

SHAHID BEHESHTI UNIVERSITY (SBU)

Networks in Cognitive Science

Advanced Computer Architecture

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Today's Presentation

OUTLINE TOPICS:

- Abstract
- Introduction to Network Science
- what is cognitive science
- Brain Connectome
- Abnormal connectomes
- Applying network science in gonitive networks
- Dynamics on networks
- Neuronal avalanche.

Abstract

Humans have more than 10^{10} neurons and 10^{15} synapses and together form a neural network and many sub-networks at many scales.

We will show how a network approach can provide insights into cognitive science and introduce Network Science to the cognitive scientists.

We survey existing work in three subsections, concerning the neural, cognitive and social levels of analysis.

And final section considers dynamical processes taking place upon networks.

What is Network Science ?

- Study of networks (Graphs), is a classic topic in mathematic which composed with set of vertics and nodes.
- Final discoveries show that many natural, artificial and complex systems can be described usefully in terms of networks.

What is Network Science ?

Interest in real complex networks has been boosted by two empirical observations:

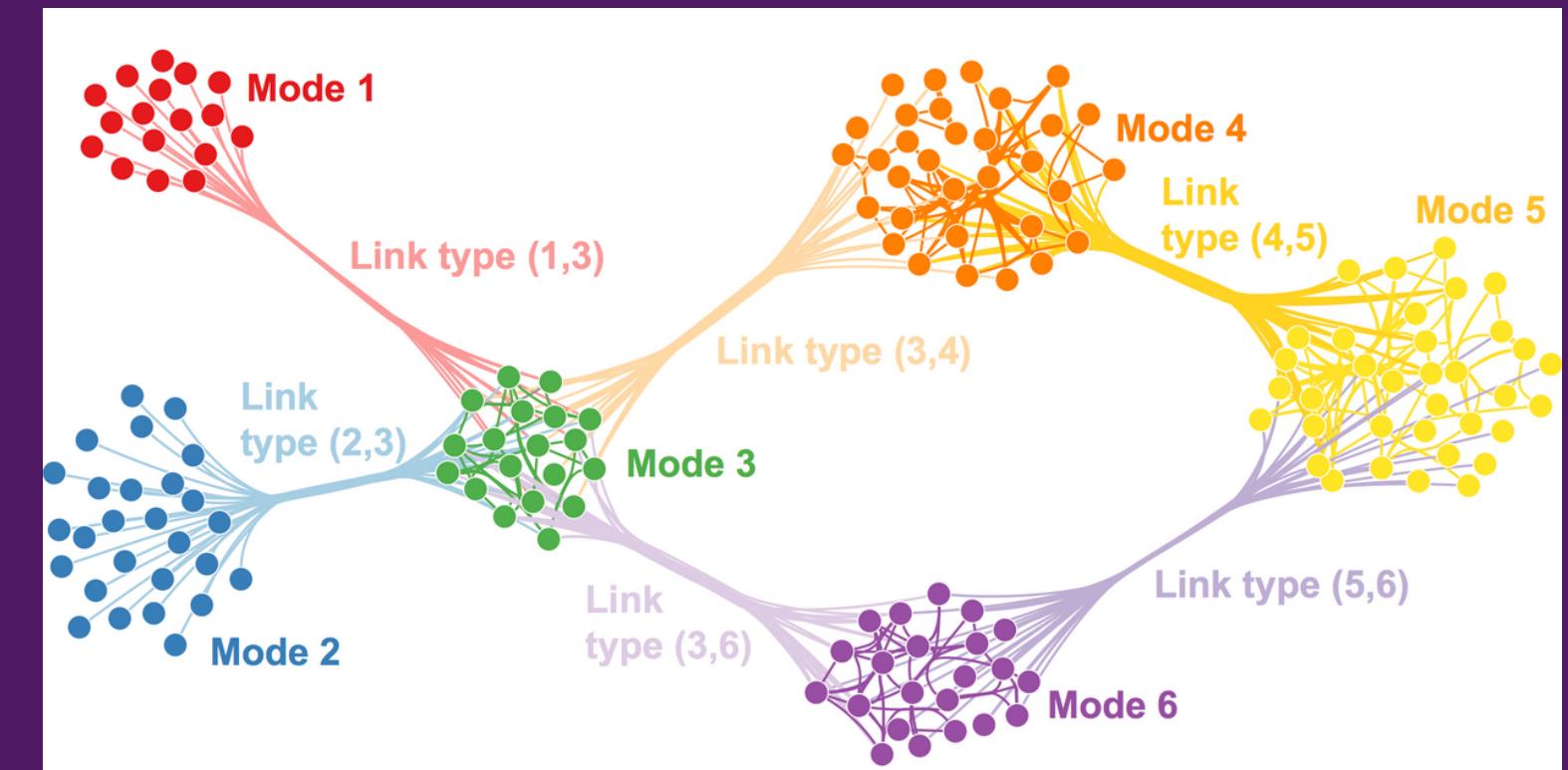
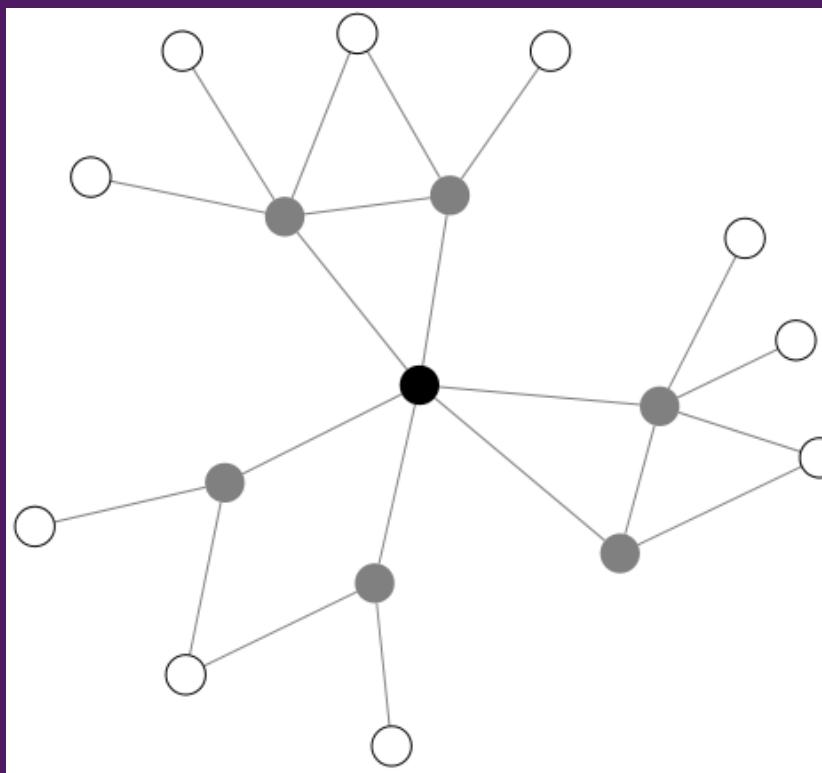
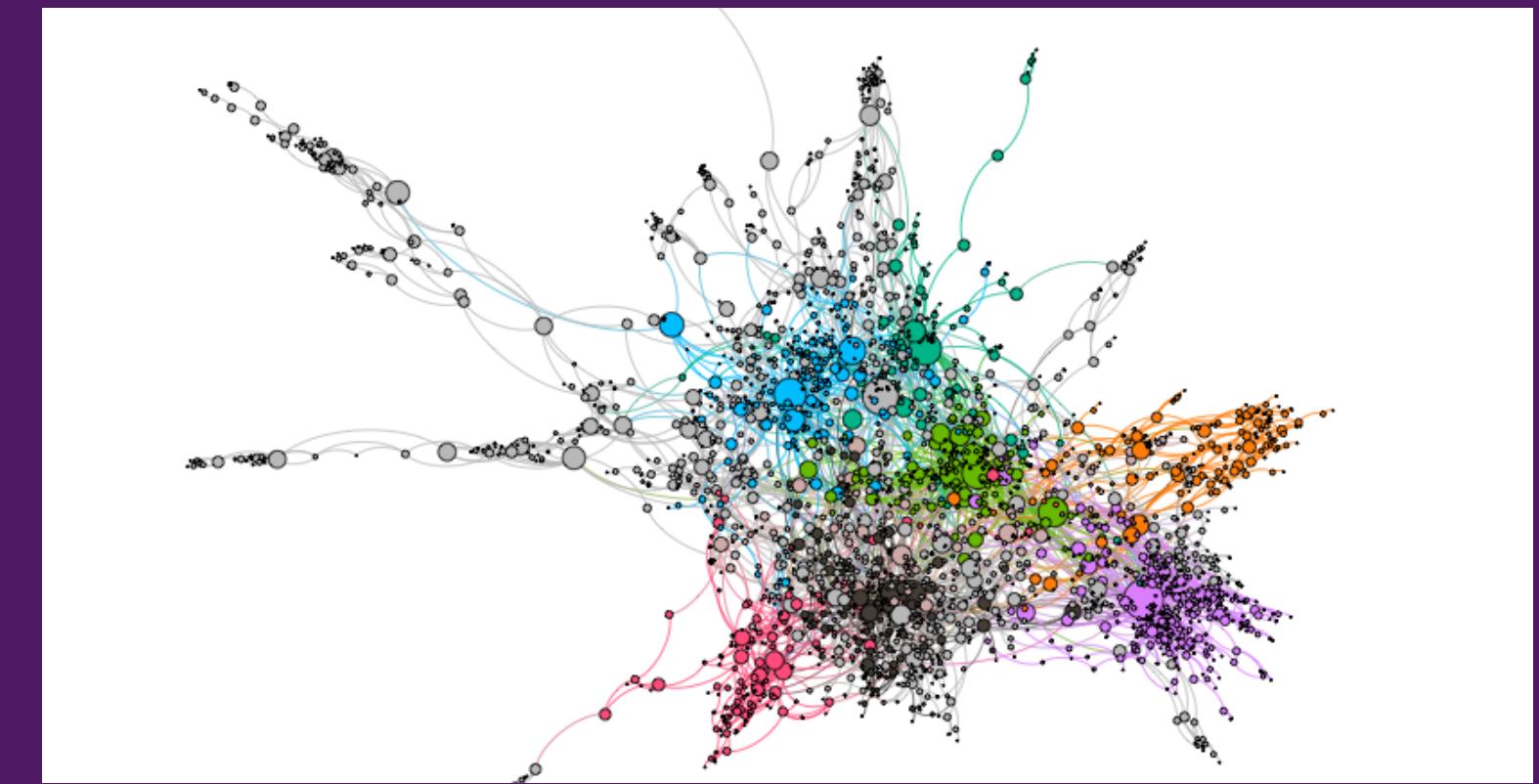
1. So-called small-world effect

Implies that there are surprisingly small shortest path length between any two vertices in most natural networks.
the popular aphorism "six degrees of separation" has issued after STANLEY MILGRAM studies.
the average distance between pairs of vertices in real networks is typically very small in relation to network size.

2. The connection structure is heterogeneous

the connectivity in most real systems are heterogeneous with skewed distribution in number of edges attached to each vertex. this kind of networks has dubbed scale-free.
this hallmark underlies many of many of most surprising properties of complex networks such as random deletion, coupled with extreme sensitivity to the targeted deletion of the most connected vertices; and strongly impacts processes such as propagation of disease.

- Pictures of heterogeneous networks



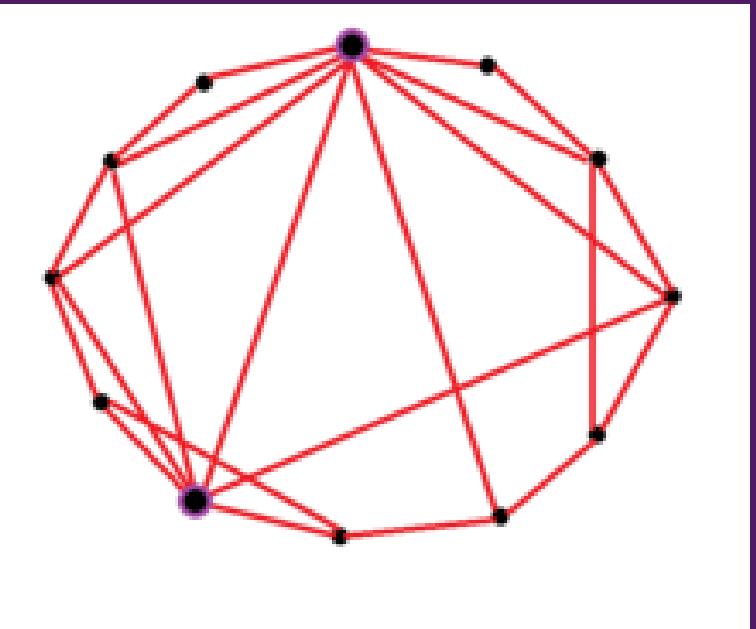
The Brain Connectome!

Normal network connectome

is characterized by: (Local processing and global integration)

1- Short Path Length (Small-World Topology)

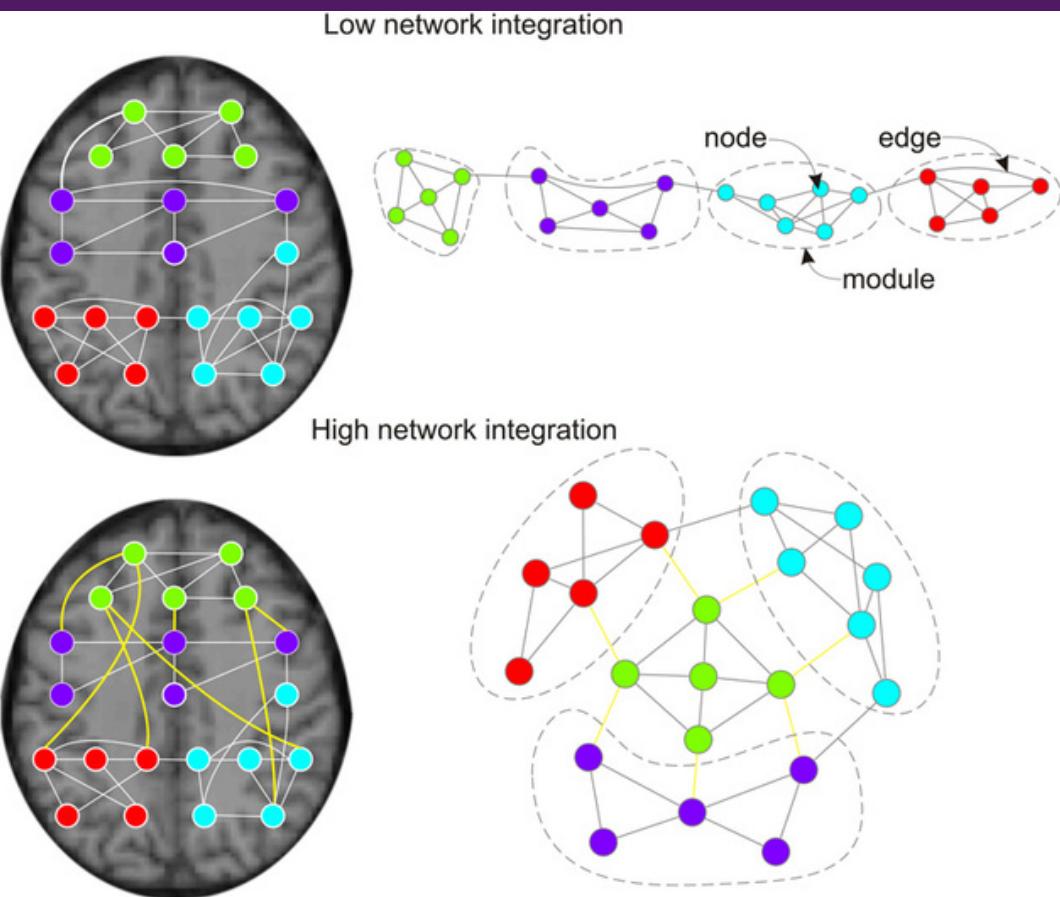
- Nodes mostly are not neighbour of each other, but the neighbour of a given node, likely neighbour of any.
- small #hops to get to any other node.
- requires for global integration of information between brain regions.



- average degree: 3.8
- average shortest path: 1.8

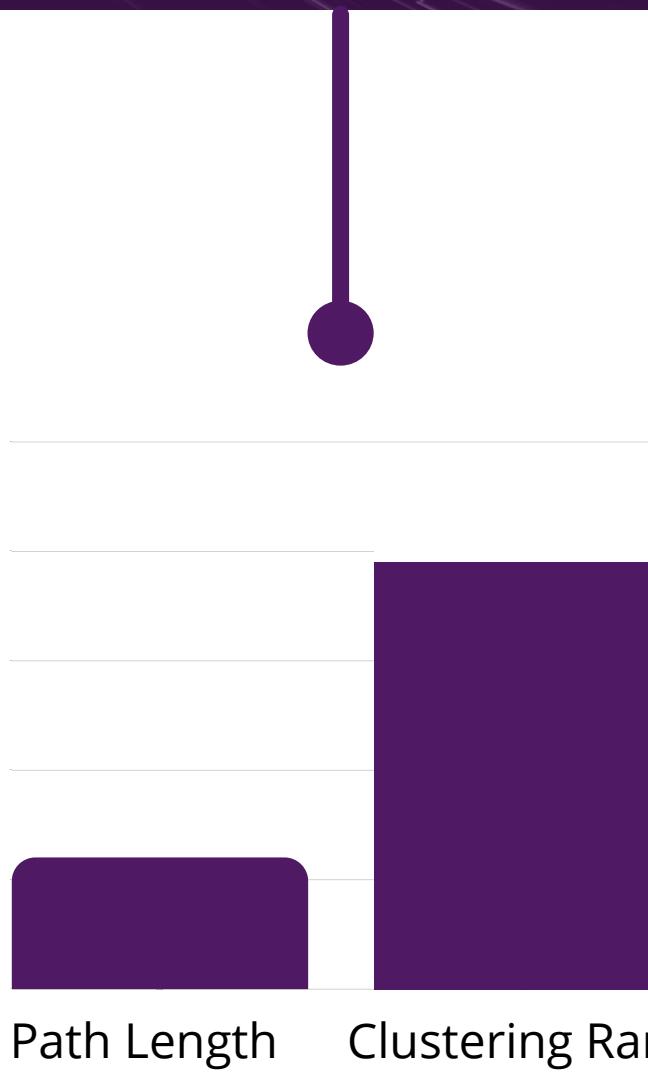
2- High Clustering

- Higher clustering ratio facilitates local processing.
- Many different approaches.

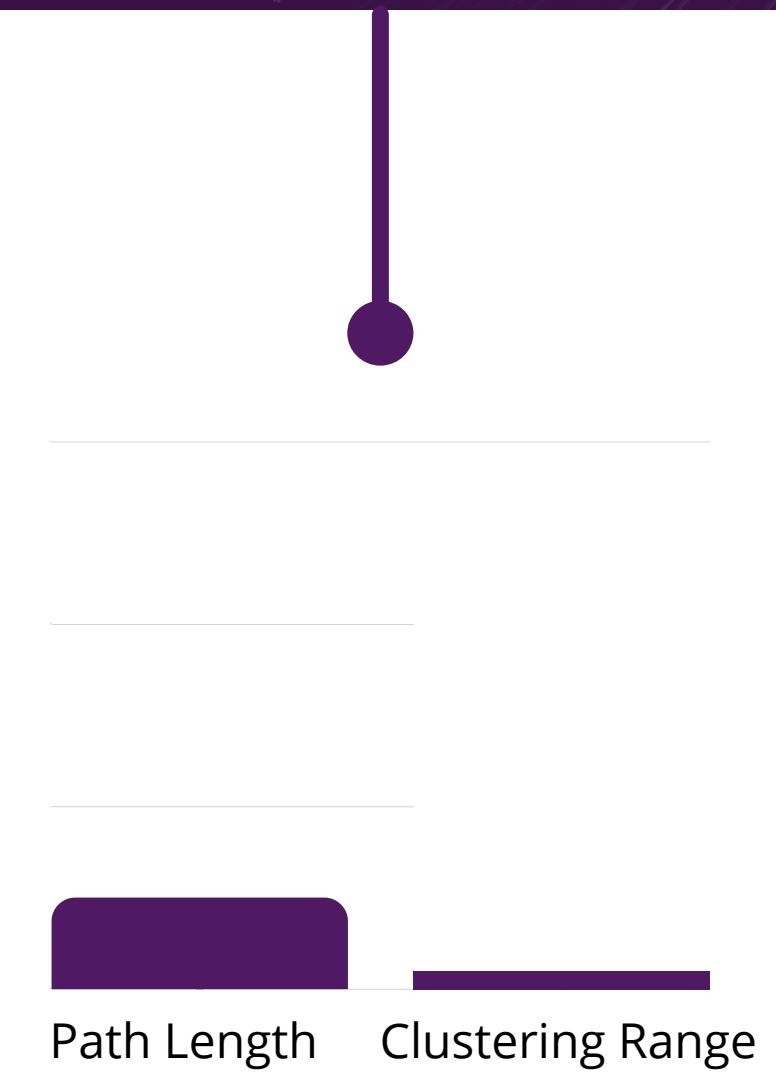


Abnormal Connectomes

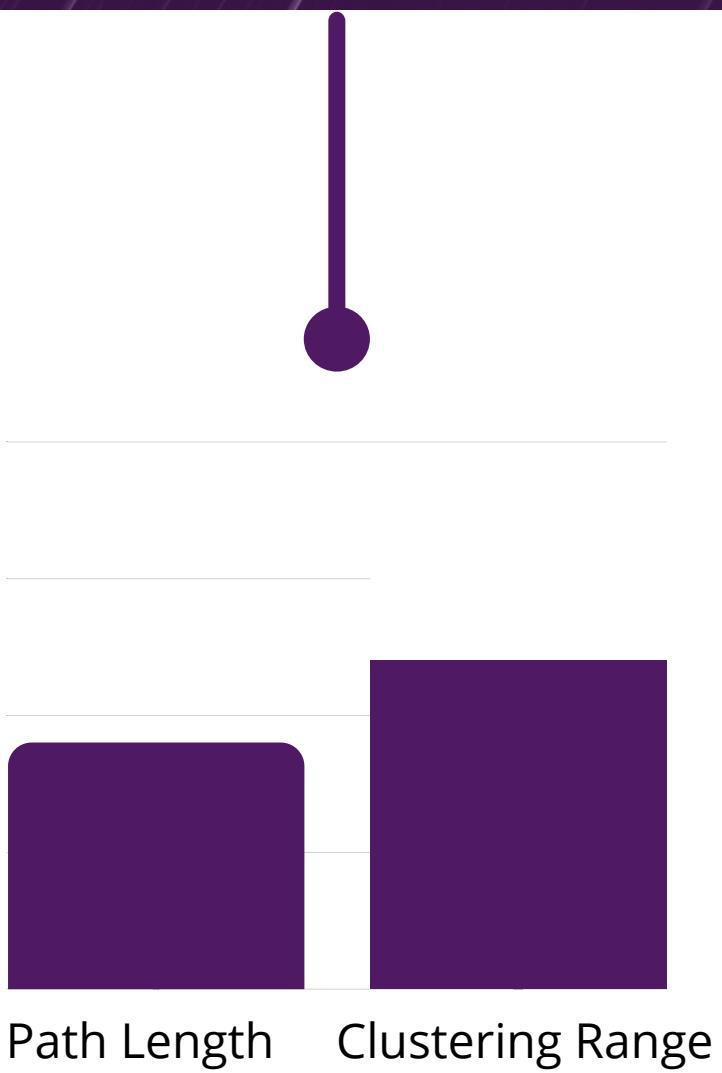
Normal Connectome



Schizophrenics



autistic spectrum



#Study_plus, alzheimer

A hallmark of **Alzheimer's disease** is the accumulation of **tau** protein around neurons. Despite the tau buildup, both the donating and accepting neurons remained healthy and capable of sending electrical messages.

The results show that tau buildup itself is not harmful, but rather it is the cellular processes, unlinks the neuron against others in network, which finally leads to their death.

in this adventure, path length drops and clustering range rises so much, which are the meaning of a abnormal connectome.

Applying network science in cognitive networks

Navigating Labyrinth

- Applies on search problems in complex area
- Codes to a weighted network (weights are distances).
- The time needed to solve out is strongly correlated to **apsortion**¹ time.
- Strongly correlated to network metrics such as vertex strength and **betweenness**².

Sequential Processing

- Processing a sequence such as sentences in brain.
- Length of a dependency between two element of a sequence, i.e.,understanding possible Grammars.
- Modeling the network to determine ordering of elements of sequence that minimizes sum of length.
- caused to **Minimum linear arrangement*** problem.

1-Apsortion time: average time taken by random walker to arrive for the first time at vertex i.

2-Betweenness: quantifies the number of times a node acts as a bridge along the shortest path between two other nodes.

Linear arrangement problem

the minimum linear arrangement problem has so far been investigated mostly in language, it applies whenever a dependency structure over elements of a sequence is defined by a network.

a promising avenue for future research is to extend network analysis to sequence of non-linguistic behaviour, such as music, dance and action sequencing.

DYNAMICS ON NETWORKS

- The neural, cognitive or social process is modeled as a dynamic process taking place upon a network.
- Concerns interactions among neuronal or cortical neurons, which often yield network level synchrony.
- New approaches suggests insights new cognitive functions during abrupt changes. (new connection during development or disconnect during aging or illness).

Neuronal Avalanche

Definition

Cascade of burst of activity in neuronal networks (the size of network can be approximated by power law¹).

RECORDINGS

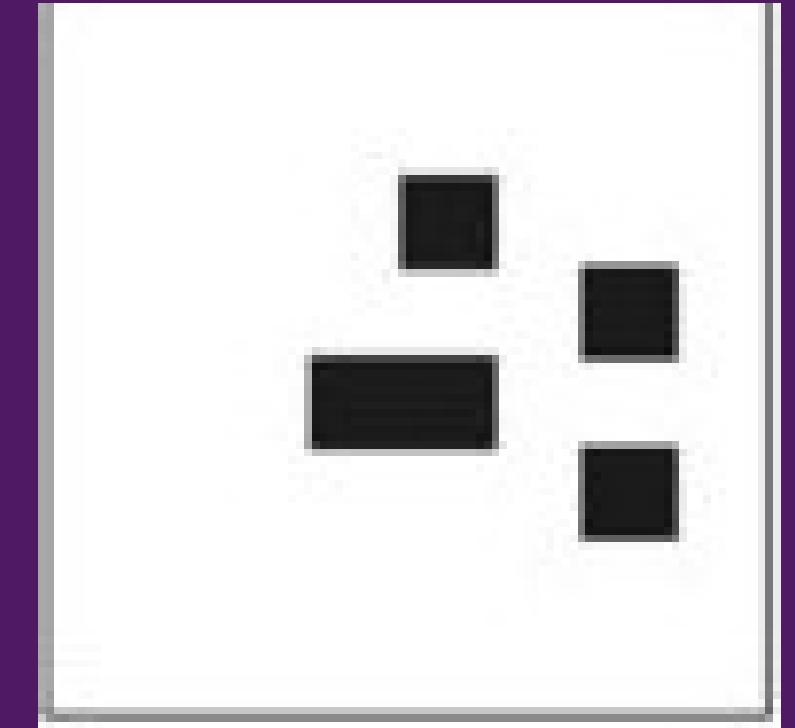
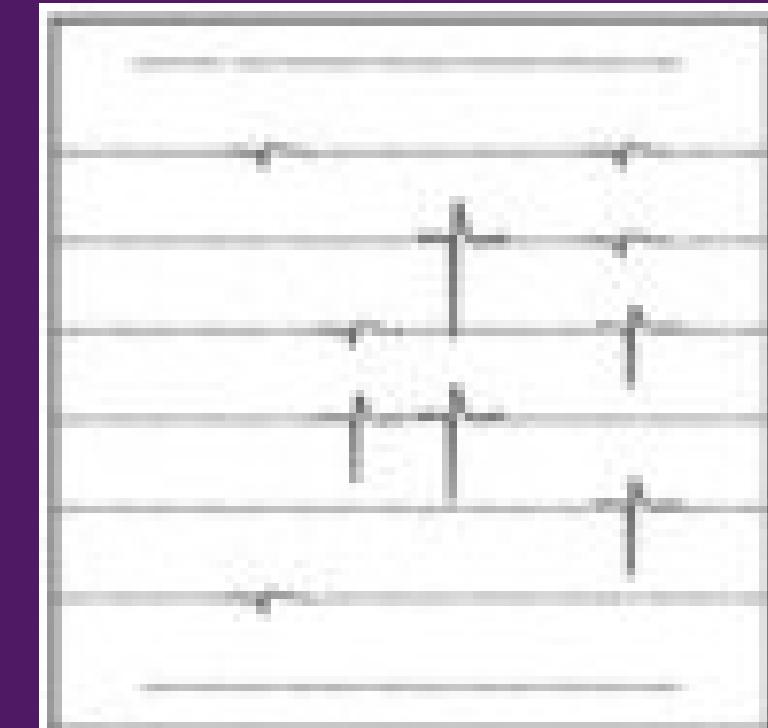
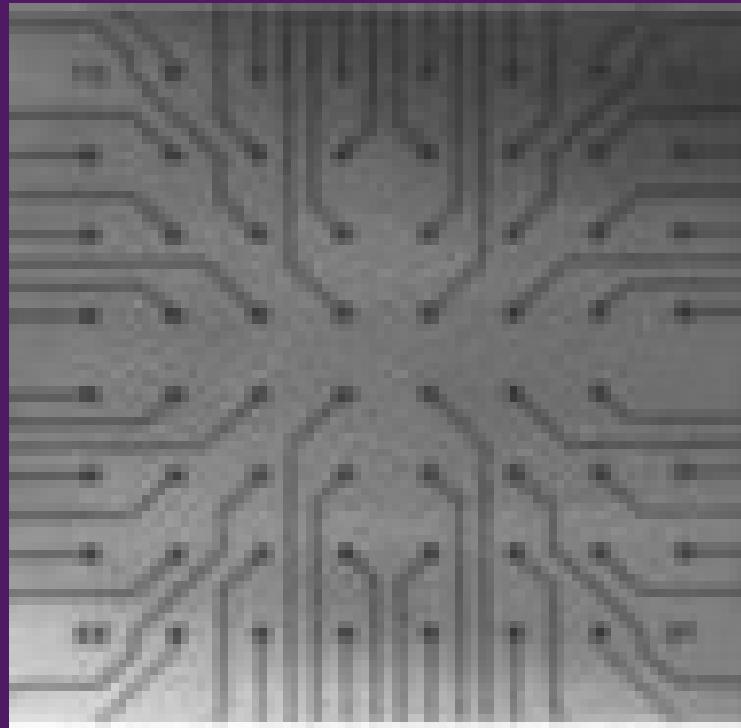
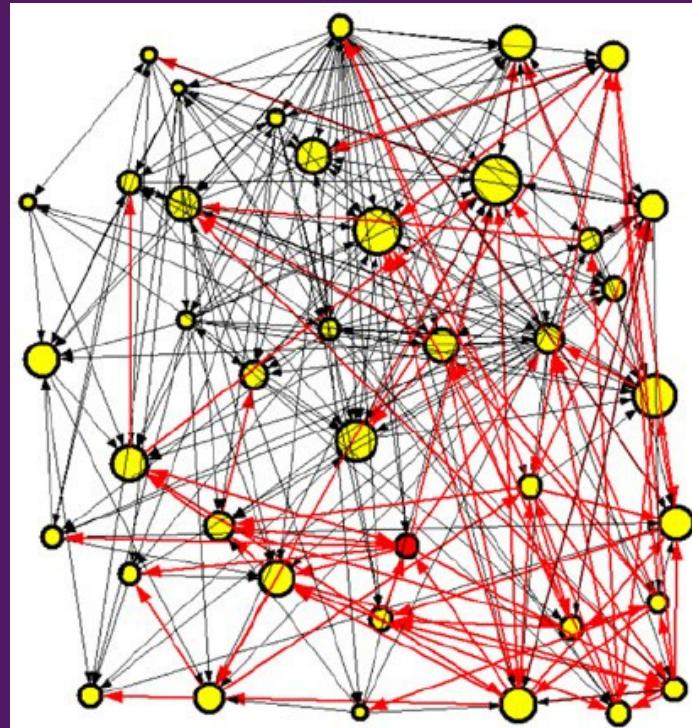
- seen in acute cortical slices.
- records with multielectrode arrays.

CHARACTERISTICS

activity is characterized by brief bursts, lasting tens of milliseconds and separated by periods of quiescence lasting several seconds.

¹-Power law: functional relationship between two quantities, considering the area of a square in terms of the length of its side

- Schematic of data(Avalanche) representation.
- Three standard deviations are represented by black squares.
- One active electrode, picks up the activity of several neurons.
- Avalanche size is 5; the number of electrodes driven over threshold.



Thankyou!

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