



Book of Abstracts from the 2nd International Conference on Autonomous Machines and Intelligent Robotics Applications (AMIRA 2026)



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**Book of Abstracts from the
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Welcome message

It is our great pleasure to welcome all participants of AMIRA 2026 to Debrecen, Hungary, and in particular to the Faculty of Engineering of the University of Debrecen. We are delighted that this international conference brings together researchers, professionals, and experts from different parts of the world to exchange knowledge, share recent results, and discuss new perspectives in the field of AMIRA (Autonomous Machines and Intelligent Robotics Applications).

The University of Debrecen is one of Hungary's traditional and internationally recognized universities, with a long-standing commitment to education, research, and innovation. Within the University, the Faculty of Engineering is a dynamically developing faculty with an increasingly important role in engineering education and research. We are especially pleased that our students will also have the opportunity to gain insight into the topics presented at AMIRA 2026 and to experience an international scientific event in their own academic environment.

It is a particular pleasure to welcome several distinguished keynote speakers to the programme. Their contributions will provide valuable perspectives and stimulate discussions on important current and future challenges in the field.

The technical programme of AMIRA 2026 reflects a rigorous and selective review process. More than 40 papers were submitted to the conference, of which only 20 have been selected for presentation. Each submission was evaluated by at least three independent reviewers, ensuring a thorough and demanding assessment of the scientific contributions. The accepted papers represent the work of authors from countries across America, Europe, Australia, Africa and Asia, highlighting the international character of the conference.

We are proud to host AMIRA 2026 in Debrecen, a city with a strong academic tradition and a rapidly developing industrial environment. The presence of major international companies such as BMW, Schaeffler, Thyssenkrupp, Krones, and EMERSON |NI reflects the city's growing industrial importance and creates new opportunities for cooperation between academia and industry.

We sincerely hope that AMIRA 2026 will provide an inspiring forum for scientific exchange, fruitful discussions, and new professional connections. We wish all participants a successful and enjoyable conference in Debrecen.

Sincerely yours,

Péter KORONDI
General Chair

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Autonomous Mobility and Transportation Systems

Track: Autonomous Mobility and Transportation Systems

Sensitivity Analysis of Bi-Level Optimization for Resource Utilization in Maritime Container Terminals Under Disruptions

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Abstract: Maritime container terminals are critical nodes in global supply chains, where disruptions and congestion can adversely affect operational efficiency and logistics performance. This paper presents a bilevel optimization framework for regulating container flows under perturbed operating conditions characterized by unusually high container arrival volumes. In particular, a disruption scenario is considered where over a time period of eight hours, every hour containers arrive at the terminal, compared to a standard scenario, in which containers arrive every twelve hours. The proposed model extends a convex container flow optimization problem by introducing a hierarchical decision structure for determining operational weighting parameters. The lower-level problem models the allocation of transport and handling resources within the terminal, while the upper-level problem selects parameter values to minimize congestion and improve container flow performance. The bilevel problem is reformulated using Karush–Kuhn–Tucker (KKT) conditions, and two solution approaches are investigated. The first approach incorporates a regularization term to improve numerical efficiency, whereas the second employs a Fischer–Burmeister-based relaxation of the complementarity constraints. The performance and solution quality of both methods are evaluated through sensitivity analyses with respect to input data and algorithmic parameters. Numerical results indicate that the relaxation-based approach is more robust to parameter and data variations than the regularization scheme. Moreover, it offers a practical tradeoff between computational efficiency and solution quality, making it suitable for congestion management in container terminals.

Keywords: *Container Terminal Operations, Robustness and Sensitivity, Bi-level Optimization, Resource Allocation, Unusual Disruptions, Relaxation and Regularization.*

Track: Autonomous Mobility and Transportation Systems

Digital Eyes for Communication between Automated Vehicle and Multiple Vulnerable Road Users: an Exploratory First Study

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Abstract: Digital eyes have been suggested as a promising mode of communication between an automated vehicle (AV) and vulnerable road users (VRUs). However, they have been tested predominantly in scenarios with a single VRU. In this work, we used virtual reality to investigate whether and how digital eyes can be used to communicate between an AV and multiple VRUs. As a first step, here we examined scenarios with up to 2 VRUs to show that digital eyes can aid in communication with multiple VRUs, though further studies are required to analyze the eye dynamics to enable this.

Keywords: *Autonomous Vehicle (AV), Vulnerable Road User (VRU), External Human Machine Interaction (eHMI), Human Behaviour.*

Data-Driven Modelling of Engineering Systems

Track: Data-Driven Modelling of Engineering Systems

Data-Driven Evaluation of Hyperelastic Models for Tribology Applications Calibrated on Multiaxial Load

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Abstract: A data-driven evaluation of hyperelastic material models calibrated on multiaxial loads is presented using a systematic parameter fitting strategy. Experimental tension, compression, and shear data were combined to assess model performance under interpolation and extrapolation conditions. The results show that model accuracy strongly depends on the selected load cases, while higher-order models exhibit pronounced overfitting when calibration is incomplete. Mooney–Rivlin models provide the most balanced performance across combined loading scenarios, whereas lower-order models offer more robust but less accurate predictions. The findings are further validated on a tribological sealing assembly case dominated by shear and compression, demonstrating that improper calibration can lead to significant errors in the predicted force response

Keywords: Hyperelasticity, Multiaxial Loading, Parameter Fitting, Neo-Hooke, Mooney-Rivlin, Arrude-Boyce, Yeoh, Ogden.

Track: Data-Driven Modelling of Engineering Systems

BoxMix-UDA: Bridging the Cross-Domain Gap in Semiconductor Load Station Inspection

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Abstract: In smart semiconductor manufacturing, verifying the physical operational state of automated Load Stations before starting wafer cassette handling is critical to prevent wafer damage and tool crashes. A visual inspection model must verify whether a Load Station is in a good operational state to use (cassette door fully open, loading port unobstructed) or an unsafe state (cassette door closed/misaligned, loading port occluded by foreign objects). However, semiconductor fabs deploy several distinct types of Load Stations across fabrication lines. Deploying a deep neural network (DNN) trained on one Load Station type to an unseen load station incurs severe domain shift due to differences in lighting, mechanical geometry, background hardware, and camera angles. Annotating data and re-training for every new station type is cost-prohibitive, and existing unsupervised domain adaptation (UDA) methods either rely on slow two-stage detectors that fail real-time throughput demands (> 60 FPS) or single-stage detectors with low adaptation accuracy. Therefore, this paper presents BoxMix-UDA, a single-stage UDA framework designed for real-time cross-station operational state inspection. Built on a Teacher–Student architecture using a single-stage YOLOv5s detector, BoxMix-UDA unifies three complementary adaptation mechanisms: (1) BoxMix pseudo-label augmentation,

embedding confidence-filtered, dilated target foreground regions into source backgrounds; (2) multi-scale Deep CORAL feature alignment across feature pyramid network (FPN) neck layers; and (3) symmetric Kullback–Leibler (KL) consistency loss between Teacher and Student prediction distributions. BoxMix-UDA adapts at the input, feature, and prediction levels without a domain discriminator. Evaluated across three industrial Load Station types under a leave-one-domain-out protocol using hybrid real and CAD-synthetic source data and unlabelled target data, BoxMix-UDA achieves 84.66% average accuracy and 85.80% average F1 score across three cross-domain scenarios, operating at 617 frames per second (FPS) on an NVIDIA RTX 4080 SUPER GPU. This recovers 74.5% of the domain shift accuracy gap without target labels, matching two-stage detector accuracy at 12× to 34× higher inference speed.

Keywords: Unsupervised Domain Adaptation, Industrial Inspection, Semiconductor Manufacturing, Teacher–Student, Pseudo-Labels, Smart Manufacturing.

Track: Data-Driven Modelling of Engineering Systems

AI Driven Smart Semiconductor Manufacturing Fab Automation Using Digital Twins, Predictive Maintenance, and Collaborative Robotics

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Abstract: Semiconductor fabrication requires high equipment availability, process precision, and workforce productivity; however, unplanned downtime, fragmented data, and labor shortages continue to constrain fab performance. This paper proposes a smart fab framework integrating artificial intelligence (AI), predictive maintenance, digital twins, and collaborative robotics. Real-time equipment data support self diagnostics, anomaly detection, and remaining-useful life estimation, advancing condition monitoring toward predictive maintenance. Digital twins evaluate equipment degradation, maintenance actions, and process adjustments before physical implementation, while mobile and collaborative robots provide repeatable inspection and equipment-service support. A wafer transfer-robot case study illustrates the use of vibration data, hybrid machine-learning models, and robotic inspection for early failure detection. The proposed framework targets improved tool output, equipment availability, overall equipment effectiveness, wafer yield, service accuracy, and labor productivity.

Keywords: Artificial Intelligence, Collaborative Robots, Digital Twins, Equipment Availability, Predictive Maintenance, Digital Enablement, Semiconductor Manufacturing, Automation, Smart Fabs, Wafer Yield.

Track: Data-Driven Modelling of Engineering Systems

Modeling Human Robot Related Attitude with Interpolative Fuzzy State Machines

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Abstract: Nowadays, it is increasingly important to endow autonomous machines, especially robots, with properties that are inspired by human emotion or animal behavior. This requires modeling behavior and emotions in an engineering manner. One of the most common modeling forms in engineering is the state space description, which is the basis of modern control theory. In standard engineering systems, the change of states is described by a system of differential equations, but this cannot be applied to emotional and behavioral models. Especially not in cases where the states do not change continuously. For solving this problem, taking account that the states are continuous, this paper suggest to adapt fuzzy state machine. This solution also supports the heuristic verbal rule-base format of the common existing emotional or ethological models. The article focuses on the mathematical tool itself and uses the specific database only as an example.

Keywords: Interpolative Fuzzy Reasoning, Fuzzy State Machine, Psychological Modelling.

Drone Technologies and Industrial Applications

Track: Drone Technologies and Industrial Applications

Real-Time 3D Printing Process Monitoring and Fault Detection on Cloud-based Deep Learning

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Abstract: Fused Deposition Modelling (FDM) 3D printing is increasingly deployed in industrial-scale printer farms where manual supervision is impractical. This paper presents a scalable, real-time monitoring and fault detection system that combines multi-camera edge capture with a cloud-hosted YOLOv8x deep learning pipeline. A custom annotated dataset of 2,422 images covering nine fault classes was assembled from public datasets and original recordings, then split and augmented, expanding the training set approximately fivefold (from 1,938 to ~9,700 images) using mosaic, MixUp, and standard geometric transforms. A two-phase training strategy is applied: first at 960 px then fine-tuned at 1280 px input resolution yielded a peak mAP@0.5 of 0.901, precision of 0.937, and recall of 0.836 on the validation set (reported as validation-set, model-selection performance). The deployed system processes six frames per second across three camera streams with a per-frame inference latency of 23 ms on an NVIDIA T4 GPU (Vertex AI endpoint) and notifies operators via email and a live web dashboard upon anomaly detection. The architecture is horizontally scalable and suitable for multi-printer farm deployment.

Keywords: Additive Manufacturing, Fault Detection, Real-Time Monitoring, Computer Vision, Deep Learning, YOLOv8, Edge Computing, Cloud Computing.

Track: Drone Technologies and Industrial Applications

Cloud-Native Digital Twin Architecture for Soft Real-Time Supervisory UR3 Robot Telemetry and Control

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Abstract: Digital Twin systems are becoming fundamental components of Industry 4.0 and cyber-physical systems, enabling continuous monitoring, synchronization, and soft real-time supervisory control of physical industrial assets. This paper presents the design and implementation of a cloud-native Digital Twin architecture for a Universal Robots UR3 collaborative robot arm. The proposed system integrates edge computing, MQTT-based telemetry, serverless cloud services, Infrastructure as Code, and 3D web visualization into a scalable edge-to-cloud architecture. Telemetry is partitioned into a low-latency Hot Path for live 3D synchronization and a high-throughput Cold Path for archival and historical replay. The architecture combines AWS IoT Core, AWS Lambda, AppSync GraphQL subscriptions, Amazon DynamoDB, S3, Kinesis Firehose, and Terraform-based CI/CD automation. Experimental measurements across European and transatlantic AWS regions demonstrate end-to-end roundtrip latencies of 1,912 ms and 2,072 ms respectively, validating the feasibility of public cloud infrastructure for bidirectional supervisory Digital Twins of collaborative industrial robots.

Keywords: Digital Twins, Cloud Computing, Collaborative Robots, Industry 4.0, Edge Computing, Real-Time Systems, Supervisory Control.

Track: Drone Technologies and Industrial Applications

Game-Theoretic Resilient Control of Nonlinear Multi-Agent Systems under Stochastic Adversarial Attacks

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Abstract: This paper develops a fully decentralized secure consensus framework for nonlinear multi-agent systems subject to stochastic false-data-injection (FDI) actuator attacks, Lipschitz nonlinearities, process and measurement noise. By modeling local agent interactions as zero-sum dynamic games between a defender and an adversary, we establish the existence and uniqueness of a game-theoretic saddle-point solution via a Lipschitz-robustified game algebraic Riccati equation (GARE). For the interconnected network, we construct a second-moment operator that captures all decentralized Bernoulli attack patterns and prove that mean-square stability holds if and only if its spectral radius lies strictly within the unit circle. Furthermore, we provide explicit bounds proving that the consensus disagreement error converges to a bounded neighborhood of zero, governed by noise covariance, the Lipschitz constant, and the stability margin. Finally, a policy-iteration reinforcement learning algorithm is shown to converge quadratically to the saddle-point gains. The proposed framework delivers a unified theoretical foundation for resilient control in attack-corrupted multi-agent networks.

Keywords: Attack, Defend, Game Theory, Nonlinear Multi-Agent Systems, Reinforcement Learning, Resilience Control.

Education and Other Related Topics

Track: Education and Other Related Topics

Junior Programmers AI-Emergence: Teaching Computer Network (CN) OSI Layers with Pluralism Epistemology (Electronics Intra- and Audio Inter-Disciplinary)

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Abstract: This position paper explores the integration of pluralism epistemology in teaching junior programmers through the lens of the Computer Network (CN) OSI model, emphasizing the interconnectedness of software and hardware in computer networks. By utilizing a technical framework for teaching that incorporates both Intra-Disciplinary and inter-disciplinary approaches, the study highlights how different actors - human and non-human, play complementary roles in achieving educational outcomes (EOs). The methodology involves controlling simulated electronic devices, such as lamps and buzzers, across the seven OSI layers, with an added focus on music melody and AI tools to enhance engagement and creativity in learning.

The methodology is designed using a scaffolding approach that consists of two main phases. In PHASE 1, which aims at activities without AI integration - "No-AI Simulation", students participate in Intra-Disciplinary pedagogy, focusing on Computer Networking, Software Engineering, and Hardware Electronics concepts, to understand the OSI layers. This is followed by an Inter-Disciplinary approach that integrates Music. In PHASE 2, the curriculum evolves to incorporate AI tools through a "With-AI Simulation", combining the aforementioned Intra-Disciplinary concepts with an AI API interface (e.g. Gemini/ChatGPT) to send prompt requests and receive responses ultimately generating musical melodies and showing Audio Engineering Inter-Disciplinary integration. In contrast to a monistic approach that focuses only on a single perspective, the proposed pluralistic approach incorporates intra- and inter-disciplinary elements, alongside both No-AI and AI integrated learning. This approach not only prepares students for the complexities of modern programming but also encourages critical reflection on the ethical implications of technology while fostering adaptability in the rapidly evolving technology landscape, ultimately enriching inclusive educational experiences.

Keywords: *Pluralism, Monism, Computer Network (CN), OSI (Open System Interconnection), API (Application Programming Interface), Generative Artificial Intelligence (GenAI) Large Language Models (LLM).*

Track: Education and Other Related Topics

Virtual Reference Feedback Tuning for Liquid Level Control of a Vertical Three Tank System

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Abstract: This paper presents the design of three monovariable control system structures for the liquid level control of a vertical three tank system using the Virtual Reference Feedback Tuning (VRFT) technique to tune the parameters of the linear controllers. The VRFT technique is particularly attractive in the framework of data-driven control techniques since it allows the parameters of linear feedback controllers to be identified directly from experimental input-output data, without needing a detailed parametric mathematical model of the process in a one-shot manner. Two types of controllers with 4 and 5 tuning parameters and integral action were considered for each control structure in order to conduct a comparative analysis. The designed control structures are tested in two scenarios: with a step reference input and with a pulse width modulated reference input. The experimental results demonstrate the potential of the VRFT in controlling this nonlinear system.

Keywords: *Data-Driven Control, Vertical Three Tank System, VRFT, Windsurfing Approach.*

Human Robot Interaction

Track: Human Robot Interaction

An Edge-AI and LF-RFID Guided Intelligent Station for Urban Animal Care and Tracking

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Abstract: Open stray-cat feeding points are common in Abu Dhabi, but any animal, including rats, can reach them, while public dog-waste bag dispensers are often emptied by people who take bags without a dog. This paper presents the design and proof-of-concept functional verification of an animal care station that combines an embedded edge-AI vision sensor (HUSKYLENS, Kendryte K210) with a 125 kHz low-frequency RFID (LF-RFID) reader. The station gates access to a cat feeder and a waste-bag compartment, logs visits of cats whose transponder ID is on a registered list, and releases a live-capture trap door and sends a GSM (SMS) alert when an unregistered cat or a rat is detected; a water bowl with level sensing stays open to all animals. The laboratory prototype, built around two Arduino UNO boards, was verified with photographs, plush and plastic animal figures, and two glass-encapsulated LF transponders; no live animals were used. All intended behaviors were demonstrated, but classification accuracy, RFID read range and false-activation rates were not quantified. A corrected power analysis gives a continuous input power of about 8.1 W (195 Wh/day) with the prototype's linear regulator, of which about 4.8 W is dissipated as heat; a buck converter would reduce this to about 3.7 W (89 Wh/day). The limitations of using transponder identity as a proxy for sterilization status, the welfare requirements for any trapping function, and a protocol for quantitative field evaluation are discussed.

Keywords: *Edge AI, HUSKYLENS, LF-RFID, ISO 11784/11785, Trap-Neuter-Return (TNR), Animal Welfare, Embedded Systems, Smart City.*

Navigation and Localization Systems

Track: Navigation and Localization Systems

Graph Signal Processing for Range-Based Mobile Robot Localization Learning

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Abstract: Mobile robot localization based on radio range measurements is challenged by measurement noise and occasional outliers caused by multipath and non-line-of-sight propagation. This paper investigates whether Graph Signal Processing (GSP) can improve localization by exploiting the spatial relationships among anchors. GSP is applied to the range residuals and integrated into least-squares trilateration and the Extended Kalman Filter (EKF). Four localization methods are evaluated in a Webots simulation using RSS-based range measurements. The results demonstrate that graph-based residual smoothing significantly reduces localization error, approximately halving the trilateration error and mitigates peak errors induced by outliers by a factor of three. These improvements are achieved with only a modest computational overhead, indicating that the proposed approach is suitable for real-time localization applications.

Keywords: Graph Signal Processing (GSP), Extended Kalman Filtering (EKF), Localization, Trilateration.

Track: Navigation and Localization Systems

Mobile Robot Navigation Algorithm with an Enhanced Reinforcement Learning Method

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Abstract: Mobile robot navigation is still a challenge, especially in dynamic environments. Robots struggle to adapt to changes in their environment, for example, when a random or moving obstacle appears. Traditional path planning algorithms like A* and Dijkstra demonstrate effective performance in a static environment; however, they show a lack of flexibility and adaptability when faced with dynamic changes in their environment. This study investigates different types of algorithms (graph-based, sample-based, local, and global). The algorithms were compared in different conditions, static and dynamic, before finally integrating the reinforcement learning method to enhance path planning and execution. This study demonstrates the potential of a hybrid navigation system that uses a global planner (Hybrid A* or D* Lite) combined with a local planner (potential field method for reactive steering) as well as the Q-learning method for speed control. The simulation was run on Webots using the built-in TurtleBot3 Burger. The results indicate that a global planner or a local planner alone struggles to adapt to dynamic changes and that a hybrid approach is essential for better adaptability, although the method should be refined to ensure stability and consistency in performance.

Keywords: Local Path Planning, Global Path Planning, Reinforcement Learning, Q-learning.

Track: Navigation and Localization Systems

Edge-Based 3D Reconstruction and Remote Monitoring Using a Stepper-Actuated 2D LiDAR over MQTT

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Abstract: Three-dimensional spatial perception is essential for low-cost robotic monitoring, yet commercial multi-beam LiDAR sensors remain expensive and computationally heavy. Actuation of a 2D LiDAR offers an affordable alternative, but limited scan coverage and

embedded hardware constraints present clear operational challenges. This paper introduces an economical spatial monitoring architecture that combines a planar 2D Robotis LDS-01 LiDAR, a 0.9-degree pitch actuator, and a Raspberry Pi 3B edge processor. Coordinate conversion, mechanical tilt alignment, and voxel-based motion filtering execute entirely on the edge node. Processed 3D point clouds stream through an MQTT/WebSockets pipeline to a browser interface powered by Three.js. Benchmark trials across 1,000 frames demonstrated a stable ingestion rate of 4.94 Hz with zero application-level frame loss. Under baseline conditions, QoS 0 achieved a smaller P95 latency than QoS 2. System latency also showed high stability under combined CPU and network stress, exhibiting only minor variations. Motion evaluation yielded a 7.10 percent alert-frame ratio and 100 percent event-level recall, alongside zero false-positive triggers across 500 static control frames. Future work will incorporate reference-based spatial calibration, quantitative dynamic-scene evaluation, adaptive scanning, and more predictable communication mechanisms toward robust deployment beyond controlled laboratory settings.

Keywords: 2D LiDAR, 3D Point Cloud Reconstruction, MQTT Protocol.

Track: Navigation and Localization Systems

A Comparative Evaluation of Local Planners for Differential-Drive Mobile Robots

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Abstract: Motion planning plays a significant role in mobile robots. This task is generally addressed in two layers. The global planner generates the reference path that leads the robot to the goal, while the local planner is responsible for producing collision-free velocity commands as it follows this path. This paper presents a fair comparison of the Dynamic Window Approach (DWA), Model Predictive Path Integral (MPPI), and Regulated Pure Pursuit (RPP) local planners in ROS 2 on a TurtleBot3 Burger. All planners were evaluated under consistent navigation parameters across four scenarios: static environment, dynamic environment and two narrow corridors. Prior to the main comparison, a parameter sensitivity analysis was carried out for each planner. The aim of this analysis was to examine the effect of the critical parameters that govern planner performance and to identify the most suitable parameter values for each planner. Each configuration was tested ten times in each scenario, resulting in a total of 520 trials. The performance of the local planners was compared using a set of metrics covering safety, efficiency, smoothness, and tracking accuracy. The findings indicate that no planner is universally superior. MPPI exhibited the largest safety margin, particularly in the environment containing moving obstacles. RPP produced the smoothest motion and the shortest paths in open environments and in corridors with 90° turns. DWA exhibited the largest variations in the velocity commands and the lowest motion smoothness. While DWA successfully completed all trials in the narrow corridor with 90° turns, it struggled in the diagonal narrow corridor requiring 135° turns and failed in one of the trials even with its most suitable parameter configuration. These findings provide a quantitative and scenario-dependent analysis for local planner selection in mobile robot applications.

Keywords: Mobile Robots, Local Path Planning, ROS 2, Nav2, Autonomous Navigation, Benchmarking.

Social and Service Robots

Track: Social and Service Robots

Contexts and Prospects of Humanoid Robots Deployment in Academic Libraries

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Abstract: In recent times, humanoid robots, which have been identified for their capability in fostering socio-economic development, have attracted considerable interest from researchers. Educational libraries are progressively transforming into hybrid institutions, serving multiple roles such as facilitating learning, digital scholarship, research, inclusiveness, outreach, and innovation. In such scenarios, the utilization of humanoid robots opens innovative avenues in terms of services, without the need to replace librarians, but rather as intelligent systems to enhance and personalize library services. This paper examines the current development trends and challenges hindering global adoption of humanoid robots in academic libraries using literature analysis, product assessment, and applications. Concurrently, through an examination of emerging technologies and development trends, this paper also outlines deployment prospects of humanoid robots in libraries, intending to serve as guidelines in the development of intelligent academic libraries.

Keywords: Academic Libraries, Artificial Intelligence, Humanoid Robots, Human-Robot Collaboration, Library Innovation.

Track: Social and Service Robots

Social Service Robots for the Chinese Aging Population: Key Technologies, Application Scenarios and Localized Implementation

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Abstract: Against the backdrop of China's rapid population aging, the supply gap in traditional elderly care services is becoming increasingly prominent, and social service robots are regarded as a promising solution for smart elderly care. However, existing research has paid relatively little attention to a paradox: technology continues to mature, yet actual implementation outcomes remain persistently divergent. This paper is a narrative review. Drawing on literature from robotics, human-computer interaction, and gerontology, it sorts out the core technology system of social service robots, compares three typical application scenarios, identifies implementation bottlenecks from five dimensions, and proposes optimization pathways. This paper proposes an explanatory view limited to domestic elderly care scenarios: whether social service robots for elderly care can be successfully implemented may depend more on the degree of alignment between technological solutions and the social realities of local elderly care than on technological advancement. This paper provides an analytical perspective on the localization and large-scale implementation of social service robots.

Keywords: Social Service Robots, Localized Implementation, Older Adults, China.

Track: Social and Service Robots

Design, Sensor Fusion Architecture, and Experimental Validation of an Embedded Mechatronic System for Multi-Stream Urban Waste Classification

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Abstract: The design, implementation, and physical validation of a laboratory-scale mechatronic system for the automated separation of three waste material classes: cellulose (paper), polymer (plastic), and ferrous metal, are presented in this paper. The prototype uses an ATmega328P-based controller, a belt-driven NEMA-17 carriage, an optical beam- break sensor, an inductive metal sensor, and a TCRT5000 reflective infrared sensor. Instead of using a learned or probabilistic classifier, the deterministic Weighted Evidential Sensor Fusion (WESF) scheme is designed as an ordinally weighted evidence-and-priority decision process. Class precedence, sensor thresholds, object-presence gating, and reject conditions are all made clear in the updated formulation. There are 500 sorting cycles in the physical assessment: 150 ferrous, 180 polymer, and 170 cellulose items. 473 correct classifications, or 94.6% overall accuracy, are found in the reported confusion matrix; a Wilson 95% confidence interval calculated from these counts is 92.3% – 96.3%. For ferrous, polymer, and cellulose, the corresponding class recall is 98.0%, 93.9%, and 92.4% respectively. The prototype produced an estimated throughput of 507 items per hour and a reported end-to-end response of roughly 1.6 seconds per lateral stroke. The stepper-drive kinematics were the 200 mm rail that required 16,000 microsteps, with 8,000 microsteps from the left limit to the 100 mm home position, and the theoretically commanded displacement at 1/16 micro stepping was 0.0125 mm per microstep. For cost accounting clarity, the component cost subtotals of \$48.20 were separated from the reported total prototype build cost of roughly 300 AED (≈\$81.7). The manuscript clearly states experimental limitations, clarifies benchmark comparability, and reinforces the literature basis.

Keywords: Automated Waste Sorting, Sensor Fusion, Mechatronics, Embedded Systems, Micro Stepping, Material Classification, Recycling.

Track: Social and Service Robots

Design and Experimental Validation of an Off-Grid Smart Solar-Powered Food Composter Bin (SoliBin)

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Abstract: A major global sustainability issue, food waste accumulation speeds up the depletion of landfill space and increases anthropogenic greenhouse gas emissions, particularly carbon dioxide (CO₂) and methane (CH₄). Conventional municipal and residential disposal techniques, like incineration, landfilling, and passive composting, have serious drawbacks in terms of process kinetics, reliance on grid energy, or localized environmental contamination. In this paper, an autonomous, off-grid Smart Solar Food Composter Bin (SoliBin) is developed, optimized, and rigorously validated through experiments. The system converts 3.0 L of heterogeneous raw organic food waste into 0.3 L of stabilized, nutrient-rich compost in a 6-hour thermophilic cycle, achieving an accelerated 90% volume reduction. Using a 200 W/12 V photovoltaic array controlled by an active dual-axis solar tracking gimbal and buffered by a 12 V, 4.5 Ah sealed lead-acid battery, SoliBin runs completely off the grid. An ATmega328P microcontroller interfaces with a high-precision, real-time sensor array that tracks temperature (DS18B20), hazardous gas emissions (MQ-135), and substrate matrix pH (SEN0161-V2) to carry out system orchestration. A multi-stage mitigation architecture that includes a UV-C sterilization array, activated carbon filtration, a biochar/zeolite absorption matrix, and high-performance silicone perimeter gaskets is used to preserve hygiene and achieve zero-odor escape. The SoliBin configuration outperforms traditional passive and grid-tied electric alternatives, according to multi-criteria decision analysis, with scores of 4.60/5.00 across standardized engineering performance indexes. Complete energy autonomy and highly repeatable processing kinetics appropriate for decentralized urban waste deployment are confirmed by thorough statistical analysis over twenty repeated test cycles, empirical mass balance tracking, and detailed mathematical modeling of system thermodynamics.

Keywords: IoT sensors, Off-Grid Systems, Circular Economy, Waste Reduction, Smart Compost, Solar Tracking System, Food Waste Management.