An Overview of Smart Glasses and Some Research Issues

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Abstract. The concept of Smart Glasses has evolved since the introduction of early prototypes of the 1990s, only to gain wide acceptance recently. The global smart glasses market has recently experienced significant growth and is predicted for further expansion. They can be tailored to many types of consumer classes and industries, with several benefits. Like other IoT devices, Smart Glasses may be embedded with sensors to gather data which is then shared with other devices. Machine learning algorithms can be used for processing, sensor fusion, or classification and decision-making. Smart Glasses can also enhance productivity for medical practitioners, allowing them to view patient records or assist them during surgical procedures. New apps utilization such eyewear can also be an assistive technology, enhancing the quality of life for People with Disabilities. The paper provides a review of recent research on the applications of smart glasses, address critical research challenges, and the status of current smart glasses on the market. It also highlights key research issues that should be addressed in the short and long term to bring these powerful tools into mainstream usage.

Keywords: Smart Glasses, Assistive Technologies, Image Recognition

1 Introduction

The term Smart Glasses refers to devices as simple as devices worn over the eyes with built-in headphones to goggles with a full digital display, including the ability to access web apps. Smart Glasses are eyewear that are integrated with computing technology, allowing users to view and interact with digital information [23]. Smart glasses may have built-in cameras, speakers, microphones, and even built-in screens for Augmented Reality (AR) experiences. With these additional built-in hardware components, some of the common functions of Smart Glasses include taking images and videos, making calls, receiving notifications, interacting with other devices, and additional computer-like capabilities. Recently, there has been a rapid interest in Smart Glasses and possible new apps. Fig.1 shows the basic components of an advanced Smart Glasses unit; a typical model may have a subset of these components, such as a camera, microphone, and speakers.

The global smart glasses market has recently experienced significant growth and is predicted for further expansion. In 2022, the market size was valued at 1,232 million

USD and is projected to grow at a CAGR of 27.1%, reaching 8,187.1 million USD by 2030 [6]. Additionally, global smart glasses shipments have grown from 0.23 million units in 2017 to an impressive 32.7 million units in 2022 [10]. Between 2022 and 2027, the global smart glasses market is estimated to grow by USD 65.75 million, exhibiting a CAGR of 13.35% [21].

A widely used software for people with visual impairments is the Microsoft Seeing AI app. Smart glasses can also be a tool that people with visual impairment can use to navigate through space. People without disabilities can also use smart glasses to help them understand with people with disabilities.

Smart glasses also serve as Internet of Things (IoT) devices, facilitating communication of information implicitly with other devices via internet connectivity [18]. Like other IoT devices, Smart Glasses may be embedded with sensors to gather data which is then shared with other devices. Machine learning algorithms can be used for processing, sensor fusion, or classification and decision-making. The sensors can include additional associated pieces, such as buttons or touch pads. The IoT capabilities of smart glasses allow many expanded uses and applications, especially by overcoming the limited processing power by sending data to an external computer or mobile device for processing. Moreover, Smart Glasses can be used to gather health data from various ambient or wearable sensors. Smart Glasses represent a significant advancement by integrating Augmented Reality (AR) and artificial Intelligence through IoT to create an interactive experience for the user. These advancements have the potential to significantly impact different fields and industries, enhancing the quality of work and convenience for everyone.

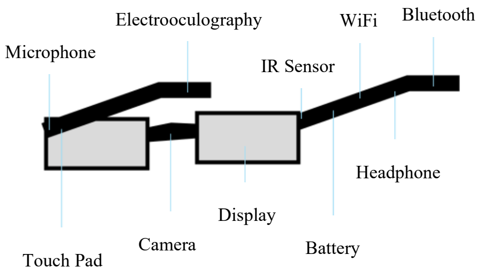

Fig. 1. The main components of a smart glasses unit.

2 Technical Challenges

Smart glasses can serve a variety of purposes by existing as a unique and human-centric avenue of mounting technology; as a head-mounted device, smart glasses closely emulate the natural locations of human eyes and ears. To gather input, smart glasses utilize sensors like cameras or microphones. They then relay the data to a computer, either one on the glasses themselves or via IoT connectivity to edge or cloud devices, for processing. The computer's task is dependent upon the glasses' purpose. For tasks where the glasses detect objects around the user, the computer may perform classification or detection on the provided data through computer vision models. After processing the input data and drawing the desired conclusions, the computer then relays its results to the glasses' output apparatus. The output may take the form of audio, visual, or tactile stimuli, dependent on the task or identity of the user.

For assistive smart glasses, various smart health tools can be developed to help people with disabilities and healthcare workers to better communicate with audio-visual data. For such apps, machine learning is an important system component. Machine learning algorithms can be used to process and classify sensor data, especially where the sensors have high dimensionality or multiple sources. These algorithms typically require larger processing capability, thus exemplifying the necessity of external machines for higher-power processing [1]. For smart glasses, machine learning is vital for computer vision to determine the contents of an image or video feed by detecting and recognizing objects within a picture. Additional computing resources can also allow further analysis of important device factors such as device power consumption and performance.

User Interface Design: Many Smart Glasses contain in-built screens that both have the purpose of displaying information to the user or even Augmented Reality (AR) capabilities. When developing these displays, many challenges arise on how to implement or even how to make a display that users can interact with while still seeing what is happening around them. The main reason for this problem can arise because most headsets have a narrow Field of View (FOV) which can impact how much a user can see [8]. The natural human Field of View (FOV) is 180 degrees horizontally, but many Smart Glasses with augmented reality features are usually around 28 degrees. Extending the Field of View (FOV) is often the most challenging part when designing Smart Glasses with in-built screens [19].

Another technical challenge from the User Interface (UI) perspective is that the screens shouldn't overwhelm the user, while not overloading the user with too much information [8]. Balancing these factors poses a large technical hurdle when trying to create the best set-up for displays in smart glasses. Various user interface controls include eye movement, remote devices, hand gestures, voice, and touch.

Display Design: Smart Glasses have three general types of displays: virtual reality, video see-through, optical see-through. Video see-through display and optical see-through display form an augmented reality experience. The optical see-through display is the most like prescription eyeglass, where the user can see their surroundings with their own eyes, and there is a screen display projected to the glass in the user's field of vision. Users cannot see their surroundings directly with their own eyes through video see-through displays; alternatively, video see-through displays use a camera to record from the user's point of view of the user's surroundings and then projects it onto the glasses display. In virtual reality displays, the user will not be able to see its own surroundings at all. They will only be able to see whatever the headset is projecting to them.

Overcoming Hardware Limitations: The development of Smart Glasses has many technical challenges that are due to the hardware components that make up the glasses themselves. One of the major issues is the addition of inductively coupled coils for wireless power transfer and communication, which must be very small to fit within the thin frame of glasses [20]. This coil placement size is also important to minimize power loss and interference [20]. Furthermore, Smart Glasses need to be very durable and be able to withstand some mechanical stresses and environmental factors such as dust and moisture, to be useful for daily tasks or even industrial tasks [13].

Additionally, most smart glasses have limited battery supplies because of size constraints, which makes it a challenge to effectively manage power for extended use of the Smart Glasses [13]. One of the most essential features of smart glasses is the camera. Notwithstanding, the camera drains the smart glasses' battery immensely. Many people want to use smart glasses, but the less than two hours of battery life on smart glasses is not conducive for whole-day use [4]. Schaer *et al.* [17] had to connect the smart glasses to an external battery to complete a fictional emergency situation response. These challenges underline the complexity of balancing both functionality and usability when integrating certain hardware parts and features of smart glasses.

Lightweight Machine Learning Models: Cameras are the most ubiquitous feature of smart glasses. Due to this, machine learning models are often utilized for computer vision in order to add additional functionality. This includes object detection, object recognition, and facial recognition. Due to the hardware limitations of smart glasses, lightweight machine learning models are often necessary for the desired image recognition tasks. Variations of the You Only Look Once (YOLO) model are popular deep learning methods for many object recognition and classification tasks, especially for their efficient speeds and high accuracies.

The first-generation YOLO model has been used for traffic light/ sign classification [7]. The results of this classification are fairly accurate, but the succeeding YOLO models, YOLOv3 and YOLOv7, provide greater accuracy and speed of image classification. YOLOv3 is used in [9] for general image recognition on the COCO image dataset. The same architecture is used in [14] for classification of leaves for the detection of leaf diseases. Additionally, the YOLOv3 model is found to be approximately 900 times faster than Region-Based Convolutional Neural Network (R-CNN) for image classification tasks, which is a commonly used non-light-weight image classification model [14].

YOLOv3 can be augmented to further improve the overall classification speed [16]. This improvement is made with the use of the Darknet CNN which separates regions of a captured image into small areas with assigned weights which allows for faster object classification. The YOLOv7 model is an architecture based on the YOLO-R (You Only Learn One Representation) and YOLOv4 models. YOLOv7 is able to achieve higher classification accuracy compared to YOLOv3 [15].

Other non-light-weight models have been used for image recognition tasks with great accuracy. Examples include Deep Neural Networks, YuNet, CNN MobileNet, and Histogram of Gradients [15]. In some smart glasses applications, these models could be used offline or on an external, internet connected computer. However, if the application requires retraining models online, the machine learning models must be light-weight enough to run efficiently on the limited hardware of smart glasses devices.

User Adaptation: Another notable user interface challenge of smart glasses is the learning curve of the technology. For the smart glasses to be useful, the users must be able to know how to adequately know how to use it. Some smart glasses are connected directly to smartphones, so it is remotely controlled. Other smart glasses require the user to learn eye or hand movements to control the smart glasses [23]. All smart glasses have their unique combination of user interface controls that they offer.

3 Overview and Classification of Available Smart Glasses

There are several different smart glasses that are sold to consumers worldwide for personal use. There are many types of smart glasses. As seen in Figure 2, not all smart glasses have a built-in augmented reality display. Those that do not use an augmented reality display rely on a remote device for control.

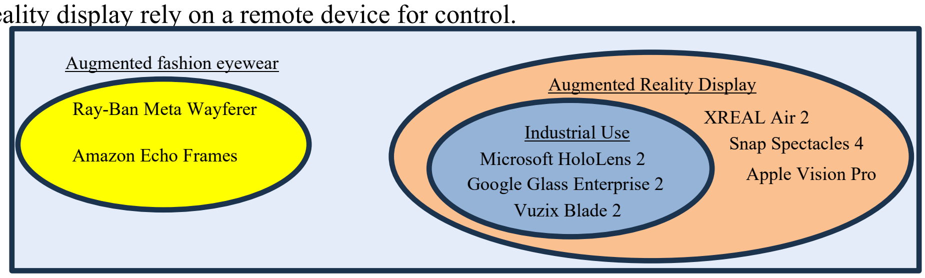

Fig. 2. Smart glasses classification.

3.1 Augmented Eyewear

Ray-Ban Meta Wayfarer: Ray-Ban and Meta have recently released a new Smart Glasses product. The Ray-Ban Meta Wayfarer is equipped with a 12 mp camera that allows users to take photos, videos, and livestream. The Ray-Ban Meta Wayfarer has in-built speakers, allowing users to listen to music or other media. The Ray-Ban Meta Wayfarer is also equipped with a microphone allowing users to make calls, text, and use voice commands. The user can also interact with Meta AI which is Meta's virtual assistant. The Ray-Ban Meta Wayfarer has a touchpad on the side of them that users can press to control certain functionalities. Meta created an app to go along to these Smart Glasses that allows the user to control the device from their mobile device [11].

Amazon Echo Frames (3rd Gen): Amazon released the Echo Frames 3rd Gen that have a built microphone and Open-ear audio speakers that are built into the frame. These parts allow the user to make calls and listen to music as well. The Echo Frames also have Amazon Alexa built in that allow the user to use Alexa as a voice assistant. These frames have a larger battery built in, allowing for up to 14 hours of moderate usage [2].

3.2 Augmented Reality Features

Google Glass Enterprise 2: Google Glass Enterprise 2 is the last model of Smart Glasses with Augmented reality that was released in 2019. The Google Glass has a built-in 8-megapixel camera that is capable of performing video recording in 1080p.

The Google Glass has a 640x360 display built along with Wifi and Bluetooth Capability. The system is controlled by a user using the in-built touchpad. The Operating System on these glasses is Android OS allowing third party applications to also function these Smart Glasses. Many applications have been integrated to use Augmented Reality to help industry workers that use Google Glass [5].

Vuzix Blade 2: The Vuzix Blade 2 is the most current model of the Vuzix Blade smart glasses. The Vuzix Blade 2 has a 480x480 color display with a field of view of 20 degrees. The Vuzix Blade 2 allows user to control functionalities through voice controls through the microphone or use the touchpad integrated on the side of the glasses. The Vuzix Blade 2 also has an 8 megapixel camera built-in, allowing users to take videos and photos. The Vuzix Blade 2 runs on Android 11 OS allowing for current development features using the Android APK [22].

Microsoft HoloLens 2: The Microsoft HoloLens 2 holds many features and functionalities, creating a mixed reality experience for the user. The Microsoft HoloLens 2 has 8 mp hd camera, microphone, 2k display, and Wifi and Bluetooth capabilities. The Microsoft HoloLens 2 uses environmental understanding practices like spatial mapping and world scale positional tracking. For industrial use, Microsoft HoloLens 2 features applications like Dynamics 365 Remote Assist or Dynamics 365 Guides, which allow remote collaboration and hands-free functionality [12].

Apple Vision Pro: Apple has launched the Vision Pro that is a headset that meshes a computer and augmented reality into one device. The Vision Pro utilizes cameras to provide current scene vision to the user. The user can use various techniques with their hands, eyes, and voice to interface with the Vision Pro. The Vision Pro can be connected to a computer to allow the user to use the Vision Pro as a larger monitor. Developers can also develop different apps using the Vision Pro's abilities, so there is a lot of potential for these smart glasses [3]. Table 1 shows common features of some prominent smart glasses.

Table 1. Features and applications of available Smart Glasses

Model	Camera	Audio	Voice Assistant	Display	Control	Battery Life	Connectivity	Operating System	AR Features	Application
Ray-Ban Meta Wayfarer	12 MP	In-built speakers	Meta AI	None	Touchpad	Unknown	Meta app	Unknown	None	Photography, media
Amazon Echo Frames (3rd gen)	None	Open-ear audio speakers	Amazon Alexa	None	None	Up to 14 hours	None	Unknown	None	Calls, music
Google Glass Enterprise 2	8 MP	None	None	640x360	Touchpad	Unknown	Wifi, Bluetooth	Android OS	None	Industrial, AR
Vuzix Blade 2	8 MP	None	None	480x480	Touchpad, voice	Unknown	None	Android 11 OS	None	Photography, media
Microsoft HoloLens 2	8 MP HD	Microphone, speakers	Yes	2K display	Voice, hand, eye tracking	Unknown	Wifi, Bluetooth	Unknown	Mixed reality	Industrial, mixed reality
Apple Vision Pro	Built-in	Built-in	None	Yes	Hands, eyes, voice	Unknown	Computer connectivity	Unknown	AR, VR	AR, VR, computer

4 Conclusions

Smart Glasses represent an evolving field of technology integrating Augmented Reality (AR), Artificial Intelligence (AI), and the Internet of Things (IoT) to enhance user interaction with digital information. From consumer conveniences to increasing industrial productivity and assistive technologies for People with Disabilities (PWD), Smart Glasses offer many applications that significantly improve efficiency and productivity. Despite many of the technical challenges that come with Smart Glasses development the global market is experiencing rapid growth which is promoting research and expansion.

Acknowledgments. This project was funded by the National Science Foundation under Award Number: 2150484.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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