東北大学 電気通信研究所

研究室外部評価資料

(2016 年度-2018 年度)

Activity Report of Research Laboratory for External Review

April 2016 - March 2019
(FY.2016-2018)

Research Institute of Electrical Communication
Tohoku University

ソフトコンピューティング集積システム研究室

Soft Computing Integrated System

April 2016 - March 2019 (FY. 2016-2018)

A. 研究室名 / Research Laboratory

ソフトコンピューティング集積システム研究室
Soft Computing Integrated System

B. 構成員 / Faculty and Research Staff (as of May 1, 2019)

※ 欄を適宜追加削除等調整して下さい．期間内に異動等があった場合には，在籍期間を記載して下さい．

教授 / Professor	
氏名 Name	堀尾 喜彦 Yoshihiko Horio (April 2016 -)
分野名 Research Field	ソフトコンピューティング集積システム研究分野 Soft Computing Integrated System
准教授 / Associate Professor	
氏名 Name	
分野名 Research Field	
助教 / Assistant Professor	
氏名 / Name	
他 / Others	

C. 研究目的 / Research Purpose

本研究室では，脳に特有な諸機能を実現するブレインモルフィックコンピューティングの技術を開拓，実用化するために，半導体ナノデバイス・集積回路等による「物理ダイナミカルプロセスによる情報処理」に着目し、小型で低消費電力でありながら、実世界の様々な問題に高速に対処できる、新しい脳型コンピュータハードウェアに関する研究を行っている．

Our research group develops novel small-size low-power brain-type hardware focusing on information processing through physical dynamical process using semiconductor nano-devices and integrated circuits. We aim at a brainmorphic computing paradigm where brain specific functions will emerge.

D. 主な研究テーマ / Research Topics

1. ブレインモルフィックコンピューティングの研究
2. 複雑ダイナミクスを活用した情報処理 VLSI システムの開発とその応用
3. 脳型アナログ VLSI 回路の開発に関する研究
4. 意識過程の実現を目指す脳型 VLSI システムの開発に関する研究
5. ナノデバイスの物理に基づくニューラルネットワークハードウェアの研究

1. Brainmorphic computing paradigm
2. VLSI information processing systems based on complex dynamics
3. Brain-inspired neuromorphic analog VLSI circuits
4. Brain-inspired VLSI system with consciousness
5. Development of neural network hardware based on nano-device physics

E. 学術論文等の編数 / The Number of Research Papers

	2013	2014	2015	2016	2017	2018	Total
(1) 査読付学術論文 Refereed journal papers	-	-	-	1	1	2	4
(2) 原著論文と同等に扱う 査読付国際会議発表論文 Full papers in refereed conference proceedings equivalent to journal papers	-	-	-	0	0	0	0
(3) 査読付国際会議 Papers in refereed conference proceedings	-	-	-	1	5	2	8
(4) 査読なし国際会議・シンポジウム等 Papers in conference proceedings	-	-	-	0	5	4	9
(5) 総説・解説 Review articles	-	-	-	0	1	0	1
(6) 査読付国内会議 Refereed proceedings in domestic conferences	-	-	-	0	1	0	1
(7) 査読なし国内研究会・講演会 Proceedings in domestic conferences	-	-	-	12	11	12	35
(8) 著書 Books	-	-	-	0	1	0	1
(9) 特許 Patents	-	-	-	0	1	1	1
(10) 招待講演 Invited Talks	-	-	-	4	9	4	17

F. 特筆すべき研究成果 / Significant Research Achievements (FY.2013-2018)

See Ref. 1. "#" mark indicates research carried out at a former organization.

2013-2018 年度の研究成果（論文・特許など）のうち，前半（2013-2015 年度）と後半（2016-2018 年度）それぞれで代表的な数件（2-3 件程度ずつ）について，参考資料を引用して，その特徴と学術的意義などを簡単に紹介する．英文のみ，もしくは和文と英文で記載．
要約は 300 字程度．論文誌の要約/Abstract のコピー可．学術面での国際的インパクトならびに社会的影響を 100 字程度で記載．
<u>必ずしも当該期間内に発表・出版したものに限るのではなく，例えば過去に発表したものでもこの期間内に成果が得られたり，評価されるようになったりしたものも含むものとする．</u>
インパクトファクターや被引用件数など，できる限り第三者が定量的に評価できる指標を用いてアピールすること．それらの指標にはそぐわない場合には，その事情とそれに変わる適当な評価指標・尺度を示すこと．

[2016-2018]

1. W.A. Borders, H. Akima, S. Fukami, S. Moriya, S. Kurihara, Y. Horio, S. Sato, and H. Ohno, "Analogue spin–orbit torque device for artificial-neural-network-based associative memory operation," Applied Physics Express, vol. 10, pp. 013007-1 - 013007-4, 2016. [IF: 2.772], [Times Cited: 59]

Abstract: We demonstrate associative memory operations reminiscent of the brain using nonvolatile spintronics devices. Antiferromagnet–ferromagnet bilayer-based Hall devices, which show analogue-like spin–orbit torque switching under zero magnetic fields and behave as artificial synapses, are used. An artificial neural network is used to associate memorized patterns from their noisy versions. We develop a network consisting of a fieldprogrammable gate array and 36 spin–orbit torque devices. An effect of learning on associative memory operations is successfully confirmed for several 3 x 3-block patterns. A discussion on the present approach for realizing spintronics-based artificial intelligence is given.

International impact on both academic and social aspects: This work is the world first physical demonstration of a working artificial neural network in which spin-orbit torque (SOT) devices are used as analog synapses. The hardware system proved that the analog memory property of a SOT device can be employed in a learning system. These facts accelerated the research on analog SOT mechanism in physics, and that on neuromorphic hardware in engineering. At the same time, several semiconductor companies got interests in our work for future edge AI devices.

2. Y. Horio, N. Ichinose, and M. Ogawa, "Experimental verification of quasi-periodic-orbit stabilization using a switched-capacitor chaotic neural network circuit," Nonlinear Theory and Its Applications, IEICE, vol. 9, no. 2, pp. 218-230, 2018. [Web of Science h-index: 7], [Times Cited: Currently registering to Scopus]

Abstract: Pole assignment control for stabilizing a quasi-periodic orbit in a discrete-time dynamical system has been previously proposed. In this paper, the pole assignment method is applied to a switched-capacitor chaotic neural network circuit. For circuit experiments in which there are unknown circuit characteristics and parameters, and inevitable noise, the control method is modified by introducing new control input signals. As a result, the quasi-periodic orbits are successfully stabilized through pole assignment control. In order to confirm the quasi-periodicity of the obtained orbits, bifurcation diagrams and phase-plane portraits are provided. In addition, a statistical test designed for noisy experimental data, in particular, further confirms the quasi-periodicity. Through circuit experiments, the feasibility, usefulness, efficacy, and robustness of pole assignment control for quasi-periodic orbits are verified.

International impact on both academic and social aspects: This work experimentally demonstrated for the first time that the pole assignment control can stabilize a quasi-periodic orbit of a real physical system even with inevitable noise. In ordinary stabilizations, only periodic or chaotic trajectories can be stabilized, however, this work broke through the wall for controlling the quasi-periodicity. In the academic society, this result opened new area for complex control theory, while in industry, this work affected to the use of quasi-periodic orbits instead of avoiding them.

G. 特筆すべき活動 / Significant Activities (FY.2013-2018)

See Ref. 2-9. “#” mark indicates research carried out at a former organization.

研究室外部評価参考資料の 2 以降を参照しながら，2013-2018 年度のなどの活動の中から特筆すべきものを取り出し，前半（2013-2015 年度）と後半（2016-2018 年度）に分けて簡単に紹介する．英文のみ，もしくは和文と英文で記載．

[2016-2018]

2.(1)[1]

As a member of the board of directors, I expanded the JNNS activities to International Neural Network Society (INNS) and Asian Neural Network Society (ANNS).

2.(1)[2],[4]

Since I was the first chairman of the NOLTA society, IEICE, I have been working hard to revitalize the international activities of the society as a core member of the NOLTA society.

2.(2)[5]

As an advisor for the NOLTA2017 conference, I succeeded in negotiation to hold the NOLTA2021 in Croatia, in which I will serve as the general chair.

2.(3)[1]

I heavily contributed to improve the review system including AE memberships of the Journal. As a result, I was elected to the Editor-in-chief of the Journal for the term beginning from June 2019.

3.(2)[1]

Over 250 people from TDK attended to my lecture in which I stressed on the importance of mutual understanding between neuro-scientists and device engineers through brainmorphic computation for future AI systems. As a result, many device engineers including CEO had much interests in the brainmorphic computational paradigm.