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GUEST EDITORIAL

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Special issue on smart interactions in cyber-physical systems: Humans, agents, robots, machines, and sensors

In recent years, there has been increasing interaction between humans and non-human systems as we move further beyond the industrial age, the information age, and as we move into the fourth-generation society. The ability to distinguish between human and non-human capabilities has become more difficult to discern. Given this, it is common that cyber-physical systems (CPSs) are rapidly integrated with human functionality, and humans have become increasingly dependent on CPSs to perform their daily routines.

The constant indicators of a future where human and non-human CPSs relationships consistently interact and where they allow each other to navigate through a set of non-trivial goals is an interesting and rich area of research, discovery, and practical work area. The evidence of convergence has rapidly gained clarity, demonstrating that we can use complex combinations of sensors, artificial intelligence, and data to augment human life and knowledge. To expand the knowledge in this area, we should explain how to model, design, validate, implement, and experiment with these complex systems of interaction, communication, and networking, which will be developed and explored in this special issue. This special issue will include ideas of the future that are relevant for understanding, discerning, and developing the relationship between humans and non-human CPSs as well as the practical nature of systems that facilitate the integration between humans, agents, robots, machines, and sensors (HARMS).

Contributions that demonstrate the integration of HARMS using practical experimental results were invited for this issue. Papers that show the design, models, or techniques of advancement were selected in the wider context of large, complex systems, including those involving multiple, heterogeneous actors.

The first paper "Deep Compression of Convolutional Neural Networks with Low-Rank Approximation," by Marcella Astrid and Seung-Ik Lee, captures the application of deep neural networks (DNNs) to connect the world with cyber-physical systems (CPSs), which have attracted much attention. However, DNNs require a large amount of memory and computational cost, which hinders their use in the relatively low-end smart devices that are widely used in CPSs. In this paper, the authors aim to determine whether DNNs can be efficiently deployed and operated in low-end smart devices. To do this, they develop a method to reduce the memory requirement of DNNs and to increase the inference speed, while maintaining the performance (for example, accuracy) close to the original level. The parameters of DNNs are decomposed using a hybrid of canonical polyadic–singular value decomposition, and are approximated using a tensor power method, and they are fine-tuned by performing iterative one-shot hybrid fine-tuning to recover from the decreased accuracy. In this study, they evaluate their method on frequently used networks. The authors also present results from extensive experiments on the effects of several fine-tuning methods, as well as the importance of iterative fine-tuning and decomposition techniques. The authors demonstrate the effectiveness of the proposed method by deploying compressed networks in smartphones.

The second paper, "Human-like Sign Language Learning Method with Deep Learning," by Ki-Baek Lee and others proposes a human-like sign language learning method with a deep learning technique. Inspired by the fact that humans can learn sign language from just a set of pictures in a book, in the proposed method, the input data are pre-processed into an image. In addition, the network is partially pretrained to imitate the preliminarily obtained knowledge of humans. The learning process is implemented with a well-known network, that is, a convolutional neural network. Twelve sign actions are learned in ten scenarios and can be recognized with an accuracy of 99% in an environment involving low-cost equipment and limited data. The results demonstrate that the system is highly practical as well as accurate and robust.

The third paper, "Optimization-based Humanoid Robot Navigation Using Monocular Camera in Indoor Environment," shows how robot navigation gives robots mobility. For this reason, mobility is one of the robot fields that have been extensively studied since robots have been developed. In recent years, there has been increased interest in personal service robots for homes and public facilities. As a result, the navigation of the robot in the home environment, which represents one of the indoor environments, is under study. However, the problem with conventional navigation algorithms is that they require long computation times to map buildings and for path-planning processes. This problem makes it difficult to cope with environments that change in real time. Consequently, they propose a humanoid robot-navigation algorithm composed of an image processing and optimization algorithm. This algorithm enables navigation in a less computation time than conventional navigation algorithms using the map building and path-planning processes, and with the proposed method, it is possible to perform navigation in environments that change in real time.

The fourth paper is "Incremental Hierarchical Roadmap Construction for Efficient Path Planning" by Byungjae Park and others. This paper proposes a hierarchical roadmap (HRM) and its construction process to efficiently represent navigable areas in an indoor environment. HRM is adopted to solve the path-planning problems for a mobile robot in an indoor environment. HRM has a multi-layered graphical structure to abstract and cover navigable areas using a smaller number of nodes and edges than a probabilistic roadmap. In the incremental process of constructing an HRM, the information of navigable areas is abstracted using a sonar grid map when a mobile robot navigates an unexplored area. The HRM-based planner efficiently searches for paths to answer queries by reducing the search-space size using the multilayered graphical structure. The benefits of an HRM were verified experimentally in real indoor environments.

The fifth paper is "Approach toward Footstep Planning Considering the Walking Period:

Optimization-based Fast Footstep Planning for Humanoid Robots," and it proposes the need for a walking period in footstep planning and details of scenarios in which a walking period should be considered. They also present an optimization-based fast footstep planner that considers the walking period. The proposed footstep planner consists of three stages. First, a binary search is used to determine the walking period. Second, the front stride, side stride, and walking direction are determined using the modified rapidly exploring random tree algorithm. Finally, particle-swarm optimization (PSO) is conducted to ensure feasibility without significantly departing from the results determined by the two stages. The parameters determined by the previous two stages are optimized together through the PSO. Fast footstep planning is essential to cope with dynamic obstacle environments; however, optimization techniques may require significant computation time. The two stages play an important role in limiting the search space in the PSO. This framework enables fast footstep planning without losing the benefits of a continuous optimization approach.

The sixth paper is "Comprehensive Architecture for Intelligent Adaptive Interface in the field of Single-Human Multiple-Robot Interaction," by Mahdi Ilbeygi and Mohammad Reza Kangavari. The paper highlights progress in robotic science given that the design and implementation of a mechanism for human–robot interaction with a low workload is inevitable. One notable challenge in this field is the interaction between individual humans and a group of robots. Therefore, they propose a new comprehensive framework for single-human multiple-robot remote interaction that can form an efficient intelligent adaptive interaction (IAI). Their interaction system can thoroughly adapt itself to changes in interaction context and user states. Some advantages of their devised IAI framework are lower workload, a higher level of situational awareness, and efficient interaction. In this paper, they introduce a new IAI architecture as a comprehensive mechanism. To practically examine the architecture, they implemented the proposed IAI to control a group of unmanned aerial vehicles (UAVs) under different scenarios. The results show that the devised IAI framework can effectively reduce human workload and the level of situational awareness and concurrently fosters the mission completion percentage of the UAVs.

In the seventh paper, "Vector Space based Augmented Structural Kinematic Feature Descriptor for Human Activity Recognition in Videos," a vector space-based augmented structural kinematic feature descriptor is proposed for human activity recognition. An action descriptor is built upon integrating the structural and kinematic properties of the actor using vector space-based augmented matrix representation. The separate use of the local or global information may not provide sufficient action characteristics. The proposed action descriptor combines both the local (pose) and global (position and velocity) features using an augmented affix schema and thereby increases the robustness of the descriptor. A multiclass support vector machine is used to learn each action descriptor for the corresponding activity classification and understanding. The performance of the proposed descriptor is experimentally analyzed using the Weizmann and KTH dataset. The average recognition rates for the Weizmann and KTH dataset are 100% and 99.89%, respectively. The computational time for the proposed descriptor learning is 0.003 s, which is an improvement of about 1.4% over the existing methods.

The eighth paper, "Work Chains-based Inverse Kinematics of Robot to Imitate Human Motion with Kinect" focuses on human motion imitation using robots owing to the development of artificial intelligence. However, it is not easy to imitate human motion completely because of the physical differences between human bodies and robots. In this paper, the authors propose a work chain-based reverse kinematics for the robot to imitate the human motion of an upper limb in real time. Two work chains are built on each arm to guarantee both the similarities of the end effector trajectory and the angle configuration. Moreover, a two-step filter is used for the control of joint angles together with the self-collision avoidance scheme maintain the stability of robots during the imitation. Experimental results verify the efficiency of our solution on the humanoid robot Nao-H25 in terms of real time, accuracy, and stability.

The final paper, "Intelligent Robotic Walker with Actively Controlled Human Interaction" by Ihn-Sik Weon and Soon-Geul Lee developed a robotic walker that actively controls its speed and direction of movement according to the user's gait intention. Sensor fusion between a low-cost light detection and ranging (LiDAR) sensor and inertial measurement units (IMUs) helps to determine the user's gait intention. The LiDAR determines the walking direction by detecting both knees, and the IMUs attached on each foot obtain the angular rate of the gait. The user's gait intention is given as the directional angle and the speed of movement. The two motors in the robotic walker are controlled using these two variables, which represent the user's gait intention. The estimated direction angle is verified by performing a comparison with a Kinect sensor that detects the centroid trajectory of both the user's feet. They validated the robotic walker experimentally by controlling it using the estimated gait intention.

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