Study Plan: Quantitative Analysis of Neural Networks with Application to Biological Modeling

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1 Area Definition

The primary focus of the comprehensive exam and corresponding presentation paper is network analysis. The motivation and background for network analysis presented in this paper is biological modeling. Artificial neural network models are constructed as biological models either by synthesis or training. These network models are then tested for validity and used to infer further biological predictions. My proposed area uses engineering control theory to provide network analysis tools that identify unique networks, give a more detailed description of network dynamics, and assesses functionality and contribution of nodes within neural networks.

To provide background into this work, the comprehensive paper includes three major parts. First, a biological background into neural networks and their subsequent modeling methods are provided. Following that, is a summation of major types of artificial neural networks. Finally, a discussion of modern neural network analysis techniques is presented, which includes my proposed research.

2 Reading List

The reading list is divided up into four parts: Neural Networks, Science/Engineering, Computational Science/Biological Modeling, and Biology.

2.1 Neural Networks

[McCulloch and Pitts, 1943], [Hopfield, 1982], [Narendra and Parthasarathy, 1990], [Sima et al., 2000], [Michel and Liu, 2002], [Picton, 2001], [Hopfield, 1984], [Elman, 1990], [Weigend, 1996], [Milo et al., 2004], [Albertini and Sontag, 1992], [Milo et al., 2002], [Norgaard et al., 2000], [Chen and Narendra, 2004], [Narendra and Li, 1996], [Duch, 2003], [Aharonov et al., 2003], [Masters, 1993], [Masters, 1995], [Alon, 2003]

2.2 Science/Engineering

[Press et al., 1992], [Seborg et al., 2003], [Dorogovtsev and Mendes, 2003], [Strogatz and Watts, 1998], [Barabsi and Albert, 1999], [Wagner and Fell, 2001]

[Chen and Narendra, 2004] Chen, L. and Narendra, K. S. (2004). Identification and control of a nonlinear discrete-time system based on its linearization: A unified framework. *IEEE Transactions on Neural Networks*, 15(3):663–673.

[Dayan and Abbott, 2001] Dayan, P. and Abbott, L. (2001). *Theoretical Neuroscience*. MIT Press, Cambridge, MA.

[Dorogovtsev and Mendes, 2003] Dorogovtsev, S. and Mendes, J. (2003). *Evolution of Networks: From Biological Nets to the Internet and www*. Oxford Press.

[Drew and Abbott, 2003] Drew, P. J. and Abbott, L. F. (2003). Model of Song Selectivity and Sequence Generation in Area HVc of the Songbird. *J Neurophysiol*, 89(5):2697–2706.

[Duch, 2003] Duch, W. (2003). Coloring black boxes: visualization of neural network decisions. In *International Joint Conference on Neural networks*, volume 1, pages 1735–1740. IEEE.

[Elman, 1990] Elman, J. (1990). Finding structure in time. *Cognitive Science*, 14:179–211.

[Hillel et al., 1999] Hillel, J., Beer, R., and Gallagher, J. (1999). Evolution and analysis of model cpgs for walking: I. dynamical modules. *Journal of Computational Neuroscience*, 7(2):43–62.

[Hopfield, 1984] Hopfield, J. (1984). Neurons with graded response have collecive computational properties like those of two-state neurons. *Proc Natl Acad Sci U S A*, 81:3088–3092.

[Hopfield, 1982] Hopfield, J. J. (1982). Neural networks and physical systems with emergent collective computational abilities. *Proc Natl Acad Sci U S A*, 79(8):2554–8.

[Lockery and Sejnowski, 1993] Lockery, S. and Sejnowski, T. (1993). Realistic network models of distributed processing in the leech. In Gardner, D., editor, *The Neurobiology of Neural Networks*, pages 107–136. Bradford Books, MIT Press, Cambridge.

[Masters, 1993] Masters, T. (1993). *Practical Neural Network Recipies in C++*. Morgan Kaufmann, New York.

[Masters, 1995] Masters, T. (1995). *Advanced algorithms for neural networks*. Wiley and Sons, New York.

[McCulloch and Pitts, 1943] McCulloch, W. and Pitts, W. (1943). A logical calculus of ideas immanent in nervous activity. *Bull. Math. Biophys.*, 5:115–133.

[Michel and Liu, 2002] Michel, A. and Liu, D. (2002). *Qualitative Analysis and Synthesis of Recurrent Neural Networks*. Macel Dekker, Inc.

[Milo et al., 2004] Milo, R., Itzkovitz, S., Kashtan, N., Levitt, R., Shen-Orr, S., Ayzenshtat, I., Sheffer, M., and Alon, U. (2004). Superfamilies of evolved and designed networks. *Science*, 303(5663):1538–1542.

[Sima et al., 2000] Sima, Orponen, and Antti-Poika (2000). On the computational complexity of binary and analog symmetric hopfield nets. *NEUR-COMP: Neural Computation*, 12.

[Sontag et al., ress] Sontag, E., Kiyatkin, A., and Kholodenko, B. (in Press). Inferring dynamic architecture of cellular networks using time series of gene expression, protein and metabolite data. *Bioinformatics*.

[Strogatz and Watts, 1998] Strogatz, S. H. and Watts, D. J. (1998). Collective dynamics of 'small-world' networks. *nature*, 393:440–442.

[Wagner and Fell, 2001] Wagner, A. and Fell, D. (2001). The small world inside large metabolic networks. *Proc R Soc Lond B Biol Sci*, 268(1478):1803–1810.

[Weigend, 1996] Weigend, A. S. (1996). *Mathematical Perspectives on Neural Networks*, chapter 12: Time Series Analysis and Prediction, pages 395–449. Lawrence Erlbaum Associates, Mahwah, New Jersey.

[Wicks et al., 1996] Wicks, S., Roehrig, C., and Rankin, C. (1996). A dynamic network simulation of the nematode tap withdrawal circuit: Predictions concerning synaptic function using behavioral criteria. *J. of Neurosci.*, 16:4017–4031.