

Article

Opportunities and Challenges of Smartglass-Assisted Interactive Telementoring

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Abstract: The widespread adoption of wearables, extended reality, and metaverses has accelerated the diverse configurations of remote collaboration and telementoring systems. This paper explores the opportunities and challenges of interactive telementoring, especially for wearers of smartglasses. In particular, recent relevant studies are reviewed to derive the needs and trends of telementoring technology. Based on this analysis, we define what can be integrated into smartglass-enabled interactive telementoring. To further illustrate this type of special use case for telementoring, we present five illustrative and descriptive scenarios. We expect our specialized use case to support various telementoring applications beyond medical and surgical telementoring, while harmoniously fostering cooperation using the smart devices of mentors and mentees at different scales for collocated, distributed, and remote collaboration.

Keywords: augmented reality; extended reality; mentor–mentee relationship; smartglass; telementoring; remote collaboration; wearable computing



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1. Introduction

The number of computing devices that people encounter in their daily life is increasing. Beyond the typical form factor of a desktop computer, computing devices are becoming smaller, more abundant, and ubiquitously available. The vision of “ubiquitous computing” is more apparent today due to the myriad of connected everyday appliances known as the Internet-of-Things (IoT). Both ubiquitous computing and IoT emphasize environment-centric sensing and service provision through ambient intelligence. On the other hand, wearable computing complements the aforementioned environment-centric view with an intimate first-person view realized by always on, always accessible, and always connected wearables. Rapid advancements in ubiquitous computing and wearable computing have established a viable infrastructure to connect people over long distances to neutralize the barriers of physical locations. The recent COVID-19 pandemic has accelerated the use of this type of technology [1,2] in forms of remote collaboration, working-from-home, teleconferencing, online education, and metaverses enriched with various configurations of digital twins (DTs) [3], augmented reality (AR), virtual reality (VR), mixed reality (MR), and extended reality (XR).

There are numerous reports and surveys supporting the wide spread and adoption of wearables, XR, and metaverses in the foreseeable future. According to BCG and Motor Intelligence, XR markets are growing and will reach 30.7 billion USD in 2021 and 300 billion USD by 2024, respectively. Another report by the IDC forecast that consumer spending on AR and VR technology is approximately 6.36 billion USD, accounting for 53% of global AR and VR spending in 2020. A survey published in February 2021 by ARtillery Intelligence highlights that enterprise AR glasses hardware and software revenue will rise to 2.05 billion USD in 2021 and 11.99 billion USD by 2024, respectively. XR industry experts forecast that such immersive technologies will have a great impact on the healthcare and medical sector [4].

In this paper, we explore the opportunities and challenges of smartglass-assisted interactive telementoring and its applications. Specifically, our contribution is threefold, as follows:

1. First, we elicit requirements and trends by reviewing recent telementoring studies;
2. Second, we define a terminology “smartglass-assisted interactive telementoring (SAIT)” to refer to specialized use cases of telementoring and elaborate on its distinguishable characteristics;
3. Third, we identify opportunities and challenges of SAIT applications through five illustrative and descriptive scenarios.

2. Related Work

In this section, we review recent attempts at remote collaboration [5] and XR collaboration [6] using wearable displays and various interaction styles [7–9] to elicit requirements for effective telementoring. Rather than the systematic review or meta-review approaches elaborated in [10,11], we specifically focus on recent remote collaboration and telementoring studies from 2015 to 2021.

Schäfer et al. have presented a comprehensive survey on synchronous remote collaboration systems based on AR/VR/MR technology [5]. They have identified the category of “remote experts” to include collaboration systems involving a local and a remote user [5] that share similar fundamental concepts and application areas as XR collaboration [6], as well as our soon to be defined smartglass-assisted interactive telementoring approach.

2.1. Wearable Displays

Remote collaboration attempts to remove physical barriers between remote workers. One such technique is the capability of sharing a remote worker’s view and displaying it on a local site’s displays. Wearable displays such as head-mounted displays (HMDs) worn by collaborators enable the sharing of other users’ views, as well as supporting hands-free actions naturally. Wearable displays present additional information to the wearer. This characteristic has enabled various applications to be implemented using wearable displays. Wearable displays can be categorized as optical see-through (OST) or video see-through (VST) displays, and there are many trade-offs. In OST HMDs, the wearer can naturally see the real world through half-transparent mirrors placed in front of the wearer’s eyes, which optically reflect a combination of real and computer-generated images to the eyes without processing latency or delays [12]. In VST HMDs, the real world is first captured with video cameras of the wider field of view (FoV) mounted on the HMD, and then the computer-generated images are electronically combined over the captured video [12].

Google Glass launched in 2013 and demonstrated a viable use of OST HMDs through various situated applications in information visualization and augmented reality using images and instructions. Since then, commercial smartglasses from Microsoft [13–21], Google [22,23], HTC [7,8], Vuzix [24], Epson [25,26] and Brother [27] have integrated a wearable display with a computationally sufficient computing unit that provides connectivity and a multi-modal user interface. For example, the latest OST HMDs such as HoloLens 2 and MagicLeap One provide high-resolution displays (i.e., up to 2048×1080), a wide FoV (i.e., 52 and 50 degrees), and tracking and control capabilities. For a comprehensive review on HMD for medical usages, readers are referred to [28].

2.2. Medical and Surgical Telementoring

Telementoring is most beneficial when local and remote users have different degrees of knowledge, experience and expertise. Promising application domains for telementoring (satisfying the conditions for remoteness and mentoring as shown in Table 1) are medical, surgical, and healthcare domains in which there exist a sufficient knowledge and experience gap between two groups of people (i.e., also known as mentors and mentees). Medical or often surgical telementoring is a well-examined application area that exploits these

conditions to enhance or improve the overall performance of the involved users, as shown in Table 1.

Ballantyne et al. stated that telementoring “permits an expert surgeon, who remains in their own hospital, to instruct a novice in a remote location on how to perform a new operation or use a new surgical technology [29].” El-Sabawi and Magee III explained that “surgical telementoring involves the use of information technology to provide real-time guidance and technical assistance in performing surgical procedures from an expert physician in a different geographical location. Similar to traditional mentoring, it plays a dual role of educating and providing care at the same time [30].” Semsar et al. defined that “these remote work practices entail a local worker performing a physical task supported by a remote expert who monitors the work and gives instructions when needed - sometimes referred to as telementoring [31].” From the aforementioned views and previous medical and surgical telementoring studies, two types of telementoring can be identified. The first type is sharing the view of a mentor to teach mentees where mentees can learn from the mentor’s direct and real-time practice via learning by examples or demonstration strategies. The second type is sharing the view of a mentee, so mentors can appropriately give advice and deliver feedback in real-time for training and instruction purposes. For example, guidelines can be provided to surgeons to train them to perform new operations [29,32]. Despite the differences in who takes the initiative in telementoring, both types of telementoring can benefit from high-definition videoconferencing, wearable technology, robotic telementoring platforms, and augmented reality [30]. For a comprehensive review on surgical, medical, and healthcare telementoring studies, readers are referred to [10,11].

Table 1. Post-2015 Remote Collaboration and Telementoring Studies.

Reference	Remoteness	Mentoring	Domain
Kim et al. [33]	No	No	Nursing Education
Klinker et al. [13]	No	No	Medical
Kopetz et al. [22]	No	No	Nursing Education
Rochlen et al. [25]	No	No	Medical
Huang et al. [27]	No	No	Medical
Aebersold et al. [34]	No	No	Medical
Hanna et al. [14]	Yes	Yes	Medical
Yoon et al. [23]	Yes	Yes	Medical
Lacy et al. [35]	Yes	Yes	Medical
Rio et al. [26]	Yes	Yes	Medical
Greenberg et al. [32]	Yes	Yes	Medical
Liu et al. [15]	Yes	Yes	Medical
Meijer et al. [36]	Yes	Yes	Medical
Andersen et al. [37,38]	Yes	Yes	Medical
STAR [16–19]	Yes	Yes	Medical
Mitsuno et al. [20]	Yes	Yes	Medical
Mentis et al. [39]	Yes	Yes	Medical, Industrial
Lin et al. [40]	Yes	Yes	Medical
Gasques et al. [21]	Yes	Yes	Medical
Hassan et al. [41]	Yes	Yes	Medical
Giuseppe et al. [42]	Yes	Yes	Industrial
Semsar et al. [31]	Yes	Yes	Medical
Wang et al. [7]	Yes	Yes	Industrial
Wang et al. [8]	Yes	Yes	Physical Task

2.3. Interaction Styles of Telementoring

Telementoring systems have employed numerous interaction techniques. Often, these interaction techniques were dominated by devices and displays used (i.e., mobile, wearables, and large-screen displays). Schäfer et al. identified nine common interactive elements in remote collaboration systems as 3D object manipulation, media sharing, AR annotations,

2D drawing, AR viewport sharing, mid-air drawing in 3D, hand gestures, shared gaze awareness, and conveying facial expression [5]. In our review of recent telementoring studies, we have similarly identified four main interaction styles as touch-based user interface, voice-based user interface, gesture-based user interface, and telestration user interface.

2.3.1. Touch-Based User Interface

A touch-based user interface (UI) is a common and direct interaction style used in many telementoring systems [16–19,33]. Most users are already familiar with touchscreens on smartphones and tablets, therefore touch-based UIs do not require much training time. However, in the medical and surgical domains, the use of hands is strictly restricted or prohibited to maintain hygiene. For other domains, touch-based UIs for wearables are popular and considered default. Smartglasses such as Google Glass, HoloLens, and Vuzix Blade all provide on-device touch-based UIs. Figure 1 shows illustrations of touch-based interaction styles where the wearer can control the device by touching it (i.e., touchpad).



Figure 1. Illustrations of touch-based interaction styles.

2.3.2. Voice-Based User Interface

A voice-based UI is another common style of interaction found in telementoring systems. Voice-based UIs are used between mentors and mentees to provide timely feedback and verbally communicate using conversations to request appropriate guidance. Unlike touch-based UIs, voice-based UIs can be implemented entirely hands-free, avoiding hygienic concerns for medical and surgical telementoring. The use of naturally spoken language is intuitive and highly expressive. Moreover, the performance of speech recognizers is greatly improved recently with artificial intelligence. Nonetheless, situations and environments involving many speakers, noisy workplaces, microphone quality, and the requirements of large vocabulary pose implementation and deployment issues. Often, a microphone is integrated with the device used for telementoring (i.e., smartglasses and notebooks). Previous telementoring studies using smartglasses have provided variations of voice-based UIs [13,14,16–19,23,31,42]. Figure 2 illustrates hands-free and voice-based interaction styles.



Figure 2. Illustrations of voice-based interaction styles.

2.3.3. Gesture-Based User Interface

A gesture-based UI mostly refers to exploiting hand gestures in telementoring systems. Commercial smartglasses such as Oculus Quest 2 and Microsoft HoloLens 2 provide hand tracking via computer vision or separate controllers. Furthermore, specialized hardware and software for data gloves and suits from Manus, BeBop sensors, Feel the Same, and Tesla can be adopted to include gesture-based UIs. Similar to voice-based UIs, gesture-based UIs can be used in hands-free and touch-less manner. On the downside, the less expressive gesture-based UIs often require additional and costly sensors, processing units, and heavy computation. In our review, several studies incorporated gesture-based UIs in their systems [22,36,42]. Figure 3 demonstrates typical touch-less gesture-based interaction styles.

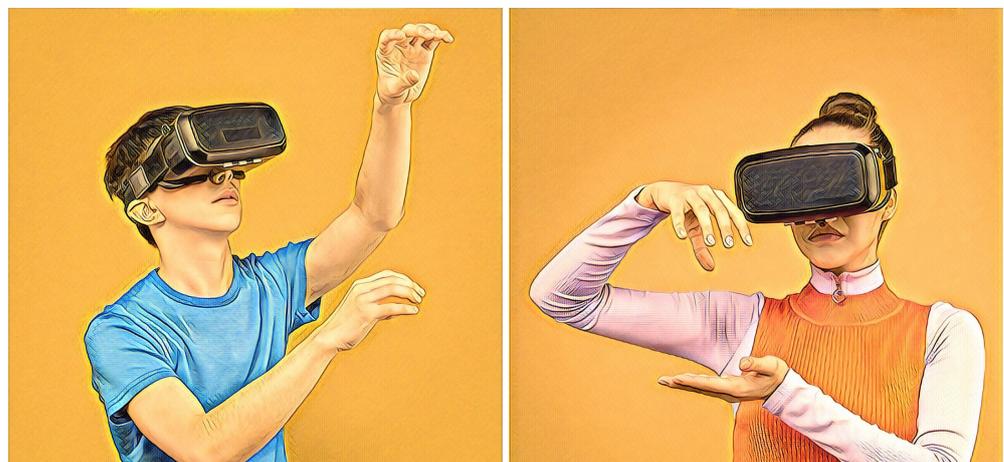


Figure 3. Illustrations of gesture-based interaction styles.

2.3.4. Telestration User Interface

A telestrator refers to a device that can draw sketches over still or video images. In many telementoring systems, similar functionalities of pointing, annotating, and drawing are called telestration as depicted in Figure 4. Such telestration enables mentors to visually instruct and point out areas of interest quickly. Furthermore, telestration from mentees can be used to highlight problematic areas. Several studies in our review also used some forms of telestration in their systems [14–21,26,31,37–40], often with voice-based UIs [14,16–20,31,39].

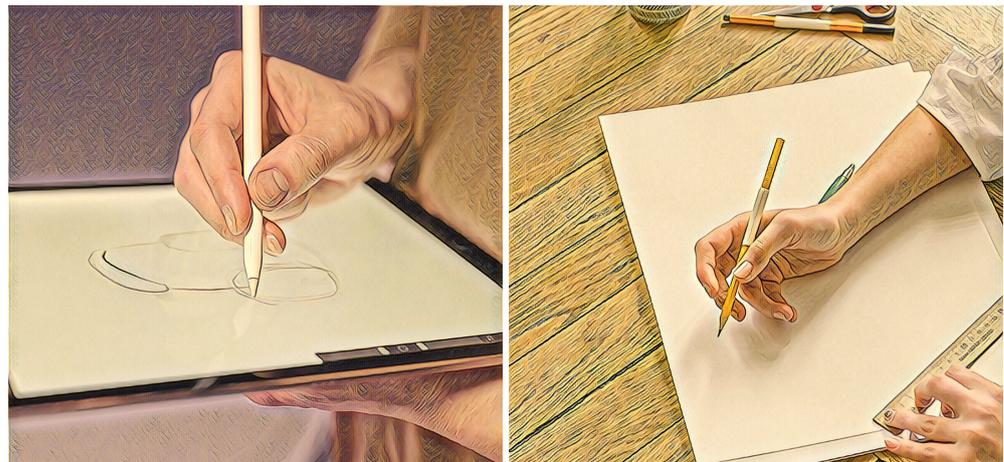


Figure 4. Illustrations of telestration interaction styles.

2.3.5. Other Types of User Interfaces

There are other interaction styles such as using tangible UIs [25], foot pedal [27] and avatars [21]. We think that using foot pedals depicted in Figure 5, could go well with the aforementioned types of UIs (touch-based, voice-based, and gesture-based) and complement shortcomings of these interaction styles. For example, foot pedals could replace on-device and touch-based UIs in the medical and surgical settings. This interaction style can be used to confirm correctly recognized gestures or cancel incorrectly recognized gestures. Table 2 identifies telementoring systems with smartglasses and their employed interaction styles discussed in this section.

Table 2. Telementoring Studies with Smartglasses and Interaction Styles.

Reference	Telementoring	Smartglass	Interaction Styles
Kim et al. [33]	No	Vuzix Blade	Touch-based
Klinker et al. [13]	No	MS HoloLens	Voice-based
Kopetz et al. [22]	No	Google Glass	Gesture-based
Rochlen et al. [25]	No	Epson Moverio BT-200	Tangible UI
Huang et al. [27]	No	Brother AiRScouter WWD-200B	Wireless Two-button Foot Pedal
Aebersold et al. [34]	No	N/A	Video, Quiz
Hanna et al. [14]	Yes	MS HoloLens	Voice-based, Telestration
Yoon et al. [23]	Yes	Glass Enterprise Edition 2	Voice-based
Lacy et al. [35]	Yes	N/A	Voice-based
Rio et al. [26]	Yes	Epson Moverio BT-200	Telestration
Greenberg et al. [32]	Yes	N/A	Voice-based
Liu et al. [15]	Yes	MS HoloLens	Telestration
Meijer et al. [36]	Yes	N/A	Gesture-based
Andersen et al. [37,38]	Yes	N/A	Touch-based, Telestration
STAR [16–19]	Yes	MS HoloLens	Touch-based, Voice-based, Telestration
Mitsuno et al. [20]	Yes	MS HoloLens	Voice-based, Telestration
Mentis et al. [39]	Yes	N/A	Voice-based, Telestration
Lin et al. [40]	Yes	MS HoloLens	Telestration
Gasques et al. [21]	Yes	MS HoloLens, HTC Vive Pro	Telestration, Avatar
Hassan et al. [41]	Yes	N/A	N/A
Giuseppe et al. [42]	Yes	Head-mounted Camera	Voice-based, Gesture-based
Semsar et al. [31]	Yes	N/A	Voice-based, Telestration
Wang et al. [7]	Yes	HTC Vive HMD	Gesture-based, Head Pointer, Telestration
Wang et al. [8]	Yes	HTC Vive HMD	Gesture-based, Head Pointer, Eye Gaze, Telestration



Figure 5. Illustrations of an interaction style using foot pedals.

3. Smartglass-Assisted Interactive Telementoring

In our review of recent remote collaboration and telementoring studies in the previous section, we identified studies that use smartglasses and satisfy telementoring requirements as shown in Table 2. Using these selected studies, we define a specialized use case of telementoring, which we call “smartglass-assisted interactive telementoring (SAIT)”. As the terminology suggests, smartglasses are the required hardware display unlike traditional medical and surgical telementoring that allow other alternative displays [31]. More specifically, the SAIT has the following characteristics over typical remote collaboration or telementoring in general.

- *Mentors and Mentees of Different Levels.* The SAIT involves two groups of users categorized as mentors and mentees. Mentors are the sufficiently more knowledgeable and experienced groups with professional or technical expertise. Mentees are the less knowledgeable and experienced groups who would benefit or improve their performance with the help received from their mentors.
- *Sharing of First-person and Eye-level View via Smartglass.* Either or both mentors and mentees share their eye-level view captured by their HMDs with sufficient FoV to provide enough details and video quality for the intended telementoring tasks.
- *Extended Use Cases with Bi-directional Interaction.* The SAIT aims to cover flexible and casual use cases beyond the medical and surgical telementoring scenarios. In the SAIT, mentors and mentees are preferably on the go, situated, and hands-free for exploiting multiple interaction channels for various occasions.

To elaborate on these characteristics of the SAIT applications, five illustrative and descriptive scenarios are presented in the next section.

4. Five Scenarios for Smartglass-Assisted Interactive Telementoring

As we have discussed in Section 2, many remote collaboration and telementoring systems have been developed in the healthcare sector. In a survey of XR industry experts, training simulations in the healthcare sector are the favored major application [4]. Tables 3–6 show XR industry experts’ views on the promising XR applications in various domains reported in 2020 Augmented and Virtual Reality Survey Support [4]. Training simulations and assisted surgeries are the top applications of immersive technologies in the healthcare sector, as shown in Table 3. Immersive teaching experiences and soft skills development are expected to be a major application of XR technologies in the education sector, as shown in Table 4. In the manufacturing sector, real-time remote assistance and workforce training are expected to be major XR applications, as shown in Table 5. Improvements in navigation solutions and urban planning are the top applications of immersive technologies in smart cities, as shown in Table 6.

Table 3. Top 7 XR Applications in Healthcare, source: [4].

Top 7 XR Applications in Healthcare	Share of Respondents
Training simulations	68%
Assisted surgeries	56%
Studying diseases like cancer in 3D	53%
Addressing visual disorders	46%
Pain management	43%
Emergency navigation	42%
Assessing and addressing mental health conditions	40%

Table 4. Top 5 XR Applications in Education, source: [4].

Top 5 XR Applications in Education	Share of Respondents
Immersive teaching experiences	66%
Soft skills development	57%
Build interactive 3D models for learning	55%
Exploratory expeditions	49%
Recreation/simulation of past experiences for new learners	40%

Table 5. Top 6 XR Applications in Manufacturing, source: [4].

Top 6 XR Applications in Manufacturing	Share of Respondents
Offering real-time remote assistance	75%
Workforce training	48%
Reduction of assembly errors	45%
Improvement of supply chain management	45%
Remote inspection and maintenance	43%
Prevention of accidents	40%

Table 6. Top 5 XR Applications in Smart Cities, source: [4].

Top 5 XR Applications in Smart Cities	Share of Respondents
Navigation	66%
Urban planning	57%
Smart traffic signals and camera monitoring	55%
Smart parking	49%
Smart building management systems	40%

Based on various XR applications across different domains, we have chosen five specific scenarios to elaborate on the concept and characteristics of the SAIT. The selected telementoring scenarios include the SAIT for paramedics, maintenance, culinary education and certification, hardware engineers, and foreigner navigation.

4.1. SAIT for Paramedics Scenario

- *Mentors and Mentees of Different Levels.* This SAIT scenario involves dispatched paramedics as mentees and more experienced mentors at the medical center. The paramedics are trained to perform various skills in emergency settings (i.e., airway management, breathing, circulation, cardiac arrest, intravenous infusion, patient assessment, wound management) and provide emergency medications. Mentors with more medical expertise can guide and instruct the less-experienced mentees (i.e., newly employed, treatment for exceptional cases).
- *Sharing of First-person and Eye-level View via Smartglass.* The mentees can allow their views captured by HMDs to be shared when they need assistance. Then, the mentors can intervene to assess a patient's condition visually or walk through medical treatment together with the mentee. Figure 6 illustrates dispatched paramedics mentees in this SAIT scenario.

- *Extended Use Cases with Bi-directional Interaction.* In this scenario, voice-based UIs are used dominantly to communicate between mentors and mentees in real-time.



Figure 6. An illustration of SAIT for paramedics scenario.

4.2. SAIT for Maintenance Scenario

- *Mentors and Mentees of Different Levels.* This SAIT scenario involves on-site workers as mentees and remote experts as mentors. As illustrated in Figure 7, working conditions on the site may be too narrow and confined to hold multiple workers physically. In this scenario, mentors with more experience and expertise support and assist mentees to carry out maintenance or repairing tasks successfully.
- *Sharing of First-person and Eye-level View via Smartglass.* The mentees share their views captured by HMDs with remote expert mentors. Then the mentors can intervene to assess the equipment and cables visually as well as instructing complex procedures to the mentees.
- *Extended Use Cases with Bi-directional Interaction.* In this scenario, voice-based UIs are used to communicate between mentors and mentees in real-time. Furthermore, telestration UIs will enhance communication to be more clear and allow identifying problematic areas of interest. For example, the mentor can highlight parts to be examined or replaced.



Figure 7. An illustration of SAIT for maintenance scenario.

4.3. SAIT for Culinary Education and Certification Scenario

- *Mentors and Mentees of Different Levels.* This scenario involves mentees who are interested in culinary education or getting a culinary certification. It is helpful to be trained by experienced chefs when you are learning to cook something new that requires new recipes or techniques. For example, a barista trainee can learn from winners of the World Barista Championships or learn from renowned chefs as illustrated in Figure 8.
- *Sharing of First-person and Eye-level View via Smartglass.* The mentors' eye-level view captured by their HMDs can be shared with mentees when the mentees are assessed for getting certification. Another use case is that the mentor's view captured by their HMDs are shared with multiple mentees to educate and train them by demonstration strategies.
- *Extended Use Cases with Bi-directional Interaction.* In this scenario, voice-based UIs are used to communicate between mentors and mentees in real-time. Furthermore, telestration UIs can be used to draw attention to specific areas of interest. For example, the mentor can highlight where to cut.



Figure 8. An illustration of SAIT for culinary education and certification scenario.

4.4. SAIT for Hardware Engineers Scenario

- *Mentors and Mentees of Different Levels.* This scenario enables mentees to receive help from expert hardware engineers. For example, teachers as mentors can teach school courses that require hardware engineering as shown in Figure 9. Remote mentors can also provide support for Do-It-Yourself (DIY) mentees.
- *Sharing of First-person and Eye-level View via Smartglass.* It is often difficult to figure out hardware problems or explain the problem clearly. In this scenario, mentees share their eye-level view captured by their HMD smartglasses with mentors to receive supportive feedback.
- *Extended Use Cases with Bi-directional Interaction.* In this scenario, voice-based UIs are used to communicate between mentors and mentees in real-time. Furthermore, telestration UI can be used to draw attention to specific areas of interest. For example, the mentor can highlight where to connect or dismantle.

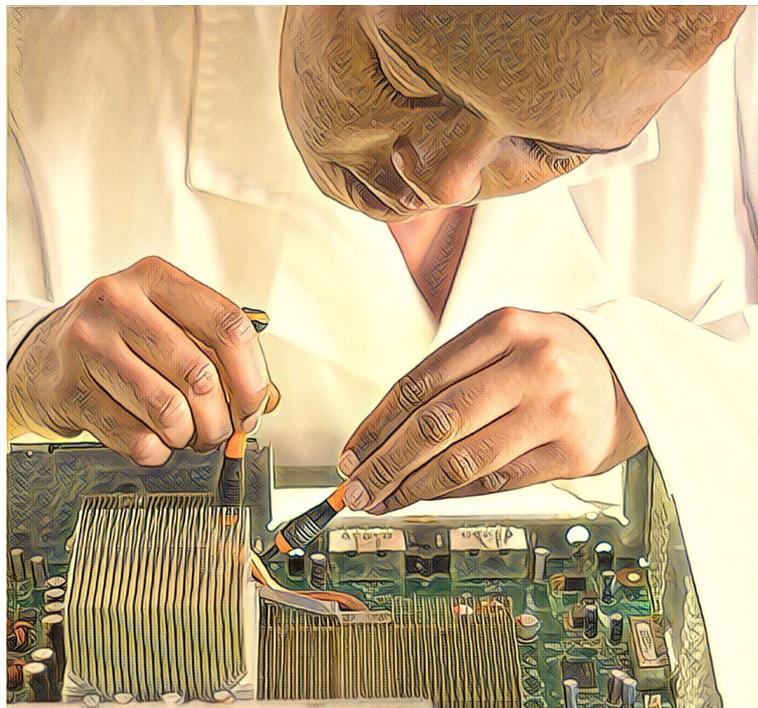


Figure 9. An illustration of SAIT for hardware engineer scenario.

4.5. SAIT for Foreigner Navigation

- *Mentors and Mentees of Different Levels.* This scenario involves foreign travelers as mentees who do not have much information on where and how to find their destination as illustrated in Figure 10. It will be helpful if local experts can accompany them to guide their navigation. For this purpose, local residents can play the role of mentors to help the mentees in their travel.
- *Sharing of First-person and Eye-level View via Smartglass.* The mentees' eye-level view captured by their HMDs is shared with mentors. Since the mentors are familiar with the local site, they can give useful information such as where to find good restaurants or which public transportation to use.
- *Extended Use Cases with Bi-directional Interaction.* In this scenario, voice-based UIs are used to communicate between mentors and mentees in real-time. Furthermore, telestration UIs can be used to draw attention to specific areas to explore and navigate. For example, the mentor can highlight and recommend popular landmarks to visit.



Figure 10. An illustration of SAIT for foreigner navigation scenario.

5. Opportunities and Challenges of SAIT

In this section, we discuss the foreseeable opportunities and challenges of the proposed use case of the SAIT.

5.1. Opportunities

As reviewed in our related work section, a great amount of remote collaboration and telementoring studies focus on the medical, surgical, and healthcare domains. We presented a specialized use case of telementoring as the SAIT with three defining characteristics of mentors and mentees of different levels, sharing of first-person and eye-level view via smartglass, and extended use cases with bi-directional interaction. We believe that there are more application domains to be explored for remote collaboration and telementoring. In an attempt to go beyond the typical medical and surgical applications, we have presented five illustrative and descriptive SAIT scenarios that are more casual, tied with the use of smartglasses, and across several domains of healthcare, education, manufacturing, and smart cities, as shown in Tables 3–6.

Several interaction styles such as touch-based UIs [33,43], voice-based UIs [23] and telestration UIs for the SAIT are already in the mature stage (i.e., supported by Microsoft HoloLens 2, as shown in Table 2), while novel interaction styles are emerging. For example, gesture-based UIs for finer granularity such as HaptX Gloves and exploiting all five channels of human senses (i.e., Virtuix Omni treadmill) are being developed. Facebook Reality Labs envision contextually aware, AI-powered interface for AR glasses using electromyography signals to perform “intelligent click” and wristband haptics for feedback. Facebook also patented artificial reality hat as an alternative to traditional AR headsets and smartglasses. Apple announced AssistiveTouch for Apple Watch that can detect subtle differences in muscle movement and tendon activity. Moreover, the widespread of IoT and edge computing [44] enable flexible, adaptive, and seamless orchestration among smart devices and objects [44–47].

5.2. Technical and Societal Challenges

For our presented SAIT to be successful in XR telementoring, there are many technical as well as societal challenges to overcome. Many XR industry experts also have identified urgent areas of improvement [4] as shown in Figure 11.

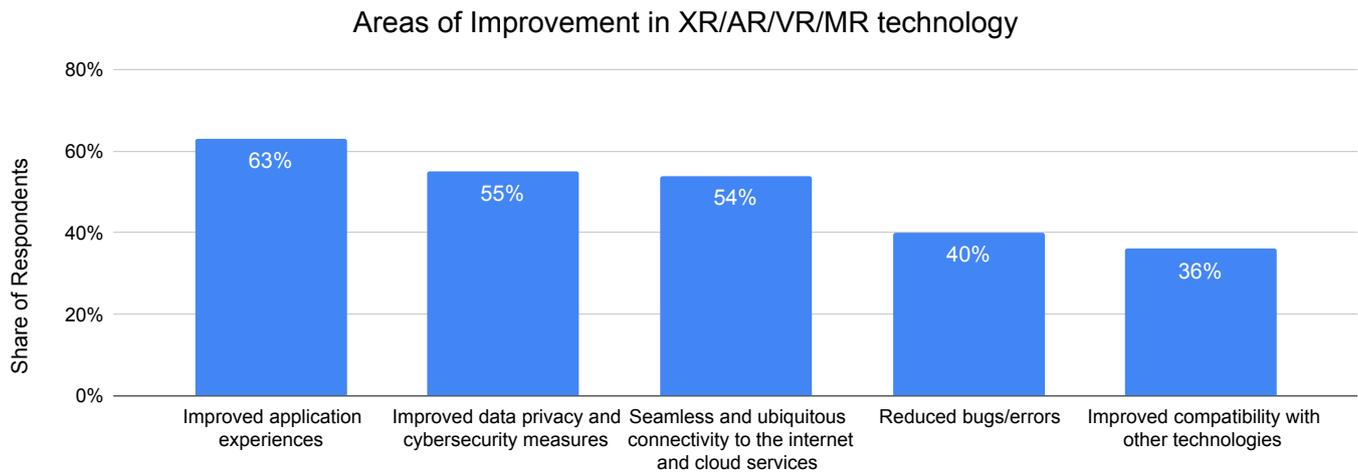


Figure 11. Areas of improvement in XR/AR/VR/MR technology, source: [4].

Since the SAIT requires the use of smartglasses on mentors and mentees, various challenges of smartglasses are identified and being improved upon [48,49]. For example, to support the SAIT on everyday occasions, the weight of the HMD should be lighter. To provide a clear and crisp view captured by the HMD's camera, wider FoV and higher resolution are preferred. Such specifications and performance measures of smartglasses including latency, content reproducibility, repeatability, synchronization, and warnings should be enforced through guidelines and standards. For example, there are international standards for VR and AR in environment safety (IEEE P2048.5), immersive user interface (IEEE P2048.6), eyewear display (IEC TR 63145-1-1:2018), and VR content (ISO/IEC TR 23842:2020), respectively.

Furthermore, XR experiences in our scenarios are limited since most informational contents (i.e., live video streams and annotations) are hardly considered as XR contents. Easy to use XR authoring tools for developers and service providers are desirable to provide multiple AR, VR, and XR applications [50] and experiences in the SAIT scenarios. Moreover, establishing sufficient network bandwidth for high-resolution videos is also important to share the view and contents [51] of mentors or mentees without interruptions and delays. As more interaction data between mentors and mentees are accumulated, we can benefit from deep learning approaches [52–54] that enhance various steps involved in the XR pipeline (i.e., registration, tracking, rendering and interaction, task guidance [55,56]).

There are societal challenges regarding the SAIT. Concerns of involved users' security, safety and privacy issues should be carefully managed. As witnessed in the medical and surgical sectors, use of camera in the operation room is very sensitive and controversial. In most countries, installation of and monitoring with closed-circuit television (CCTV) are strictly prohibited. For such sensitive and intimate scenarios, mentors or mentees could be disallowed to use smartglasses at all. There should be a general consensus and regulations among the society about the needs and social acceptance for smartglasses in the discussed SAIT scenarios.

Tables 7–11 summarize various technical and societal issues aligned with the areas of improvement [4] in the discussed SAIT scenarios.

Table 7. User experience issues in SAIT scenarios.

SAIT Scenarios	User Experience Issues
Paramedics	Capturing a mentor's view in sufficient detail and FoV for identifying patient conditions
Maintenance	Capturing a mentor's view in sufficient detail and FoV for identifying equipment conditions and problems
Culinary Education & Certification	Providing mentees with unobtrusive and naturalistic UX
Hardware Engineers	Enhancing and enlarging a mentor's view in sufficient detail for working with small parts
Foreigner Navigation	Providing accurate localization and culture-awareness to mentors

Table 8. Privacy and security issues in SAIT scenarios.

SAIT Scenarios	Privacy and Security Issues
Paramedics	Keeping a mentor's view on patients private and secure
Maintenance	Keeping a mentor's view on confidential and private facilities private and secure
Culinary Education & Certification	Keeping training and certification results private and secure
Hardware Engineers	No significant issues
Foreigner Navigation	No significant issues

Table 9. Seamless connectivity issues in SAIT scenarios.

SAIT Scenarios	Seamless Connectivity Issues
Paramedics	Preparing stable and sufficient network bandwidth for high-quality audio/video (A/V) streaming in outdoor and unprepared environments, for identifying patient conditions
Maintenance	Preparing stable and sufficient network bandwidth for high-quality A/V streaming in outdoor and unprepared environments, for identifying equipment conditions and problems
Culinary Education & Certification	Preparing stable and sufficient network bandwidth for high-quality audio/video (A/V) streaming and recording in indoor environments
Hardware Engineers	No significant issues
Foreigner Navigation	Preparing stable connection and accurate indoor/outdoor localization

Table 10. Error prevention issues in SAIT scenarios.

SAIT Scenarios	Error Prevention Issues
Paramedics	Presenting real-time audio feedback for mentor-mentee communication
Maintenance	Presenting real-time audio feedback, interactive instruction slides, and an official manual for reference for mentor-mentee communication
Culinary Education & Certification	Keeping a track of mentors' mistakes for possible de-briefing afterward
Hardware Engineers	Presenting real-time audio feedback, interactive instruction slides, and an official manual for reference for mentor-mentee communication
Foreigner Navigation	Providing navigation information in the mentor's language

Table 11. Compatibility & interoperability issues in SAIT scenarios.

SAIT Scenarios	Compatibility & Interoperability Issues
Paramedics	Supporting mentors' smartglasses and mentors' differently configured computers
Maintenance	Supporting mentors' smartglasses, mentors' differently configured computers, and automatic equipment classification by deep learning
Culinary Education & Certification	Supporting applications and services across different education and certification organizations
Hardware Engineers	Supporting virtualized mentor assistance for pre-recorded FAQs and animated instruction videos
Foreigner Navigation	Supporting various modes of navigation such as cars, walks, cycle, and public transportation

6. Conclusions

In this paper, we explored XR concepts of remote collaboration and telementoring focusing on the use of smartglasses. To elicit requirements and the trends of telementoring, we reviewed recent studies from 2015 to 2021. Based on the literature review, we defined what three characteristics the SAIT (smartglass-assisted interactive telementoring) features. To elaborate on this specialized use case of telementoring, we presented five illustrative and descriptive scenarios including paramedics, maintenance, culinary education and certification, hardware engineers, and foreigner navigation. Lastly, we identified opportunities, technical and societal challenges to overcome for successfully realizing the SAIT.

Our current approach has limitations and shortcomings that deserve further study. First, our approach was not the systematic review or meta-review in nature as other researchers have explored [10,11]. We investigated relevant studies mostly using commercially available smartglasses, which might have missed custom-designed prototypical approaches presented earlier than 2015. Indeed, as it turns out, our approach only covered high-fidelity smartglasses with stable hardware design, but there could be low-fidelity approaches of surgical telementoring applications [10,11] that we have not included in our analysis. Another limitation of our work is that our newly proposed SAIT scenarios are situated outdoor and involves multiple simultaneous user interactions. This complexity calls for carefully orchestrated security and privacy measures in wearable computing as well as XR settings which we were not able to cover due to the scope of the paper.

Nonetheless, we expect our proposed SAIT has its merits to support various telementoring applications beyond medical and surgical telementoring, while harmoniously fostering cooperation using the smart devices of mentors and mentees at different scales for collocated, distributed, and remote collaboration.

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Abbreviations

The following abbreviations are used in this manuscript:

IoT	Internet-of-Things
DT	Digital Twin
AR	Augmented Reality
VR	Virtual Reality
MR	Mixed Reality
XR	eXtended Reality
SAIT	Smartglass-Assisted Interactive Telementoring
HMD	Head-Mounted Displays
OST	Optical See-Through
VST	Video See-Through
FoV	Field of View
UI	User Interface
DIY	Do-It-Yourself
CCTV	Closed-Circuit Television

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