Emerging Affect Detection Methodologies in VR and future directions

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ABSTRACT

The uses of Virtual reality are constantly evolving, from healthcare treatments to evaluating commercial products, all of which would benefit from a better understanding of the emotional state of the individual. There is ongoing research into developing specially adapted methods for the recognition of the user's affect while immersed within Virtual Reality. This paper outlines the approaches attempted and the available methodologies that embed sensors into wearable devices for real-time affect detection. These emerging technologies are introducing innovative ways of studying and interpreting emotion related data produced within immersive experiences.

CCS CONCEPTS

• Human-centered computing ⟶ Interaction Paradigms: Virtual reality; • Information systems ⟶ Sentiment analysis; • Human-centered computing ⟶ Interactive systems and tools

KEYWORDS

Virtual reality, Affect, Emotion, Emerging Technologies

ACM Reference format:

FirstName Surname, FirstName Surname and FirstName Surname. 2018. Insert Your Title Here: Insert Subtitle Here. In *Proceedings of ACM Woodstock conference (WOODSTOCK'18). ACM, New York, NY, USA, 2 pages.* https://doi.org/10.1145/1234567890

1 Introduction

The applications for Virtual Reality (VR) are expanding rapidly, from research and training facilities to entertainment and healthcare. VR is no longer exclusive to laboratory settings as recent technological advancements have brought low-cost personal and portable VR headsets to the consumer market. This allowed for the sale of 13.5 million headsets units in 2017 [1]. From a research perspective, VR provides the platform for controlled experimental conditions while granting ecological validity and content resources [2]. Consequently, it is expected that more and more researchers will adapt VR for experimental design and execution. This is evidenced by the fact that there were over a million articles involving VR published in the last decade alone [3].

Regardless of the technological advances providing real time content interaction via input controllers, movement synchronisation and body capture, the emotional state recognition tools are only just emerging, due to the growing demand. The potential applications of affect detection in VR are abundant. With the visions of Affective computing in mind, emotionally intelligent algorithms for VR applications could unlock new paths for interactive realistic experiences, leading to a potentially better understanding of the process of immersion and presence in VR. Simultaneously, quantifying the state of the user can contribute to medical and psychology related applications, either to identify possible pathologies or to assist in the development of well-being tools and health-care related solutions [4]. Most of these applications require real-time data acquisition and vigorous analysis from multichannel sources, which in turn requires further technological and analytical advancement.

2 Related Work

The nature of VR poses limitations to traditional affect detection techniques. The Head-Mounted Displays (HMD) cover almost two thirds of the user's face, which prevents expression detection via conventional camera tracking methods as well as the use of additional, external modalities around the area of the face and the head of the user. Additionally, due to the freedom of movement in room-scale VR experiences, the use of limb-embedded physiological sensors for affect recognition can be often erroneous while also insufficient for affect detection. Explicitly defined and adapted methodologies for affect recognition in VR are required, considering the parameters of the wearability, usability and comfort of the user while also the quality and value of the data handled.

2.1 Affect detection methods

Understanding the emotional state of the user in VR could assist in a range of use cases. It would aid real-time continuous affect recognition and the awareness of the user's state changes, affective design and adaptive control of the surrounding environment. Adaptive control is when specific signals can be utilised to alter the environmental parameters, which in turn can possibly alter the user's affect, as a feedback loop. In research on affective computing for real-time applications, most researchers prefer the use of traditional emotion models, such as the circumflex dimensional model [5]. This model is preferred over others as the various affective states are illustrated within a 2-dimensional space consisting of two primary axes; valence (positive or negative polarity of affect) and arousal (the excitement or intensity of the affective state).

Typically, the most common methods for systematic emotion analysis include biometric signal acquisition (e.g. speech, facial expressions, gestures, physiological signals) and analysis, in conjunction with subjective ratings from users (i.e. self-reports) and behavior-related observations [6]. However, an issue with the use of self-report techniques such as surveys, interviews and self-rating questionnaires is that they are reported to provide highly subjective responses and therefore those responses can be variant between participant results [7], meaning the data obtained often does not correspond to the actual emotional experience and concurrent physiological readings. This effect can be due to the subjective nature of interpersonal and cultural differences when rating emotion [8, 9]. Additionally, the incorporation of self-ratings in VR settings, either verbal or visual, could impede the user's overall experience of presence and immersion while also interrupting the narrative, or indeed any given task [10]. Ideally, researchers and experience designers would benefit from the combination of methods and the utilization of unobtrusive and continuous, objective measures throughout a VR experience.

Apart from conventional unimodal methods such as camera tracking or heart-rate sensors, recent software and hardware prototypes have emerged that combine multimodal approaches and affective read-outs specifically adapted for real-time applications. Commercial technologies including, Emotiv Epoc, LooxidLabs, Enobio, Neurable and EmteqVR [11, 12, 13, 14, 15] have emerged in recent years to provide real-time emotional feedback and affect recognition readings in VR. Although only a small amount of studies using these technologies in VR are published, we were able to gather some of the more relevant findings as well as the practical implications of each technology.

Arousal detection in VR, and especially the detection of stress, has been synonymised with analysing heartrate and electrodermal activity (EDA) changes [16]. The Q sensor by Affectiva [17] a wireless wearable biosensor has been used on a wide variety of studies, including one which investigated the levels of stuttering whilst in anxiety provoking VR environments. [18]. Although the Q sensor is no longer available on the market, Affectiva has designed and developed software solutions for affect detection, offering a software development kit (SDK) for developers using the Unity3D game engine [19].

For valence detection in VR, researchers and developers can utilise technologies that incorporate electroencephalography (EEG) sensors and/or electromyography (EMG) sensors. A recent study aiming to assess emotional responses induced in virtual reality found statistically significant correlations between the reported valence and arousal picture ratings and the EEG bands outputted from the Emotiv EPOC+ 14 channel EEG headset [20]. The system is light and easy to use, involving a short preparation of hydration of the sensors before usage. A limitation when using this headset alongside the HTC Vive VR system is the difficulty of ensuring precise localization of the electrodes which can increase variability of readings between participants but also between sessions of the same participant. Therefore, the Emotiv EPOC+ should be used in the correct context to ensure accurate affect detection.

Additionally, a new wave of portable EEG devices designed for gaming and VR purposes has emerged. The Neurable headset combines EEG sensors with the HTC Vive [21] HMD to ensure consistent localization, allowing user intent to be detected and used as interaction input in virtual environments [22, 23]. Further to this, Neurable have also developed an SDK for Unity 3D for developers [24]. Combining the SDK with the ability to measure gamma waves means there is potential for real-time affect detection in VR, as it has been found that gamma waves correlate with emotionality [25]. In 2016, a study examining the effect of body ownership in virtual reality using a different EEG sensor technology, Enobio (32 sensor set-up) noted that both augmented and virtual reality produce higher brain activity in beta and gamma waves than when present in the real world, which is something to consider when using EEG sensors in Virtual Reality research [26]. Another technology that came out in 2018 is the LooxidLabs headset, which combines 9 dry EEG electrodes and built-in eye tracking cameras into their own VR HMD. Unfortunately, we have little evidence of the system's accuracy of detecting affective states as it has not yet been used in an emotion related VR research study.

Currently, emotional valence is difficult to measure in room-scale VR (non-seated experience) and the current EEG approaches may add additional movement constrains to the user. The method of measuring electromyographic signals (EMG) from the face of the user in VR could give us a reliable indication of their affective state [27]. In this context, another recent example of multimodal affect detection technology is EmteqVR interface, whereby EMG and Photoplethysmograph (PPG) sensors are embedded on a foam VR insert, allowing it's use on commercial head-mounted displays (HMDs). Studies investigating the detection of valence and arousal using this device have shown promising results [28, 29]. EmteqVR and the aforementioned technologies could be improved further by the addition of eye motion tracking, to monitor the individual's gaze while in the virtual environment, thus, allowing a fully rounded analysis of the individual's affective state when experiencing an emotional stimulus.

The technologies presented in this paper, showcase the growing need for multimodal signal analysis to understand the user's emotional state in VR. As sensors become smaller and easier to integrate, we expect a rapid growth of affect-detecting technologies in the next years. The importance of heir unobtrusive wear-ability and usability in VR is paramount for VR research, as low levels of immersion and presence are correlated with hardware related distracting factors and reduced freedom of movement [30]. Ideally, researchers and developers in VR would benefit from the combination of metrics for simultaneous arousal and valence recognition, in user-centred hardware approaches that promote free movement and easy integration with HMDs.

Discussion and Concluding Remarks

The continuously evolving affect recognition technologies for Virtual Reality are forming a strong new emerging technologies category. This could go on to enable new avenues for personalized experiences, user-centered interactions and well-being applications. The affect detection approaches, research findings and limitations per interface are briefly discussed to provide future directions towards further development of VR-embedded biometric sensors for activity and affect recognition for immersive technologies.

ACKNOWLEDGMENTS

This work is supported by the UK EPSRC via the Centre of Digital Entertainment ("Emotion in VR", Grant No. EP/L016540/1).

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