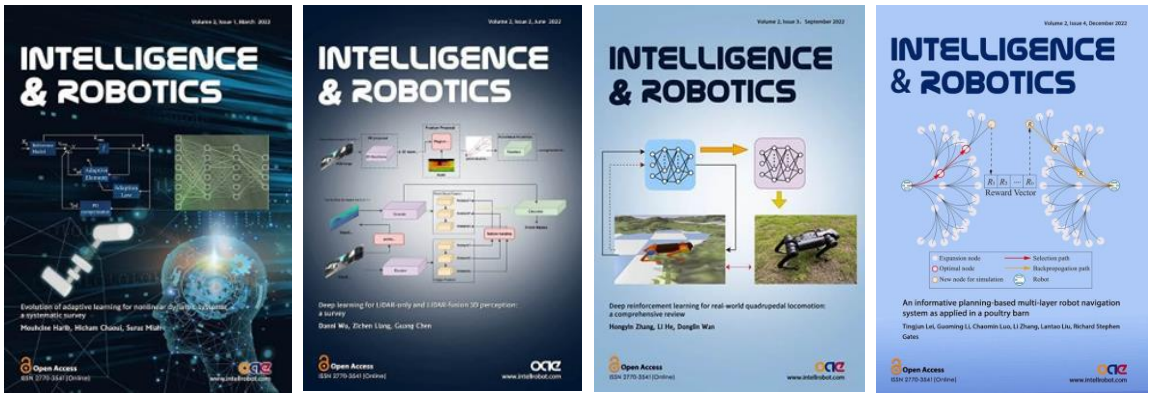

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Review

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.

Keywords: Intelligent detection, crack detection, deep learning, data fusion, feature extraction

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.

Keywords: Deep reinforcement learning, quadrupedal locomotion, reality gap

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.

Keywords: Fairness, causality, fairness-enhancing mechanisms, machine learning, fairness notions

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.

Keywords: Bionic robot fish, motion mechanism, motion coordination, group communication

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.

Keywords: Unmanned underwater vehicles, motion planning, path planning, task assignment, tracking control

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.

Keywords: LiDAR, sensor fusion, object classification, object detection, object tracking, segmentation

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.

Keywords: Adaptive control, deep reinforcement learning, manipulators, neural networks, reinforcement learning, robotics

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.

Keywords: Adaptive cruise control, T-S fuzzy model predictive control, robust positively invariant set, lateral 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.

Keywords: Remotely operated vehicle, search and rescue, underwater object detection and tracking, underwater grasping

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.

Keywords: Adjacent node selection (ANS) algorithm, safety-aware roads, path planning, multiple-waypoint optimization, navigation and mapping

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.

Keywords: Directed coverage path planning, informative planning protocol (IPP), broiler mortality, YOLO V4, hub-based multi-target routing (HMTR) scheme

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.

Keywords: Multi-area power systems, round-robin scheduling, try-once-discard scheduling, load frequency control

6. ℋ∞ 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. ℋ ∞ 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 ℋ ∞ 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.

Keywords: ℋ∞ leader-following consensus, multi-agent systems, channel fading, semi-Markov switching topologies, semi-Markov kernel

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.

Keywords: Non-stationary, opponent modeling, contrastive learning, trajectory representation, data balance

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.

Keywords: Deep reinforcement learning, autonomous driving, federated reinforcement learning, platooning

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.

Keywords: Moving object detection, ViBe-based approach, dynamic background, shadow detection

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.

Keywords: High-speed parallel robot, open-closed-loop, iterative learning control, trajectory tracking control

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.

Keywords: Facial expression recognition, emotion detection, convolutional neural network, deep residual network

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.

Keywords: UAV, FANET, drone, fifth generation, fuzzy system, handover

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.

Keywords: Plastic, transfer learning, recycling, waste, classification