Abstract collection of
the 2022 International Symposium on
Nonlinear Theory and its Applications (NOLTA2022)

Virtual online conference,
December 12–15, 2022.

Abstract collection of NOLTA2022

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2022 International Symposium on Nonlinear Theory and its Applications

Virtual online conference
December 12–15, 2022

Organizer:
NOLTA Society, IEICE

In Cooperation with:
Technical Group on Nonlinear Problems, IEICE
Technical Group on Complex Communication Sciences, IEICE

Supported by:
Support Center for Advanced Telecommunications Technology Research, Foundation (SCAT)

Welcome Message from the General Co-Chairs

Dear Colleagues,

We sincerely welcome all of you with our great honor to the 2022 International Symposium on Nonlinear Theory and Its Applications (NOLTA2022). The NOLTA2022 is organized by the NOLTA Society, IEICE, as its flagship symposium in cooperation with the Technical Committee on Nonlinear Problems, IEICE, and the Technical Committee on Complex Communication Science, IEICE.

Many excellent papers were submitted, so that we have a variety of high quality presentations in the regular and special sessions. Furthermore, three remarkable professors from U.S.A., Sweden, and Japan will give their exciting plenary talks. We surely believe that the NOLTA2022 will provide a rich opportunity for researchers, especially students, to exchange their latest, precious, and valuable ideas over the Internet.

The authors of the presented papers in the NOLTA2022 have privilege to submit the full versions of their papers to the Special Section on Recent Progress in Nonlinear Theory and Its Applications in the international journal, NOLTA, IEICE, which will be issued on April 1, 2023. In addition, the Student Paper Award will be given to the excellent student presentations during the symposium to encourage young researchers.

Finally, we would like to thank all organizing committee members for their efforts and cooperation. We also thank all the participants of the NOLTA2022 for their contributions. We hope participants will attend multiple sessions taking advantage of full online format, and enjoy the NOLTA2022.

Igor Mezić
UC Santa Barbara, U.S.A.

Yoshihiko Horio
Tohoku University, Japan

General Co-Chairs, NOLTA 2022

Technical Program Co-Chairs' Message

On behalf of the Technical Program Committee, we would like to welcome you to the 2022 International Symposium on Nonlinear Theory and Its Applications (NOLTA 2022). Although we hoped to meet in the coastal resort of Opatija, Croatia, the world's events have again prevented us from doing so; therefore, we are holding NOLTA 2022 as a virtual online conference on December 12-15, 2022.

We are grateful for the volume and quality of papers submitted to the technical program of the conference. This year's meeting has 52 oral sessions in which a total of 206 papers will be presented. Of that number, 163 papers are classified according to 17 topics presented in 41 special sessions. The remaining 43 papers will be presented in 11 regular sessions. A substantial number of presenters have chosen to submit the extended version of their contributions to the Special Section of the open-access journal "Nonlinear Theory and Applications (NOLTA) IEICE" related to this year's NOLTA symposium, to be published in the April 2023 issue.

A particular thank you goes to this year's plenary speakers, Prof. Predrag Cvitanović (Georgia Institute of Technology, USA), Prof. Johan Åkerman (University of Gothenburg, Sweden), and Prof. Takashi Hikihara (Kyoto University, Japan), who will be speaking respectively on Dec 12, 13, and 14.

We are especially thankful to the organizers of the special sessions for selecting the topics and inviting contributors to the symposium. Our deepest gratitude goes to the Technical Program Committee, all the Editors of special section of NOLTA, IEICE, and the reviewers who made sure that the technical program adheres to highest academic standards. Thank you also to all the support staff involved in the organization of the symposium that made sure everything falls in its place.

We hope that the participants will enjoy the technical program at NOLTA 2022 and that it will lead to new connections, ideas, and future development of the field of nonlinear theory and its applications.

Marko Budišić
Clarkson University, U.S.A.

Shigeki Shiokawa
Kanagawa Institute Technology, Japan

Hiroya Nakao
Tokyo Institute of Technology, Japan

Technical Program Co-Chairs, NOLTA 2022

Note from the Organizing Committee

The NOLTA2022 was originally planned to be held in the town of Opatija, Croatia, which is a beautiful scenic historic resort facing the Mediterranean Sea. Unfortunately, due to the hard-to-vanish COVID-19 pandemic and the military conflict in Europe, the Officers of the NOLTA Society decided that the NOLTA2022 was moved to online.

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Special Session Organizers

A2L-B Complex Systems, Complex Networks and Bigdata Analyses I

A3L-B Complex Systems, Complex Networks and Bigdata Analyses II

Organizer Atsushi Tanaka (Yamagata University)

A2L-C Synergetic Behavior in Complex Networks

Organizer Jian Gao (Beijing University)

A2L-D Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation I

A3L-D Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation II

A4L-D Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation III

A5L-D Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation IV

Organizers Shigeo Sato (Tohoku University) and Hideyuki Suzuki (Osaka University)

A3L-C Laser Dynamics and Complex Photonics I

A4L-C Laser Dynamics and Complex Photonics II

A5L-C Laser Dynamics and Complex Photonics III

B1L-C Laser Dynamics and Complex Photonics IV

B2L-C Laser Dynamics and Complex Photonics V

B3L-C Laser Dynamics and Complex Photonics VI

B4L-C Laser Dynamics and Complex Photonics VII

Organizers Kazutaka Kanno (Saitama University), Fumiyoshi Kuwashima (Fukui University of Technology), and Atsushi Uchida (Saitama University)

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A5L-B Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications II

A6L-B Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications III

B1L-B Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications IV

Organizers Milan Korda (LAAS-CNRS) and Alexandre Mauroy (University of Namur)

A6L-D Geometric Mechanics, Optimization and Control in Applications I

B1L-D Geometric Mechanics, Optimization and Control in Applications II

Organizer Vakhtang Putkaradze (University of Alberta)

B2L-B Cellular Dynamical Systems I

B3L-B Cellular Dynamical Systems II

B4L-B Cellular Dynamical Systems III

Organizer Hiroyuki Torikai (Hosei University)

B3L-D Fundamentals and Applications of Complex Communication Science (CCS) I

B4L-D Fundamentals and Applications of Complex Communication Science (CCS) II

Organizers Megumi Akai-Kasaya (Hokkaido University) and Kosuke Sanada (Mie University)

C2L-B Power Processing and Its Applications

Organizers Ryo Takahashi (Kyoto University of Advanced Science), Shiu Mochiyama (Kyoto University), and Alberto Castellazzi (Kyoto University of Advanced Science)

C2L-C Novel Perspectives of Quantum Walks for Information and Communications Applications

Organizers Makoto Naruse (University of Tokyo) and Etsuo Segawa (Yokohama National University)

C2L-D Modeling and Control of Cyber-Physical Systems

Organizer Hikaru Hoshino (University of Hyogo) and T. John Koo (Hong Kong Applied Science and Technology Research Institute)

C3L-B Taming Chaos in Diverse Physical Systems

Organizer Yueheng Lan (Beijing University of Posts and Telecommunications)

C3L-C Optimization Algorithms with Nonlinear Dynamics I

C4L-C Optimization Algorithms with Nonlinear Dynamics II

Organizers Tomoyuki Sasaki (Shonan Institute of Technology) and Yoshikazu Yamanaka (Utsunomiya University)

C3L-D Nonlinear Circuits and Networks with a Variety of Couplings and Network Topologies I

C4L-D Nonlinear Circuits and Networks with a Variety of Couplings and Network Topologies II

Organizers Yoko Uwate (Tokushima University), Tadashi Tsubone (Nagaoka University of Technology), and Keiji Konishi (Osaka Metropolitan University)

C4L-B Nonlinear Vibrations, Waves, and Localizations I

C5L-B Nonlinear Vibrations, Waves, and Localizations II

D1L-B Nonlinear Vibrations, Waves, and Localizations III

D2L-B Nonlinear Vibrations, Waves, and Localizations IV

Organizers Yusuke Doi (Osaka University) and Masayuki Kimura (Setsunan University)

D1L-C Algorithms for Dynamical/Statical Nonlinear Networks I

D2L-C Algorithms for Dynamical/Statical Nonlinear Networks II

Organizer Yuichi Tanji (Kagawa University)

D1L-D Koopman Operator Approach to Power System Nonlinear Dynamics I

D2L-D Koopman Operator Approach to Power System Nonlinear Dynamics II

Organizers Marcos Netto (National Renewable Energy Laboratory) and Yoshihiko Susuki (Kyoto University)

Session at a Glance

December 12, 2022 (Monday)

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December 14, 2022 (Wednesday)

9:00–10:00	C1L-A Plenary Talk 3, Prof. Takashi Hikihara (Kyoto University) Chair: Igor Mezić (UC Santa Barbara) Place: Room A			
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12:00–13:00	Closing Ceremony Place: Room A			

Abstracts

A1L-A (P1) Plenary Talk

DATE: 2022/12/12 09:20–10:20
PLACE: Room A
Chair: Igor Mezić (UC Santa Barbara)

A1L-A1 **Exact Coherent Structures and Dynamics of Turbulent Flows**
Predrag Cvitanović (Georgia Institute of Technology)

In the world of moderate, everyday turbulence of fluids flowing across planes and down pipes, a quiet revolution is taking place. Applied mathematicians can today compute 'exact coherent structures' numerically precise 3D, fully nonlinear Navier-Stokes solutions: unstable equilibria, traveling waves, and (relative) periodic orbits. Experiments carried out at Georgia Tech today yield measurements as detailed as the numerical simulations; our experimentalists measure such 'exact coherent structures' and trace out their unstable manifolds. What emerges is a picture of low-Reynolds turbulence as a walk among sets of weakly unstable invariant solutions. We take you on a tour of this newly breached, hitherto inaccessible territory. Mastery of fluid mechanics is no prerequisite, and perhaps a hindrance: the talk is aimed at anyone who had ever wondered why - if no cloud is ever seen twice - we know a cloud when we see one? And how do we turn that into mathematics?

A2L-B (S3-1) Complex Systems, Complex Networks and Bigdata Analyses I

DATE: 2022/12/12 10:40–12:00
PLACE: Room B
Chair: Atsushi Tanaka (Yamagata University)

A2L-B1 **Which Are More Probable Research Collaborators? Organizational or Disciplinary Neighbors**
Tetsuo Imai (Hiroshima City University), Yuta Ohkubo (Hiroshima City University)
⇒ Proc. pp. 1–4, [Paper ID: 5188]

In research collaborations, in some field collaborative research teams might tend to be formed among members who belong to the same organization, in another filed there might be many joint research teams that cross organizational boundaries. We verified the tendency using the link prediction problem in the coauthor network of academic articles. We investigated which is more effective to improve the link prediction accuracy in coauthor networks of nursing and informatics: attribute information on the similarity of organizational affiliations between authors or that of their research disciplines.

Keywords: Link prediction problems, Coauthor networks, Complex networks, Network science

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A2L-B2 **Implementation of Secure and Fast Pseudo-Random-Number Generator on GPU**
Hitoaki Yoshida (Iwate University), Takeshi Murakami (Iwate University)
⇒ Proc. pp. 5–8, [Paper ID: 5074]

A novel iteration method with the modified activation function has been proposed to implement the secure and fast pseudo-random number generator (PRNG). The modified activation function has accelerated the pseudo-random-number (PRN) generation rate to 56.8 Tb/s by using NVIDIA GPU (A100). The PRNG consists of 1.67×107 Chaotic and Random Neural Networks (CRNNs), and the whole period of the PRN series is estimated at $P \approx 10^{100000000}$ based on the L.C.M. of the 10000 PRN series. The result is expected to apply the information security of the Controller Area Network (CAN) and that of the Autonomous GPU Accelerated systems, especially intelligent vehicle systems.

Keywords: Pseudo-random number, Neural network, GPU

A2L-B3 **Spatial Monte Carlo Integration for Learning Restricted Boltzmann Machines**
Kaiji Sekimoto (Yamagata University), Muneki Yasuda (Yamagata University)
⇒ Proc. pp. 9–12, [Paper ID: 5070]

A restricted Boltzmann Machine is a probabilistic machine learning model and has various applications. The learning is computationally difficult because it involves a combinatorial explosion. We provide a new and efficient learning method based on Spatial Monte Carlo integration which is a extension of the standard Monte Carlo integration and performs high-accuracy approximations for such intractable expectations. We present that the proposed method has

superior learning speed to the conventional method, however that learning fails in a simple learning setup. Under using a heuristic method, this failure is suppressed and the proposed method shows high learning performance.

Keywords: Restricted Boltzmann Machine, Approximate learning, Monte Carlo integration

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A2L-B4 **Multidimensional Data Analysis of Sleep State at Hot Spa in Onogawa Onsen**

Tomochika Harada (Yamagata University), Michio Yokoyama (Yamagata University), Morimasa Kato (Yamagata Prefectural Yonezawa University of Nutrition Sciences)
⇒ Proc. pp. 13–16, [Paper ID: 5199]

In this paper, we try to study society implementation research of a hot spring bathing and sleeping at hot spa in Onogawa utilizing the IoT / ICT technology with a view to the society after COVID-19. As the part of it, we analyze and evaluate the sleep state and condition caused by bathing in a hot spring by multidimensional data analysis. From the results, although there are individual differences, we find that it is better to use the hot springs to sleep better.

Keywords: Multidimensional Data Analysis, Hot Spa, Sleep Sensor, OSA-MA, POMS

A2L-C (S16) Synergetic Behavior in Complex Networks

DATE: 2022/12/12 10:40–12:00
PLACE: Room C
Chair: Jian Gao (Beijing University of Posts and Telecommunications)

A2L-C1 **Breathing Cluster in Complex Neuron-Astrocyte Networks**

Xingang Wang (Shaanxi Normal University)
⇒ Proc. p.17, [Paper ID: 5017]

The brain activities are featured by non-stationary dynamical patterns, yet the underlying mechanism remains not clear. Here, by introducing astrocyte-induced adaptive couplings, we investigate the collective behaviors on complex networks of coupled neural oscillators. It is found that during the process of network evolution, a portion of the oscillators are synchronized in an intermittent fashion, while the whole network remains as desynchronized. We conduct a theoretical analysis on the stability of the cluster, and give the necessary conditions for observing this phenomenon. This type of non-stationary pattern, which is named breathing cluster, reveals from a new perspective the interplay between network structure and dynamics, and has important implications to the functionalities of brain system.

Keywords: Cluster synchronization, Adaptive neural network, Breathing phenomenon

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A2L-C2 **Impact of Network Motifs on Response Dynamics**

Peng Ji (Fudan University)
⇒ Proc. p.18, [Paper ID: 5059]

Here, we show that basic motifs along the propagation path may jointly determine the previously proposed regimes of distance-limited propagation and degree-limited propagation, or even cease their existence. Our analysis suggests not only a radical departure from these scaling regimes but provides a deeper understanding of the interplay of self-dynamics, interaction dynamics, and topological properties.

Keywords: Information spreading, Networks, Collective Dynamics

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A2L-C3 **Complexity Based Approach for El Niño Magnitude Forecasting Before the“ Spring Predictability Barrier ”**

Jun Meng (Beijing University of Posts and Telecommunications / Potsdam Institute for Climate Impact Research), Jingfang Fan (Potsdam Institute for Climate Impact Research), Josef Ludescher (Potsdam Institute for Climate Impact Research), Agarwal Ankit (Potsdam Institute for Climate Impact Research), Xiaosong Chen (Beijing Normal University), Armin Bunde (Justus-Liebig-Universität Giessen), Jürgen Kurths (Potsdam Institute for Climate Impact Research / Humboldt University), Hans Joachim Schellnhuber (Potsdam Institute for Climate Impact Research)
⇒ Proc. p.19, [Paper ID: 5020]

We introduce a new method – system sample entropy– for calculating the complexity of a complex system composed of several time series. We use this method to quantify the system complexity of the Nino 3.4 region and forecast the El nino magnitude one year ahead.

Keywords: System complexity, Entropy, El Nino forecasting

A2L-C4 **Cascading Formation of Synchronous Clusters of Coupled Second-Order Kuramoto Oscillators**

Jian Gao (Beijing University of Posts and Telecommunications), Konstantinos Efstathiou (Duke Kunshan University)
⇒ Proc. p.20, [Paper ID: 5057]

We consider the second-order Kuramoto oscillators with inertias and show a new type of synchronization process, the cascading formation of clusters. Several clusters of oscil-

lators are synchronized in sequence with a fixed coupling strength. The formation of some clusters is a necessary condition for the formation of other ones, forming a cascading chain. The intermediate states in the process are all metastable. We propose a generalized self-consistent method to determine the positions, sizes, and orders of the clusters. This process will be stopped in the first round of cascade in the limit of zero inertias as the classical Kuramoto oscillators.

Keywords: Synchronziation, Kuramoto oscillators, Self-consistent method

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A2L-D (S10-1) Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation I

DATE: 2022/12/12 10:40–12:00
PLACE: Room D
Chair: Hideyuki Suzuki (Osaka University)

A2L-D1 Predicting Traffic Breakdown in Expressways Using Linear Combination of Vehicle Detector Data

Rikuto Shigemi (University of Tsukuba), Hiroyasu Ando (Advanced Institute for Materials Research, Tohoku University), Kentaro Wada (University of Tsukuba), Risa Mukai (Hanshin Expressway Co., LTD)
⇒ Proc. pp. 21–24, [Paper ID: 5195]

Traffic congestion brings about a variety of social issues to be solved urgently. In this study, we examine a precision of traffic prediction with a simple linear model. Instead of improving the complex models, we appropriately select training data with a linear model, and verify the feasibility of prediction by exploring "data complexity".

Keywords: Prediction, Traffic congestion, Linear model, Regression, Explainability, Detector data

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A2L-D2 Variational Integrator for Hamiltonian Neural Networks

Yuhan Chen (Kobe University), Takashi Matsubara (Osaka University), Takaharu Yaguchi (Kobe University)
⇒ Proc. pp. 25–28, [Paper ID: 5071]

Hamiltonian neural networks are a type of neural networks for learning equations of motion that describe physical phenomena from given observed data. Such models should be used in physical simulations; however, it is known that when general-purpose numerical integrators are used for discretization, the energy conservation law and other laws of physics are destroyed. Structure-preserving numerical methods such as the variational integrator are effective to address this problem. We propose a variational integrator for Hamiltonian neural networks in this paper.

Keywords: Neural network, Hamilton equation, Variational integrator

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A2L-D3 Learning Generic Systems Using Neural Symplectic Forms

Baige Xu (Kobe University), Yuhan Chen (Kobe University), Takashi Matsubara (Osaka University), Takaharu Yaguchi (Kobe University)
⇒ Proc. pp. 29–32, [Paper ID: 5083]

The GENERIC formulation is a way of describing non-equilibrium thermodynamic systems, and GENERIC systems are systems formulated as such. For learning such systems from data, GFINN is an existing method. In this talk, we improved it by applying the recently proposed neural symplectic form, so that it becomes possible to model general GENERIC systems on general symplectic manifolds using data represented by general coordinate systems.

Keywords: symplectic form, non-equilibrium thermodynamic, GENERIC, Neural network

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A2L-D4 Herding with Self-Organizing Multiple Starting Point Optimization

Hiroshi Yamashita (University of Tokyo), Hideyuki Suzuki (Osaka University), Kazuyuki Aihara (International Research Center for Neuro intelligence, University of Tokyo)
⇒ Proc. pp. 33–36, [Paper ID: 5015]

The herding algorithm is a prominent sampling algorithm using the complex behavior of high-dimensional nonlinear dynamics. Its procedure is composed of the step of nonconvex optimization and that of updating the state depending on its output. This completely deterministic algorithm is interesting as it connects optimization algorithm, nonlinear dynamics and sampling. In this paper, we propose a multiple starting point heuristic for the optimization step of herding and discuss the behavior of the algorithm that is also worth pursuing in itself as a nonlinear dynamical system. In particular, we observe that the candidate states in the algorithm keep distance from each other, although it is not designed explicitly.

Keywords: Sampling, Optimization, Herding

A2L-E (R1 and 4-1) Nonlinear Phenomena/Complex Networks and Systems I

DATE: 2022/12/12 10:40–12:00
PLACE: Room E
Chair: Shiu Mochiyama (Kyoto University)

A2L-E1 **Study of Nonlinear Phenomena in Current-Mode Controlled DC-DC Converter with TEM via a Closed-Form Mapping Without Approximation**

Daiki Hozumi (Okayama University of Science), Shota Uchino (National Institute of Technology, Anan College), Takuji Kousaka (Chukyo University), Hiroyuki Asahara (Okayama University of Science)
⇒ Proc. pp. 37–40, [Paper ID: 5045]

In this study, we analyze the bifurcation phenomena that occur in a power conversion circuit with a thermoelectric module (TEM) connected as a power source and investigate its dynamic behavior. First, we show a simple equivalent circuit model. Next, we derive the Poincaré map, which discretize the inductor current and capacitor voltage at each clock cycle. Then, we calculate the one-parameter bifurcation diagram in the case of TEM based on the simulation results of the Poincaré map. Finally, we compute the one-parameter bifurcation diagram and clarify the qualitative properties of a power conversion circuit with TEM.

Keywords: Thermoelectric module, DC-DC converter, Bifurcation phenomenon, Poincaré map

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A2L-E2 **Experimental Investigation of Chatter Switching on High-Side Gate Driver Circuit for DC-DC Converter**

Daisuke Ito (Gifu University), Takuji Kousaka (Chukyo University), Hiroyuki Asahara (Okayama University of Science)
⇒ Proc. pp. 41–44, [Paper ID: 5157]

In this study, a chattering phenomenon in a high-side gate driver circuit composed of a gate driver and bootstrap circuit has been investigated experimentally. We focus on the degradation of a capacitor contained in the bootstrap circuit and the duty ratio of the pulse input. We have observed waveforms of the bootstrap circuit. From experimental results, it is confirmed that the capacitance reduction due to capacitor degradation causes the chattering phenomenon and increases the number of chattering. From parametric experiments about the duty ratio and capacitances, the boundary structure of the number of chattering on the circuit experiments has similar to the numerical analysis results.

Keywords: chatter switching, bifurcation phenomena, high-side gate driver circuit

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A2L-E3 **Effects of a Nonlinear Packet Drop Probability Function on Red Performance**

Kaito Kato (Chukyo University), Hideyuki Kato (Oita University), Hiroyuki Asahara (Okayama University of Science), Daisuke Ito (Gifu University), Takuji Kousaka (Chukyo University)
⇒ Proc. pp. 45–48, [Paper ID: 5166]

This paper introduces nonlinearity to the packet drop probability function of Random Early Detection (RED). The RED controls network congestions by actively managing a router's queue. We investigate the nonlinearity contribution to the network performance. The effects of the imposed nonlinearity on the RED performance are investigated under different traffic loads. When the network traffic is not too heavy, the RED with nonlinearity achieves better network performance than the original RED. This work suggests the performance improvement of networks by optimizing the nonlinearity degree of the packet drop probability.

Keywords: congestion control, RED, nonlinear packet drop probability function, NS-2

A2L-E4 **Asymptotic Phase for Stochastic and Quantum Nonlinear Oscillators Based on Koopman Operator Theory**

Yuzuru Kato (Future University Hakodate), Hiroya Nakao (Tokyo Institute of Technology)
⇒ Proc. pp. 49–52, [Paper ID: 5006]

The asymptotic phase is a fundamental quantity for analyzing classical limit-cycle oscillators. In this study, we introduce a definition of the asymptotic phase for stochastic and quantum nonlinear oscillators by using the eigenfunction of the Koopman operator associated with the fundamental oscillation frequency. Our definition of the asymptotic phase can be used for analyzing synchronization of stochastic and quantum nonlinear oscillators.

Keywords: Koopman operator, asymptotic phase, synchronization, quantum oscillator

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A3L-B (S3-2) Complex Systems, Complex Networks and Bigdata Analyses II

DATE: 2022/12/12 13:00–14:20
PLACE: Room B
Chair: Atsushi Tanaka (Yamagata University)

A3L-B1 **Discriminative Restricted Boltzmann Machine with Adapted-Sparse Hidden Layer**

Muneki Yasuda (Yamagata University), Tomu Katsumata (KADOKAWA Connected Inc.)
⇒ Proc. pp. 53–56, [Paper ID: 5003]

A discriminative restricted Boltzmann machine (DRBM) is a probabilistic three-layered neural network for solving classification problems. This study attempts to improve the generalization property of the DRBM. Regularization methods such as L1 or L2 regularizations can be used to control the representation power of the model and suppress over-fitting to a dataset. To control the representation power of DRBM, an alternative regularization approach is proposed in which a sparse regularization is imposed on the values of the hidden variables. In the resultant model, the sparse regularization controls the effective size of the hidden layer. Unlike standard regularization methods, in the proposed model, parameters that control the sparsity strength are automatically tuned during training together with the other learning parameters. The method is validated through numerical experiments using datasets obtained from benchmark datasets.

Keywords: statistical machine learning, classification, restricted Boltzmann machine, sparse modeling

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A3L-B2 **Backdoor Poisoning Attacks on Meta-Learning-Based Few-Shot Classifiers**

Ganma Kato (Supership Inc.), Chako Takahashi (Yamagata University), Koutarou Suzuki (Toyohashi University of Technology)
⇒ Proc. pp. 57–60, [Paper ID: 5090]

Few-shot classification is a classification made on the basis of very few samples, and meta-learning methods are often employed to accomplish it. Research on poisoning attacks against meta-learning-based few-shot classification is now beginning. While poisoning that violates the classifier's availability has been investigated by Xu et al., and Oldewage et al., backdoor poisoning has only been briefly evaluated by Oldewage et al. under limited conditions. We formulate a backdoor poisoning attack on meta-learning-based few-shot classification in this study. We show that the proposed backdoor poisoning attack is effective against the few-shot classification using model-agnostic meta-learning through experiments.

Keywords: adversarial attacks, backdoor poisoning attacks, few-shot classification, meta-learning

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A3L-B3 **Effective Algorithm for Counting Non-Intersecting Path Pairs**

Atsushi Tanaka (Yamagata University), Yukio Hayashi (Japan Advanceed Institute of Sciece and Technology)
⇒ Proc. pp. 61–64, [Paper ID: 5132]

In This paper, an algorithm for counting non-intersecting path pairs in directed graphs is proposed. The algorithm is basically based on the determinant of the path matrix. However, in some intricate graphs, it was found that exceptional situations arise that cannot be solved by this algorithm. We showed an example with a network based on EU country-level adjacencies. Once an efficient algorithm for the exceptional situation is known, various regression algorithms can be developed and it will contribute to the formation of various resilient networks.

Keywords: resilience, Non-intersecting path

A3L-C (S7-1) Laser Dynamics and Complex Photonics I

DATE: 2022/12/12 13:00–14:20
PLACE: Room C
Chair: Fumiyoshi Kuwashima (Fukui University of Technology)

A3L-C1 **A Quantum Walk Model for the Energy Transfer of a Dressed Photon**

Motoichi Ohtsu (Research Origin for Dressed Photon), Etsuo Segawa (Yokohama National University), Kenta Yuki (Middenii)
⇒ Proc. pp. 65–68, [Paper ID: 5004]

This paper reports a two-dimensional quantum walk (QW) model to describe the spatio-temporal behavior of the dressed photon (DP) energy transfer. DP is a quantum field that is created as the result of interaction among photons and electrons in a nanometer-sized complex system. Experimental studies have suggested that the temporal behavior of the DP energy transfer should be described by the QW model, not by a conventional random walk model. Thus, the QW model was used to study the efficiency of the DP creation on the tip of a conventionally used fiber probe device. Numerical calculations successfully evaluated the dependences of the DP energy transfer on basic physical quantities; the dependences on the ratio between the DP-hopping energy and the DP-phonon coupling energy, and on the phase of the unitary matrix in the spatio-temporal evolution equation.

Keywords: Quantum walk, Dressed Photon, Energy Transfer

A3L-C2 **On the Schroedinger Picture in C*-Algebraic Quantum Theory**

Kazuya Okamura (Research Origin for Dressed Photon)
⇒ Proc. pp. 69–72, [Paper ID: 5008]

We discuss state transitions in C*-algebraic quantum theory and reconsider state changes, usually called the Schroedinger picture in quantum theory. We introduce

C*-probability structure and transition probability in C*-algebraic quantum theory. By using them, we define category of state transitions. Next, we explain the historical background of this work related to quantum measurement theory.

Keywords: C*-probability structure, transition probability, category of state transitions

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A3L-C3 **Destabilizing Two-Dimensional Optical Bistable Device by External Feedback**

Takashi Isoshima (RIKEN Cluster for Pioneering Research)

⇒ Proc. pp. 73–76, [Paper ID: 5066]

Bistable system with a spatial expanse can provide a wavefront, an interface between two stable states, that can propagate. We investigate a two-dimensional optical bistable device (2DOBD) for natural computing including maze exploration. Our device can present both extension and reduction of on-state area controlled not only by the light intensity but also by the path width and device temperature.. In this paper we introduce an external refractory feedback that reduces the light intensity when turn-on is detected, to realize spontaneous turn-off resulting into pulse activity like in a neural cell.

Keywords: Nonlinear optics, Optical instability, wavefront propagation, external feedback

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A3L-C4 **Nonlinear Dynamical Simulation of the Universal Single-Mode Lasing in Fully-Chaotic Microcavity Lasers**

Mengyu You (Waseda University), Susumu Shinohara (Komatsu University), Satoshi Sunada (Kanazawa University), Takahisa Harayama (Waseda University)

⇒ Proc. pp. 77–78, [Paper ID: 5035]

We numerically simulate the lasing of the D- shaped microcavity laser, and show that lasing occurs in single mode, even when the pumping power is so high that many resonance modes have positive gain. Our numerical results support the universal single-mode lasing conjecture for fully-chaotic microcavity lasers.

Keywords: Microcavity lasers, Nonlinear

A3L-D (S10-2) Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation II

DATE: 2022/12/12 13:00–14:20
PLACE: Room D

Chair: Hideyuki Suzuki (Osaka University)

A3L-D1 **Efficient Hessian Vector Products Calculation of Neural ODE Based on Second-Order Adjoint Method**

Atsuhiro Hada (Osaka University), Satoru Iwasaki (Osaka University)

⇒ Proc. pp. 79–82, [Paper ID: 5103]

Neural ordinary differential equations (Neural ODEs) are types of the neural net architectures, and its intermediate layers are modeled as ordinary differential equations instead of discrete sequence of hidden layers. In Neural ODEs, we can not compute Hessians by conventional automatic differentiation methods since its intermediate layer possesses ODE forms. In this study, we propose methodologies to get second order derivatives of loss functions of Neural ODEs and this will allow us to analyze loss landscapes of Neural ODEs.

Keywords: Neural Ordinary Differential Equations, Hessians, Second-Order Adjoint Method

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A3L-D2 **Mental Simulation on Reservoir Computing as an Efficient Planning Method for Mobile Robot Navigation**

Yoshihiro Yonemura (Future University Hakodate), Yuichi Katori (Future University Hakodate)

⇒ Proc. pp. 83–86, [Paper ID: 5113]

Machine learning methods have been applied for autonomous mobile robot navigation. Despite the achievement of the methods, their learning cost is the most significant remaining problem. We propose a mental simulation framework on reservoir computing to perform efficient learning and action planning. Mental simulation is a process that simulates the interaction between the model and the environment. Reservoir computing is appropriate for mental simulation because it can process complex time series efficiently. In this research, we implemented action planning with mental simulation on reservoir computing, and we confirmed that the robot could reach the target point by the planning.

Keywords: reservoir computing, reinforcement learning, mental simulation, robot navigation

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A3L-D3 **Online Reinforcement Learning on Reservoir Based Actor-Critic Model with Gibbs's Policy**

Tatsuro Nagai (Future University Hakodate), Yuichi Katori (Future University Hakodate)

⇒ Proc. pp. 87–90, [Paper ID: 5184]

Reinforcement learning methods can be applied to many real-world applications by targeting partially observable Markov decision processes (POMDPs). In this research, we extend the actor-critic algorithm so that the agent can evaluate the state value with the agent's action history and can handle noisy observables for POMDP. In order to reflect a

history of actions to the agent's decision, we use an echo state network (ESN) for both the actor and the critic. In the experiment, we use an autonomous mobile robot environment. We evaluate the task accomplishment rate in a noisy environment.

Keywords: ESN, Actor-Critic algorithm, reinforcement learning, POMDP

A3L-D4 **Visual Predictive Coding Model with Reservoir Computing for Reinforcement Learning Tasks in 3D Environment**

Tomohito Izumi (Future University Hakodate), Yuichi Katori (Future University Hakodate)

⇒ Proc. pp. 91–94, [Paper ID: 5162]

Computational models are an indispensable tool for understanding the mechanism of the brain. Previous studies employ reservoir computing to construct a predictive coding model and have shown its ability to replicate the brain's properties. However, reservoir computing models cannot be directly applied to broad brain functions due to performance limitations. Here, we propose a visual predictive coding model with reservoir computing that can handle the high-dimensional input to extend the scope of the application. We believe that our approach presents a novel dynamical mechanism of visual processing in the brain and fundamental technology for a brain-like artificial intelligence system.

Keywords: Computational Neuroscience, Predictive Coding, Reservoir Computing

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A3L-E (R1 and 4-2) Nonlinear Phenomena/Complex Networks and Systems II

DATE: 2022/12/12 13:00–14:20
PLACE: Room E
Chair: Yuu Miino (Naruto University of Education)

A3L-E1 **Analysis of Functional Connectivity of EEG Reflecting Circadian Rhythm Using Phase Lag Index**

Yoshiki Yasuda (Chiba Institute of Technology), Iinuma Yuta (Chiba Institute of Technology), Sou Nobukawa (Chiba Institute of Technology, National Center of Neurology and Psychiatry), Haruhiko Nishimura (University of Hyogo)

⇒ Proc. pp. 95–98, [Paper ID: 5170]

Medical disorders and mood disorders are related to circadian rhythm disturbances. The development of biomarkers of circadian rhythm is important for the appropriate treatment of these conditions. Previous studies on EEG reflecting circadian rhythm have used complexity analysis; however, it is difficult to perform brain region-specific analysis from complexity. Therefore, we analyzed functional connectivity using the Phase Lag Index (PLI) to clarify the brain region-specificity of the EEG reflecting circadian rhythms. Consequently, significant changes in functional connectivity of the theta, delta, and beta bands were observed between daytime and nighttime.

Keywords: Circadian Rhythm, Functional Connectivity, Phase Lag Index, EEG

A3L-E2 **Estimation of the Critical Transition Probability Using Quadratic Polynomial Approximation with Skewness Filtering**

Makito Oku (University of Toyama)

⇒ Proc. pp. 99–102, [Paper ID: 5005]

In this study, I propose a nonlinearity-based method for estimating the critical transition probability. It is based on my previous method using quadratic polynomial approximation, and skewness filtering is added. The proposed method uses either the least squares method (LSM) or maximum likelihood estimation (MLE). The results of numerical simulations using May model show that the proposed method has much better precision than the previous method without skewness filtering. It is also found that MLE requires much less data points than LSM if auto-correlation is weak.

Keywords: critical transition, early warning signal, saddle-node bifurcation

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A3L-E3 **Nonlinear Trends Extraction for COVID-19 Daily New Cases in Japan**

Fumihiko Ishiyama (Nippon Telegraph and Telephone Corp.)

⇒ Proc. pp. 103–106, [Paper ID: 5013]

We have developed a nonlinear method of time series analysis, that allows us to obtain multiple nonlinear trends from a given set of numerical data. We propose to apply the method to recognize the ongoing status of COVID-19 infection, and applied to the time series of daily new cases in Japan. We found that there is only a single nonlinear trend, and this result justifies the use of a week-based infection growth rate as an index. In addition, the fitting with the obtained nonlinear trend holds for a duration of more than three months for the Delta variant infection time series. The fitting also visualizes the transition to the Omicron variant.

Keywords: nonlinear method of time-frequency analysis, covid-19, mode decomposition with general complex functions

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A3L-E4 **The Effects of Symmetrization of k-Nearest**

Neighbor Recurrence Plot on Superfamily Phenomena in Time Series

Masato Kawaguchi (Oita University), Hideyuki Kato (Oita University)

⇒ Proc. pp. 107–110, [Paper ID: 5033]

It has been shown that superfamily phenomena are observed in nonlinear dynamical systems from the order of network motif patterns in networks created from time series in phase space. This approach seems to be attractive because solutions of nonlinear dynamical systems can be discriminated and classified. In the approach, the k-nearest neighbor recurrence plot (RP) is employed to transform a time series to a network. In this study, we replace the RP to a different type of RP and evaluate its effects on the discrimination of solutions in some dynamical systems.

Keywords: Network motif, Time series analysis, Solution classification

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A4L-B (S15-1) Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications I

DATE: 2022/12/12 14:40–16:00
PLACE: Room B
Chairs: Milan Korda (LAAS-CNRS) and Alexandre Mauroy (University of Namur)

A4L-B1 **An Application of Frequency-Domain Prony Method to Koopman Mode Decomposition**

Yoshihiko Susuki (Kyoto University)

⇒ Proc. p.111, [Paper ID: 5002]

We study our idea of using the so-called frequency-domain Prony method for computation of Koopman eigenvalues and Koopman modes directly from time-series data in the framework of dynamic mode decomposition.

Keywords: Koopman operator, Koopman mode decomposition, Prony method

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A4L-B2 **Time-Series Analysis of Phase Dynamics in a Campus Distribution Grid Using Short-Term Koopman Mode Decomposition**

Munetaka Noguchi (Osaka Prefecture University), Yoshihiko Susuki (Kyoto University), Atsushi Ishigame (Osaka Metropolitan University)

⇒ Proc. pp. 112–115, [Paper ID: 5178]

Short-term Koopman mode decomposition is introduced from the Koopman operator framework of non-linear time-variant systems. In this report, we apply the short-term Koopman mode decomposition to time-series data on voltage-phase differences on a campus distribution network in Osaka Metropolitan University, Japan, and we extract temporal features of the time-series data of voltage-phase differences.

Keywords: Power grid, Synchrophasor, Time-series data, Koopman mode decomposition

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A4L-B3 **Velocity Prediction for Nonlinear Swarm Formation in Unknown External Potential Using Koopman Theory**

Yanran Wang (Kyoto University), Takashi Hikihara (Kyoto University)

⇒ Proc. p.116, [Paper ID: 5105]

Formation control in Swarm Intelligence system has earned significant research interests in both theorical aspect and applications over the past two decades. We present a formation control algorithm for mobile robots travelling in nonlinear external potential. Experiments are performed on real mobile robots to verify the algorithm, and the effectiveness of Dynamic Mode Decomposition in robot's velocity prediction in unknown environment is demonstrated.

Keywords: Swarm formation, Nonlinear dynamical systems, Koopman theory, Dynamic mode decomposition

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A4L-B4 **Dynamic Mode Decomposition for Elementary Cellular Automata**

Keisuke Taga (Waseda University), Hiroya Nakao (Tokyo Institute of Technology)

⇒ Proc. pp. 117–120, [Paper ID: 5201]

Dynamic mode decomposition (DMD) provides a data-driven approach to analyzing dynamical systems and has been applied to various systems. In this study, we performed DMD and Extended DMD analysis for elementary cellular automata (ECA) as a typical example of finite-state spatially-extended dynamical systems. ECA can exhibit various dynamics including chaotic ones, and thus be useful for examining the validity of the results obtained by DMD.

Keywords: Dynamic mode decomposition, Cellular Automaton

A4L-C (S7-2) Laser Dynamics and Complex Photonics II

DATE: 2022/12/12 14:40–16:00
PLACE: Room C
Chair: Kazutaka Kanno (Saitama University)

A4L-C1 **Chaotic Synchronization of Randomly Coupled Chaotic Systems with Many Degrees of Freedom**

Ken Umeno (Kyoto University)

⇒ Proc. p.121, [Paper ID: 5209]

A model of randomly coupled chaotic systems with many degrees of freedom is newly investigated. By using ergodic theory and the central limit theorem, we discovered that chaotic synchronization phenomena exists even in the infinite limit. Evidence of this phenomenon and some phase transition between chaotic synchronization and desynchronization is also provided as well as the theoretical and analytical foundation in terms of conditional Lyapunov exponent using ergodic theory.

Keywords: Chaos, Synchronization

A4L-C2 **Ultra-Long-Distance Synchronization of DFB Lasers Induced by Common Digital-Phase Modulation CW Light**

Anbang Wang (Taiyuan University of Technology), Xiaohui Peng (Taiyuan University of Technology), Lin Jiang (Southwest Jiaotong University), Lianshan Yan (Southwest Jiaotong University), Yuncai Wang (Guangdong University of Technology)

⇒ Proc. pp. 122–124, [Paper ID: 5144]

We propose and experimentally demonstrate a scheme of ultra-long-distance chaos synchronization of DFB lasers injected by a common digital-phase modulation CW light. Results show that high-quality synchronization can be achieved even when error bits exist between the driving signals. By utilizing long-distance optical coherent transmission of the digital signal, chaos synchronization over 8000-km single-mode fiber link is achieved.

Keywords: synchronization, semiconductor laser, chaos

A4L-C3 **Chaos Synchronization Over 1040-km Fiber Relay Transmission Using Hybrid Amplification**

Longsheng Wang (Taiyuan University of Technology), Yushan Wu (Taiyuan University of Technology), Yuehui Sun (Guangdong University of Technology), Anbang Wang (Taiyuan University of Technology), Yuncai Wang (Guangdong University of Technology)

⇒ Proc. pp. 125–127, [Paper ID: 5124]

We propose a scheme of long-distance chaos synchronization using the hybrid amplification of erbium doped fiber amplifiers (EDFAs) and distributed fiber Raman amplifiers (DFRAs). The DFRA has a low noise figure and can help to reduce the ASE noise caused by the EDFA, and resultantly the long-distance chaos synchronization can be expected. Numerical and experimental results show that 1040-km chaos synchronization can be achieved by cascaded relay of EDFA and DFRA over eight 130-km single-span fiber. This scheme can pave the way of high-speed chaotic optical communication in the 1000-km interurban network.

Keywords: laser chaos, hybrid amplification, chaos synchronization, chaotic optical communication

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A4L-C4 **Multi-Wavelength Broadband Chaos in Long-Cavity FP Lasers Subject to Optical Feedback**

Zhiwei Jia (Taiyuan University of Technology), Xinhong Zhong (Taiyuan University of Technology), Anbang Wang (Taiyuan University of Technology), Yuncai Wang (Guangdong University of Technology)

⇒ Proc. pp. 128–130, [Paper ID: 5091]

Broad laser chaos synchronization is very desired for its application in secure communication. Limited by intrinsic relaxation oscillation, the bandwidth of laser chaos is lower than 10 GHz. Many methods have been proposed and demonstrated to obtain broadband chaos by breaking the limitation of relaxation oscillation. However, the chaos synchronization becomes difficult. Here we demonstrate the generation and synchronization of broadband chaos in long-cavity FP lasers. Enhanced by modes beating in 1.5 mm-long-cavity FP lasers, the bandwidth of laser chaos is up to 37 GHz. By filtering multiple wavelength slices, multi-wavelength broadband chaos is obtained with synchronization above 0.98.

Keywords: Laser chaos, long-cavity FP lasers, broadband, multi-wavelength

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A4L-D (S10-3) Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation III

DATE: 2022/12/12 14:40–16:00
PLACE: Room D
Chair: Shigeo Sato (Tohoku University)

A4L-D1 **Pattern Recognition Using FRET Networks: A Preliminary Study**

Masaki Nakagawa (Fukuoka Institute of Technology)

⇒ Proc. p.131, [Paper ID: 5123]

Förster resonance energy transfer (FRET) network is a promising physical phenomenon for realizing high-speed, high-efficient, and compact information-processing devices. Previous experimental studies revealed that FRET networks generate rich spatiotemporal signals, which are helpful for information processing. Furthermore, our previous numerical study using a mathematical model showed that FRET networks have the capability for time-series prediction, thanks

to their nonlinearity and some memory. This study proposes pattern recognition using FRET networks based on their nonlinearity. Numerical simulations using the mathematical model show that FRET networks are capable of pattern recognition, such as MNIST hand-written digit recognition tasks.

Keywords: FRET, Quantum dots, Pattern recognition, MNIST

A4L-D2 **Design of a Low-Power FPGA-Based CNN Accelerator Based on Nonvolatile Logic-in-Memory Circuitry**

Daisuke Suzuki (University of Aizu), Masanori Natsui (Tohoku University), Akira Tamakoshi (Tohoku University), Yasuhiro Takako (Tohoku University), Takahiro Hanyu (Tohoku University)

⇒ Proc. pp. 132–135, [Paper ID: 5126]

A nonvolatile (NV) field-programmable gate array (FPGA) is quite attractive hardware platform for a binary convolutional neural network (BCNN) accelerator in terms of reconfigurability and ultra-low-power standby power consumption. Moreover, the use of NV logic-in-memory (LIM) circuitry makes it possible to improve both area efficiency and energy efficiency. In this paper, some related topics about NV-FPGA, NV-LIM circuitry, and its application to the BCNN accelerator are presented and its effectiveness is demonstrated.

Keywords: FPGA, Nonvolatile, Convolutional neural network, Edge computing, Hardware accelerator

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A4L-D3 **Prospects of Energy-Efficient Edge-AI Accelerator Architecture Using Nonvolatile Logic**

Masanori Natsui (Tohoku University), Daisuke Suzuki (University of Aizu), Yasuhiro Takako (Tohoku University), Akira Tamakoshi (Tohoku University), Takahiro Hanyu (Tohoku University)

⇒ Proc. pp. 136–138, [Paper ID: 5102]

The realization of energy-efficient edge-AI hardware is an important issue for utilizing it as a fundamental technology for the next-generation IoT society. Nonvolatile logic-circuit technology based on MTJ devices is a key to solving this challenge. In this paper, we discuss design guidelines and prospects for edge-AI hardware that enables energy-saving operation by maximizing the use of nonvolatile memory functions.

Keywords: Edge AI, Nonvolatile logic, Magnetic tunnel junction, Power gating, Neural network

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A4L-D4 **Tunnel Conductance Modeling of Spintronics Devices Based on Device Temperature Dynamics**

Yushi Kikuchi (Research Institute of Electrical Communication, Tohoku University), Yoshihiko Horio (Research Institute of Electrical Communication, Tohoku University), Shunsuke Fukami (Research Institute of Electrical Communication, Tohoku University), Hiroyasu Ando (Advanced Institute for Materials Research, Tohoku University)

⇒ Proc. pp. 139–142, [Paper ID: 5190]

Spintronics devices are known to reproduce some functions of synapses (e.g., spike-timing-dependent plasticity (STDP)) and neurons (e.g., leaky integration of input spikes). However, only a few models have been investigated for the use of spintronics devices in neural network circuits. Herein, we develop a mathematical model for the application of spintronics devices to spiking neural network circuits. The proposed mathematical model describes the relationship between the input and the value of the tunneling conductance of the spintronics device.

Keywords: Spintronics Device, Dynamics, Neural Network

A4L-E (R1 and 4-3) Nonlinear Phenomena/Complex Networks and Systems III

DATE: 2022/12/12 14:40–16:00
PLACE: Room E
Chair: Ryo Takahashi (Kyoto University of Advanced Science)

A4L-E1 **Predicting a Parameter Value at Which a Critical Transition Occurs from Lyapunov Exponents in an Estimated Parameter Space**

Yoshitaka Itoh (Hokkaido University of Science)

⇒ Proc. pp. 143–146, [Paper ID: 5042]

This study estimates a parameter space only from two time-series data sets in order to predict a critical transition caused by saddle-node bifurcation. We confirm that the Lyapunov exponents can be approximated in the estimated parameter space and corresponded to the bifurcation diagram. In numerical experiments, we estimate a parameter space for coupled dynamics of water and vegetation.

Keywords: Critical Transition, Parameter Space Estimation, Extreme Learning Machine, Bifurcation Diagram Reconstruction

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A4L-E2 **Rigorous Analysis of Hysteresis Structure Observed in Arnol'd Tongue**

Mizuki Urushibara (Nagaoka University of Technology), Tadashi Tsubone (Nagaoka University of Technology), Naohiko Inaba (Shonan Institute of Technology)

⇒ Proc. pp. 147–150, [Paper ID: 5117]

This study investigates Arnold tongues generated by 2-D piecewise-constant driven oscillator. In this paper, we derived analytically some of the bounds of the fundamental harmonic entrainment for increasing time period T. We also confirmed the transition from the periodic solution to the two chaotic attractors and then back to the periodic solution.

Keywords: Arnold tongue, chaos, saddle-node bifurcation, piecewise-constant oscillator

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A4L-E3 **Analysis of Arrhythmias Generation in a Mathematical Ventricular Cell Model**

Ryosuke Fujiwara (Kagawa University), Hiroyuki Kitajima (Kagawa University)

⇒ Proc. pp. 151–154, [Paper ID: 5131]

We investigated the occurrence of early and delayed afterdepolarization (EAD and DAD) by varying two parameters (L-type calcium current conductance and intracellular sodium concentration) in a mathematical model (Shannon model). As a result, we obtained that the conductances of the L-type calcium current and intracellular concentration of sodium are keys to generation of EADs and DADs. We identified the parameter regions in which EADs, DADs, fibrillations and tachycardias occur.

Keywords: EAD, DAD, Mathematical Model

A4L-E4 **Bifurcations in a Forced Wilson-Cowan Neuron Pair**

Masaki Yoshikawa (Tokushima University), Kentaro Ono (Tokushima University), Tetsushi Ueta (Tokushima University)

⇒ Proc. pp. 155–158, [Paper ID: 5151]

We investigate bifurcations of periodic solutions observed in the forced Wilson-Cowan neuron pair by both the brute-force computation and the shooting method. By superimposing results given by both methods, a detailed topological classification of periodic solutions is achieved. Totally different shapes of bifurcation sets compared with other literature are found.

Keywords: Neimark-Sacker bifurcation, bifurcation structure

A5L-B (S15-2) Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications II

DATE: 2022/12/12 16:20–17:40
PLACE: Room B
Chairs: Milan Korda (LAAS-CNRS) and Alexandre Mauroy (University of Namur)

A5L-B1 **Global Stability of Nonlinear Systems on the Polydisc: Construction of a Lyapunov Function by the Koopman Operator Approach**

Christian Mugisho Zagabe (University of Namur), Alexandre Mauroy (University of Namur)

⇒ Proc. p.159, [Paper ID: 5136]

We study the global stability of nonlinear dynamical systems on the polydisc using the Koopman operator approach. To do so, we propose a Lyapunov function of the system in a precise invariant subset of the polydisc

Keywords: Koopman operator, Lyapunov function, Global stability

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A5L-B2 **Set-Valued Koopman Theory for Control Systems**

Benoît Bonnet-Weill (LAAS-CNRS), Milan Korda (LAAS-CNRS)

⇒ Proc. p.160, [Paper ID: 5096]

In this talk, we will present a new formalism leveraging the tooling of set-valued analysis to transpose the Koopman framework to control systems. Taking inspiration from the natural reformulation of control systems as differential inclusions, we introduce set-valued Koopman operators, define the underlying Liouville and Perron-Frobenius operators, and discuss some of their properties.

Keywords: Koopman operators, control systems, set-valued analysis

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A5L-B3 **Sparsity Structures for Koopman Operators**

Corbinian Schlosser (LAAS-CNRS), Milan Korda (LAAS-CNRS)

⇒ Proc. p.161, [Paper ID: 5094]

Sparse structures of dynamical systems induce decompositions of the Koopman and Perron-Frobenius operator. This is particularly the case for eigenfunctions and eigenmeasures for these operators. We extend such a result for invariant measures and illustrate at a numerical example how dynamic mode decomposition can benefit from exploiting sparsity.

Keywords: Koopman operator, Perron-Frobenius operator, Sparsity

A5L-B4 **Numerical Aspects of the Koopman Operator Framework for Computational Analysis of Nonlinear Dynamical Systems**
Zlatko Drmač (University of Zagreb)
⇒ Proc. pp. 162–163, [Paper ID: 5210]

We discuss several numerical aspects of the Koopman operator framework for computational analysis of nonlinear dynamical systems. Our main message is that the state of the art numerical linear algebra can provide considerable contributions to the development of robust numerical software tools for computational analysis of nonlinear dynamical systems.

Keywords: Kopman operator, DMD, EDMD

A5L-C (S7-3) Laser Dynamics and Complex Photonics III

DATE: 2022/12/12 16:20–17:40
PLACE: Room C
Chair: Sheng-Kwang Hwang (National Cheng Kung University)

A5L-C1 **Passive Optical-to-Terahertz Wavelength Conversion Without Using Nonlinear Optical Phenomena**
Mona Jarrahi (University of California, Los Angeles)
⇒ Proc. p.164, [Paper ID: 5039]

We demonstrate passive optical-to-terahertz conversion through plasmon-coupled surface states. When excited with an optical pump beam, photogenerated carriers in a photoabsorbing substrate are swept to an array of terahertz radiating nanoantennas by a surface-state-induced built-in electric field formed between the nanoantennas and substrate. The nanoantennas are used to couple optically-excited surface waves to the interface region where the built-in electric field is maximized to provide high optical-to-terahertz conversion efficiencies. We have used this scheme to develop a fiber-coupled bias-free terahertz source that provides more than a 110 dB dynamic range over a 5 THz bandwidth.

Keywords: terahertz, plasmonics

A5L-C2 **High Stability of Optical Beats in Laser Chaos**
Fumiyoshi Kuwashima (Fukui University of Technology), Mona Jarrahi (University of California, Los Angeles), Semih Cakmakyapan (University of California, Los Angeles), Osamu Morikawa (Japan Coast Guard Academy), Takuya Shirao (Fukui University of Technology), Kazuyuki Iwao (Fukui University of Technology), Kazuyoshi Kurihara (University of Fukui), Hideaki Kitahara (Research Center for Development of Far-Infrared Region, University of Fukui), Takashi Furuya (Research Center for Development of Far-Infrared Region, University of Fukui), Kenji Wada (Osaka Prefecture University), Makoto Nakajima (Osaka University), Masahiko Tani (University of Fukui),
⇒ Proc. pp. 165–166, [Paper ID: 5111]

Stability of optical beats in a chaotically oscillating laser is compared to that of a free-running continuous-wave laser using a highly efficient plasmonic photomixer. Using a chaotically oscillating laser diode, stable optical beats are observed over an operation current range of 60-90 mA. And stability of optical beats near the laser threshold level in a chaotically oscillating laser is also evaluated. The high stability of chaotically oscillating lasers makes these lasers promising candidates for optical pump sources in terahertz time-domain spectroscopy systems.

Keywords: Laser chaos

A5L-C3 **Transfer Characteristics of Sub-THz Waves in Volcanic Ash Erupted from Volcanoes in Japan**
Yuki Kawakami (National Institute of Technology KOSEN, Fukui College), Fumiyoshi Kuwashima (Fukui University of Technology)
⇒ Proc. pp. 167–168, [Paper ID: 5080]

There are over 100 active volcanoes in Japan. A novel rescue system is needed can search for a survivor covered with volcanic ash. Toward the application of Sub-THz waves to the rescue system, we have already clarified the transmission characteristics of Sub-THz waves in the Sakurajima volcanic ash. Since ash compositions vary from volcano to volcano, the transmission characteristics are expected to vary from volcano to volcano. In this paper, transmission characteristics of sub-THz waves are measured on volcanic ash erupted from several volcanoes in Japan. In addition, we confirm the difference in transmission characteristics due to volcanic ash.

Keywords: THz-TDS, Sub-THz, Volcanic Ash

A5L-C4 **Terahertz Time-Domain Spectroscopy for Nondestructive Evaluation and Material Characterization**
Alexandre Locquet (IRL 2958 Georgia Tech-CNRS), Min Zhai (IRL 2958 Georgia Tech-CNRS), Haolian Shi (IRL 2958 Georgia Tech-CNRS), Junliang Dong (IRL 2958 Georgia Tech-CNRS), David Citrin (Georgia Institute of Technology)
⇒ Proc. pp. 169–170, [Paper ID: 5204]

We present applications of terahertz time-domain spectroscopy for the nondestructive evaluation of fiber-reinforced polymers, of coatings on metal substrates and in the field of cultural heritage. We focus on signal and image process-

ing techniques that increase axial and lateral resolution and demonstrate their importance for applications.

Keywords: terahertz, THz, THz-TDS, time-domain spectroscopy, nondestructive evaluation, nondestructive testing, NDE, NDT

A5L-D (S10-4) Nonlinear Dynamics of Neuromorphic Computing and Hardware Implementation IV

DATE: 2022/12/12 16:20–17:40
PLACE: Room D
Chair: Shigeo Sato (Tohoku University)

A5L-D1 Ultra-Low Power Analog CMOS Implementation of Spiking Neural Networks for Reservoir Computing Applications

Satoshi Moriya (Tohoku University), Hideaki Yamamoto (Research Institute of Electrical Communication, Tohoku University), Shigeo Sato (Research Institute of Electrical Communication, Tohoku University), Yasushi Yuminaka (Gunma University), Yoshihiko Horio (Research Institute of Electrical Communication, Tohoku University), Jordi Madrenas (Universitat Politecnica de Catalunya)
⇒ Proc. pp. 171–172, [Paper ID: 5189]

Spiking neural networks (SNNs) have the potential to process time-series information with low-power consumption. To realize dedicated hardware that simulates the dynamics of SNNs, we fabricated SNN circuits with 0.18 um standard CMOS process. The neuron and SNN circuits of the fabricated chip generate the expected activity patterns and that it can be applied to time-series information processing based on the framework of reservoir computing. The results contribute to the development of edge devices, wherein the energy resource is limited.

Keywords: Analog Circuit, Spiking Neural Network, Neuromorphic Hardware

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A5L-D2 Time-Series Classification in Micropatterned Neuronal Network Reservoirs

Takuma Sumi (Research Institute of Electrical Communication, Tohoku University), Hideaki Yamamoto (Research Institute of Electrical Communication, Tohoku University), Yuichi Katori (Future University Hakodate), Koki Ito (Research Institute of Electrical Communication, Tohoku University), Shigeo Sato (Research Institute of Electrical Communication, Tohoku University), Ayumi Hirano-Iwata (Research Institute of Electrical Communication, Tohoku University)
⇒ Proc. pp. 173–175, [Paper ID: 5120]

Reservoir computing provides a novel framework to understand how the dynamics within biological neuronal networks (BNNs) is linked to information processing. Here, we used micropatterned substrates to fabricate BNNs with modular topology, one of the important structural features of brain networks, and realized a reservoir system with the modular BNN. Using image and time-series classification tasks, we evaluated the reservoir computing properties of the BNN reservoirs. The results show that modularity facilitates the separation between the trajectories of the neuronal responses to different spatial patterns, pointing to the functional advantage of the animals to modular topology within the nervous systems.

Keywords: Reservoir computing, Cultured neuronal network, Cell engineering

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A5L-D3 Stochasticity and Bifurcation in Spintronics Device for Probabilistic Computing

Shun Kanai (Tohoku University), Takuya Funatsu (Tohoku University), Jun'Ichi Ieda (Japan Atomic Energy Agency), Shunsuke Fukami (Research Institute of Electrical Communication, Tohoku University), Hideo Ohno (Tohoku University)
⇒ Proc. pp. 176–177, [Paper ID: 5169]

Physics of the stochastic behavior of spintronics devices for probabilistic computing is discussed. We experimentally access the potential landscape of nanoscale stochastic magnetic tunnel junctions (MTJs) perturbed under spin-transfer torque (STT) and magnetic field, and discuss the result based on the local bifurcation theory. In addition, we discuss a design guideline of the switching event time for the faster operation of the probabilistic computing and its relation to the fluctuation-dissipation theorem. Based on the guideline, we demonstrate the nanosecond relaxation time of the nanoscale stochastic MTJ device.

Keywords: Bifurcation, Stochasticity, Relative entropy, Spintronics, Probabilistic Computing, Magnetic Tunnel Junction

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A5L-D4 Multi-Model Spiking Neural Network Hardware Execution

Bernardo Vallejo (Universitat Politecnica de Catalunya), Jordi Madrenas (Universitat Politecnica de Catalunya), Mireya Zapata (Universidad Tecnologica Indoamerica), Satoshi Moriya (Tohoku University), Shigeo Sato (Research Institute of Electrical Communication, Tohoku University)
⇒ Proc. pp. 178–179, [Paper ID: 5088]

There is a wide variety of models that describe neural behavior, differentiated because some are better at emulating the behavior of biological networks and others focus more on

their computational efficiency [1]. This work demonstrates the execution of two different neural models applied to two groups of neurons using the same HEENS (Hardware Emulator of Evolved Neural System) architecture. This allows combining several models executing in real-time.

Keywords: SNN, HEENS, Multi-Model Emulation

A5L-E (R1 and 4-4) Nonlinear Phenomena/Complex Networks and Systems IV

DATE: 2022/12/12 16:20–17:40
PLACE: Room E
Chair: Yuu Miino (Naruto University of Education)

A5L-E1 **Detecting Determinism in Noisy Time Series with Variable Minimal Diagonal Line Length in Recurrence Quantification Analysis**

Nina Sviridova (Tokyo University of Science), Tohru Ikeguchi (Tokyo University of Science)
⇒ Proc. pp. 180–183, [Paper ID: 5175]

Determinism is an important property of deterministic dynamical systems. In many applied studies determinism is estimated by the recurrence quantification analysis (RQA) applied to the recurrence plot (RP). The presence of the noise disturbs and shortens the diagonal lines in the RP. Minimal diagonal line length is one of the parameters involved in estimating determinism value by RQA; therefore, its choice might affect the results of the determinism estimation in the presence of noise. This study estimated its effect on the determinism evaluation in noisy data. The results demonstrated that the determinism value as a function of the minimal diagonal line length has a different decrease trend for noise-free and noisy data.

Keywords: recurrence quantification analysis, determinism

A5L-E2 **An Application Software for Bifurcation Point Detection of Dynamical Systems with Nested-Layer Particle Swarm Optimization**

Tomo Hasegawa (Tokyo University of Technology), Haruna Matsushita (Kagawa University), Takuji Kousaka (Chukyo University), Hiroaki Kurokawa (Tokyo University of Technology)
⇒ Proc. pp. 184–187, [Paper ID: 5186]

This paper reports on developing the most straightforward software for bifurcation point detection in discrete-time dynamical systems. The application requires little prior knowledge of the system of interest or bifurcation analysis. Furthermore, the parallel computing technique employed in the application reduces the time required to derive a bifurcation diagram by a factor of 14 at most, even using common computing resources.

Keywords: bifurcation point detection, particle swarm optimization, parallel computing, tools, CUDA, OpenMP

A5L-E3 **Rule Dynamics of Cellular Automata Realizing Losslees Compression Description of Digital Sound**

Shota Nakayama (University of Fukui), Kyogo Yamanada (University of Fukui), Jousuke Kuroiwa (University of Fukui), Tomohiro Odaka (University of Fukui), Izumi Suwa (Women's College of Jin-ai)
⇒ Proc. pp. 188–191, [Paper ID: 5194]

In this paper,we investigate the dynamic properties of three rule sets of 1-2-3 CA that realize lossless compression description of digital sound. We adapt Chua's complexity, Wolfram's classification and density parameter with d-spectrum classification as dynamical properties. From the results, almost three-rules sets have complex feature for each dynamical property. Also, in d-spectrum classification, each class may change properties depending on boundary conditions. So, we have concluded that rules whose properties vary with boundary conditions play an important role in sound description by coexisting with each other.

Keywords: Cellular Automata, Digital Sound , Rule Dynamics

A5L-E4 **An Effective Routing Strategy with Congestion Signaling for Communication Networks**

Konosuke Hiraki (Nippon Institute of Technology), Jun Adachi (Nippon Institute of Technology), Takafumi Matsuura (Nippon Institute of Technology), Takayuki Kimura (Nippon Institute of Technology)
⇒ Proc. pp. 192–195, [Paper ID: 5160]

Recently, a routing strategy using gravitational centrality, has been proposed to find the best routes for the packets. Since this strategy uses fixed costs for links, it is difficult to cope with a large number of packets flows in the communication network. To overcome these problems, a routing strategy by using congestion signals has already been proposed. In this study, we evaluated this strategy if different types of centralities are incorporated into costs of links, instead of the gravitational centrality. Numerical experiments illustrated that our strategy mitigated the congestion of packets even if other types of centralities were incorporated.

Keywords: Communication networks, Packet routing problem, Congestion signal

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A6L-B (S15-3) Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications III

DATE: 2022/12/12 18:00–19:20
PLACE: Room B
Chairs: Alexandre Mauroy (University of Namur) and Milan Korda (LAAS-CNRS)

A6L-B1 **Spectral Clustering of Directed and Time-Evolving Graphs Using Koopman Operator Theory**
Stefan Klus (University of Surrey), Natasa Djurdjevac Conrad (Zuse Institute Berlin)
⇒ Proc. p.196, [Paper ID: 5029]

Transport networks, electrical grids, and computer networks such as the internet, but also gene regulatory networks, neural networks, and social networks can be represented as directed or undirected graphs by abstracting individual components or entities as nodes and relationships between them as edges. In order to understand such complex networked systems, it is essential to identify community structures or clusters, i.e., sets of nodes that share similar properties. A popular and well-established approach to detect community structures in undirected graphs is spectral clustering. Detecting clusters in directed and time-varying graphs, however, remains a challenging problem. We extend spectral clustering algorithms to directed and time-evolving graphs using transfer operators, which are frequently used to study complex dynamical systems.

Keywords: spectral clustering, Koopman operator, coherent sets

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A6L-B2 **Koopman Operator with Control Input**
Vít Cibulka (Czech Technical University in Prague), Milan Korda (LAAS-CNRS), Tomáš Haniš (Czech Technical University in Prague)
⇒ Proc. p.197, [Paper ID: 5203]

This paper discusses a new approach for estimating the Koopman operator from data. Unlike the current state of the art, we do not assume prior knowledge about some linearizing state transformation, also called lifting function. Furthermore, this work is, to the best of our knowledge, the first to transform the control input as well.

Keywords: Nonlinear control, Koopman operator

A6L-B3 **Finite Data Error Bounds for Koopman Based Prediction and Control Including Bayesian Online Updates**
Sebastian Peitz (Paderborn University), Feliks Nüske (Max Planck Institute for Dynamics of Complex Technical Systems), Friedrich Philipp (Technische Universität Ilmenau), Manuel Schaller (Technische Universität Ilmenau), Karl Worthmann (Technische Universität Ilmenau)
⇒ Proc. pp. 198–201, [Paper ID: 5202]

We prove a finite-data probabilistic error bound for the Koopman generator associated with stochastic differential equations, both for the i.i.d. as well as ergodic sampling settings. Numerical results show that bounds on the individual entries of the matrices C and V – required for the calculation of the Koopman matrix representation in a finite-dimensional subspace – are comparatively accurate, while the bound on the overall operator becomes quite conservative. Due to this, future work includes the improvement of these conservative bounds using Bayes' theorem for online updates of the bound.

Keywords: Koopman operator, control, error bounds, online learning

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A6L-B4 **Matched Input Disturbance Rejection for Nonlinear Systems in the Koopman Framework**
Bart Kieboom (Delft University of Technology), Matin Jafarian (Delft University of Technology)
⇒ Proc. pp. 202–203, [Paper ID: 5098]

We study the problem of output regulation for a class of nonlinear systems experiencing matched input disturbances, with the disturbance signal generated by an autonomous dynamical system. Using the Koopman operator, the nonlinear dynamical system is represented as a bilinear dynamical system. Inspired by the linear output regulation problem, a linear dynamic error feedback controller is designed for the system. With the aid of a Lyapunov-based stability analysis, we characterize a set of initial conditions for which the output is regulated

Keywords: Nonlinear output regulation, Koopman operator

A6L-D (S5-1) Geometric Mechanics, Optimization and Control in Applications I

DATE: 2022/12/12 18:00–19:20
PLACE: Room D
Chair: Vakhtang Putkaradze (University of Alberta)

A6L-D1 **Variational Formulation of the Generalized Langevin Equation**
Hiroaki Yoshimura (Waseda University), Tomohiro Yanao (Waseda University)
⇒ Proc. pp. 204–205, [Paper ID: 5212]

We study a Lagrangian variational formulation for the generalized Langevin equation, which describe the motion of the system of a Brownian particle interacting with a heat bath. We consider the system as an interconnected system of a Brownian particle, the heat bath as well as their interaction and hence the variational approach is based on Hamilton's principle for the Lagrangian of the interconnected system. We finally show how the generalized Langevin equation can be recovered from the variational formulation.

Keywords: Lagrangian variational formulation, generalized Langevin equation, interconnected systems

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A6L-D2 **A Structure-Preserving Finite Element Method for MHD That Preserves Energy, Cross-Helicity, Magnetic Helicity, divB = 0**

François Gay-Balmaz (CNRS - Ecole Normale Supérieure), Evan S. Gawlik (University of Hawaii at Manoa)

⇒ Proc. pp. 206–209, [Paper ID: 5163]

We construct a structure-preserving finite element method and time-stepping scheme for inhomogeneous, incompressible magnetohydrodynamics (MHD). The method preserves energy, cross-helicity (when the fluid density is constant), magnetic helicity, mass, total squared density, pointwise incompressibility, and the constraint div B = 0 to machine precision, both at the spatially and temporally discrete levels.

Keywords: Structure-preserving discretization, magnetohydrodynamics, finite element method, variational formulation, conservation laws

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B1L-B (S15-4) Recent Advances in the Koopman Operator Framework - Theory, Numerics, and Applications IV

DATE: 2022/12/13 09:00–10:20
PLACE: Room B
Chairs: Alexandre Mauroy (University of Namur) and Milan Korda (LAAS-CNRS)

B1L-B1 **Existence and Uniqueness of Koopman Eigenfunctions Near Stable Equilibria and Limit Cycles**

Matthew Kvalheim (University of Michigan)

⇒ Proc. pp. 210–211, [Paper ID: 5146]

The existence and uniqueness theory for smooth Koopman eigenfunctions, in the vicinity of an exponentially stable equilibrium or limit cycle, is described in the author's talk. This document is an attempt to briefly convey the flavor of some of these results and to illustrate, for equilibria, some of these in a simple setting.

Keywords: Koopman operator, Koopman eigenfunctions, principal eigenfunctions, asymptotically stable equilibrium, existence, uniqueness, Laplace averages

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B1L-B2 **Koopman Operators and Inverse Problems**

Haoran Wang (Virginia Polytechnic Institute and State University), John Burns (Virginia Polytechnic Institute and State University), Jia Guo (Georgia Institute of Technology), Andrew Kurdila (Virginia Polytechnic Institute and State University), Sai Tej Paruchuri (Virginia Polytechnic Institute and State University), Nathan Powell (Virginia Polytechnic Institute and State University)

⇒ Proc. pp. 212–214, [Paper ID: 5207]

This paper derives the error bounds for the approximations of the Koopman operators. The error bounds are derived by interpreting the Koopman operators in terms of an inverse problem. By using the Jackson and Bernstein inequalities for approximation in native spaces, errors bounds are derived in terms of the fill distance of samples in the configurations spaces.

Keywords: Koopman, Inverse Problems, Approximation

B1L-B3 **Discovering Sparse Subnetworks via Koopman Mode Decomposition**

William Redman (University of California, Santa Barbara), Maria Fonoberova (AIMdyn Inc.), Ryan Mohr (AIMdyn Inc.), Ioannis Kevrekidis (Johns Hopkins University), Igor Mezić (University of California, Santa Barbara)

⇒ Proc. pp. 215–216, [Paper ID: 5038]

As deep neural networks get increasingly large, they often become increasingly powerful, but at the cost of consuming considerably more time and computational resources. One way to mitigate these costs is to find sparse subnetworks, embedded within the full deep neural network, that perform well in isolation. Here we discuss recent work that leveraged Koopman operator theory to perform this sparsification. Surprisingly, such Koopman pruning algorithms, which require dynamic time series data, were found to be equivalent to existing heuristic methods, which use static snapshots. We discuss how this sheds new light on phenomena associated with the training of deep neural networks, as well as how it provides new theoretical backing to these existing sparsification methods.

Keywords: Sparse machine learning, Koopman operator theory

B1L-B4 **Spectral Analysis of Koopman Operator and Hamilton Jacobi Equation**

Umesh Vaidya (Clemson University)

⇒ Proc. pp. 217–218, [Paper ID: 5206]

We present an approach based on the spectral analysis of Koopman operator for the approximate solution of the Hamilton Jacobi equation. It is well-known that one can associate an Hamiltonian dynamical system with the Hamilton Jacobi equation. Furthermore, Lagrangian submanifold plays of the Hamiltonian dynamical system plays a fundamental role in the solution of Hamilton Jacobi equation. We show that the principal eigenfunctions of the Koopman operator associated with the Hamiltonian dynamical system can be used in the construction of Lagrangian submanifold thereby approximating the solution of the Hamiltonian Jacobi equation. The construction procedure for the approximate solution of Hamiltonian Jacobi equation is convex and data-driven. The application of the developed framework is demonstrated on solving the optimal control and robust control problems. Simulation results are presented to validate the main findings of the paper.

Keywords: Koopman Operator, Hamilton Jacobi Equation, Optimal and Robust Control.

B1L-C (S7-4) Laser Dynamics and Complex Photonics IV

DATE: 2022/12/13 09:00–10:20
PLACE: Room C
Chair: Satoshi Sunada (Kanazawa University)

B1L-C1 Photonic Neural Field Dynamics and its Application to Reservoir Computing

Kohei Arai (Kanazawa University), Tomoya Yamaguchi (Kanazawa University), Tomoaki Niiyama (Kanazawa University), Satoshi Sunada (Kanazawa University)
⇒ Proc. pp. 219–220, [Paper ID: 5049]

Photonic reservoir computing hardware has been expected as a novel photonic hardware enabling high- speed and high-efficiency information processing, but it remains challenges in terms of the network scalability. In this study, we introduce a concept of photonic neural field, which corresponds to a spatially continuous neural network, and show the implementation of the photonic neural field on a silicon chip. We demonstrate that the photonic neural field on a silicon chip is capable of high-density and large- scale reservoir network processing for benchmark tasks, including chaotic time series prediction and image classification.

Keywords: Photonic reservoir computing, Optical microcavity

B1L-C2 Characteristics Representation of Reservoir Set Based on Memory Capacity and Nonlinearity

Tomoya Kitamura (Tottori University), Kazuyuki Yoshimura (Tottori University)
⇒ Proc. pp. 221–224, [Paper ID: 5069]

Reservoir Computing has various degrees of freedom in terms of reservoir parameters, topology and activation functions; however, the design strategy of a good reservoir is still unclear. In this study, we focus on memory capacity and nonlinearity, where the memory and nonlinearity indices represent the characteristics of the reservoir dynamics. And we show that the two indices correlate with the information processing performance of the reservoir for a particular benchmark task.

Keywords: reservoir computing, memory, nonlinearity, information processing perfomance

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B1L-C3 Photonic Reservoir Computing for Prediction and Replication of Chaotic Dynamical Systems

Atsuya Kawakami (Saitama University), Kazutaka Kanno (Saitama University), Atsushi Uchida (Saitama University)
⇒ Proc. pp. 225–228, [Paper ID: 5086]

We perform short-term prediction and replication of chaotic attractors of the Rössler model using photonic reservoir computing based on a semiconductor laser with optical feedback. We succeed in short-term prediction for several periods of the Lyapunov time of the Rössler model. We also succeed in replicating the chaotic attractor based on the prediction and inference of the original variables.

Keywords: Reservoir computing , Time series prediction , Attractor replication

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B1L-C4 Transfer Learning Based on Photonic Reservoir Computing Using Semiconductor Laser with Optical Feedback

Rie Sakamaki (Saitama University), Kazutaka Kanno (Saitama University), Masanobu Inubushi (Tokyo University of Science), Atsushi Uchida (Saitama University)
⇒ Proc. pp. 229–232, [Paper ID: 5087]

Transfer learning has been studied to reduce the learning cost when the system parameters are changed. We numerically investigate transfer learning based on photonic reservoir computing using a semiconductor laser with optical feedback modulation. We succeed in inferring the dynamics of one variable in the Lorenz model whose parameters are changed from the learning scheme.

Keywords: Photonic reservoir computing, Transfer learning

B1L-D (S5-2) Geometric Mechanics, Optimization and Control in Applications II

DATE: 2022/12/13 09:00–10:20
PLACE: Room D
Chair: Vakhtang Putkaradze (University of Alberta)

B1L-D1 **Toda Flows, Gradient Flows, and Total Positivity**
Anthony Bloch (University of Michigan), Steven Karp (LACIM, University of Quebec)
⇒ Proc. pp. 233–235, [Paper ID: 5140]

We outline various connections between the Toda flows, gradient flows and the theory of total positivity

Keywords: gradient flows, Hamiltonian flows.

B1L-D2 **Relative Dynamics and Stability of Point Vortices on the Sphere**
Tomoki Ohsawa (University of Texas at Dallas)
⇒ Proc. pp. 236–239, [Paper ID: 5156]

We exploit the SO(3)-symmetry of the Hamiltonian dynamics of N point vortices on the sphere to derive a Hamiltonian system for the relative dynamics of the vortices. The resulting system combined with the energy–Casimir method helps us prove the stability of the tetrahedron relative equilibria when all of their circulations have the same sign—a generalization of some existing results on tetrahedron relative equilibria of identical vortices.

Keywords: Point vortices, Hamiltonian dynamics, Symplectic reduction, Lie–Poisson equation

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B1L-D3 **Variational Accelerated Optimization on Riemannian Manifolds**
Valentin Duruisseaux (University of California, San Diego), Melvin Leok (University of California, San Diego)
⇒ Proc. pp. 240–241, [Paper ID: 5095]

Efficient optimization has become one of the major concerns in data analysis. Nesterov's Accelerated Gradient method (NAG) was shown to converge quadratically, improving on the linear convergence of standard gradient descent methods, which is the phenomenon referred to as acceleration. It was shown that NAG limits to a second order ODE. In this talk, we will recall how the continuous time-convergence be accelerated to an arbitrary convergence rate by considering flow maps generated by Bregman Lagrangian and Hamiltonian systems. We will then present our main result, which is a generalization of the variational framework to the setting of Riemannian manifolds.

Keywords: Accelerated Optimization, Geometric Integration, Riemannian Optimization

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B1L-D4 **Tracing Trajectories in Figure Skating**
Meghan Rhodes (University of Alberta), Vakhtang Putkaradze (University of Alberta)
⇒ Proc. pp. 242–243, [Paper ID: 5167]

This paper develops a control algorithm for the movement of a model figure skater, represented by the Chaplygin's sleigh with a moving mass having coordinates (a, b) with respect to the body. We show that the circular arcs traced by the system on ice represent special types of trajectories allowing simplification of the control procedure. The given pattern on ice is reproduced by piecewise approximations of the desired curve by circular arcs, with the condition of minimizing the relative kinetic energy of the moving mass, *i.e.*, the quantity $\dot{a}^2 + \dot{b}^2$ given the constraint of the system tracing a circular arc on ice.

Keywords: Nonholonomic systems, controls

B1L-E (R2-1) Computational Intelligence I

DATE: 2022/12/13 09:00–10:20
PLACE: Room E
Chair: Yuichi Yokoi (Nagasaki University)

B1L-E1 **Long-Tailed Distribution of Excitatory Postsynaptic Potentials Enhances Learning Performance of Liquid State Machine**
Ibuki Matsumoto (Chiba Institute of Technology), Sou Nobukawa (Chiba Institute of Technology, National Center of Neurology and Psychiatry), Nobuhiko Wagatsuma (Toho University), Tomoki Kurikawa (Kansai Medical University)
⇒ Proc. pp. 244–247, [Paper ID: 5030]

In the cerebral cortex, excitatory postsynaptic potentials (EPSPs) exhibit a long-tailed distribution. It is known that the long-tailed characteristic of EPSPs induces spontaneous activity and stochastic resonance. In this context, we hypothesized that a long-tailed distribution of EPSPs would improve the learning performance of machine learning. Therefore, we input a spiking neural network with long-tailed characteristics of EPSPs into liquid state machine (LSM), and then evaluated the learning performance of LSM via a memory capacity task. These results suggest that long-tailed distributions of EPSPs enhance higher memory capacity. This finding might help improve the learning performance of LSM.

Keywords: Excitatory postsynaptic potentials, Long-tailed, Liquid state Machine

B1L-E2 **Fully Augmented Complex-Valued Neural Networks**

Tohru Nitta (Rikkyo University)

⇒ Proc. pp. 248–251, [Paper ID: 5034]

In this paper, we propose a new complex-valued neural network based on the widely linearity, taking advantage of its geometric structure, and show that it can learn geometric transformations that the conventional neural networks cannot. We find in the experiments that the multi-layered fully augmented complex-valued neural network composed of usual complex-valued neurons and degenerated fully augmented complex-valued neurons, has the different ability to learn 2D affine transformation from that of the usual complex-valued neural network.

Keywords: neural network, complex number, learning, back-propagation, affine transformation

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B1L-E3 **Investigation of the Influence of Datasets on Image Generation Using Sentence-BERT**

Masato Izumi (Tokyo City University), Kenya Jin'no (Tokyo City University)

⇒ Proc. pp. 252–255, [Paper ID: 5056]

We verified the degree to which sentence vectors, which are distributed representations of sentences generated by Sentence-BERT, capture the meaning of sentences using k-means and UMAP, and have confirmed that the sentence vectors generated by Sentence-BERT capture the meaning of sentences extremely well. In this article, we examine image generation from sentence vectors generated by Sentence-BERT to see if it is possible to generate images that match the meaning of the sentences. We conduct some experiments using various datasets to investigate the differences in training results among datasets in the Sentence-BERT sentence vector-based image generation model. We then discuss the optimal dataset for the Sentence-BERT sentence vector-based image generation model.

Keywords: BERT, Sentence-BERT, image generation, sentence vector, expressive learning

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B1L-E4 **Feature of Latent Variables in Rotational Transformation of Face Images by U-Net**

Saki Okamoto (Tokyo City University), Kenya Jin'no (Tokyo City University)

⇒ Proc. pp. 256–259, [Paper ID: 5063]

We confirm that the quality of the output images can be improved by using U-Net, which applies a contracting path (Concat) for each different resolution layer in AE. We will conduct some experiments to confirm the role of latent variables conveyed by each contracting path and its effect. As a result, we experimentally clarify that the role changes depending on the resolution layer, and that color information, face information, and face rotation information are conveyed. We also decompose the RGB components of the color input images and confirm that our model does not mix color information between input and output.

Keywords: U-Net, Auto Encoder, Contracting Path, latent variable, image transformation

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B2L-B (S2-1) Cellular Dynamical Systems I

DATE: 2022/12/13 10:40–12:00
PLACE: Room B
Chair: Hiroyuki Torikai (Hosei University)

B2L-B1 **Application of Denoising Image Restoration to Anomaly Detection**

Yu Kashihara (Osaka University), Takashi Matsubara (Osaka University)

⇒ Proc. pp. 260–263, [Paper ID: 5081]

Generative models learn complicated distributions and generate new samples that follow the learned distributions. Approximating the input image with the learned model is called reconstruction. However, existing generative models often lose the original features in the reconstructions, such as the original orientation and the flaws with production. The anomaly detection often fails if the reconstruction loses the original features. We propose the anomaly detection model based on the diffusion model to avoid this problem. In this study, the model is evaluated on industrial anomaly detection dataset and demonstrates excellent anomaly detection performance and restoration of anomalous regions.

Keywords: anomaly detection, generative models, diffusion models, restoration

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B2L-B2 **Comparizon Between Spatiotemporally Discrete LCR Circuit Model and a Quantum Counterpart**

Ibuki Nakamura (Hiroshima City University), Hisato Fujisaka (Hiroshima City University)

⇒ Proc. pp. 264–267, [Paper ID: 5012]

Electric networks consisting of LCR elements are dissipative wave systems while quantum energyconservative systems are dispersive wave systems. We compared wave propagation on spatiotemporally discretized models of the electric networks and on corresponding quantum systems. The two wave systems are parameterized with one common parameter. Although two kinds of propagation and their depen-

dence on initial conditions are different because of lossy and lossless characteristics of the two systems, variances of the distributed waves depend similarly on the common parameter.

Keywords: LCR circuit, cellular array, quantum walk

B2L-B3 **Application of Elementary Cellular Automata to Music Synthesis**

Wataru Kojima (Hosei University), Toshimichi Saito (Hosei University)

⇒ Proc. pp. 268–270, [Paper ID: 5122]

Elementary cellular automata (ECAs) are simple digital dynamical systems in which time, space, and state are all discrete. Depending on simple rules, the ECAs can exhibit a variety or periodic orbits. We present music generation algorism based on periodic orbits from the ECAs. The algorism, typical example are demonstrated.

Keywords: cellular automata, music generation, periodic orbits

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B2L-B4 **Analysis of Various Periodic Orbits in Coupled Digital Maps**

Yuken Kijima (Hosei University), Toshimichi Saito (Hosei University)

⇒ Proc. pp. 271–274, [Paper ID: 5073]

The digital spike maps (Dmaps) are digital dynamical system defined by a set of points. The Dmaps cannot generate chaos, but it can generate periodic spike-trains in steady state. In this paper, we analyze the basic dynamics of the Couple digital maps (CDMs) which are obtained by coupling two Dmaps.

Keywords: digital dynamical system, periodic orbits

B2L-C (S7-5) Laser Dynamics and Complex Photonics V

DATE: 2022/12/13 10:40–12:00
PLACE: Room C
Chair: Atsushi Uchida (Saitama University)

B2L-C1 **Tunable Period-One Dynamical Millimeter-Wave Generation by Cascaded Injection of Lasers**

Luan Zhang (City University of Hong Kong), Sze-Chun Chan (City University of Hong Kong)

⇒ Proc. pp. 275–278, [Paper ID: 5055]

For generating tunable photonic millimeter-wave (mm-wave) signals, the period-one (P1) nonlinear dynamics of semiconductor lasers are investigated through cascaded optical injection. Starting from a continuous-wave master laser, a primary slave laser is optically injected into P1 dynamics at a microwave frequency f0. It in turn injects a secondary slave laser that enhances the harmonic component of the intensity oscillations at 2f0, which is typically in the mm-wave band. By applying on the injection a subharmonic modulation at f0/3, the frequency fluctuation of the harmonic component is stabilized. By adjusting the operating conditions of lasers, the wide frequency tunability of P1 dynamics enables the continuous tuning of 2f0. Experimentally, tunable photonic mm-wave generation of 2f0 is demonstrated from 36 GHz to 42 GHz, while the electrical linewidth is maintained below 300 Hz by the subharmonic modulation.

Keywords: Period-One Dynamics, Semiconductor Lasers, Millimeter-Waves

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B2L-C2 **High-Frequency Microwave Generation Using Period-One Dynamics of Two Mutually Coupled Semiconductor Lasers**

Chin-Hao Tseng (National Cheng Kung University), Bin-Kai Liao (National Cheng Kung University), Sheng-Kwang Hwang (Advanced Optoelectronic Technology Center, National Cheng Kung University)

⇒ Proc. pp. 279–281, [Paper ID: 5028]

This study investigates an all-optical microwave generation scheme using a semiconductor laser operating at period-one nonlinear dynamics. In particular, a novel all-optical stabilization approach based on highly asymmetric mutual injection is introduced to improve the phase quality of such generated microwaves. As a result, microwave generation at 55 GHz with a side-peak suppression ratio above 45 dB and a 3-dB linewidth below 3.6 kHz is generated. The stabilized microwave generation across the entire V-band (40-75 GHz) and W-band (75-110 GHz) can be achieved by tuning the frequency and power of optical injection using our proposed scheme.

Keywords: High-frequency microwaves, Linewidth narrowing, Semiconductor lasers, Period-one dynamics, Mutual coupling

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B2L-C3 **Highly Efficient Harmonic Microwave Down-Conversion Using Stably Injection-Locked Semiconductor Lasers**

Guan-Ting Lu (National Cheng Kung University), Chin-Hao Tseng (National Cheng Kung University), Sheng-Kwang Hwang (Advanced Optoelectronic Technology Center, National Cheng Kung University)

⇒ Proc. pp. 282–284, [Paper ID: 5114]

Microwave down-converters play an important role in many applications such as wireless communication, radars,

and radio-over-fiber systems. Photonic microwave down-converters have attracted much interest recently because of their inherent advantages, including low conversion loss, broad bandwidth, and good electromagnetic interference immunity. When semiconductor lasers are subjected to strong external optical injection, stable-locking dynamics can be induced. In this paper, a highly efficient harmonic microwave down-conversion scheme using semiconductor lasers at stable-locking dynamics is proposed and experimentally demonstrated. The proposed scheme provides a conversion gain of more than 25 dB over a frequency range of 4 GHz without phase noise deterioration.

Keywords: semiconductor lasers, laser dynamics, photonic microwave mixing, stable locking dynamics

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B2L-C4 **Control of Intermittent Chaos in Semiconductor Laser with Short External Cavity**

Sota Inoue (Saitama University), Kazutaka Kanno (Saitama University), Atsushi Uchida (Saitama University)

⇒ Proc. pp. 285–288, [Paper ID: 5106]

We predict the occurrence of intermittent chaos in a semiconductor laser with a short external cavity. We observe the trajectory of intermittent chaos in the phase space to analyze the characteristics of chaotic bursts. We succeed in preventing the occurrence of intermittent chaos by perturbing the optical feedback phase in the semiconductor laser.

Keywords: Control of chaos, Prediction, Prevention, Semiconductor laser

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B2L-E (R2-2) Computational Intelligence II

DATE: 2022/12/13 10:40–12:00
PLACE: Room E
Chair: Yuichi Tanji (Kagawa University)

B2L-E1 **Recognition Using YOLO for Degraded Images on Visible Light Communication**

Hiroko Matsuda (Kagawa University), Haruna Matsushita (Kagawa University), Shintaro Arai (Okayama University of Science)

⇒ Proc. pp. 289–292, [Paper ID: 5064]

This paper focuses on the visible light communication (VLC) and proposes a signal demodulation method using a You Only Look Once (YOLO). Especially, VLC used in intelligent transport systems (ITS), we assume that a transmitter is a LED traffic light and a receiver is a high-speed on-vehicle camera. The VLC requires a high image recognition accuracy from captured images and a high-speed decoding processing. This study proposes a YOLO-based demodulation method for the VLC. Simulation results show that our method was able to exactly demodulate the transmitted images with almost 100% probability.

Keywords: Light Emitting Diode (LED), Visible Light Communication (VLC), You Only Look Once (YOLO)

B2L-E2 **Simplified Secure Distributed Processing of BP with Decomposition Data**

Hirofumi Miyajima (Nagasaki University), Noritaka Shigei (Kagoshima University), Hiromi Miyajima (Kagoshima University), Norio Shiratori (Chuo University)

⇒ Proc. pp. 293–296, [Paper ID: 5068]

Much research on secure and safe AI analysis methods for users has been conducted. In the previous paper, we proposed a learning method for secure distributed processing using decomposition data and parameters. The characteristic feature of this method is to achieve a high degree of privacy (confidentiality) through distributed processing by using decomposition of data and parameters, but it leads to an increase in computational complexity and deterioration of computational accuracy. In this paper, we propose a simplified secure distributed processing of BP method to suppress the computational complexity associated with an increase in the number of servers.

Keywords: Secure Distributed Processing, Machine learning, Neural Network

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B2L-E3 **Rich Spike Patterns from the Izhikevich Neuron Model in Response to Periodic Inputs**

Yota Tsukamoto (Tokyo University of Science), Honami Tsushima (Tokyo University of Science), Tohru Ikeguchi (Tokyo University of Science)

⇒ Proc. pp. 297–300, [Paper ID: 5085]

In this study, we investigated the responses of various spike patterns of the Izhikevich neuron model to sinusoidal inputs. We obtained the period–amplitude planes of sinusoidal inputs, which are mainly divided into two domains: periodic responses and non-periodic ones. Results show that the boundary between the two domains is relevant to the positional relationship of the two nullclines of the Izhikevich neuron model.

Keywords: Izhikevich neuron model, Interspike Interval, Hybrid Spiking Neuron Model

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B2L-E4 **Toward the Realization of Lightweight CNN**

Mizuki Dai (Tokyo City University), Kenya Jin'no (Tokyo City University)

⇒ Proc. pp. 301–304, [Paper ID: 5104]

In recent years, many systems using transformers such as ViT have been proposed for image identification.Although such systems are highly accurate, they require a large amount of training data and a very long learning time.Compared to these systems, CNNs are very simple and can be used in embedded systems.In this paper, we experimentally investigate a lightweight CNN with high accuracy.

Keywords: Convolutional neural network, dropout, BatchNormalization, image classification, CIFAR-10

B3L-B (S2-2) Cellular Dynamical Systems II

DATE: 2022/12/13 13:00–14:40
PLACE: Room B
Chair: Hiroyuki Torikai (Hosei University)

B3L-B1 **Implementation of Max-Plus Algebra-Based Morphological Wavelet Transform Algorithm with CAM-Based Massive-Parallel SIMD Matrix Core**

Kyosuke Kageyama (Kindai University), Takeshi Ogura (Ritsumeikan University), Tomohiro Fujita (Ritsumeikan University), Takeshi Kumaki (Ritsumeikan University)
⇒ Proc. pp. 305–308, [Paper ID: 5143]

Recently, the mobile devices is required to have digital convergence. In this paper, a CAM-based massive-parallel SIMD matrix core (CAMX) is proposed as mobile device accelerator for high-performance, programmability, and versatility. Besides, recently, the watermarking technology used a Max-plus algebra-based Morphological wavelet Transform (MMT) is known as the secureness technique in the mobile devices. In this paper, as a preparation before the watermarking technology is embedded, CAMX simulates the MMT processing. From this result, the CAMX can process 128 × 128 pixels image in parallel: decomposition is 3,637 clock cycles and reconstruction is 3,297 clock cycles.

Keywords: CAM module, SIMD, Parallel processing, CAMX

B3L-B2 **A Blending Stabilization Method of Discrete Mechanics and Nonlinear Optimization for 2-Dimensional Nonlinear Films**

Tatsuya Kai (Tokyo University of Science), Makoto Koike (Sumitomo Chemical Company, Limited)
⇒ Proc. p.309, [Paper ID: 5127]

This study develops a new stabilization method for 2-dimensional nonlinear film based on discrete mechanics and nonlinear optimization. An optimal stabilization control problem of the nonlinear film is formulated as a finite-dimensional nonlinear programming problem, and the control inputs can be calculated as solution of the problem by the sequential quadratic programming method. Simulation results show that the vibration of the film is suppressed and whole of the film is stabilized.

Keywords: Stabilization, Nonlinear Distributed Parameter Systems, Discrete Mechanics, Nonlinear Optimization, Nonlinear Films

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B3L-B3 **Traffic Signal Control for a Burgers' Cellular Automaton Traffic Flow Model with Right and Left Turns Based on Particle Swarm Optimization**

Tatsuya Kai (Tokyo University of Science), Munehiro Sato (Kikkoman Corporation)
⇒ Proc. p.310, [Paper ID: 5128]

The aim of this study is to propose a new systematic traffic signal control method for a burgers cellular automaton traffic flow model with right and left turns. First, the burgers' cellular automaton traffic flow model with right and left turns is constructed by using burgers cellular automaton equations. Next, an optimal traffic signal control problem is formulated, and a new algorithm to solve the problem based on particle swarm optimization. Then, some numerical simulations show that the new control method can reduce the total number of traffic jam the most in the three methods.

Keywords: Burgers' Cellular Automaton, Traffic Flow Model, Signal Control, Particle Swarm Optimization

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B3L-B4 **Progressive Image Transmission by Sigma-Delta Cellular Neural Network Having Coupled Cells**

Fumitoshi Nakashima (Chukyo University), Taishi Iriyama (Saitama University), Tsuyoshi Otake (Tamagawa University), Hisashi Aomori (Chukyo University)
⇒ Proc. pp. 311–312, [Paper ID: 5129]

Progressive image transmission technology is widely used in fields such as remote sensing and medicine. In this paper, a progressive image transmission framework by sigma-delta cellular neural network(SD-CNN) is proposed. This framework utilizes a simple artificial vision system based on the human visual information transfer mechanism. In our method, by utilizing complex dynamics of coupled cells, progressive image performance transmission is drastically improved.

Keywords: SD-CNN, coupled cell, progressive image transmission

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B3L-B5 **A Novel Ergodic Cellular Automaton Multi-Dimensional Gene Network Mode**

Shogo Shirafuji (Hosei University), Hiroyuki Torikai (Hosei

University)
⇒ Proc. p.313, [Paper ID: 5153]

The purpose of this study is to build a design method of efficient hardware-based gene network simulators. In this paper, as an example, a novel erogidc cellular automaton multidimensional gene network model is presented. The presented model reproduces Hopf bifurcation relied on time delays. Furthermore, it is shown that presented model consumes lower power and has less circuit elements than straightforward numerical integration method (forward Euler Method).

Keywords: Cellular Dynamics, Nonlinear, FPGA

B3L-C (S7-6) Laser Dynamics and Complex Photonics VI

DATE: 2022/12/13 13:00–14:40
PLACE: Room C
Chair: Takatomo Mihana (University of Tokyo)

B3L-C1 Haptic Sensing Based on Deep Learning and Laser Speckles

Koyo Sagehashi (Kanazawa University), Kei Kitagawa (Kanazawa University), Tomoaki Niiyama (Kanazawa University), Satoshi Sunada (Kanazawa University)
⇒ Proc. pp. 314–315, [Paper ID: 5052]

We propose a haptic soft sensing approach based on optical scattering techniques and deep learning. The use of the optical scattering techniques in a soft material allows for highly sensitive encoding of various external stimuli to the material as an optical interference pattern, whereas deep learning enables a decoding of the information of the external stimuli from the optical pattern. Accordingly, various external stimuli can be captured with a single soft material without multiple sensing devices. We made an artificial finger, where the proposed sensing method is implemented, and demonstrate the identification of touching objects with the finger.

Keywords: Haptic sensing, Laser speckle

B3L-C2 Experimental Demonstration of Physical Deep Learning Based on Optimal Control Using Optoelectronic Delay System

Rin Nogami (Saitama University), Kazutaka Kanno (Saitama University), Satoshi Sunada (Kanazawa University), Atsushi Uchida (Saitama University)
⇒ Proc. pp. 316–319, [Paper ID: 5130]

The development of machine learning has realized in solving complex problems. Various physical hardware implementations of machine learning have been proposed to reduce the energy consumption and computational cost in machine learning. We present an experimental demonstration of physical deep learning based on optimal control. We exploit the dynamics of a continuous-time system and represent it as deep learning in a single delay system. We implement the handwritten digits classification task (MNIST) and show that high classification accuracy can be achieved.

Keywords: Machine learning, Opto-electronic delay system

B3L-C3 Analysis of Dynamical Systems Using Symbolic Regression

Soichiro Kanaya (Kanazawa University), Toma Takano (Kanazawa University), Satoshi Sunada (Kanazawa University), Tomoaki Niiyama (Kanazawa University)
⇒ Proc. pp. 320–322, [Paper ID: 5050]

We propose an identification method of dynamical systems' equations from the measurement data samples with the aid of symbolic regression and the AI-Feynman proposed by Tegmark et al. The symbolic regression based on a genetic algorithm is used for finding the system equations from measurement data, combined with neural networks and a physics-inspired model, whereas the AI- Feynman can be used for detecting simplified representations of the system equations, such as symmetry and separability. In this study, we apply our identification model for chaotic dynamical systems, such as Lorenz systems, and discuss the identification performance.

Keywords: Symbolic regression, dynamical system, genetic algorithm

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B3L-C4 All-Optical Real-Time Physical Random Bit Generator

Pu Li (Taiyuan University of Technology), Qiang Cai (Taiyuan University of Technology), Qizhi Li (Taiyuan University of Technology), Yuncai Wang (Guangdong University of Technology)
⇒ Proc. pp. 323–326, [Paper ID: 5040]

We experimentally demonstrate an all-optical method for random bit generation where chaotic pulses are quantized into a physical random bit stream in the all-optical domain by means of a length of highly nonlinear fiber. In our proof-of-concept experiment, a 10 Gb/s random bit stream is successfully generated on-line using our method. Note that the single-channel real-time rate is limited only by the chaos bandwidth. Considering the Kerr nonlinearity of silica fiber with an ultrafast response of few femtoseconds, this scheme thus may operate potentially at much higher real-time rates than 100 Gb/s provided that a chaotic entropy source of sufficient bandwidth is available

Keywords: Chaos, Random Number Generation, Semiconductor Lasers, Optical Signal Processing

B3L-C5 **Experiment on Random Number Generation with Chaotic Dynamics of Complex Electric-Field Amplitude in Semiconductor Laser**

Shota Kudo (Saitama University), Shin Numata (Saitama University), Kazutaka Kanno (Saitama University), Atsushi Uchida (Saitama University)

⇒ Proc. pp. 327–330, [Paper ID: 5109]

We experimentally observe the real and imaginary parts of complex electric-field amplitude in a chaotic semiconductor laser using coherent detection. We extract phase and frequency dynamics from the complex electric-field amplitude. We perform random number generation using the chaotic dynamics of the intensity, phase, and frequency, and evaluate the statistical characteristics of randomness.

Keywords: Random number generation, Complex electric-field, Chaotic dynamics, Coherent detection

B3L-D (S4-1) Fundamentals and Applications of Complex Communication Science (CCS) I

DATE: 2022/12/13 13:00–14:40
PLACE: Room D
Chair: Megumi Akai-Kasaya (Hokkaido University)

B3L-D1 **An Efficient Observation Algorithm That Achieves the Minimum Number of Measurements for Pairing Optimization**

Naoki Fujita (University of Tokyo), André Röhm (University of Tokyo), Takatomo Mihana (Saitama University, University of Tokyo), Ryoichi Horisaki (University of Tokyo), Aohan Li (University of Electro-Communications), Mikio Hasegawa (Tokyo University of Science), Makoto Naruse (University of Tokyo)

⇒ Proc. pp. 331–334, [Paper ID: 5089]

Pairing optimization plays a critical role in the latest information and communication technologies, such as non-orthogonal multiple access (NOMA) in wireless communications. Here, all elements in the system should be pair-wise, or pairing is necessary. The problem is how to maximize the total performance of the entire system, which we call total compatibility. Understanding the relationships among elements, called compatibility, is indispensable prior to pairing optimization. This study demonstrates an efficient algorithm that allows grasping all compatibility information via the minimum number of observations. Such an efficient strategy is crucial for dynamically changing environments, notably by mobile wireless communications.

Keywords: Pairing, Optimization

B3L-D2 **An Application of Reinforcement Learning to Ground Station Selection in Satellite-Terrestrial Optical Communication**

Keigo Makizoe (Tokyo University of Science), Atsuhiro Yumoto (Tokyo University of Science), Koji Oshima (Innovation Design Initiative, National Institute of Information and Communications Technology), Kenji Suzuki (Space Communication Systems Laboratory, National Institute of Information and Communications Technol), Mikio Hasegawa (Tokyo University of Science)

⇒ Proc. pp. 335–338, [Paper ID: 5054]

Optical satellite communications, one of the fundamental technologies for a non-terrestrial network in Beyond 5G/6G, enable high-capacity communications. It is affected by the interruption of optical communications due to clouds on the communication path. Satellite can mitigate the interruption by switching its destination ground station to another, though it brings additional delays in acquiring the beam. In this study, we propose a ground station selection method using a reinforcement learning algorithm to realize a fast and stable satellite-terrestrial optical communication system. We show its effectiveness through simulation evaluation using pseud and real data.

Keywords: NTN, Optical Communication, Ground Station Selection, DQN

B3L-D3 **Fast Resource Allocation for the NOMA System Using Coherent Ising Machine**

Teppei Otsuka (Science University of Tokyo), Aohan Li (University of Electro-Communications), Hiroki Takesue (NTT Basic Research Laboratories, NTT Corporation.), Kensuke Inaba (NTT Basic Research Laboratories, NTT Corporation.), Kazuyuki Aihara (International Research Center for Neuro intelligence, University of Tokyo), Mikio Hasegawa (Tokyo University of Science)

⇒ Proc. pp. 339–342, [Paper ID: 5036]

In this study, we investigate a method for fast optimizing the resource allocation problem in non-orthogonal multiple access (NOMA) using a Coherent Ising Machine (CIM), a type of Ising Machine. The CIM is a hardware capable of obtaining fast solutions to the Ising problem. In order to perform NOMA resource allocation using CIM, the data rate maximization problem in NOMA systems is transformed into the Ising problem. The formulation for stable operation on the actual CIM machine is also discussed. Simulation results show that the proposed method is superior not only speed of optimization but also reaching the optimal solution.

Keywords: Ising Machine, Resource Allocation, Non-Orthogonal Multiple Access

B3L-D4 **Performance Evaluation of CSS-APCMA by Experiments Using 500 Devices for Massive IoT**

Kentaro Honda (Tokyo University of Science), Atsushi Nakamura (Tokyo University of Science), Ferdinand Peper (National Institute of Information and Communications), Kenji Leibnitz (National Institute of Information and Communications), Naoki Wakamiya (Osaka University), Mikio Hasegawa (Tokyo University of Science)

⇒ Proc. pp. 343–346, [Paper ID: 5110]

Low Power Wide Area (LPWA) systems suitable for IoT have been widely deployed. However, collisions and interferences become a severe problem in high-density networks. This paper applies the asynchronous pulse code multiple access (APCMA) communication scheme to a massive IoT environment. APCMA uses pulses for data transmissions and is effective for high-density wireless environments. We have designed a CSS-APCMA that satisfies a Japanese regulation standard ARIB STD-T108 and developed 500 transmitters. We evaluate the performance of simultaneous communications up to 500 transmitters by experiments in an actual environment. Our experimental results show that the proposed system has a high performance even in a high-density environment.

Keywords: Massive IoT, LPWA, Chirp Spread Spectrum

B3L-D5 **Investigation of Metrics for Readout-Independent Evaluation of the Functional Robustness of Liquid State Machines**

Naoki Hirata (Osaka University), Naoki Wakamiya (Osaka University)

⇒ Proc. pp. 347–350, [Paper ID: 5125]

Physical reservoir computing, which is the physical implementation of reservoir computing models, has attracted attention of researchers. Although it has a variety of applications, as a physical entity, it is prone to physical failures. Therefore, it is necessary to design a reservoir which is functionally robust to failures. More specifically, it is desired that a reservoir maintains the dynamics even after failures. For this purpose, in this paper, we investigate metrics to evaluate the functional robustness of a reservoir. By comparing distance metrics, we found that D-spike and D-interval were suitable for such evaluation.

Keywords: Liquid State Machine, Physical Reservoir Computing, Physical Failure, Functional Robustness, Distance Metric

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B3L-E (R2-3) Computational Intelligence III

DATE: 2022/12/13 13:00–14:40
PLACE: Room E
Chair: Hikaru Hoshino (University of Hyogo)

B3L-E1 **Spatiotemporal Chaotic Characteristics with Multidimensional Inputs in Echo State Networks**

Takahiro Iinuma (Chiba Institute of Technology), Sou Nobukawa (Chiba Institute of Technology, National Center of Neurology and Psychiatry)

⇒ Proc. pp. 351–354, [Paper ID: 5161]

An echo state network (ESN) is a recurrent neural network model with higher learning efficiency. Recent various studies have attempted to input multidimensional data to ESN, although the performance of ESN under multidimensional inputs deteriorates. We focused on the synchrony of states of reservoir neurons and investigated the ESN characteristics under multidimensional inputs using the measure of mean correlation coefficient of pairs among all reservoir neuron states. The results showed that in the case of high-dimensional inputs, maximum memory performance is achieved when the state exhibits less than zero MLE and minimum synchronization.

Keywords: Echo State Network, Multidimensional Input, Synchronization, Reservoir Computing, Recurrent Neural Network

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B3L-E2 **Common Space Learning with Gaussian Embedding for Multi-Modal Entity Alignment**

Kenta Hama (Osaka University), Takashi Matsubara (Osaka University)

⇒ Proc. pp. 355–358, [Paper ID: 5172]

Knowledge graphs are used in various systems that represent relationships between objects as a graph. Entity alignment is the task of finding entities that have the same object between two knowledge graphs. When utilizing multi-modal information for entity alignment, it is important to neglect unnecessary information contained in the data set. However, existing methods such as MMEA fail to consider the importance of information for each modal. In this study, we propose a method that expresses the importance of each information as the probability distribution. The proposed method outperforms MMEA in the entity alignment task of two multi-modal knowledge graphs.

Keywords: knowledge graph, entity alignment, multi-modal, gaussian embedding

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B3L-E3 **Posture Determination Method for Muscular Exercise Support System**

Yuma Matsui (University of Fukui), Jousuke Kuroiwa (University of Fukui), Tomohiro Odaka (University of Fukui), Izumi Suwa (Women's College of Jin-ai)
⇒ Proc. pp. 359–362, [Paper ID: 5179]

In this paper, we investigate a posture determination method for muscular exercise support system. We extract the feature quantities from the joint coordinates of the subject's images. Using these quantities, we investigate two methods, (1) the empirical rule and (2) the machine learning. In the empirical rule, based on the threshold values chosen from training data empirically, we determine whether user's posture is optimal or not. In the machine learning, we employ SVM trained from the same training data. From computer experiments, it has suggested that the machine learning method is more practical in the posture determination than the empirical method.

Keywords: Smartphone application, support system, posture determination, muscular exercise, Artificial Intelligence

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B3L-E4 **Biometric Authentication Based on Unconscious Arm Swing Action with Acceleration Sensor**

Motoharu Nakajima (University of Fukui), Jousuke Kuroiwa (University of Fukui), Tomohiro Odaka (University of Fukui), Izumi Suwa (Women's College of Jin-ai)
⇒ Proc. pp. 363–366, [Paper ID: 5181]

In this paper, we investigate a simple and robust personal authentication method for smartphone applications. We focus on arm swing actions which are unconscious. Therefore, the purposes of this paper are (i) to present a novel authentication method based on their characteristic features, and (ii) to show the authentication ability of the method. From the computer evaluations, it suggests that the proposed personal authentication method based on arm swing actions is quite robust and practical.

Keywords: Smartphone, arm swing action, acceleration, authentication, Cross-validation, standardized Euclidean distance

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B3L-E5 **Genre Classification of Modern Japanese Literary Works Based on Word Vectors**

Shiori Takenaka (University of Fukui), Jousuke Kuroiwa (University of Fukui), Tomohiro Odaka (University of Fukui), Izumi Suwa (Women's College of Jin-ai)
⇒ Proc. pp. 367–370, [Paper ID: 5192]

We show that even Japanese literary works by the same writer have different characteristics depending on the genre of the works using word vectors. Because we expect the word vector which quantitatively represent the meaning of the word in a low-dimensional way, are effective enough for expressing the feature of Japanese literary works. The result of the genre classification using word vectors is as accurate as the result of humans classification. Therefore, the word vectors are effective enough for expressing the feature of Japanese literary works.

Keywords: Word2vec, Cbow, Natural Language Processing, Classification

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B4L-B (S2-3) Cellular Dynamical Systems III

DATE: 2022/12/13 15:00–16:40
PLACE: Room B
Chair: Hiroyuki Torikai (Hosei University)

B4L-B1 **A Novel Ergodic Cellular Automaton Hexapod Central Pattern Generator Model and Analyses of its Transient Phenomena Caused by Time-Varying Coupling Weight**

Shoma Sato (Hosei University), Hiroyuki Torikai (Hosei University)
⇒ Proc. pp. 371–373, [Paper ID: 5078]

A generalized ergodic cellular automaton central pattern generator (CPG) model is proposed. It is shown that the proposed model exhibits various synchronization patterns to realize gaits of a hexapod robot. In this paper, we analyze transient phenomena of synchronization patterns caused by time-varying coupling weight and show that there exist a parameter setting that realizes smooth transitions. The proposed model is implemented by a field-programmable gate array (FPGA). It is shown that the proposed model can realize some typical gaits of hexapod robots and their smooth transitions.

Keywords: ergodic cellular automaton, central pattern generator model, transient phenomena

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B4L-B2 **Hierarchical Lossless Compression Method for Color Images Using CNN Predictors**

Hideharu Toda (Chukyo University), Hisashi Aomori (Chukyo University), Tsuyoshi Otake (Tamagawa University), Ichiro Matsuda (Tokyo University of Science), Susumu Itoh (Tokyo University of Science)
⇒ Proc. pp. 374–375, [Paper ID: 5191]

In this paper, we propose the hierarchical lossless compression method for color images using CNN predictors. In general, the selection of color space in encoding is important in terms of compression ratio. As opposed to the RGB color space, the YCoCg-R color space is known to have good coding efficiency, although it has the disadvantage of expanding the dynamic range of the color difference signals. In addition, the histogram packing technique is employed to deal

with the expanded dynamic range. The experimental results on test images show that the proposed method achieves better coding performance than conventional methods.

Keywords: cellular neural network, hierarchical lossless color image coding, YCoCg-R color space, histogram packing technique, predictor optimization

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B4L-B3 **Bit-Depth Enhancement with Frequency Domain-Based Loss Function**

Taishi Iriyama (Saitama University), Hisashi Aomori (Chukyo University), Tsuyoshi Otake (Tamagawa University)

⇒ Proc. p.376, [Paper ID: 5046]

Many convolutional neural network-based image restoration models are generally optimized by the mean square error (MSE) loss function to achieve an objective improvement in the peak signal-to-noise ratio assessment. In the bit-depth enhancement task, it has been reported that utilizing the MSE loss function results in remaining artifacts such as false contours. This paper presents that a model optimized with frequency-domain-based loss function using discrete cosine transform (DCT) is objectively and subjectively superior to a model optimized with other loss functions. The DCT loss is expected to focus on restoring flat regions with critical artifacts in the bit-depth enhancement.

Keywords: Bit-Depth Enhancement, Convolutional Neural Network, Discrete Cosine Transform

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B4L-B4 **Modification of a Mathematical Cardiac Model to Produce More Realistic Membrane Potentials**

Abe Kento (Kagawa University), Kitajima Hiroyuki (Kagawa University), Yazawa Toru (Tokyo Metropolitan University)

⇒ Proc. pp. 377–380, [Paper ID: 5133]

The Luo-Rudy model is one of the current mathematical models of cardiomyocyte. However, the membrane potential produced by the Luo-Rudy model has a notch that is clearly different from the membrane potential of actual animal models. Therefor, in this study, the Luo-Rudy model was modified. As a result, the time-dependent current IK and inward current Isi were found to be closely related to the notch generation.

Keywords: Mathematical model, Luo-Rudy model

B4L-B5 **Transient Early Afterdepolarization in a Methematical Cardiac Model**

Haruki Yamamoto (Kagawa University), Hiroyuki Kitajima (Kagawa University)

⇒ Proc. pp. 381–384, [Paper ID: 5134]

In the heart, depolarization may occur early in the repolarization of the action potential, which causes induced activity. This induced activity is called early afterdepolarization (EAD) and considered to be the arrhythmia itself and, may cause sudden death. The study of arrhythmias using cardiac mathematical models is important to reduce the risk of sudden death. In this study, we use a cardiac mathematical model to elucidate the mechanism of EAD generation.

Keywords: EAD, human ventricular model

B4L-C (S7-7) Laser Dynamics and Complex Photonics VII

DATE: 2022/12/13 15:00–16:40
PLACE: Room C
Chair: Sze-Chun Chan (City University of Hong Kong)

B4L-C1 **Uplink Grant-Free NOMA Using Laser Chaos Decision Maker**

Aohan Li (University of Electro-Communications), Zengchao Duan (Tokyo University of Science), Makoto Naruse (University of Tokyo), Mikio Hasegawa (Tokyo University of Science)

⇒ Proc. pp. 385–388, [Paper ID: 5021]

Grant-free Non-Orthogonal Multiple Access (NOMA) scheme is considered a promising technique to enable massive Machine-Type Communication (mMTC) in 6G to provide massive connectivity to devices with different protocols. In a grant-free NOMA system, fast and efficient channel-power resource block selection is extremely important to guarantee communication quality for the rapidly changing communication environment, such as vehicle networks. To achieve that, we propose an uplink grant-free NOMA system using a laser chaos decision maker in this paper. In our proposed system, the channel-power resource block can be selected in real-time. Simulation results show the effectiveness of our proposed system in the probability of successful communication.

Keywords: Uplink Grant-Free NOMA, Decentralized Transmission Parameters Selection, Laser Chaos Decision Maker

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B4L-C2 **Asymmetric Collective Decision Making Through Quantum Interference**

Honoka Shiratori (University of Tokyo), Hiroaki Shikawa (University of Tokyo), André Röhm (University of Tokyo), Nicolas Chauvet (University of Tokyo), Guillaume Bachelier (Institut Néel, Université Grenoble Alpes– CNRS), Jonathan Laurent (Institut Néel, Université Grenoble Alpes–

CNRS), Takatomo Mihana (Saitama University, University of Tokyo), Ryoichi Horisaki (University of Tokyo), Makoto Naruse (University of Tokyo)
⇒ Proc. pp. 389–392, [Paper ID: 5058]

Collective decision-making is important in recent information and communication systems. Therein, decision conflicts among multiple agents inhibit maximizing the potential utilities of the total system under study. It has been known that quantum processes can realize conflict-free joint decisions by utilizing entanglement of photons or quantum interference of orbital angular momentum of photons among two agents. However, the resultant joint decisions always result in a symmetric manner. Although this is a good aspect in view of ensuring equality, it is not sufficient to reduce disparities. Indeed, various forms of problematic inequalities are observed nowadays, such as educational disparity and gender gap, where preserving existing equality seems insufficient. In this study, we theoretically and numerically demonstrate conflict-free and asymmetric collective decision-making by utilizing entangled photons or quantum interference of photons carrying OAM. Whereas the asymmetry is indeed possible, photon loss is inevitable in the proposed models. The achievable range of asymmetry is analytically clarified.

Keywords: Collective decision-making, Quantum, Affirmative action

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B4L-C3 **Decision Making for Multi-Armed Bandit Problem Using Two Different Dynamics in Laser Network**

Keigo Sasaki (Saitama University), Takatomo Mihana (Saitama University, University of Tokyo), Kazutaka Kanno (Saitama University), Makoto Naruse (University of Tokyo), Atsushi Uchida (Saitama University)
⇒ Proc. pp. 393–396, [Paper ID: 5116]

We experimentally demonstrate decision making to solve the multi-armed bandit problem using two different dynamics of low frequency fluctuations and chaos in a semiconductor laser network. We make decision by associating slot machines with semiconductor lasers in the laser network, and controlling the coupling strengths among the lasers based on the result of slot machine selection. We compare the performance of decision making between the low frequency fluctuations and chaos.

Keywords: Decision making, Multi-armed bandit problem, Chaos, Low frequency fluctuations

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B4L-C4 **Experiment on Decision Making Using Chaotic Multi-Mode Semiconductor Laser with Optical Feedback and Injection**

Ryugo Iwami (Saitama University), Takatomo Mihana (Saitama University, University of Tokyo), Kazutaka Kanno (Saitama University), Makoto Naruse (University of Tokyo), Atsushi Uchida (Saitama University)
⇒ Proc. pp. 397–400, [Paper ID: 5031]

Photonic decision making has been investigated for solving the multi-armed bandit problem, which is one of the important problems in reinforcement learning. Photonic decision making using controlling chaotic itinerancy in a multi-mode semiconductor laser has been reported in numerical simulations. In this study, we experimentally investigate photonic decision making using chaotic itinerancy in a multi-mode semiconductor laser with optical feedback and injection. We solve the two-armed bandit problem by controlling the optical injection strengths to the multi-mode semiconductor laser.

Keywords: Decision making, Multi-mode semiconductor laser, Chaotic dynamics

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B4L-C5 **Experiment on Spatiotemporal Dynamics Generation and Parallel Decision Making Using Spatial Light Modulator and Semiconductor Laser**

Kento Takehana (Saitama University), Kensei Morijiri (Saitama University), Takatomo Mihana (Saitama University, University of Tokyo), Kazutaka Kanno (Saitama University), Makoto Naruse (University of Tokyo), Atsushi Uchida (Saitama University)
⇒ Proc. pp. 401–404, [Paper ID: 5092]

We experimentally demonstrate parallel implementation of photonic decision making for solving the multi-armed bandit problem using a spatial light modulator, a camera, and a semiconductor laser. We achieve experimental decision making in a multi-armed bandit problem with up to 512 slot machines using chaotic spatiotemporal dynamics generated from the semiconductor laser.

Keywords: Decision making, Semiconductor laser, Spatial light modulator

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B4L-D (S4-2) Fundamentals and Applications of Complex Communication Science (CCS) II

DATE: 2022/12/13 15:00–16:40
PLACE: Room D
Chair: Kosuke Sanada (Mie University)

B4L-D1 **Subthreshold CMOS Bistable Circuit for Stochastic Memory Device**

Seiya Muramatsu (Hokkaido University), Kohei Nishida (Hokkaido University), Kota Ando (Hokkaido University),

Megumi Akai-Kasaya (Hokkaido University and Osaka University), Tetsuya Asai (Hokkaido University)
⇒ Proc. pp. 405–408, [Paper ID: 5025]

One of the problems in stochastic computing is the high cost of memory utilization. To solve this problem, we propose a bistable circuit and a parallel shift circuit to realize stochastic memory. The bistable circuit forms a double-well potential using the subthreshold characteristics of MOSFETs, and the output voltage is stabilized at two values. The parallel shift circuit shifts the potential left and right in parallel by the gate voltage of a floating-gate MOSFET. In SPICE simulation, the probability of the output bit sequence is shown to vary with the floating gate voltage.

Keywords: Analog CMOS, Bistable, Subthreshold, Stochastic Computing, Memory

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B4L-D2 **Various Burst Phenomena and Automatic Cellular Differentiation Method of a Piecewise Constant Spiking Neuron Model**

Kengo Hosoi (Hosei University), Hiroyuki Torikai (Hosei University)
⇒ Proc. pp. 409–410, [Paper ID: 5079]

In this paper, a novel hardware-based cellular differentiation method of a piecewise constant neuron model is proposed. Circuit implementations and experimental measurements validate that the proposed differentiation method implemented by an FPGA enables the PWC neuron model implemented by an analog nonlinear circuit to reproduce typical neuron-like burst phenomena of an ordinary differential equation neuron model.

Keywords: PWC neuron model

B4L-D3 **A Memory-Efficient FORCE Learning Based on Ensemble Kalman Filter**

Kazuki Nakada (TDK Corporation), Eiji Suzuki (TDK Corporation), Keita Suda (TDK Corporation), Yukio Terasaki (TDK Corporation), Tetsuya Asai (Hokkaido University), Tomoyuki Sasaki (TDK Corporation)
⇒ Proc. pp. 411–414, [Paper ID: 5100]

In this work, we propose a memory-efficient FORCE learning based on ensemble Kalman filtering for Reservoir Computing (RC). In the conventional FORCE learning, the size of the largest memory array required for computing the Kalman gain becomes the square of the number of reservoir's elements, leading to a computational bottleneck. In contrast, the maximum size of the memory arrays is up to the number of the elements x the number of ensemble members in the ensemble FORCE learning. We demonstrate that the prediction accuracy can be enough for practical use even if the number of the ensemble members is sufficiently less than the number of the elements.

Keywords: Reservoir Computing, FORCE Learning, Ensemble Kalman Filter

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B4L-D4 **A Modified Radiation Model for Human Mobility: Effects of Distinct Job-Seeker Expectation and Job-Offer Benefit Distributions**

Yunhan Du (Tohoku University), Naoya Fujiwara (Tohoku University)
⇒ Proc. pp. 415–418, [Paper ID: 5108]

Predicting human mobility is fundamental to human societies, and various models have been introduced. One of the prevailing frameworks, the radiation model, predicts the mobility flow in a closed formula of population distribution. However, the same distributions of job-seeker expectations and job-offer benefits are assumed in the radiation model, which does not necessarily hold in general situations. In this research, we propose a modified radiation model based on the theoretical derivation with distinct job-seeker expectations and job-offer benefits distributions. Furthermore, we compare the prediction results with the radiation model using a flow dataset between counties in the United States.

Keywords: human mobility, the radiation model

B4L-D5 **An Active Charge Balancer Towards CMOS Integration of an Array of Neural Stimulators**

Seiichi Bun (Hokkaido University), Kota Ando (Hokkaido University), Megumi Akai-Kasaya (Hokkaido University and Osaka University), Tetsuya Asai (Hokkaido University)
⇒ Proc. p.419, [Paper ID: 5174]

Neuromorphic engineering, which reconstructs the structure of neural system and exploits its applications on CMOS integrated circuits, presents various developments. This study is about the interface technology that adapts CMOS integrated circuits to neural system. Existing neural stimulators are designed to accurately transmit signals and to stimulate the nerves accurately, but they are difficult to embed into brain due to the limitation of their size and the power. One solution is to reduce the circuit area and power consumption at the expense of certain precision. This paper proposes CMOS neural stimulating circuits with low power consumption and small area.

Keywords: CMOS, neural stimulator, low power consumption, integrated circuit

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B4L-E (R2-4) Computational Intelligence IV

DATE: 2022/12/13 15:00–16:40
PLACE: Room E
Chair: Shiu Mochiyama (Kyoto University)

B4L-E1 **Dependence of Identification Accuracy on Swipe Pattern Complexity**
Hiromu Inoue (University of Fukui), Jousuke Kuroiwa (University of Fukui), Tomohiro Odaka (University of Fukui), Izumi Suwa (Women's College of Jin-ai)
⇒ Proc. pp. 420–423, [Paper ID: 5193]

The purposes of this paper are (i) to show the existence of the personal features in the swiping motion even if the length changes, and (ii) to show the personal authentication ability for various length. From the authentication experiments, the personal features exist among almost feature points for all the lengths. FAR takes almost zero value except for the two cases. On the other hand, if we choose the optimal threshold value, FRR could becomes smaller for all the length.

Keywords: Swipe Motion, Individual Authentication, Significance Test, Standardized Euclidean Distance

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B4L-E2 **Evaluation of Temperature-Control-Free Replica-Replica-Interactive Simulated Annealing Using 100 Max-Cut Problems**
Akio Yoshizawa (National Institute of Advanced Industrial Science and Technology)
⇒ Proc. pp. 424–427, [Paper ID: 5016]

The path-integral quantum Monte Carlo method (PIQMC) is widely used as a classical simulation algorithm for quantum annealing. Replicas represent different points in imaginary time. We propose and demonstrate a temperature-control-free simulated annealing algorithm inspired by the PIQMC method. Replicas help mutually as if a swarm searches for the ground state. We solve 100 max-cut problems for algorithm evaluation, each of which corresponds to a graph of 100 vertices. We use a conventional method based on the analogy of the Metropolis algorithm for comparison.

Keywords: Quantum Annealing, Metropolis Method, Path-Integral Quantum Monte Carlo, Swarm Intelligence, Max-Cut Problem

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B5L-A (P2) Plenary Talk

DATE: 2022/12/13 17:00–18:00
PLACE: Room A
Chair: Yoshihiko Horio (Tohoku University)

B5L-A1 **Spin Hall Nano-Oscillator Based Ising Machines for Combinatorial Optimization**
Johan Åkermana (University of Gothenburg)

In my talk I will first briefly review the fundamentals of Ising Machines and describe different types of quantum and classical implementations. These range from D-waves Quantum Annealer, so-called Coherent Ising Machines based on Degenerate Optical Parametric Oscillators (DOPO), and most recently breadboard and PCB based LCR oscillator networks. I will then describe our recent progress in highly nonlinear mutually synchronized nano-constriction based spin Hall nano-oscillator (SHNO) chains and two-dimensional arrays and the possibility of using them for Ising Machines. I will describe how we can generate different types of spin wave modes and control those with voltage cates. In our most recent work, we have now added memristive functionality to these SHNOs and demonstrated non-volatile control of mutual synchronization and how this can be used for neuromorphic computing. Using microwave current injection locking and phase-sensitive micro-Brillouin Light Scattering microscopy, such two-dimensional SHNO arrays can be efficiently phase-binarized, which is a prerequisite for oscillator based Ising Machines, and solve MAX-CUT problems.

C1L-A (P3) Plenary Talk

DATE: 2022/12/14 09:00–10:00
PLACE: Room A
Chair: Igor Mezić (UC Santa Barbara)

C1L-A1 **Phenomena and Boundary in Nonlinear Dynamical System (Tentative)**
Takashi Hikihara (Kyoto University)

In the analysis of nonlinear dynamical systems, some assumptions are at the boundaries of the analysis domain. Some of them are to facilitate the analysis, while others are to faithfully describe the typical phenomena. However, we always come up against the problem of how to deal with the phenomena that these boundaries create. The method of analysis does not determine the boundaries. Whether experimental, numerical, or theoretical, the measurements are subject to the assumptions of the boundary setting. In this talk, I will review the setting applied to the computation and observation of phenomena in nonlinear dynamical systems as analytical techniques have progressed.

C2L-B (S14) Power Processing and Its Applications

DATE: 2022/12/14 10:20–12:00
PLACE: Room B
Chair: Ryo Takahashi (Kyoto University of Advanced Science)

C2L-B1 **Exhaustive Search of Digitized Gate Voltage for SiC MOSFETs**
Hajime Takayama (Kyoto University), Shuhei Fukunaga (Osaka University), Takashi Hikihara (Kyoto University)
⇒ Proc. p.428, [Paper ID: 5072]

This work analyzes the distribution of switching characteristics of MOSFETs under digital active gate-driving. The gate voltage waveform is shaped digitally using three variables, each of which is expressed by a 4-bit binary sequence. Exhaustive search is performed to obtain all the achievable solutions and clarify their trend.

Keywords: Combinatorial optimization, Digital active gate drive, Exhaustive search, Power switching, SiC MOSFET

C2L-B2 **A PDM-Based Strategy for Power Packet Dispatching on Shared Power Line**
Shiu Mochiyama (Kyoto University)
⇒ Proc. p.429, [Paper ID: 5041]

Power processing based on power packetization has been proposed and studied intensively for seamless coordination of information and communications technologies with electric power distribution. In this study, the author proposes a pulse density modulation (PDM) based strategy to constitute the packetized power supply sequence that achieves an optimized drive of a load under the limitation of the power line capacity.

Keywords: Power Packet, Pulse Density Modulation, Signal Quantization

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C2L-B3 **Self-Rotation Stability of Squirrel-Cage Induction Motor Using Nonlinear Electric Field-Current Density Constitutive Equation of High-Temperature Superconducting Winding**
Taketsune Nakamura (Kyoto University), Kenjiro Matsuki (Kyoto University)
⇒ Proc. p.430, [Paper ID: 5180]

Self-rotation stability characteristics of a high temperature superconductor squirrel-cage winding was analyzed by using the non-linear voltage-current property of the high temperature superconductor. The stable rotation condition for the starring process was analytically investigated based on the nonlinear voltage equations and the equation of motion. As a result of the analysis, it was clarified that the rotor accelerates stably in an extremely short time of less than 1 s.

Keywords: High Temperature Superconductor, Squirrel-cage Rotor, Nonlinear Voltage-Current Property, Rotation Stability

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C2L-B4 **New Approach to 150 kHz WPT by Sinusoidally Modulated Step-Down Converter**
Yutaro Sakuraba (Kyoto University of Advanced Science), Ryo Takahashi (Kyoto University of Advanced Science), Alberto Castellazzi (Kyoto University of Advanced Science)
⇒ Proc. pp. 431–432, [Paper ID: 5198]

This paper proposes an original approach to the development of a power converter for wireless-power-transfer applications. The idea is to use a buck topology modulated sinusoidally, so as to remove the need for resonating circuits and be able to exploit conventional inductive coupling solutions. The advantage of this approach is twofold: first, the synthesized voltage can be controlled on the primary side by a simple voltage feedback loop and kept at nominal value even in the presence of varying load and coupling conditions; second, the efficiency can be made much higher than in conventional resonant approaches. As a case-study, a 150 kHz fast-charging system for drone battery is presented, with a nominal power rating of 25 W.

Keywords: Wireless-power-transfer, sinusoidal modulation, gallium nitride, high switching frequency

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C2L-B5 **Performance Evaluation of Discontinuous-PWM Y-Inverter AC Motor Drive System Focusing on a Wide Range of Motor Rotation Speeds**
Ryo Takahashi (Kyoto University of Advanced Science), Takahiro Mamiya (Kyoto University), Shiu Mochiyama (Kyoto University), Hamzeh Jaber (Kyoto University of Advanced Science), Takashi Hikihara (Kyoto University), Alberto Castellazzi (Kyoto University of Advanced Science)
⇒ Proc. p.433, [Paper ID: 5150]

The recent proposed Y-inverter has attractive features which are expected to be well matched with the electric vehicle. Here, assuming a battery electric vehicle, this study compares the performance of the Y-inverter with a discontinuous pulse width modulation or a standard sinusoidal pulse width modulation for a three-phase permanent magnet synchronous motor drive over a wide rotation speed range in the numerical simulations.

Keywords: PWM, Inverter, Motor Drive

C2L-C (S12) Novel Perspectives of Quantum Walks for Information and Communications Applications

DATE: 2022/12/14 10:20–12:00
PLACE: Room C
Chair: Makoto Naruse (University of Tokyo)

C2L-C1 **Combinatorial Graph Structures Induced by Quantum Walks**
Etsuo Segawa (Yokohama National University), Yusuke Higuchi (Gakushuin University)
⇒ Proc. pp. 434–437, [Paper ID: 5043]

We consider the quantum walk on graph with boundary which receives inflow from the outside and releases outflow to the outside at every time step. The inflow has the frequency which is independent of the boundary. We show the comfortability, which is the squared norm of the stationary state restricted to the internal graph, and the scattering on the surface of the graph can be expressed by using some graph structure.

Keywords: Quantum walk, Circuit equation, Stationary state, Complexity, Odd unicyclic factor

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C2L-C2 **Correlated Random Walk Model for Decision Making Acceleration by Time-Correlated Time Sequences**
Tomoki Yamagami (University of Tokyo), Norihiro Okada (Tokyo University of Science), Yusuke Ito (Tokyo University of Science), Mikio Hasegawa (Tokyo University of Science), Makoto Naruse (University of Tokyo)
⇒ Proc. pp. 438–441, [Paper ID: 5026]

Chaotically oscillating time series from a laser, called laser chaos, provides the ability to solve multi-armed bandit problems at GHz order. Furthermore, it has been known that the negative autocorrelation inherent in time series accelerates decision making. However, the underlying mechanism is unknown. Here we demonstrate a theoretical model to account for the acceleration of decision-making by correlated time sequence by correlated random walk, where the correlated time series subjected to the decision-making system and the internal status of the system therein are taken into account in a unified manner. The theory agrees well with the numerical simulations. This study constructs a fundamental in validating the usefulness of correlated time series for intelligent functions.

Keywords: Random walk, Correlated random walk, Decision making, Quantum walk

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C2L-C3 **Time Averaged Distributions for CTQWs and DTQWs on the Path**
Yusuke Ide (Nihon University)
⇒ Proc. pp. 442–445, [Paper ID: 5060]

In this talk, we will focus on the time averaged distributions for continuous-time quantum walks (CTQWs) and Szegedys walk a type of discrete-time quantum walks (DTQWs) on the path graph induced by the birth and death chain (discrete-time random walk with reflecting walls) on it.

Keywords: Quantum Walk, Time averaged distribution

C2L-C4 **Skeleton Structure Inherent in Quantum Walks**
Tomoki Yamagami (University of Tokyo), Etsuo Segawa (Yokohama National University), Ken'Ichiro Tanaka (University of Tokyo), Takatomo Mihana (Saitama University, University of Tokyo), André Röhm (University of Tokyo), Ryoichi Horisaki (University of Tokyo), Makoto Naruse (University of Tokyo)
⇒ Proc. pp. 446–449, [Paper ID: 5048]

This paper demonstrates that a common underlying structure, or a skeleton structure, is present behind quantum walks with a homogeneous coin matrix. More specifically, we examine the transition probabilities of random walks that replicate the probability distribution of quantum walks. We show that the transition probability contains a skeleton structure by considering the weak limit that excludes the oscillatory behavior. Remarkably, the skeleton structure does not depend on the coin matrix or the initial condition of the quantum walk.

Keywords: Quantum walk, Random walk, Transition probability

C2L-D (S8) Modeling and Control of Cyber-Physical Systems

DATE: 2022/12/14 10:20–12:00
PLACE: Room D
Chair: Hikaru Hoshino (University of Hyogo)

C2L-D1 **Black Box Checking of Mobile Robot Path Planning Satisfying Safety Hyperproperties**
Naomi Kuze (Osaka University), Keiichiro Seno (Osaka University), Toshimitsu Ushio (Osaka University)
⇒ Proc. pp. 450–453, [Paper ID: 5007]

A k-safety hyperproperty is a hyperproperty that is characterized by bad prefixes. For example, it can express security policies for safety-critical and safety-related systems. Black box checking (BBC) is a promising formal verification method of systems whose internal structure is unknown. However, a BBC method for verifying hyperproperties has

not been considered yet. We extend a BBC for k-safety hyperproperties, and apply it to verification of a security policy for path planning of a mobile robot, and demonstrate it with an illustrative example.

Keywords: Black box checking, k-safety hyperproperties, automaton

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C2L-D2 **Output Feedback Ultimate Boundedness Control with Decentralized Event-Triggering**

Koichi Kitamura (Hokkaido University), Koichi Kobayashi (Hokkaido University), Yuh Yamashita (Hokkaido University)

⇒ Proc. pp. 454–457, [Paper ID: 5101]

Event-triggered control over a sensor network is studied as one of the control methods of cyber-physical systems. Event-triggered control is a method that communication occurs only when the measured value is widely changed. As a control specification, we consider the notion of uniformly ultimate boundedness. Using this notion, it is guaranteed that if the state reaches a certain set containing the origin, the state stays within this set. Using this notion, the occurrence of events in the neighborhood of the origin is inhibited. First, the problem is formulated. Next, it is reduced to an LMI optimization problem.

Keywords: cyber-physical system, sensor networks, event-triggered control

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C2L-D3 **Mathematical Modeling of Road Heating System with Underground Distribution Line Based on Nonlinear ODE Model**

Yuya Muto (Toyama Prefectural University), Chiaki Kojima (Toyama Prefectural University), Yuki Okura (Toyama Prefectural University)

⇒ Proc. pp. 458–461, [Paper ID: 5067]

In regions with heavy snowfall, snow accumulation causes problems such as falls on sidewalks and traffic congestion. In this paper, we present a road heating system using underground power distribution lines. In this paper, the system is decomposed into four layers: voltage and current distribution in underground distribution lines, thermal dissipation in cables, thermal diffusion in the ground, and snow melting on the ground surface. We derive a mathematical model of the road heating system based on the nonlinear ordinary differential equation (ODE) model. The validity of the model is verified by a numerical simulation.

Keywords: Power system, Nonlinear system, Road heating

C2L-D4 **Screening Curve Method for Optimal Sizing of Photovoltaic and Battery Storage Systems for a Household**

Hikaru Hoshino (University of Hyogo)

⇒ Proc. pp. 462–465, [Paper ID: 5173]

This paper proposes a simple method, called Screening Curve Method (SCM), for economic analysis of solar photovoltaic (PV) and battery storage systems at consumer side. While the SCM has been known as an intuitive method to estimate the least-cost expansion of generation capacity in a bulk power system, this paper applies it to the problem of optimal sizing of PV and battery for a household. A case study using time-series data of demand and PV generation is presented to show the effectiveness of the proposed method.

Keywords: Optimization, Photovoltaics, Battery, Multiscale

C3L-B (S17) Taming Chaos in Diverse Physical Systems

DATE: 2022/12/14 13:00–14:20
PLACE: Room B
Chair: Yueheng Lan (Beijing University of Posts and Telecommunications)

C3L-B1 **Topological Charge-Density Method of Identifying Phase Singularities and Singular Filaments in Cardiac Arrhythmias**

Yin-Jie He (Zhejiang Institute of Modern Physics, Zhejiang University), Hong Zhang (Zhejiang Institute of Modern Physics, Zhejiang University)

⇒ Proc. p.466, [Paper ID: 5018]

In this presentation, we will describe how to use the topological charge-density method to identify phase singularities and singular filaments in cardiac arrhythmias. In the first part of this presentation, we review the derivation of the topological charge-density method in two dimensions. Then, in the second part, we turn to the case in three dimensions, i.e., using the topological charge-density-vector method to identify singular filaments.

Keywords: Spiral waves, phase singularities, singular filaments

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C3L-B2 **Nonlinear Phenomena in the Complex Earth System**

Jingfang Fan (Beijing Normal University)

⇒ Proc. p.467, [Paper ID: 5205]

Global warming, extreme climate events, earthquakes and their accompanying natural disasters pose significant risks to humanity. Yet due to the nonlinear feedback, multiple interactions and complex structure of the Earth system, the un-

derstanding and in particular the predicting of such disruptive events represent formidable challenges for both scientific and policy communities. During the past years, the emergence and evolution of Earth system science has attracted much attention and produced new concepts and frameworks. Especially, novel statistical physics and complex networks-based techniques have been developed and implemented to substantially advance our knowledge for a better understanding of the Earth system. I will present a brief review on the recent scientific progress in the development and application of how combined statistical physics and complex systems science approaches can be applied to complex Earth systems.

Keywords: Nonlinear phenomena, complex Earth system, Network

C3L-B3 **Transient Stability in Renewable-Energy-Dominating Power Systems**

Meng Zhan (Huazhong University of Science and Technology)

⇒ Proc. p.468, [Paper ID: 5010]

With the fast development and increasing integration of renewable energy including wind and solar powers, building a renewable-energy-dominating power system has become one of key national strategies in China. Very recently on July 28, 2021, China association for science and technology has proposed ten key frontier scientific problems, including one problem: What is the path optimization and stability mechanism of the renewable-energy-dominating power systems? Clearly the renewable-energy-dominating power system stability faces some big, basic challenges, such as complex system, nonlinearity, multi-time scale, complicated dynamical interaction, hybrid dynamics, intermittent behavior, low inertia, unclear instability characteristics, etc. Some are common for any general complex nonlinear systems. In this talk, I will deep into the transient stability problems in renewable-energy-dominating power systems. I will also introduce some of our recent works. I hope that these basic problems could arouse general interest of researchers in the fields of not only electrical engineering, but also system engineering, nonlinear dynamics, and complex nonlinear systems.

Keywords: renewable-energy-dominating power systems, transient stability, nonlinear dynamics

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C3L-B4 **Perturbations in Cycle Expansions**

Yueheng Lan (Beijing University of Posts and Telecommunications), Huanyu Cao (Beijing University of Posts and Telecommunications)

⇒ Proc. p.469, [Paper ID: 5019]

To compute averages of observables in a nonlinear system, a perturbation technique is developed to cope with possibly existing non-hyperbolicity, in which cycle expansions are used to treat the hyperbolic part while an analytic approximation is made to take care of the regular dynamics. In addition, based on the framework provided by periodic orbits, we are able to design a perturbation scheme in the presence of chaos, which could be used to compute averages over a continuous family of dynamical systems based on the periodic orbit theory.

Keywords: Nonlinear dynamics, Chaos, Averages, Cycle expansions, Perturbation

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C3L-C (S13-1) Optimization Algorithms with Nonlinear Dynamics I

DATE: 2022/12/14 13:00–14:20
PLACE: Room C
Chair: Tomoyuki Sasaki (Shonan Institute of Technology)

C3L-C1 **Learning a Simple Multilayer Perceptron with PSO**

Riku Takato (Tokyo City University), Kenya Jin'no (Tokyo City University)

⇒ Proc. pp. 470–473, [Paper ID: 5082]

In this article, we attempt to learn the parameters of a multilayer perceptron (MLP) using the particle swarm optimization (PSO) method which is one of the approximate solution methods for optimization problems without using the derivative information of the objective function. We use gradient method and PSO to learn to classify a linearly inseparable data set with an MLP in the middle layer with a small number of neurons. As a result, we experimentally confirm that PSO outperforms gradient-based learning.

Keywords: particle swarm optimization, multilayer perceptron, learning, accuracy, gradient method

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C3L-C2 **Finding the Minimum Value of a Function Using the Emergence Phenomenon of Boids**

Yusuke Nakazato (Tokyo City University), Kenya Jin'no (Tokyo City University)

⇒ Proc. pp. 474–477, [Paper ID: 5149]

Living organisms often behave as if they have a will as a group by individually receiving influences from their surroundings and acting in accordance with those influences. Research on artificial life aims to reproduce this behavior on a computer and to create new information processing technologies from it. In this paper, we focus on Boids, one of the most famous artificial life models. The roles of producer, primary consumer, and secondary consumer for each agent in Boids, and the phenomena that emerge in a system that also incorporates the annihilation and division functions of the agents themselves, are discussed.

Keywords: artificial life, agent, swarm, emergent, interaction

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C3L-C3 **Proposal of a New Zero-Shot Evaluation Index for Simple CNN**

Chisato Takahashi (Tokyo City University), Kenya Jin'no (Tokyo City University)

⇒ Proc. pp. 478–481, [Paper ID: 5155]

Network Architecture Search (NAS), which aims to optimize the structure of neural networks themselves, has attracted much attention in recent years. The evaluation of the structure of a neural network in NAS is basically performed by actually training the neural network and measuring its performance. However, this method requires an enormous amount of computation. For this reason, the other zero-shot method that evaluates the structure without actually performing the training has begun to be proposed. The ultimate goal of this research is to create an evaluation index that can evaluate the structure in a zero-shot manner for NAS. In this article, we experimentally investigate the relationship between basic CNN structures and their performance, we create an index that can measure performance in a zero-shot environment.

Keywords: neural networks, CNN, network architecture search, accuracy, CIFAR-10

C3L-C4 **Solving the Vehicle Routing Problem with Time Window and Fluctuating Demand by Using Simple Heuristics**

Misa Fujita (Chukyo University)

⇒ Proc. p.482, [Paper ID: 5197]

The shortage of truck drivers is a serious problem all over the world. Thus, an algorithm that creates a robust delivery plan under the fluctuation of the amount of cargo with a small number of track drivers is desired. The vehicle routing problem with time window and fluctuating demand is a model of this problem.

Keywords: Vehicle routing problem, Combinatorial optimization, Heuristics

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C3L-D (S9-1) Nonlinear Circuits and Networks with a Variety of Couplings and Network Topologies I

DATE: 2022/12/14 13:00–14:20
PLACE: Room D
Chair: Yoko Uwate (Tokushima University)

C3L-D1 **Oscillatory Behaviors of Axon Membrane Potential Using Multi-Compartment Model of Bonhoeffer-Van der Pol Oscillator**

Naoki Matsumiya (Chiba Institute of Technology), Kuniyasu Shimizu (Chiba Institute of Technology), Naohiko Inaba (Shonan Institute of Technology)

⇒ Proc. pp. 483–486, [Paper ID: 5148]

This paper investigates multi-compartment model mimicing axon membrane potential by using the simplified model of Hodgkin-Huxley model; Bonhoeffer-Van der Pol oscillator. In this study, we assume that a sinusoidal perturbation is injected to the membrane potential at the single edge of the nerve fibre. We reports that the traveling membrane potential consisting of mixed-mode oscillations is observed. Futhermore, the increment of small peaks of the mixed-mode oscillations originates from the coupling effect. In addition, the small peaks are also influenced by the angular frequency of the periodic perturbation.

Keywords: Bonhoeffer-Van der Pol oscillator, Mixed-mode oscillator

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C3L-D2 **Synthesis of Permutation Binary Neural Networks**

Kento Saka (Hosei University), Toshimichi Saito (Hosei University)

⇒ Proc. pp. 487–490, [Paper ID: 5032]

This paper studied a simple synthesis method of permutation binary neural networks. The network is characterized by local binary connection, global permutation connection, and the signum activation function. Depending on the connection, the network generates various periodic orbits of binary vectors. The synthesis method is based on the genetic algorithm. Performing basic numerical experiments, efficiency of the synthesis method is confirmed.

Keywords: Binary neural networks, permutation, periodic orbits, stability

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C3L-D3 **A Generalized Ergodic Cellular Automaton Model of Central Pattern Generator and its Bifurcation Analyses Induced by Chopper Type Mixed Gaits**

Jumpei Kamitoko (Hosei University), Hiroyuki Torikai (Hosei University)

⇒ Proc. pp. 491–494, [Paper ID: 5076]

In this paper, we propose a generalized ergodic cellular automaton model of a central pattern generator. The proposed model can realize synchronization phenomena, which can realize typical gaits of a quadruped robot. It is shown that by mixing coupling matrices based on a chopper manner, the proposed model can realize mixed gaits of the quadruped robot depending on the ratios of the matrices in the chop-

per. Also, it is shown that the proposed model is more hardware-efficient compared to a straightforward implementation of an ordinary differential equation central pattern generator model.

Keywords: ergodic cellular automaton, CPG

C3L-D4 **A Novel Hardware Efficient Wireless Walking Assist Device Model and Analyses of its Various Synchronization Phenomina**

Masaya Kudo (Hosei University), Hiroyuki Torikai (Hosei University)

⇒ Proc. pp. 495–498, [Paper ID: 5077]

In this paper, a network of ergodic cellular automaton (CA) oscillators coupled via impulse radio sequences is proposed. The network is implemented by a field programmable gate array and experiments show that the network can exhibit synchronizations with various phase differences. Then, it is discussed that the results of this paper will contribute for developing a wireless walking assist device based on a wireless central pattern generator.

Keywords: wireless walking assist device

C3L-E (R3-1) Engineering Applications I

DATE: 2022/12/14 13:00–14:20
PLACE: Room E
Chair: Hikaru Hoshino (University of Hyogo)

C3L-E1 **Investigations of Degree Period of Commutative Polynomials Defined by Fourth-Order Recurrence Relations with Two Variables Over Z_{2^k}**

Takuma Nishizaka (Sojo University), Daisaburo Yoshioka (Sojo University)

⇒ Proc. pp. 499–502, [Paper ID: 5159]

In recent years, a public-key cryptosystem based on Chebyshev polynomials over Z_{2^k} has been presented. Unfortunately, however, the cryptosystem is broken using knowledge of the periodic properties of Chebyshev polynomials. Although commutative polynomials with two variables can be candidates for the cryptosystem instead of Chebyshev polynomials, the periodic properties of the polynomials should be discussed carefully. In this study, we investigated the degree period of commutative polynomials with two variables over residue ring Z_{2^k}.

Keywords: cryptography, period, recurrence relation

C3L-E2 **Design of Single-Electron Unicursal Curve Drawing Circuit for Solving Undirected Graph**

Seiji Tsukada (Yokohama National University), Takahide Oya (Yokohama National University)

⇒ Proc. pp. 503–506, [Paper ID: 5084]

We propose a new single-electron (SE) circuit that shows a unique information-processing operation for solving unicursal curves' problem. It is known that the graph theory including the unicursal curves' theorem has effectiveness for solving nonlinear problems. We here designed and tested our SE unicursal curve drawing circuit by computer simulation. We confirmed that the designed circuit is possible to derive basic unicursal curve's procedure correctly although some problems remain. We are now testing SE circuit that can solve unicursal curves' problem on any Euler graph successful. We believe our single-electron unicursal curve drawing circuit can operate correctly in near future.

Keywords: single-electron, nanodevice

C3L-E3 **Reduction of Communication Cost in Distributed Orthogonal Approximate Message Passing**

Ken Hisanaga (Kwansei Gakuin University), Motohiko Isaka (Kwansei Gakuin University)

⇒ Proc. pp. 507–510, [Paper ID: 5118]

In this paper, we introduce a framework of distributed orthogonal approximate message passing for recovering sparse vector based on sensing by multiple nodes. The iterative recovery process consists of local computation at each node and global computation at a master node that aggregates the transferred estimations. We propose a method to reduce the communication cost between the nodes while maintaining the recovery performance.

Keywords: compressed sensing, orthogonal message passing, distributed system

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C3L-E4 **Design of a New Information-Processing Single-Electron Circuit Mimicking Behavior of Herd of Wolves**

Riku Ogawa (Yokohama National University), Takahide Oya (Yokohama National University)

⇒ Proc. pp. 511–514, [Paper ID: 5147]

We propose a new information-processing single-electron (SE) circuit mimicking the behavior of a herd of wolves. There are four important wolf behaviors that can be considered as a kind of information processing: exploration, pursuit, siege and attack.We believe our unique wolf herd-inspired single-electron circuit will be used in near future.

Keywords: nanodevices,single-electron,wolves

C4L-B (S11-1) Nonlinear Vibrations, Waves, and Localizations I

DATE: 2022/12/14 14:40–16:00
PLACE: Room B
Chair: Yusuke Doi (Osaka University)

C4L-B1 **Phonon Scattering by Discrete Breather in Nonlinear Lattice with Potential Symmetry**
Kazuyuki Yoshimura (Tottori University), Yudai Hirata (Tottori University)
⇒ Proc. pp. 515–518, [Paper ID: 5062]

We study the scattering of phonons by standing discrete breather in two types of one-dimensional nonlinear lattices which have long-range quartic nonlinear and nearest neighbor harmonic interactions. Each lattice has a particular hidden symmetry in its potential function. It is shown that both of the lattices exhibit anomalous properties in the phonon scattering process, compared with the ordinary Fermi-Pasta-Ulam-Tsingou lattice.

Keywords: discrete breather, phonon, scattering, nonlinear lattice

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C4L-B2 **Ballistic Charge Transport by Polarokinks and Polarobreathers**
Juan F. R. Archilla (Universidad de Sevilla), Jānis Bajārs (University of Latvia), Yusuke Doi (Osaka University), Masayuki Kimura (Setsunan University)
⇒ Proc. p.519, [Paper ID: 5154]

Some materials of the mica group experience hyperconductivity, the transport of electric charge without an electric field. The charge transport is stimulated by ion bombardment that produces nonlinear waves that transport charge. We have developed a semiclassical model using physical principles and empiric potentials and found nonlinear waves that are able to transport charge.

Keywords: Charge Transport, Kinks, Crowdions, Breathers, Semiclassical, Silicates

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C4L-B3 **Resonance of a Traveling Intrinsic Localized Mode in Balanced Cubic and 5th Order Nonlinear Transmission Lines**
Masayuki Sato (Kanazawa University), Hiroki Furusawa (Kanazawa University), Yukihiro Soga (Kanazawa University)
⇒ Proc. pp. 520–522, [Paper ID: 5065]

Normal mode excitation due to a traveling intrinsic localized mode is called a resonance. To investigate the resonance in balanced nonlinear lattices, cubic and 5th order nonlinear lattices have been studied by simulations. Very small resonance has been observed for those lattices.

Keywords: Intrinsic localized mode, traveling mode

C4L-B4 **Estimation of Initial Conditions for Generating Moving ILMs from Wavenumber-Frequency Spectrum of Static ILMs in FPU-NKG Mixed Lattice**
Kosuke Kawasaki (Kyoto University), Masayuki Kimura (Setsunan University), Shinji Doi (Kyoto University)
⇒ Proc. pp. 523–526, [Paper ID: 5182]

Intrinsic localized mode (ILM) is localized vibration of energy in nonlinear coupled oscillator arrays. Estimating initial values of moving ILMs is required in order to investigate the characters of moving ILMs. In this report, moving ILMs are generated by estimating initial values from static ILMs in frequency-wavenumber plane. In the estimation, an approximation by Gaussian function is used. The created initial values move successfully and their localization sustains for a long time.

Keywords: Intrinsic Localized Modes, wavenumber-frequency plane

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C4L-C (S13-2) Optimization Algorithms with Nonlinear Dynamics II

DATE: 2022/12/14 14:40–16:00
PLACE: Room C
Chair: Yoshikazu Yamanaka (Utsunomiya University)

C4L-C1 **Biobjective Optimization Problems in Paralleled Boost Converters**
Hiroto Iizuka (Hosei University), Toshimichi Saito (Hosei University)
⇒ Proc. pp. 527–530, [Paper ID: 5011]

This paper studies biobjective optimization problems in paralleled boost converters for robust and efficient energy supply. The first objective evaluate circuit stability and the second objective evaluate power efficiency. Applying piecewise linear circuit modeling, objective functions are described exactly and precise analysis is possible. Performing precise numerical analysis, we obtain the Pareto front between the two objectives.

Keywords: multi-objective optimization, renewable energy

C4L-C2 **Swarm Intelligence Algorithm Based on Spiking Neural-Oscillator Network, Coupling Interactions and Search Performances**

Tomoyuki Sasaki (Shonan Institute of Technology), Hidehiro Nakano (Tokyo City University)

⇒ Proc. pp. 531–534, [Paper ID: 5061]

Optimizer based on spiking neural-oscillator networks (OSNNs) is a deterministic swarm intelligence algorithm, which consists of plural simple spiking neural-oscillators ('oscillators'). In OSNNs, the oscillators can search a good solution effectively by interacting with each other. Due to such interaction, an oscillator can take synchronization or asynchronization dynamics. However, parameter conditions, which determine synchronization or asynchronization dynamics, are not clarified. Here, we analyzed the interactions among oscillators using simple network topology, and attempt to clarify the parameter conditions. In addition, we investigated the relationship between search performances of OSNNs and the synchronization or asynchronization dynamics.

Keywords: Swarm intelligence algorithm, particle swarm optimization, optimizer based on spiking neural-oscillator networks, deterministic system

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C4L-C3 **A Tracking Performance Comparison of Different Particle Swarms Using Tolerance Update**

Yoshikazu Yamanaka (Utsunomiya University), Shoki Hirose (Utsunomiya University), Katsutoshi Yoshida (Utsunomiya University)

⇒ Proc. p.535, [Paper ID: 5142]

In some real optimization problems, the optimal solutions would be multiple and they can be changed depending on the time. Optimization algorithms to solve these problems require two abilities: finding the multiple optimal solutions in a single trial run, and tracking them while the optimal solutions are shifting. In this paper, we compared the tracking performance between our proposed optimizers based on dynamical systems with the tolerance update and consider which dynamical system is appropriated to track the optimal solutions.

Keywords: Swarm intelligence, optimization, dynamic environment, tracking

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C4L-C4 **Performance Evaluation of Tabu Search Method and Adaptive Large Neighborhood Search Method in the Electric Vehicle Routing Problems with Time Windows**

Jun Adachi (Nippon Institute of Technology), Konosuke Hiraki (Nippon Institute of Technology), Takafumi Matsuura (Nippon Institute of Technology), Takayuki Kimura (Nippon Institute of Technology)

⇒ Proc. pp. 536–539, [Paper ID: 5187]

We are required to reduce greenhouse gas emissions in delivery. To determine the shortest tours by using the Electric Vehicles(EV), the electric vehicle routing problem with time windows(EVRPTW) has been established. Further, an adaptive large neighborhood search(ALNS) has been proposed as one of the methods for solving EVRPTW. To improve this problem, we proposed the ALNS with tabu search method. In this work, we investigate the performance of our proposed method for difficult instances of EVRPTW. Numerical experiments then showed that our method also obtained good performance for various types of benchmark problems.

Keywords: Electric Vehicle Routing Problem with Time Windows, Combinatorial optimization problems, Metaheuristic, Tabu Search

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C4L-D (S9-2) Nonlinear Circuits and Networks with a Variety of Couplings and Network Topologies II

DATE: 2022/12/14 14:40–16:00
PLACE: Room D
Chair: Tadashi Tsubone (Nagaoka University of Technology)

C4L-D1 **Stability Analysis of Partial Amplitude Death in Delay-Coupled Star Networks**

Ryuya Kawano (Ibaraki University), Yoshiki Sugitani (Ibaraki University)

⇒ Proc. pp. 540–543, [Paper ID: 5051]

This report analyzes the stability of partial amplitude death (PAD) in delay-coupled star networks. In PAD, the hub oscillator of the star networks is quenched and the other oscillators remain oscillating. The stability region of PAD is compared with that of amplitude death. These results are confirmed by numerical simulations.

Keywords: Partial amplitude death, Delay coupling

C4L-D2 **Investigation of Synchronization Phenomena for Systems of Van der Pol Oscillators Coupled as 3 × 3 and 3 × 4 Torus Shape via Electronic Circuit Experiment and Computer Simulation**

Fumito Shinomiya (Hiroshima Institute of Technology), Yoshihito Todani (Hiroshima Institute of Technology), Hikaru Onda (Hiroshima Institute of Technology), Masayuki Yamauchi (Hiroshima Institute of Technology), Tetsuro Endo (Former Meiji University)

⇒ Proc. pp. 544–547, [Paper ID: 5138]

In this paper, we observe synchronization phenomena on torus shape networks, which 3 × 3 or 3 × 4 van der Pol oscillators are coupled by inductors, using simulations, and actual circuit experiments. The value of frequency in each synchronization state is compared by using theoretical calculation, simulations and actual circuit experiments.

Keywords: Synchronization phenomena, Coupled oscillators, Torus shape

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C4L-D3 **Reservoir Computing with Stability Transformation Method to Detect Unstable Fixed Point of Chaotic Map**

Shuma Iinuma (Nagaoka University of Technology), Tadashi Tsubone (Nagaoka University of Technology)

⇒ Proc. pp. 548–551, [Paper ID: 5075]

Detecting unstable periodic orbits in chaotic systems based on the time series is a fundamental problem in nonlinear dynamics, but it often becomes extremely challenging one. In this study, we propose a new approach for detecting unstable fixed point using reservoir computing and stability transformation method. We connects reservoir computing, a well-known machine learning technique, and stability transformation method, which can detects unstable periodic orbits in chaotic dynamical systems, to perform unstable fixed point detection in a data-driven and model-free process. In this paper, we use an example of an Hénon map to demonstrate detecting unstable fixed point and unstable 2-periodic points.

Keywords: Reservoir Computing, Stability Transformation Method, Unstable Periodic Orbits

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C4L-D4 **Clustering Using Chaos Synchronization with Learning Algorithm**

Yoko Uwate (Tokushima University), Martin Schule (Zurich University of Applied Sciences), Thomas Ott (Zurich University of Applied Sciences), Yoshifumi Nishio (Tokushima University)

⇒ Proc. pp. 552–555, [Paper ID: 5176]

In this study, we propose a clustering method based on a new chaotic coupled circuit network applying Hebbian rule. For a more complex clustering example, we consider a circuit layout with overlapping clusters. By using computer simulations, we confirm that chaotic circuit network with the Hebbian rule is more effective than the standard chaotic circuit network.

Keywords: Clustering, Synchronization, Chaotic Circuit Networks, Hebbian Learning

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C4L-E (R3-2) Engineering Applications II

DATE: 2022/12/14 14:40–16:00
PLACE: Room E
Chair: Yoshiki Sugitani (Ibaraki University)

C4L-E1 **Design of Multivalued Frequency Response Filters by Using Nonlinear Feedback - Part I**

Maide Bucolo (University of Catania), Arturo Buscarino (University of Catania), Luigi Fortuna (University of Catania), Salvina Gagliano (University of Catania)

⇒ Proc. pp. 556–559, [Paper ID: 5165]

The topic of this contribution regards the design of multiband multivalued frequency response filters based on nonlinear design feedback techniques. The interest in this topic regards the possibility of analysing sinusoidal signals in real-time as regards increasing or decreasing frequency in a fixed set of windows. This can be done by using the effects of frequency hysteresis of the proposed devices.

Keywords: nonlinear dynamics, jump resonance, digital filters

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C4L-E2 **Global Stabilization for Nonlinear Two-Port Characteristics of Bidirectional DC/DC Converter**

Kenta Yamamoto (Kyoto University), Takashi Hisakado (Kyoto University), Mahfuzul Islam (Kyoto University), Osami Wada (Kyoto University)

⇒ Proc. pp. 560–563, [Paper ID: 5185]

This paper describes the nonlinear two-port characteristics of bidirectional DC/DC converters and its two different operating points. The nonlinearity of the two-port characteristics affects global stability. We show that global stabilization of the bidirectional DC/DC converter can be achieved by a feedback method based on the nonlinear two-port characteristics. Experiment confirms the proposed feedback method to realize global stability.

Keywords: Bidirectional DC/DC Converter, Time-Variable Transformer, Nonlinear Two-Port Characteristics, Global Stability

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C4L-E3 **Design of Multivalued Frequency Response Filters by Using Nonlinear Feedback - Part II**

Maide Bucolo (University of Catania), Arturo Buscarino (University of Catania), Luigi Fortuna (University of Catania), Salvina Gagliano (University of Catania)

⇒ Proc. pp. 564–567, [Paper ID: 5196]

Even if the research on multivalued frequency response systems is still in progress and more items are to be more deeply approached from a theoretical point of view, in this paper

some aspects outlined in a companion contribution to Nolta 2022 will be focused by introducing further example. Moreover, the discretization of the system is discussed in order to provide a digital implementation of the nonlinear filter with multivalued frequency response.

Keywords: nonlinear dynamics, jump resonance, digital filters

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C4L-E4 **A Concentrated Winding Permanent-Magnet Motor Improved with Magnetic Saturation**

Yuichi Yokoi (Nagasaki University), Yuichi Murakami (Nagasaki University), Tsuyoshi Higuchi (Nagasaki University)

⇒ Proc. pp. 568–571, [Paper ID: 5053]

This paper proposes a core structure to achieve variable-flux characteristics enhanced by magnetic saturation in fractional-slot concentrated winding (FSCW) configurations. The magnetic saturation in the stator core achieves the variable-flux characteristics that are effective for decreasing electromotive force (EMF) with an identical torque or increasing torque with an identical EMF. The efficacy of the proposed design is determined by estimating motor performance through a finite element method analysis.

Keywords: Motor, Magnetic Saturation, Variable-Flux Characteristics, Concentrated Windings

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C5L-B (S11-2) Nonlinear Vibrations, Waves, and Localizations II

DATE: 2022/12/14 16:20–18:00
PLACE: Room B
Chair: Yusuke Doi (Osaka University)

C5L-B1 **A Numerical Study on Maximum Speed of Localized Vibrations Following a Moving External Coil on Resonant Circuit Array**

Kenta Miyazaki (Kyoto University), Masayuki Kimura (Setsunan University), Shinji Doi (Kyoto University)

⇒ Proc. pp. 572–575, [Paper ID: 5183]

In the wireless power transfer technology, a power transmission method using localized mode is possible by using an LC resonant circuit array in the transmitter circuit. This transmission method can suppress the efficiency variation with the horizontal position of the receiving coil and can selectively concentrate the power around the receiving coil[1]. In the previous studies, only the condition in which the power receiving coil is stationary has been discussed. However, from the viewpoint of practical use, it is assumed that the power receiving coil may move. In this study, we numerically investigate the tracking of the localized energy to the movement of the receiving coil.

Keywords: localized mode, resonant circuit array

C5L-B2 **Geometric Numerical Integration of Semi-Classical Hamiltonain Lattice Dynamics**

Jānis Bajārs (University of Latvia), Juan F. R. Archilla (Universidad de Sevilla)

⇒ Proc. pp. 576–579, [Paper ID: 5145]

In this work we provide a brief overview of recently proposed symplecticity-preserving symmetric splitting methods for semi-classical Hamiltonian dynamics of charge transfer by intrinsic localized modes in nonlinear crystal lattice models. Without loss of generality, we consider one-dimensional crystal lattice models described by classical Hamiltonian dynamics, whereas charge particle is modeled as quantum particle within the tight-binding approximation. Canonical Hamiltonian equations for the coupled lattice-charge dynamics are derived. Structure-preserving splitting methods are constructed by splitting the total Hamiltonian into the sum of Hamiltonians which individual dynamics can be solved exactly. Exactly charge conserving symplectic splitting methods are also proposed which require only one solution of a linear system of equations per time step. Developed computationally efficient non-dissipative methods provide new means for long-time simulations of charge transfer by nonlinear lattice excitations.

Keywords: Semi-classical Hamiltonian dynamics, Splitting methods, Symplectic integrators, Lattice models, Charge transfer, Intrinsic localized modes

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C5L-B3 **Supratransmission-Induced Discrete Rogue Wave in Nonlinear Chain**

Alain Bertrand Togueu Motcheyo (University of Ebolowa, Higher Technical Teacher's Training College), Masayuki Kimura (Setsunan University), Yusuke Doi (Osaka University), Juan F. R. Archilla (Universidad de Sevilla)

⇒ Proc. p.580, [Paper ID: 5164]

We numerically generate a discrete rogue wave in a chain of a nonlinear pendulum using the nonlinear supratransmission way and the instability of shaken pendulum. This could open the way for the application of discrete rogue waves within simple devices.

Keywords: Nonlinear supratransmission, Discrete rogue wave

C5L-E (R3-3) Engineering Applications III

DATE: 2022/12/14 16:20–18:00
PLACE: Room E
Chair: Yoshiki Sugitani (Ibaraki University)

C5L-E1 **Simple Initial Function and Network Topology for Basin Estimation in a DC Bus Network System with Delayed Feedback Control**
Koki Yoshida (National Institute of Technology, Toyama College), Keiji Konishi (Osaka Metropolitan University)
⇒ Proc. pp. 581–584, [Paper ID: 5099]

This paper proposes a simple initial function and a simple network topology for basin estimation in a direct current bus network system with delayed feedback control. The initial function and network topology allow us to derive an equivalent system with a few state variables. The equivalent system leads to fast numerical simulations for the basin estimation.
Keywords: Basin, Constant power load, DC bus network, Delayed feedback control

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C5L-E2 **Detection of Least Acceleration Fluctuation Point of Moving Object by Using Inertial Sensor**
Shotaro Ikemoto (Osaka Prefecture University), Daisuke Izutsu (Osaka Prefecture University), Tsuyoshi Mizuguchi (Osaka Metropolitan University)
⇒ Proc. pp. 585–588, [Paper ID: 5112]

A method is proposed to detect the least shaken point on a moving object to which an inertial sen- sor is attached by analyzing time series of acceleration and angular velocity measured by the sensor. The calculation procedure is derived and it is applied to the time series ob- tained from an experiment using a pendulum to estimate the position of the least shaken point. The accuracy of the method is evaluated by comparing it with data obtained by an image analysis.
Keywords: Inertial Sensor, Kinematic analysis

C5L-E3 **Identification of Avoidance Starting Points by Reinforcement Learning-Based Multi-Ship Course Search Method with Target Courses as Actions**
Takeshi Kamio (Hiroshima City University), Hiroki Kimura (Hiroshima City University), Takahiro Tanaka (Japan Coast Academy), Kunihiko Mitsubori (Takushoku University), Hisato Fujisaka (Hiroshima City University)
⇒ Proc. pp. 589–592, [Paper ID: 5137]

Since navigation rules (NRs) only roughly define how to avoid collisions between two ships, the actual navigators must make decisions about the direction and timing for avoidance based on their experience. Therefore, the decisions of the unskilled navigators tend to be ambiguous. Against this background, we have discussed course efficiency and safety using a multi-agent reinforcement learning system (MARLS) to search ships' courses. However, we have not discussed avoidance timing. In this paper, we propose a method to identify avoidance starting points using our MARLS. Through numerical experiments, we have confirmed that our proposed MARLS can find efficient courses and converge the avoidance starting points corresponding to each avoidance to a small area.
Keywords: Reinforcement Learning, Multi-Ship Course Problems, Course Efficiency, Learning Efficiency, Detection of Avoidance Starting Points

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C5L-E4 **Corrected Error Bound for the Real Gamma Function Using the De Formula**
Tomoaki Okayama (Hiroshima City University)
⇒ Proc. pp. 593–596, [Paper ID: 5119]

Using the double-exponential (DE) formula, Yamanaka et al. proposed a verified numerical computation method for the real gamma function. The method is useful especially for automatic result verification in arbitrary-precision arithmetic. In the method, an error bound of the DE formula is used to guarantee the accuracy of the approximation, but it is found that the bound is not rigorously proved. This study aims to correct this error bound.
Keywords: Gamma function, double-exponential formula, self-validating numerics

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D1L-B (S11-3) Nonlinear Vibrations, Waves, and Localizations III

DATE: 2022/12/15 09:00–10:20
PLACE: Room B
Chair: Masayuki Kimura (Setsunan University)

D1L-B1 **Active Porous Media: Waves and Muscles**
Tagir Farkhutdinov (University of Alberta), François Gay-Balmaz (CNRS - Ecole Normale Supérieure), Vakhtang Putkaradze (University of Alberta)
⇒ Proc. pp. 597–598, [Paper ID: 5168]

Many parts of biological organisms are comprised of deformable porous media. The biological media is both pliable enough to deform in response to an outside force and can deform by itself using the work of an embedded muscle. We derive the equations of motion for the dynamics of such an active porous media (emphi.e., a deformable porous media that is capable of applying a force to itself with internal muscles), filled with an incompressible fluid. These

equations of motion extend the earlier derived equation for a passive porous media filled with an incompressible fluid. We extend this theory by computing the case when both the active porous media and the fluid are incompressible, with the porous media still being deformable, which is often the case for biological applications. We derive interesting conservation laws for the motion, perform numerical simulations in both cases and show the possibility of self-propulsion of a biological organism due to a particular running wave-like application of the muscle stress.

Keywords: Porous media, variational methods, muscles, waves

D1L-B2 **Analysis and Experiment of Magnetic Solitons Based on Permanent Magnet Flux Biased Inductor**

Yukifumi Oda (Ibaraki University), Masayuki Kato (Ibaraki University)

⇒ Proc. p.599, [Paper ID: 5141]

Magnetic solitons are excited on an LC ladder circuit array using a permanent-magnet-flux-biased (PMFB) inductor due to its exponential inductance. In this paper, we fabricated a prototype PMFB inductor and measured its Φ – I characteristics. We will fabricate several similar PMFB inductors and build a nonlinear LC ladder circuit by them and linear capacitors. Then, we are going to observe the excitation of magnetic solitons in the LC ladder circuit.

Keywords: LC circuit, magnetic saturation, soliton

D1L-B3 **The Computational Ability of the Duffing Oscillator Array**

Md Raf E Ul Shougat (North Carolina State University), Edmon Perkins (North Carolina State University)

⇒ Proc. pp. 600–602, [Paper ID: 5211]

The Duffing oscillator array has been extensively studied in the context of localization phenomena. By using the nonlinear dynamics of a physical system, machine learning can unlock computational ability from these physical systems. The Duffing oscillator array can be used as a reservoir computer, and multiple benchmark tasks were used to quantify its computing ability. However, many of the dynamic phenomena that are observed in the array are also mirrored in the computational ability of the reservoir computer.

Keywords: Duffing oscillator, array, reservoir computer

D1L-B4 **Numerical Simulation of Unstable Dynamics of Zone Boundary Modes in Pairwise Interaction Symmetric Lattices**

Yusuke Doi (Osaka University), Rintaro Yoneda (Osaka University), Akihiro Nakatani (Osaka University)

⇒ Proc. pp. 603–604, [Paper ID: 5208]

Modulational instability of zone boundary mode (ZBM) in the pairwise interaction symmetric lattice (PISL) which is an extension of the Fermi-Pasta-Ulam-Tsingou lattice with long-range interactions, is investigated numerically. Numerical results of unstable dynamics of ZBM are consistent with our theoretical analysis. Dynamics of traveling discrete breather after the modulational instability is also discussed from the viewpoint of a degree of truncation of the long-range interactions.

Keywords: Discrete breather, Modulational Instability

D1L-C (S1-1) Algorithms for Dynamical/Statical Nonlinear Networks I

DATE: 2022/12/15 09:00–10:20
PLACE: Room C
Chair: Yuichi Tanji (Kagawa University)

D1L-C1 **Use of Support Vectors for Open Set Recognition with a Nearest Neighbor Distance Ratio in Dissimilarity-Based Feature Spaces**

Yuta Fujioka (Kagawa University), Yo Horikawa (Kagawa University)

⇒ Proc. pp. 605–608, [Paper ID: 5115]

open set recognition aims to build a discriminator that can correctly recognize samples belonging to known classes and also assign samples that are not similar to any known classes to an unknown class. in this study, we employ support vectors instead of the class centers for a dissimilarity-based feature vector. then, we apply the feature vector to open set recognition with the nearest neighbor distance ratio and evaluate its classification performance.

Keywords: open set recognition, nearest neighbor classifier, nearest neighbors distance ratio, support vector

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D1L-C2 **Application of a Multi-Layer Reservoir Neural Network to the Prediction of Spatiotemporal Chaos**

Shoki Yabu (Kagawa University), Yo Horikawa (Kagawa University)

⇒ Proc. pp. 609–612, [Paper ID: 5121]

reservoir computing (rc) is one of recurrent neural networks that can process temporal information. in the rc, the weights of input and reservoir layers are fixed and only the weights of an output layer are learned. in this study, we apply a multilayer reservoir neural network to the prediction of spatiotemporal chaos. the model has hierarchical structure with parallel reservoirs stacked in a pyramid-like shape. we then com-

pare its performance with a single-layer reservoir network.

Keywords: reservoir computing, recurrent neural networks, spatiotemporal chaos

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D1L-C3 **Application of Parameterized Nonlinear Model Order Reduction to CT Image Reconstruction**

Takeshi Suehiro (Kagawa University), Yuichi Tanji (Kagawa University)

⇒ Proc. pp. 613–616, [Paper ID: 5044]

A nonlinear dynamical system is used for CT image reconstruction. Since the nonlinear dynamical system is very large scale, the image reconstruction requires huge computational efforts. Thus, we reduce the order of the dynamical system. Here, proper orthogonal decomposition is used as a nonlinear model order reduction algorithm. Moreover, applying the parameterized reduction scheme, the proposed method is effective for many image patterns. We will confirm the effectiveness of the proposed method.

Keywords: model order reduction, POD, CT

D1L-C4 **Continuous-Time Method to Plan Volumetric Modulated Arc Therapy**

Fumino Obayashi (Kagawa University), Ken'Ichi Fujimoto (Kagawa University)

⇒ Proc. pp. 617–620, [Paper ID: 5047]

Volumetric modulated arc therapy (VMAT) is a treatment method that irradiates X-rays to target tissues within human body while continuously rotating a gantry. Since the intensity of X-rays must be controlled throughout the rotation, large changes of X-ray intensity are not desirable. The problem of finding a VMAT plan can be formulated as an inverse problem and solved with a dynamical system. In this paper, to find VMAT plans, we proposed an objective function with regularization related to the intensity of X-rays and a dynamical system to minimize the objective function. Our experimental results showed that the proposed system worked well for a toy problem on VMAT.

Keywords: Volumetric modulated arc therapy, Continuous-time dynamical system, Regularization, Total variation

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D1L-D (S6-1) Koopman Operator Approach to Power System Nonlinear Dynamics I

DATE: 2022/12/15 09:00–10:20
PLACE: Room D
Chair: Marcos Netto (NREL)

D1L-D1 **On Analytical Construction of Observable Functions in Extended Dynamic Mode Decomposition for Nonlinear Estimation and Prediction**

Marcos Netto (National Renewable Energy Laboratory), Yoshihiko Susuki (Kyoto University), Venkat Krishnan (PA Consulting), Yingchen Zhang (Utilidata, Inc.)

⇒ Proc. p.621, [Paper ID: 5009]

We propose an analytical construction of observable functions in the extended dynamic mode decomposition (EDMD) algorithm. EDMD is a numerical method for approximating the spectral properties of the Koopman operator. The choice of observable functions is fundamental for the application of EDMD to nonlinear problems arising in systems and control.

Keywords: Extended dynamic mode decomposition, EDMD, Koopman spectral analysis, Lie derivative, nonlinear estimation and prediction, observable function

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D1L-D2 **Learning Koopman Eigenfunctions and Invariant Subspaces from Data: Symmetric Subspace Decomposition**

Masih Haseli (University of California, San Diego), Jorge Cortés (University of California, San Diego)

⇒ Proc. p.622, [Paper ID: 5014]

We provide several data-driven methods to identify Koopman eigenfunctions and invariant subspaces associated with unknown nonlinear systems. We show that by applying the well-known Extended Dynamic Mode Decomposition (EDMD) algorithm forward and backward in time, one can identify all Koopman eigenfunctions in an arbitrary finite-dimensional space of functions. Moreover, we provide an algorithm termed Symmetric Subspace Decomposition (SSD) that can identify the maximal Koopman-invariant subspace of any arbitrary finite-dimensional space of functions almost surely. In addition, we provide several extensions for the proposed algorithm to accommodate the scenario of large and streaming data sets as well as the approximation of Koopman-invariant subspaces with tunable level accuracy.

Keywords: Koopman Operator, nonlinear system, identification, learning, dynamic mode decomposition

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D1L-D3 **Data-Driven Identification of Nonlinear Power System Dynamics Using Output-Only Measurements**

Pranav Sharma (Iowa State University), Venkataramana Ajjarapu (Iowa State University), Umesh Vaidya (Clemson University)

⇒ Proc. p.623, [Paper ID: 5027]

In this work, we propose a novel approach for the data-driven characterization of power system dynamics. The developed method of Extended Subspace Identification (ESI) is suitable for systems with output measurements when all the

dynamics states are not observable. It is particularly applicable for power systems dynamic identification using Phasor Measurement Units (PMUs) measurements. As in the case of power systems, it is often expensive or impossible to measure all the internal dynamic states of system components such as generators, controllers, and loads. PMU measurements capture voltages, currents, power injection, and frequencies, which can be considered as the outputs of system dynamics. The ESI method is suitable for system identification, capturing nonlinear modes, computing participation factor of output measurements in system modes, and identifying system parameters such as system inertia. The developed method addresses some of the known deficiencies of existing data-driven dynamic system characterization methods. The approach is validated for multiple network models and dynamic event scenarios with synthetic PMU measurements.

Keywords: PMU measurements, System identification, Extended Subspace Identification, Koopman operator, Power system dynamics, Output measurements

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D1L-D4 **Nonlinear Power System Analysis Using Koopman Mode Decomposition and Perturbation Theory**

Marcos Alfredo Hernández-Ortega (Universidad Autónoma de Guadalajara), Arturo Román Messina (Cinvestav)

⇒ Proc. p.624, [Paper ID: 5093]

A new model-based framework for studying the nonlinear dynamic behavior of stressed power systems that combines Koopman mode analysis and perturbation theory is proposed. First, a systematic approach to deriving high-dimensional representations of nonlinear dynamical systems based on perturbation theory is presented. Nonlinear behavior is interpreted as a projection of the Koopman operator eigenfunctions of an extended coordinate system onto the physical variables of the system. Analytical formulations are then obtained for the construction of the extended coordinate system based on perturbation theory. The analysis methodology is demonstrated on three test systems: A single-machine, infinite-bus system, a three-machine test system, and the IEEE 50-machine test system.

Keywords: Koopman mode analysis, Koopman eigenfunctions, nonlinear oscillations, perturbation theory

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D2L-B (S11-4) Nonlinear Vibrations, Waves, and Localizations IV

DATE: 2022/12/15 10:40–12:00
PLACE: Room B
Chair: Masayuki Kimura (Setsunan University)

D2L-B1 **Intrinsic Localized Modes in a Magnetically Coupled Two-Degree-of-Freedom Resonator Array**

Masayuki Kimura (Setsunan University)

⇒ Proc. p.625, [Paper ID: 5024]

A flexible nonlinear chain consisting of elastic rods with permanent magnets is fabricated and modeled for investigation on intrinsic localized modes (ILMs). In this research, the stability of ILMs is mainly investigated numerically. In addition, additional magnet arrays are introduced to the flexible chain for discussing the effect of on-site potential on the stability of ILMs.

Keywords: Intrinsic Localized Mode, Discrete Breather, Nonlinear Lattice

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D2L-B2 **Modeling of Dynamics of Nonlinear Wave Propagation in Phononic Crystals**

Jun Takayanagi (Osaka University), Yusuke Doi (Osaka University), Akihiro Nakatani (Osaka University)

⇒ Proc. pp. 626–629, [Paper ID: 5023]

We construct a nonlinear lattice model in order to investigate the dynamics of nonlinear behavior in phononic crystals (PnCs). Two types of mass points and springs are introduced in the model to represent the difference in material properties between the scatterers and background in PnCs. The nonlinearity is introduced to the model by changing the mass of each mass point in response to the displacement of the mass points. In linear regime, the existence of band gap in the 1D and 2D model is confirmed. Moreover, in the 1D nonlinear model, switching behavior of wave propagation is found.

Keywords: Phononic crystal,Band gap,Switching structure,Modeling of dynamics

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D2L-B3 **Excitation and Interaction of Nonlinear Localized Oscillations in a Mass-Spring Chain**

Yosuke Watanabe (Setsunan University), Yusuke Doi (Osaka University)

⇒ Proc. p.630, [Paper ID: 5152]

Excitation, propagation, and interaction of nonlinear localized oscillations in a mass-spring chain are studied. Letting the mass at one end of the chain driven sinusoidally at high frequency and large amplitude, localized oscillations can be excited intermittently near the end and propagated down the chain one after another at a constant speed. We have experimentally observed the phenomena, supratransmission, by a mechanical mass-spring chain which emulates the Fermi-Pasta-Ulam one of beta type.

Keywords: Intrinsic Localized Modes, Discrete Breathers, Mass-spring Chain, Fermi-Pasta-Ulam Lattice, Supratransmission

D2L-B4 **Non-Invasive Treatment of Cystic Fibrosis (CF) Using Ultrasonic Transducers**

Suketu Naik (Hawaii Pacific University)

⇒ Proc. pp. 631–634, [Paper ID: 5097]

In Cystic fibrosis (CF) the defective gene, CFTR, changes a protein that creates thick mucus. The mucus clogs the airways and traps bacteria leading to infections, extensive lung damage, and failure. The objective of the proposed research is to develop and utilize novel Focused Ultrasound (FU) systems to investigate muco-modulation (the ability to alter the properties of mucus) for CF. The immediate goals of the research are as follows: 1) to utilize unfocused/focused ultrasound system to observe muco-modulation in a simulation study and 2) to design and develop customized FU system to target multiple sites to modulate mucus structure/function in a targeted area, without disrupting gross tissue function.

Keywords: Ultrasonic transducers, Non-invasive therapy, Cystic Fibrosis

D2L-C (S1-2) Algorithms for Dynamical/Statical Nonlinear Networks II

DATE: 2022/12/15 10:40–12:00
PLACE: Room C
Chair: Yuichi Tanji (Kagawa University)

D2L-C1 **Investigation of Bifurcation Point Detection Method Based on a Differential Evolution**

Ryo Adachi (Kagawa University), Haruna Matsushita (Kagawa University), Hiroaki Kurokawa (Tokyo University of Technology), Takuji Kousaka (Chukyo University)

⇒ Proc. pp. 635–637, [Paper ID: 5139]

Nested-Layer particle swarm optimization (NLPSO) has been proposed as a bifurcation point derivation method that does not require gradient information of the objective function. However, due to its structure, the NLPSO requires a lot of computation to detect the bifurcation point set. This study proposes a single-structure bifurcation point search method based on Differential Evolution (DE) and confirms its effectiveness.

Keywords: Bifurcation point detection, bifurcation analysis, discrete-time dynamical systems, particle swarm optimization (PSO), differential evolution (DE

D2L-C2 **Time Series Classification by Neural Network Using Features of Attractors After Smoothing Process**

Ryosuke Shimizu (Tokushima University), Yoko Uwate (Tokushima University), Yoshifumi Nishio (Tokushima University)

⇒ Proc. pp. 638–641, [Paper ID: 5171]

Time series classification is an important and challenging problem in data analysis. Recently, time series analysis using neural networks (NN) has attracted much attention. However, the analysis of time series data with complex oscillations is difficult. Therefore, it is important to search for effective features of the data. In this study, we transform the dimensionality of the data and search for features suitable for NN classification. In this study, we investigate the effect of smoothed data on the classification accuracy of the dimensionality reduction method and the features of the data.

Keywords: Neural Networks,chaos,Time Series Classification

D2L-D (S6-2) Koopman Operator Approach to Power System Nonlinear Dynamics II

DATE: 2022/12/15 10:40–12:00
PLACE: Room D
Chair: Marcos Netto (NREL)

D2L-D1 **Propagating Parameter Uncertainty in Power System Nonlinear Dynamic Simulations Using a Koopman Operator-Based Surrogate Model**

Yijun Xu (Southeast University), Marcos Netto (National Renewable Energy Laboratory), Lamine Mili (Virginia Polytechnic Institute and State University)

⇒ Proc. p.642, [Paper ID: 5022]

We propose a Koopman operator-based surrogate model for propagating parameter uncertainties in power system nonlinear dynamic simulations. First, we augment a prior known state-space model by reformulating parameters deemed uncertain as pseudo-state variables. Then, we apply the Koopman operator theory to the resulting state-space model and obtain a linear dynamical system model. This transformation allows us to analyze the evolution of the system dynamics through its Koopman eigenfunctions, eigenvalues, and modes. Of particular importance for this presentation, the obtained linear dynamical system is a surrogate that enables the evaluation of parameter uncertainties by simply perturbing the initial conditions of the Koopman eigenfunctions associated with the pseudo-state variables. Simulations carried out on the New England test system reveal the excellent performance of the proposed method.

Keywords: oopman operator, statistical dynamic simulation, Uncertainty Quantification

D2L-D2 **An Application of Koopman Operator-Based Participation Factors to a Planar Self-Oscillatory System**

Kenji Takamichi (Osaka Prefecture University), Yoshihiko Susuki (Kyoto University), Marcos Netto (National Renewable Energy Laboratory), Atsushi Ishigame (Osaka Metropolitan University)

⇒ Proc. p.643, [Paper ID: 5177]

The participation factors are introduced to evaluate the mutual relation between state variables and modes in linear systems. We generalized them to nonlinear systems, based on spectral properties of the Koopman operators defined for nonlinear systems and on the idea of "sensitivity." To evaluate their potential to analysis of nonlinear systems with various dynamics, we apply the generalized factors to the well-known planar self-oscillatory system—that is, a nonlinear system with a stable limit cycle—van del Pol oscillator.

Keywords: Koopman operator, nonlinear system, participation factor, limit-cycling system

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