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Tracking and Visualizing Dynamic Structures in Multichannel EEG Coherence Networks

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Abstract

An electroencephalography (EEG) coherence network represents functional brain connectivity, and is constructed by calculating the coherence between pairs of electrode signals as a function of frequency. Visualization of coherence networks can provide insight into unexpected patterns of cognitive processing and help neuroscientists understand brain mechanisms. However, most studies have been limited to static EEG coherence networks or were focused on individual network nodes. In this poster, we consider groups of nodes for visualizing the evolution of network communities and their corresponding spatial location. We use a timeline-based representation to provide an overview of the evolution of functional units (FUs) and their corresponding spatial location over time. This representation can help the viewer identify functional units across the whole time window, as well as to identify relations between functional units and brain regions. In addition, a time-annotated FU map is provided to facilitate comparison of the behavior of the nodes between consecutive FU maps. This time-annotated FU map provides more detail about how the classification of electrodes into FUs changes over time. Our method is proposed as a first step towards a complete analysis of EEG coherence networks.

Categories and Subject Descriptors (according to ACM CCS): H.5.0 [Information Interfaces and Presentation]: General—

1. Introduction

A brain functional network is an abstract representation of brain organization, in which vertices represent distinct brain regions and connections are relationships between these regions. Visualization of brain networks can provide insight into unexpected patterns in cognitive processing and help neuroscientists to understand how the brain works. An important goal of visualization is to facilitate the discovery of evolution of brain connectivity at the group level. However, recent techniques focus on the visualization of groups of vertices either in static networks or dynamic networks without considering the spatial information. Visualization approaches which do not take into account the spatial information make it hard to identify how the functional pattern is related to brain areas and the underlying mechanism.

An EEG coherence network is a model of functional brain connectivity. For a multichannel EEG coherence network, the traditional network visualization suffers from the problem of visual clutter. To solve this problem, a data-driven approach was proposed to divide electrodes into several functional units (FUs) [TMR08]. Each FU is a set of spatially connected electrodes. For a certain EEG coherence network, FUs can be derived by the FU detection method and displayed in a so-called FU map (Fig. 1).

Our goal is to provide techniques for visualizing dynamic structures, including the FUs and brain areas, in EEG coherence networks. The following tasks are supported: **Task 1:** Discover how FUs are changing over time; **Task 2:** Explore how the functional units are related to brain areas; **Task 3:** Compare FU maps between consecutive time steps.

2. Methods

Before visualizing the evolution of FUs in a dynamic coherence network, we first introduce a dynamic FU identification framework, similar to what Greene [GDC10] did, to detect dynamic FUs. A dynamic FU is a series of similar FUs existing in consecutive coherence networks. This dynamic FU can be interpreted as a stable functional connectivity pattern in cognitive processing.

We use a timeline-based representation to represent the evolution of FUs over time for task 1 (Fig. 2). In order to easily capture the relation between functional units and brain areas for task 2, the spatial information is encoded in the line color. In the timeline-based view, the lines are colored the same as the corresponding electrodes in the EEG placement layout (Fig. 3). In this layout, electrodes are partitioned into several regions based on the EEG placement system [OP01] and each region has a unique color generated from [HB03]. For tracking the evolution of dynamic FUs easily for task 1, we order FUs by their position, and order the electrodes within FUs based on the brain region to which the electrode belongs for each time step (Fig. 2).

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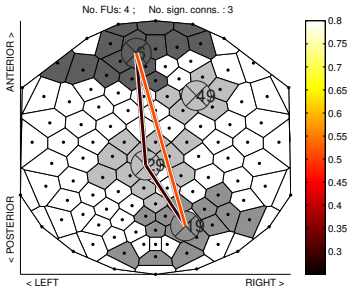

Figure 1: *Example of an FU map. Spatial groups of similarly colored cells correspond to FUs, while white cells belong to small FUs whose size is less than 4. Circles overlayed on the cells represent the barycenters of the FUs that are connected by lines whose color indicates average coherence between all electrodes of the FUs (see color bar) [TMR08].*

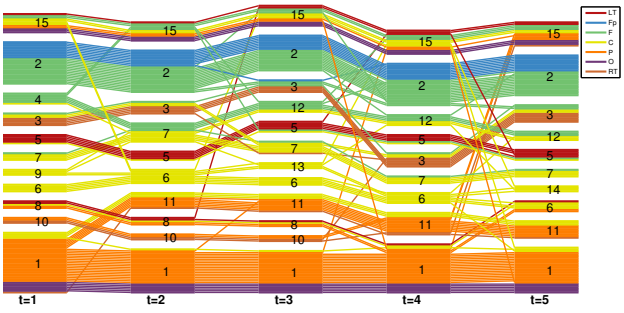

Figure 2: *Example of the timeline-based representation of the evolution of dynamic FUs across five time steps for frequency band $8-12Hz$. For each time step, the FUs are ordered by their barycenter and within each FU the brain regions are ordered as follows: LT, Fp, F, C, P, O, RT (Fig. 3). The line color reflects the location of the electrodes (see the legend). The number stacked on the lines corresponds to the dynamic FU and the largest number corresponds to the set of electrodes that belongs to an FU with size less than 4.*

In Fig. 2, the largest two dynamic FUs D_2 and D_{14} exist for all time steps. D_2 is located in the anterior part and D_{14} is located in the posterior part of the brain. D_2 and D_5 have stable members over time. The main members of D_2 come from the Fp and F regions, while the main members of D_5 come from the LT region. The most variable region is C, and electrodes belonging to this region usually are part of small FUs. The most stable region is Fp, all electrodes in this region are part of D_2 except at time step 3.

To focus on specific changes, we provide a time-annotated FU map to facilitate the comparison of FU maps between consecutive time steps for task 3, as shown in Fig. 4.

In this time-annotated FU map, the color of the cell represents the dynamic FU to which the corresponding electrode belongs at time step t, and the color of the inner circle represents the dynamic FU to which the electrode belongs at time step $t-1$.

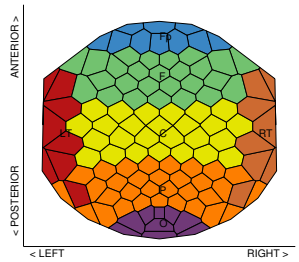

Figure 3: *119 electrodes, represented by cells, are divided into seven regions based on the electrodes placement: LT (Left Temporal), Fp (Fronto polar), F (Frontal), C (Central), P (Parietal), O (Occipital), RT (Right Temporal). Each region has a unique color.*

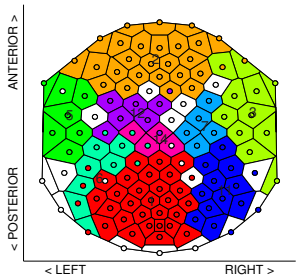

Figure 4: *Time-annotated FU map at time step 5 (see Fig. 2). The numbers correspond to the labels of the dynamic FUs. The color of the cell represents the dynamic FU to which the corresponding electrode belongs at timestep 5, and the color of the inner circle overlaid on the cell represents the dynamic FU to which the corresponding electrode belongs at timestep 4. The white cells belong to the FUs with size smaller than 4.*

3. Conclusions

We use a timeline-based representation to visualize dynamic FUs and corresponding spatial information across time. This can be used to investigate the relation between functional units and brain regions. The time-annotated FU map is used to compare electrode grouping at consecutive time steps in detail. This can help viewers compare FU maps at node level, as well as group level.

One limitation of our methods is that there is no visualization of relationships between FUs over time. We plan to look into this in future work.

Acknowledgements

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