Applications, Challenges, and Prospects of Augmented Reality (AR) Technology in Public Safety from the Perspective of Human-Computer Interaction

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Abstract. Augmented reality (AR) technology is an up-and-coming tool of human-computer interaction with proven high application capability in the sphere of public safety. This paper discusses the use of AR technology in two significant areas: fire emergency response and large-scale event security through the lens of human-computer interaction. AR helmets help rescue workers conduct life-saving and environmental surveys during fire emergencies, superimposing infrared thermal images and building data; in large-scale operations, AR glasses aid security officers in scanning the crowd and recognizing license plates. Analysis indicates that AR technology can be successfully applied to improving the perceptions and judgment abilities of the frontline personnel. Based on this, and taking into account the advancement of AR technology applications in mobile policing, this paper goes further to present the possibility of integrating facial recognition and emotion recognition to issue an early warning in the case of border patrol, to serve as a guide in future studies.

Keywords: Human-computer interaction, AR technology, Intelligent fire protection, Emergency rescue, Intelligent policing.

1 Introduction

In the contemporary city government and emergency response systems, a situation of public safety is always a high risk and pressure scenario. These situations are usually characterized by extreme time sensitivity and multiple activities occurring at the same moment: the deep smoke and fast-evolving fire at a fire site, the dynamic marshaling of people and possible dangers during major event security, and the intricate geography and absence of predictability during border patrol requiring frontline staff to process enormous quantities of information within a very limited duration and simultaneously act in multiple capacities: evacuation, rescue, and analysis. The limitations of traditional information support systems become glaringly apparent in this kind of situation: The dependence on handheld terminals or voice reports in command centres not only distracts them but also results in delays and inaccuracy in the emergency environment; they are confined to viewing two-dimensional information on screens, which is severely out of touch with the physical world, which makes them extremely susceptible to decision-making bias in high-stress situations; independent of their role in a crisis, requiring personnel to invest heavily in cognitive effort of what can be termed

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information translation and scene mapping, highly vulnerable to cognitive bias. Consequently, the essence of the pain point in the public safety scenario can be simply defined as a bottleneck in the perception and decision-making effectiveness of the personnel. How to enable the frontline personnel to more effectively observe, comprehend and utilise the most important information is critical to the success or failure of the emergency response.
To overcome this bottleneck, a user-centric logic of interaction design needs to be developed, i.e., the logic of information presentation should be relevant to the natural cognitive habit of people on-site, and the strategy of interaction should be aligned with the practical needs of hands-free operation and visual focus. The recent technology of Augmented Reality (AR) can be an ideal medium of human-computer interaction and serves this demand perfectly. AR technology is a rapidly emerging field; it overlaps significantly with computer vision, human-computer interaction and sensing technology. Its essential worth consists in the fact that with the optical display and spatial computing, the virtual information fuses with real-life in real-time. In contrast to fully immersive Virtual Reality (VR), AR technology is implemented on top of existing real-world views and includes such digital information as text, signs, 3D models, and situational heatmaps that would enable people to receive an information-enhanced perceptual experience without leaving the scene. The graphic interactive nature fits in perfectly with the twofold requirement of two-hand operation coupled with complicated information in public security situations. At present, AR technology has been used in various aspects. This paper is devoted to the two significant public safety events: the response to fire emergencies and event security. The practical implications of AR technology are reviewed. The article will also be prospective in the use of AR in mobile policing including border patrol. This article is a systematic review of the application of AR glasses in fire prevention and security in large-scale events; with the human-computer interaction viewpoint, the article discusses how AR technology may evolve the way information is packaged to assist on-site human resources. Aside from this, this article progressively discusses the potential development of AR technology as the technology may be used to integrate personnel identity checks, emotion checking, and hazard checks to provide direction for extending its application in the field of public safety.

2 AR and its application in fighting and rescuing fires

2.1 Survival and navigation in the fire rescue

Rescue and firefighting are very dynamic and the situational awareness of the firefighters correlates directly with the precision of rescue decisions and the safety of operations. When they lose the path in the smoke or in the intense heat, they have high chances of being wounded or killed. Despite the gradual implementation of firefighting robots, the manual operations performed by firefighters in complex fire events involve going into risky areas to complete the main task. Nonetheless, the possibilities of current equipment to support information are not enough and this only heightens the risks [1]. The national fire and rescue teams handled 908,000 fire reports, according to the announcement of the National Fire and Rescue Bureau, in 2024, and 2,001 deaths, 2,665 injuries and direct property losses were 7.74 billion yuan. The 70 major fire incidents with 249 deaths represented decreases of 2 incidents and 10 deaths respectively compared to 2023, while the 3 serious fire incidents with 44 deaths remained at the same level as 2023 [2]. To enhance the extent and precision of the perception of the disaster situation, DJI Innovations introduced the Moverio AR smart glasses and drone collaborative operation system in 2018, which took on a new technical direction of fire rescue. The system has an ability to visualize the photographs taken by the drone on the transparent display screen of the AR glasses worn by the firefighters (Figure 1) in real time, such that they are able to view the information provided by a panoramic view and ground vision of the rescue site simultaneously, thus overcoming the traditional field of vision restriction [3]. It has been revealed that AR systems can be used successfully to improve the effectiveness of developing fire safety facilities [4]. This technology also helps the firefighters to maintain the dynamism of the situation and changes in the fire at any given moment throughout the missions, supplying them with key information to make scientific decisions and achieve successful rescues.

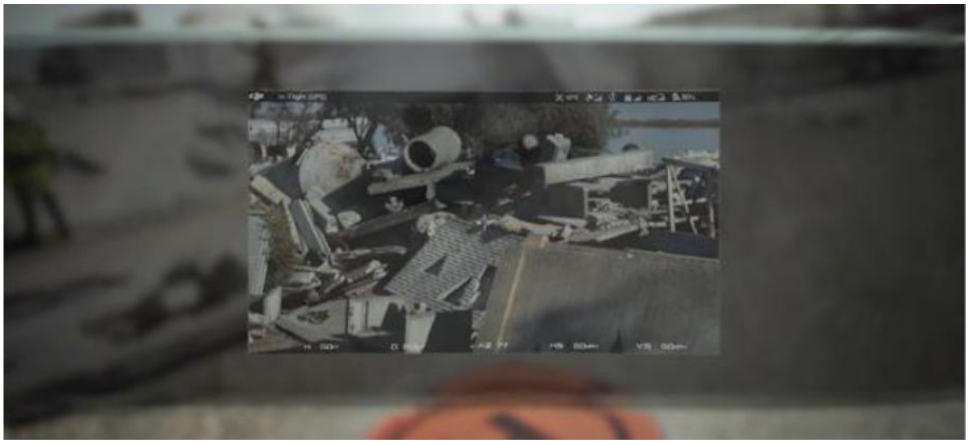

Fig. 1. Moverio AR firefighting drone footage [3]

2.2 Pre-hospital emergency care and collaborative care

Common to emergent areas that need serious security measures, rescuing (both emergency and drone search) is rife with failures in the conventional models: emergency rescue is in the serial model of a single-process mode. Despite the efforts made to use 5G technology, its implementation process is untimely and does not coordinate the information throughout the whole process. The communication and the heterogeneity of the systems make it hard to provide an efficient exchange of information within the site of the emergency, inside the transport vehicles and the hospitals, thus creating delays in the handover of treatment. The radio communication used within the drone search and rescue has several issues that the remote and on-site operators rely on, including the fact that the communication lacks the visualization of information, it is prone to interference, and it can be cumbersome to interpret, allowing communication to easily deviate. On the one hand, the current process does not offer real-time triage and treatment instructions support at the emergency location and is yet to establish a complete process information coordination system encompassing the location, transport and hospital. Conversely, over fifty percent of the medical personnel feel that the medical history of the patient is very critical in quick diagnosis and the cross-institutional sharing of medical records is a necessity [5]. The inherent constraints of the conditions of on-site communication, the heterogeneity of the systems make it hard to ensure efficient and reliable communication between the location of the emergency, the vehicles of transport and the hospitals where the patient can be taken, which means that in-hospital specialists cannot access the most important medical information in time and cannot provide the patient with remote guidance, which will result in delayed treatment and a passive reaction. To solve this problem, Yuyao Municipal Health and Wellness Bureau introduced a mobile smart micro-hospital vehicle [6], which established an integrated and fast-responsive mobile medical service platform. The car also features at least a few laboratory and other medical devices, and is powered by a 5G communication base station, which guarantees the car's operation in an Internet environment. Through the 5G network and AR, medical personnel at the grassroots level can enjoy live communication with remote specialists in the car with high-definition audio and video (Figure 2), and achieve real-time consultation and surgical instructions, enabling patients to receive specialist consultations from high-level hospitals on-site. The model is effective in reducing the issue of inaccessibility and the inconveniences of medical services in mountainous and remote regions, the ability of medical resources coverage to be more flexible and efficient, and the ability of the front line medical rescue, on-site screening and early intervention is much-needed, but the VizCom-AR system compensates for the deficiencies of traditional radio communication in visualizing the situation, anti-interference and interpretation efficiency [7]. Indeed, the use of AR technology in the emergency sphere is an embodiment of its enhanced efficiency in passing and interacting with information. The technology has already been shown to streamline knowledge transfer in education, industry and geriatric care. However, because of its non-generalizability, its popularization and the realization of its value in areas like public safety and emergency response have been curtailed to some degree [8].

Fig. 2. Doctors provide on-site medical services to patients using "5G+AR" technology [6]

3 AR technology use in security and command

In the case of security in large-scale events, it is essential to consider the use of AR technology in crowd observation and early warning of abnormalities that require the construction of a 3D command system involving the use of AR cameras as front-end sensing nodes and a strong connection with intelligent transportation and other systems. AR cameras can be used at the front end to overlay critical information tags like names, locations, and historical cases on the real-time video streams to allow security guards to intuitively and swiftly comprehend the scenario and identify abnormalities. Together with field-of-view management and connection with the cameras in its surroundings, and with panorama-based and detailed options of connection technologies, it generates the blind-spot free coverage of small scenes and smooth tracking of significant targets. This technology has an intelligent transportation system on the back end, which combines the whole picture of the traffic situation, multi-service data, and real-world maps through an AR video map engine to fuse macro and micro trends and patterns, and shows them uniformly at the back end. It is also able to analyze and visualize data at the backend in depth and provide strong technical support for environmental monitoring, smart early warning, traffic control, and combined command during massive events. Using the example of the first AR-generation camera introduced by Gosuncn Technology Group at the 2014 Security China Expo [9], as illustrated in Figure 3, it can be seen that AR has clearly shown the developmental direction of AR monitoring, starting with the components of single-point enhancement to structure an integrated "air-ground-space" three-dimensional perception network without a blind spot, beginning with a connection between the real and virtual information with the tags, and finally integrating drones and panoramic cameras. At present, this technological system has shifted from the conceptual innovation phase to massive practical implementation, radically changing the model of the security of large-scale events. It allows the integration of comprehensive panoramic monitoring and precise local tracking in the most important locations like train stations, airports, and stadiums. Not only does this practically eradicate the blind spots and fragmented area-level information, but more importantly, by accurately superimposing virtual information onto physical reality, it dramatically reduces the time between the security personnel seeing something and decoding it to make a decision, providing a strong technological basis for creating an intelligent, proactive new security system.

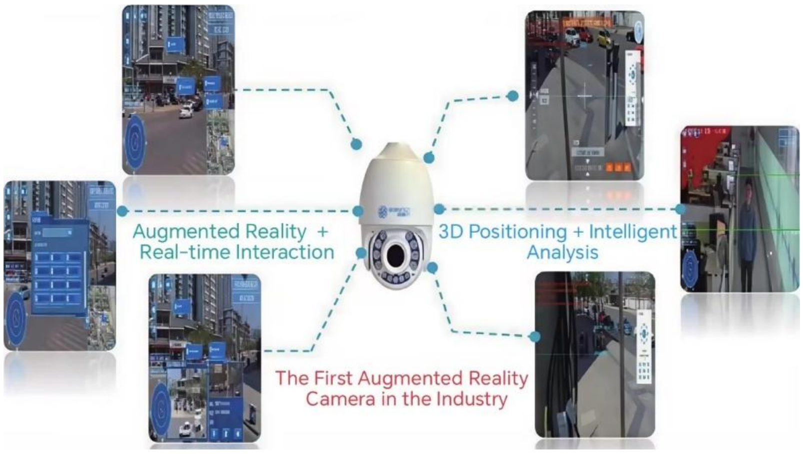

Fig. 3. AR camera[9]

4 Analysis and discussion

This chapter first reviews the current limitations of AR systems in individual identification, then examines an emerging industry solution, and finally proposes a multimodal early-warning framework integrating emotion recognition, outlining its implementation workflow.

4.1 Current limitations and emerging solutions

The current modes of the AR technology have achieved significant success in improving display and integration of information, but in a real sense, they remain a one-way information transmission. It consists of either footage taken by the drone and perceived by firefighters, or surveillance tags identified by security personnel that describe the known state of the situation, whether there is a fire or congestion, but does not anticipate potential or unmet threats.
To address this bottleneck of inadequate individual identification capabilities, selected industry leaders have advanced the thorough integration of technology. Take Beijing LLVision Technology Co., one of the enterprises in the AR area of China, as an example: the company has been actively engaged in the security track since 2016, laying down the key technologies. It has effectively developed Zhentan - Mobile Individual Intelligent Identification System through an industry-university-research partnership, and wide scope of industry involvement. The system uses Zhentan intelligent police glasses as the center of interaction, combining the self-developed deep learning engine Laffe and the patented portrait model. Not only can it identify fugitives, key personnel, and temporary control targets quickly, but it can also access vehicle big data to verify vehicles that have been stolen and key vehicle information. Meanwhile, it enables live audio and video transmission to the command center, achieves the effect of first-person vision, and constructs data + AI intelligent perception capabilities for the front-line police officers. As depicted in Figure 4, the system was deployed during the Spring Festival travel rush of 2018, helping the police officers arrest several online fugitives inside a railway station. It was heavily covered in the media and acknowledged by the Ministry of Public Security, and made it into the 012 police equipment procurement list.

Fig. 4. Application of "Zhentan" Smart Police Glasses [10]

4.2 Proposed framework: emotion recognition and risk assessment

Nevertheless, while the current AR technology is good at analyzing group behavioral characteristics such as density and flow of people, it remains weak at accurately recognizing and evaluating potential risks of individual persons. Cameras are able to identify crowds, but they cannot identify key individuals within these crowds immediately. This is a weakness since this overall limitation makes the system unable to detect and intervene in the event of suspicious people amongst the crowd or fugitives in time. All of these deficiencies are linked to a central point of failure: the existing AR system has provided its users with a new set of superhuman senses, but has not yet provided a means to allow them to see the future.

To address this gap, the present paper creatively suggests that through emotion recognition and potential danger assessment, AR technology may be included in multimodal fusion analysis technology, and the interplay of the three dimensions of individuals, technology and environment as the heart of it, can be utilized to create a visionary biological intelligent early warning defense line outside the physical limit of the conventional security. As an illustration of this, a data analysis table to be used in decision making must be provided to the staff regarding the field of view of AR glasses. It is to be presented in an understandable manner, presenting the components and the confidence level of risk appraisal such as identity verification (matching the database with whether there is a criminal record), real-time physiological status (emotional stress index, intention concealment index), behavioral and environmental adaptability (behavioral movement, current environment) and overall risk level. As illustrated in Figure 5, the flowchart presents the final decision-making authority to the individual. This process of man-machine collaborative handling is based on AR technology serving as its carrier, which incorporates multi-source perception and smart analysis technologies to build a unified, intelligent process of law enforcement activities on the site. The implementation steps proceed as follows:

1. Initialization: Law enforcement officers turn on the supporting AR terminal equipment when the implementation of the patrol mission begins. Multi-modal sensors of the equipment such as the vision, infrared and acoustic sensors are then organized on the entire area to record real-time and synchronous information about the physical environment in the patrol area.

2. Target detection and locking: Based on inherent intelligent algorithms, the system completes the processes of detecting the suspicious targets, identifying them accurately, and executing continuous dynamic lockout on them in the area.

3. Multi-dimensional biometric analysis: When the system has filtered and identified valid targets bearing analytical value, it immediately enters into a multi-dimensional phase of biometric comprehensive analysis — effecting visual analysis of the target, voiceprint analysis and analysis of physical characteristics of the target to extract key information of the characteristics of the target in a three-dimensional descriptive fashion.

4. Dynamic risk intelligent assessment: The system profoundly incorporates the feature information obtained on various dimensions and provides the intent of the target. Together with the constructed physiological-behavioral-environment three-dimensional correlation analysis framework, it performs a comprehensive correlation and analysis of the physiological state, behavioral performance as well as on-site environmental scenario of the target. It creates a dynamic threat coefficient and the reliability of the assessment outcomes through quantitative calculation, and automatically generates graded and concrete risk warning suggestions based on a preset indicator system.

5. Differentiated response: The system automatically adjusts differentiated handling actions based on the level of risk evaluation: in the case of a low-threat (i.e., the system false-alarm position), the device triggers a silent recording regime, only recording the necessary

information in the background without interrupting the normal patrols; in the case of medium risk, a yellow warning icon appears on the AR display in real-time, indicating the location of the target and core risk zones, and proposing auxiliary inspection recommendations; in the case of high risk, the red alarm is immediately activated, marking the target.

6. Scientific disposal and feedback: The factual information given by AR devices is used as the foundational justification by the law enforcement officers alongside the real-life situation on the ground to execute scientific and uniform disposal measures. Once the disposal is done, the results and key data are recycled back to the back-end system to optimize the algorithm model parameters and recognition logic through iteration.

Thus, this creates a cyclical system of the whole process of full-domain collection, multi-dimensional analysis, intelligent decision-making, feedback of the result, and model optimization, which yields active improvement in human-machine joint disposal systems.

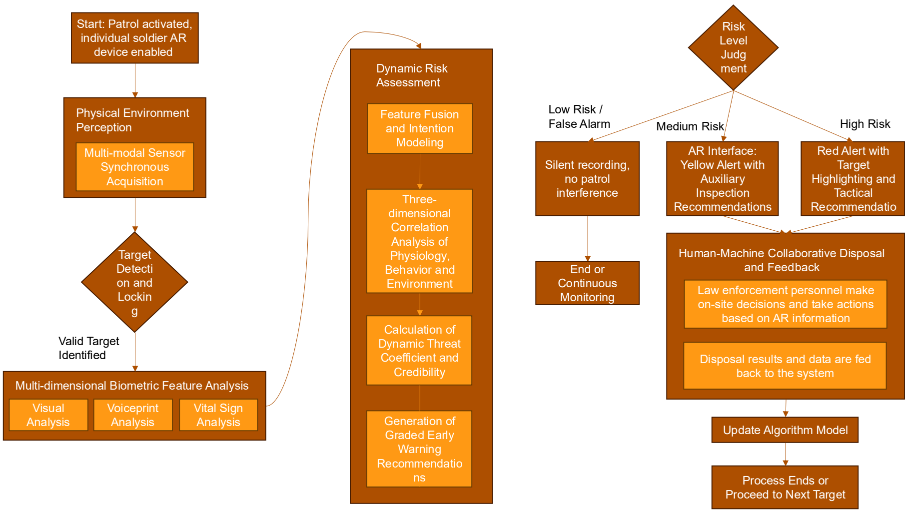

Fig. 5. Risk assessment flowchart (Picture credit: Original)

5 Conclusion

Empowering millions of frontline personnel to safeguard the public safety of 1.4 billion people is a global challenge lacking mature case studies. Focusing on this industry pain point, this paper leverages continuously innovative technologies to address the core needs of efficiency improvement and cost optimization in the security field. The mature and reliable mobile law enforcement products are widely used in scenarios such as personnel and vehicle screening, dynamic deployment, and command and dispatch for major emergencies. Adhering to the understanding that AR is a universally applicable interaction method, we firmly believe it will follow a technological evolution path of "enterprise-level applications first, then penetration into consumer-level applications." Future research should continue to deepen the integration of AI, data, and scenarios, not only making the actions of relevant personnel more efficient, accurate, and convenient, but also striving to create value upgrades of "first-person perspective + intelligent collaboration" for more industries.

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