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Technology-Driven Innovation and Contextual Adaptation: Research on Multidimensional Applications of Virtual Digital Humans in International Communication

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Abstract. The rapid advancement of technologies such as artificial intelligence, computer graphics, and natural language processing has positioned virtual digital humans (VDHs) as key actors in international communication. This study examines the technological drivers, scenario reconstruction patterns, and multidimensional applications of VDHs in this domain, analyzing practical cases in areas such as intercultural communication, broadcast journalism, and educational entertainment. The research also highlights ethical risks, cultural adaptation challenges, and technological limitations associated with VDH deployment. It indicates that VDHs contribute to technological facilitation, scenario simulation, and cultural adaptation in global communication. However, they also encounter challenges, including cultural differences, misinformation, privacy breaches, and technological constraints. The study proposes corresponding strategies to address these issues. It is anticipated that, in the future, VDHs will assume a more central role in intelligent, personalized, and globalized communication. Strategies such as optimizing design with cultural considerations, establishing ethical frameworks, enhancing technology R&D, and integrating blockchain and localization can improve the deployment of VDHs in international communication.

Keywords: Virtual digital humans, international communication, artificial intelligence, scene reconstruction, cross-cultural adaptation.

1. Introduction

The wave of digital transformation is sweeping across the globe, with the boundaries between virtual and real increasingly blurred through the interaction of algorithms and data [1]. Generative artificial intelligence is driving the widespread adoption of hyper-realistic digital avatars, while metaverse technologies are reshaping communication environments and user experiences. The international discourse is currently undergoing a technological revolution centered around "digital humans." Data indicates that from 1973 to 2020, the United States and China collectively filed 35,576 patents in the field of virtual digital humans, accounting for 79.45% of global related patent

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applications. The United States, as the pioneer in virtual digital human technology, maintained a dominant position for an extended period until 2017, when China surpassed it in the number of patent applications [2]. As an emerging force within the domain, China urgently needs to seize the initiative in the highly competitive global virtual digital industry market.

This study focuses on the application of virtual digital humans in China's international communication domain, specifically examining technological breakthroughs, scene adaptation, and cultural exchange. It explores how virtual digital humans overcome language barriers, time zone differences, and regional restrictions to play a unique role in international dissemination—serving as media intermediaries, commercial ambassadors, and cultural new avatars. Currently, research within academia on the deployment of virtual digital humans in international communication remains in its nascent stage. This study aims to fill this research gap, offering new perspectives and content to enhance the theoretical framework, and holds significant interdisciplinary value for advancing the integration of communication studies and technological philosophy. Methodologically, the research employs literature analysis to identify and review relevant materials, leveraging this approach's strength in systematically organizing information on virtual digital humans to facilitate in-depth investigation. Additionally, real-world case studies are incorporated to bolster the feasibility of the findings. The ultimate goal is to provide strategic recommendations for mainstream Chinese media to adopt virtual digital human technology in international communication, thereby enhancing China's global influence and cultural affinity, and strengthening the international dissemination of Chinese culture. Furthermore, the study aims to inform the internationalization of the virtual digital human industry, promote innovative technological applications in the field of international communication, and support industry upgrading and sustainable development. To achieve these objectives, the research critically examines the illusion of technological neutrality, focusing on ethical regulatory risks and technical limitations in virtual digital human applications within international dissemination, with the intention of fostering healthy development and innovative use of virtual digital human technology in this domain.

2. Literature review

In recent years, numerous scholars have conducted in-depth research on virtual digital humans from various perspectives, including technological development, application domains, cultural dissemination, and information security. This paper primarily categorizes these studies according to stages of technological evolution, emphasizing the impact of technological iteration on application models of virtual digital humans. Within a temporal framework, it integrates three major themes—technology-driven innovation, scene reconstruction, and cross-cultural communication—to synthesize and analyze relevant literature.

Regarding technological progression, Wengrui Liao highlights that under the guidance of artificial intelligence theory, virtual digital humans have diversified industry models derived from symbolic, connectionist, and behaviorist approaches, thereby expanding multimedia dissemination pathways. Jiayi Shen and Kai Wen focus on digital clones generated through volumetric video capture technology, noting their enhanced immersiveness, which allows integration of objective form and subjective perception, thereby breaking multiple boundaries.

In the realm of scene application, scholars primarily concentrate on embodied communication and narrative characteristics. Yuge Jiang posits that Chinese-style virtual digital humans have achieved a triple shift in body, technology, and boundaries, serving as ambassadors of Chinese civilization, yet facing challenges such as technological iteration and privacy breaches. Xiuduan Ye emphasizes that short videos featuring virtual digital humans, through innovative visual storytelling,

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reconstruct aesthetic scenes of traditional Chinese culture, eliciting emotional resonance and value recognition.

In cross-cultural communication and diplomacy, Yihan Li and Lixin Zhou explore differences in Western and Eastern body language, underscoring the importance of non-verbal communication. Mingyi Yang and colleagues examine the technical pathways through which virtual idol Luming establishes quasi-social relationships with overseas audiences, exploring the potential for cultural exchange. Allahverdiyeva introduces the concept of virtual diplomacy, addressing security issues within digital communication and international relations. Lane et al. investigate how virtual humans learn cross-cultural communication skills, focusing on feedback mechanisms and fidelity factors.

Addressing risks and challenges associated with the international dissemination of virtual digital humans, Gong Xuandi and colleagues analyze the evolution of virtual digital human technology and propose strategic recommendations to enhance China's global competitiveness in this domain. Hong Shaohua and others note that mainstream domestic media actively explore virtual digital human applications but encounter pain points, suggesting pathways such as expanding application scenarios and emphasizing emotional design for improvement. Jianzhe Liu points out that virtual digital humans are rapidly infiltrating the media sector, facing high entry barriers, and recommends leveraging the metaverse as an overarching platform. Yu Zhao and Mengqian Li analyze how anthropomorphic features of virtual hosts influence human-machine emotional interactions, identifying various emotional interaction types while also highlighting ethical risks and governance challenges.

Despite the extensive exploration of virtual digital humans across technological, cultural, and media fields, certain research gaps remain. Firstly, in cross-cultural communication, questions persist regarding how virtual digital humans can more accurately adapt to diverse cultural backgrounds to reduce misinterpretation and enhance dissemination efficacy. Secondly, as virtual digital human technology advances, the development of ethical and regulatory frameworks becomes increasingly urgent to ensure their application in international contexts aligns with moral and legal standards, thereby mitigating potential ethical risks and governance issues. This paper will focus on the integration of technology, scene design, and cultural adaptation, proposing strategies for the cross-cultural applicability of virtual digital humans and the development of relevant ethical and legal standards. The aim is to promote broader and sustainable application in international communication, addressing existing research gaps and fostering responsible innovation.

3. The paradigm breakthrough under human-machine intelligent collaboration

The development of virtual digital humans fundamentally results from breakthroughs in technological convergence, exhibiting distinct stage-specific characteristics throughout its evolutionary trajectory. Based on technological maturity and application depth, virtual digital human technology can be delineated into three prominent developmental phases: Stage 1.0, characterized by perceptual intelligence centered on realistic appearance and basic interaction; Stage 2.0, marked by cognitive intelligence enabling semantic comprehension and dynamic feedback; and the emerging Stage 3.0, which aims to establish decision-making intelligence, endowing virtual digital humans with autonomous judgment and cross-scenario adaptability. This progression not only reflects iterative upgrades in underlying technologies but also signifies a fundamental shift in human-computer interaction paradigms—from unidirectional display to bidirectional engagement, ultimately progressing toward intelligent collaboration [3].

In terms of autonomous judgment, the interactive capabilities of virtual digital humans serve as critical indicators of their decision-making and communicative efficacy within the domain of

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international communication. Recent breakthroughs in this field predominantly focus on multimodal integration and adaptive interaction. Within multimodal interaction technologies, large language models exemplified by ChatGPT-4.0 have advanced virtual digital humans toward human-like qualities, endowing them with contextual understanding and emotional reasoning abilities. Leveraging these capabilities, virtual digital humans can generate natural, fluent language responses based on conversational content and concurrently produce subtle facial expressions, achieving precise cross-modal alignment between language and expression. This enhances the realism of interactions significantly [4]. Concurrently, major advancements in real-time translation technology have fundamentally eliminated language barriers in cross-lingual dissemination. For instance, systems such as Akool Live Camera support real-time translation across more than 150 languages, maintaining speaker vocal characteristics and lip-sync during conversion. The seamless multilingual capabilities of virtual digital humans open new avenues for the international dissemination of Chinese culture.

The breakthroughs in adaptive interactive technology warrant significant attention. The next-generation virtual digital humans possess the capability to perceive environmental changes in real time and dynamically adjust their expressive strategies accordingly. Specifically, they can automatically optimize facial shading effects under intense lighting conditions; enhance speech clarity in noisy environments; and adjust speech tempo and content emphasis based on micro-expressions such as frowning or distraction. This dual "environment-emotion" response mechanism enables virtual digital humans to transcend mere tool-like functions, establishing a foundational level of contextual intelligence that provides robust technical support for adaptive expression in cross-cultural communication.

In terms of scene adaptation, the application of virtual digital humans in the field of international communication primarily centers on modeling technologies, which exhibit diversified developmental pathways. Current mainstream modeling approaches can be categorized into three types based on the degree of human involvement: purely manual modeling, device-assisted modeling, and AI-driven modeling. Notably, volumetric capture technology is pioneering new forms of virtual digital humans. This technique employs optical scanning to generate authentic 4D digital clones of real individuals, achieving a one-to-one dynamic reproduction that surpasses traditional modeling methods in visual realism and emotional transmission efficiency [5]. Such "hyper-realistic virtual entities" elevate cultural dissemination from unidirectional information transfer to immersive emotional resonance. For example, recreating historical figures to narrate Chinese stories offers an immersive experience that is reshaping aesthetic paradigms in cross-cultural communication.

In summary, the technological evolution of virtual digital humans is underpinned by supporting paradigms of artificial intelligence, with three major schools demonstrating distinct strengths. Symbolism enhances semantic expression frameworks through knowledge representation and logical reasoning, enabling precise transmission of news and cultural symbols; connectionism, relying on neural network learning mechanisms, strengthens emotional bonding capabilities of virtual idols, fostering cross-cultural community building and identification; behaviorism, through reinforcement learning, improves the environmental adaptability of service-oriented digital humans, allowing flexible responses across diverse cultural scenarios. The integrated application of these paradigms facilitates virtual digital humans in effectively conveying cultural symbols and eliciting emotional resonance, thereby providing multidimensional support for international communication.

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4. Virtualized scenario-based communication transcends spatiotemporal barriers

In the current globalized communication landscape, the application of VDHs has become a prominent feature in international dissemination, with diverse practical scenarios that can be broadly categorized into service-oriented and identity-oriented VDHs. Service-oriented VDHs, leveraging their instrumental functionality, are capable of replacing human agents in various contexts, an approach particularly prevalent in Chinese streaming platforms' international outreach. Within artificial intelligence frameworks, virtual anchors are playing increasingly vital roles in news dissemination and social companionship domains, where their anthropomorphic characteristics significantly influence the patterns and effectiveness of human-machine affective interaction. Regarding anthropomorphic gradation, virtual anchors exhibit three developmental dimensions: object-simulated, human-simulated, and reality-approximated, with anthropomorphic designs generally fostering more positive human interaction [6]. A representative example is "Gu Xiaoyu," the service-oriented VDH host deployed during the Hangzhou Asian Games. Its meticulously crafted visual design authentically recreates Southern Song Dynasty aesthetics. During event coverage, it transcended basic broadcasting functions by infusing each segment with distinctive cultural elements from the Southern Song era. When appearing before audiences in period-accurate attire, delivering commentary with refined diction and graceful mannerisms, it effectively transported viewers back to that culturally flourishing historical period. The VDH accurately conveyed event information while skillfully incorporating Southern Song cultural references—when introducing traditional Wushu competitions, it contextualized them within the martial arts' historical development during the Southern Song Dynasty; when reporting on athletes' competitive spirit, it cited motivational poetry from Southern Song literati. This cultural-technological integration significantly enriched the Games' presentation, enabling global audiences to simultaneously appreciate athletic competitions and Southern Song cultural heritage, thereby adding unique cultural dimensions to international communication.

In international communication contexts, VDHs are driving profound transformations in traditional dissemination models through cutting-edge technologies. Avatar technology facilitates spatial deterritorialization, creating "placeless" communication scenarios that transcend geographical limitations in the physical world. This technology enables VDHs to manifest in culturally adapted forms across global digital spaces—regardless of physical location, network connectivity allows VDHs to interact with local audiences through avatar representations. Such deterritorialized communication scenarios eliminate spatial constraints on information dissemination, dramatically expanding its reach and impact [7]. For instance, a brand's VDH representative might appear as a kimono-clad guide in Japan's virtual marketplace while simultaneously manifesting as a sarong-wearing assistant in Indonesia, providing product consultations tailored to local cultural contexts, thereby enhancing the brand's international appeal through localized virtual services.

Conversely, digital twin technology enables persistent presence of communication content, making physical embodiment non-essential. This technology maintains VDHs' consistent appearance and functionality in virtual environments, ensuring uninterrupted information delivery and interactive services. Even without human creators being physically present, digital twins can conduct real-time exchanges with users following predetermined protocols—for example, an expert's VDH twin might participate in international virtual symposiums, addressing participant inquiries and sharing research findings throughout the event. This "disembodied" news dissemination approach not only simplifies operational logistics for communicators but also provides audiences with more accessible and efficient communication experiences, significantly

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improving the timeliness and breadth of information diffusion. These technological innovations have fundamentally transformed VDH-mediated communication paradigms, creating new developmental opportunities for international dissemination.

5. IP-based symbolic communication enhances emotional connectivity

In the complex context of cross-cultural communication, virtual digital humans leverage their hyper-realistic appearances to establish unique intellectual property (IP), crafting distinctive emotional symbols that serve as a vital medium for fostering cultural exchange and emotional resonance. Among these, identity-oriented VDHs place greater emphasis on cultivating unique personality archetypes. Such VDHs are particularly prevalent on overseas social media platforms, where they are meticulously designed through diverse forms like illustrations and CGI animation. Though lacking physical embodiment, they actively engage in performance-based activities within virtual spaces, attracting massive fanbases through their charismatic appeal.

Take the virtual idol Liu Yexi as an example. Her dissemination on TikTok successfully employs Eastern aesthetic digital imagery, effectively lowering cognitive barriers for global audiences toward Chinese Xuanhuan (fantasy) culture. Her character design integrates traditional Chinese attire, makeup, and mythological elements, with every gesture exuding oriental charm. Her short videos often feature storylines set in ancient Chinese fantastical landscapes—such as immortal grottos and mystical forests—accompanied by classical instrumentation, constructing an enigmatic and captivating Eastern fantasy ambiance. This deliberate visual and contextual framing has captivated international viewers, sparking their fascination with the once-unfamiliar yet mystifying Chinese Xuanhuan culture. Through the emotions and narratives conveyed by Liu, global audiences progressively comprehend and embrace the underlying values and aesthetic paradigms of this cultural genre, exemplifying how VDHs achieve cultural propagation via cultural adaptation [8].

Another illustrative case is Turkey's virtual influencer Berk Vadi, who played a pivotal role in Middle East crisis coverage. Equipped with advanced affective computing technology, he accurately simulates micro-expressions to achieve ethical representation of traumatic narratives. In reporting grave topics like the Middle East crisis, Berk Vadi's nuanced facial expressions vividly depict victims' emotions and plights, enabling audiences to empathetically grasp the anguish inflicted by warfare. Each micro-expression conveys profound compassion, transforming news reporting from cold factual accounts into humanistic discourse brimming with emotional depth. This case underscores how VDHs utilize cultural calibration and technological affordances to facilitate affective transmission across cultural boundaries, amplifying the emotional impact and persuasive power of cross-cultural communication—offering a valuable paradigm for VDHs' applied practices in global contexts.

6. Discussion and recommendations

While virtual digital humans (VDHs) demonstrate significant potential in international communication, they face multiple challenges requiring urgent resolution. From a cultural communication perspective, substantial regional variations in aesthetic preferences and interaction modes for virtual personas may compromise communication effectiveness. Content delivered through VDHs risks diminished efficacy when cultural disparities are overlooked, while linguistic translation processes frequently encounter semantic deviations, necessitating comprehensive localization adaptations across different regions.

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Technological risks demand equal attention, particularly concerning the misuse of deepfake technology. As an emerging technology, deepfake poses substantial conflicts with civil rights through potential infringements. Most jurisdictions have addressed this tension through legislative interventions to establish equilibrium between technological applications and civil protections [9]. Additional concerns include the proliferation of disinformation and identity impersonation. Furthermore, VDH training relies heavily on extensive datasets involving user privacy information during collection and storage, creating persistent data breach vulnerabilities. Technical limitations also manifest in affective interaction capabilities—current algorithmic dependencies for vocal, facial, and gestural expressions restrict fully naturalistic anthropomorphic interactions, thereby constraining international communication outcomes.

To optimize VDH applications in global communication and ensure sustainable development, multilateral strategies should be implemented. Primary emphasis must be placed on cultural adaptation and localized operations. Target market characteristics require systematic research to optimize VDH persona design, linguistic patterns, and interaction protocols, ensuring alignment with regional preferences. Localization strategies should integrate cultural specialists to mitigate cross-cultural misunderstandings, enhancing cultural affinity and audience receptivity [10].

Ethical frameworks and industry standards constitute another critical pillar. Establishing comprehensive ethical oversight mechanisms through international collaboration can define accountability structures and usage guidelines, preventing technological misuse while fostering healthy development environments [11].

Technological innovation remains the core driver for advancement. Increased investment in natural language processing (NLP) and emotion recognition technologies will strengthen cross-cultural adaptability, enabling more nuanced understanding of diverse audience needs. Blockchain integration can ensure data traceability and security, addressing privacy concerns. Continued breakthroughs in vocal, facial, and gestural simulation algorithms will progressively achieve more authentic non-verbal interactions—a crucial element in successful cross-cultural communication by minimizing cultural misinterpretations [12].

7. Conclusion

This study systematically examines the technological drivers, scenario adaptation pathways, and cultural mediation strategies of virtual digital humans (VDHs) in international communication, revealing their dual nature as innovative media with both transformative potential and inherent challenges. The research demonstrates how algorithmic and AI technologies are reconstructing communication paradigms through VDHs' "perception-cognition-decision" tri-phase intelligent evolution. Technological breakthroughs in volumetric capture, multimodal interaction, and adaptive response mechanisms collectively dismantle spatiotemporal barriers, establishing a new technological infrastructure for global communication.

The study contributes an original "technology-scenario-culture" triaxial analytical framework, addressing a critical gap in systematic research on VDH-mediated international communication while providing interdisciplinary theoretical linkages between communication studies, artificial intelligence, and cross-cultural research. Limitations include insufficient case coverage from Middle Eastern and African contexts, and the absence of quantitative metrics for evaluating cultural adaptation efficacy thresholds.

Future research should prioritize three dimensions: First, technological humanization through developing cross-cultural affective computing models integrated with brain-computer interfaces to enhance non-verbal symbol recognition accuracy and mitigate the "uncanny valley" effect. Second,

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narrative localization via constructing global cultural symbol databases and dynamic cultural sensitivity assessment algorithms for autonomous behavioral adaptation. Third, normative standardization by proposing an "Ethical Convention for Virtual Digital Humans" and establishing blockchain-enabled transnational data governance frameworks to balance innovation with risk management.

As strategic vectors for "Digital China's" international communication, VDHs must achieve synergistic evolution in technological controllability, cultural inclusivity, and ethical compliance to truly fulfill their potential as "digital cultural ambassadors" for a shared human future.

Authors contribution

All the authors contributed equally and their names were listed in alphabetical order.

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