RoamiO - Indoor Autonomous Robot Navigation

Literature Review

Indoor autonomous navigation has become a significant area of research in robotics, with applications spanning service robots, healthcare, warehouse automation, and intelligent surveillance. The challenge lies in enabling robots to traverse structured and semi-structured environments efficiently while avoiding static and dynamic obstacles. The development of robust navigation systems integrates path planning algorithms, obstacle detection, and user interaction models.

Pathfinding and Navigation Algorithms

The **A*** algorithm is among the most widely adopted pathfinding techniques in robotics and game development due to its efficiency and optimality (Hart, Nilsson, & Raphael, 1968). It combines the benefits of uniform-cost search and greedy best-first search by using a heuristic function to estimate the cost of reaching the goal. While effective in static environments, traditional A* struggles with dynamic obstacles, prompting extensions such as D*-Lite (Koenig & Likhachev, 2002) and Theta* for smoother paths.

Obstacle Avoidance

Obstacle avoidance remains critical in autonomous navigation. Indoor spaces often contain both **static obstacles** (walls, furniture) and **dynamic obstacles** (humans, moving robots). Reactive obstacle avoidance methods, such as the **Dynamic Window Approach (Fox, Burgard, & Thrun, 1997)**, complement global pathfinding algorithms by allowing robots to adapt trajectories in real time. Hybrid methods often integrate A* for global planning and local reactive controllers for safety.

Human-Robot Interaction

User interaction enhances robot navigation by providing intuitive ways to set goals and monitor progress. Click/tap-based target selection in simulated or real environments is common in robotic teleoperation and semi-autonomous navigation systems. Smart camera systems, such as overhead or following perspectives, improve user understanding of robot movement and system state.

Simulation Platforms

Unity has emerged as a robust platform for robotics simulation due to its physics engine, ease of visualization, and support for both 2D and 3D environments. Previous studies have highlighted Unity's potential in developing proof-of-concept navigation systems before transitioning to real-world robots (Craighead et al., 2007). Its compatibility with C# and integration with machine learning libraries further expands possibilities for future autonomous navigation research.

Future Directions

Recent research emphasizes the role of **multi-robot navigation**, **path optimization using splines/Bezier curves**, and **machine learning-based approaches** such as reinforcement learning for adaptive navigation. Additionally, immersive technologies like **VR and AR** are increasingly leveraged to simulate complex environments and enhance training.

Conclusion

Indoor robot navigation systems such as *RoamIO* integrate foundational methods like A* with modern simulation capabilities provided by Unity. While the current implementation demonstrates efficient pathfinding and obstacle avoidance, future work lies in scaling to multi-agent systems, improving path smoothness, and exploring adaptive learning-based models for real-world deployment.