**Title**

Parallel Toolkits for Fast Mapping of High-Resolution Human Brain Connectome

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Nowadays, graph theoretical approaches combined with non-invasive neuroimaging technologies are widely used for mapping and topological description of complex human brain networks, represented as the human connectomes (Bullmore and Sporns, 2012). The construction and analysis of high-resolution brain connectomes at a voxel scale are important because they provide finer spatial information without prior parcellations (Hayasaka 2010). However, the increasing amount of datasets and the growing network size bring forward high requirements for the computational capabilities in the high-resolution human connectome study. Here, we developed a parallel graph-theoretical analysis of ??? (Pagani-) using a hybrid CPU-GPU accelerated framework.

**Introduction**

**Methods**

This hybrid CPU-GPU platform for brain network analysis(BNA) consists of a series of graph-theoretical algorithms and corresponding graphical user interface(GUI).

The workflow of BNA platform can be summarized as network construction and network analysis(Fig 1). For first step，GPU-based acceleration algorithm is applied for preprocessed BOLD signal in order to achieve the voxel-level brain network construction. For network analysis, with the continuous updating the platform can deal with both binary and weighted networks now according to whether to take connectivity strength into account. The parameters of networks that have been constructed fall into two classes: global metrics and nodal metrics. With regard to global metrics we calculate the parameters aimed at whole network, including characteristic path length, clustering coefficient, modularity and small-worldness. The nodal metrics provided by the platform are as follow: 1) nodal efficiency, clustering coefficient(for each node) and participation coefficient; 2) centrality, such as degree centrality, betweenness centrality, eigenvector centrality; and 3) output NII format algorithm with which user can convert these nodal metrics conveniently to NII format for further treatment, like visualization.

Among these global and nodal metrics, getting some parameters of them is extremely time-consuming for voxel-level brain network especially for characteristic path length, modularity and centrality, etc. Therefore, much work has been done for for purpose of acceleration via [parallelization](javascript:void(0);) and algorithmic improvement. If you want to probe deeper, see Haixiao et al (2013). Besides, for those parameters that may is unaccommodated with GPU implementation, we still take full advantage of CPU for optimization to obtain a better performance. The CPU-GPU hybrid framework makes it possible for rapid analysis of high-resolution or even voxel-based brain network.

A GUI was meticulously designed for practicability and better promotion of BNA platform.

**Results**

Both the source code and already packed software within GUI and .exe files of all algorithm can be downloaded freely on the NITRC web site (网址) or Github web site (网址). Thereinto, the GUI is shown in Fig 2.

For same brain network, we calculated the running time for computing each network metric on the CPU, GPU and CPU-GPU hybrid platform(Table 1). As can be seen from the table, the introduction of CPU-GPU hybrid framework has brought greatly comprehensive superiority.

**Conclusions**

As a complete tool the BNA platform can assist researchers to execute voxel-based analysis of brain networks in an easy and quick way