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研究課題名（和文）A Declarative Memory Neural Model for Continual Self-Supervised Learning of Intelligent Agents

研究課題名（英文）A Declarative Memory Neural Model for Continual Self-Supervised Learning of Intelligent Agents

研究代表者

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研究成果の概要（和文）：神経科学における補完学習システム（CLS）理論に触発され、エピソード-意味記憶に基づくフレームワークが注目され研究されている。従来の手法は、データ一括正規化を行う必要があり、異なるデータセット間で警戒ハイパーパラメータに敏感である。正規化せずに入力データを連続的に学習し、警戒ハイパーパラメータの影響を受けにくいRobust Growing Memory Network (RGMN)を提案する。RGMNは人間のエピソード記憶をモデル化した自己組織化トポロジカルネットワークであり、そのネットワークサイズはデータに対応して成長・縮小することができる。

研究成果の学術的意義や社会的意義
生涯学習は、計算機モデルや自律型エージェントにとって不可欠でありながら複雑な要素である。この分野での進歩は目覚しいが、既存の生涯学習モデルは、柔軟性、信頼性、拡張性の点で生物システムに大きく及ばない。正規化せずに入力データを継続的に学習し、パラメータ設定に頑健な人間のエピソード記憶をモデル化したRGMNを提案する。今後の課題として、より挑戦的なデータセットを用いて提案手法の有効性をさらに検証する予定です。また、人間のジェスチャー認識や行動分類などの時系列アプリケーションに、メモリネットワークの時空間接続性を利用することも将来の研究課題である。

研究成果の概要（英文）：Machine learning models perform well when given precisely structured, balanced, and homogenized data. However, when several jobs with incremental data are provided, the performance of the majority of these models suffers. Inspired by the Complementary Learning Systems (CLS) theory in neuroscience, episodic-semantic memory-based frameworks have received much attention and research. Conventional methods are needed to perform data batch normalization and are sensitive to vigilance hyperparameters across different datasets. I propose a Robust Growing Memory Network (RGMN) that continuously learns incoming data without normalization and is unlikely to be affected by the vigilance hyperparameter. The RGMN is a self-organizing topological network that models human episodic memory, and its network size can grow and shrink in response to data. The long-term memory buffer retains the largest and smallest data values that will use for learning.

研究分野：Artificial Intelligence

キーワード：lifelong learning　topological map　continual learning　self organizing　active learning　memory neural network　cognitive robotics

１．研究開始当初の背景

The general success criterion for an artificial intelligence system is its ability to mimic human brain learning. Throughout a lifetime, the human brain is capable of continual learning. The acquired information is kept, augmented, fine-tuned, and utilized to complete new tasks in the future. At the moment, machine learning models perform well when given precisely structured, balanced, and homogenized data. However, when several jobs with incremental data are provided, the performance of the majority of these models suffers. Inspired by the Complementary Learning Systems (CLS) theory in neuroscience, episodic-semantic memory-based frameworks have received much attention and research. On the other hand, conventional methods are needed to perform data batch normalization and are sensitive to vigilance hyperparameters across different datasets.

２．研究の目的

Humans have remarkable learning abilities and acquire knowledge gradually, which is an essential feature of learning. Deep neural networks (DNNs) have demonstrated ex- ceptional performance in many specific applications. However, it remains a critical difficulty for deep learning, which entails learning several tasks simultaneously. A typical scenario is that DNN gradually forgets previously learned knowledge while training on a new assignment. This scenario is known as *"catastrophic forgetting."* Furthermore, machine learning models are often developed for stationary contexts in which the process of generating the data remains steady throughout time. However, in many real-world circum- stances, the data is created by evolving processes; therefore, the underlying probability distribution may shift, resulting in a phenomenon known as concept drift.

I propose a Robust Growing Memory Network (RGMN) that continuously learns incoming data without normalization and is unlikely to be affected by the vigilance hyperparameter. The RGMN is a self-organizing topological network that models human episodic memory, and its network size can grow and shrink in response to data. The long-term memory buffer retains the most significant and minor data values used for learning. To evaluate the performance of the proposed method, we conducted comparative experiments on real-world datasets, and the results showed that the proposed method outperforms existing memory-based baseline frameworks in terms of accuracy.

３．研究の方法

I propose a Robust Growing Memory Network (RGMN) to overcome the abovementioned limitations. The proposed RGMN continually learns sensory data without normalization and achieves comparable performance with conventional methods requiring normalization. In addition, the RGMN is relatively robust to the vigilance parameter. The learning of RGMN is stable across different datasets and achieves a similar performance regardless of the setting of the vigilance parameter. The RGMN continually generates new nodes for encoding data information and topological connections for associating nodes and encoding their relationships to learn incoming data. To encode spatiotemporal information, the RGMN learns the activation patterns of episodic memory nodes. The RGMN maintains network stability and flexibility by continually producing nodes in the presence of novel data and updating notes weights if the received data is similar to previously learned knowledge.

Figure 1 illustrates the overview of the Robust Growing Memory Network architecture. The memory network receives data input from sensors and performs lifelong learning. Episodic memory replay happens in the serial memory network when no sensory input feeds into the networks.

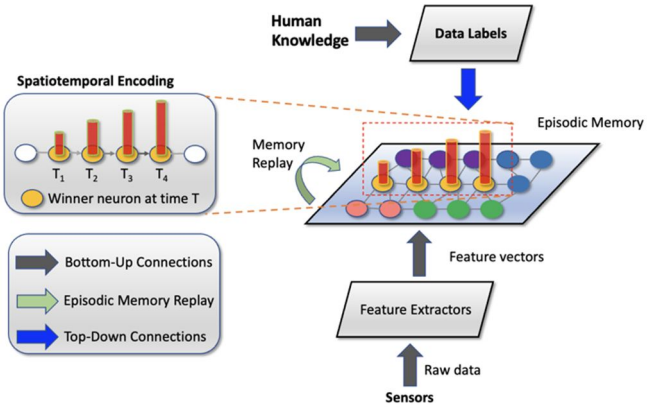

Figure 1: Overview of the proposed method

4．研究成果

Lifelong learning is an essential yet intricate element of computational models and autonomous agents. Despite tremendous progress in this area, existing models of lifelong learning fall well short of biological systems in terms of flexibility, reliability, and scalability. This paper proposes a Robust Growing Memory Network (RGMN) that models human episodic memory for continually learning input data without normalization and robust vigilance parameter setup. The RGMN constantly learns and responds to incoming input by expanding and shrinking its memory structure in the networks. The proposed method has been validated with several benchmark datasets and physical robot implementation for robot navigation. Figure 2 shows the results on benchmark datasets. Figure 3 shows the real robot and experimental environment. Figure 3 shows the physical robot and the experiment environment. The results of actual robot implementation are shown in Figure 4 and Figure 5.

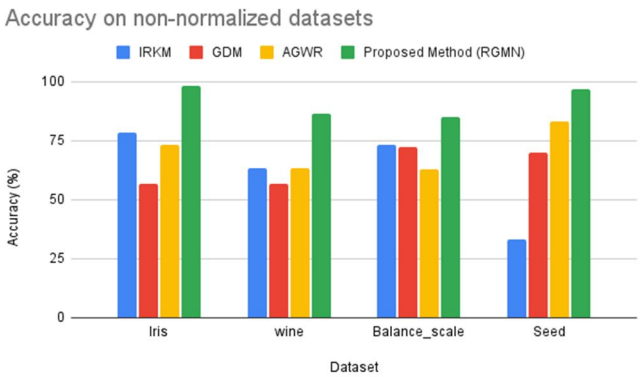

Figure 2: The classification accuracy of non-normalized datasets

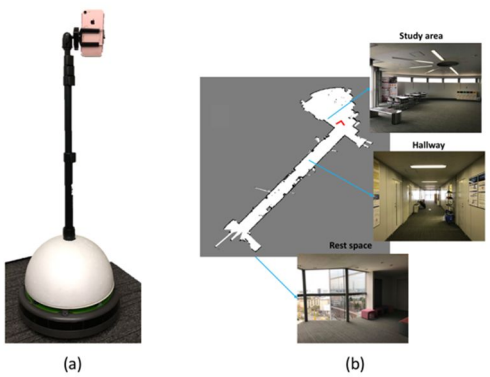

Figure 3: Robot and experimental environment

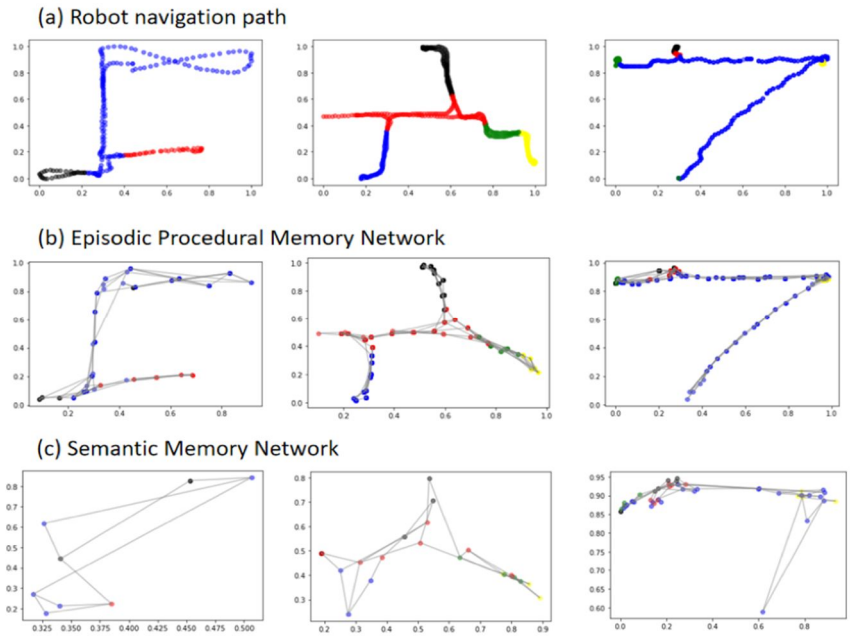

Figure 4: Row (a) shows the robot's path in different environments. Row (b) and (c) show the topological map of the episodic-semantic memory network.

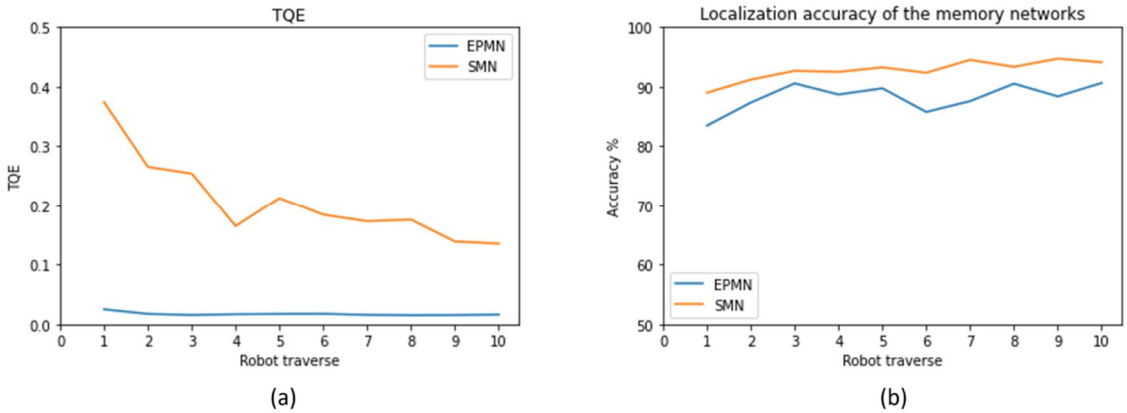

Figure 5: (a) The quality of the generated topological map is evaluated with the TQE metric; the lower, the better. (b) The localization accuracy of the memory networks for each traverse; the higher, the better.

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　1件）

１．著者名 Jiahui Yu, Hongwei Gao, Wei Yang, Yueqiu Jiang, Weihong Chin, Naoyuki Kubota, Zhaojie Ju	４．巻 8
２．論文標題 A discriminative deep model with feature fusion and temporal attention for human action recognition	５．発行年 2020年
３．雑誌名 IEEE Access	６．最初と最後の頁 43243-43255
掲載論文のDOI（デジタルオブジェクト識別子） 10.1109/ACCESS.2020.2977856	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

〔学会発表〕　計13件（うち招待講演　0件／うち国際学会　13件）

１．発表者名 Wei Hong Chin, Chu Kiong Loo, Stefan Wermter
２．発表標題 Multichannel Recurrent Kernel Machines for Robot Episodic-Semantic Map Building
３．学会等名 1st SMILES (Sensorimotor Interaction, Language and Embodiment of Symbols) workshop, ICDL 2020（国際学会）
４．発表年 2020年

１．発表者名 Wen Bang Dou, Cheng Hui Liu, Wei Hong Chin, Naoyuki Kubota
２．発表標題 Intelligent capturing system for beast damage control
３．学会等名 2021 World Automation Congress (WAC)（国際学会）
４．発表年 2021年

１．発表者名 Cheng Tang, Ryota Inoue, Wei Hong Chin, Naoyuki Kubota
２．発表標題 Development of an inspection system for waterway tunnels based on visual SLAM by an autonomous water robot
３．学会等名 2021 World Automation Congress (WAC)（国際学会）
４．発表年 2021年

１．発表者名
Adnan Rachmat Anom Besari, Azhar Aulia Saputra, Wei Hong Chin, Naoyuki Kubota

２．発表標題
Feature-based Egocentric Grasp Pose Classification for Expanding Human-Object Interactions

３．学会等名
2021 IEEE 30th International Symposium on Industrial Electronics (ISIE)（国際学会）

４．発表年
2021年

１．発表者名
Rino Kaburagi, Yudai Ishimaru, Wei Hong Chin, Akihiro Yorita, Naoyuki Kubota, Simon Egerton

２．発表標題
Lifelong Robot Edutainment based on Self-Efficacy

３．学会等名
2021 5th IEEE International Conference on Cybernetics (CYBCONF)（国際学会）

４．発表年
2021年

１．発表者名
Taiga YOKOTA, Yasunari FUJIMOTO, Ryota INOUE, Cheng TANG, Weihong CHIN, Naoyuki KUBOTA, Naoyuki TAKESUE, Shinichi TAKARABE, Koji SHIN, Yoshiyuki OKIYASU

２．発表標題
Development and Control of Unmanned Floating Observer (UFO) for Inspection of Irrigation Tunnel and Canal

３．学会等名
The 7th International Conference on Advanced Mechatronics (ICAM 2021)（国際学会）

４．発表年
2021年

１．発表者名
Adnan Rachmat Anom Besari, Wei Hong Chin, Naoyuki Kubota

２．発表標題
Ecological Approach for Object Relationship Extraction in Elderly Care Robot

３．学会等名
2020 21st International Conference on Research and Education in Mechatronics (REM)（国際学会）

４．発表年
2020年

１．発表者名
Wen Bang Dou, Wei Hong Chin, Naoyuki Kubota

２．発表標題
Hand Gesture Communication using Deep Learning based on Relevance Theory

３．学会等名
2020 Joint 11th International Conference on Soft Computing and Intelligent Systems and 21st International Symposium on Advanced Intelligent Systems (SCIS-ISIS)（国際学会）

４．発表年
2020年

１．発表者名
Kenya Umetsu, Simon Egerton, Wei Hong Chin, Naoyuki Kubota

２．発表標題
Body-Sharing Multi-Robot System in Robot Theater towards Social Implementation

３．学会等名
2020 IEEE International Conference on Systems, Man, and Cybernetics (SMC)（国際学会）

４．発表年
2020年

１．発表者名
Yuta Kusakari, Wei Hong Chin, Naoyuki Kubota

２．発表標題
A Deep Neural Model for Pedestrians Detection with Danger Estimation

３．学会等名
2020 International Symposium on Community-centric Systems (CcS)（国際学会）

４．発表年
2020年

１．発表者名
Azhar Aulia Saputra, Chin Wei Hong, Auke Jan Ijspeert, Naoyuki Kubota

２．発表標題
A muscle-reflex model of forelimb and hindlimb of felidae family of animal with dynamic pattern formation stimuli

３．学会等名
2020 International Joint Conference on Neural Networks (IJCNN)（国際学会）

４．発表年
2020年

１．発表者名 Wei Hong Chin, Noel Nuo Wi Tay, Naoyuki Kubota, Chu Kiong Loo
２．発表標題 A Lightweight Neural-Net with Assistive Mobile Robot for Human Fall Detection System
３．学会等名 2020 International Joint Conference on Neural Networks (IJCNN)（国際学会）
４．発表年 2020年

１．発表者名 Kurnianingsih Kurnianingsih, Nur Fajri Al Faridi Hadi, Eni Dwi Wardihani, Naoyuki Kubota, Wei Hong Chin
２．発表標題 Ensemble learning based on soft voting for detecting methamphetamine in urine
３．学会等名 2020 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)（国際学会）
４．発表年 2020年

〔図書〕　計1件

１．著者名 Wei Hong Chin, Naoyuki Kubota and Chu Kiong Loo	４．発行年 2022年
２．出版社 IntechOpen	５．総ページ数 18
３．書名 Cognitive Robotics: An Episodic-Procedural Semantic Memory Model for Continuous Topological Sensorimotor Map Building	

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関