Investigation on Complex Network Theory based ANN Optimization

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***Abstract*— In this paper, we introduce the usage of complex network theory for artificial neural network optimization and usage of artificial neural network techniques for complex network topology optimization. The goal is to give the readers a starting point in applying complex network tools for their AI/ML research.**

Keywords: Complex Networks, Artificial Neural Network, Topology Optimzation

I. INTRODUCTION

Complex network theory is a multi-disciplinary area that lies on the boundary of several different academic disciplines such as mathematics, statistical mechanics, and computer science. Artificial intelligence and machine learning is another important multi-disciplinary area that has become the key technology in providing intelligence, such as self-driving vehicles. It is natural to ask oneself, what about combining these two powerful multi-disciplinary areas: complex network theory and artificial intelligence. In this paper, we introduce the usage of complex network theory for artificial neural network optimization and usage of artificial neural network techniques for complex network topology optimization.

II. CNT AND ANN OPTIMIZATION

The basis behind the complex network theory (CNT) is to represent and study a complex systems', such as computer network, topology based on nodes and pattern of connection between these nodes. Using mathematically graph $G = \{V, E\}$ modes is used, where V is a set of N vertices and E is a set of edges connecting V nodes. Small-world network, constructued with rewiring probability, and scale-free network, constructed based on preferential attachment are most popular complex network models. Artificial neural networks (ANN) are computing systems that are inspired by human brain's biological neural networks based on connections of artifical neurons with weights between nodes. From early 2000, study on relationship between ANN and CNT existed with limited result in ANN performance improvement.

Recently, study on improving complex network topology based on ANN application have been reported. In [1], a multilayer perceptron neural network (MLPNN) was used as the reconstruction tool to reconstruct a damaged complex network system. The MLPNN was trained using the link information matrix describing the minimal structure of the damaged complex network topology and desired original complex network theory.

Furthermore, many studies on improving ANN based on CNT optimization tools have been reported. For example, in [2], the authors have investigated on defending an ANN against backdoor attacks, which causes targeted misclassification while the accuracy on clean data is not affected. The basic idea is to remove the node connections that are vulnerable against neural attack and to strengthen the ANN topology by changing the fully-connected networks to scale-free structures. From the simulation analysis, it was found that the scale-free network based optimization improved the robustness of ANN against the backdoor attack compared to the popular conventional method such as fine pruning method. For further study on the recent research results on usage of complex network theory for artificial neural network optimization, the readers are recommended to review main findings in [3].

Physical Systems (CPS) have been recently proposed as a key concept of Industry 4.0 architectures and digital twin is a virtual model that can generate virtual output data for any given real-time physical input data and continuously self-learn using this cycle. Since digital twins collect and process a huge volume of data with the help of ANN, it is vulnerable to cyber attacks. Thus, one of the main concern and growing interest in digital twin research is cybersecurity challenge and opportunities. It is of our opinion that CNT for ANN robustness in digital twin will be one of the key technology to provide cybersecurity solution in the future of digital twin advancement.

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