Introduction to the Special Section on Cognitive Robotics on 5G/6G Networks

5G networks have made significant progress towards developing a low latency tactile access network and opening new opportunities for innovative automation of network resources and operations. Continuing the deployment of 5G, we are starting to define 6G networks. Meanwhile, cognitive computing breaks the boundary between neuroscience and computer science. It paves the way for machines to have reasoning abilities which is analogous to humans. The research field of cognitive computing is interdisciplinary, and uses knowledge and methods from many areas such as psychology, biology, signal processing, physics, information theory, mathematics, and statistics. The development of cognitive robotics will keep cross-fertilizing these research areas. However, in cognitive robotics applications there still remain many open problems in using 5G/6G networks. Technologies like millimeter wave band-based MIMO and software defined networking are driving as the best tools for upgrading the networked robots with near-human intelligence, which can be intended to physically interact with humans in a shared workspace.

The next generation of cognitive robotics will resemble the nervous system to create new smart infrastructures that feature proactive, secure and adaptive paradigms. With the increase of large autonomy of systems, the protection of cognitive robotics against malicious attacks becomes significantly more important.

The overall aim of this special issue is to collect the state-of-the-art contributions on the architecture technologies of 5G/6G networks, and related applications in robotics. The Journal invites submissions for a special issue on "Cognitive Robotics on 5G/6G Networks" that aims to attract high-quality papers that describe state-of-the-art technologies and new findings both in soft computing and robotics research fields.

From a total of 43 papers submitted to this special issue, 8 high-quality articles were selected, resulting in an acceptance rate of 18.6%. Each paper was peer reviewed by three or more experts during the assessment process. The selected articles have exceptional diversity in terms of Internet of Things and robotic techniques and applications. They represent the most recent development in both theory and practice. The contributions of these papers are briefly described as follows.

For the multiple-robot system, the first paper [1] casts grid map merging into point set registration problem, where the objective function is optimized by ICP variant algorithm. To provide initial transformations, the authors propose the context-based descriptor and designs scale-based correspondence expansion to obtain correct feature matches between grid map pairs. Given a set of correct feature matches, initial transformations are estimated for ICP variant, which can achieve accurate grid map merging. Since the proposed method considers the scale information of interest points in the descriptor with correspondence expansion, it is able to merge grid maps in the same or diverse resolutions.

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Traditional optimization tools such as brute force or random search is often used to solve the design of Symmetric-Key primitives. To improve search efficiency and optimize search results, the second paper [2] designs a novel metaheuristic algorithm, named **particle swarm-like normal optimization algorithm (PSNO)** to design the Symmetric-Key primitives of SKINNY. Experimental results show that our algorithm is superior to existing algorithms in search results and search efficiency. The algorithm can also be extended to the design of Symmetric-Key primitives of other lightweight block ciphers with clear evaluation indicators, where the corresponding indicators can be used as the objective functions.

Emotional cognitive ability is a key technical indicator to measure the friendliness of interaction. Therefore, this research aimed to explore robots with human emotion cognitive. By discussing the prospects of 5G technology and cognitive robots, the main direction of the study is the cognitive robots. For the emotional cognitive robots, the analysis logic similar to humans is difficult to imitate; the information processing levels of robots are divided into three levels in this study: cognitive algorithm, feature extraction, and information collection by comparing human information processing levels. More, multi-scale **rectangular direction gradient histogram (R-HOG**) is used for facial expression recognition, and **robust principal component analysis algorithm (RPCA)** is used for facial expression recognition. The algorithm explored in this paper [3] can realize accuracy cognition of emotions. From the above research results, it can be seen that the research method in this study can intuitively reflect the proportion of human expressions, and the recognition methods based on facial expressions and micro-expressions have good recognition effects, which is in line with human intuitive experience.

Human emotions play an important role in the open-domain dialogue system. In Lan's work [4], the authors propose a Chinese emotional dialogue response generation algorithm based on reinforcement learning. With the help of reinforcement learning, the reward function is constructed based on both the emotion and the content. Therefore, the proposed method can generate responses not only according to content but also according to emotion. A diversity beam search algorithm is also applied to avoid safe responses and diversify dialogue. The comparative experiments demonstrate that the proposed model achieves satisfactory results in terms of both automatic and human evaluations.

Timely and accurate load forecasting is crucial for power system plan and robot motor control. In the fourth paper [5], they propose load forecasting model by using improved gene expression programming and abnormal load recognition. We first use probability distribution and cross validation to deal with abnormal load. And we design a series of strategies to optimize population parameters, individual evolution, and genetic operation probability of gene expression programming. Experimental results show that the proposed model is superior to the other algorithms.

With the development of 5G/6G networks and cognitive robotics, cognitive robots have been widely applied in human activities. **Sentence semantic matching (SSM)** is crucial for implementing human-robot language interactions. The paper [6] proposes a novel model for SSM based on 3D CNN. It first devises the feature cube network to transform 1D sentences into multi-dimensional semantic feature cubes, then employs 3D CNN to encode the cubes to capture their interactive features, followed by a sigmoid function to judge their matching degree. Exhaustive experiments demonstrate that our model has achieved remarkable results, which shows better or comparable performance with BERT-based models.

The article "Cognitive Wearable Robotics for Autism Perception Enhancement" [7] proposed a novel **artificial intelligence (AI)**-based first-view-robot architecture to explore this robot-based approach. By providing care from the first-person perspective, the proposed wearable robot overcomes the difficulty of the absence of cognitive ability in the third-view of traditional robotics and improves the social interaction ability of children with Autism Spectrum Disorders (ASD).

On the basis of this architecture, the authors proposed a deep architecture-based learning assessment model for children with ASD. In addition, a robot-assisted interaction mechanism between children with ASD and the interaction environment is proposed.

Multi-robot navigation and coordination are addressed in [8]. All the robots are subjected to their own kinematic and dynamic constraints. Genetic algorithm tuned fuzzy logic-based motion planner is compared with the potential field-based motion planner. To avoid conflicts during the navigation, two different coordination schemes namely strategic and heuristic are implemented. Results are compared through computer simulation. Simulation experiments were started with eight robots initially and the number of robots was increased up to 17 later due to the need for a coordination scheme for the maximum number of robots. A strategic coordination scheme along with the genetic-fuzzy-based motion planner is found to perform better than the other combinations concerning the quality of solutions and time taken to reach the goal positions. The computational complexity of different methods has also been compared and presented.

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