# OCOsense Glasses – Monitoring Facial Gestures and Expressions for Augmented Human-Computer Interaction

OCOsense Glasses for Monitoring Facial Gestures and Expressions

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## ABSTRACT

The paper presents the OCOsense™ smart glasses system, which recognizes and monitors facial gestures and expressions by using non-contact optomyographic OCO™ sensors and an IMU placed inside the frames of the glasses. The glasses stream the sensor data via Bluetooth to a mobile device, where data-fusion algorithms are applied, to recognize facial gestures and expressions in real time. The recognized gestures and expressions are then used as input to interact with the mobile device. We will demonstrate how the system is used in practice, i.e., a participant will wear the OCOsense™ glasses and will interact with the mobile device by doing facial gestures and expressions. Three use cases will be presented: video control, call control, and game control. We believe that the OCOsense™ glasses are the next generation in wearables, which will allow for a better understanding of the user's context and emotional state, and will allow numerous ways to interact with smart devices and computer systems, even within Augmented and Extended Reality environments. Future versions of the system can be used in a variety of domains, including, affective computing, remote mental-health monitoring, and hands-free human-computer interaction, thus improving accessibility and inclusivity of future technologies.


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## CCS CONCEPTS

• **Human-Computer Interaction**; • **Sensors and actuators**; • **Ubiquitous and mobile computing**; • **Machine Learning**;

## KEYWORDS

Glasses, Facial Expressions, Facial Gestures, Emotion Recognition, Affective Computing, OMG, IMU, Machine Learning

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## 1 WEARABLES, FACIAL GESTURES AND EXPRESSIONS

Wearable devices equipped with sensors are being intensively developed in various forms, including head-worn (e.g., glasses and earbuds), wrist-worn (e.g., watches and bracelets), and torso-worn (e.g., smart textiles). Wearables, combined with machine learning, can bring significant and sustainable improvements to our lives – from improved patient monitoring and decreased healthcare costs, to enhanced sports performance and improved quality of life [1, 2]. The sensors within these devices are a key technology that provides information about the user and the user's environment. Today we are witnessing a wide range of sensors frequently embedded into wearable devices such as accelerometers (measures the acceleration force that is applied to a device on all three physical axes), ambient light sensors (measures the ambient light level – illumination), ambient temperature sensors, air humidity sensors (measures relative ambient humidity), barometers (measures ambient pressure), gyroscopes (measures orientation and angular velocity), magnetometers (measures the ambient geomagnetic field for all three physical axes), proximity sensors, etc. Additionally, a variety of physiological sensors are also used, including electrocardiogram (ECG – represents heart electrical activity), electroencephalogram (EEG – represents brain electrical activity), electromyogram (EMG – represents muscle activity), blood volume pulse (BVP) or photoplethysmogram (PPG, both represent cardiovascular dynamics), galvanic skin response (GSR – represents sweating rate), electrooculogram (EOG – represents eye movements), phonocardiogram (heart sounds), etc.

Our work falls into the domain of head-worn wearable computing. In particular, wearable devices that can monitor users' head movements and facial expressions. The face is one of the most expressive mediums of our body [3], communicating emotional and mental states, as well as behavioural intentions, via facial muscle activations and configurations which in turn construct expressions. The behavioural research on facial expressions has been an active topic since 1872 (see Darwin [4] and Duchenne [5]). In 2021, we presented to the research community the ML enabled version of our facial dry EMG sensing device that incorporates seven facial EMG electrodes for capturing facial muscle activation [6–8]. The electrodes are positioned to overlap specific facial muscles: the frontalis (left and right side of the forehead; the orbicularis (left and right side of the eyes); the zygomaticus (left and right side of the cheeks); and the corrugator muscle (between the eyebrows). In addition to the EMG sensors, the device contains a PPG, and an inertial measurement unit (IMU) sensor integrated within a soft frame that fits on the face of the wearer.

In this paper, we present a novel multimodal wearable device, featuring sensor-enabled glasses – the OCOsense$^{TM}$ (shown in Figure 1). OCOsense$^{TM}$ is a pair of smart glasses with integrated OCO$^{TM}$ sensors based on non-contact optomyographic (OMG) technology [9]. The data from the OMG sensors are used to recognize and monitor the user's facial gestures and expressions, by using data processing and machine learning techniques implemented on a mobile device. The recognized gestures and expressions are then used as a source to interact with the mobile device. We will demonstrate how the system is used in practice, i.e. a participant will wear the OCOsense$^{TM}$ glasses and will interact with the mobile device by doing facial gestures and expressions. The key innovation in OCOsense$^{TM}$ is the potential to address known limitations in real-world emotion detection by linking a facial expression to the context in which it is performed [10] (see Figure 1, right panel). Our prototype demo application allows the recording of data within a stimuli-presentation contained screen, similar to well-known mood induction study paradigms, and replays the experience back along with the sensor data and expressions detections using a proprietary Affective Artificial Intelligence Engine, in a moment-by-moment fashion.

Compared to similar glasses-based devices, the OCO$^{TM}$ sensors are always oriented towards the user/wearer, thus avoiding one of the biggest privacy issues that smart glasses have. For example, Google Glass – and similar solutions from Sony (SmartEyeGlass) [1] and Vuzix (M300) [2] – introduce privacy concerns as these devices could continuously record video using a front-mounted cameras, compromising bystanders' privacy [11]. Regarding other face-tracking tools, camera-based systems are frequently used to track facial expressions and infer emotional states in the wild, however their effectiveness is not without controversy [12] and privacy concerns have frequently been raised when such methods have been utilized in public. Measuring emotional expressions in the wild with camera-based tools remains challenging due to restrictions on sensor location, lighting, intrusiveness, and movement.

## 2 OCOSENSE SYSTEM

The OCOsense$^{TM}$ system consists of multi-sensor wearable glasses (shown in Figure 1 left), and a tablet application (shown in Figure 1 right). **The OCOsense$^{TM}$ glasses** are a novel multi-sensor wearable device that can measure and detect facial muscle activations through its integrated non-contact OCO$^{TM}$ sensors inside the frame of the glasses. The OCO$^{TM}$ sensors are optical non-contact sensors that can read facial movement in 3 dimensions, providing a higher resolution signal (±4.7$\mu$m X&Y-axis, ±4.0$\mu$m Z-axis) than the average camera-based solution and has advantages over EMG-based systems. EMG electrodes require firm and constant contact with the skin in order to achieve an acceptable signal-to-noise ratio, which is not practical in a glasses format; instead, the OCO$^{TM}$ sensors are optical based, therefore they don't require skin contact and can function accurately from 4mm to 30mm away from the skin. **The OCOsense$^{TM}$ application** connects via Bluetooth Low Energy (BLE) to the glasses. The app receives the sensor data, which are then analysed and visualized by proprietary machine-learning algorithms in real-time. In particular, emteq's Affective AI Engine first uses calibration techniques to analyse the person's face and then provides high-level interpretations including expression types, intensity, gestures, and activities.

## 3 INTERACTIVE DEMONSTRATION

We will demonstrate how the system is used in practice, i.e., a user will wear the OCOsense$^{TM}$ glasses and will interact with the tablet by doing facial gestures and expressions. First, we will show how the OCOsense$^{TM}$ glasses are placed on the face and how to check the glasses' fit. Then, we will show how the users can choose different options and calibrate the sensors and the algorithms to their face. Next, we will show how the data is recorded and visualized in the app in real time. Finally, we will show how the users can interact with the tablet, by presenting three use cases: video control, call control, and game control.

**Video Control** - This use case, allows the user to control a video that is played on the tablet (Figure 2). In this demo we have four controls, namely (1) zooming in, (2) zooming out, (3) taking a screenshot, (4) changing the play speed of the video, either forward or backwards. The user can select from a list of gestures and head movements to connect or map to the four controls. In our example, we have mapped taking a screenshot to performing a

[1] https://www.aniwaa.com/product/vr-ar/sony-smarteyeglass/
[2] https://www.vuzix.com/pages/smart-glasses


**Figure 1: . OCOsense$^{TM}$ glasses and sensor placement (left), the mobile application (right). The coloured rectangles represent the OCO$^{TM}$ sensors within the frame, upon major facial muscles: frontalis (red), zygomaticus (blue) and corrugator (purple). The green OCO$^{TM}$ sensors are positioned over the temples. Also, there is a 9-axis IMU and altimeter - yellow circle. The stimuli emotional analysis screen on the mobile device is shown with the expression/gesture detected from the wearer (right).**

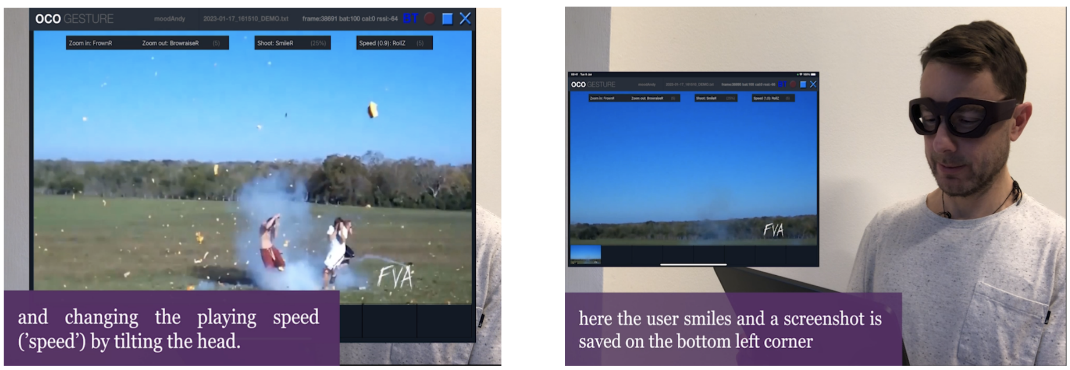


**Figure 2: Controlling a video playback on the mobile device.**

smile, changing the playing speed of the video by tilting the head, raising the eyebrows to zoom out and frowning (squeezing, lowering eyebrows) to zoom in; etc. Thus, we are demonstrating an alternative way of interaction, where the wearer can simply control functionalities without using their hands.

**Call Control** - This use case allows the user to control a call that is received on the mobile device (Figure 3), i.e., it allows the user to accept the call, to snooze it, to message back or to decline it. This interaction is allowed by tilting the head to the left and right to move to the different options and then nodding with the head to choose the selected option. Additionally, by smiling the user is choosing the appropriate option. In order to navigate up or down in the menu, the user either performs an eyebrow rase expression for upwards navigation or a frown expression for downwards navigation.

**Game Control** - This use case allows the user to control a game (Figure 4). The user is controlling the ball on the screen, by moving the head (tilting, rotating, nodding, etc.). In another example, the user is controlling the red car in the game, by partial smiles with the left and right cheek to steer car left and right respectively.

## 4 OCOSENSE$^{TM}$ FOR IMPROVED ACCESSIBILITY AND INCLUSIVENESS IN HUMAN-COMPUTER INTERACTION

Besides the three use cases presented in this paper, future versions of the system can be used in a variety of domains, including hands-free HCI, affective computing studies, and remote mental-health monitoring. For hands-free HCI, the data from the OCO$^{TM}$ sensors can be used to recognize user-specific controls that could be further used as input in other systems, e.g., hands-free control of a wheelchair. In the affective computing domain, the OCOsense$^{TM}$ data can be used to monitor the activity of different facial muscles around the eyes, typical markers for smiling, raising the eyebrows and frowning facial expressions. More advanced solutions could further utilize the monitoring of smiles and frowns. One example scenario would be a system for improving a user's emotional intelligence (e.g., by providing feedback to the user/wearer about their displayed facial expressions with respect to different scenarios/contexts). Another example would be the timely detection and improved management of mood disorders. Such a system can be used by researchers interested in affective computing and expression detection, within real-world scenarios or longitudinal studies where comfort and wearability are crucial. Remote solutions for


**Figure 3: Controlling an incoming call by performing various head and facial movements.**

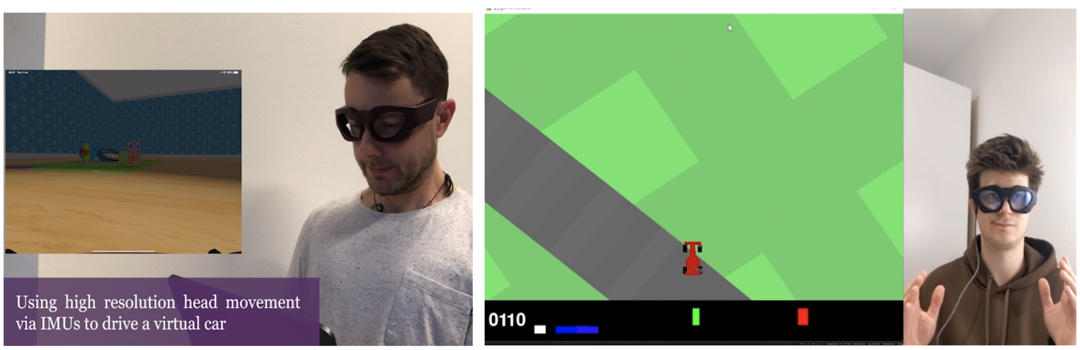


**Figure 4: Game control scenario. IMU control of virtual car (left), facial expression control of a car game (right).**

timely detection and improved management of emotion disorders will positively impact the lives of over one hundred million people in the EU alone who experience mental health problems [11]. This situation was further aggravated by the COVID-19 pandemic, which increased mental health problems' prevalence [12]. Lastly, our team envisions the glasses being used daily to monitor and provide feedback to users in various settings for healthcare and well-being management.

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