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Dynamic Environment Navigation Using Hybrid Control Algorithms for Autonomous Mobile Robots

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Introduction. Mobile robots have become indispensable across various domains such as agriculture, military, medicine, education, mining, space exploration, and entertainment. Equipped with advanced artificial intelligence, these robots autonomously navigate environments, comprehend surroundings, plan paths, and avoid obstacles without human intervention [1]. Pathfinding is a critical aspect of robot navigation, ensuring optimal movement while avoiding collisions [2].

Neural networks (NNs) are widely used for signal processing, classification, and forecasting, offering nonlinear, multi-layered regression capabilities [3]. Meanwhile, fuzzy logic effectively handles uncertainty, complexity, and nonlinearity in decision-making. The integration of NNs and fuzzy logic, known as neuro-fuzzy systems, enhances adaptability by combining learning capabilities with human-like reasoning [4].Various navigation strategies have been explored, often integrating multiple techniques for improved efficiency. Reactive approaches, such as the Artificial Potential Field (APF) method, are particularly effective in dynamic environments, where obstacles and targets change unpredictably [5]. Several studies have also addressed path planning for moving targets, proposing methods that allow mobile robots to adapt in real time while minimizing deviations from optimal trajectories[6]. This study presents an approach that combines APF for pathfinding, a Bayesian Regressing Neural Network (BRNN) for obstacle classification, and fuzzy logic for adaptive collision avoidance. Unlike traditional methods, it extends navigation beyond static obstacles to account for dynamic targets, improving real-time adaptability. The system is implemented in MATLAB and validated in the V-REP simulation environment.

Main Part. The proposed system for autonomous mobile robot navigation integrates multiple techniques to ensure efficient and adaptive movement. The Artificial Potential Field (APF) algorithm generates a safe trajectory by balancing attractive forces toward the goal and repulsive forces from obstacles, enabling effective path planning while avoiding static obstacles.

To enhance perception, three ultrasonic sensors provide distance measurements, while relative velocity and angle data assist in hazard assessment. A Bayesian Regressing Neural Network (BRNN) classifies obstacles into Zone 1 (High Risk) or Zone 2 (Low Risk) based on collision probability. When an obstacle falls into Zone 1, fuzzy logic dynamically adjusts the robot’s wheel velocities, ensuring smooth and efficient obstacle avoidance without abrupt stops or unnecessary detours.

A key feature of this approach is dynamic target tracking, allowing the robot to navigate toward a moving target while continuously monitoring and avoiding obstacles in real time. Unlike traditional methods, this enhances adaptability in complex environments. The system is implemented in MATLAB and tested in V-REP (CoppeliaSim). Simulation results confirm its robustness, adaptability, and efficiency in handling both static and dynamic obstacles while tracking a moving target.

Conclusion. The proposed system effectively tackles dynamic obstacle avoidance in unknown environments. By utilizing APF for path planning and integrating BRNN classification with fuzzy logic control, the robot efficiently navigates while avoiding obstacles. The MATLAB and V-REP simulation environment serves as a robust platform for testing and validating the system's performance.

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