingerinput: Capturing expressive single-hand thumb-to-finger microgestures," *Proceedings of the 2018 ACM International Conference on Interactive Surfaces and Spaces*, 2018.

[544] D. Song, Y. Wang, H. Chen, C. Xu, C. Xu, and D. Tao, "Addersr: Towards energy efficient image super-resolution," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 15 648–15 657, 2021.

[545] B. Soni and P. Hingston, "Bots trained to play like a human are more fun," in *2008 IEEE International Joint Conference on Neural Networks (IEEE World Congress on Computational Intelligence)*, IEEE, pp. 363–369, 2008.

[546] A. D. Souchet, S. Philippe, F. Ober, A. Léveque, and L. Leroy, "Investigating cyclical stereoscopy effects over visual discomfort and fatigue in virtual reality while learning," *2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 328–338, 2019.

[547] M. Speicher, J. Ehrlich, V. Gentile, D. Degraen, S. Sorce, and A. Krüger, "Pseudo-haptic controls for mid-air finger-based menu interaction," in *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, pp. 1–6, 2019.

[548] M. Speicher, B. D. Hall, and M. Nebeling, *What is Mixed Reality?* New York, NY, USA: Association for Computing Machinery, pp. 1–15, 2019.

[549] M. Speicher, B. D. Hall, A. Yu, B. Zhang, H. Zhang, J. Nebeling, and M. Nebeling, "Xd-ar: Challenges and opportunities in cross-device augmented reality application development," *Proc. ACM Hum.-Comput. Interact.*, vol. 2, no. EICS, 2018.

[550] M. Speicher, K. Lewis, and M. Nebeling, "Designers, the stage is yours! medium-fidelity prototyping of augmented & virtual reality interfaces with 360theater," *Proceedings of the ACM on Human-Computer Interaction*, vol. 5, pp. 1–25, 2021.

[551] The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, *Extended Reality in A/IS*, URL: https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/ead/EAD1e_extended_reality.pdf, 2021.

[552] P. L. Stanchev, D. Paneva-Marinova, and A. Iliev, "Enhanced user experience and behavioral patterns for digital cultural ecosystems," in *Proceedings of the 9th International Conference on Management of Digital EcoSystems,* MEDES '17, New York, NY, USA: Association for Computing Machinery, pp. 287–292, 2017.

[553] E. Steinbach, S. Hirche, M. Ernst, F. Brandi, R. Chaudhari, J. Kammerl, and I. Vittorias, "Haptic communications," *Proceedings of the IEEE*, vol. 100, no. 4, pp. 937–956, 2012.

[554] P. L. Strandholt, O. A. Dogaru, N. C. Nilsson, R. Nordahl, and S. Serafin, "Knock on wood: Combining redirected touching and physical props for tool-based interaction in virtual reality," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* CHI '20, New York, NY, USA: Association for Computing Machinery, pp. 1–13, 2020.

[555] J. Sturm, N. Engelhard, F. Endres, W. Burgard, and D. Cremers, "A benchmark for the evaluation of rgb-d slam systems," in *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, IEEE, pp. 573–580, 2012.

[556] Y. Su, J. Rambach, N. Minaskan, P. Lesur, A. Pagani, and D. Stricker, "Deep multi-state object pose estimation for augmented reality assembly," in *2019 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, IEEE, pp. 222–227, 2019.

[557] R. Sundara Raman, P. Shenoy, K. Kohls, and R. Ensafi, "Censored planet: An internet-wide, longitudinal censorship observatory," in *Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security,* CCS '20, New York, NY, USA: Association for Computing Machinery, pp. 49–66, 2020.

[558] S. Suryavansh, C. Bothra, M. Chiang, C. Peng, and S. Bagchi, “Tango of edge and cloud execution for reliability,” in *Proceedings of the 4th Workshop on Middleware for Edge Clouds & Cloudlets*, pp. 10–15, 2019.

[559] I. Sutherland, “The ultimate display,” 1965.

[560] G. B. Al-Suwaidi and M. J. Zemerly, “Locating friends and family using mobile phones with global positioning system (GPS),” in *2009 IEEE/ACS International Conference on Computer Systems and Applications*, IEEE, pp. 555–558, 2009.

[561] K. Suzuki, T. Hachisu, and K. Iida, “Enhancedtouch: A smart bracelet for enhancing human-human physical touch,” *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2016.

[562] J. Svensson and J. Atles, “Object detection in augmented reality,” *Master’s theses in mathematical sciences*, 2018.

[563] K. Takeuchi, Y. Yamazaki, and K. Yoshifuji, “Avatar work: Telework for disabled people unable to go outside by using avatar robots,” in *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction,* HRI ’20, New York, NY, USA: Association for Computing Machinery, pp. 53–60, 2020.

[564] T. Taleb, I. Afolabi, K. Samdanis, and F. Z. Yousaf, “On multi-domain network slicing orchestration architecture and federated resource control,” *IEEE Network*, vol. 33, no. 5, pp. 242–252, 2019.

[565] H. Tan, J. Lee, and G. Gao, “Human-drone interaction: Drone delivery & services for social events,” in *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems,* DIS ’18 Companion, New York, NY, USA: Association for Computing Machinery, pp. 183–187, 2018.

[566] K. Tanaka, Y. Kishino, M. Miyamae, T. Terada, and S. Nishio, “An information layout method for an optical see-through head mounted display focusing on the viewability,” *2008 7th IEEE/ACM International Symposium on Mixed and Augmented Reality*, pp. 139–142, 2008.

[567] V. Tanriverdi and R. J. Jacob, "Interacting with eye movements in virtual environments," in *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pp. 265–272, 2000.

[568] L. Tanzi, P. Piazzolla, F. Porpiglia, and E. Vezzetti, "Real-time deep learning semantic segmentation during intra-operative surgery for 3D augmented reality assistance," *International Journal of Computer Assisted Radiology and Surgery*, pp. 1–11, 2021.

[569] L. Tarouco, B. Gorziza, Y. Corrêa, É. M. H. Amaral, and T. Müller, "Virtual laboratory for teaching Calculus: An immersive experience," in *2013 IEEE Global Engineering Education Conference (EDUCON)*, pp. 774–781, 2013.

[570] J. L. Tennison and J. L. Gorlewicz, "Non-visual perception of lines on a multimodal touchscreen tablet," *ACM Transactions on Applied Perception (TAP)*, vol. 16, no. 1, pp. 1–19, 2019.

[571] J. Terrace, E. Cheslack-Postava, P. Levis, and M. J. Freedman, "Unsupervised conversion of 3D models for interactive metaverses," in *2012 IEEE International Conference on Multimedia and Expo*, pp. 902–907, 2012.

[572] A. Thaler, A. C. Wellerdiek, M. Leyrer, E. Volkova-Volkmar, N. F. Troje, and B. J. Mohler, "The role of avatar fidelity and sex on self-motion recognition," in *Proceedings of the 15th ACM Symposium on Applied Perception, SAP '18*, New York, NY, USA: Association for Computing Machinery, 2018.

[573] B. Thoravi Kumaravel, C. Nguyen, S. DiVerdi, and B. Hartmann, "TutoriVR: A video-based tutorial system for design applications in virtual reality," in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, pp. 1–12, 2019.

[574] *Time(7) linux user's manual*, 5.13, 2020.

[575] A. Tirmizi, C. Pacchierotti, I. Hussain, G. Alberico, and D. Prattichizzo, "A perceptually-motivated deadband compression approach for cutaneous haptic feedback," *IEEE Haptics Symposium, HAPTICS*, vol. 2016-April, pp. 223–228, 2016.

[576] X. Tong, A. Gupta, H. Lo, A. Choo, D. Gromala, and C. D. Shaw, "Chasing lovely monsters in the wild, exploring players' motivation and play patterns of pokémon go: Go, gone or go away?" In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing,* CSCW '17 Companion, New York, NY, USA: Association for Computing Machinery, pp. 327–330, 2017.

[577] O. Torro, H. Jalo, and H. Pirkkalainen, "Six reasons why virtual reality is a game-changing computing and communication platform for organizations," *Commun. ACM*, vol. 64, no. 10, pp. 48–55, 2021.

[578] G. M. Troiano, M. Wood, and C. Harteveld, "“and this, kids, is how i met your mother”: Consumerist, mundane, and uncanny futures with sex robots," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* CHI '20, New York, NY, USA: Association for Computing Machinery, pp. 1–17, 2020.

[579] K. Tsiakas, D. Cnossen, T. H. C. Muyrers, D. R. C. Stappers, R. H. A. Toebosch, and E. Barakova, "Futureme: Negotiating learning goals with your future learning-self avatar," in *The 14th PErvasive Technologies Related to Assistive Environments Conference,* PETRA 2021, New York, NY, USA: Association for Computing Machinery, pp. 262–263, 2021.

[580] E. Tsykunov, R. Ibrahimov, D. Vasquez, and D. Tsetserukou, "Slingdrone: Mixed reality system for pointing and interaction using a single drone," in *25th ACM Symposium on Virtual Reality Software and Technology,* VRST '19, New York, NY, USA: Association for Computing Machinery, 2019.

[581] E. J. Tuegel, A. R. Ingraffea, T. G. Eason, and S. M. Spottswood, "Reengineering aircraft structural life prediction using a digital twin," *International Journal of Aerospace Engineering*, vol. 2011, 2011.

[582] S. Turkmen, "Scene understanding through semantic image segmentation in augmented reality," 2019.

[583] R. Tyminski, "Addiction to cyberspace: Virtual reality gives analysts pause for the modern psyche," *International Journal of Jungian Studies*, vol. 10, pp. 91–102, 2018.
[584] H. Uchiyama and E. Marchand, "Object detection and pose tracking for augmented reality: Recent approaches," in *18th Korea-Japan Joint Workshop on Frontiers of Computer Vision (FCV)*, 2012.
[585] J. Urban Davis, F. Anderson, M. Stroetzel, T. Grossman, and G. Fitzmaurice, "Designing co-creative ai for virtual environments," in *Creativity and Cognition,* C&C '21, New York, NY, USA: Association for Computing Machinery, 2021.
[586] A. Urquhart, "The inefficiency of bitcoin," *Economics Letters*, vol. 148, pp. 80–82, 2016.
[587] L. S. Vailshery, *Internet of things (IoT) and non-IoT active device connections worldwide from 2010 to 2025*, 2021, URL: https://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worldwide/.
[588] M. Van Alstyne, "Why not immortality?" *Commun. ACM*, vol. 56, no. 11, pp. 29–31, 2013.
[589] I. Vázquez-Martín, J. Marín-Sáez, M. Gómez-Climente, D. Chemisana, M. Collados, and J. Atencia, "Full-color multiplexed reflection hologram of diffusing objects recorded by using simultaneous exposure with different times in photopolymer bayfol® hx," *Optics and Laser Technology*, vol. 143, p. 107 303, 2021.
[590] M. Venkataraman and M. Chatterjee, "Inferring video qoe in real time," *IEEE Network*, vol. 25, no. 1, pp. 4–13, 2011.
[591] A. Vernaza, V. I. Armuelles, and I. Ruiz, "Towards to an open and interoperable virtual learning enviroment using Metaverse at University of Panama," in *2012 Technologies Applied to Electronics Teaching (TAEE)*, pp. 320–325, 2012.
[592] S. Viljoen, "The promise and limits of lawfulness: Inequality, law, and the techlash," *International Political Economy: Globalization eJournal*, 2020.

[593] K. Virginia Dufresne and B. Stout, *Anchorhold Afference: Virtual Reality, Radical Compassion, and Embodied Positionality.* New York, NY, USA: Association for Computing Machinery, 2021.

[594] P. Wacker, A. Wagner, S. Voelker, and J. O. Borchers, "Heatmaps, shadows, bubbles, rays: Comparing mid-air pen position visualizations in handheld ar," *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 2020.

[595] L. D. Wall, *Fractional reserve cryptocurrency banks*, 2019, URL: https://www.atlantafed.org/cenfis/publications/notesfromthevault/04-fractional-reserve-cryptocurrency-banks-2019-04-25.

[596] F.-Y. Wang, J. J. Zhang, X. Zheng, X. Wang, Y. Yuan, X. Dai, J. Zhang, and L. Yang, "Where does alphago go: From church-turing thesis to alphago thesis and beyond," *IEEE/CAA Journal of Automatica Sinica*, vol. 3, no. 2, pp. 113–120, 2016.

[597] H. Wang, Y. Gao, and X. Chen, "Rl-dot: A reinforcement learning npc team for playing domination games," *IEEE Transactions on Computational Intelligence and AI in Games*, vol. 2, no. 1, pp. 17–26, 2009.

[598] J. Wang, Y. Song, T. Leung, C. Rosenberg, J. Wang, J. Philbin, B. Chen, and Y. Wu, "Learning fine-grained image similarity with deep ranking," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 1386–1393, 2014.

[599] J. Wang, S. Tan, X. Zhen, S. Xu, F. Zheng, Z. He, and L. Shao, "Deep 3d human pose estimation: A review," *Computer Vision and Image Understanding*, p. 103 225, 2021.

[600] L. Wang, Y. Chae, and K.-J. Yoon, "Dual transfer learning for event-based end-task prediction via pluggable event to image translation," *ICCV*, 2021.

[601] L. Wang, Y. Chae, S.-H. Yoon, T.-K. Kim, and K.-J. Yoon, "Evdistill: Asynchronous events to end-task learning via bidirectional reconstruction-guided cross-modal knowledge distillation," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 608–619, 2021.

[602] L. Wang, Y.-S. Ho, K.-J. Yoon, *et al.*, "Event-based high dynamic range image and very high frame rate video generation using conditional generative adversarial networks," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 10 081–10 090, 2019.

[603] L. Wang, T.-K. Kim, and K.-J. Yoon, "Eventsr: From asynchronous events to image reconstruction, restoration, and super-resolution via end-to-end adversarial learning," in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 8315–8325, 2020.

[604] L. Wang, T.-K. Kim, and K.-J. Yoon, "Joint framework for single image reconstruction and super-resolution with an event camera," *IEEE Transactions on Pattern Analysis & Machine Intelligence*, no. 01, pp. 1–1, 2021.

[605] L. Wang and K.-J. Yoon, "Coaug-MR: An MR-based interactive office workstation design system via augmented multi-person collaboration," *arXiv preprint arXiv:1907.03107*, 2019.

[606] L. Wang and K.-J. Yoon, "Knowledge distillation and student-teacher learning for visual intelligence: A review and new outlooks," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2021.

[607] L. Wang and K.-J. Yoon, "PSAT-GAN: Efficient adversarial attacks against holistic scene understanding," *IEEE Transactions on Image Processing*, 2021.

[608] L. Wang and K.-J. Yoon, "Semi-supervised student-teacher learning for single image super-resolution," *Pattern Recognition*, vol. 121, p. 108 206, 2022.

[609] P. Wang, X. Bai, M. Billinghurst, S. Zhang, X. Zhang, S. Wang, W. He, Y. Yan, and H. Ji, "AR/MR remote collaboration on physical tasks: A review," *Robotics and Computer-Integrated Manufacturing*, vol. 72, p. 102 071, 2021.

[610] R. Wang, F. M. Harper, and H. Zhu, "Factors influencing perceived fairness in algorithmic decision-making: Algorithm outcomes, development procedures, and individual differences," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* CHI '20, New York, NY, USA: Association for Computing Machinery, pp. 1–14, 2020.

[611] S. Wang, Y. Zhang, and Y. Zhang, "A blockchain-based framework for data sharing with fine-grained access control in decentralized storage systems," *IEEE Access*, vol. 6, pp. 38 437–38 450, 2018.

[612] S. Wang, Y. Ruan, Y. Tu, S. Wagle, C. G. Brinton, and C. Joe-Wong, "Network-aware optimization of distributed learning for fog computing," *IEEE/ACM Transactions on Networking*, 2021.

[613] X. Wang, Y. Wang, Y. Shi, W. Zhang, and Q. Zheng, "Avatarmeeting: An augmented reality remote interaction system with personalized avatars," in *Proceedings of the 28th ACM International Conference on Multimedia*, pp. 4533–4535, 2020.

[614] Z. Wang, D. Lu, D. Zhang, M. Sun, and Y. Zhou, "Fake modern chinese painting identification based on spectral–spatial feature fusion on hyperspectral image," *Multidimensional Systems and Signal Processing*, vol. 27, no. 4, pp. 1031–1044, 2016.

[615] Z. Wang, X. Liao, X. Zhao, K. Han, P. Tiwari, M. J. Barth, and G. Wu, "A digital twin paradigm: Vehicle-to-cloud based advanced driver assistance systems," in *2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring)*, IEEE, pp. 1–6, 2020.

[616] P. Weber, T. Ludwig, S. Brodesser, and L. Grönewald, "'It's a kind of art!': Understanding food influencers as influential content creators," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems,* CHI '21, New York, NY, USA: Association for Computing Machinery, 2021.

[617] C. Webster, F. Garnier, and A. Sedes, "Empty Room, an electroacoustic immersive composition spatialized in virtual 3D space, in ambisonic and binaural," in *Proceedings of the Virtual Reality International Conference - Laval Virtual 2017,* VRIC '17, New York, NY, USA: Association for Computing Machinery, pp. 1–7, 2017.

[618] X. Wei, L. Yin, Z. Zhu, and Q. Ji, "Avatar-mediated face tracking and lip reading for human computer interaction," in *Proceedings of the 12th Annual ACM International Conference on Multimedia,* MULTIMEDIA '04, New York, NY, USA: Association for Computing Machinery, pp. 500–503, 2004.

[619] Y. Wei, X. Qin, X. Tan, X. Yu, B. Sun, and X. Zhu, "The design of a visual tool for the quick customization of virtual characters in OSSL," in *2015 International Conference on Cyberworlds (CW)*, pp. 314–320, 2015.

[620] Y. Wei, X. Tan, X. Qin, X. Yu, B. Sun, and X. Zhu, "Exploring the use of a 3D virtual environment in Chinese cultural transmission," in *2014 International Conference on Cyberworlds*, pp. 345–350, 2014.

[621] G. White, A. Zink, L. Codecá, and S. Clarke, "A digital twin smart city for citizen feedback," *Cities*, vol. 110, p. 103 064, 2021.

[622] G. Wiegand, C. Mai, K. Holländer, and H. Hussmann, "Incarar: A design space towards 3d augmented reality applications in vehicles," in *Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications,* AutomotiveUI '19, New York, NY, USA: Association for Computing Machinery, pp. 1–13, 2019.

[623] J. G. W. Wildenbeest, D. A. Abbink, C. J. M. Heemskerk, F. C. T. Van Der Helm, and H. Boessenkool, "The impact of haptic feedback quality on the performance of teleoperated assembly tasks," *IEEE Transactions on Haptics*, vol. 6, no. 2, pp. 242–252, 2013.

[624] P. Willemsen, M. B. Colton, S. H. Creem-Regehr, and W. B. Thompson, "The effects of head-mounted display mechanics on distance judgments in virtual environments," in *Proceedings of the 1st Symposium on Applied Perception in Graphics and Visualization*, pp. 35–38, 2004.

[625] R. Winkler, S. Hobert, A. Salovaara, M. Söllner, and J. M. Leimeister, "Sara, the lecturer: Improving learning in online education with a scaffolding-based conversational agent," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems,* CHI '20, New York, NY, USA: Association for Computing Machinery, pp. 1–14, 2020.

[626] Wired, *Kevin Kelly.* URL: https://www.wired.com/author/kevin-kelly/.

[627] M. J. Won, S. Park, S. Hwang, and M. Whang, "Development of realistic digital expression of human avatars through pupillary responses based on heart rate," in *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems,* CHI EA '15, New York, NY, USA: Association for Computing Machinery, pp. 287–290, 2015.

[628] P. C. Wong, K. Zhu, and H. Fu, "Fingert9: Leveraging thumb-to-finger interaction for same-side-hand text entry on smartwatches," *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 2018.

[629] A. Woodruff, S. E. Fox, S. Rousso-Schindler, and J. Warshaw, "A qualitative exploration of perceptions of algorithmic fairness," in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems,* CHI '18, New York, NY, USA: Association for Computing Machinery, pp. 1–14, 2018.

[630] Y. Wu, "Cloud-edge orchestration for the internet-of-things: Architecture and ai-powered data processing," *IEEE Internet of Things Journal*, 2020.

[631] M. P. Wylie-Green and T. Svensson, "Throughput, capacity, handover and latency performance in a 3GPP LTE FDD field trial," in *2010 IEEE Global Telecommunications Conference GLOBECOM 2010*, IEEE, pp. 1–6, 2010.

[632] Q. Xia, E. B. Sifah, K. O. Asamoah, J. Gao, X. Du, and M. Guizani, "Medshare: Trust-less medical data sharing among cloud service providers via blockchain," *IEEE Access*, vol. 5, pp. 14 757–14 767, 2017.

[633] C. Xie, Y. Kameda, K. Suzuki, and I. Kitahara, "Large scale interactive ar display based on a projector-camera system," *Proceedings of the 2016 Symposium on Spatial User Interaction*, 2016.

[634] C. Xiong, Y. Zhang, R. Yang, G. Li, Y. Lei, and Y. Han, "MoWIE for network aware application," Internet Engineering Task Force, 2021. URL: https://datatracker.ietf.org/doc/html/draft-huang-alto-mowie-for-network-aware-app-03.

[635] D. Xu, Y. Li, X. Chen, J. Li, P. Hui, S. Chen, and J. Crowcroft, "A survey of opportunistic offloading," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 2198–2236, 2018.

[636] D. Xu, A. Zhou, X. Zhang, G. Wang, X. Liu, C. An, Y. Shi, L. Liu, and H. Ma, "Understanding operational 5g: A first measurement study on its coverage, performance and energy consumption," in *Proceedings of the Annual Conference of the ACM Special Interest Group on Data Communication on the Applications, Technologies, Architectures, and Protocols for Computer Communication*, pp. 479–494, 2020.

[637] X. Xu and J. Zhu, "Artistic color virtual reality implementation based on similarity image restoration," *Complexity*, 2021.

[638] Z. Xu, P. C. Wong, J. Gong, T.-Y. Wu, A. S. Nittala, X. Bi, J. Steimle, H. Fu, K. Zhu, and X.-D. Yang, "Tiptext: Eyes-free text entry on a fingertip keyboard," *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*, 2019.

[639] Yahoo, *How big is the metaverse?* 2015. URL: https://www.highfidelity.com/backlog/how-big-is-the-metaverse-cbe750cae69.

[640] Yahoo, *Real-world metaverse 'twinworld' selected as 5g telco edge cloud testbed for 3 global mobile carriers*, 2021, URL: https://finance.yahoo.com/news/real-world-metaverse-twinworld-selected-161500696.html.

[641] R. Yan, Y. Li, D. Li, Y. Wang, Y. Zhu, and W. Wu, "A stochastic algorithm based on reverse sampling technique to fight against the cyberbullying," *ACM Trans. Knowl. Discov. Data*, vol. 15, no. 4, 2021.

[642] A. Yaqoob and G.-M. Muntean, “A combined field-of-view prediction-assisted viewport adaptive delivery scheme for 360° videos,” *IEEE Transactions on Broadcasting*, vol. 67, no. 3, pp. 746–760, 2021.

[643] N. Yee and J. Bailenson, “The proteus effect: The effect of transformed self-representation on behavior,” *Human Communication Research*, vol. 33, pp. 271–290, 2007.

[644] X. Yi, E. Walia, and P. Babyn, “Generative adversarial network in medical imaging: A review,” *Medical Image Analysis*, vol. 58, p. 101 552, 2019.

[645] G. Yiping, L. Xinyu, and L. Gao, “A deep lifelong learning method for digital twin-driven defect recognition with novel classes,” *Journal of Computing and Information Science in Engineering*, vol. 21, no. 3, 2021.

[646] J. Ylipulli, J. Kangasvuo, T. Alatalo, and T. Ojala, “Chasing digital shadows: Exploring future hybrid cities through anthropological design fiction,” in *Proceedings of the 9th Nordic Conference on Human-Computer Interaction,* NordiCHI ’16, New York, NY, USA: Association for Computing Machinery, pp. 1–10, 2016.

[647] M. K. Young, J. J. Rieser, and B. Bodenheimer, “Dyadic interactions with avatars in immersive virtual environments: High fiving,” in *Proceedings of the ACM SIGGRAPH Symposium on Applied Perception, SAP ’15*, New York, NY, USA: Association for Computing Machinery, pp. 119–126, 2015.

[648] A. Younis, B. Qiu, and D. Pompili, “Latency-aware hybrid edge cloud framework for mobile augmented reality applications,” in *2020 17th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON)*, IEEE, pp. 1–9, 2020.

[649] F. Z. Yousaf, M. Gramaglia, V. Friderikos, B. Gajic, D. Von Hugo, B. Sayadi, V. Sciancalepore, and M. R. Crippa, “Network slicing with flexible mobility and QoS/QoE support for 5G networks,” in *2017 IEEE International Conference on Communications Workshops (ICC Workshops)*, IEEE, pp. 1195–1201, 2017.

[650] Y.-T. Yue, Y.-L. Yang, G. Ren, and W. Wang, "Scenectrl: Mixed reality enhancement via efficient scene editing," in *Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology,* UIST '17, New York, NY, USA: Association for Computing Machinery, pp. 427–436, 2017.

[651] C. Yun, Z. Deng, and M. Hiscock, "Can local avatars satisfy a global audience? A case study of high-fidelity 3D facial avatar animation in subject identification and emotion perception by us and international groups," *Comput. Entertain.*, vol. 7, no. 2, 2009.

[652] A. Zamansky, "Dog-drone interactions: Towards an ACI perspective," in *Proceedings of the Third International Conference on Animal-Computer Interaction,* ACI '16, New York, NY, USA: Association for Computing Machinery, 2016.

[653] A. Zarifis, L. Efthymiou, X. Cheng, and S. Demetriou, "Consumer trust in digital currency enabled transactions," in *International Conference on Business Information Systems*, Springer, pp. 241–254, 2014.

[654] F. Zeng, W. Zeng, and Y. Gan, "Orb-slam2 with 6dof motion," in *2018 IEEE 3rd International Conference on Image, Vision and Computing (ICIVC)*, IEEE, pp. 556–559, 2018.

[655] C. Zhang, A. Bedri, G. Reyes, B. Bercik, O. T. Inan, T. Starner, and G. D. Abowd, "Tapskin: Recognizing on-skin input for smartwatches," *Proceedings of the 2016 ACM International Conference on Interactive Surfaces and Spaces*, 2016.

[656] H. Zhang, B. Han, C. Y. Ip, and P. Mohapatra, "Slimmer: Accelerating 3d semantic segmentation for mobile augmented reality," in *2020 IEEE 17th International Conference on Mobile Ad Hoc and Sensor Systems (MASS)*, IEEE, pp. 603–612, 2020.

[657] J. Zhang, B. Chen, Y. Zhao, X. Cheng, and F. Hu, "Data security and privacy-preserving in edge computing paradigm: Survey and open issues," *IEEE Access*, vol. 6, pp. 18 209–18 237, 2018.

[658] J. Zhang, L. Contreras, K. Gao, F. Cano, P. Cano, A. Escribano, and Y. R. Yang, "Sextant: Enabling automated network-aware application optimization in carrier networks," in *2021 IFIP/IEEE International Symposium on Integrated Network Management (IM)*, IEEE, pp. 586–593, 2021.

[659] L. Zhang and S. Oney, "Flowmatic: An immersive authoring tool for creating interactive scenes in virtual reality," *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology*, 2020.

[660] L. Zhang, S. Wang, and R. N. Chang, "Qcss: A qoe-aware control plane for adaptive streaming service over mobile edge computing infrastructures," in *2018 IEEE International Conference on Web Services (ICWS)*, pp. 139–146, 2018.

[661] R. Zhang, C. Walshe, Z. Liu, L. Guan, K. Muller, J. Whritner, L. Zhang, M. Hayhoe, and D. Ballard, "Atari-head: Atari human eye-tracking and demonstration dataset," in *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 34, pp. 6811–6820, 2020.

[662] T. Zhang, Y.-T. Li, and J. P. Wachs, "The effect of embodied interaction in visual-spatial navigation," *ACM Trans. Interact. Intell. Syst.*, vol. 7, no. 1, 2016.

[663] T. Zhang, Y. Shen, G. Zhao, L. Wang, X. Chen, L. Bai, and Y. Zhou, "Swift-eye: Towards anti-blink pupil tracking for precise and robust high-frequency near-eye movement analysis with event cameras," *IEEE Transactions on Visualization and Computer Graphics*, 2024.

[664] W. Zhang, Y. Ma, D. Zhu, L. Dong, and Y. Liu, "Metrogan: Simulating urban morphology with generative adversarial network," in *Proceedings of the 28th ACM SIGKDD Conference on Knowledge Discovery and Data Mining*, pp. 2482–2492, 2022.

[665] W. Zhang, B. Han, and P. Hui, "Jaguar: Low latency mobile augmented reality with flexible tracking," in *Proceedings of the 26th ACM International Conference on Multimedia*, pp. 355–363, 2018.

[666] W. Zhang, S. Lin, F. Bijarbooneh, H.-F. Cheng, T. Braud, P. Zhou, L.-H. Lee, and P. Hui, "Edgexar: A 6-dof camera multi-target interactionframework for mar with user-friendly latency-compensation using edge computing," in *Proceedings of the ACM on HCI (Engineering Interactive Computing Systems)*, 2022.

[667] W. Zhang, J. Chen, Y. Zhang, and D. Raychaudhuri, "Towards efficient edge cloud augmentation for virtual reality mmogs," in *Proceedings of the Second ACM/IEEE Symposium on Edge Computing*, pp. 1–14, 2017.

[668] Y. Zhang, W. Kienzle, Y. Ma, S. S. Ng, H. Benko, and C. Harrison, "ActiTouch: Robust touch detection for on-skin AR/VR interfaces," *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*, 2019.

[669] H. Zhao, X. Qi, X. Shen, J. Shi, and J. Jia, "Icnet for real-time semantic segmentation on high-resolution images," in *Proceedings of the European Conference on Computer Vision (ECCV)*, pp. 405–420, 2018.

[670] J. Zhao, R. S. Allison, M. Vinnikov, and S. Jennings, "Estimating the motion-to-photon latency in head mounted displays," in *2017 IEEE Virtual Reality (VR)*, IEEE, pp. 313–314, 2017.

[671] M. Zhao, H. Qu, and M. Sedlmair, "Neighborhood perception in bar charts," *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 2019.

[672] X. L. Zhao and Y. G. Wang, "Optimization and simulation of image restoration in virtual reality," *Computer Simulation*, vol. 34, no. 4, pp. 440–443, 2017.

[673] S. Zhe, T. N. Wong, and L. H. Lee, "Using data envelopment analysis for supplier evaluation with environmental considerations," in *2013 IEEE International Systems Conference (SysCon)*, pp. 20–24, 2013.

[674] C. Zheng, W. Wu, T. Yang, S. Zhu, C. Chen, R. Liu, J. Shen, N. Kehtarnavaz, and M. Shah, "Deep learning-based human pose estimation: A survey," *arXiv preprint arXiv:2012.13392*, 2020.

[675] P. Zhou, T. Braud, A. Zavodovski, Z. Liu, X. Chen, P. Hui, and J. Kangasharju, "Edge-facilitated augmented vision in vehicle-to-everything networks," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 10, pp. 12 187–12 201, 2020.

[676] P. Zhou, B. Finley, X. Li, S. Tarkoma, J. Kangasharju, M. Ammar, and P. Hui, "5g mec computation handoff for mobile augmented reality," *arXiv preprint arXiv:2101.00256*, 2021.

[677] P. Zhou, P. Kortoçi, Y.-P. Yau, T. Braud, X. Wang, B. Finley, L.-H. Lee, S. Tarkoma, J. Kangasharju, and P. Hui, "Augmented informative cooperative perception," *ArXiv*, vol. abs/2101.05508, 2021.

[678] P. Zhou, W. Zhang, T. Braud, P. Hui, and J. Kangasharju, "Arve: Augmented reality applications in vehicle to edge networks," in *Proceedings of the 2018 Workshop on Mobile Edge Communications*, pp. 25–30, 2018.

[679] M. Zhu, Z. Sun, Z. Zhang, Q. Shi, T. He, H. Liu, T. Chen, and C. Lee, "Haptic-feedback smart glove as a creative human-machine interface (HMI) for virtual/augmented reality applications," *Science Advances*, vol. 6, no. 19, 2020.

[680] X. Zhu, R. Zheng, D. Yang, H. Liu, and J. Hou, "Radio-aware tcp optimization in mobile network," in *2017 IEEE Wireless Communications and Networking Conference (WCNC)*, IEEE, pp. 1–5, 2017.

[681] Y. Zhu, X. Li, C. Liu, M. Zolfaghari, Y. Xiong, C. Wu, Z. Zhang, J. Tighe, R. Manmatha, and M. Li, "A comprehensive study of deep video action recognition," *arXiv preprint arXiv:2012.06567*, 2020.

[682] J. Zoshak and K. Dew, *Beyond Kant and Bentham: How Ethical Theories Are Being Used in Artificial Moral Agents*. New York, NY, USA: Association for Computing Machinery, 2021.

[683] M. Žuži, J. Čejka, F. Bruno, D. Skarlatos, and F. Liarokapis, "Impact of dehazing on underwater marker detection for augmented reality," *Frontiers in Robotics and AI*, vol. 5, p. 92, 2018.

[684] G. Zyskind, O. Nathan, *et al.*, "Decentralizing privacy: Using blockchain to protect personal data," in *2015 IEEE Security and Privacy Workshops*, IEEE, pp. 180–184, 2015.