Integrating Extended Reality and Neural Headsets for Enhanced Emotional Lifelogging: A Technical Overview

Adrian Aiordăchioae
Interdisciplinary Cloud and Big Data Center
"Ștefan cel Mare" University of Suceava
Suceava, Romania
adrian.aiordachioae2@student.usv.ro

Alin Calinciuc
ASSIST Software
Suceava, România
alin.calinciuc@assist.ro

Maria Doina Schipor
Faculty of Educational Sciences
"Ștefan cel Mare" University of Suceava
Suceava, Romania
doina.schipor@usm.ro

***Abstract*—Lifelogging represents a burgeoning social trend characterized by the use of personal devices to record various aspects of one's life, facilitating future recollection and reminiscence. Concurrently, advancements in technology have made mixed and virtual reality increasingly accessible, largely attributed to the development of smart glasses for different realms. Moreover, EEG headsets are now providing a wealth of information concerning brain activity, particularly regarding emotions, further augmenting our understanding of cognitive processes. In this paper, we present the technical details of a lifelogging system designed to capture the visual subtleties of daily experiences from reality or provided by various models of AR or VR smart glasses, complemented by the Emotiv EPOC X neural headset for the detection and analysis of emotions.**

Keywords— Lifelogging, Extended Reality, smartglasses, EEG headsets, Emotion recognition

I. Introduction

The practice of digital lifelogging [1] has evolved into a burgeoning social trend, propelled by the expanding array of personal digital devices such as smartphones, smartwatches, smartglasses, and neural headsets. These devices, in conjunction with cloud-based storage resources, empower users to effortlessly record and store their daily experiences. The outcome is the creation of a personal record of one's daily life in a varying amount of detail, for a variety of purposes.

The surge in popularity of smart glasses for augmented reality (AR) and virtual reality (VR) is undeniable. These devices, equipped with sophisticated sensors, cameras, and displays, provide immersive experiences by seamlessly integrating digital content with real-world surroundings (AR) or by immersing users in fully virtual environments (VR). At the same time, neural headsets play a pivotal role in today's technological landscape due to their ability to provide valuable insights into brain activity and emotional states.

Neuroscientific evidence reveals that imagery and emotion are highly interconnected brain processes. Studies on neurocognitive models of image [2] and research investigations using neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), have shown that engaging in mental imagery activates brain regions associated with emotion processing, including the amygdala and insula [3], [4]. The process of recalling images is influenced by emotional processing, leading to an enhanced feeling of remembering for emotional images and events [5], [6]. Furthermore, studies on emotionally charged imagery support the role of emotional imagery in modulating emotional experiences [7], [8].

This paper aims to explore the integration of smart glasses with neural headsets, unlocking opportunities to create lifelogs that are rich in diverse information. This fusion allows for lifelog to be sorted based on various criteria, including time, location, concepts, or emotional states, providing users with a comprehensive and customizable experience. Such functionality enables users to efficiently access desired data from the lifelog, thereby enhancing usability and convenience.

To achieve this goal, we designed and implemented a system capable of recording images from various types of smart glasses, processing them to extract concepts and objects, and also recording the user's emotional states using the Emotiv EPOC X neural headset.

II. Related Work

A. Lifelogging

Lifelogging represents a phenomenon whereby people can digitally record their own daily lives in varying amounts of detail, for a variety of purposes [1]. Dodge and Kitchin [9] describe the lifelogging activity as a form of ubiquitous computing representing "*a unified digital record of the totality of an individual's experiences, captured multimodally through digital sensors and stored permanently as a personal multimedia archive*"(p. 431). Prior research on lifelogging applications has delved into diverse areas, including food journals [10], monitoring computer usage [11] , tracking sleep patterns [12], evaluating aspects related to the quality of life [13], memory rehabilitation [14] and assistance [15], lifelogging within vehicular contexts [16], [17], and thing-logging tailored for the Internet of Things [18].

As an illustration, Kitamura et al. [10] introduced a "food-logging" system that achieved an 88% accuracy in recognizing images containing food, a 73% accuracy in estimating food balance, and provided users with a visual representation of their food journal. Another significant real-world application of visual lifelogging is offering memory support, particularly for individuals with Alzheimer's [19], [20].

B. Emotion recognition

Emotions constitute a crucial aspect of human existence, significantly influencing how individuals perceive and comprehend the world around them [21], [22], [23] and their recognition can be useful including for therapeutic purposes [24], [25], [26]. Emotion recognition employs diverse modalities [27], including facial expressions [28], speech signals [29], physiological responses [23], [30], [31], and textual expressions [32], each encompassing specialized

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methods such as neural networks for facial analysis [28], signal processing for speech [29], biochemical signal analysis for physiological responses [23], [30], [31] and advanced Natural Language Processing techniques for textual understanding [32].

The most used way to recognize emotions is currently represented by the use of EEG sensors that monitor brain activity [23], [30], [31]. Brain–computer interfaces (BCIs), also known as brain–machine interfaces (BMIs), frequently utilize EEG to obtain real-time data for controlling mechanical and electronic devices [33]. Buyser et al. [33] explored the potential of combining smart glasses and consumer-grade EEG/EMG headsets for controlling IoT appliances in smart homes. The system uses smart glasses to detect the user's visual attention on an object and an EEG/EMG headset to trigger commands to the recognized object.

C. *Emotion driven lifelogging*

Emotion-driven lifelogging refers to the process of continuously recording and documenting an individual's life experiences, activities, or events based on changes in their emotional states. EEG lifelogging [34], [35] involves systematically recording electrical activity in the brain, known as electroencephalogram (EEG) data, over an extended period. Widely used in neuroscience and clinical settings to explore brain function, lifelogging involves the continuous monitoring and recording of EEG signals during daily activities or specific experiences [36]. By capturing electroencephalogram signals, EEG lifelogging facilitates the observation of changes in neural patterns associated with key psychotherapeutic processes such as emotional regulation, cognitive processing, and attentional focus [34], [37]. Furthermore, through EEG lifelogging, individual neurobiological profiles are customized, neural biomarkers of therapeutic progress are identified, and the therapeutic process is made more targeted and effective [38], [39].

For example, EEGLog [35] is the first system for EEG logging during music listening, compatible with various EEG devices. Tested on four consumer-grade devices with 24 participants, it enables self-reflection and emotion regulation. The participants, logging data for 4 to 24 days, provided valuable feedback, contributing to the exploration of neural-centric interactions, and encouraging further research in human self-tracking with EEG devices; Memento [34] is an innovative emotion-driven lifelogging system designed for wearables that detects users' emotional changes and initiates lifelogging accordingly, making it the first-of-its-kind system. It integrates EEG and employs a two-phase emotion recognition technique, ensuring efficiency and affordability on wearables. Memento outputs lifelogs tagged with emotional information, potentially enhancing various existing services; BrainAtWork [40] serves as a workplace engagement and task logger, offering users valuable insights into their cognitive states. The system, evaluated in a lab study with eleven participants, successfully classified tasks into central, peripheral, and meta work spheres.

D. *Lifelogging in extended reality*

Extended Reality (XR) [41], [42], [43] is a comprehensive term covering a range of immersive technologies that blend the physical and virtual worlds, providing users with an interactive and enhanced experience. XR includes three main categories: Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR). Although there are many papers that refer to XR, we have identified only one paper in the literature that presents a MR lifelogging application [44].

LifeTags-MR [44] stands out as the pioneering application in achieving mixed reality lifelogging, enabling the overlay of virtual objects onto the physical environment. This innovative approach involves the dual recording of data in Lifelog-MR once the scene is established: eye-level perspective video of the real-world surroundings using the HoloLens built-in video camera and the virtual objects integrated into the user’s field of view. Following this, individual snapshots are extracted from the physical world video at a rate of 2 frames per second, adhering to tag-based lifelog recording guidelines outlined in [45]. These snapshots are then processed by a computer vision service to autonomously identify physical-world objects and concepts. Simultaneously, virtual objects are registered at the same 2 fps rate, ensuring synchronization with the recorded data from the physical world.

III. SYSTEM

In this section, we introduce our lifelogging system, designed to gather data from the Emotiv EPOC X neural headset and capture images using various models of smart glasses across different realms: reality, augmented reality, and virtual reality.

A. *Design requirments*

We have incorporated the following four quality attributes into our system, aligning with the Software Quality Requirements and Evaluation (SQuaRE) ISO/IEC 25000 series of standards adopted also by Euphoria [46]:

Q1. **Adaptability** assesses a system's capacity to adeptly and efficiently respond to changes in its operating environment, such as the addition or removal of new smart devices or software modules. This quality is fundamental to our system, which is intentionally designed to seamlessly accommodate a diverse range of smart devices acquiring data in various formats and store them effectively.

Q2. **Modularity** gauges the extent to which modifications in one component influence others, a critical factor for achieving low coupling. Within our system, modularity stands out as a crucial feature, enabling the seamless integration of a wide array of smart devices that collect data from embedded sensors.

Q3. **Interoperability** describes the extent to which two or more systems can collaborate towards a shared objective, such as exchanging or synchronizing data. This capability enables heterogeneous smart devices and software components to function effectively together.

Q4. **Flexibility** refers to the system's ability to operate reliably in unforeseen contexts, even beyond the scope of initial requirements, with little or no external intervention. Our system must demonstrate flexibility to effortlessly adapt to various scenarios, including capturing data from reality, augmented reality, and virtual reality, while necessitating only minimal adjustments to its architecture.

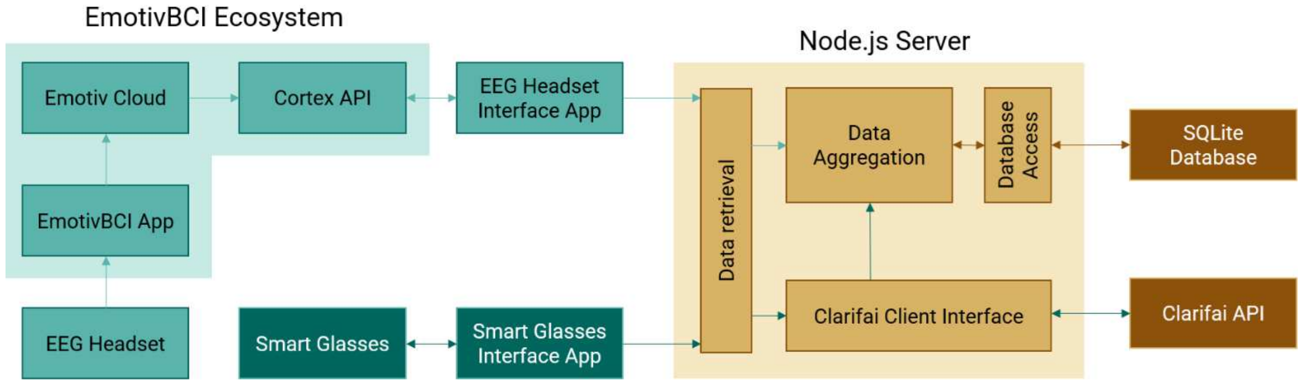

Fig. 1. Block architecture diagram of the proposed lifelogging system showing devices, components, third-party services, and dataflows.

B. Architecture

The system architecture comprises smart devices responsible for data acquisition, transmitting said data to a node.js server application, which then synchronizes in data aggregation module and stores it in SQLite database.

For instance, raw data collected from the 14 electrodes of the Emotiv EPOC X neural headset is retrieved by the EmotivBCI app and securely saved in the Emotiv CLOUD, allowing for unlimited storage and swift processing of brain activity data without local infrastructure constraints. Post-processing of the raw data yields additional information, such as emotional states and facial expressions, with a certain degree of probability. The Cortex API facilitates access to this data in JSON format via websockets using various programming languages. Leveraging a JavaScript application (EEG Headset Interface App, see Fig. 1), we retrieve emotional states from users, forwarding them to our node.js server application through the HTTP post method within the Data Retrieval module.

Furthermore, data from smart glasses—comprising images captured from physical or virtual reality, as well as virtual objects projected within augmented reality scenes—is accessed through a tailored Smart Glasses Interface Application, adapted to the specific type of glasses from which the data is obtained. This data, which includes base64-encoded images, is subsequently transmitted to the node.js application through the HTTP post method within the Data Retrieval module, encapsulated within a JSON object. The node.js server employs the Clarifai Client Interface module to facilitate the transmission of received images to the Clarifai API and the retrieval of extracted concepts from them post-processing.

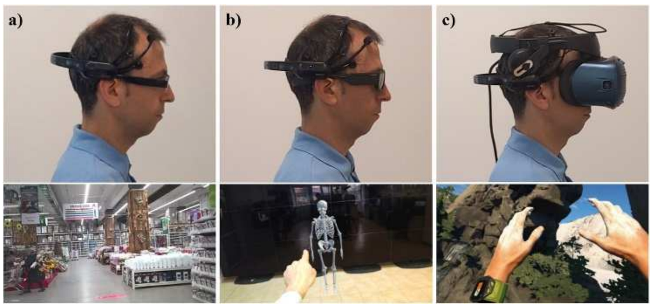

Fig. 2. Examples of scenarios involving the user wearing various types of smart glasses, each offering distinct visual experiences: a) interacting with physical reality, b) engaging with augmented reality overlays, c) immersing oneself in virtual reality environments.

To ensure synchronization of data from both the neural headset and the glasses, the node.js application employs Data Aggregation module. This module harmonizes data from the two sources under a single timestamp, accommodating the different frequencies of data reception – emotional data at 0.1 Hz and images from the glasses, for example, at 2 Hz. The unified data, encapsulated within a JSON object, comprises several crucial components: the image in base64 format along with its acquisition timestamp, concepts and objects extracted by the Clarifai API, the user's emotional states, and potentially the names of virtual objects projected by the AR/VR smart glasses. Finally, the aggregated data can be stored in a database for subsequent lifelog queries, offering various filtering options such as temporal, conceptual, or emotional states.

C. Application scenarios

The lifelogging system outlined demonstrates potential in enhancing personal experiences and immortalizing memories during events or activities across various scenarios and different realms: reality, augmented reality, and virtual reality (see Figure 2).

Based on the type of smart glasses utilized, we encounter the following three usage scenarios:

- Lifelogging in real-life exploring a mall.

In this scenario, the user wears AI-IP60 eyeglasses, which are equipped with a full HD video micro camera boasting a resolution of 1920×1080, as they navigate a shopping mall. Images are captured by an Android Interface Application at a rate of 2 images per second, following its default setting. These images are then transmitted to the data retrieval module of the node.js server, where the Clarifai API is employed to extract concepts and objects from them (see Fig. 3, right).

Simultaneously, the user's emotions are monitored by the Emotiv EPOC X neural headset, providing feedback at a rate of 1 record per 10 seconds, aligning with the standard rate offered by the Cortex API for users without a premium account. Following the processing of raw data obtained from the 14 electrodes of the neural headset on the Emotiv CLOUD server, the user's emotional state is characterized by six fundamental emotions: focus, engagement, excitement, stress, relaxation and interest. Each emotion is represented by a coefficient ranging from 0 to 1, indicating the significance of that particular emotion within the user's overall emotional state (see Fig. 3, left).

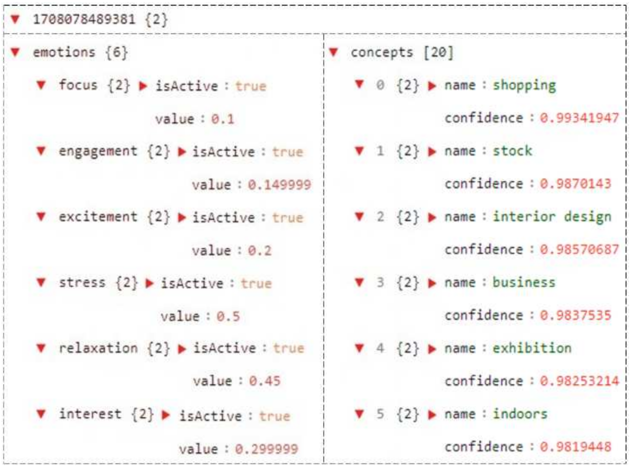

Fig. 3. An example of aggregated data presented in JSON format, extracted from processing images acquired from AI-IP60 smart glasses (right) and analyzing signals from the neural headset EMOTIV EPOC X (left).

- Augmented reality lifelogging for education.

In this scenario, we have the option to utilize Vuzix Blade AR glasses to showcase a 3D projection of a virtual human skeleton, thereby facilitating educational exploration. With this approach, students can engage with interactive 3D models of bones, allowing for a comprehensive understanding of human anatomy. Under the guidance of their instructor, students delve into a detailed examination of each bone, discerning key features and comprehending their respective functions.

To capture the visual lifelog, we can employ a JavaScript application operating within the browser. Once granted permission by the Vuzix Blade AR glasses, this application can access its augmented reality video stream, enabling the capture of screenshots. These screenshots can then be sent to the node.js server for analysis and storage, along with the concepts and virtual objects extracted from the scene. For recording emotions, the procedure is like the one in the previously described scenario.

- Lifelogging in virtual reality through gaming experiences.

Consider the scenario of a passionate gamer named John, who is enthusiastic about both lifelogging and virtual reality (VR), using an HTC Vive headset. John decides to embark on a lifelogging adventure within his beloved VR gaming environment, "The Climb 2."

The HTC Vive headset requires a gaming computer for operation. To lifelog in VR, one could either capture screenshots directly from the computer or develop a VR app in Unity to automatically log objects within the user's field of view in the scene. However, there is a limitation when it comes to wearing the Emotiv EPOC X headset with the HTC Vive. The speakers of the HTC Vive headset come into contact with the neural headset, failing to reach the ear area (see Fig. 2c for details). Consequently, most of the weight of the HTC Vive headset is supported by the neural headset, making prolonged wear impractical for users like John.

IV. Conclusion and Limitations

In this paper we present the technical details of a lifelogging system designed to capture the visual subtleties of daily experiences from reality or provided by various models of AR or VR smart glasses, complemented by the Emotiv EPOC X neural headset for the detection and analysis of emotions. Simultaneously using smart glasses and a neural headset may lead to discomfort due to their physical form factor, weight, and wiring requirements, impacting user comfort and device usability. Therefore, it is advisable for such systems to utilize a single device that combines the functionalities of both smart glasses and neural headsets.

In our future work, we intend to explore the feasibility of incorporating the system into smart environments [47], [48] and hyper-connected cars [49], [50] while also examining its potential utility for individuals with visual [51], [52], [53] or motor impairments[54].

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