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The Evolution of AI-Driven and Immersive Video Conferencing Technologies: A Comprehensive Review and Future Outlook

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Abstract
Telecom Rapid expansion of video conferencing, is a critical communication media, collaboration and Training to most of the verticals, especially after the outbreak is over. In this paper, the summary of the recent studies on the concepts of Evolution of video, ease of use and future direction in conference system is provided. There are early theories (Technology Acceptance Model (TAM) and Media Simultaneity Theory (MST) which explain adoption habits and user-involvement. User satisfaction fatigue Digital conferencing and QoE research has given latency and interface design and cognitive aspects as roles in User satisfaction. The latest developments introduce artificial intelligence, Real-time streaming (WebRTC), and 3D/volumetric streaming telepresence to offer a better degree of immersion and social presence, users with vision and hearing impairments do not enjoy the same degree of accessibility, scaling fatigue remain issues to allow a seamless experience. Some of the new trends that are increasingly being adopted are mixed reality, augmented reality based on communication and gesture support, and artificial intelligence. Debriefs will become the virtual world of interactivity and inclusivity that will transform the world, and they are justified. The information presented in this article gives a glimpse of the theoretical knowledge and Empirical information to comprehend the development of video conferencing by two domains: Immersive, intelligent, Human Centric communication ecosystems.

Keywords: *Video Conferencing, Artificial Intelligence (AI), Machine Learning (ML), Mixed Reality (MR), Augmented Reality (AR), Virtual Reality (VR), Volumetric Communication, Gesture Recognition, WebRTC, Telepresence, Human–Computer Interaction (HCI), Quality of Experience (QoE).*

1. Introduction
Video The technologies of video conferencing have been rapidly developing in the last decade, which has changed the nature of interaction, collaboration, and communication among long-distance people. Naturally, there were early examples like the gesture-sensitive augmented reality communications of Brehmer. [1], which were earlier than systems of volumetric 3D communication like VoluMe [2]. This preconditioned further intelligent, more natural, and expressive virtual communication. The problems inherent in networking were resolved by researchers when digital communication became popular, more than ever, even after the COVID-19 pandemic. To have scalable and secure video conferencing, real-time. In a thorough investigation on WebRTC systems, browser-to-browser communication was emphasized [3]. In the meantime, the emergence of centralized platforms led to the concerns of performance and user experience, which prompted research that evaluated the condition, problems and the trends of technology of the video conferencing platforms of today [4]. By increasing realism to boost user engagement, augmented and mixed reality systems began to offer potent solutions for remote procedural training and immersive collaboration (Figure 1). Rebol et al. showed how real-time AR based communication promotes effective procedural skill transfer [5]; further MR-based research has demonstrated the potential of holographic projections in emergency and instructional scenarios [6]. Simultaneously with these developments, dataset-driven research, such as the VCD video conferencing dataset, made it possible to optimize streaming speed and video compression [7]. On the communication

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intelligence front, meeting summarizing and AI-assisted analysis acquired great impetus, as surveys revealed major development in abstractive summary techniques [8], [9]. There are different theories for the uptake and user acceptability of video conferencing systems from behavioral and socio-technical standpoints, employing variables such as performance expectancy and media synchronicity [10].

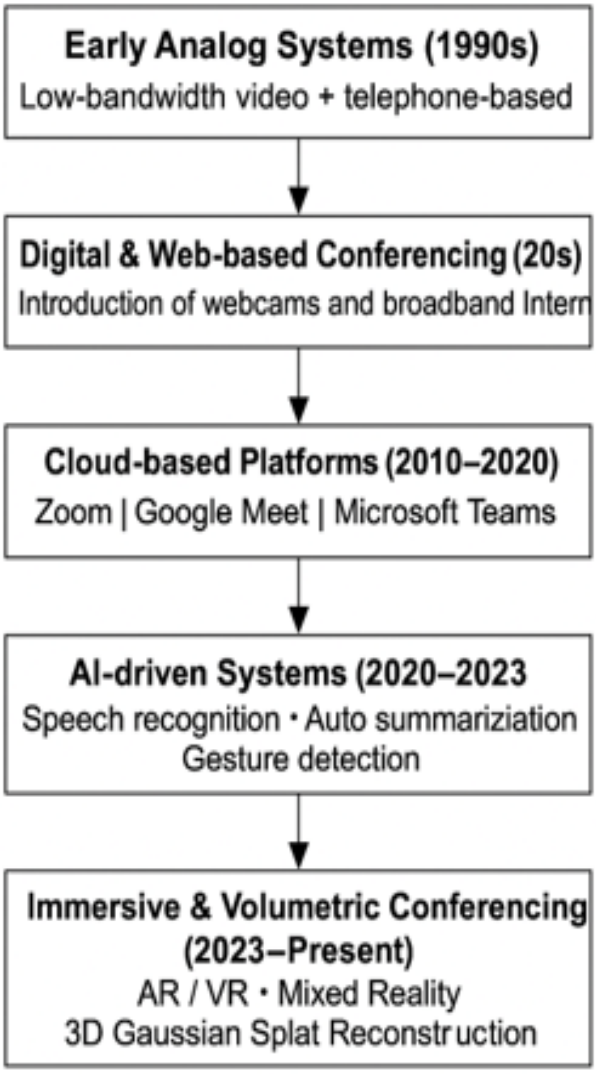

Figure 1 The Development of Video Conferencing Methods

State-of-the-art volumetric- and compression-efficient video systems have also been investigated extensively to increase the quality in streaming with restricted bandwidth [11]. In addition, avatar-based communication combining behavioral AI has increased social presence and engagement during distant meetings [12], whereas research into the limitations of video conferencing systems discovered major concerns involving latency, privacy threats, and user weariness [13]. Accessibility research has also revealed significant shortcomings in the assistance provided to visually impaired users, necessitating inclusive interface design and universal design [14]. The use of video conferencing in educational settings was advanced by remote learning at COVID-19 [15], and new architectures aiming at enhancing privacy, scalability, and network dependability were presented by decentralized forms of communication, such as DecVi [16]. By connecting technological data with human variables, the QoE model offered an organized method for assessing conference performance [17]. There is also another important addition such as systems that facilitate the accessibility and sign language interpretation such as Aikyam that assists Deaf and Dumb community by converting motions into texts [18], [19]. In order to replicate the real world dynamics, however, My recent conferencing systems have also added such capabilities as gaze visualization Look At Chat) to facilitate how eye contact can help facilitate fruitful interaction [20], [21]. As they are viewed as a whole, these studies point at obvious change in terms of antique webcam-based solutions to AI-enhanced, immersive, inclusive and agile ecosystems of digital communication - the technologies that are becoming the future in terms of remote collaboration.

a. History of Video Conferencing Solutions

Video conferencing capabilities have indeed progressed a long way off the initial stages of poor quality analog systems. This is today expressed as high-definition telepresence and cloud based communication environment. Initially, the conferencing systems were low bandwidth, failed to match syncing and could only be in small business or large enterprises [1]. Additionally, the progress in the digital networks, web-cams and high-speed networks made live audio and video communication available to anyone around the globe [2]. The significant step in this development was the release of the Web Real-Time Communication, also known as WebRTC. WebRTC WebRTC provides secure P2P audio and video, without the use of any plug-ins, with higher

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latency, responsiveness, and cross-platform compatibility [3], [4].

i. Intelligent Conferencing System Development

AI and ML have enhanced automation and intelligence of video conferencing systems. Actually, the more sophisticated functionality that is already provided by the new platforms includes automatic meeting summary and real-time transcription, as well as speech-to-text synthesis [5], [6]. Moreover, because of providing information about facial expressions, movements, and behavioral patterns, the technology of gesture recognition and emotion-detection enhances the level of nonverbal communication and user interaction [7], [8], and [9].

ii. Immersive and Volumetric Environment Development

The other major change in conference technology is the move towards immersive 3D and volumetric telepresence, instead of the previous 2D video stream of meetings. Such systems as VoluMe will have the ability to make 3D holographic repersons of its users appear incredibly realistic because of techniques such as Gaussian splatting and depth-sensing [10], [11]. CPR based are examples of MR technologies. instructional systems, make teamwork possible by simulating real life conditions virtually, being able to reproduce all the details of facial expression, gazes, and motions of the body to form a real communication [12]. It is evidenced by the avatar-based conferencing platforms such as SealMates, which can potentially enhance group interaction and redirect attention by means of AI-mediated behaviour. They may include technologies such as LookAtChat that enable natural eye contact and reduces cognitive exhaustion during an online meeting by displaying gaze in real time.

iii. Accessibility and Inclusivity Should Be Improved

Accessibility is one of the primary objectives of the development of video conferencing nowadays. Several technologies that employ deep-learning algorithms, like Aikyam, can translate motions in the sign-language into text and successfully communication within the Deaf and Dumb community takes place [16]. As a matter of fact, as per various studies, most of the conferencing systems do not provide support to visually impaired users, through features like un labelled buttons, poor keyboard navigation and poor auditory feedback. Also, Abu Doush et al. point out such weaknesses and suggest applying UDL criteria to ensure that the engagement will be equal [17].

iv. Decentralization and Optimization of Networks

The conventional centralized conferencing systems are often faced with issues of delay, congestion, privacy, and reliance on infrastructure. In order to address these issues, decentralized and peer-to-peer (P2P) systems like DecVi have been developed. The reasons DecVi enhances reliability, reduces bottlenecks and facilitates security is because it embraces adaptive routing mechanisms, and is especially applicable in low-resource and distant settings [18].

2. Literature Review

a. Theoretical and Analytical Frameworks

Behavioral, cognitive, and communication theoretical frameworks have substantially affected earlier research about the adoption and performance of video conferencing. These frameworks assist explain why users accept various platforms, how they evaluate satisfaction, and which elements contribute to good remote collaboration [1], [2], [3], [4].

i. Technology Acceptance Model (TAM)

One of the most widely applied theories in evaluating technology adoption is the Technology Acceptance Model. Two major factors determine the acceptance and continued use of any conferencing platform by its users, according to TAM:

- Perceived usefulness (PU)
- Perceived ease of use (PEOU)

Research into conferencing tools has established that users are more likely to adopt systems where increases in productivity, decreases in effort, and reliable outcomes are observed [1]. During the COVID-19 pandemic, TAM-based evaluations identified that higher usability, better interface design, and stronger system performance significantly enhanced the effectiveness of Zoom and Microsoft Teams for learning and professional communication [2], [4].

ii. Media Synchronicity Theory (MST)

MST provides a The Media Synchronicity Theory

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helps explain how well a communication medium supports the simultaneous exchange of information.

- Video conferencing platforms that offer:
- Live feedback
- Screen sharing
- Breakout rooms
- Symbol variety: audio, video, chat
- Reprocessability

are shown to improve group coordination, task performance, and immediacy in distributed teams. Recent studies indeed confirm that when the media capabilities match the task complexity, user engagement is significantly heightened [3].

iii. Quality of Experience (QoE) Model

The QoE framework connects technical quality with human perception and consequently provides a multidimensional evaluation of conferencing systems. QoE Examines:

- Latency, jitter, packet loss
- Resolution and frame rate
- Cognitive load
- User fatigue
- Engagement and comfort

Skowronek et al. suggested a standardized QoE template considering both system influence factors, like network conditions, and human influence factors, such as attention and mental workload [4]. Today, the QoE model is considered central to the assessment of telemeeting system.

b. Evolution of Video Conferencing Technologies

i. Transition from Analog to Digital Systems

Due to the low bandwidth and poor signal synchronization of analog telephony, early video conferencing tools were only used in business environments with small groups of attendees [5]. The usage of internet connection and affordable cameras enable for high-quality real-time communication in general, enabling video conferencing simpler than previously [6].

ii. Cloud-Based and Real-Time Platforms

Introduction of WebRTC brought a radical change in browser-based communication by facilitating low latency, plugin-free audio, and video transmission [7],[8]. However, even dominant centralized platforms such as Zoom, Google Meet, and Webex suffer from various issues, such as:

- Latency
- Privacy and security
- Regional network congestion [9], [8]

iii. Immersive and AI-Driven Conferencing

The focus of modern research is increasingly directed at the creation of an immersive, naturalistic communication environment using AI, AR, and MR systems. Examples include:

- VoluMe — which generates 3D volumetric avatars using a single webcam stream [10].
- Mixed Reality emergency assistance - enabling holographic collaboration [11]
- Gesture-aware AR systems: enhancing Nonverbal communication and expressiveness [12]

Behavioral AI is used by avatar-based platforms such as SealMates in order to enhance group participation and attention allocation [13]. In contrast, Look At Chat uses mutual gaze to enhance group cooperation and lessen "Zoom fatigue" [14], [9].

c. Accessibility, Inclusivity and User Well-being

i. Inaccessibility Issues

Despite technological progress, most video conferencing tools still lack comprehensive support for accessibility. Usability analyses reveal:

- Unlabeled UI components
- Missing audio cues
- Inconsistent keyboard navigation
- Poor support for screen readers

According to Abu Doush et al. found that Zoom and Microsoft Teams presents serious difficulties for people who are blind. One such tool is Aikyam, which supports inclusive communication by using deep learning-based sign language recognition for deaf and dumb users [16].

ii. Mental Strain and Cognitive Fatigue

Zoom weariness can occasionally result from extended online meetings, as evidenced by: strain on the eyes Reduced focus Mental exhaustion Additionally, this fatigue increases as camera delays or audio-video synchronization latency increase [9].

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Furthermore, Quality of Experience (QoE) indicates a clear correlation between delayed reflexes, interface design, and increased cognitive burden study [4]. Using Social and Behavioral Computing to Promote Inclusivity, equitable participation in virtual meetings is made possible by behavior-driven avatars and adaptive interface designs. Video conferencing is now more human-centered than merely functional thanks to these advancements.

3. Current Challenges & Limitation

Network constraints, mental strain, privacy concerns, and uneven platform accessibility support are the causes of these problems. Despite such rapid growth, modern video conferencing systems are confronted with serious challenges in performance, accessibility, security, and overall user well-being. Prior art also pinpointed several limitations consistently due to network constraints, cognitive load, privacy vulnerability, and a lack of standardized accessibility features [12], [13], [14]. These need to be addressed for next-generation reliable, inclusive, secure, and human-centric conferencing ecosystems.

a. Network and System Limitations

The overwhelming majority of popular conferencing services are based on centralized servers in clouds, which introduce delay, jitter, packet loss, and bandwidth overload, particularly when there is a high traffic session [4]. Even small delays have an immense impact on the flow of conversation, leading to less user engagement and inadequate interaction. In fact, research indicates that audio-visual delay should not be greater than 200 ms for natural communication and efficient decision-making in collaborative settings [15]. Adaptive routing techniques get around these restrictions by intelligently distributing traffic among decentralized P2P infrastructures like DecVi. By reducing traffic, this can increase availability, particularly in isolated or underserved areas [16]. However, there are still some issues that decentralized systems may face:

- Synchronization issues in multi-user environments
- Scalability limitations
- High computational overhead

They are thus not extensively used, despite their advantages.

b. Privacy and Data-Security Concerns

Real-time video as well as audio, behavior information, gaze patterns, and interaction logs are all collected by contemporary video conferencing tools, increasing the possibility of misuse, surveillance, and unauthorized access to the data [12], [15].

- Data leaks and unauthorized video feed scraping are still threats to centralized systems.
- Leakage of personal or company data
- Algorithmic exposure of sensitive behavioral cues

Security is increased via blockchain-based authorization, end-to-end encryption, and decentralized identity verification, including that suggested in DecVi. Despite these advances, obtaining low-latency, fully private, end-to-end encrypted conferencing remains a challenging task in research.

c. Cognitive Fatigue and Psychological Effects

Prolonged video conferencing typically leads to Zoom fatigue, which is manifested through:

- Eye strain
- Reduced attention
- Burnout
- Emotional detachment

This, apart from constant self-view monitoring, camera delays, and poor interface layouts, significantly enhances mental workload [12], while QoE-based assessments confirm that delays in audio-visual synchronization contribute directly to cognitive overload [15]. Emerging technologies try to reduce fatigue:

- Dynamic layouts and focus-switching interfaces
- Gesture-aware AR systems that support more natural interaction [1], [5]
- Avatars with behavior-driven interfaces that reduce screen-overload pressure

Such improvements could allow conferencing systems to be more human-centered and emotionally adaptive.

d. Accessibility and Inclusivity Issues

Despite the claims of universal use made by all video conferencing solutions, there are still glaring access barriers. For visually impaired participants:

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- Unlabeled UI elements
- Lack of keyboard shortcuts
- Missing audio descriptions
- Non-adaptive interfaces [14]

Very few systems have integrated sign-language recognition for hearing-disabled users. Deaf and dumb users can be included by using tools like Aikyam, which enable machine learning recognizers to convert gestures into text [18]. But commercial platforms are still inconsistent in terms of accessibility, and universal standards are underdeveloped.

e. Social Presence and Engagement Gaps

Traditional Conventional 2D video screens do not provide the transmission of such key non-verbal cues as direction of gaze, position, motion, and joint attention. These are required to establish a sense of trust, collaboration, emotional expressiveness and conversational balance, according to [12] and [21].

- Advanced research explores how it is possible to reintroduce the sense of space.
- SealMates makes use of behavioral-driven avatars to sustain group attention and social cues [12].
- LookAtChat is a virtualization of the real-time gaze of individuals to mimic a natural mutual gaze [21].

These technologies are promising but they need additional refinement in order to scale, be more precise and accepted by users. These barriers should be overcome to make the conferencing environments stronger and more human centered.

4. Future Directions and Technological Advancements

Video conferencing is going to enter a new era powered by immersive media, distributed frameworks, real-time AI, and highly customized user experiences. The objective for future systems is to be more realistic, secure, accessible, intelligent, and emotionally adaptable, supported by hardware improvements, artificial intelligence, ML, and networking at high speeds.

a. Integration of Artificial Intelligence and Automation

i. Smart Meeting Summarization and Analytics

AI-driven tools now allow automatic:

- Attendance tracking
- Note-taking
- Meeting summarization
- Action-item detection

Advanced Another advanced capability is that of analyzing the conversational flow, prioritizing what is being discussed, and extracting key decisions, allowing for greater efficiency when it comes to completing tasks after a meeting [8], [9]. If this is implemented directly from the conferencing software, it means less work and greater organizational productivity.

ii. Gesture Recognition and Emotion Detection

Real time ML algorithms can make systems that are able to detect:

- Facial Expression
- Upper-body gestures
- Emotional signals
- Attention patterns

These models enable conferencing platforms to adjust the layouts dynamically, highlight the active speaker, and even trigger intelligent camera zooming [1], [5], [12].

Emotion-aware interfaces will provide a more natural and human-like communication flow.

b. Immersive and Volumetric Communication

i. 3D Holographic Telepresence

Advanced technologies like VoluMe use Gaussian scattering and depth modeling to render realistic 3D 3-dimensional avatars in real time [2]. Mixed Reality contexts, such as CPR-based communication systems, can produce realistic spatial interactions [6] that enhance remote training and interactive problem-solving.

ii. Mixed and Extended Reality Meeting Spaces

MR and XR offer virtual collaboration on 3D content with numerous users [5], [22], generating advantages in work performance in medical, design, engineering, and education (Table 1). However:

- XR hardware costs
- Rendering optimization
- Real-time scaling

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Table 1 Summary of Key Research Contributions in Video Conferencing Technologies

Author(s)	Year	Focus Area	Technology /Model Used	Key Contribution
Brehmer [1]	2025	Gesture-aware AR video	AR + Pose recognition	Improved data-rich presentation engagement
.De La Gorce [2]	2025	Volumetric 3D calls	Gaussian Splat Prediction	Real-time authentic 3D telepresence
Wei & Venkatakrish nan [16]	2022	Decentralized conferencing	P2P adaptive routing	Reduced latency, enhanced privacy
Abu Doush et al. [14]	2022	ccessibility	Usability Testing	Identified gaps for visually impaired users
rmstrong et al. [12]	2024	Avatar-mediated communication	Behavioral AI	Improved group engagement & empathy
Rebol eal. [6]	2023	Mixed Reality	MR + Holographic Projection	Enhanced procedural skill training
Skowronek et al. [17]	2022	QoE evaluation	Cognitive & technical factors	Standardized QoE framework

c. Adaptive and Context-Aware Conferencing Systems

i. Personalized Quality of Experience (QoE)

AI-based QoE engines dynamically adjust:

- Video resolution
- Audio bitrate
- Latency settings
- Adaptive layouts

dependent on device capability, network strength, and user behavior [15]. Additionally, this guarantees a constant user experience under fluctuating network circumstances [23]-[25].

ii. Decentralization and Network Optimization:

Future systems will likely combine:

- Peer-to-peer architectures
- Edge computing Blockchain authentication to offer scalable
- low-latency
- and privacy-preserving conferencing [16]

Conclusion

In digital world more over automation, flexibility and potential of real time optimization in the user experience was essentially possible due to the introduction of AI, ML and WebRTC. Not only has the AR, MR and volumetric 3D communication that we've been making progress on recently – particularly in where this could be leading with regards to remote collaboration teams but also now significantly improved over face-to-face. However, even with all the good because of the modern videoconferencing technology, there are still issues of reliable network infrastructure, user exhaustion and privacy issues regarding the type of data sent and information processing1 and unable to allow disabled people to attend. It will require an interdisciplinary solution to such challenges and that should be technology innovation, user-centered design, and security. security features [26]-[28]. In the future, research should aim to develop context- aware conferencing systems that would automatically adjust to user behavior and network conditions, as well as to incorporate emotion recognition, gesture input, and haptic feedback on the user side to improve participation and realism [29],[30]. The joining of AI, immersive media, and decentralized communication is a fresh and powerful era for telepresence, providing the possibility of a highly interactive and human-like virtual environment that at the same time is inclusive,

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guarantees privacy, and has a good quality of experience (QoE). Eventually, the coming days of video conferencing will be characterized by the perfect blend of intelligence, immersion, and inclusivity—this will be the milestone for the next generation of human communication.

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