Abstract

The emergence of neurodevelopmental disorders among children is a significant concern that demands attention and support from society as a whole. Autism is a complex neurodevelopmental condition that occurs within the first three to seven years of human life. Autism is known as autism spectrum disorder (ASD) as there is a wide variability of symptom expression and functioning. ASD is characterized by impairments in social interaction and communication, which commonly exhibit repetitive behaviors and restricted interests. As the exact cause of ASD is unknown, there is no medical detection or cure for autism. However, the identification of early ASD biomarkers is crucial to support the development and life outcomes of an autistic child.

This thesis aims to identify early cognitive and neurodevelopmental disabilities by using resting-state neuroimaging signals. ASD impacts the nervous system and affects the overall cognitive, emotional, social, and physical health of the affected individual. This study uses magnetoencephalogram (MEG) signal, a non-invasive and reference-free neuroimaging method, to measure brain activity. The MEG signal can be used to identify neural markers of autism in young children as it offers good spatial resolution along with excellent temporal resolution (in order of milliseconds); also, MEG signal acquisition requires less preparation time which is suitable for young children. By analyzing large-scale neuromagnetic responses in a machine-learning classification framework, we distinguished autistic children from age and gender-matched controls. Here, the temporal structure of the MEG signal was considered to investigate spectral, spatial, and functional connectivity features to identify unique attributes that effectively discriminate autistic from normal/ typically developing (TD) children. For pattern classification, this study explores artificial neural networks and support vector machine-based modeling schemes to differentiate ASD from TD children by analyzing their ongoing brain responses.

In the spectral domain analysis, we have proposed a novel feature, the preferred phase angle (PPA), which utilizes frequency band-wise phase consistency. We demonstrated that the PPA-based classifier outperformed the conventional power spectral density-based classifier. The complementarity of power and phase-based spectral features are demonstrated in this work using a fusion-based machine learning framework.

To identify the possible cortical spatial pattern behind the autism spectral disorder, we have introduced a common spatial pattern (CSP) based machine learning approach using MEG signals. We have proposed spatial filtering-based logarithmic band power (LBP) features and demonstrated that our proposed feature performed better than the conventional logarithmic variance (LV) spatial pattern, over the entire frequency range. In frequency band-wise analysis, the high gamma frequency band performed best with the proposed feature. The most distinct spatial pattern in autistic children is observed in the occipital region over the whole frequency range. This study demonstrates that spatial brain activation patterns can be utilized as potential biomarkers of autism in young children.

To understand how different brain regions in a neuronal system interact, functional connectivity analysis using the coherence feature is introduced. Coherence-based connectivity network both region-wise and whole-brain-wise reflects frequency-band-specific connectivity patterns and their relationships with the symptoms of autism. Overall, the connectivity analysis gives further insights into autism among young children which helps us to improve autism detection using the MEG signals.

With the use of three-dimensional domains—time, frequency, and space—this thesis, as a whole, explores a new perspective on the applicability of machine learning approaches to the detection of autism utilizing neurosignal-based biomarkers.

Keywords: Autism Spectrum Disorder; Magnetoencephalography; Preferred phase angle; Common spatial pattern; Logarithmic band power; Functional connectivity; Coherence; Feature fusion; Classification.