Task-adaptive physical reservoir computing

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ABSTRACT

Reservoir computing is a neuromorphic architecture that potentially offers viable solutions to the growing energy costs of machine learning. The majority of neuromorphic computing is currently software-based, where neural network properties and performance can be reconfigured to suit different computational tasks. This critical functionality is missing in "physical" reservoir computing schemes that exploit nonlinear and history-dependent memory responses of physical systems for data processing. Here, we experimentally present a 'task-adaptive' approach to physical reservoir computing, capable of reconfiguring key reservoir properties (nonlinearity, memory-capacity and complexity) to optimise computational performance across a broad range of tasks. As a model case of this, we use the temperature and magnetic-field controlled spin-wave response of Cu_2OSeO_3, that hosts skyrmion, conical and helical magnetic phases, providing on-demand access to a host of different physical reservoir responses. We quantify phase-tunable reservoir performance, characterise their properties and discuss the correlation between these in physical reservoirs. This task-adaptive approach overcomes key prior limitations of physical reservoirs, opening opportunities to apply thermodynamically stable and metastable phase control across a wide variety of physical reservoir systems.

Introduction

Physical separation between processing and memory units in the current computer architecture causes significant energy waste due to repeated shuttling of data, known as the von Neumann bottleneck. To circumvent this, neuromorphic computing[1-3], which emulates the brain's neural network to co-locate memory and processor to integrated 'memcomputing' units, has attracted a great deal of attention as a promising future technology for artificial intelligence processing. Reservoir computing[4-7] is a type of neuromorphic architecture with complex recurrent pathways (the 'reservoir') that map input data to a high-dimensional space. Weights within the reservoir are randomly initialised and fixed, and only the small one-dimensional weight vector that linearly connects the reservoir to the output requires optimisation using a computationally-cheap linear regression. As such, reservoir computing can achieve powerful neuromorphic computation at a fraction of the processing cost relative to other schemes, e.g. deep neural network, where the whole (typically more than millions of) weight network must be trained[8].

While reservoir computing was originally conceived in software[4], nonlinear and history-dependent responses of physical systems have also been exploited as reservoirs[9-11]. The field of physical reservoir computing has been rapidly expanding with several promising demonstrations using optical systems[12], analogue electronic circuits[13], memristors[14,15], ferroelectrics[16], magnetic systems[17-21] and even a bucket of water[22]. Skyrmions, topologically non-trivial magnetic whirls, have also been proposed as hosts for reservoir computing[23,24] as part of rapidly growing research efforts towards neuromorphic computing[25-28]. Very recently, there have been a few experimental studies

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Body Imaging and the Neuroscience of Art Innovation and Creativity held in Cancun Mexico and Valencia Spain to explore these topics this book intertwines disciplines and investigates not only their individual products art and data but also something more substantive and unique the international pool of contributors reveals something larger about humanity by revealing the state of the art in collaboration between arts and sciences and providing an investigational roadmap projected from recent advances Mobile Brain Body Imaging and the Neuroscience of Art Innovation and Creativity is written for academic researchers professionals working in industrial and clinical centers independent researchers and artists from the performing arts and other readers interested in understanding emergent innovations at the nexus of art science engineering medicine and the humanities The book contains language design features illustrations diagrams to develop a conversational bridge between the disciplines involved supplemented by access to video artistic presentations and the results of a hackathon from the MoBI conferences   **The ^AOxford Handbook of Algorithmic Music** Alex McLean,Roger T. Dean,2018-01-18 Featuring chapters by emerging and established scholars as well as by leading practitioners in the field this Handbook both describes the state of algorithmic composition and also set the agenda for critical research on and analysis of algorithmic music   *Memetics* Tim Tyler,2011-08-19 Memetics is the name commonly given to the study of memes a term originally coined by Richard Dawkins to describe small inherited elements of human culture Memes are the cultural equivalent of DNA genes and memetics is the cultural equivalent of genetics Memes have become ubiquitous in the modern world but there has been relatively little proper scientific study of how they arise spread and change apparently due to turf wars within the social sciences and misguided resistance to Darwinian explanations being applied to human behaviour However with the modern explosion of internet memes I think this is bound to change With memes penetrating into every mass media channel and with major companies riding on their coat tails for marketing purposes social scientists will surely not be able to keep the subject at arm s length for much longer This will be good because an understanding of memes is important Memes are important for marketing and advertising They are important for defending against marketing and advertising They are important for understanding and managing your own mind They are important for understanding science politics religion causes propaganda and popular culture Memetics is important for understanding the origin and evolution of modern humans It provides insight into the rise of farming science industry technology and machines It is important for understanding the future of technological change and human evolution This book covers the basic concepts of memetics giving an overview of its history development applications and the controversy that has been associated with it   **Trends and Innovations in Urban E-Planning** Nunes Silva, Carlos,2022-03-04 The digital transformation of the 21st century has affected all facets of society and has been highly advantageous in many industries including urban planning and regional development The practices strategies and developments surrounding urban e planning in particular have been constantly shifting and adapting to new innovations as they arrive Trends and Innovations in Urban E Planning provides an updated panorama of the main

trends challenges and recent innovations in the field of e planning through the critical perspectives of diverse experts This book adds new and updated evidence on recent changes in this field and provides critical insights on these innovations Covering topics such as citizen engagement land property management and spatial planning this book is an essential resource for students and educators of higher education researchers urban planners engineers public officials community groups and academicians   Adaptive Systems in Drug Design Gisbert Schneider,Sung-Sau So,2002-10-01 A brief history of drug design presented to make clear that there are fashions in this important field and that they change rather rapidly This is due in part to the fact that the way that a new paradigm is accepted in a drug company often does not depend on its scientific merit alone   The Fundamentals of Control Systems , Welcome to the forefront of knowledge with Cybellium your trusted partner in mastering the cutting edge fields of IT Artificial Intelligence Cyber Security Business Economics and Science Designed for professionals students and enthusiasts alike our comprehensive books empower you to stay ahead in a rapidly evolving digital world Expert Insights Our books provide deep actionable insights that bridge the gap between theory and practical application Up to Date Content Stay current with the latest advancements trends and best practices in IT Al Cybersecurity Business Economics and Science Each guide is regularly updated to reflect the newest developments and challenges Comprehensive Coverage Whether you re a beginner or an advanced learner Cybellium books cover a wide range of topics from foundational principles to specialized knowledge tailored to your level of expertise Become part of a global network of learners and professionals who trust Cybellium to guide their educational journey www cybellium com

Megatron-LM Techniques for Scalable Language Model Training William Smith,2025-08-19 Megatron LM Techniques for Scalable Language Model Training Megatron LM Techniques for Scalable Language Model Training is a comprehensive guide to the state of the art practices in designing training and deploying massive language models Beginning with a historical overview the book traces the rapid evolution of language models highlighting the transition from modest neural architectures to today s trillion parameter behemoths It offers a meticulous examination of both the systemic and architectural challenges in scaling up detailing how modern GPU clusters high speed networks and robust data pipelines form the foundation for efficient large scale machine learning Through clear explanations of the Megatron LM framework its modules workflow and integration with the PyTorch and DeepSpeed ecosystems readers gain a deep understanding of how current industry class models are engineered and orchestrated The core of the book delves into parallelism strategies foundational to scalable model training such as data model and hybrid parallelism Readers are guided through the intricacies of partitioning techniques sharding memory optimization and communication patterns that underpin ultra large model training Special attention is given to customization and architectural tailoring for transformers at scale covering advanced topics like attention mechanism optimization activation checkpointing dynamic graph updates and extensibility for research led modifications The book not only explains how to maximize throughput and efficiency but also discusses robust

approaches to distributed training orchestration fault tolerance and their implementation in real world production grade environments Beyond technical execution this work provides critical insight into benchmarking validation and the imperative of reproducibility in distributed machine learning research Chapters on security privacy and ethical compliance address the escalating concerns of protecting data and model assets with pragmatic coverage of audit logging adversarial testing and responsible evaluation of model outputs Finally the book explores future research directions from federated training to zero redundancy optimizations and next generation hardware integration empowering professionals and researchers to innovate at the frontier of scalable language model development **Generative AI: Techniques, Models and Applications** Rajan Gupta,Sanju Tiwari,Poonam Chaudhary,2025-03-26 This book unlocks the full potential of modern AI systems through a meticulously structured exploration of concepts techniques and practical applications This comprehensive book bridges theoretical foundations with real world implementations offering readers a unique perspective on the rapidly evolving field of generative technologies From computational foundations to ethical considerations the book systematically covers essential topics including foundation models large scale architectures prompt engineering and practical applications The content seamlessly integrates complex technical concepts with industry relevant examples making it an invaluable resource for researchers academicians and practitioners Distinguished by its balanced approach to theory and practice this book serves as both a learning tool and reference guide Readers will benefit from Clear explanations of advanced concepts Practical implementation insights Current industry applications Ethical framework discussions Whether you re conducting research implementing solutions or exploring the field this book provides the knowledge necessary to understand and apply generative AI technologies effectively while considering crucial aspects of security privacy and fairness **Research & Creative Activity** ,1996 **Neural Information Processing** Bao-Liang Lu,Liqing Zhang,James Kwok,2011-10-26 The three volume set LNCS 7062 LNCS 7063 and LNCS 7064 constitutes the proceedings of the 18th International Conference on Neural Information Processing ICONIP 2011 held in Shanghai China in November 2011 The 262 regular session papers presented were carefully reviewed and selected from numerous submissions The papers of part I are organized in topical sections on perception emotion and development bioinformatics biologically inspired vision and recognition bio medical data analysis brain signal processing brain computer interfaces brain like systems brain realistic models for learning memory and embodied cognition Clifford algebraic neural networks combining multiple learners computational advances in bioinformatics and computational intelligent human computer interaction The second volume is structured in topical sections on cybersecurity and data mining workshop data mining and knowledge doscovery evolutionary design and optimisation graphical models human originated data analysis and implementation information retrieval integrating multiple nature inspired approaches kernel methods and support vector machines and learning and memory The third volume contains all the contributions connected with multi agent systems natural language processing and intelligent Web information processing

neural encoding and decoding neural network models neuromorphic hardware and implementations object recognition visual perception modelling and advances in computational intelligence methods based pattern recognition *Reader's Guide to the Social Sciences* Jonathan Michie,2014-02-03 This 2 volume work includes approximately 1 200 entries in A Z order critically reviewing the literature on specific topics from abortion to world systems theory In addition nine major entries cover each of the major disciplines political economy management and business human geography politics sociology law psychology organizational behavior and the history and development of the social sciences in a broader sense **Quantum Machine Learning in Industrial Automation** Anupam Ghosh,Soumi Dutta,Asit Kumar Das,Vinod Kumar Shukla,Fernando Moreira,2025-10-03 This book focuses on quantum machine learning that harnesses the collective properties of quantum states such as superposition interference and entanglement uses algorithms run on quantum devices such as quantum computers to supplement expedite or support the work performed by a classical machine learning program The devices that perform quantum computations are known as quantum computers Quantum computers have the potential to revolutionize computation by making certain types of classically intractable problems solvable A few large companies and small start ups now have functioning non error corrected quantum computers composed of several tens of qubits and some of these are even accessible to the public through the cloud Additionally quantum simulators are making strides in fields varying from molecular energetics to many body physics Most known use cases fit into four archetypes quantum simulation quantum linear algebra for AI and machine learning quantum optimization and search and quantum factorization Advantages of quantum computing are many and to list a few first they re fast Ultimately quantum computers have the potential to provide computational power on a scale that traditional computers cannot ever match In 2019 for example Google claimed to carry out a calculation in about 200 seconds that would take a classical supercomputer around 10 000 years Second they can solve complex problems The more complex a problem the harder it is for even a supercomputer to solve When a classical computer fails it s usually because of a huge degree of complexity and many interacting variables However due to the concepts of superposition and entanglement quantum computers can account for all these variables and complexities to reach a solution Last but not the least they can run complex simulations The speed and complexity that quantum computing can achieve means that in theory a quantum computer could simulate many intricate systems **Closed-Loop Systems for Next-Generation Neuroprostheses** Timothée Levi,Paolo Bonifazi, Paolo Massobrio,Michela Chiappalone,2018-04-26 Millions of people worldwide are affected by neurological disorders which disrupt the connections within the brain and between brain and body causing impairments of primary functions and paralysis Such a number is likely to increase in the next years and current assistive technology is yet limited A possible response to such disabilities offered by the neuroscience community is given by Brain Machine Interfaces BMIs and neuroprostheses The latter field of research is highly multidisciplinary since it involves very different and disperse scientific communities making it fundamental to create

connections and to join research efforts Indeed the design and development of neuroprosthetic devices span involve different research topics such as interfacing of neural systems at different levels of architectural complexity from in vitro neuronal ensembles to human brain bio artificial interfaces for stimulation e g micro stimulation DBS Deep Brain Stimulation and recording e g EMG Electromyography EEG Electroencephalography LFP Local Field Potential innovative signal processing tools for coding and decoding of neural activity biomimetic artificial Spiking Neural Networks SNN and neural network modeling In order to develop functional communication with the nervous system and to create a new generation of neuroprostheses the study of closed loop systems is mandatory It has been widely recognized that closed loop neuroprosthetic systems achieve more favorable outcomes for users then equivalent open loop devices Improvements in task performance usability and embodiment have all been reported in systems utilizing some form of feedback The bi directional communication between living neurons and artificial devices is the main final goal of those studies However closed loop systems are still uncommon in the literature mostly due to requirement of multidisciplinary effort Therefore through eBook on closed loop systems for next generation neuroprostheses we encourage an active discussion among neurobiologists electrophysiologists bioengineers computational neuroscientists and neuromorphic engineers This eBook aims to facilitate this process by ordering the 25 contributions of this research in which we highlighted in three different parts A Optimization of different blocks composing the closed loop system B Systems for neuromodulation based on DBS EMG and SNN and C Closed loop BMIs for rehabilitation   **Research Centers Directory** ,2005

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