An Ant Colony Biological Inspired Way For Statistical Shortest Paths In Complex Brain Networks*

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ABSTRACT
What is the mechanism of information transferring, when some of the brain nerves' links do not work? Brain is the most complex, ingenious processing system in world. The complex brain networks is an inter-discipline of complex networks and neuroscience. In this paper, an ant colony optimizations are introduced to solve the crux, shortest path for information transferring mechanism. Some reviews are presented on progress of complex brain networks and computational neuroscience firstly. The deep research on brain complex networks will have a profound effects on artificial intelligence methods which models the mechanisms. Then simulations are done to finding shortest path in probabilities for theoretical nerve networks through ant colony optimization methods. The results show the proposed way is a successful method in detecting the statistical shortest path in brain networks when nerves' link broken, with the advantages of fast convergence and robustness.

*The work was carried out during the tenure of the ERCIM Alain Bensoussan Fellowship Programme, which is supported by the Marie Curie Co-funding of Regional, National and International Programmes (COFUND) of the European Commission. The work is also supported by Supported by Scientific Research Foundation for Returned Scholars from Ministry of Education of China (No. 20111j0032), the HOME Program No. 11044(Help Our Motherland through Elite Intellectual Resources from Overseas) funded by China Association for Science and Technology, the NSFC projects No. 10647141, No.60773210 of China, the Natural Science Foundation No.2009CBD213 of Hubei Province of China, the Fundamental Research Funds for the Central Universities of China, the self–determined and innovative research funds of WUT No. 2012–Ia–035, 2012-Ia-041, 2010–Ia–004, The National Soft Science Research Program 2009GXS1D012 of China, the National Science Foundation for Post–doctoral Scientists of China No. 20080431004. Corresponding author: Fei GAO, email: hgaofei@gmail.com

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Categories and Subject Descriptors
C.2.1 [**Network Architecture and Design**]: [Network communications, Network topology]

General Terms
Algorithms, Theory

Keywords
Ant colony optimization; brain networks; biology inspired methods; statistical shortest path

1. INTRODUCTION
How the brain's thinking? What is the transmission mechanism when some links of the nerve do not valid?

Understanding the biological principles of the brain, including the genetic basis and the neural network's mechanism, is one of the most important scientific challenges in the 21st century. Developments in this area will not only unveil the mysteries of the brain system, but also have a profound effect on a wide range of social development. Therefore there are two main research parts came into being: Brain complex networks and computational neuroscience.

The complex brain networks is an inter–discipline of complex networks and neuroscience[7, 9]. In this area, complex networks methods and concepts are introduced into the area of neuroscience to find the mechanisms and functions of the brain. And artificial intelligence methods, such as evolutionary computation, swarm intelligence methods are modeling the mechanisms of the brain. the networks inside of these methods have the similar structures and evolution mechanisms with those of the brain. Thus the deep research on

BODYNETS 2012, September 24-26, Oslo, Norway

DOI 10.4108/icst.bodynets.2012.249961

brain complex networks and the computational neuroscience will have a profound effect on artificial intelligence methods.

The objective of this work is to present a simple but effective method to resolve the information transferring mechanism with a biology inspired way when some links broken down in complex brain networks. In which some new research topics, developments and novel directions are discussed firstly. The rest is organized as follows. Section 2, some developments and new research directions of complex brain networks are discussed. Section 3 some artificial intelligence methods are introduced firstly. Then after comparisons, ant colony optimization are chosen to resolve the theoretical shortest path when some nerves' link broken. Conclusions are summarized briefly in Section 5.

2. COMPLEX BRAIN NETWORKS

Normally, brain network can be divided into three types: structure network, functional network, effective network. Now we introduce them briefly.

- Structure network is a kind of network consisting of the electrical or chemical connections between neural synapses, which is generally determined by the anatomical or magnetic resonance imaging methods. And the brain's structural network can change through learning and diseases. Up to now, the only complete nervous system with structural integrity is C. Elegans Neural Network[14, 1]. However there is no such kind of elaborate structure networks of human brain ever reported, because the current anatomical and imaging tools is not enough to show this.
- Functional networks are undirected networks to describe statistical connection relationship between nodes of the cortical network. They can be built based on phase synchronization analysis, cross correlation methods such as the EEG, MEG, fMRI and other signals. Considering the undirected networks obtained and the theories of graph and complex networks, functional networks is one of the focus problem in complex brain networks.
- Effective networks are directed networks to describe the interaction or information flow between various nodes of cortical neural networks. Compared to the function networks, the effective networks can be used to examine the strength of the relationship between the different brain functional area, rather than the relations between them. However we have to say there are much more difficulties and fewer measures in directed networks than in undirected networks. Therefore there more researches in undirected networks than in directed networks.

A multicolor neuron labeling technique in Drosophila melanogaster is developed to subdivide neural expression patterns recently, which combines the power of specifically target different neural populations with the label diversity provided by stochastic color choice. Nerve bundles, and even individual neurites hundreds of micrometers long, can be followed with definitive color labeling[6].

Based on functional complementation between two nonfluorescent GFP fragments, the GFP reconstitution across synaptic partners (GRASP) technique[3] can detect the location of synapses quickly, accurately and with high spatial resolution. However, it requires substantial modification for use in the mammalian brain. To solve the problem, Kim and Zhao developed mammalian GRASP (mGRASP) by optimizing transmembrane split–GFP carriers for mammalian synapses[8]. And by integrating molecular and cellular approaches with a computational strategy for the three-dimensional reconstruction of neurons, they applied mGRASP to both long–range circuits and local microcircuits in the mouse hippocampus and thalamocortical regions, analyzing synaptic distribution in single neurons and in dendritic compartments. In this way, they made the reconstruction of neural networks with high–throughput possible.

Then the theories of complex networks can be used to analyze the networks. For example, it might be used to investigate what happens in the networks mathematically, by using the mGRASP to see the mechanism of real neural networks when Autism, Parkinson's disease happens.

Modern complex network approaches are beginning to reveal fundamental principles of brain architecture and function. The brain networks offers a synthesis of the complex networks and the brain that will be an essential foundation for future research. In this area, there is interesting job[11] in complex brain networks, he describes how the integrative nature of brain function can be illuminated from a complex network perspective and highlights the many emerging points of contact between neuroscience and network science[11, 4].

Characterizations of functional networks are associated with several important methodological problems, such as the inability to characterize densely connected and weighted functional networks, the neglect of degenerate topologically distinct high–modularity partitions of these networks and etc. A set of methods to overcome these problems is proposed recently[10]. Specifically, they generalize measures of modularity and centrality to fully connected and weighted complex networks, describe the detection of degenerate high–modularity partitions of these networks, and introduce a weighted–connectivity null model of these networks.

3. BIOLOGICAL INSPIRED ARTIFICIAL INTELLIGENCE

Actually, under certain scales and conditions, the random networks, small world networks, scale free networks[5, 1, 13, 12] are found in brain networks. These led inter–research in complex networks, statistical mechanics and the brain networks. The mechanisms inside of the brain networks have a deep effects on artificial intelligence methods, whose success are determined by the network mechanism their population have. Artificial intelligence methods are modeling the way of the brain's thinking, human being, swarm of animals, and the societies work. When we studies the areas of above sections, we might have some more deep thoughts of the inner mechanisms of the artificial intelligence algorithms, such as the genetic algorithms, the swarm intelligence methods, the evolutionary computation and etc. Following are some artificial intelligent methods.

4. SIMULATIONS ON STATISTICAL BRAIN NETWORKS

Now we consider a theoretical statistical brain network, some links of nerve network are broken. The reason we choose ant colony system is that the individual(path) structure, which is totally different to the other artificial intelligence methods. The individuals' structures of all the intelligent algorithms are nearly the same, or at least similar enough. The only differences among them are the next step, the diverse genetic operations or operations of evolution algorithms in section 3.

At first, in view of the rules for coding of paths in networks, they are simply a combination of cities' numbers. However the following operations are totally different. That is, almost all the operations of artificial intelligence algorithms are done to a whole path including all the cities. When it comes to a statistical network not a fully connected one, many these artificial intelligent algorithms are not effective, because the operations are done to the whole paths not to intact paths, which could be the shortest path in probabilities. Thus almost all these methods have to be modified to adapt to the incomplete paths before they are efficient.

However, there is one exception at least, that is ant colony optimization methods. It has some inner mechanism for its particular paths' coding techniques. It has the tabu list to exclude the cities visited. Thus its operations will be much more effective to some shorter paths not for the whole paths. These mean that no more modifications are done to adapt to the incomplete networks with less links. This is the motivation that we choose the ant colony optimization for simulations. The more details about the ant colony optimizations can be found in Ref. [2].

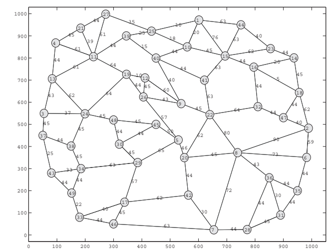
Now we consider a real statistical sparse brain network. Some of links of the networks are missing, some links are varying with the time. A shortest path are going to be determined for the information transferring. For example, some patients get recovered after having a stroke. That means some the links are regained in some degree or some networks with decompensation become effective in brain networks.

Then how the brain networks function when it comes to the regain or decompensation? That is, how to find a statistical shortest path for information transferring in a network with links time varying ?

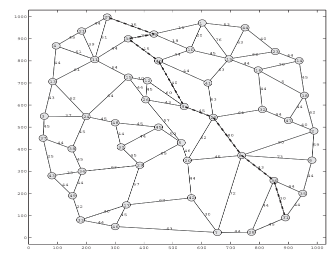
To resolve the problem, we have to simplify the case in some reasonable way. Take a time window at t_k, then the time varying brain network becomes some stable clusters connected with some inner links unconnected.

And for all the simulations, the parameters for ant colony optimization are as following. The start and end nerve nodes are 27 and 31. The maximum iteration number is 100, the number of the ants in colony is 10, $\alpha = 1, \beta = 5, \rho = 0.1, Q = 100$.

Now, we take one cluster for example. That means a single incomplete network. The network data are generated randomly as following. Firstly, a stable brain network model is taken for instance.



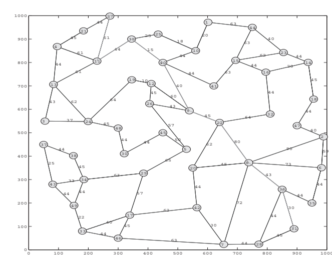
(a) Original network



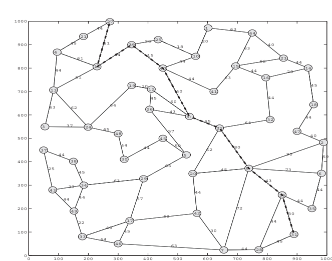
(b) Shortest path

Figure 1: Shortest path for stable brain network model

Secondly, a brain network model is taken in above stable network with fixed probability $0,1$ to each edge.



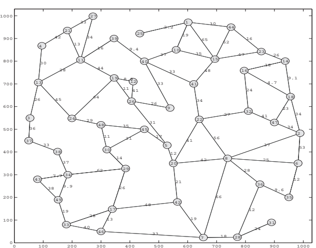
(a) Network model with fix probability $0,1$



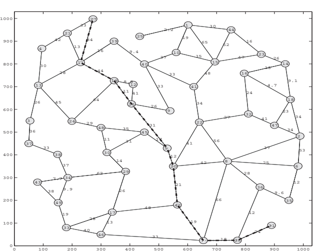
(b) Shortest path

Figure 2: Shortest path for brain network model with fix probability $0,1$

Thirdly, a statistical brain network model is taken in above stable network with random probability $[0,1]$ to each edge. The the shortest path is not a stable path. It is an exsected path in a changed network under recovering the nerves' networks. As the network is changed with time, it is hard to get this path, thus we take a fix time window. Random probabilities generated for each edges of the stable network above. To have more real background, we take all the nodes unconnected with the probability less than 0.2. Then the ant colony are suppose to find an expected path for information transferring. All the parameters are set as above.



(a) Network model with random probability



(b) Shortest path

Figure 3: Shortest path for statistical brain network model

According to Fig. 1, 2, 3, the ant colony optimization converges quickly for brain networks.

5. CONCLUSIONS

In this paper, a simple but effective way are presented for information transferring through a biological ants colony, in complex brain networks and computational neuroscience. And simulation results showed the proposed method is efficient and robust. The deep research on brain complex networks and the computational neuroscience will have a profound effect on artificial intelligence methods which models the mechanisms.

However, the paper only discussed the strategy as time window for complex networks with time varying edges. In the future, further researches will be done to this case.

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