Tracking and Visualizing Dynamic Structures in Multichannel EEG Coherence Networks

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Introduction

An EEG coherence network is a model of functional brain connectivity. For a multichannel EEG coherence network, it can be visualized by an FU map (Fig. 1).

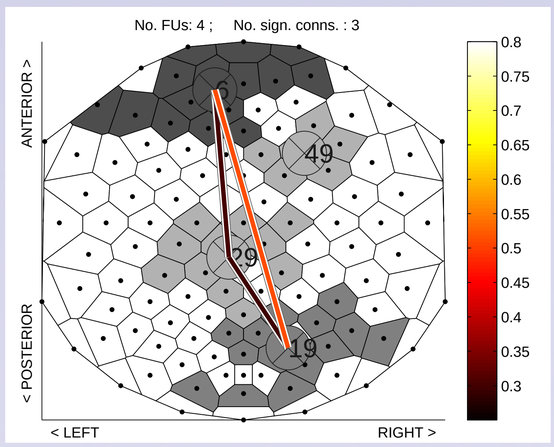

Figure 1: *Example of an FU map. Spatial groups of similarly colored cells representing electrodes correspond to FUs, while white cells belong to small FUs whose size is less than 4. Circles overlayed on the cells represent the barycenters of the FUs and are connected by lines whose color indicates average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

For an evolving coherence network, our goal is to provide techniques for visualizing dynamic structures in EEG coherence networks over time.

Dynamic FU

A dynamic FU D_i consists of a series of similar FUs $C_{t,j}$ at consecutive time steps, with at least one node in common (Fig. 2). Each dynamic FU contains at most one FU at each time step, and each FU is included in only one dynamic FU.

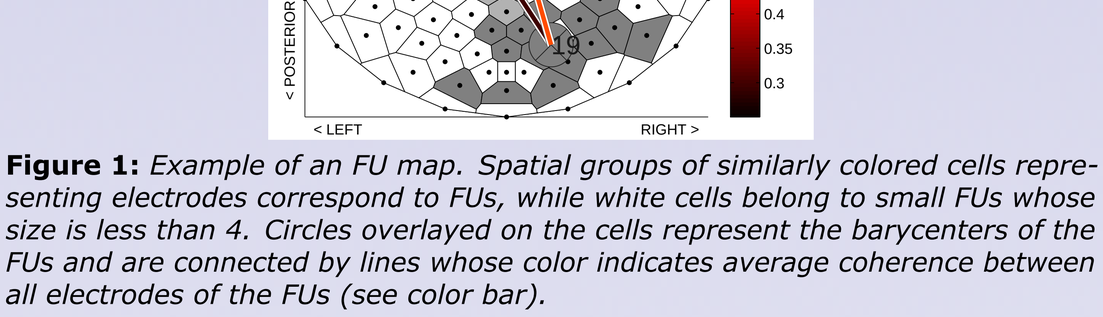

Figure 2: *Synthetic FU maps with five dynamic FUs tracked over five time steps. Each cell corresponds to an electrode. Cell colors indicate different dynamic FUs: red represents $D_1 : \{C_{1,1}, C_{2,1}, C_{3,1}, C_{4,1}, C_{5,1}\}$, blue represents $D_2 : \{C_{1,2}\}$, cyan represents $D_3 : \{C_{1,3}, C_{2,3}, C_{3,3}, C_{4,2}, C_{5,3}\}$, green represents $D_4 : \{C_{2,2}, C_{3,2}\}$, and magenta represents $D_5 : \{C_{5,2}\}$; the white cells represent electrodes belonging to small FUs with size less than two.*

Timeline-based Representation

A timeline-based representation is used to visualize the evolution of FUs over time (Fig. 3). In the timeline-based view, the lines represent electrodes, and a bundle of lines represents an FU. FUs are ordered based on their barycenter for each time step. The spatial information is encoded in the line color (Fig. 4).

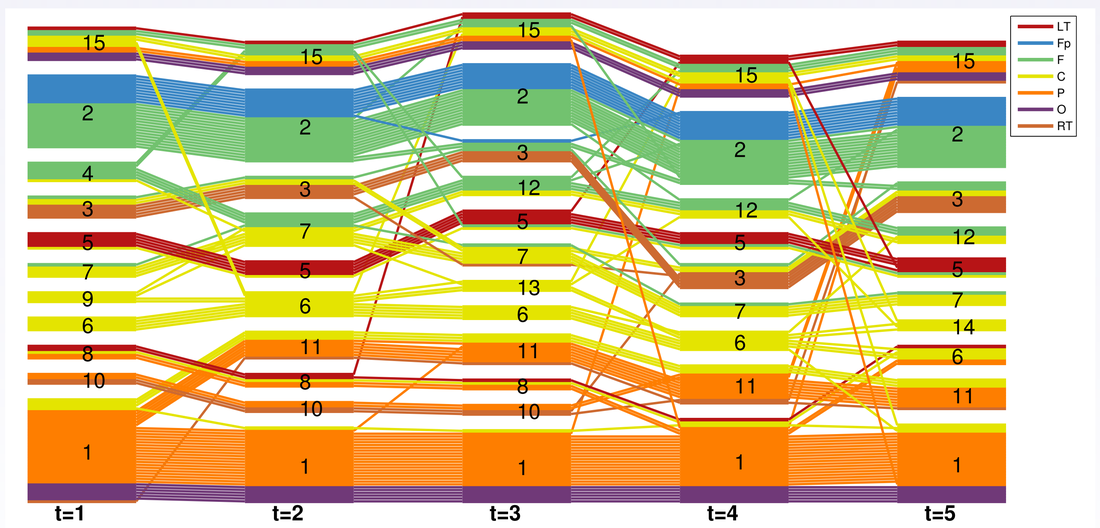

Figure 3: *Example of a timeline-based representation of the evolution of dynamic FUs across five time steps. The line color reflects the location of the electrodes (see the legend). The number stacked on the lines corresponds to the dynamic FU and the largest number corresponds to the set of electrodes that belongs to an FU with size less than 4.*

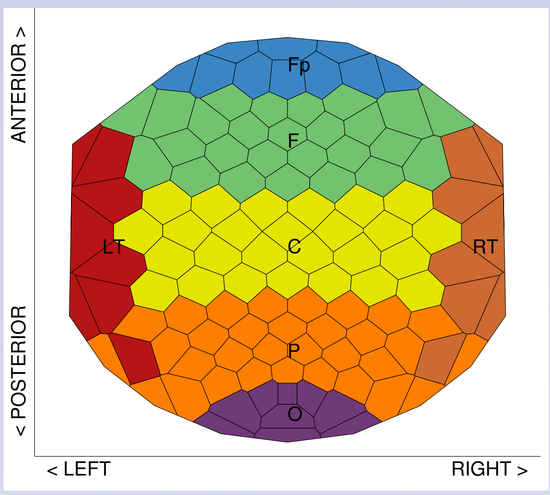

Figure 4: *119 electrodes, represented by cells, are divided into seven regions based on the electrodes placement: LT (Left Temporal), Fp (Fronto polar), F (Frontal), C (Central), P (Parietal), O (Occipital), RT (Right Temporal). Each region has a unique color.*

In Fig. 3, 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.

Time-annotated FU map

A time-annotated FU map is used to facilitate the comparison of FU maps between consecutive time steps (Fig. 5).

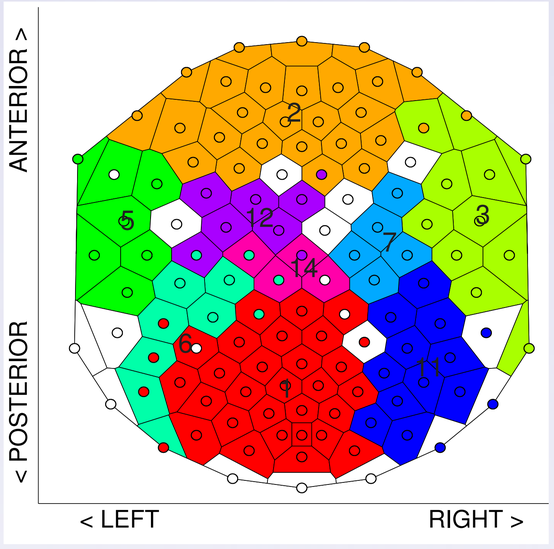

Figure 5: *Time-annotated FU map. The numbers correspond to the labels of the dynamic FUs. The cell colors indicate the state of electrodes at time step 5 while the color of the inner-circle represents the state at time step 4. The white cells belong to the FUs with size smaller than 4.*

Conclusions

We use a timeline-based representation to visualize dynamic FUs and corresponding spatial information across time. A feature of this method is that it provides information on the variation of FUs and brain regions. 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 the coherence network 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.

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