論 文 内 容 の 要 旨

博士論文題目　Neural Decoding of Electrocorticographic Signals
（皮質脳波を用いた脳情報デコーディング）

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（論文内容の要旨）

Over the last decade, neural decoding technology based on machine learning has enabled us to extract fine information on visual experiences and motor commands from measured neural signals, which is becoming a powerful tool for investigating neural representations and generating commands for controlling brain- machine interfaces (BMIs). To extract information with high predictive performance, neural recording methods that provide high spatiotemporal resolution and signal stability are required. One candidate is electrocorticogram (ECoG), which measures population activity of neurons with electrodes placed on the surface of the brain. Here, with the aim of high-performance decoding with ECoG, we tested the utility of ECoG systems in animal and human studies, and improved techniques to extract information from ECoG data. As the first contribution of this thesis, the signal stability of ECoG responses recorded via a newly developed high-density mesh electrode array was tested. Collaborators applied it to the visual cortex in rats and this thesis demonstrates above-chance, generalized decoding performance for simple visual stimulation, using six hours of continuous data (chapter 2). Second, by applying decoding analysis to simultaneously recorded ECoG, LFP, and MUA signals from the monkey IT cortex, extractable information on visually presented objects was compared. The resultant decoding performance with ECoG was high and comparable to LFP and MUA (chapter 3). Next, ECoG was used to investigate how face-selective regions and written word-selective regions are distributed on the human cortex, which is considered a challenging task with fMRI. Results reveal that there exist multiple, separate face- and written word-selective regions in the human cortex (chapter 4). Finally, using ECoG responses from human patients when they viewed objects, efficient input signal features for decoding analysis were explored. Spectral powers, phases, and temporal correlations of ECoG signals were used as input features, and the decoding performances were compared. Results show the performance using temporal correlations between ECoG electrodes is higher than using spectral powers and phases in individual electrodes (chapter 5). Those results suggest that combining ECoG recordings and neural decoding techniques is a powerful approach for extracting neural information, and we can considerably improve a decoder's predictive performance by using signal features that take into account fine temporal patterns in ECoG signals.

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（論文審査結果の要旨）

脳における情報処理の仕組みを解明するには，高い時空間解像度を持つ計測が必要であるが，これまでの主流である fMRI は時間解像度，頭皮脳波は空間解像度が不足していた．
本研究では皮質脳波(ECoG)が有望な計測法であることを示したものである．

本研究ではまず，新たに開発された高密度 ECoG 電極を用いることを提案している．これは皮質の上に直接電極を置くので高い時間解像度と S/N を持つ上，高密度化により空間解像度も高めている．動物実験により，その安定性を確認するとともに，高い空間解像度を利用して皮質脳波と LFP や MUA の関係をも明らかにした．

さらにヒトを対象とした実験により，その神経科学における有効性を示した．具体的には，顔を認識する神経細胞と単語を認識する神経細胞が混在する領域において，それぞれがどのように表現されているかを明らかにした．また，ECoG 信号の時間相関に情報が含まれていることを明らかにした．

以上をまとめると，本論文は，ECoG による脳機能解明の手法を提案するとともに，従来の手法では解明できない知見を実際に示した研究であり，博士（理学）の学位に値するものと認められる．