Section focused on machine learning methods for high-level cognitive capabilities in robotics

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PREFACE

Section focused on machine learning methods for high-level cognitive capabilities in robotics

Integrating high- and low-levelognitive capabilities is essential for developing robotic systems that can adaptively act in our daily environment in active collaboration with humans. Recent advances in machine learning techniques, including deep learning and hierarchical Bayesian modeling, are providing us with new possibilities to integrate high- and low-level cognitive capabilities in robotics. It became clear that such learning methods are indispensable to create robots that can effectively address uncertainties while acting smart in the real world.

We had organized workshops, named 'Machine Learning Methods for High-Level Cognitive Capabilities in Robotics,' in IROS 2016 and 2017. In the workshops, we solicited excellent papers related to the demand for accelerating the synergies of low- and high-level cognitive capabilities. It would enable us to develop methods that address real-world problems in a more robust manner. Hence, we aim to share knowledge regarding state-of-the-art machine learning methods that contribute to modeling sensory-motor and cognitive capabilities in robotics and to exchange views among cutting-edge robotics researchers with a special emphasis on adaptive high-level cognition.

Through the workshops, researchers from cognitive robotics, speech processing, artificial intelligence, machine learning, computer vision, natural language processing, and so on were gathered to discuss the current challenges in machine learning methods for high-level cognitive capabilities in robotics. Typical keywords discussed in the workshop were as follows: Multimodal communication, learning motor skills and segmentation of time-series information, concept formation, probabilistic models, language acquisition, human–robot communication and collaboration, deep learning, the theory of mind and model of others, skill transfer, Bayesian modeling, application in communicable service robots, and so on. These keywords should be organized using Figure 1, which was used in the workshop discussion in 2017.

Our daily environment is full of uncertainties, with complex objects and challenging tasks. A robot is not only required to deal with things appropriately in a physical manner, but also perform logical and linguistic tasks in the real world. Consider a scenario where a human user tells a robot, 'please move it into the blue box.' In addition to solving a manipulation task, the robot must move the target object to a particular blue box and estimate what 'it' represents. In addition to solving the manipulation task, the robot should estimate the meaning of 'into,' representing the relationship between 'it' and 'the blue box' in a real-world environment. When a robot attempts to communicate and collaborate with human users in a real-world environment, bridging high- and low-level cognitive capabilities is critical. Low-level cognitive capabilities include physical control, behavioral motion generation, and sensory perception (node (i) in Figure 1). In contrast, high-level cognitive capabilities include logical inference, planning, and language (node (ii) in Figure 1).

Conventionally, symbol-based and/or rule-based approaches have been employed to model high-level cognitive capabilities in robotics. However, it has been reported that such conventional methods could not create a robot that could address inevitable uncertainties in the physical environment and natural human–robot communications. In other words, the difficulty of direct transformation between nodes (i) and (ii) was the major cause of the low performance of natural human–robot communications. However, recent advances in machine learning techniques have provided a bridge between node (i) and the top node, and between node (ii) and the top node, as shown in Figure 1. It has become increasingly clear that machine learning methods are indispensable for creating robots that address uncertainties. In addition to machine learning techniques, big data in human–robot interactions through a virtual reality environment can be applied to accelerate the learning process to connect the high- and low-level cognitive capabilities.

We organized a new type of submission strategy at the second workshop in 2017. Authors could choose from two submission categories:

(A) Extended abstract (maximum 2 pages in length)
(B) Full paper (maximum 6 pages in length)

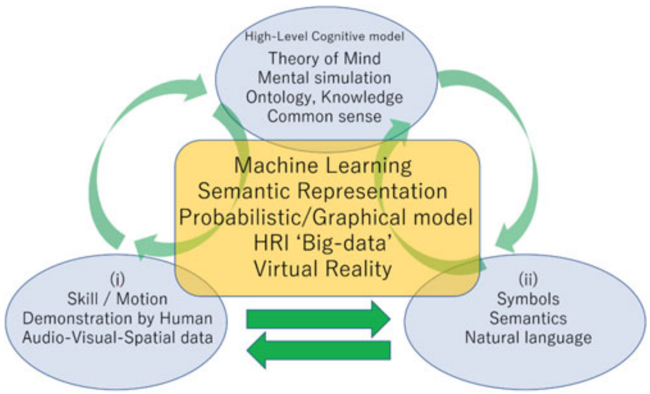

Figure 1. Bridge between low-level cognitive capabilities, i.e. node (i), and high-level cognitive capability, i.e. node (ii). Direct transformation between nodes (i) and (ii) is difficult using conventional methods; however, recent machine learning techniques provide high-level cognitive models, depicted as the top node that solves the gap between (i) and (ii).

All the papers submitted to the workshop are reviewed for consideration as both (A) and (B). The difference between (A) and (B) is that the reviewer process for the special issue in Advanced Robotics begins at the submission for the workshop. The review process for the journal is independent of the review process for this workshop; however, the authors can receive the review result from the editors of Advanced Robotics within approximately 90 days (on average). This implies that the authors might be able to state in the workshop that the paper will be published in the journal later. Hence, the paper for category (B) should not be published in the workshop proceedings. We believe that this new strategy would result in a good opportunity for and encourage young researchers to join an international discussion community to improve their ideas through discussions at the workshop and review processes. Unfortunately, only one paper will be accepted through category (B); however, we have received many papers using this submission and review strategy. We plan to adopt this strategy in future workshops.

The first paper, entitled 'Navigation Behavior based on Self-organized Spatial Representation in Hierarchical Recurrent Neural Network' by Wataru Noguchi et al. is accepted using the above submission category (B). This paper proposes a cognitive map representation based on hierarchical recurrent neural networks. The model acquires the relationship between a sequence of images and navigation skill through navigation experiences. This relationship is illustrated as a part of Figure 1, i.e. the bidirectional arrow between node (i) (motion skill and image sequence) and the top node (cognitive map representation).

The second paper is entitled 'Bidirectional Estimation Between Context and Motion in Motion Sequence in Which Context Changes' by Takashi Ogura et al. This paper proposes an architecture for the bidirectional recognition of motion patterns and background context. Motion recognition affects context estimation, and context estimation affects motion recognition. This relationship is depicted as a part of Figure 1, i.e. between the top node for context and node (i) for motion patterns.

Our research community organized a workshop named 'Language and Robotics' in IROS in 2018. The name of the workshop was changed; however, the positioning of the research interest was almost the same as that of the workshops in 2017. The understanding of the natural language by social service robots in daily life environment requires high-level cognitive information and numerous raw sensor information related to human activity, which is depicted as node (i) in Figure 1. We believe that the section focusing on this issue should be the starting point for the development of cognitive intelligent robot systems, including the use of language ability.

Disclosure statement

No potential conflict of interest was reported by the authors. Q4

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