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Emotion Recognition Technologies in Virtual Reality Film Experiences: A Review

Pengcheng Du
Faculty of Creative Industries, City University Malaysia, Petaling Jaya 46100, Selangor, Malaysia

Rina Binti Abd Shukor
University Selangor, Selangor, Malaysia

Zhijing Chen
Creative Computing Institute, University of the Arts London, London WC1V 7EY, UK

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ABSTRACT: Virtual reality (VR) film has emerged as a representative form of immersive media, providing audiences with highly engaging and emotionally rich viewing experiences. Compared with traditional screen-based films, VR films place viewers within a three-dimensional narrative environment and offer a stronger sense of presence, embodiment, and interactivity. As emotional responses play a critical role in audience engagement, narrative comprehension, and overall user experience, emotion recognition has become an increasingly important research direction in VR film studies.

This paper reviews recent advances in emotion recognition technologies applied to virtual reality film experiences. It summarizes commonly used physiological and behavioral signals, including electroencephalography (EEG), electrodermal activity (EDA), heart rate variability (HRV), eye tracking, and facial expression analysis. In addition, representative machine learning and deep learning methods, such as support vector machines, convolutional neural networks, long short-term memory networks, and Transformer-based models, are discussed. The paper further examines key application scenarios, including audience experience evaluation, adaptive storytelling, therapeutic VR, and educational environments. However, existing studies still face challenges regarding multimodal data synchronization, individual variability, and the lack of standardized evaluation frameworks for VR film experiences.

The review indicates that multimodal physiological signal analysis provides an effective and objective approach for understanding emotional responses in immersive narrative experiences. Despite challenges related to individual differences, data synchronization, motion artifacts, and privacy concerns, continuous advances in sensor technology and artificial intelligence are expanding the potential of emotion-aware VR filmmaking. This study provides a theoretical reference for future research and practical guidance for creators seeking to develop more responsive and emotionally engaging virtual reality films.

KEYWORDS: Virtual Reality Film; Emotion Recognition; Physiological Signal Analysis; Affective Computing; Immersive Storytelling

INTRODUCTION

The rapid development of virtual reality (VR) technology has profoundly transformed the production and experience of audiovisual media. By providing immersive and interactive environments, VR enables audiences to experience stories from a first-person perspective and interact with narrative spaces in unprecedented ways. As a result, VR film has emerged as a new cinematic form that extends the language of traditional filmmaking and offers new possibilities for storytelling, emotional engagement, and audience participation.

Compared with conventional films, VR films are characterized by 360-degree viewing, spatial audio, and embodied interaction, all of which significantly enhance the viewer's sense of presence. These features not only alter narrative structures but also intensify emotional responses. Emotional engagement is widely regarded as a key determinant of audience satisfaction, memory retention, empathy, and narrative impact. Therefore, understanding how viewers emotionally respond to VR films has become a critical issue in immersive media research.

Traditional methods for evaluating emotional responses, such as questionnaires and interviews, rely heavily on subjective reports and are often limited by recall bias and interruptions to immersion. In contrast, physiological signal analysis provides objective and continuous measurements of emotional states. Signals such as EEG, EDA, HRV, and eye movements can capture subtle changes in neural, autonomic, and behavioral responses during VR experiences, offering valuable insights into audience engagement.

The integration of affective computing and VR filmmaking has created new opportunities for both academic research and creative practice. Emotion recognition technologies can help filmmakers objectively evaluate audience reactions, optimize narrative pacing, and develop adaptive storytelling systems that respond to viewers' emotional states in real time.

This paper provides a comprehensive review of emotion recognition technologies in VR film experiences by analyzing physiological signals, machine learning approaches, and practical applications. It also discusses current limitations and proposes future research directions for emotion-aware immersive storytelling.

Figure 1. Emotion Recognition Framework in VR Films

THEORETICAL FRAMEWORK

The study of emotion recognition in virtual reality film experiences draws upon several interdisciplinary theoretical foundations, including affective computing, immersive storytelling, presence theory, and psychophysiology.

The concept of affective computing was introduced by Rosalind Picard (MIT researcher and author of *Affective Computing*), who defined it as the development of systems capable of recognizing, interpreting, and responding to human emotions. This framework established the technological basis for using physiological and behavioral signals to infer affective states.

Presence theory is another important foundation. Mel Slater (virtual reality researcher) described presence as the subjective feeling of "being there" within a mediated environment. In VR films, a strong sense of presence enhances emotional involvement and contributes to more intense and authentic reactions.

Immersive storytelling theory emphasizes the role of embodiment, interactivity, and spatial narrative design in shaping audience experiences. Unlike traditional films, VR narratives place viewers inside story worlds, making emotional responses more immediate and personally meaningful.

From a psychophysiological perspective, emotions are associated with measurable changes in brain activity, autonomic nervous system responses, and observable behavior. EEG reflects neural processing, EDA measures sympathetic arousal, HRV captures emotional regulation, and eye tracking reveals attentional allocation.

Together, these theoretical perspectives provide a comprehensive framework for understanding how emotion recognition technologies can be applied to evaluate and optimize VR film experiences.

These theories collectively explain how immersive environments influence emotional perception and why physiological computing is suitable for evaluating audience experiences in VR films.

EMOTION RECOGNITION IN VIRTUAL REALITY FILM EXPERIENCES

Emotion recognition plays a crucial role in understanding audience responses to immersive narratives. In traditional cinema studies, emotional engagement is often assessed through self-report scales and interviews. Although these methods provide useful subjective insights, they are limited in their ability to capture rapid and unconscious affective changes.

In VR film experiences, emotion recognition technologies offer a more objective and fine-grained approach. Physiological signals can be continuously recorded throughout a viewing session, enabling researchers to identify specific scenes that evoke excitement, fear, empathy, or relaxation. This information can be used to evaluate narrative effectiveness, compare different editing strategies, and optimize cinematic techniques.

Emotion recognition also supports personalized and adaptive storytelling. By analyzing real-time affective responses, a VR system may dynamically modify music, lighting, character behavior, or narrative branches to maintain engagement and emotional resonance. Such emotion-aware systems represent a significant shift from static storytelling toward responsive cinematic experiences.

Beyond entertainment, emotional monitoring is valuable in therapeutic and educational contexts. In reminiscence therapy, for example, positive emotional responses may indicate effective stimulation of autobiographical memory and social engagement.

PHYSIOLOGICAL SIGNALS FOR EMOTION RECOGNITION

Physiological signals provide objective indicators of emotional states and are widely used in affective computing research.

Table 1. Common Physiological Signals Used in VR Emotion Recognition

Signal	Measures	Emotional Meaning
EEG	Brain activity	Attention / Valence
EDA	Skin conductance	Arousal
HRV	Heart rhythm	Stress / Relaxation
Eye Tracking	Gaze & pupil	Attention
Facial Expression	Facial movement	Emotion category

Electroencephalography (EEG)

EEG measures electrical activity generated by the brain and offers millisecond-level temporal resolution. It is particularly useful for detecting neural correlates of attention, arousal, and emotional valence. Common EEG features include power spectral density in alpha, beta, theta, and gamma bands, as well as frontal alpha asymmetry.

Electrodermal Activity (EDA)
EDA measures skin conductance changes associated with sweat gland activity. It is considered a reliable indicator of physiological arousal and is frequently used to assess suspense, excitement, and stress during immersive experiences.
Heart Rate Variability (HRV)
HRV reflects fluctuations in the intervals between heartbeats and provides insight into autonomic nervous system balance. Lower HRV is often associated with stress, whereas higher HRV may indicate relaxation and emotional regulation.
Eye Tracking
Eye tracking captures gaze direction, fixation duration, saccades, and pupil dilation. These measures reveal attentional focus and cognitive load and help identify visual elements that attract viewers' interest.
Facial Expression Analysis
Computer vision techniques can classify facial expressions into emotional categories such as happiness, sadness, fear, and surprise. Despite occlusion challenges posed by head-mounted displays, recent approaches use lower-face cameras and multimodal fusion to improve recognition accuracy.
Additional Signals
Respiration, skin temperature, electromyography (EMG), and body movement can provide supplementary information and enhance multimodal emotion recognition systems.

MACHINE LEARNING METHODS FOR EMOTION RECOGNITION

The classification of emotional states from physiological signals depends on machine learning and deep learning algorithms.
Support Vector Machine (SVM) is one of the most widely used algorithms in affective computing. It performs well on small and medium-sized datasets and is effective in high-dimensional feature spaces.
Random Forest (RF) combines multiple decision trees and offers robustness against overfitting while providing feature importance estimates.
Convolutional Neural Networks (CNNs) automatically learn spatial patterns from transformed signal representations, such as EEG topographical maps and spectrograms.
Long Short-Term Memory (LSTM) networks are designed to capture temporal dependencies in sequential data, making them suitable for modeling time-varying physiological responses.
Hybrid CNN-LSTM architectures combine spatial and temporal learning capabilities and have shown strong performance in multimodal emotion recognition.
Transformer-based models use self-attention mechanisms to model long-range dependencies and cross-modal relationships. These models are increasingly used in advanced affective computing applications.
Traditional machine learning methods such as SVM and Random Forest are computationally efficient and suitable for smaller datasets, whereas deep learning approaches achieve higher recognition accuracy but often require large-scale labeled data and higher computational resources. Transformer-based architectures further improve multimodal fusion capabilities but remain challenging for real-time VR applications due to latency and hardware constraints.

Table 2. Comparison of Machine Learning Methods

Method	Strength	Limitation
SVM	Small datasets	Limited temporal modeling
CNN	Spatial feature learning	Requires more data
LSTM	Temporal modeling	Training complexity
Transformer	Multimodal fusion	High computational cost

APPLICATIONS OF EMOTION RECOGNITION IN VR FILMS

Emotion recognition technologies have been applied in several important areas of VR film research and practice.

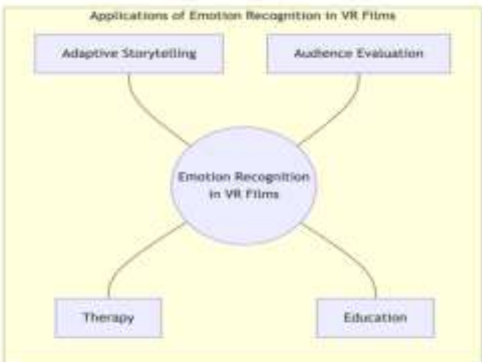

Figure 2. Applications of Emotion Recognition in VR Films

Audience Experience Evaluation
Researchers can objectively assess engagement, immersion, and emotional intensity by correlating physiological responses with specific narrative events.
Narrative Optimization
By identifying scenes that evoke strong emotional reactions, filmmakers can refine pacing, visual composition, and sound design to improve storytelling effectiveness.
Adaptive Storytelling
Real-time emotion recognition enables VR systems to dynamically alter narrative pathways, environmental elements, and character interactions according to viewers' emotional states.
Therapeutic Applications
Emotion-aware VR films are increasingly used in mental health interventions, reminiscence therapy, stress reduction, and exposure therapy.
Educational Applications
In educational settings, affective feedback can be used to evaluate learner engagement and optimize immersive instructional content.

CHALLENGES AND FUTURE TRENDS

Despite significant progress, several challenges remain.

First, physiological responses vary substantially across individuals, making it difficult to develop universally applicable models. Second, head and body movement in VR environments can introduce noise and motion artifacts into sensor data. Third, there is a lack of large-scale public datasets specifically designed for VR film experiences. Fourth, physiological data contain sensitive personal information, raising concerns about privacy, informed consent, and ethical use.

Future research is expected to focus on real-time emotion-adaptive VR films, integration with artificial intelligence-generated content (AIGC), lightweight wearable sensors, and standardized multimodal evaluation frameworks. As these technologies mature, emotion recognition will become increasingly central to immersive storytelling and interactive media production.

CONCLUSION

Emotion recognition technologies have become an important methodological and creative tool for understanding audience responses in virtual reality film experiences. By combining physiological signal analysis with machine learning and multimodal data fusion, researchers and creators can objectively assess emotional engagement and gain deeper insights into immersive storytelling.

This review summarized the theoretical foundations, commonly used biosignals, major recognition algorithms, application scenarios, and emerging trends in this field. The findings demonstrate that emotion recognition has significant potential to support audience experience evaluation, narrative optimization, adaptive storytelling, and therapeutic applications.

Although challenges remain in data quality, individual variability, and ethical governance, continuous advances in sensor technology and artificial intelligence are rapidly expanding the possibilities of emotion-aware VR filmmaking. As immersive media continues to evolve, emotion recognition is expected to play an increasingly important role in creating more responsive, personalized, and meaningful cinematic experiences.

In the future, the convergence of affective computing, artificial intelligence, and immersive cinema may fundamentally transform how audiences interact with narrative media.

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