RESERVOIR COMPUTING

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1 INTRODUCTION

This document presents an overwiew of the work presented in my 2nd exam paper, along with a recommended reading list of papers on the topic.

ABSTRACT

Even before Artificial Intelligence was its own field of computational science, men have tried to mimic the activity of the human brain. In the early 1940s the first artificial neuron models were created as purely mathematical concepts. Over the years, ideas from neuroscience and computer science were used to develop the modern Neural Network. The interest in these models rose quickly but fell when they failed to be successfully applied to practical applications, and rose again in the late 2000s with the drastic increase in computing power, notably in the field of natural language processing, for example with the state-of-the-art speech recognizer making heavy use of deep neural networks.

Recurrent Neural Networks (RNNs), a class of neural networks with cycles in the network, exacerbates the difficulties of traditional neural nets. Slow convergence limiting the use to small networks, and difficulty to train through gradient-descent methods because of the recurrent dynamics have hindered research on RNNs, yet their biological plausibility and their capability to model dynamical systems over simple functions makes then interesting for computational researchers.

Reservoir Computing emerges as a solution to these problems that RNNs traditionally face. Promising to be both theoretically sound and computationally fast, Reservoir Computing has already been applied successfully to numerous fields: natural language processing, computational biology and neuroscience, robotics, even physics. The survey paper will explore the history and appeal of both traditional feed-forward and recurrent neural networks, before describing the theory and models of this new reservoir computing paradigm. Finally recent papers using reservoir computing in a variety of scientific fields will be reviewed.

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2 RECOMMENDED READING LIST

2.1 Historical Papers

P. Werbos, "Beyond regression: New tools for prediction and analysis in the behavioral sciences." (1974).

P.Werbos, "Backpropagation through time: what it does and how to do it." Proceedings of the IEEE 78.10 (1990): 1550-1560.

2.2 Reservoir Computing Overview

M. Lukoševičius, and J. Herbert, "Reservoir computing approaches to recurrent neural network training." Computer Science Review 3.3 (2009): 127-149.

2.3 Reservoir Computing Applications

F. Triefenbach, A. Jalalvand, B. Schrauwen, and J.-P. Martens, “Phoneme recognition with large hierarchical reservoirs,” in Advances in Neural Information Processing Systems, Neural Information Processing System Foundation, (2010).

L. Appeltant, M. C. Soriano, G. Van der Sande, J. Danckaert, S. Massar, J. Dambre, B. Schrauwen, C. R. Mirasso, and I. Fischer, “Information processing using a single dynamical node as complex system,” Nature communications, (2011)

A. Bernacchia, H. Seo, D. Lee, and X.-J. Wang, “A reservoir of time constants for memory traces in cortical neurons,” Nature Neuroscience, (2011).

A. Jalalvand, “Connected digit recognition by means of reservoir computing,” Interspeech, (2011).

X. Hinaut, “On-line processing of grammatical structure using reservoir computing,” Artificial Neural Networks and Machine Learning ICANN 2012, (2012).

M. Oubbati, T. Oess, C. Fischer, and G. Palm, “Multiobjective reinforcement learning using adaptive dynamic programming and reservoir computing,” European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases, (2012).

X. Hinaut, M. Petit, G. Pointeau, and P. F. Dominey, “Exploring the acquisition and production of grammatical constructions through human-robot interaction with echo state networks,” Frontiers in Neurorobotics, (2014).

2.4 Related Works

G.-B. Huang, D. H. Wang, and Y. Lan, “Extreme learning machines: a survey,” International Journal of Machine Learning and Cybernetics, (2011).

L. Appeltant, G. Van der Sande, J. Danckaert, and I. Fischer, “Constructing optimized binary masks for reservoir computing with delay systems,” Scientific reports, (2014).