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Connecting Research from Assistive Vision and Smart Eyewear Computing with Crisis Management and Mitigation Systems: A Position Paper

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Abstract. This article presents an overview of several results obtained in the framework of the "Senses++" initiative and research project with the goal to design and engineer interactive wearable prototypes to enhance visual perception for people with visual impairments by means of assistive vision techniques implemented on smart eyewear devices. Three scientific contributions are described in the specific context of lifelogging, video streaming, and Augmented Reality research: (1) life abstraction as a new concept for privacy-preserving lifelogging systems, (2) broadcasting of video content to remote audiences, and (3) assistive, mediated and augmented vision for see-through head-mounted displays. Several opportunities are discussed for transferring these results from the area of assistive vision to the application domain of Information Technology systems designed to support crisis management and mitigation. To this end, each application opportunity regarding a potential transfer of knowledge and technology, originally developed in the context of assistive mediated and augmented vision, is evaluated from the perspective of fulfilling six criteria representing distinct objectives for crisis management systems: (1) crisis coordination, (2) handling of abnormal situations, (3) handling limited resources, (4) resource allocation, (5) identification and execution of missions, and (6) archival of crisis information. In the context of the special issue of the Romanian Journal of Information Science and Technology on the topic of "Information Science and Technology in Crises," this article takes the form of a position paper in order to draw attention to the possibility of reusing, adopting, and adapting research results and developments achieved in other fields and areas of scientific investigation for the purpose of crises management and mitigation.

Keywords: Assistive vision; Sensory augmentation; Augmented vision; Mediated vision; Human-Computer Interaction; Smart devices; Smart wearables; Wearable computing; Applications; Information Technology in crisis management.

1. Introduction

Practical applications of concepts, technology, and results from Information Science and Technology (IST) to the management and mitigation of crisis situations have involved design and engineering of systems addressing a wide range of application domains, from knowledge management based on social media [16] and social networks [30], aspect-oriented software development processes [14], network-centric architectures [14], Augmented Reality (AR) systems for spatial information management [9] and for urban search and rescue [17], and mobile devices [22] to tangible and wearable user interfaces (UIs) to support collaboration among emergency workers [6] and to assist first responders [7].

Crises are characterized by the simultaneous occurrence of a threat situation, the element of surprise, and a short decision time [29], which IST can address by leveraging sensing, computing, and communications resources. Some areas of IST, however, may seem more disconnected compared to others from the practical possibility to support crisis management and mitigation systems, but this position paper argues that this perception is only a matter of perspective. For instance, assistive vision employs image processing and computer vision techniques to provide vision rehabilitation to people with visual impairments, such as in the form of applications for smart eyewear devices that deliver magnification, contrast enhancement, color correction, person identification, emotion recognition, among other features; see examples from the scientific literature on assistive vision [37,39,40,41].

The main contribution of this article is an examination, by means of practical examples, of the way in which scientific contributions from the area of assistive, augmented, and mediated vision can be transferred to support crisis management and mitigation systems. To this end, this article focuses on three prototypes designed for (1) vision augmentation and mediation, (2) life abstraction, and (3) broadcasting of personal visual realities to remote audiences, which were created in the framework of the Senses++ project [31].

The method adopted in this article is represented by an exploration of application opportunities regarding the transfer of research results from the area of assistive, mediated, and augmented vision to IST systems applied to crisis management. To this end, we implement the following steps: (1) presentation of the general context in which a specific problem or challenge has been identified in assistive vision, *e.g.*, the increasing amount of personal big data and concerns about privacy created by lifelogging devices and consumers' practices for sharing video content in social media networks; (2) description of a solution to the specified problem in the framework of the Senses++ project, *e.g.*, the Life-Tags [1] prototype implements privacy-oriented design requirements for lifelogging video camera-based smartglasses; and (3) identification of opportunities for transferring the solution to the area of IST applied to crisis management. Regarding the latter, the following criteria for crisis management and mitigation systems are employed to characterize the feasibility of transferring research results from one scientific and application area to another, informed by the requirements from Kienzle *et al.* [13] regarding general objectives that need to be met by crisis management systems, including those based on software:

- O1. The system helps in the coordination and handling of the crisis.
- O2. The system ensures that abnormal or catastrophic situations that may occur during the crisis do not go out of hand.
- O3. The system helps to minimize the effects of the crisis by handling the various situations using limited resources.
- O4. The system allocates and manages in an effective manner the distribution of the available resources.
- O5. The system identifies, creates, and executes missions to manage the crisis.
- O6. The system archives the crisis information for future analysis.

2. The "Senses++" Project: Sensory Augmentation for Low-Vision Conditions using Smart Wearables

Senses++ represents a two-year research initiative and project focused on the design and development of new interactive technology based on smart wearables, such as smartglasses and head-mounted displays (HMDs) with the goal to deliver a better understanding of the visual world to people with visual impairments; see [31] for an overview and results. Examples include providing users with improved contrast vision, better long-distance vision, and color correction according to the specific type and severity of the visual impairment.

Design and implementation of assistive technology for vision assistance and/or vision rehabilitation are complemented by investigations addressing people without visual impairments, who may temporarily found themselves in life situations in which they would benefit from augmented vision. This latter category of applications for assistive vision addresses situationally-induced disabilities and impairments [28,38], which are frequently caused by eye fatigue, inattentional blindness, or other causes that temporarily hinder visual perception for. The Senses++ project [31] sets the following objectives:

- Understand end users' needs, desires, and preferences for augmented and mediated vision by conducting literature reviews, user studies, surveys, interviews, and controlled experiments.
- Design and development of wearable prototypes and applications for smart eyewear devices to support vision augmentation and mediation for users with and without visual impairments.
- Design of interaction techniques based on voice and gesture input to implement effective operation and control of augmented vision for smart eyewear devices as well as for sharing users' first-person, eye-level field of view to third party viewers and remote audiences in the context of alternate realities [8].

The scientific investigation scope of Senses++ [31] is located at the intersection of computer-generated and computer-mediated realities (such as Augmented Reality [3,5], Mixed Reality [20,21,35], Mediated Reality [18,19], Alternate Reality [8], and Cross-Reality [23]), wearable computing, ubiquitous computing, interactive media, and human-computer interaction; see Figure 1 for a Venn diagram. Consequently, the main scientific contributions achieved in the framework of Senses++ [31] have been disseminated in these scientific communities [1,2,24,25,26,32]. However, potential applications of the results may equally benefit other domains or areas of scientific investigation, of which ITS applied to crisis mitigation and management systems represents one example. The following three sections of this article represent a position statement regarding the suitability of research in assistive vision to sustain developments in ITS systems for crisis management, such as for situations characterized by public measures that enforce restrictions, sanitary regulations, and even lockdowns of cities and countries.

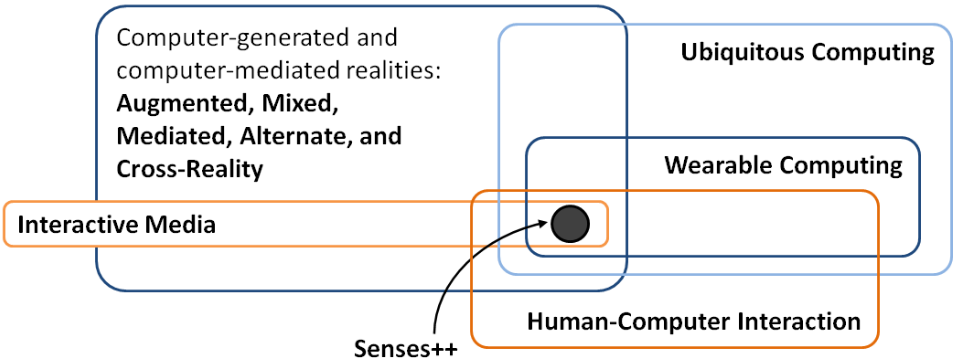

Figure 1. A visualization of the scope of the Senses++ project [31] in the form of a Venn diagram showing the intersection of various areas of scientific investigation from Information Science and Technology.

3. New Uses of Lifelogging and Life Abstraction Systems

Lifelogging represents the practice of using and wearing sensors, such as video cameras, that passively collect information about the user's life, such as in the form of datasets of photos and videos [10]. These datasets can be queried at a later time to support information retrieval, recollecting, reminiscing, reflecting, and remembering intentions, *i.e.*, the five "R's" of memory access discussed by Sellen and Whittaker [33]. The large availability of commercial wearable cameras, such as MeCam[1] or the Narrative Clip,[2] has boosted the practice of lifelogging, which has been characterized as a phenomenon and personal big data [10]. Moreover, the recent availability of high-definition video camera glasses, such as Spectacles by Snapchat,[3] enable readily integration of lifelogging, social media, social networks, *e.g.*, Spectacles users can take snapshots and videos and post them on Snapchat directly, export and share the photos, and relive a memory and invite friends to experience that memory on YouTube VR. In this context, lifeloggers generate a large amount of data, including video content and, in order to be effective as a memory support, the lifelog needs to be indexed and queried using effective techniques. Another challenge of lifelogging systems and applications and, in general, of video camera-based smartglasses worn in public places is their social acceptability by bystanders, who may react to being captured on video without their consent. Such aspects have started to be addressed in the scientific literature in order to promote privacy-preserving design requirements for bystanders and ethical use of video camera-based recording and streaming devices and applications in public places [11,12,15].

In this context, Life-Tags [1] was introduced to mitigate privacy aspects while keeping the advantages of lifelogging systems. At the same time, Life-Tags introduced a specific form of lifelogging called “life abstraction,” which consists in archiving a processed form of the raw video data instead of the actual photos and videos. To this end, Life-Tags processes each snapshot captured from the video camera glasses in order to identify and extract objects (*e.g.*, bus, tree, desk, people, etc.) and concepts (*e.g.*, winter, travel, rain, flood, etc.), which are stored as textual descriptions of the user’s life events instead of the actual snapshots and video recordings. This way, Life-Tags mitigates privacy aspects directly since the actual recordings of bystanders or of other sensitive information that may be collected in public places are not stored as in conventional lifelogging systems. This desiderate was enforced by design, and Life-Tags followed six design criteria or requirements: (1) passive and automatic lifelogging, (2) first-person perspective and eye-level point of view, (3) inconspicuousness and privacy-oriented operation, (4) memory support and memory access at various levels of granularity, (5) easy integration with other devices, and (6) easy integration with personal web logs and social networks; see Aiordăchioae and Vatavu [1] for details. Figure 2 illustrates a cloud of tags describing objects and concepts identified by Life-Tags, which represents the visual abstraction of life. The tags are arranged and sized according to their frequency of appearance over the time span of the lifelog that may range from a few minutes to an entire month [1].

The tag cloud illustrated in Figure 2 was specifically chosen to depict an outdoor scenario, where crisis management and mitigation actions may need to be implemented. Although not introduced for the purpose of crisis management systems, Life-Tags may have other applications, such as to assist with automatic evaluations of how a crisis is progressing in order to inform the next actions to be taken. For example, first responders can wear Life-Tags devices, which passively collect snapshots and process them, while the results are sent to a control center in the form of visual life tags, as shown in Figure 2. Key concepts, such as “calamity” or “offence,” could be automatically picked up from the life tag and the personnel alerted in consequence, while a live video stream connection could be simultaneously initiated with the wearer of the Life-Tags device that detected those specific concepts (the next section discusses video streaming aspects in more detail). Also, the frequency of detection of some words, such as “accident” or “storm” (see Figure 2), may inform other types of actions for the mitigation of the crisis by other categories of first responders. From this perspective, this new application of Life-Tags implements the following objectives for crisis management systems: O_1 (the system helps in the coordination and handling of the crisis), O_5 (the system identifies, creates, and executes missions to manage the crisis), and O_6 (the system archives the crisis information for future analysis). Future work in this direction could address security aspects regarding communications implemented between Life-Tags devices and control centers as well as explorations of imagining technology operating in other regions of the electromagnetic spectrum, such as thermal sensing. Moreover, Life-Tags systems could be deployed for other contexts of use, such as robotic vehicles or drones.

[1] https://mecam.me/

[2] http://getnarrative.com/

[3] https://www.spectacles.com/

Figure 2. An example of a tag cloud containing concepts automatically extracted from snapshots collected by a video camera-based smartglasses over a period of 30 minutes, during which the user traveled by bus in a congested city landscape; see Aiordăchioae and Vatavu [1] for more details regarding how tag clouds are created, including a technical evaluation of the Life-Tags system.

4. New Modalities for Video Streaming to Third Party Viewers

The availability of photo cameras, mobile devices with embedded video cameras, and camera-based smartglasses has enabled users with easy ways to capture and share their life events in the form of recorded video and live video streaming in social networks. For example, five hundred hours of video are uploaded to YouTube every minute, and over one billion hours of YouTube videos are watched on a single day [34]. By connecting the increasing practice of lifelogging with the desire to share one's life events with a remote audience (*e.g.*, friends, family members, colleagues and, more generally, "followers"), new challenges emerge for managing big data while maintaining the same high quality standards [4] for video content over the Internet. In this regard, video streaming research has examined real-time streaming protocols [27] and adaptive multimedia streaming services [36].

In the Senses++ [31] project, we addressed various aspects of video streaming, which we compiled into a conceptual space with two axes: *broadcast* (what is shared with the remote audience) and *time* (when sharing takes place) with multiple distinct design possibilities for video broadcasting to a remote audience. For instance, the broadcast axis distinguishes between video and non-video content. In the first category, we identify first-person video (as delivered by lifelogging and wearable cameras that are clipped onto clothes), first-person and eye-level video (delivered by video camera-based smartglasses), mediated video (*i.e.*, the video captured by the camera glasses is modified before broadcast), augmented video (the video is augmented by superimposing computer-generated content), and virtual-world video (the video is replaced by a full virtual reconstruction). In the second category, we identify broadcast summaries (represented by single snapshots that are broadcast instead of video), life abstractions (in the form of tag clouds as delivered by the Life-Tags [1] system discussed in the previous section), and three forms of news tickers delivering life abstractions by means of visual, auditory, and haptic (*e.g.*, vibrotactile) cues; see [31] for details. The time axis specifies four categories of synchronous and asynchronous communications, as follows: real-time or near real-time video streaming (enabled, for instance, by the WebRTC[4] protocol),

[4] https://webrtc.org/

low-latency streaming (*e.g.*, Low-Latency HLS[5]), high-latency streaming (MPEG-DASH[6] and HLS[7]), and archived content (*e.g.*, content available from video servers and video service providers, such as YouTube).

While the broadcast-time conceptual space for life broadcasting to remote audiences was motivated by practical needs of lifelogging and sharing life events with peers in the form of various presentation modalities for cross-reality [23] and alternate reality systems [8], a new application may be to support effective communications for crisis management and mitigation. For example, to resume the discussion from the previous section, live video streams could be automatically initiated with Life-Tags users triggered by the detection of specific keywords having frequencies of occurrence above specified thresholds. However, effective network bandwidth management is essential when a lot of communications need to take place, especially during crisis situations and, consequently, choosing carefully the kind of content that is broadcast as well as the synchronicity overlapping between the broadcaster and the receiver may help save essential bandwidth resources. Examples include streaming high-quality video for situations that are absolutely urgent, shifting to broadcast summaries (*i.e.*, series of snapshots captured at specific time intervals) when the urgency attenuates, and to visual news tickers (*i.e.*, a series of words describing the current situation) for monitoring less urgent situations. The broadcast-time conceptual space can effectively be employed for such purposes in order to implement the following objectives for crisis management and mitigation systems: O_1 (the system helps in the coordination and handling of the crisis), O_2 (the system ensures that abnormal or catastrophic situations that may occur during the crisis do not go out of hand), O_3 (the system helps to minimize the effects of the crisis by handling the various situations using limited resources), and O_4 (the system allocates and manages in an effective manner the distribution of the available resources).

5. New Uses of Assistive, Mediated and Augmented Vision

In the previous two sections, we discussed life abstraction implemented with video camera-based smartglasses and options for streaming video content, in various forms, to a remote audience that may or may not be synchronized temporally with the broadcaster. In the following, we focus on assistive, mediated, and augmented vision and discuss the opportunity of broadcasting it to a remote audience. By *mediated vision*, we understand any modification of the video content that is presented to the user by means of image processing and computer vision algorithms, *e.g.*, brightness and contrast adjustment, magnification, color replacement, edge highlighting, etc. Mediated vision has been employed for the purpose of vision rehabilitation in the form of assistive vision applications for smartglasses and HMDs [37,39,41]. By *augmented vision*, we understand any modification of the video that is presented to the user by superimposing computer-generated content, *e.g.*, from bounding rectangles that highlight objects and regions of interest in video, such as detected faces, to navigation instructions and highlighting products on a shelf [40], and to virtual characters aligned with the physical world for AR applications [3,5]. Note that videos can be augmented and mediated at the same time, in which case we rely on Mann *et al.*'s [19] definition of Augmediated Reality to refer to the end results.

In the context of the Senses++ [31] project, we developed an application for the Microsoft HoloLens HMD[8] (1st generation) to provide vision mediation and augmentation to people with visual impairments. We implemented various visual filters designed to process video frames captured by the camera embedded in the HoloLens HMD and display the result to the user via the see-through lens; see Figure 3 for an example of the edge highlighting visual filter. While the purpose of this application was vision rehabilitation, we can envision

[5] https://developer.apple.com/documentation/http_live_streaming/protocol_extension_for_low-latency_hls_preliminary_specification
[6] https://www.iso.org/standard/75485.html
[7] https://developer.apple.com/streaming/
[8] https://www.microsoft.com/en-us/hololens

its integration in the context of the discussion from the previous two sections regarding crises management and mitigation systems. For example, vision mediation and augmentation can be employed to improve visual perception for first responders involved in the local monitoring of a crisis, *e.g.*, by improving their contrast vision in low ambient light, enabling better vision during nighttime by incorporating other imaging sensors, such as thermal sensing, or by highlighting specific objects of interest on the see-through lens to increase the effectiveness and efficiency of visual search tasks [40]. Different forms of mediated and augmented vision may be broadcast to different command centers in order to support their decisional process regarding measures taken for the management and mitigation of the crisis. Such applications implement the following criteria for crisis management and mitigation applications: O_1 (the system helps in the coordination and handling of the crisis), O_2 (the system ensures that abnormal or catastrophic situations that may occur during the crisis do not go out of hand), and O_5 (the system identifies, creates, and executes missions to manage the crisis).

Figure 3. Mediated vision showing highlighted edges of the objects present in the user's field of view. *Note:* implementation using the Microsoft HoloLens HMD.

6. Conclusion

We presented in this article the perspective of transferring scientific results, technology, and knowledge from the area of assistive vision to applications of IST for crisis management and mitigation systems. The approach adopted in this article was that of a position paper, where we drew attention to several opportunities to connect two distinct areas of scientific investigation. Table 1 resumes the characteristics of the contributions from the Senses++ [31] project discussed in this article in relation to the six objectives of crisis management systems [13]. Future work will address in-depth investigations of these connections, including implementations of the presented concepts for crisis management scenarios and evaluations of technical performance and the degree of fulfillment of the objectives for crisis management systems [13], but also regarding aspects of user performance. Other connections with other topics from the areas of scientific investigation illustrated in Figure 1, such as interactive media, computer-generated and mediated realities, and human-computer interaction, are equally envisaged; for instance, using methodology and tools from human-computer interaction to perform practical evaluations of usability, user experience, and social acceptability of interactive systems and applications for crisis management scenarios. We hope that our discussion from this article will be useful to researchers and practitioners activating in this area toward the design and engineering of more effective and efficient systems for crisis management and mitigation based on various video streaming modalities, life abstraction, and Augmented Reality technology.

Table 1. Summary of the contributions from the area of assistive vision [31] discussed in this article and their application to crisis management systems according to the six objectives from [13].

Contribution from AV*	Application to CMS**	Objectives for CMS [13] ***					
		O_1	O_2	O_3	O_4	O_5	O_6
Life abstraction [1,31]	Automatic detection of key concepts from live video, notifications to control centers, automated processes for warning and alerting systems, extension of the Life-Tags system to robotic vehicles and drone computing	✓				✓	✓
Video and content broadcasting [2,31]	Adaptation of the broadcast content according to the urgency of the situation, from high-quality video streaming to visual news tickers	✓	✓	✓	✓		
Mediated and augmented vision [25,26,31]	Improved visual perception for first responders, adaptive processing of video content before streaming to various third parties, imaging in other regions of the electromagnetic spectrum beyond visible light, *e.g.*, thermal imagining	✓	✓			✓	

*AV = Assistive Vision

*CMS = Crisis Management System

*** See the Introduction section for details.

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