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MusicalBSI - musical genres responses to fMRI signals analysis with prototypical model agnostic meta-learning for brain state identification in data scarce environment

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ABSTRACT

Functional magnetic resonance imaging is a popular non-invasive brain-computer interfacing technique to monitor brain activities corresponding to several physical or neurological responses by measuring blood flow changes at different brain parts. Recent studies have shown that blood flow within the brain can have signature activity patterns in response to various musical genres. However, limited studies exist in the state of the art for automatized recognition of the musical genres from functional magnetic resonance imaging. This is because the feasibility of obtaining these kinds of data is limited, and currently available open-sourced data is insufficient to build an accurate deep-learning model. To solve this, we propose a prototypical model agnostic meta-learning framework for accurately classifying musical genres by studying blood flow dynamics using functional magnetic resonance imaging. A test with open-sourced data collected from 20 human subjects with consent for 6 different mental states resulted in up to 97.25 ± 1.38% accuracy by training with only 30 samples surpassing state-of-the-art methods. Further, a detailed evaluation of the performances confirms the model's reliability.

1. Introduction

Mental state identification is the process of determining a person's cognitive or emotional state through the analysis of neural signals and can be used for brain-computer interfacing (BCI). It has broad applications ranging from medical rehabilitation to neuroprosthetics [1]. Various modalities are utilized in mental state identification for capturing and interpreting neural signals, such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and brain implants (brain chips) [2]. Functional Magnetic Resonance Imaging (fMRI) detects adaptations in blood flow, providing detailed spatial resolution, but exhibits a lower temporal resolution [3]. Electroencephalography (EEG) has enhanced temporal resolution, making it ideal for real-time applications, but it has limited spatial resolution [4]. Brain implants, also known as brain chips, provide precise spatial resolution and are used in research, medical treatments, and the developing field of BCI to improve cognitive abilities. However, this is a surgically invasive procedure [5]. BCI with fMRI, EEG, and brain implants in neuroscience and tech provide promise for revolutionary healthcare applications, communication, and human enhancement [6]. Revolutionary neuroimaging methodologies such as fMRI amplify BCIs by furnishing accurate spatial localization of neural substrates and conveying comprehensive whole-brain neurophysiological insights [7]. The non-invasive nature and improved temporal resolution of fMRI enables rapid deployment for dynamic brain activity tracking [8]. Thus, exploring fMRI towards BCI development has proved to be a revolutionary breakthrough in neurotechnology.

The BCI market has been witnessing steady expansion. The global market for brain-computer interfaces will witness a robust Compound Annual Growth Rate (CAGR) of 15.11%, valued at $1505.06 million in 2021, and is predicted to extend, will arrive at a value of $5340.38 million by 2030, as stated by Strategic Market Research [9]. The Market share is chiefly directed by North America, with Europe ensuing proximately. A BCI operates as a communication and control system, interpreting the human mind into concrete engagements devoid of depending on conventional neural pathways and muscles. This technology empowers individual entities to straightaway control machines,

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