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論文審査の要旨及び審査員

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論文審査の要旨 (2000 字程度)

This thesis is titled “Cross-sensory EEG emotion recognition under multimodal stimulation.” To overcome the problem of sensory-dependent EEG emotion recognition in previous study, the author aimed to investigate EEG responses to multimodal stimulation and resolve the core issue of cross-sensory EEG emotion recognition in affective Brain-Computer Interface (a-BCI) systems. It comprises five chapters.

Chapter 1 establishes the foundational motivations and background of this research by thoroughly examining issues related to cross-sensory EEG emotion recognition under multimodal stimulation. The author reviewed previous studies and discussed the EEG-based a-BCI systems that inspired this study's objective, research method, and strategy. This brought the foundational understanding of this research topic and the importance of addressing cross-sensory EEG emotion recognition.

Chapter 2 explores EEG patterns under multimodal emotional stimulation. An experiment was designed to investigate six different conditions (two emotions: pleasure, unpleasure; three sensory modalities: audio, visual, and audio-visual). It pioneers a comparative study of emotion and sensory factors affecting cross-sensory emotion EEG. Utilizing power spectral density analysis in conjunction with brain functional area and sub-band analysis, this study examined the relative changes in emotion and sensory-related patterns across the six conditions with feature analysis. The findings revealed spatial, spectral, and quantitative characteristics of emotion and sensory-related patterns. Specifically, the author indicated that: emotion-related changes exhibited greater diversity in regional changes of the brain in spatial aspect; emotion-related changes exhibited greater diversity in band-spectral aspect; sensory-related changes exhibited greater diversity in quantitative-spectral aspect. This chapter deepens understanding of how emotion and sensory patterns change in EEG data under multimodal stimulation.

Chapter 3 focuses on the design and implementation of a method for cross-sensory EEG emotion recognition. Based on feature analytic results from Chapter 2, the author developed a robust method for extracting and recognizing emotional components under cross-sensory situations. The proposed method was termed Filter Bank Adversarial Domain Adaptation with Riemannian Feature (FBADR). In the proposed method, frequency variety from emotion was extracted by filter banks with ensemble learning, spatial diversity from emotion was extracted by Riemannian method, and sensory-related difference was reduced by adversarial domain adaptation. The author examined the proposed method from experimental analysis, including baseline comparison, comparative classification and robustness verification. The results revealed the method's effectiveness, achieving a state-of-the-art

accuracy of $89.01\% \pm 5.06\%$ for cross-sensory emotion recognition, indicating its potential applicability in the a-BCI field.

Chapter 4 comprehensively discusses the individual and collective contributions of the cross-sensory EEG analytic results and methods presented in Chapters 2 and 3. The author emphasized the first-time achievement of cross-sensory EEG emotion recognition, independent of sensory input type, and evaluated the effectiveness of the proposed model through comparison with previous studies. The author also discussed the broader implications of the research, suggesting that the cross-sensory emotion EEG features analytic results and realization of cross-sensory EEG emotion recognition could benefit diverse cross-sensory processing and further applications beyond the scope of this study. The chapter concludes with an analysis of study limitations and suggestions for future research.

Chapter 5 concludes this thesis by summarizing the comprehensive approach undertaken to investigate and achieve cross-sensory EEG emotion recognition under multimodal stimulation. The author underscored the thesis' contributions to understanding the neurological evidence of emotion and sensory patterns, as well as the practical achievement of cross-sensory EEG emotion recognition.

In summary, this thesis presented an essential and systematic exploration of cross-sensory EEG emotion recognition. Through the acquisition of cross-sensory emotion EEG data, the analysis of emotion and sensory-related pattern under cross-sensory emotion EEG, and the development of cross-sensory EEG emotion recognition method, this thesis significantly advances the understanding and capabilities of a-BCI systems. Therefore, this thesis meets the criteria to complete the degree of Doctor of Philosophy.

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