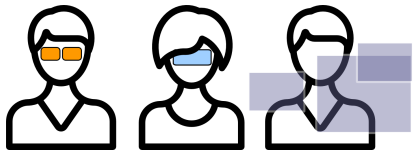

BACKGROUND: Augmented Reality
Augmented Reality technology (AR) enables development of applications that span the boundary between the physical and the digital world, primarily addressing users' **visual sensory channel**. The main characteristics of any AR system are (i) a mix of physical and digital, (ii) interactiveness in real time, and (iii) 3-D perspective [4]. Current AR applications target mobile devices predominantly, such as smartphones and tablets. These devices feature an embedded video camera, which is used to capture visual snapshots of the physical world, on top of which computer-generated digital content is rendered. Recently, smart eyewear has started to become more affordable in the form of smartglasses and head-mounted displays, such as Vuzix Blade (www.vuzix.com/products/blade-smart-glasses) or Magic Leap One (www.magicleap.com/magic-leap-one), which opens up the opportunity of designing new kinds of first-person AR experiences.

Augmented Reality has seen a remarkable evolution in the last decade with applications in many areas, from video games to e-commerce. Among these, prior work has also applied AR concepts and technology to home entertainment, including immersive video games [10, 11] and television expanded to entire living-room walls [20].

Towards Visual Augmentation of the Television Watching Experience: Manifesto and Agenda

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ABSTRACT

We present an agenda for the visual augmentation of television watching based on recently booming technology, such as smart wearables and Augmented/Mixed Reality technology. Our agenda goes beyond second-screen viewing trends to explore the opportunities delivered by wearable devices and gadgets, such as smartglasses and head-mounted displays, to deliver rich visual experiences to users. While still a work-in-progress, we hope that our contribution will be inspiring to the TVX community and, consequently, foster critical and constructive discussions towards new devices, application opportunities, and tools to augment visually the television watching experience.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; **Ubiquitous and mobile devices**; *Interactive systems and tools*.

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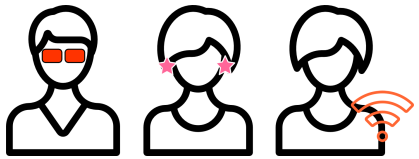
Augmented Reality (continued)
Jones *et al.* [10, 11] introduced "IllumiRoom" and "RoomAlive," two systems that employed room-sized video projections on the wall behind the TV set and, respectively, in the entire room to deliver immersive experiences to video game players. Vatavu [20] presented "Around-TV," a system that used a video projector to display virtual TV screens and user interface controls around the TV set and enabled fluid transfers of content between the physical TV screen and the video projection on the wall behind it. Other examples of AR applications for television include synchronized sign language interpretation rendered by HoloLens [24], joint use of tablets and headsets for mixed reality television [5], projecting a remote audience on top of the TV broadcast in the form of body silhouettes of other viewers [21], and 360-degree video for immersive mixed reality performances [17].



BACKGROUND: Wearable Computing and Sensory Augmentation
Wearable computers, such as smartwatches, smartglasses, smart jewelry, and smart clothes, embed sensors that can detect and recognize users' motions, gestures, and actions and, consequently, can assist with adaptive and personalized services. One such service is **sensory augmentation** [26, 28, 29].

KEYWORDS

Visual augmentation, smart TVs, wearables, smartglasses, Augmented Reality, low vision.

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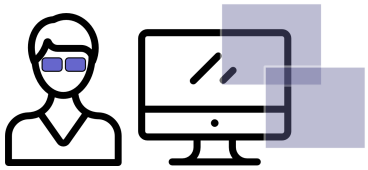
INTRODUCTION

Today's smart TVs feature a variety of capabilities [15], such as high, 8K resolution displays, wide field of view, curved form factors that favor immersion and the perception of depth, and connectivity to the Internet and to other devices, such as smartphones and tablets. A few initiatives have started to connect Augmented Reality technology with television [2] to create rich visual experiences, while recent research has also looked at other human senses and examined flavors, taste, and mid-air haptics for multisensory storytelling [1, 23]. Such advances and developments open up entirely new perspectives for delivering new television experiences to viewers. Also, while television watching rests primarily a visual experience, the augmentation of the visual sense can benefit greatly from the favorable context created by the recent boom in Augmented Reality and smart wearables. These technologies can deliver the technical means to create new, visually augmented experiences for television, such as content displayed around the TV screen [2, 11, 20] and in the entire room [10]. However, besides a few research projects on Augmented Reality for TV, *there has been little exploration overall for augmenting visually the television watching experience for viewers*. In this work, we present a proposal for an agenda regarding the visual augmentation of the television watching experience using smart wearables, and invite the community to react via a dedicated web page, companion to this paper, available at http://www.eed.usv.ro/~vatavu/projects/AR-TV. We hope that our initiative will generate constructive discussion towards defining and materializing new opportunities in the TVX community to invent and design rich visual experiences for television viewers.

BACKGROUND: KEY CONCEPTS, FIELDS OF RESEARCH, AND SELECTED PRIOR WORK

There are several fields of research on which we base our agenda for the visual augmentation of the television watching experience, such as Augmented Reality, Wearable Computing, and Human Sensory Augmentation. While the limited space of a work-in-progress paper precludes extensive treatment of such wide literature, we nevertheless provide a brief overview of the main concepts from these established fields in the side panels on this page, the previous page, and the next one. We also point to examples from the literature regarding Augmented Reality for television and smart eyewear systems and applications for the augmentation of human vision.

Wearable Computing and Sensory Augmentation (continued)
Especially relevant to our investigation is **visual augmentation**, where users are presented with an enhanced visual perspective of the physical reality. Examples of relevant prior work include "ForeSee" [28], an application for head-mounted displays that features magnification, contrast and edge enhancement, and text extraction; and "WatchThru" [25], a smartwatch with a wrist-worn transparent display to extend smartwatch glanceability. A notable recent effort towards making smart eyewear accessible to everyone and, thus, foster new AR application development is represented by the open source "EyeTap" initiative [14].



BACKGROUND: Take-away message
Despite considerable research and prior work in Augmented Reality, Wearable Computing, and Human Sensory Augmentation, there has been little attention in the TVX community on how these technologies can be used to enhance the television watching experience. To this end, our paper represents a **manifesto**, as we outline an **agenda** for the visual augmentation of television watching, which we hope to foster discussion and attract attention towards an exciting research niche, still left to be explored by the TVX community.

AGENDA FOR THE VISUAL AUGMENTATION OF TELEVISION WATCHING

We outline a research agenda for the visual augmentation of television watching consisting in nine items that cover users, devices, smart TV environments, as well as connections to other fields.

1) Understanding user preferences

One important aspect to inform design and development of I/O devices, interaction techniques, user interfaces, and applications is to understand what users want and need. Several research questions can be envisaged regarding the visual augmentation of the television watching experience: What are users' preferences for the visual augmentation of TV watching in terms of devices, digital content, and applications? Are there specific types of content or television genres for which visual augmentation is more desirable? Do various age groups, *e.g.*, children, young adults, and elderly, have different preferences regarding the visual augmentation of their television watching experience?

2) Devices to support visual augmentation for television

Visual augmentation can be performed using a variety of AR devices, from smartphones and tablets [2], to wearables, such as head-mounted displays [13], smartglasses [26], and the holographic computer HoloLens [24]. Other types of wearables, such as smartwatches with custom designs [25], can also be employed to this purpose. According to Azuma [4], wide field-of-view, optical see-through near-eye displays in compact form factors, as well as interfaces to control such displays represent two out of the four key challenges to be overcome for viable AR platforms and applications to happen.

3) From smart TVs to smart TV environments

Beyond smart TVs, the entire room can serve as a canvas to display computer-generated graphics to augment television watching [10, 11, 20]. From this perspective, mobile devices, wearables, the smart TV, and sensors and display technology from the physical environment constitute a "smart TV space," for which flexible software architecture is needed to connect heterogeneous I/O devices; Euphoria [18] is one example of such architecture, specifically designed for smart environments.

4) Accelerating research from multimedia to ambient media

Delivering viewers with a visually-augmented TV experience will likely need new ways to represent and transfer digital content, accelerating developments towards ambient media and implementations of its principles, *i.e.*, manifestation, morphing, intelligence, experience, and collaboration [12].

5) Interaction techniques to operate visual augmentation

The TV remote control is unlikely to scale effectively for viewers to operate AR and ambient media content that is 3-D, overlaying the physical environment, and interactive in real-time [4]. Alternative

Figure 1: A graphical summary of the nine items of our agenda regarding the visual augmentation of the television watching experience: users, devices, smart environments, content and ambient media, interaction techniques, viewers with visual impairments (low vision), tools, applications, and connections to other fields.

input modalities, such as free-hand and whole-body gestures [19], wearables [8], on-body input [7], voice [16], and eye gaze input [9], will need to be explored and evaluated in this context.

6) Visual augmentation of television for viewers with visual impairments

According to a 2018 survey [6] from Comcast and the American Foundation for the Blind, adults with visual impairments tune-in to television as much as people without impairments. Visual augmentation is especially important for people with *low vision* (*i.e.*, visual impairments that cannot be corrected with contact lenses, medication, or surgery) who, unlike blind people, do rely on their visual abilities for everyday activities, but experience challenges caused by vision disturbances. A few studies have been conducted recently to understand the perceptions of people with low vision regarding commercial AR glasses [27], and to inform design of smartglasses applications for this user category [3], but scientific explorations are still needed for the particular context of television watching.

7) Tools to support visual augmentation for television

Tools are important to support development of practical applications. Example of tools relate to the creation of digital content, prototyping user interfaces for augmented TV using mobile and wearable devices, and tools for the analysis of user performance with AR TV, such as visual attention [22].

8) New applications

Examples of new applications for visually augmented TV include collaborative television watching with remote audiences, multi-platform TV, immersive TV shows, or on-demand content consumption. Also, new forms of television are likely to emerge supported by Augmented Reality technology.

9) Connections to other fields of research

Important knowledge needs to be brought in from other fields, such as Psychology (understanding users), Wearable Computing (new I/O devices), Human-Computer Interaction (UI design, evaluation methodologies), and Augmented Reality (rendering techniques and tools for overlaying computer-generated content onto the physical world). Ethical and privacy protection aspects also fall under this agenda item and should be thoroughly explored.

CONCLUSION

We presented a proposal of **an agenda for the visual augmentation of the television watching experience** mediated by smart wearables and Augmented Reality technology. At this moment, our agenda is work-in-progress, as we expect constructive feedback and discussions from the community, including researchers, practitioners, and the industry. **Our agenda also represents a manifesto,** inviting the TVX community to react and explore the opportunities offered by Augmented Reality and wearable technology towards the creation of rich interactive visual experiences for television viewers.

INVOLVING THE COMMUNITY

Intended to start up a **community effort**, we hope that our initiative will stimulate exciting research and development at the boundaries of Augmented Reality, Wearable Computing, and Human Vision Augmentation with focus on the television watching experience.

To this end, we provide practical means for such an effort to materialize. Our manifesto has a **dedicated web page**, where our agenda is available to everyone to consult and provide feedback. We plan to update the online agenda as discussion develops in the interested community and as we receive proposals and suggestions for improvement. At this moment, TVX researchers and practitioners are invited to react and contribute at the web address www.eed.usv.ro/~vatavu/projects/AR-TV

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SALES AND REVENUES IN AR, WEARABLES, AND SMART TVS

We present in this side panel a few statistics on the markets of Augmented Reality, smart TVs, and wearables, as well as forecasts about these markets for the upcoming years. These figures come to support the motivation behind our agenda.

Smart TVs

As of 2018, 70 percent of TVs that are sold worldwide are smart TVs, and 259 million units are projected for global TV set unit sales by 2020; see the "Smart & Connected TVs - Statistics & Facts" report at https://www.statista.com/topics/4761/smart-and-connected-tvs/

Augmented Reality

Shipments of smartglasses for Augmented Reality applications are forecast to reach 5.4 million units by 2020, while the global AR market is expected to 90 millions US dollars. Revenues from AR are projected three times as high as those from VR; see the "Statistics & Facts on Augmented Reality (AR)" report at https://www.statista.com/topics/3286/augmented-reality-ar/

Smart wearables

According to Gartner's November 2018 report on wearable electronic devices, worldwide shipments of wearables is expected to reach 225 millions of units in 2019, including smartwatches, head-mounted displays, smart clothing, ear-worn, wristbands, and sports watch devices; see press release at https://www.gartner.com/en/newsroom/press-releases/2018-11-29-gartner-says-worldwide-wearable-device-sales-to-grow-

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