Graph-theoretical approaches in neuroscience from neurons to brain regions

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The human brain can be seen as a giant complex network from a dual point of view: structural connections among neurons return a stable picture of brain circuits while neural interactions (functional connections) show a dynamical representation which enables a vast repertoire of transient behaviors (action, perception, cognition, motion, etc). In an ideal scenario, such functional networks should be acquired at a millisecond of temporal resolution and at a single neuron of spatial resolution. However, current technologies forbid investigations at such spatiotemporal scales, therefore, so far, the functional dynamics of the whole brain neuronal network are mostly elusive.

Summarily, the available levels of investigations are two: i) the level of neurons where only very small fractions of the neuronal network are observable; ii) a coarse-grain perspective that considers the brain as a collection of regions (nodes) and where comprehensive pictures of the entire network are available to the detriment of the spatial resolution.

Since technological limitations are far to be overcome, more feasible scopes has been proposed by the neuroscientific community to elucidate this complex multiresolution scenario.

A first remarkable frontier concerns the development of methods able to integrate multiple measurements from experiments performed at microscopic scales. Specifically, in advanced experimental setups, neuronal population activities from different brain regions are massively recorded and classical methodologies are fundamentally inadequate to compose a coherent depiction of the mechanisms governing the observations. Another important proposal concerns the advancement of formal models able to describe the temporal evolution of the whole brain functional networks. Indeed, brain functional networks are essentially non-stationary and recent evidences empathize the need for proper models which explain the time changes of such functional graphs.

The scope of the present talk is to present concepts, problems, recently proposed methods and theories related to these topics.