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2023

Review Article

1. A Review of Intelligent Methods of Health Assessment Technology

Authors: Diyi Liu, Linyuan Peng, Zhiyao Zhao

How to cite: Jiang C, Xu Q, Song Y, Yuan X, Pang B, Li Y. Discrete sequence rearrangement based self-supervised chinese named entity recognition for robot instruction parsing. *Intell Robot* 2023;3(3):337-54. http://dx.doi.org/10.20517/ir.2023.21

Abstract: The core technology of prognostics and health management, a key technology that detects system anomalies, is health assessment, which analyzes and diagnoses the current system working status and quantitatively assesses the health of the system. This paper reviews the development of health assessment technology in recent years from three aspects: health definition, health assessment indicators, and health assessment approaches. In terms of health definition, this paper summarizes three common definition methods. Health assessment indicators are reviewed from four levels: process variables, data features, residuals, and fusion indicators. Finally, health assessment approaches are divided into model-based, data-driven, and fusion approaches. Concerning the data-driven approach, rapidly developing health assessment research based on an intelligent approach is discussed. The paper also compares various approaches and identifies the current challenges and development prospects of this technology.

2. Intelligent Flood Forecasting and Warning: A Survey

Authors: Yue Zhang, Daiwei Pan, Jesse Van Griensven, Simon X. Yang, Bahram Gharabaghi

How to Cite: Zhang Y, Pan D, Van Griensven J, Yang SX, Gharabaghi B. Intelligent flood forecasting and warning: a survey. *Intell Robot* 2023;3(2):190-212. http://dx.doi.org/10.20517/ir.2023.12

Abstract: Accurately predicting the magnitude and timing of floods is an extremely challenging problem for watershed management, as it aims to provide early warning and save lives. Artificial intelligence for forecasting has become an emerging research field over the past two decades, as computer technology and related areas have been developed in depth. In this paper, three typical machine learning algorithms for flood forecasting are reviewed: supervised learning, unsupervised learning, and semi-supervised learning. Special attention is given to deep learning approaches due to their better performance in various prediction tasks. Deep learning networks can represent flood behavior as powerful and beneficial tools. In addition, a detailed comparison and analysis of the multidimensional performance of different prediction

models for flood prediction are presented. Deep learning has extensively promoted the development of real-time accurate flood forecasting techniques for early warning systems. Furthermore, the paper discusses the current challenges and future prospects for intelligent flood forecasting.

3. An Overview of Intelligent Image Segmentation Using Active Contour Models

Authors: Yiyang Chen, Pengqiang Ge, Guina Wang, Guirong Weng, Hongtian Chen

How to cite: Chen Y, Ge P, Wang G, Weng G, Chen H. An overview of intelligent image segmentation using active contour models. *Intell Robot* 2023;3(1):23-55. http://dx.doi.org/10.20517/ir.2023.02

Abstract: The active contour model (ACM) approach in image segmentation is regarded as a research hotspot in the area of computer vision, which is widely applied in different kinds of applications in practice, such as medical image processing. The essence of ACM is to make use ofuse an enclosed and smooth curve to signify the target boundary, which is usually accomplished by minimizing the associated energy function by means ofthrough the standard descent method. This paper presents an overview of ACMs for handling image segmentation problems in various fields. It begins with an introduction briefly reviewing different ACMs with their pros and cons. Then, some basic knowledge in of the theory of ACMs is explained, and several popular ACMs in terms of three categories, including region-based ACMs, edge-based ACMs, and hybrid ACMs, are detailedly reviewed with their advantages and disadvantages. After that, twelve ACMs are chosen from the literature to conduct three sets of segmentation experiments to segment different kinds of images, and compare the segmentation efficiency and accuracy with different methods. Next, two deep learning-based algorithms are implemented to segment different types of images to compare segmentation results with several ACMs. Experimental results confirm some useful conclusions about their sharing strengths and weaknesses. Lastly, this paper points out some promising research directions that need to be further studied in the future.

4. Formation Control of Multiple Autonomous Underwater Vehicles: A Review

Authors: Tao Yan, Zhe Xu, Simon X. Yang, S. Andrew Gadsden

How to cite: Yan T, Xu Z, Yang SX, Gadsden SA. Formation control of multiple autonomous underwater vehicles: a review. *Intell Robot* 2023;3(1):1-22. http://dx.doi.org/10.20517/ir.2023.01

Abstract: This paper presents a comprehensive overview of recent developments in formation control of multiple autonomous underwater vehicles (AUVs). Several commonly

used structures and approaches for formation coordination are listed, and the advantages and deficiencies of each method are discussed. The difficulties confronted in synthesis of a practical AUVs formation system are clarified and analyzed in terms of the characteristic of AUVs, adverse underwater environments, and communication constraints. The state-of-the-art solutions available for addressing these challenges are reviewed comprehensively. Based on that, a brief discussion is made, and a list of promising future work is pointed out, which aims to be helpful for the further promotion of AUVs formation applications.

5. Deep learning-based scene understanding for autonomous robots: a survey

Authors: Jianjun Ni, Yan Chen, Guangyi Tang, Jiamei Shi, Weidong Cao, Pengfei Shi

How to Cite: Ni J, Chen Y, Tang G, Shi J, Cao W, Shi P. Deep learning-based scene understanding for autonomous robots: a survey. *Intell Robot* 2023;3(3):374-401. http://dx.doi.org/10.20517/ir.2023.22

Abstract: Autonomous robots are a hot research subject within the fields of science and technology, which has a big impact on social-economic development. The ability of the autonomous robot to perceive and understand its working environment is the basis for solving more complicated issues. In recent years, an increasing number of artificial intelligence-based methods have been proposed in the field of scene understanding for autonomous robots, and deep learning is one of the current key areas in this field. Outstanding gains have been attained in the field of scene understanding for autonomous robots based on deep learning. Thus, this paper presents a review of recent research on the deep learning-based scene understanding for autonomous robots. This survey provides a detailed overview of the evolution of robotic scene understanding and summarizes the applications of deep learning methods in scene understanding for autonomous robots. In addition, the key issues in autonomous robot scene understanding are analyzed, such as pose estimation, saliency prediction, semantic segmentation, and object detection. Then, some representative deep learning-based solutions for these issues are summarized. Finally, future challenges in the field of the scene understanding for autonomous robots are discussed.

Research Article

1. Discrete Sequence Rearrangement based Self-Supervised Chinese Named Entity Recognition for Robot Instruction Parsing

Authors: Cong Jiang, Qingyang Xu, Yong Song, Xianfeng Yuan, Bao Pang, Yibin Li

How to Cite: Jiang C, Xu Q, Song Y, Yuan X, Pang B, Li Y. Discrete sequence rearrangement based self-supervised chinese named entity recognition for robot

instruction parsing. *Intell Robot* 2023;3(3):337-54. http://dx.doi.org/10.20517/ir.2023.21

Abstract: Named entity recognition (NER) plays an important role in information extraction tasks, but most models rely on large-scale labeled data. Getting the model to move away from large-scale labeled datasets is challenging. In this paper, a SCNER (Self-Supervised NER) model is proposed. The BiLSTM (Bidirectional LSTM) is adopted as the named entity extractor, and an Instruction Generation Subsystem (IGS) is proposed to generate "Retelling Instructions", which analyzes the similarities between the input instructions and "Retelling Instructions" as the losses for model training. A series of rules based on traditional learning rules have been proposed for discrete forward computation and error backpropagation. It mimics language learning in human infants and constructs a SCNER model. This model is used for robot instruction understanding and can be trained on unlabeled datasets to extract named entities from instructions. Experimental results show that the proposed model is competitive with the supervised BiLSTM-CRF and BERT-NER models. In addition, the model is applied to a real robot, which verifies the practicality of SCNER.

2. Stability Compensation of An Admittance-controlled Cartesian Robot Considering Physical Interaction with A Human Operator

Authors: Narawich Songthumjitti, Takeshi Inaba

How to Cite: Songthumjitti N, Inaba T. Stability compensation of an admittance-controlled cartesian robot considering physical interaction with a human operator. *Intell Robot* 2023;3(3):306-36. http://dx.doi.org/10.20517/ir.2023.20

Abstract: In human-machine systems, admittance control is widely used for controlling robots. However, the problem with this method is that the stability can be impacted by the stiffness of the machine and the human operator. In order to minimize the oscillation issue that is caused by insufficient structure stiffness, this study used compensation methods, specifically feed-forward and acceleration feedback. Simulation results show that both compensation methods can expand the stability region of the system. Nevertheless, feedback compensation is more appropriate than feed-forward when taking into account uncertainties in the structure parameters of the system. Even when the system is not perfectly implemented, feedback compensation can keep the system stable, whereas feed-forward compensation causes a significantly reduced stability region. From the experiment, it is also confirmed that the feedback system has an advantage over the feed-forward system, and this simple feedback using an accelerometer can compensate for the insufficient stiffness of the robot structure and greatly enhance the stability of the human-machine system.

3. Robust Distributed Model Predictive Control of Connected Vehicle Platoon against DoS Attacks

Authors: Hao Zeng, Zehua Ye, Dan Zhang, Qun Lu

How to Cite: Zeng H, Ye Z, Zhang D, Lu Q. Robust distributed model predictive control of connected vehicle platoon against DoS attacks. *Intell Robot* 2023;3(3):288-305. http://dx.doi.org/10.20517/ir.2023.19

Abstract: This paper investigates the robust distributed model predictive control (DMPC) of connected vehicle platoon (CVP) systems subject to denial-of-service (DoS) attacks. The main objective is to design a DMPC algorithm that enables the CVP system to achieve exponential tracking performance. First, a switched system model is proposed for the networked CVP system in the presence of DoS attacks. Then the sufficient conditions for the exponential stability of tracking the performance of the CVP control system under DoS attacks are obtained by constructing a specific Lyapunov function and using the topological matrix decoupling technique. In our paper, the DoS attack phenomenon is handled by introducing the frequency and duration parameters, and a quantitative relationship between the exponential decay rate of the CVP system and the DoS attacks parameters is established based on the conditions proposed in the system design, and the critical value of the DoS attack duration ratio is also derived. Finally, the effectiveness of the proposed algorithm is verified through a simulation of a CVP system consisting of one leading vehicle and three following vehicles.

4. GPI Observer-based Active Disturbance Rejection Control for A Morphing Quadrotor

Authors: Chunhui He, Haosheng Sun, Qingxiang Wu, Yuanhao Su, Ning Sun

How to Cite: He C, Sun H, Wu Q, Su Y, Sun N. GPI observer-based active disturbance rejection control for a morphing quadrotor. *Intell Robot* 2023;3(3):274-87. http://dx.doi.org/10.20517/ir.2023.18

Abstract: Quadrotors are widely used in transportation, aerial photography, agricultural protection, and other important fields. Nevertheless, quadrotors with a fixed structure will face great challenges when crossing through or entering narrow spaces for operations. To improve quadrotor crossing ability in different environments, a morphing quadrotor is designed in this paper, and four servo motors are added to independently change four arm rotation angles. Meanwhile, the dynamic model and dynamic control allocation matrix are established. In addition, considering that the internal dynamic variation caused by morphologic changes and external disturbances may compromise system stability, a control method based on the generalized proportional integral (GPI) observer is proposed to increase the system robustness, and the corresponding stability analysis is provided. Finally, simulation results demonstrate the effectiveness of the proposed GPI observer-based active disturbance rejection control method.

5. State-Sensitive Event-triggered Path Following Control of Autonomous Ground Vehicles

Authors: Hong-Tao Sun, Jinming Huang, Zhi Chen, Zhiwen Wang

How to Cite: Sun HT, Huang J, Chen Z, Wang Z. State-sensitive event-triggered path following control of autonomous ground vehicles. *Intell Robot* 2023;3(3):257-73. http://dx.doi.org/10.20517/ir.2023.17

Abstract: This paper investigates an improved event-triggered control based on the perception of state measurement for path following control of autonomous ground vehicles. Firstly, in order to regulate the event-triggered thresholds dynamically, a barrier-like function is first used to develop such a novel state-sensitive event-triggered communication (SS-ETC) scheme. Different from the existing variable-threshold ETC schemes, the proposed SS-ETC incorporates the state measurements directly in the event threshold adjustment, eliminating the need for additional terms or dynamics introduced in previous works. Secondly, the networked path following control modeling issues, which include both physical dynamics and the SS-ETC scheme, are characterized by the input delay approach. The controller design method is well derived, ensuring the preservation of input-to-state stability of the path following control system. The main advantage of this paper lies in the proposed SS-ETC, which shows a better trade-off between control and communication. Finally, several simulation experiments are conducted to verify the effectiveness of the proposed event-triggered control scheme.

6. Robust Coverage Control of Multiple USVs with Time-Varying Disturbances

Authors: Qihai Sun, Zhi-Wei Liu, Ming Chi, Ming-Feng Ge, Dingxin He

How to Cite: Sun Q, Liu ZW, Chi M, Ge MF, He D. Robust coverage control of multiple USVs with time-varying disturbances. *Intell Robot* 2023;3(3):242-56. http://dx.doi.org/10.20517/ir.2023.15

Abstract: This paper investigates the problem of optimal coverage control for multiple unmanned surface vehicles (USVs) in the presence of time-varying disturbances. To solve this problem, the disturbance vector observer is designed to approximate the unknown time-varying disturbances. It is demonstrated that the estimated disturbance vector converges to the actual disturbance vector within a finite time. To achieve the optimal coverage effect of the task region, the control idea of layer-by-layer design is borrowed, and the desired velocities of the USV are designed. By following the desired velocities, the USV network can achieve the optimal coverage effect of the task region. Based on the estimated disturbances, a robust coverage controller is designed to achieve the tracking of desired velocities by the USV within a finite time, ultimately achieving optimal coverage effect of the task region by the USV network. Finally, corresponding simulation results are

provided to validate the effectiveness of the proposed approach.

7. A Bio-Inspired Algorithm in Image-Based Path Planning and Localization Using Visual Features and Maps

Authors: Daniel Short, Tingjun Lei, Chaomin Luo, Daniel W. Carruth, Zhuming Bi

How to Cite: Short D, Lei T, Luo C, Carruth DW, Bi Z. A bio-inspired algorithm in image-based path planning and localization using visual features and maps. *Intell Robot* 2023;3(2):222-41. http://dx.doi.org/10.20517/ir.2023.14

Abstract: With the growing applications of autonomous robots and vehicles in unknown environments, studies on image-based localization and navigation have attracted a great deal of attention. This study is significantly motivated by the observation that relatively little research has been published on the integration of cutting-edge path planning algorithms for robust, reliable, and effective image-based navigation. To address this gap, a biologically inspired Bat Algorithm (BA) is introduced and adopted for image-based path planning in this paper. The proposed algorithm utilizes visual features as the reference in generating a path for an autonomous vehicle, and these features are extracted from the obtained images by convolutional neural networks (CNNs). The paper proceeds as follows: first, the requirements for image-based localization and navigation are described. Second, the principles of the BA are explained in order to expound on the justifications for its successful incorporation in image-based navigation. Third, in the proposed image-based navigation system, the BA is developed and implemented as a path planning tool for global path planning. Finally, the performance of the BA is analyzed and verified through simulation and comparison studies to demonstrate its effectiveness.

8. The Cooperatability of the First-Order Multi-Agent Systems Consisting of A Leader and A Follower with Multiplicative Noises under Markov Switching Topologies

Authors: Dianqiang Li, Tao Li

How to Cite: Li D, Li T. The cooperatability of the first-order multi-agent systems consisting of a leader and a follower with multiplicative noises under Markov switching topologies. *Intell Robot* 2023;3(2):213-21. http://dx.doi.org/10.20517/ir.2023.13

Abstract: We investigate the cooperatability of the first-order leader-following multi-agent systems consisting of a leader and a follower with multiplicative noises under Markov switching topologies. Each agent exhibits first-order linear dynamics, and there are multiplicative noises along with information exchange among the agents. What is more, the communication topologies are Markov switching topologies. By utilizing the stability theory of the stochastic differential equations with Markovian switching and the Markov chain theory, we establish the necessary and sufficient conditions for the cooperatability of

the leader-following multi-agent systems. The conditions are outlined below: (ⅰ) The product of the system parameter and the square of multiplicative noise intensities should be less than 1/2; (ⅱ) The transition rate from the unconnected graph to the connected graph should be twice the system parameter; (ⅲ) The transition rate from the connected graph to the unconnected graph should be less than a constant that is related to the system parameter, the intensities of multiplicative noises, and the transition rate from the unconnected graph to the connected graph. Finally, the effectiveness of our control strategy is demonstrated by the population growth systems.

9. Adaptive Backstepping Control of High-Order Fully Actuated Nonlinear Systems with Event-Triggered Strategy

Authors: Chengyuan Yan, Jianwei Xia , Xinru Liu, Huarong Yue, Chong Li

How to Cite: Yan C, Xia J, Liu X, Yue H, Li C. Adaptive backstepping control of high-order fully actuated nonlinear systems with event-triggered strategy. *Intell Robot* 2023;3(2):176-89. http://dx.doi.org/10.20517/ir.2023.11

Abstract: This paper investigates the problem of adaptive event-triggered fuzzy control for nonlinear high-order fully actuated systems. In this paper, a completely unknown nonlinear function is considered, and its prior knowledge is unknown. To solve this problem, the fuzzy logic system technology is applied to approximate the unknown nonlinear function. In order to save communication resources, a novel high-order event-triggered controller is proposed under backstepping control. With the help of Lyapunov stability theory, it is proved that all signals of the closed-loop system are bounded. Finally, the theoretical results are applied to the robot system to verify their validity.

10. Reinforcement Learning with Parameterized Action Space and Sparse Reward for UAV Navigation

Authors: Shiying Feng, Xiaofeng Li, Lu Ren, Shuiqing Xu

How to Cite: Feng S, Li X, Ren L, Xu S. Reinforcement learning with parameterized action space and sparse reward for UAV navigation. *Intell Robot* 2023;3(2):161-75. http://dx.doi.org/10.20517/ir.2023.10

Abstract: Autonomous navigation of unmanned aerial vehicles (UAVs) is widely used in building rescue systems. As the complexity of the task increases, traditional methods based on environment models are hard to apply. In this paper, a reinforcement learning (RL) algorithm is proposed to solve the UAV navigation problem. The UAV navigation task is modeled as a Markov Decision Process (MDP) with parameterized actions. In addition, the sparse reward problem is also taken into account. To address these issues, we develop the HER-MPDQN by combining Multi-Pass Deep Q-Network (MP-DQN) and

Hindsight Experience Replay (HER). Two UAV navigation simulation environments with progressive difficulty are constructed to evaluate our method. The results show that HER-MPDQN outperforms other baselines in relatively simple tasks. Especially for complex tasks involving relay operations, only our method can achieve satisfactory performance.

11. Application of Distributed and Decentralized Technologies in the Management of Intelligent Transport Systems

Authors: Luba Eremina, Anton Mamoiko, Guo Aohua

How to Cite: Eremina L, Mamoiko A, Aohua G. Application of distributed and decentralized technologies in the management of intelligent transport systems. *Intell Robot* 2023;3(2):148-60. http://dx.doi.org/10.20517/ir.2023.09

Abstract: Shifting focus from the field of distributed and decentralized technologies in the management of intelligent transportation systems (ITS), we now delve into the specific application of blockchain in transportation management. Blockchain is a fundamental component of distributed and decentralized technologies. The research paper discusses the utilization of blockchain technology in managing transportation systems through multi-agent systems. Specifically, the use of blockchain technology is examined in the context of the quick road system (QRS) in ITS to provide a service for obtaining a special fare status. This service aims to establish a decentralized network that facilitates real-time road lane sharing. The study indicates that depending on traffic situations, drivers can share their lane space with other vehicles traveling on the same route by exchanging incentives via blockchain with other private car owners, thereby allowing for faster travel for individuals in a hurry or those requiring priority access to fast lanes. The paper also addresses the increasing number of connected devices in ITS due to the development of the internet of things (IoT) technology. It highlights the importance of efficiently utilizing large datasets and identifies the internet of vehicles (IoV) as a crucial area of integration for existing IoT technologies to address smart traffic within multi-agent systems.

12. Semi-Supervised Joint Adaptation Transfer Network with Conditional Adversarial Learning for Rotary Machine Fault Diagnosis

Authors: Chun Liu, Shaojie Li, Hongtian Chen, Xianchao Xiu, Chen Peng

How to Cite: Liu C, Li S, Chen H, Xiu X, Peng C. Semi-supervised joint adaptation transfer network with conditional adversarial learning for rotary machine fault diagnosis. *Intell Robot* 2023;3(2):131-43. http://dx.doi.org/10.20517/ir.2023.07

Abstract: At present, artificial intelligence is booming and has made major breakthroughs in fault diagnosis scenarios. However, the high diagnostic accuracy of most mainstream fault diagnosis methods must rely on sufficient data to train the diagnostic models. In

addition, there is another assumption that needs to be satisfied: the consistency of training and test data distribution. When these prerequisites are not available, the effectiveness of the diagnosis model declines dramatically. To address this problem, we propose a semi-supervised joint adaptation transfer network with conditional adversarial learning for rotary machine fault diagnosis. To fully utilize the fault features implied in unlabeled data, pseudo-labels are generated through threshold filtering to obtain an initial pre-trained model. Then, a joint domain adaptation transfer network module based on conditional adversarial learning and distance metric is introduced to ensure the consistency of the distribution in two different domains. Lastly, in three groups of experiments with different settings: a single fault with variable load, a single fault with variable speed, and a mixed fault with variable speed and load, it was confirmed that our method can obtain competitive diagnostic performance.

13. Operational Control with Set-Points Tuning - Application to Mobile Robots

Authors: Xiaomo Yan, Hong Wang

How to Cite: Yan X, Wang H. Operational control with set-points tuning - application to mobile robots. *Intell Robot* 2023;3(2):113-30. http://dx.doi.org/10.20517/ir.2023.06

Abstract: This paper proposes a novel method for the optimal tuning of set points for multiple-layered control system structure widely seen in robotics and other complex industrial processes composed of a number of subsystems. The terminal sliding mode control (SMC) is used as the low-level control strategy to ensure the stability of subsystems. When uncertainties exist, it can be shown that the deteriorated system performance will be improved by the outer loop with set points tuning. For this purpose, the learning of the new set point is designed to compensate for the effects caused by uncertainties during the system operation. At the same time, the system is proven to stay with the original set point when the compensation is introduced. A practical application to a holonomic mobile robot system is given to illustrate the presented method. Desired results have been obtained

14. Human Gait Tracking for Rehabilitation Exoskeleton: Adaptive Fractional Order Sliding Mode Control Approach

Authors: Yuan Zhou, Zhe Sun, Bo Chen , Guangpu Huang, Xiang Wu, Tian Wang

How to cite: Zhou Y, Sun Z, Chen B, Huang G, Wu X, Wang T. Human gait tracking for rehabilitation exoskeleton: adaptive fractional order sliding mode control approach. *Intell Robot* 2023;3(1):95-112. http://dx.doi.org/10.20517/ir.2023.05

Abstract: To improve the rehabilitation training effect of hemiplegic patients, in this paper, a discrete adaptive fractional order fast terminal sliding mode control approach is

proposed for the lower limb exoskeleton system to implement high-precision human gait tracking tasks. Firstly, a discrete dynamic model is established based on the Lagrange system discretization criterion for the lower limb exoskeleton robot. Then, in order to design a discrete adaptive fractional order fast terminal sliding mode controller, the Grünwald–Letnikov fractional order operator is introduced to combine with fast terminal attractor to construct a fractional order fast terminal sliding surface. An adaptive parameter adjustment strategy is proposed for the reaching law of sliding mode control, which drives the sliding mode to the stable region dynamically. Moreover, the stability of the control system is proved in the sense of Lyapunov, and the guidelines for selecting the control parameters are given. Finally, the simulations are tested on the MATLAB-Opensim co-simulation platform. Compared with the conventional discrete sliding mode control and discrete fast terminal sliding mode control, the results verify the superiority of the proposed method in improving lower limb rehabilitation training.

15. UAV Maneuver Decision-making via Deep Reinforcement Learning for Short-range Air Combat

Authors: Zhiqiang Zheng, Haibin Duan

How to cite: Zheng Z, Duan H. UAV maneuver decision-making via deep reinforcement learning for short-range air combat. *Intell Robot* 2023;3(1):76-94. http://dx.doi.org/10.20517/ir.2023.04

Abstract: The unmanned aerial vehicle (UAV) has been applied in unmanned air combat because of its flexibility and practicality. The short-range air combat situation is rapidly changing, and the UAV has to make the autonomous maneuver decision as quickly as possible. In this paper, a type of short-range air combat maneuver decision method based on deep reinforcement learning is proposed. Firstly, the combat environment, including UAV motion model and the position and velocity relationships, is described. On this basic, the combat process is established. Secondly, some improved points based on proximal policy optimization (PPO) are proposed to enhance the maneuver decision-making ability. The gate recurrent unit (GRU) can help PPO make decisions with continuous timestep data. The actor network's input is the observation of UAV, however, the input of the critic network, named state, includes the blood values which cannot be observed directly. In addition, the action space with 15 basic actions and well-designed reward function are proposed to combine the air combat environment and PPO. In particular, the reward function is divided into dense reward, event reward and end-game reward to ensure the training feasibility. The training process is composed of three phases to shorten the training time. Finally, the designed maneuver decision method is verified through the ablation study and confrontment tests. The results show that the UAV with the proposed maneuver decision method can obtain an effective action policy to make a more flexible decision in air combat.

16. GMAW Welding Procedure Expert System Based on Machine Learning

Authors: Xuewu Wang, Qian Chen, Hao Sun, Xiuwei Wang, Huaicheng Yan

How to cite: Wang X, Chen Q, Sun H, Wang X, Yan H. GMAW welding procedure expert system based on machine learning. *Intell Robot* 2023;3(1):56-75. http://dx.doi.org/10.20517/ir.2023.03

Abstract: In order to simplify the robot preparation before welding and improve the automation of the whole welding process, an intelligent expert system for Gas Metal Arc Welding is designed in this paper. In the system, the user inputs the initial welding information and the output interface displays suitable welding procedure parameter schemes. The user can choose the schemes according to the actual requirements or directly generate the welding procedure specification required by the enterprise format for direct use. In addition, the system also combines the database technology and XGBoost algorithm in the field of machine learning, migrates the model trained on the data set to predict the welding raw data, accumulates more data for daily use to optimize the model, which makes the whole system more systematic and intelligent, and achieves the goal of more accurate use.

Editorial

1. ChatGPT in Connected and Autonomous Vehicles: Benefits and Challenges

Authors: Lei Lei, Hao Zhang, Simon X. Yang

How to Cite: Lei L, Zhang H, Yang SX. ChatGPT in connected and autonomous vehicles: benefits and challenges. *Intell Robot* 2023;3(2):144-7. http://dx.doi.org/10.20517/ir.2023.08

Abstract: The OpenAI chatbot ChatGPT has achieved unprecedented success since its launch in November 2022. The Artificial Intelligence (AI) technologies behind ChatGPT are expected to have far-reaching effects on various technological fields beyond natural language processing. This editorial discusses the potential benefits and challenges that ChatGPT may bring to the connected and autonomous vehicles (CAVs). CAVs have been heavily researched in both the automotive and communications industries in recent years, where the AI technologies have played an indispensable role. Exploring how and to what extent ChatGPT will affect this field is an interesting and timely research topic.

2022

Review Article

1. Intelligent Feature Extraction, Data Fusion and Detection of Concrete Bridge Cracks: Current Development and Challenges

Authors: Di Wang, Simon X. Yang

How to cite: Wang D, Yang SX. Intelligent feature extraction, data fusion and detection of concrete bridge cracks: current development and challenges. *Intell Robot* 2022;2(4):391-406. http://dx.doi.org/10.20517/ir.2022.25

Abstract: As a common appearance defect of concrete bridges, cracks are important indices for bridge structure health assessment. Although there has been much research on crack identification, research on the evolution mechanism of bridge cracks is still far from practical applications. In this paper, the state-of-the-art research on intelligent theories and methodologies for intelligent feature extraction, data fusion and crack detection based on data-driven approaches is comprehensively reviewed. The research is discussed from three aspects: the feature extraction level of the multimodal parameters of bridge cracks, the description level and the diagnosis level of the bridge crack damage states. We focus on previous research concerning the quantitative characterization problems of multimodal parameters of bridge cracks and their implementation in crack identification, while highlighting some of their major drawbacks. In addition, the current challenges and potential future research directions are discussed.

2. Deep Reinforcement Learning for Real-world Quadrupedal Locomotion: A Comprehensive Review

Authors: Hongyin Zhang, Li He, Donglin Wang

How to cite: Zhang H, He L, Wang D. Deep reinforcement learning for real-world quadrupedal locomotion: a comprehensive review. *Intell Robot* 2022;2(3):275-97. http://dx.doi.org/10.20517/ir.2022.20

Abstract: Building controllers for legged robots with agility and intelligence has been one of the typical challenges in the pursuit of artificial intelligence (AI). As an important part of the AI field, deep reinforcement learning (DRL) can realize sequential decision making without physical modeling through end-to-end learning and has achieved a series of major breakthroughs in quadrupedal locomotion research. In this review article, we systematically organize and summarize relevant important literature, covering DRL algorithms from problem setting to advanced learning methods. These algorithms alleviate the specific problems encountered in the practical application of robots to a certain extent. We first elaborate on the general development trend in this field from

several aspects, such as the DRL algorithms, simulation environments, and hardware platforms. Moreover, core components in the algorithm design, such as state and action spaces, reward functions, and solutions to reality gap problems, are highlighted and summarized. We further discuss open problems and propose promising future research directions to discover new areas of research.

3. A Review of Causality-based Fairness Machine Learning

Authors: Cong Su, Guoxian Yu, Jun Wang, Zhongmin Yan, Lizhen Cui

How to cite: Su C, Yu G, Wang J, Yan Z, Cui L. A review of causality-based fairness machine learning. *Intell Robot* 2022;2(3):244-74. http://dx.doi.org/10.20517/ir.2022.17

Abstract: With the wide application of machine learning driven automated decisions (e.g., education, loan approval, and hiring) in daily life, it is critical to address the problem of discriminatory behavior toward certain individuals or groups. Early studies focused on defining the correlation/association-based notions, such as statistical parity, equalized odds, etc. However, recent studies reflect that it is necessary to use causality to address the problem of fairness. This review provides an exhaustive overview of notions and methods for detecting and eliminating algorithmic discrimination from a causality perspective. The review begins by introducing the common causality-based definitions and measures for fairness. We then review causality-based fairness-enhancing methods from the perspective of pre-processing, in-processing and post-processing mechanisms, and conduct a comprehensive analysis of the advantages, disadvantages, and applicability of these mechanisms. In addition, this review also examines other domains where researchers have observed unfair outcomes and the ways they have tried to address them. There are still many challenges that hinder the practical application of causality-based fairness notions, specifically the difficulty of acquiring causal graphs and identifiability of causal effects. One of the main purposes of this review is to spark more researchers to tackle these challenges in the near future.

4. Designs, Motion Mechanism, Motion Coordination, and Communication of Bionic Robot Fishes: A Survey

Authors: Zhiwei Yu, Kai Li, Yu Ji, Simon X. Yang

How to cite: Yu Z, Li K, Ji Y, Yang SX. Designs, motion mechanism, motion coordination, and communication of bionic robot fishes: a survey. *Intell Robot* 2022;2(2):180-99. http://dx.doi.org/10.20517/ir.2022.10

Abstract: In the last few years, there have been many new developments and significant accomplishments in the research of bionic robot fishes. However, in terms of swimming performance, existing bionic robot fishes lag far behind fish, prompting researchers to constantly develop innovative designs of various bionic robot fishes. In this paper, the

latest designs of robot fishes are presented in detail, distinguished by the propulsion mode. New robot fishes mainly include soft robot fishes and rigid-soft coupled robot fishes. The latest progress in the study of the swimming mechanism is analyzed on the basis of summarizing the main swimming theories of fish. The current state-of-the-art research in the new field of motion coordination and communication of multiple robot fishes is summarized. The general research trend in robot fishes is to utilize more efficient and robust methods to best mimic real fish while exhibiting superior swimming performance. The current challenges and potential future research directions are discussed. Various methods are needed to narrow the gap in swimming performance between robot fishes and fish. This paper is a first step to bring together roboticists and marine biologists interested in learning state-of-the-art research on bionic robot fishes.

5. Motion Planning and Tracking Control of Unmanned Underwater Vehicles: Technologies, Challenges and Prospects

Authors: Danjie Zhu, Tao Yan, Simon X. Yang

How to cite: Zhu D, Yan T, Yang SX. Motion planning and tracking control of unmanned underwater vehicles: technologies, challenges and prospects. *Intell Robot* 2022;2(3):200-22. http://dx.doi.org/10.20517/ir.2022.13

Abstract: The motion planning and tracking control techniques of unmanned underwater vehicles (UUV) are fundamentally significant for efficient and robust UUV navigation, which is crucial for underwater rescue, facility maintenance, marine resource exploration, aquatic recreation, etc. Studies on UUV motion planning and tracking control have been growing rapidly worldwide, which are usually sorted into the following topics: task assignment of the multi-UUV system, UUV path planning, and UUV trajectory tracking. This paper provides a comprehensive review of conventional and intelligent technologies for motion planning and tracking control of UUVs. Analysis of the benefits and drawbacks of these various methodologies in literature is presented. In addition, the challenges and prospects of UUV motion planning and tracking control are provided as possible developments for future research.

6. Deep Learning for LiDAR-only and LiDAR-fusion 3D Perception: A Survey

Authors: Danni Wu, Zichen Liang, Guang Chen

How to cite: Wu D, Liang Z, Chen G. Deep learning for LiDAR-only and LiDAR-fusion 3D perception: a survey. *Intell Robot* 2022;2(2):105-29. http://dx.doi.org/10.20517/ir.2021.20

Abstract: The perception system for robotics and autonomous cars relies on the collaboration among multiple types of sensors to understand the surrounding environment. LiDAR has shown great potential to provide accurate environmental information, and thus

deep learning on LiDAR point cloud draws increasing attention. However, LiDAR is unable to handle severe weather. The sensor fusion between LiDAR and other sensors is an emerging topic due to its supplementary property compared to a single LiDAR. Challenges exist in deep learning methods that take LiDAR point cloud fusion data as input, which need to seek a balance between accuracy and algorithm complexity due to data redundancy. This work focuses on a comprehensive survey of deep learning on LiDAR-only and LiDAR-fusion 3D perception tasks. Starting with the representation of LiDAR point cloud, this paper then introduces its unique characteristics and the evaluation dataset as well as metrics. This paper gives a review according to four key tasks in the field of LiDAR-based perception: object classification, object detection, object tracking, and segmentation (including semantic segmentation and instance segmentation). Finally, we present the overlooked aspects of the current algorithms and possible solutions, hoping this paper can serve as a reference for the related research.

7. Evolution of Adaptive Learning for Nonlinear Dynamic Systems: A Systematic Survey

Authors: Mouhcine Harib, Hicham Chaoui, Suruz Miah

How to cite: Harib M, Chaoui H, Miah S. Evolution of adaptive learning for nonlinear dynamic systems: a systematic survey. *Intell Robot* 2022;2(1):37-71. http://dx.doi.org/10.20517/ir.2021.19

Abstract: The extreme nonlinearity of robotic systems renders the control design step harder. The consideration of adaptive control in robotic manipulation started in the 1970s. However, in the presence of bounded disturbances, the limitations of adaptive control rise considerably, which led researchers to exploit some “algorithm modifications”. Unfortunately, these modifications often require a priori knowledge of bounds on the parameters and the perturbations and noise. In the 1990s, the field of Artificial Neural Networks was hugely investigated in general, and for control of dynamical systems in particular. Several types of Neural Networks (NNs) appear to be promising candidates for control system applications. In robotics, it all boils down to making the actuator perform the desired action. While purely control-based robots use the system model to define their input-output relations, Artificial Intelligence (AI)-based robots may or may not use the system model and rather manipulate the robot based on the experience they have with the system while training or possibly enhance it in real-time as well. In this paper, after discussing the drawbacks of adaptive control with bounded disturbances and the proposed modifications to overcome these limitations, we focus on presenting the work that implemented AI in nonlinear dynamical systems and particularly in robotics. We cite some work that targeted the inverted pendulum control problem using NNs. Finally, we emphasize the previous research concerning RL and Deep RL-based control problems and their implementation in robotics manipulation, while highlighting some of their major drawbacks in the field.

Research Article

1. T-S Fuzzy-model-based Adaptive Cruise Control for Longitudinal Car-following Considering Vehicle Lateral Stability

Authors: Changzhu Zhang, Xiaoyu Wei, Zhuping Wang, Hao Zhang, Xuyang Guo

How to cite: Zhang C, Wei X, Wang Z, Zhang H, Guo X. T-S fuzzy-model-based adaptive cruise control for longitudinal car-following considering vehicle lateral stability. *Intell Robot* 2022;2(4):371-90. http://dx.doi.org/10.20517/ir.2022.26

Abstract: Adaptive cruise control is one of the essential technologies of advanced driver assistance systems, which is used to maintain a safe distance between an ego vehicle and a preceding vehicle and has been extensively applied in the automotive industry and control community. Note that some vehicle manoeuvres may approach handling limits to prevent collisions under complex road conditions, which often leads to vehicle lateral instability while cruising. In this study, a T-S fuzzy model predictive control framework is applied to the problem of adaptive cruise control. Variations in the preceding vehicle velocity and road surface conditions are considered to formulate adaptive cruise control as a tracking control problem of a T-S fuzzy system subject to parameter uncertainties and external persistent perturbations. Then, a robust positively invariant set is introduced to derive an admissible T-S fuzzy controller by solving a min-max optimization problem under a series of linear matrix inequality constraints. Finally, a CarSim/MATLAB joint simulation is conducted to illustrate the effectiveness of the proposed method, which ensures longitudinal adaptive cruise control for a car-following scenario with lateral vehicle stability.

2. Development and Experimental Verification of Search and Rescue ROV

Authors: Bing Sun, Wen Pang, Mingzhi Chen, Daqi Zhu

How to cite: Sun B, Pang W, Chen M, Zhu D. Development and experimental verification of search and rescue ROV. *Intell Robot* 2022;2(4):355-70. http://dx.doi.org/10.20517/ir.2022.23

Abstract: This paper presents the design of a new type of search and rescue remotely operated vehicle (ROV) system. The goal is to achieve the underwater target search and detection and small target capture and rescue operation requirements. First, the overall design of the whole underwater surface system and the layout design of the propulsion system are given. On this basis, the ROV frame structure, electronic cabin, and power cabin are designed and analyzed. To accomplish the grasping task, a grasping hand is designed based on a multifunctional manipulator to achieve underwater grasping. To make the ROV more intelligent, different kinds of underwater object detection and tracking

methods are adopted and analyzed. Finally, it was tested in a pool and the sea to verify the reliability and stability of the designed search and rescue ROV.

3. A Node Selection Algorithm to Graph-based Multi-waypoint Optimization Navigation and Mapping

Authors: Timothy Sellers, Tingjun Lei, Chaomin Luo , Gene Eu Jan, Junfeng Ma

How to cite: Sellers T, Lei T, Luo C, Eu Jan G, Ma J. A node selection algorithm to graph-based multi-waypoint optimization navigation and mapping. *Intell Robot* 2022;2(4):333-54. http://dx.doi.org/10.20517/ir.2022.21

Abstract: Autonomous robot multi-waypoint navigation and mapping have been demanded in many real-world applications found in search and rescue (SAR), environmental exploration, and disaster response. Many solutions to this issue have been discovered via graph-based methods in need of switching the robotos trajectory between the nodes and edges within the graph to create a trajectory for waypoint-to-waypoint navigation. However, studies of how waypoints are locally bridged to nodes or edges on the graphs have not been adequately undertaken. In this paper, an adjacent node selection (ANS) algorithm is developed to implement such a protocol to build up regional path from waypoints to nearest nodes or edges on the graph. We propose this node selection algorithm along with the generalized Voronoi diagram (GVD) and Improved Particle Swarm Optimization (IPSO) algorithm as well as a local navigator to solve the safety-aware concurrent graph-based multi-waypoint navigation and mapping problem. Firstly, GVD is used to form a Voronoi diagram in an obstacle populated environment to construct safety-aware routes. Secondly, the sequence of multiple waypoints is created by the IPSO algorithm to minimize the total travelling cost. Thirdly, while the robot attempts to visit multiple waypoints, it traverses along the edges of the GVD to plan a collision-free trajectory. The regional path from waypoints to the nearest nodes or edges needs to be created to join the trajectory by the proposed ANS algorithm. Finally, a sensor-based histogram local reactive navigator is adopted for moving obstacle avoidance while local maps are constructed as the robot moves. An improved B-spline curve-based smooth scheme is adopted that further refines the trajectory and enables the robot to be navigated smoothly. Simulation and comparison studies validate the effectiveness and robustness of the proposed model.

4. An Informative Planning-based Multi-layer Robot Navigation System as Applied in A Poultry Barn

Authors: Tingjun Lei, Guoming Li, Chaomin Luo, Li Zhang, Lantao Liu, Richard Stephen Gates

How to cite: Lei T, Li G, Luo C, Zhang L, Liu L, Stephen Gates R. An informative planning-based multi-layer robot navigation system as applied in a poultry barn. *Intell*

Robot 2022;2(4):313-32. http://dx.doi.org/10.20517/ir.2022.18

Abstract: Many real-world robot applications, as found in precision agriculture, poultry farms, disaster response, and environment monitoring, require search, locate, and removal (SLR) operations by autonomous mobile robots. In such application settings, the robots initially search and explore the entire workspace to find the targets, so that the subsequent robots conveniently move directly to the targets to fulfill the task. A multi-layer robot navigation system is necessary for SLR operations. The scenario of interest is the removal of broiler mortality by autonomous robots in poultry barns in this paper. Daily manual collection of broiler mortality is time- and labor-consuming, and an autonomous robotic system can solve this issue effectively. In this paper, a multi-layer navigation system is developed to detect and remove broiler mortality with two robots. One robot is assigned to search a large-scale workspace in a coverage mode and find and locate objects, whereas the second robot directly moves to the located targets to remove the objects. Directed coverage path planning (DCPP) fused with an informative planning protocol (IPP) is proposed to efficiently search the entire workspace. IPP is proposed for coverage directions in DCPP devoted to rapidly achieving spatial coverage with the least estimation uncertainty in the decomposed grids. The detection robot consists of a developed informative-based directed coverage path planner and a You Only Look Once (YOLO) V4-based dead bird detector. It refines and optimizes the coverage path based on historical data on broiler mortality distribution in a broiler barn. The removal robot collects dead broilers driven by a new hub-based multi-target path routing (HMTR) scheme, which is applicable to row-based environments. The proposed methods show great potential to navigate in broiler barns efficiently and safely, thus being a useful component for robotics. The effectiveness and robustness of the proposed methods are validated through simulation and comparison studies.

5. Networked Scheduling for Decentralized Load Frequency Control

Authors: Chen Peng, Hongchenyu Yang

How to cite: Peng C, Yang H. Networked scheduling for decentralized load frequency control. *Intell Robot* 2022;2(3):298-312. http://dx.doi.org/10.20517/ir.2022.27

Abstract: This paper investigates the scheduling process for multi-area interconnected power systems under the shared but band-limited network and decentralized load frequency controllers. To cope with sub-area information and avoid node collision of large-scale power systems, round-robin and try-once-discard scheduling are used to schedule sampling data among different sub-grids. Different from existing decentralized load frequency control methods, this paper studies multi-packet transmission schemes and introduces scheduling protocols to deal with the multi-node collision. Considering the scheduling process and decentralized load frequency controllers, an impulsive power system closed-loop model is well established. Furthermore, sufficient stabilization criteria are derived to obtain decentralized $\mathcal{H}_\infty$ output feedback controller gains and scheduling

protocol parameters. Under the designed decentralized output feedback controllers, the prescribed system performances are achieved. Finally, a three-area power system example is used to verify the effectiveness of the proposed scheduling method.

6. $\mathcal{H}_\infty$ Leader-following Consensus of Multi-agent Systems with Channel Fading under Switching Topologies: A Semi-Markov Kernel Approach

Authors: Haoyue Yang, Hao Zhang, Zhuping Wang, Xuemei Zhou

How to cite: Yang H, Zhang H, Wang Z, Zhou X. $\mathcal{H}_\infty$ leader-following consensus of multi-agent systems with channel fading under switching topologies: a semi-Markov kernel approach. *Intell Robot* 2022;2(3):223-43. http://dx.doi.org/10.20517/ir.2022.19

Abstract: This paper focuses on the leader-following consensus problem of discrete-time multi-agent systems subject to channel fading under switching topologies. First, a topology switching-based channel fading model is established to describe the information fading of the communication channel among agents, which also considers the channel fading from leader to follower and from follower to follower. It is more general than models in the existing literature that only consider follower-to-follower fading. For discrete multi-agent systems, the existing literature usually adopts time series or Markov process to characterize topology switching while ignoring the more general semi-Markov process. Based on the advantages and properties of semi-Markov processes, discrete semi-Markov jump processes are adopted to model network topology switching. Then, the semi-Markov kernel approach for handling discrete semi-Markov jumping systems is exploited and some novel sufficient conditions to ensure the leader-following mean square consensus of closed-loop systems are derived. Furthermore, the distributed consensus protocol is proposed by means of the stochastic Lyapunov stability theory so that the underlying systems can achieve $\mathcal{H}_\infty$ consensus performance index. In addition, the proposed method is extended to the scenario where the semi-Markov kernel of semi-Markov switching topologies is not completely accessible. Finally, a simulation example is given to verify the results proposed in this paper. Compared with the existing literature, the method in this paper is more effective and general.

7. Opponent Modeling with Trajectory Representation Clustering

Authors: Yongliang Lv, Yan Zheng, Jianye Hao

How to cite: Lv Y, Zheng Y, Hao J. Opponent modeling with trajectory representation clustering. *Intell Robot* 2022;2(2):168-79. http://dx.doi.org/10.20517/ir.2022.09

Abstract: For a non-stationary opponent in a multi-agent environment, traditional methods model the opponent through its complex information to learn one or more optimal response policies. However, the response policy learned earlier is prone to catastrophic

forgetting due to data imbalance in the online-updated replay buffer for non-stationary changes of opponent policies. This paper focuses on how to learn new response policies without forgetting old policies that have been learned when the opponent policy is constantly changing. We extract the representation of opponent policies and make explicit clustering distinctions through the contrastive learning autoencoder. With the idea of balancing the replay buffer, we maintain continuous learning of the trajectory data of various opponent policies that have appeared to avoid policy forgetting. Finally, we demonstrate the effectiveness of the method under a classical opponent modeling environment (soccer) and show the clustering effect of different opponent policies.

8. AVDDPG – Federated Reinforcement Learning Applied to Autonomous Platoon Control

Authors: Christian Boin, Lei Lei, Simon X. Yang

How to cite: Boin C, Lei L, Yang SX. AVDDPG – Federated reinforcement learning applied to autonomous platoon control. *Intell Robot* 2022;2(2):145-67. http://dx.doi.org/10.20517/ir.2022.11

Abstract: Since 2016 federated learning (FL) has been an evolving topic of discussion in the artificial intelligence (AI) research community. Applications of FL led to the development and study of federated reinforcement learning (FRL). Few works exist on the topic of FRL applied to autonomous vehicle (AV) platoons. In addition, most FRL works choose a single aggregation method (usually weight or gradient aggregation). We explore FRL's effectiveness as a means to improve AV platooning by designing and implementing an FRL framework atop a custom AV platoon environment. The application of FRL in AV platooning is studied under two scenarios: (1) Inter-platoon FRL (Inter-FRL) where FRL is applied to AVs across different platoons; (2) Intra-platoon FRL (Intra-FRL) where FRL is applied to AVs within a single platoon. Both Inter-FRL and Intra-FRL are applied to a custom AV platooning environment using both gradient and weight aggregation to observe the performance effects FRL can have on AV platoons relative to an AV platooning environment trained without FRL. It is concluded that Intra-FRL using weight aggregation (Intra-FRLWA) provides the best performance for controlling an AV platoon. In addition, we found that weight aggregation in FRL for AV platooning provides increases in performance relative to gradient aggregation. Finally, a performance analysis is conducted for Intra-FRLWA versus a platooning environment without FRL for platoons of length 3, 4 and 5 vehicles. It is concluded that Intra-FRLWA largely out-performs the platooning environment that is trained without FRL.

9. An Improved ViBe-based Approach for Moving Object Detection

Authors: Guangyi Tang, Jianjun Ni, Pengfei Shi, Yingqi Li, Jinxiu Zhu

How to cite: Tang G, Ni J, Shi P, Li Y, Zhu J. An improved ViBe-based approach for

moving object detection. *Intell Robot* 2022;2(2):130-44. http://dx.doi.org/10.20517/ir.2022.07

Abstract: Moving object detection is a challenging task in the automatic monitoring field, which plays a crucial role in most video-based applications. The visual background extractor (ViBe) algorithm has been widely used to deal with this problem due to its high detection rate and low computational complexity. However, there are some shortcomings in the general ViBe algorithm, such as the ghost area problem and the dynamic background problem. To deal with these problems, an improved ViBe approach is presented in this paper. In the proposed approach, a mode background modeling method is used to accelerate the process of the ghost elimination. For the detection of moving object in dynamic background, a local adaptive threshold and update rate is proposed for the ViBe approach to detect foreground and update background. Furthermore, an improved shadow removal method is presented, which is based on the HSV color space combined with the edge detection method. Finally, some experiments were conducted, and the results show the efficiency and effectiveness of the proposed approach.

10. An Open-closed-loop Iterative Learning Control for Trajectory Tracking of A High-speed 4-dof Parallel Robot

Authors: Qiancheng Li, Enyu Liu, Chuangchuang Cui, Guanglei Wu

How to cite: Li Q, Liu E, Cui C, Wu G. An open-closed-loop iterative learning control for trajectory tracking of a high-speed 4-dof parallel robot. *Intell Robot* 2022;2(1):89-104. http://dx.doi.org/10.20517/ir.2022.02

Abstract: Precise control is of importance for robots, whereas, due to the presence of modeling errors and uncertainties under the complex working environment, it is difficult to obtain an accurate dynamic model of the robot, leading to decreased control performances. This work presents an open-closed-loop iterative learning control applied to a four-limb parallel Schönflies-motion robot, aiming to improve the tracking accuracy with high movement, in which the controller can learn from the iterative errors to make the robot end-effector approximate to the expected trajectory. The control algorithm is compared with classical D-ILC, which is illustrated along with an industrial trajectory of pick-and-place operation. External repetitive and non-repetitive disturbances are added to verify the robustness of the proposed approach. To verify the overall performance of the proposed control law, multiple trajectories within the workspace, different working frequencies for a prescribed trajectory, and different design methods are selected, which show the effectiveness and the generalization ability of the designed controller.

11. Facial Expression Recognition Using Adapted Residual Based Deep Neural Network

Authors: Ibrahima Bah, Yu Xue

How to cite: Bah I, Xue Y. Facial expression recognition using adapted residual based deep neural network. *Intell Robot* 2022;2(1):72-88. http://dx.doi.org/10.20517/ir.2021.16

Abstract: Emotion on our face can determine our feelings, mental state and can directly impact our decisions. Humans are subjected to undergo an emotional change in relation to their living environment and or at a present circumstance. These emotions can be anger, disgust, fear, sadness, happiness, surprise or neutral. Due to the intricacy and nuance of facial expressions and their relationship to emotions, accurate facial expression identification remains a difficult undertaking. As a result, we provide an end-to-end system that uses residual blocks to identify emotions and improve accuracy in this research field. After receiving a facial image, the framework returns its emotional state. The accuracy obtained on the test set of FERGIT dataset (an extension of the FER2013 dataset with 49300 images) was 75%. This proves the efficiency of the model in classifying facial emotions as this database poses a bunch of challenges such as imbalanced data, intraclass variance, and occlusion. To ensure the performance of our model, we also tested it on the CK+ database and its output accuracy was 97% on the test set.

12. Unmanned Aerial Vehicle with Handover Management Fuzzy System for 5G Networks: Challenges and Perspectives

Authors: Thalita Ayass, Thiago Coqueiro, Tássio Carvalho, José Jailton, Jasmine Araújo, Renato Francês

How to cite: Ayass T, Coqueiro T, Carvalho T, Jailton J, Araújo J, Francês R. Unmanned aerial vehicle with handover management fuzzy system for 5G networks: challenges and perspectives. *Intell Robot* 2022;2(1):20-36. http://dx.doi.org/10.20517/ir.2021.07

Abstract: The next generation of wireless networks, 5G, and beyond will bring more complexities and configuration issues to set the new wireless networks, besides requirements for important and new services. These new generations of wireless networks, to be implemented, are in extreme dependence on the adoption of artificial intelligence techniques. The integration of unmanned aerial vehicles (UAV) in wireless communication networks has opened several possibilities with increased flexibility and performance. Besides, they are considered as one of the most promising technologies to be used in the new wireless networks. Thus, UAVs are expected to be one of the most important applications to provide a new way of connectivity to the 5G network, and it is expected to grow from being a 19.3 billion USD industry in 2019 to 45.8 billion USD by 2025. In this paper, we provide a proposal of handover management on aerial 5G network utilizing the fuzzy system. The simulations performed prove the benefits of our proposal by QoS/QoE (quality of service/quality of experience) metrics.

13. Deep Transfer Learning Benchmark for Plastic Waste Classification

Authors: Anthony Ashwin Peter Chazhoor, Edmond S. L. Ho, Bin Gao, Wai Lok Woo

How to cite: Chazhoor AAP, Ho ESL, Gao B, Woo WL. Deep transfer learning benchmark for plastic waste classification. *Intell Robot* 2022;2(1):1-19. http://dx.doi.org/10.20517/ir.2021.15

Abstract: Millions of people throughout the world have been harmed by plastic pollution. There are microscopic pieces of plastic in the food we eat, the water we drink, and even the air we breathe. Every year, the average human consumes 74,000 microplastics, which has a significant impact on their health. This pollution must be addressed before it has a significant negative influence on the population. This research benchmarks six state-of-the-art convolutional neural network models pre-trained on the ImageNet Dataset. The models Resnet-50, ResNeXt, MobileNet_v2, DenseNet, SchuffleNet and AlexNet were tested and evaluated on the WaDaBa plastic dataset, to classify plastic types based on their resin codes by integrating the power of transfer learning. The accuracy and training time for each model has been compared in this research. Due to the imbalance in the data, the under-sampling approach has been used. The ResNeXt model attains the highest accuracy in fourteen minutes.

2021

Review Article

1. Rail Track Condition Monitoring: A Review on Deep Learning Approaches

Authors: Albert Ji, Wai Lok Woo, Eugene Wai Leong Wong, Yang Thee Quek

How to cite: Ji A, Woo WL, Wong EWL, Quek YT. Rail track condition monitoring: a review on deep learning approaches. *Intell Robot* 2021;1(2):151-75. http://dx.doi.org/10.20517/ir.2021.14

Abstract: Rail track is a critical component of rail systems. Accidents or interruptions caused by rail track anomalies usually possess severe outcomes. Therefore, rail track condition monitoring is an important task. Over the past decade, deep learning techniques have been rapidly developed and deployed. In the paper, we review the existing literature on applying deep learning to rail track condition monitoring. Potential challenges and opportunities are discussed for the research community to decide on possible directions. Two application cases are presented to illustrate the implementation of deep learning to rail track condition monitoring in practice before we conclude the paper.

2. Bio-inspired Intelligence with Applications to Robotics: A Survey

Authors: Junfei Li, Zhe Xu, Danjie Zhu, Kevin Dong, Tao Yan, Zhu Zeng, Simon X. Yang

How to cite: Li J, Xu Z, Zhu D, Dong K, Yan T, Zeng Z, Yang SX. Bio-inspired intelligence with applications to robotics: a survey. *Intell Robot* 2021;1(1):58-83. http://dx.doi.org/10.20517/ir.2021.08

Abstract: In the past decades, considerable attention has been paid to bio-inspired intelligence and its applications to robotics. This paper provides a comprehensive survey of bio-inspired intelligence, with a focus on neurodynamics approaches, to various robotic applications, particularly to path planning and control of autonomous robotic systems. Firstly, the bio-inspired shunting model and its variants (additive model and gated dipole model) are introduced, and their main characteristics are given in detail. Then, two main neurodynamics applications to real-time path planning and control of various robotic systems are reviewed. A bio-inspired neural network framework, in which neurons are characterized by the neurodynamics models, is discussed for mobile robots, cleaning robots, and underwater robots. The bio-inspired neural network has been widely used in real-time collision-free navigation and cooperation without any learning procedures, global cost functions, and prior knowledge of the dynamic environment. In addition, bio-inspired backstepping controllers for various robotic systems, which are able to eliminate the speed jump when a large initial tracking error occurs, are further discussed. Finally, the

current challenges and future research directions are discussed in this paper.

3. Federated Reinforcement Learning: Techniques, Applications, and Open Challenges

Authors: Jiaju Qi, Qihao Zhou, Lei Lei, Kan Zheng

How to cite: Qi J, Zhou Q, Lei L, Zheng K. Federated reinforcement learning: techniques, applications, and open challenges. *Intell Robot* 2021;1(1):18-57. http://dx.doi.org/10.20517/ir.2021.02

Abstract: This paper presents a comprehensive survey of federated reinforcement learning (FRL), an emerging and promising field in reinforcement learning (RL). Starting with a tutorial of federated learning (FL) and RL, we then focus on the introduction of FRL as a new method with great potential by leveraging the basic idea of FL to improve the performance of RL while preserving data-privacy. According to the distribution characteristics of the agents in the framework, FRL algorithms can be divided into two categories, i.e., Horizontal Federated Reinforcement Learning and vertical federated reinforcement learning (VFRL). We provide the detailed definitions of each category by formulas, investigate the evolution of FRL from a technical perspective, and highlight its advantages over previous RL algorithms. In addition, the existing works on FRL are summarized by application fields, including edge computing, communication, control optimization, and attack detection. Finally, we describe and discuss several key research directions that are crucial to solving the open problems within FRL

Research Article

1. Autonomous Navigation in Unknown Environment Using Sliding Mode SLAM and Genetic Algorithm

Authors: Salvador Ortiz, Wen Yu

How to cite: Ortiz S, Yu W. Autonomous navigation in unknown environment using sliding mode SLAM and genetic algorithm. *Intell Robot* 2021;1(2):131-50. http://dx.doi.org/10.20517/ir.2021.09

Abstract: In this paper, sliding mode control is combined with the classical simultaneous localization and mapping (SLAM) method. This combination can overcome the problem of bounded uncertainties in SLAM. With the help of genetic algorithm, our novel path planning method shows many advantages compared with other popular methods.

2. Planning Robotic Agent Actions Using Semantic Knowledge for A Home Environment

Authors: Rodrigo Bernardo, João M. C. Sousa1, Paulo J. S. Gonçalves

How to cite: Bernardo R, Sousa JMC, Gonçalves PJS. Planning robotic agent actions using semantic knowledge for a home environment. *Intell Robot* 2021;1(2):116-30. http://dx.doi.org/10.20517/ir.2021.10

Abstract: Autonomous mobile robotic agents are increasingly present in highly dynamic environments, thus making the planning and execution of their tasks challenging. Task planning is vital in directing the actions of a robotic agent in domains where a causal chain could lock the agent into a dead-end state. This paper proposes a framework that integrates a domain ontology (home environment ontology) with a task planner (ROSPlan) to translate the objectives coming from a given agent (robot or human) into executable actions by a robotic agent.

3. On the Elastodynamics of A Five-axis Lightweight Anthropomorphic Robotic Arm

Authors: Guanglei Wu

How to cite: Wu G. On the elastodynamics of a five-axis lightweight anthropomorphic robotic arm. *Intell Robot* 2021;1(2):99-115. http://dx.doi.org/10.20517/ir.2021.11

Abstract: This paper presents elastodynamic modeling and analysis for a five-axis lightweight robotic arm. Natural frequencies are derived and visualized within the dexterous workspace to show the overall performances and compare them to the frequencies when the robotics is with payload. The comparison shows that the payload has a relatively small influence to the first- and second-order frequencies. Sensitivity analysis is conducted, and the system's frequency is more sensitive to the second joint stiffness than the others. Moreover, observations from the displacement response analysis reveal that the robotics produces linear elastic displacements of the same level between the loaded and unloaded working modes but larger rotational deflections under the loaded working condition. The main contribution of this work lies in that a systematic approach of elastodynamic analysis for serial robotic manipulators is formulated, where the arm gravity and external load are taken into account to investigate the dynamic behaviors of the robotic arms, i.e., frequencies, sensitivity analysis, and displacement responses, under the loaded mode.

4. Unsupervised Monocular Depth Estimation with Aggregating Image Features and Wavelet SSIM (Structural SIMilarity) Loss

Authors: Bingen Li, Hao Zhang, Zhuping Wang, Chun Liu, Huaicheng Yan, Lingling Hu

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Abstract: Unsupervised learning has shown to be effective for image depth prediction. However, the accuracy is restricted because of uncertain moving objects and the lack of other proper constraints. This paper focuses on how to improve the accuracy of depth prediction without increasing the computational burden of the depth network. Aggregated residual transformations are embedded in the depth network to extract high-dimensional image features. A more accurate mapping relationship between feature map and depth map can be built without bringing extra network computational burden. Additionally, the 2D discrete wavelet transform is applied to the structural similarity loss (SSIM) to reduce the photometric loss effectively, which can divide the entire image into various patches and obtain high-quality image information. Finally, the effectiveness of the proposed method is demonstrated. The training model can improve the performance of the depth network on the KITTI dataset and decrease the domain gap on the Make3D dataset.

Perspective

1. **Intelligent Robotics - Misconceptions, Current Trends, and Opportunities**

Author: Clarence W. de Silva

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Abstract: The concepts of “Robots” have been of interest to humans from historical times, initially with the desire to create “artificial slaves”. Since the technology was not developing to keep up with the “dreams”, initially, Robotics was primarily of entertainment value, relegated to plays, movies, stories, etc. The practical applications started in the late 1950s and the 1960s with the development of programmable devices for factories and assembly lines as flexible automation. However, since the expectations were not adequately realized, the general enthusiasm and funding for Robotics subsided to some extent. With subsequent research, developments, and curricular enhancement in Engineering and Computer Science and the resurgence of Artificial Intelligence, particularly machine learning, Robotics has found numerous practical applications today, in industry, medicine, household, the service sector, and the general society. Important developments and practical strides are being made, particularly in Soft Robotics, Mobile Robotics (Aerial - drones, Underwater, Ground-based - autonomous vehicles in particular), Swarm Robotics, Homecare, Surgery, Assistive Devices, and Active Prosthesis. This perspective paper starts with a brief history of Robotics while indicating some associated myths and unfair expectations. Next, it will outline key developments in the area. In particular, some important practical applications of Intelligent Robotics, as developed by groups worldwide, including the Industrial Automation Laboratory at the University of British Columbia, headed by the author, are indicated. Finally, some misconceptions and

shortcomings concerning Intelligent Robotics are pointed out. The main shortcomings concern the mechanical capabilities and the nature of intelligence. The paper concludes by mentioning future trends and key opportunities available in Intelligent Robotics for both developed and developing counties.

Editorial
1. Intelligence and Robotics

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