論 文 内 容 の 要 旨

博士論文題目　Neural decoding of sentences using synchronization between EEG and speech rhythm

（脳波と音声リズム間の位相同期に基づく文の脳情報デコーディング）

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要　　旨

Recent research attempts an electroencephalogram (EEG)-based speech recognition (neural decoding of speech) during speech perception or imagined speech for providing a means of communication for patients with severe motor disabilities. The goal of the thesis is to propose novel features based on knowledge of neurophysiology for the neural decoding because the previous research is performance-oriented without the understanding of the underlying neural mechanism. For the purpose, the thesis focused on neural phase synchronization with speech. The previous magnetoencephalography research had shown that synchronization during speech perception enables speech to be classified. The thesis investigated whether the synchronization enables both perceived and imagined speech to be classified using EEG.

Experiment 1 investigated the performances in EEG-based decoding of three Japanese spoken sentences using different classifiers from the previous research (template matching: baseline, logistic regression, support vector machine (SVM), and random forest) and using phase information in multiple frequency bands relevant to linguistic processing. The trained models were evaluated by subject-dependent and -independent manners. Results showed the best accuracies achieved 50.0% in SVM trained by theta and 50.5% in SVM trained by multiple frequency bands (delta, theta, alpha, beta, and gamma) in subject-dependent and -independent classification, respectively.

Experiment 2 investigated whether EEGs during imagined speech synchronize with the rhythm of the imagery. Because of the unobservable nature of the speech imagery, the imagined speech was replaced with the overt counterpart. I regressed three types of overt nonsense speech envelopes

from EEG during the speech imagery and calculate the correlation between the regressed envelope and the overt speech envelope. The template matching classified the speech to clarify whether EEG phases during the imagined speech are modulated depending on the speech imagery. The variability of the duration of the imagined speech across trials was corrected using dynamic time warping (DTW). Results showed a significant correlation between the EEG-based regressed envelope and the overt speech one. The average classification accuracy achieved 38.5%, which significantly outperformed a chance of rate (33.3%). In Experiment 3, the synchronization during the imagined speech in the linguistic relevant frequency bands (from delta to gamma) and classification performances was investigated using meaningful sentences. PLVs were calculated per frequency band. The DTW-based template matching and SVM trained by features extracted using a common spatial pattern classified three types of speech. As results, the theta band showed the marginally significant PLVs. The DTW-based template matching trained by theta phase patterns achieved marginally significant performances (43.1%) against the chance rate (33.3%) in the subject-dependent classification. These results suggest that the EEG phase information induced by neural phase synchronization are enable to classify perceived speech and imagined speech.

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（論文審査結果の要旨）

The goal of the thesis is to propose novel features based on knowledge of neurophysiology for the neural decoding because the previous research is performance-oriented without the understanding of the underlying neural mechanism. For the purpose, the thesis focused on neural phase synchronization with speech. The previous magnetoencephalography research had shown that synchronization during speech perception enables speech to be classified. The thesis investigated whether the synchronization enables both perceived and imagined speech to be classified using EEG. The thesis conducted three experiments. The first experiment investigated the performances in EEG-based decoding of three Japanese spoken sentences using different classifiers from the previous research (template matching: baseline, logistic regression, support vector machine (SVM), and random forest). Results showed the best accuracies achieved 50.0% in SVM by multiple frequency bands (delta, theta, alpha, beta, and gamma). The second experiment 2 investigated whether EEGs during imagined speech synchronize with the rhythm of the imagery speech. Results showed a significant correlation between the EEG-based regressed envelope and the overt speech one. The average classification accuracy achieved 38.5%. In the last experiment, the synchronization during the imagined speech in the linguistic relevant frequency bands (from delta to gamma) and classification performances was investigated using meaningful sentences. The DTW-based template matching trained by theta phase patterns achieved marginally significant performances (43.1%) against the chance rate (33.3%) in the subject-dependent classification. The thesis succeeded in demonstrating the neural phase information

The research proposed solutions to the problems which haven't been solved and series of his research resulted in two journal papers, one peer reviewed international conference paper, and three domestic conference papers. As a result, the thesis is sufficiently qualified as Doctoral thesis of Engineering.