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授与した学位	博　士
専攻分野の名称	工　学
学位授与番号	博甲第４１２８号
学位授与の日付	平成２２年　３月２５日
学位授与の要件	自然科学研究科　産業創成工学専攻 （学位規則第５条第１項該当）
学位論文の題目	Functional Aspects of Chaotic Dynamics in A Recurrent Neural Network Model, Theory, Applications, and Hardware Implementation （リカレント型神経回路網におけるカオス的ダイナミックスの機能性に関する理論・応用・ハードウェア実装）
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学位論文内容の要旨

Chapter 1 Introduction. This chapter presents the research background and the motivation. It comprises the understanding of brain as complex systems, the proposal of somehow harnessing the onset of chaos, and ill-posed problems that are taken as functional experiments based on this ideas. Finally, the thesis is outlined.

Chapter 2 Chaos and Dynamical Systems. This chapter gives a brief review of basic ideas and terminology in the theory of dynamical systems. Along our aim to introduce several topics of chaos, intrinsic properties of chaos are discussed and demonstrated by using several typical discrete dynamical systems.

Chapter 3 Neural Networks. This chapter begins with a brief review of artificial neural networks, and how to embed memory patterns into a recurrent neural network model (RNNM) is highlighted. An orthogonalized learning method to effectively embed memory cycles into RNNM is discussed in detail.

Chapter 4 Chaotic Dynamics in RNNM. After several memory cycles are embedded using the orthogonalized learning method, the performance of associative memory is evaluated by means of calculating an approximate basin volume via statistical method. Chaotic dynamics is introduced into RNNM by changing a system parameter, connectivity. The route from attractor to chaotic dynamics is analyzed by means of calculating bifurcation diagram and basin visiting measure.

Chapter 5 Chaos and Adaptive Control. This chapter addresses how chaos is applied to solving ill-posed problems in control tasks. A simple coding method, called motion functions are proposed so that complex dynamics with many but finite degrees of freedom in a high dimensional state space can be utilized to generate low dimensional complex motions. In terms of the motion functions, several prototype simple motions are embedded into RNNM. In turn, by the coding of motion functions, chaotic dynamics in RNNM correspondingly generates chaotic motion. A novel idea, adaptive switching of connectivity, was proposed for the application of chaotic dynamics in solving ill-posed problems. Using this idea, chaotic dynamics in RNNM is applied to solving two ill-posed problems in control tasks. Computer experiments on controlling an object to solve two-dimensional mazes and to track a moving target are successfully implemented. And then we have evaluated the performance of solving these problems using chaotic dynamics in RNNM.

Chapter 6 Hardware Implementation into An Autonomous Robot. This chapter presents how to implement those functional experiments into hardware. The construction of control system is addressed and a robot is designed and built. The robot driven by complex dynamics generated by a neuro-chaos simulator, which functions as brainmorphic device to simulate a RNNM. Those functional experiments were implemented successfully.

Chapter 7 Quasi-layered RNNM. This chapter presents a quasi-layered RNNM consisting of sensory neurons and motor neurons, which gives a biologically realistic meaning. The inherent properties of quasi-layered RNNM are analyzed by bifurcation diagram. By virtue of sensitive response of chaos, while sensory neurons respond to external signals sensitively, motor neurons respond to sensory neurons sensitively. Thus, chaotic dynamics is introduced in both sensory neurons and motor neurons. Inspired by neurobiology, presynaptic inhibition is introduced and provides the robot with naturally adaptive behaviors. Finally, functional experiments were implemented successfully in computer experiments and hardware implementation.

Chapter 8 Functional Investigation of Chaotic Neurons. This chapter presents chaotic neural network consisting of neurons with continuous states in order to confirm that the functional features of chaos do not depend on the detailed structure of models. Adaptive switching of parameters results in adaptive motions. Computer experiments on controlling an object to solve two-dimensional mazes are successfully implemented.

Chapter 9 Summary and Concluding Remarks. This chapter presents the conclusions of this thesis, and recommendations for future work.

Appendix A and **Appendix B** present the relevant information on designing the sensory system of the robot and wireless communication interface between neuro-chaos simulator and the robot in Chapter 6. This is followed by bibliography.

論文審査結果の要旨

本論文は，脳研究における電気生理学的実験に基づき理論的な考察を行い神経回路網のモデルを作り，そこにカオス的ダイナミックスを導入して「単純なルールに基づく高度な機能の実現」を目標に掲げ，計算機実験を行いカオスの持つ機能性を論じたものである。更にその結果を実際のハードウェアに実装して機能性を工学技術的に実現した結果を理論的考察とともに提出している。アイデアには新規性があり，特にカオス的ダイナミックスの機能性に着目して研究を行ったことは高く評価される。従来型の情報処理や制御関係の技術におけるカオスは，長時間後の予測が困難であるためにシステム設計上は起きないように工夫されて来た。本論文ではそれを逆転の発想のもと，カオスを積極的に応用して従来技術では困難とされる「不良設定問題の求解」に適用して成功裡に成果を得，英語で出版されている研究専門誌に投稿し高い評価を得て掲載されている参考論文の内容がより詳しく述べられている。これは現在も発展しつつあるコンピュータ技術に内在する困難性を先鋭的に捉え，その対比としての人間の脳機能に注目してその情報処理や制御の機能に関するメカニズムに迫る研究であるとともに，それらの工学的再構成実現を目指す研究と認識されるものである。

以上の内容をもとにした本論文についての審査の結果，博士の学位に相当すると認める。