ARCHIVOS REFERENCIAS-ESTADO DEL ARTE PROYECTO DE GRADO

1. Autonomous Indoor Navigator
   by Aleena Sojan , Cyril Thomas, Bhadra Raj, Sam Abraham Simon,Shajimon K John, Arukant A Jose Muthoot Institute of Technology and Science, Ernakulam, Kerala shajimonkjohn@mgits.ac.in

   Abstract
   Autonomous navigation systems play a vital role in enabling mobile robots to navigate and operate efficiently in dynamic environments without human intervention. These systems integrate various technologies, including LiDAR-based mapping, sensor fusion, localization, path planning, and obstacle avoidance, to ensure accurate and safe movement. The core components include Simultaneous Localization and Mapping (SLAM) for map generation, Adaptive Monte Carlo Localization (AMCL) for real-time positioning, and the Navigation Stack (Nav2) for path planning and execution. Sensor inputs from LiDAR, encoders, and IMUs help in refining localization and odometry, while real-time obstacle detection mechanisms enhance navigation reliability.This work demonstrates a cost-effective and scalable approach to autonomous navigation, with future enhancements planned for multi-floor navigation, improved hardware integration, and product-level development. Index Terms— robot operating system, navigation, localization, path planning,mapping,LiDAR,object detection

2. Collaborative Perception in Multi-Robot Systems: Case Studies in Household Cleaning and Warehouse Operations

   By Bharath Rajiv Nair Dept. of Mechanical Engineering Columbia University New York, USA bharathnair2637@gmail.com

   Abstract
   This paper explores the paradigm of Collaborative Perception (CP), where multiple robots and sensors in the environment share and integrate sensor data to construct a comprehensive representation of the surroundings. By aggregating data from various sensors and utilizing advanced algorithms, the collaborative perception framework improves task efficiency, coverage, and safety. Two case studies are presented to showcase the benefits of

collaborative perception in multi-robot systems. The first case study illustrates the benefits and advantages of using CP for the task of household cleaning with a team of cleaning robots. The second case study performs a comparative analysis of the performance of CP versus Standalone Perception (SP) for Autonomous Mobile Robots operating in a warehouse environment. The case studies validate the effectiveness of CP in enhancing multi-robot coordination, task completion, and overall system performance and its potential to impact operations in other applications as well. Future investigations will focus on optimizing the framework and validating its performance through empirical testing. Index Terms—Collaborative perception, multi-robot systems, deep learning, robot perception, autonomous mobile robots.

3. Development of an Indoor Delivery Mobile Robot for a Multi-Floor Environment

By TAEJIN KIM 1 , (Student Member, IEEE), GYUREE KANG 2 , (Student Member, IEEE), DAEGYU LEE 2 , (Student Member, IEEE), AND D. HYUNCHUL SHIM 2 , (Member, IEEE)

Abstract

In recent years, the demand for delivery services has increased by applying robot technology in various fields such as food services, logistics, hospitals, and hotel business. However, it is still challenging to perform autonomous delivery in multi-floor buildings. Particularly for wheeled robots, the use of elevators is essential for indoor last-mile delivery service in buildings. To tackle the problem, We have developed an indoor delivery mobile robot and present its architecture designed for multi-floor environments. The architecture consists of five modules: map management for utilizing an integrated navigation map, localization, path planning, perception, and task planning. The integrated navigation map is generated by combining multi-floor point cloud maps and topological maps based on node graphs for effective localization and path planning. Additionally, the proposed 3D route planning allows inter-floor movement. A feasible path for boarding the elevator can be generated through the perception module, and delivery services to multiple destinations can be repeatedly performed through task planning. Our architecture's effectiveness is demonstrated through a month-long field test in an ordinary building during regular business hours. This study's contributions include a novel architecture for autonomous delivery without human intervention, an integrated map for efficient indoor navigation, and the proven robustness of the system in real-world

4. “Elevator or Stairs” A Layered Reinforcement Learning Approach for Robot Multi-Floor Navigation in High-Traffic Scenarios

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   Abstract
   Robots have major cross-floor navigation problems in high-rise buildings with large traffic. Conventional techniques are flawed in that they are not able to adequately measure dynamic expenses as well as multi-modal change costs. In this paper, a hierarchical reinforcement learning method derived on the complete visual perception concept is proposed, which enables an efficient decision-making process by having a manager-executor architectural design. The high-level strategy relies on a dual-stream visual network to combine semantic data in the environment to intelligently select the with either of the two possible movement options of either elevator or staircase, whereas the low-level strategy operates a sequential vision network (CNN-LM) to decode high-level instructions into continuous motion control commands, to achieve accurate movement and avoid obstacles. Using a non-linear rewarding system to calculate the dynamic costs and mode-switching punishment, in theory, average delivery time can be reduced by 15 to 25 percent and compliance of the task is increased to more than 95 percent. It is likely to perform much better than heuristic rules and available learning baselines. The suggested hierarchical decision model offers a new theoretical platform to address vertical logistics in complicated indoor setting where service robots operate that would offer valuable information to optimize autonomous decision-making abilities of robots in highly dynamic conditions.

5. LITE: A Learning-Integrated Topological Explorer for Multi-Floor Indoor Environments

By Junhao Chen1 , Zhen Zhang1 , Chengrui Zhu1 , Xiaojun Hou1 , Tianyang Hu1 , Huifeng Wu2 , Yong Liu1,∗

Abstract

This work focuses on multi-floor indoor exploration, which remains an open area of research. Compared to traditional methods, recent learning-based explorers have demonstrated significant potential due to their robust environmental learning and modeling capabilities, but most are restricted to 2D environments. In this paper, we proposed a learning-integrated topological explorer, LITE, for multi-floor indoor environments. LITE decomposes the environment into a floor-stair topology, enabling seamless integration of learning or non-learning-based 2D exploration methods for 3D exploration. As we incrementally build floor-stair topology in exploration using YOLO11-based instance segmentation model, the agent can transition between floors through a finite state machine. Additionally, we implement an attention-based 2D exploration policy that utilizes an attention mechanism to capture spatial dependencies between different regions, thereby determining the next global goal for more efficient exploration. Extensive comparison and ablation studies conducted on the HM3D and MP3D datasets demonstrate that our proposed 2D exploration policy significantly outperforms all baseline explorers in terms of exploration efficiency. Furthermore, experiments in several 3D multi-floor environments indicate that our framework is compatible with various 2D exploration methods, facilitating effective multi-floor indoor exploration. Finally, we validate our method in the real world with a quadruped robot, highlighting its strong generalization capabilities.

6. Modified Bug Algorithm with Proximity Sensors to Reduce Human-Cobot Collisions

By: Anran Li School of Engineering and Computer Science Washington State University, Vancouver, USA anran.li@wsu.edu Hakan Gurocak School of Engineering and Computer Science Washington State University, Vancouver, US

Abstract

This paper presents an adaptation of the mobile robot bug algorithm to control a cobot to reduce collisions with a human worker in the same work cell. Collaborative robots (cobots) are popular in industry because they enable close collaboration between a human and a robot. Although the cobot can stop when a collision happens, it is not a pleasant or safe working environment for the human to be hit by the cobot possibly multiple times a day. The proposed approach uses inexpensive proximity sensors on the cobot and a simple algorithm. An adjustable yaw angle is introduced to the algorithm to further reduce collisions. Results from pick-and-place experiments with UR 10 cobot show significant reduction of collisions,

7. Multi-Robot System for Mapping and Localization

By: Glace Varghese T1 , Thambbireddygare G. C. Reddy1 , Anjana K Menon1 , Ajay Paul2 , Sreeja Kochuvila1 , Varma Divya R2 , Ravichandra Bhat2 and Navin Kumar1 1Department of Electronics and Communication Engineering, Amrita Vishwa Vidyapeetham, Bangalore, India 2Robotics - SX/PJ1-EM, Bosch Global Software Technologies, Bengaluru, India anjanamenon1203@gmail.com, goweshreereddyt@gmail.com, glacevargheset96@gmail.com, ajay.paul@in.bosh, k_sreeja@blr.amrita.edu, divya.radhakrishnavarma@in.bosch.com, ravichandra.bhat@in.bosch.com, navinkumar@ieee.org

Abstract

In this work, we developed algorithm for coordinated multi-robot system. It is developed for simultaneous localization and mapping (SLAM). Many novel applications of multi-robot system especially, in the industrial indoor environment and complex/dangerous environment are being envisioned. The proposed algorithm focuses on optimizing navigation and execution of tasks within an environment. We used TurtleBot3 Waffle model and robot operating system (ROS) platform and simulated in Gazebo for localization, navigation and comprehensive coverage. The algorithm achieves effective mapping, localization, navigation, and coverage. Algorithm also ensures seamless coordination among multiple robots within a unified transform-tree (tf-tree) facilitating synchronized movement and a holistic understanding of the environment. Furthermore, an innovative coverage path planning and submap

division is achieved using this technique. It is expected that such development would lead to practical applications in the real environment.

8. Multi-robot Systems Using Broadcast Control Framework with Visual-Based Tracking

By: Bhuvendhraa Rudrusamy School of Engineering & Physical Sciences Heriot-Watt University Malaysia Putrajaya, Malaysia b.rudrusamy@hw.ac.uk Chun Wei Tan School of Engineering & Physical Sciences Heriot-Watt University Malaysia Putrajaya, Malaysia ct100@hw.ac.uk Mun Ping Yang School of Engineering & Physical Sciences Heriot-Watt University Malaysia Putrajaya, Malaysia my32@hw.ac.uk Rohindaran Ramunathan School of Engineering & Physical Sciences Heriot-Watt University Malaysia Putrajaya, Malaysia rqr2000@hw.ac.uk Yu Jin Ng School of Engineering & Physical Sciences Heriot-Watt University Malaysia Putrajaya, Malaysia yn13@hw.ac.uk Florence Chiao Mei Choong School of Engineering & Physical Sciences Heriot-Watt University Malaysia Putrajaya, Malaysia f.choong@hw.ac.uk Mohamad Hafizulazwan Mohamad Nor Technology Disciplines Petronas Research Sdn Bhd Bangi, Selangor, Malaysia mohamadhafizula.moha@petronas.com.my

Abstract

The multi-robot application is becoming more critical in achieving complex collaborative tasks. This requires an efficient multi-agent robot system that supports distributed tasks, time and energy consumption. One of the developing control methods is the broadcast control framework. We found that variants of broadcast control techniques were validated on simulation only and lacked experimental work. Therefore, this paper focus on the experimental investigation of a variant of the broadcast control framework. To create a similar environment to the application, we developed the system using Raspberry Pi, AlphaBots, a webcam, and Bluetooth as the central controller, robots, visual tracking, and wireless communication. We successfully validated the system in an indoor environment. The experimental finding shows the travelling trajectory of the robots differs from the MATLAB simulation results. Nonetheless, the broadcast control framework system was able to achieve the final target accurately. This paper provides implementation details and challenges for future research and development of a broadcast control

framework. We propose to include obstacle avoidance in robots as a new study direction.

9. Robot-Elevator Interaction Through IoT Devices for Autonomous Robot Multi-floor Transition

   By: Zhi Song School of Mechanical and Aerospace Engineering Nanyang Technological University Singapore zhi005@e.ntu.edu.sg Shanhe Lou School of Mechanical and Aerospace Engineering Nanyang Technological University Singapore shanhe.lou@ntu.edu.sg Runjia Tan School of Mechanical and Aerospace Engineering Nanyang Technological University Singapore runjia.tan@ntu.edu.sg Chen Lv School of Mechanical and Aerospace Engineering Nanyang Technological University Singapore lyuchen@ntu.edu.sg

   Abstract

   Navigating between floors in a building poses a traditional challenge for robots, often involving manual efforts or complex solutions. This paper addresses the inherent problems focusing on Autonomous Mobile Robots. Presented here is an innovative method for automating conveyor systems, specifically elevators, to facilitate the seamless integration of AMRs into various operations. The proposed robot-elevator integration solution employs a flexible system and an IoT actuator kit that easily integrates with existing elevators, ensuring compatibility with the system already in place. Utilizing imaging sensors and machine learning for real-time object recognition, the system autonomously responds to AMRs in different zones. Proof-ofconcept results demonstrate the feasibility and advantages of the proposed approach in terms of safety and operational efficiency.

10. Multi-level control for multiple mobile robot systems

   By: Elzbieta Roszkowska · Piotr Makowski-Czerski2 · Lukasz Janiec

   Abstract

   This paper contributes with a multi-level, hierarchical control system for a fleet of mobile robots sharing a common 2D motion space. The system consists of three levels, with the top level being a supervisor based on a discrete representation of the Multiple Mobile Robot System (MMRS), in which robot motion processes are seen as sequences of stages. The supervisor controls

centrally the changes of their stages by robots, ensuring their collision-, and deadlock-free concurrent movement. The intermediate control level supervises locally the execution of robot motion on individual stages in a manner consistent with the decisions of the top level. The lowest level, robot control, is responsible for motion execution as determined by the local supervisor. We capitalize on some earlier results concerning the supervisory control of MMRS and propose a common framework for three supervisory control models. Then we propose relevant solutions for the local supervisors, in particular, a DES-based robotmotion-mode control and application of the Artificial Potential Field model for ensuring collision-free motion of two robots sharing a space sector. Next we assume simple robot control and subject the system to simulation experiments aimed at comparing the impact of the different solutions on the performance of MMRS.

11. Stairway to Success: An Online Floor-Aware Zero-Shot Object-Goal Navigation Framework via LLM-Driven Coarse-to-Fine Exploration

    By: Zeying Gong , Student Member, IEEE, Rong Li, Tianshuai Hu , Ronghe Qiu, Graduate Student Member, IEEE, Lingdong Kong , Lingfeng Zhang , Guoyang Zhao , Yiyi Ding, and Junwei Liang , Member, IEEE

    Abstract

    Deployable service and delivery robots struggle to navigate multi-floor buildings to reach object goals, as existing systems fail due to single-floor assumptions and requirements for offline, globally consistent maps. Multi-floor environments pose unique challenges including cross-floor transitions and vertical spatial reasoning, especially navigating unknown buildings. ObjectGoal Navigation benchmarks like HM3D and MP3D also capture this multi-floor reality, yet current methods lack support for online, floor-aware navigation. To bridge this gap, we propose ASCENT, an online framework for Zero-Shot Object-Goal Navigation that enables robots to operate without pre-built maps or retraining on new object categories. It introduces: 1) a Multi-Floor Abstraction module that dynamically constructs hierarchical representations with stair-aware obstacle mapping and cross-floor topology modeling, and 2) a Coarse-to-Fine Reasoning module that combines frontier ranking with LLM-driven contextual analysis for multi-floor navigation decisions. We evaluate on HM3D and MP3D benchmarks, outperforming state-of-the-art zero-shot approaches, and demonstrate real-world deployment on a quadruped robot.

12. Diseño e implementación de un sistema Multi-Robot de código abierto para ambientes colaborativos en ROS2.

    By: Anthonny Ernesto Piguave Toala y Diego Sebastian Ronquillo Manosalvas

    Abstract:

    En la actualidad, a pesar del auge de la robótica y la automatización en aplicaciones industriales, la adopción generalizada de la robótica colaborativa sigue siendo limitada debido a la falta de interoperabilidad entre robots y la baja adaptabilidad de los sistemas existentes. Solucionar esta problemática supondría un avance importante en la robótica y automatización industrial. Bajo ese contexto, en el presente proyecto se desarrolló un FrameWork MultiRobot de código abierto basado en ROS2 para la comunicación y coordinación efectiva de sistemas mecatrónicos y sensores en entornos colaborativos cerrados. Se realizó un diseño de software y control basado en simulación utilizando la herramienta de Gazebo. Se obtuvo una arquitectura centralizada con un módulo de navegación autónoma para la planificación y seguimiento de rutas de los robots, un módulo de visión por computadora para la localización y manejo de incertidumbres, y un módulo controlador de tareas para la asignación de misiones de movilización de objetos. En conclusión, utilizando ROS2 para lograr la comunicación y coordinación eficaz de diversos sistemas mecatrónicos se logra obtener una solución robusta, flexible y escalable; parámetros claves en los procesos industriales.

13. Arquitectura cognitiva para integración de usuarios humanos dentro de un sistema de mapas multinivel en una plataforma robótica asistencial

    By: Marta Jiménez Muñoz

    En este Trabajo Fin de Máster se ha abordado el diseño y el desarrollo de una aproximación a una arquitectura cognitiva para la identificación y ubicación de usuarios humanos de una plataforma robótica dentro de un mapa semántico. El sistema permite registrar y entrenar el modelo de reconocimiento facial con nuevos usuarios. Se genera un mapa de obstáculos con la ubicación de las personas más cercanas y los objetos detectados, al mismo tiempo que se crea un mapa semántico con la ubicación de cada persona siguiendo un código de colores. La arquitectura cognitiva, a través de un mapa semántico con una estructura de datos, es capaz de memorizar a los usuarios reconocidos junto a las coordenadas y la franja horaria correspondiente, así como de olvidar a

aquellos que no ha reconocido desde hace tiempo en los lugares donde solían estar. Esta aproximación a una arquitectura cognitiva ofrece la posibilidad de poder predecir la ubicación de una persona buscada en un momento concreto, lo que habilita al robot para realizar tareas de vigilancia y búsqueda. Este sistema ha sido probado con un robot asistencial real en un entorno de laboratorio, quedando preparado para una fase de despliegue en el entorno real de una residencia de mayores