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EDITORIAL

Intelligence in robotics for computer, engineering, and applied sciences

Intelligence in robotics is an extension of automation that increases the robot's intelligence with continuous learning and adaptation to helping humans more effectively. Intelligence in robotics in a real-world setting consists of intelligence in robot action or body motion, with manipulation, mobility, structural, and human–robot interaction intelligence. For instance, the robot could employ the structural intelligence to modify its configuration, use the manipulation intelligence to learn new skills during operation, develop the mobility intelligence to move independently, and utilize the human–robot interaction intelligence to interact with humans in an intuitive manner based on their intentions. Intelligence in robotics is based on computation, with learning as its core—this allows robots to mimic human behavior and to adapt to various situations. For instance, a robot vision mimics human sense of the surroundings, a robot decision-making mimics human management of tasks in a variety of situations, and a robot skill learning mimics human learning and creation.

To this end, this special issue brings together cutting-edge research findings, technological innovations, and innovative conceptual frameworks related to developing fields of robotics intelligence, including manipulation learning, bio-inspired robotics, autonomous robotics, human–robot interaction, and related fields and applications.

This special issue contains 18 papers, describing the latest advances on intelligence in robotics, disseminating the topic of intelligence in robotics to various aspects. The following is a brief summary of each paper's primary contributions.

Robot-assisted rehabilitation is an efficient utilization of the assist-as-needed (AAN) controller. In the "Bayesian optimization for assist-as-needed controller in the robot-assisted upper limb training based on energy information" by Zhang et al. [1], an adaptive AAN has been proposed to motivate subjects' participation by assigning them a personalized assistance level according to their performance and engagement estimation throughout trials. Energy-related information was utilized to estimate the engagement, and the Bayesian optimization was subsequently applied to the AAN controller to enhance the participant's performance based on a prior trial-wise performance. This minimizes the average trajectory error and reduces the energy consumption.

Estimating contact parameters (slippage and sinkage) is an important challenge for a robot moving on an uneven terrain. An in-depth description of contact parameters for mobile robots has been presented in "A contact parameter estimation method for multi-modal robot locomotion on deformable granular terrains" by Lyu et al. [2]. Compared with other direct contact measurement techniques intended for different motion modes, this convolutional neural network (CNN) and discrete wavelet transformation-based approach can not only precisely predict the contact parameters of multi-modal robot moving on an uneven terrain but also obtain a comparable or more effective performance.

Physically compliant actuators offer a multitude of advantages for robots, including heightened environmental suitability, enhanced human–robot interactions, and greater energy efficiency. These advantages stem from the inherent compliance of the actuators. In "Design and control of a compliant robotic actuator with parallel spring-damping transmission" by Yuan et al. [3], the effect of incorporating variable damping into a compliant actuator was examined. The proposed structural design, which features a variable damping element in parallel with a common series elastic actuator (SEA), achieves an improved stability and dynamic performance in the force and position control.

As the industry advances, individuals are increasingly confronted with intricate tasks that cannot be accomplished by conventional and inflexible robots. In "Design and development of an SLPM-based deployable robot" by Zhang et al. [4], a deployable robot that employs a spherical linkage parallel mechanism to meet the requirements for degrees of freedom has been proposed. A theoretical model for the robot was developed, and the connection between the motion space and drive space was established, thereby expanding the potential applications of deployable robots.

The current working conditions for sand casting workers are challenging owing to harsh environments and inadequate safety measures. Previous pouring robots lacked stability and the load-bearing capacity, which hinders their ability to conduct intelligent pouring with the requirements of the pouring process. To address these limitations, in "Design, simulation, control of a hybrid pouring robot: enhancing automation level in the foundry industry" by Wang et al. [5], a hybrid pouring robot has been developed, together with a hardware-in-the-loop control technology to solve the real-time control issues associated with the simulated pouring and the pouring process. This innovation is expected to greatly raise the casting industry's degree of automation.

The efficient transportation of luggage trolleys via robotic autonomous systems is a critical aspect of modern travel. In "A divide-and-conquer control strategy with decentralized control barrier function for luggage trolley transportation by collaborative robots" by Gao et al. [6], a comprehensive framework was proposed to handle the challenging nonholonomic constraints resulting from the formation of two collaborative robots and a line of luggage trolleys. This framework consists of a global planning approach and a real-time divide-and-conquer control strategy, with the Hybrid A∗ algorithm generating a feasible path. A model predictive controller was then developed to track the path stably.

Human activity recognition is an increasingly significant challenge in diverse fields, such as healthcare and sports. Unfortunately, there are a limited number of public available datasets for classifying and recognizing human activities. In "Hybrid deep learning model-based human action recognition in indoor environment" by Sain et al. [7], a dataset consisting of seven activities—eat, vomit, walk, exercise, shake-hand, sit-ups, and headache—was introduced and compared to other existing datasets, including Nanyang Institute of Technology-red green blue depth (NTU-RGBD) and University of California Irvine-human activity recognition (UCI-HAR). The dataset proposed in this study is available to the public.

A double-user training system is crucial for enhancing the motor skill learning, especially for complicated tasks. However, striking the right balance between the trainee's ability and level of engagement can be challenging. In "Learner engagement regulation of dual-user training based on deep reinforcement learning" by Yang et al. [8], an intelligent agent was proposed that coordinates the trainee's control privilege during operation to ensure safety. This method eliminates the need for manually tuning privilege setting by expert and does not depend on pre-modeling the learner's skill level.

Real-world collaboration task between humans and robots frequently involves instruction ambiguity and intricate scenarios. These challenges come from the need for understanding linguistic queries, discern key concepts in the visual and language information, and generate corresponding operation commands for the robot. In "Multi-modal interaction with transformers: bridging robots and human with natural language" by Wang et al. [9], a multi-modal transformer-based framework was developed to assist robots in localizing spatial interactions of objects using text queries and visual sensing. This framework enables the object operation based on human commands.

Coverage path planning is a specialized area within path planning, where a robot must visit unoccupied regions of a given domain at least once and simultaneously avoid obstacles. In some cases, the path might be refined to meet specific requirements, for example, the overall distance traveled, the number of turns taken, and the total surface area covered. In "Multi-objective optimization approach for coverage path planning of mobile robot" by Sharma and Voruganti [10], the distance traveled and number of turns made by the robot have been utilized to estimate energy consumption. The proposed strategy surpassed current methods by reducing energy cost by up to 60%.

Pattern recognition of leg movements is a vital element in gait rehabilitation. In "Online pattern recognition of lower limb movements based on sEMG signals and its application in real-time rehabilitation training" by Ye et al. [11], a personalized online pattern recognition method for lower limb motion using surface electromyography has been developed. The experiments were conducted during rehabilitation training, and took only 6 min to create a personalized classifier for four distinct types of lower limb movements, indicating the practicality of this new system.

To tackle the difficulties associated with the wide-angle mobile robot vision in various field applications, in "Panoramic visual system for spherical mobile robots" by Arif et al. [12], a spherical robot that offers a 360-degree field of view for instantaneous object detection was designed. This system employs a fade-in and fade-out algorithm to ensure seamless image fusion, which enhances not only the quality of the seam but also the performance of object detection. Furthermore, the dynamic image stitching process is accelerated through a cache-based sequential picture fusion technique.

The performance of a rice planting robot path tracking is determined by its ability to quickly achieve a stable linear path, which in turn affects the quality and efficiency of the operation. In "Path tracking control method for automatic navigation rice transplanters based on VUFC and improved BAS algorithm" by Zhu et al. [13], a control strategy based on the variable universe fuzzy control and the enhanced beetle antenna search has been developed. This increases tracking accuracy and stability and shortens the time it takes to reach the path tracking stable state. This method surpasses the pure pursuit control method.

Accurately estimating the gait phase is essential for controlling the high-level walking assistance. Although there have been significant advances in gait phase estimation for various modes of locomotion, research on transition gait phase estimation is limited, causing exoskeletons to jitter from walk to stand. In "Phase oscillator optimization eliminates jittering during transition gaits in multi-modal locomotion assisted by a portable hip exoskeleton" by Yang et al. [14], an optimized phase oscillator that accurately predicts the gait phase during the gait switching in multi-modal locomotion has been proposed and is helpful in jitter elimination.

A simultaneous localization and mapping (SLAM) system that relies on the rigid scene assumption is ineffective in providing the accurate position and mapping in intricate environments with numerous moving objects. In "Semantic geometric fusion multi-object tracking and lidar odometry in dynamic environment" by Ma et al. [15], a multi-object lidar odometry system that integrates semantic object recognition technology has been developed. This system ensures a reliable robot and semantic object localization, with the construction of a long-term static map in complicated dynamic scenes. Moreover, it extracts the environmental features that incorporate the semantic and geometric consistency constraints.

The growing popularity of robotic kitchens has underscored the requirement for sophisticated food-handling systems that incorporate food analysis, such as ingredient classification, pose recognition, and assembly strategy. However, picking the correct item from a stack of food products with similar shapes remains challenging in automated meal assembly systems. In "Vision-based food handling system for high-resemblance random food items" by Zeng et al. [16], a novel method to detect food pose and a closed-loop packing strategy were introduced. This method, driven by a CNN with a pose retrieval model, can construct the 6D pose from the RGB images alone.

Although advances have been made in minimizing the influence of dynamic objects by integrating geometric and semantic details, current methods fail to achieve both superior performance and real-time responsiveness. To address this issue, in "A Visual SLAM-based Lightweight Multi-modal Semantic Framework for an Intelligent Substation Robot" by Li et al. [17], a framework that allows intelligent robots to navigate the ever-changing surroundings in substations with a visual SLAM was designed. By incorporating object detection and instance segmentation techniques, this framework notably improved visual SLAM performance by lessening the impact of dynamic objects.

Structured light cameras are well known for delivering detailed information about construction defects. However, integrating the camera and the LiDAR data is highly reliant on the precise sensor positions, which can only be determined through extrinsic calibration. In "Automatic Extrinsic Calibration for Structured Light Camera and Repetitive LiDARs" by Ge et al. [18], a unique calibration algorithm that utilizes a customized board for structured light cameras and repetitive LiDARs has been developed, allowing for the automation of construction robots and enhancing accuracy and robustness.

With all these new advances, we hope the readers can see the current development in the intelligence in robotics and gain some inputs and inspiration from this special issue.

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