Thesis: Metareasoning, Opportunistic Exploration, and Explanations for Autonomous Indoor Navigation

Abstract: Autonomous indoor navigation is an important task for mobile robots deployed without a map in real-world environments, such as museums or offices. While it travels, an autonomous robot navigator must contend with lack of prior knowledge, sensor noise, actuator error, and inquisitive people. This dissertation addresses these challenges with a cognitively-based hierarchical reasoning architecture that incorporates learning, exploration, reactivity, planning, heuristics, and explanations. Evaluation by simulation in large, complex, indoor environments shows that a robot controller can successfully navigate without a map when it performs limited initial global exploration and plans in its learned spatial model.

This dissertation makes multiple contributions. It introduces novel spatial representations of freespace that abstract noisy sensor data and facilitate flexible action selection. It presents new exploration algorithms that focus on initial global connectivity and opportunistic local discovery to forgo the need for mapping. It addresses failure to make progress towards a target with metareasoning that intervenes with appropriate reactive planners. It formulates a hierarchical planning approach in the learned freespace-based spatial model that allows the robot to take novel shortcuts and to delay action selection until execution time. Finally, it exploits the robot controller’s cognitive basis to generate diverse, understandable natural language explanations of its behavior, confidence, and intentions. Together these contributions produce a robust, self-sufficient, human-friendly robot controller for autonomous indoor navigation.

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