WPI Aerospace Engineering Dept


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PhD Candidate


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**Dissertation Committee:**

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Prof. David Olinger, Aerospace Engineering Department, WPI

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## PhD Dissertation Defense Presentation

# Optimal Path Planning in Unknown, Dynamic Environments


Abstract:

Autonomous vehicles operating in unknown, dynamic environments must make navigation decisions while learning about the surrounding environment from sparse observations gathered during mission execution. This dissertation studies that coupled sensing, estimation, and planning problem in two settings: navigation through evolving threat fields motivated by wildfire propagation, and minimum-time traversal in urban environments with initially unknown winds. In both cases, sensing is treated not as a separate preliminary task, but as part of the mission itself, with value determined by its effect on future path decisions.

The first research thrust develops an actively coupled sensing and planning framework for unknown, time-varying threat fields. This framework is extended to a wildfire setting in which a ground vehicle relies on small aerial sensing vehicles to gather observations relevant to future path cost. To make information-driven sensing tractable in a large dynamic state space, approximate formulations of context-relevant mutual information and standard mutual information are introduced. A later journal extension replaces this approximation with a reduced-order proper orthogonal decomposition formulation for compressed information evaluation while preserving the coupled sensing-and-planning structure.

The second research thrust addresses small uncrewed aerial vehicles operating in urban wind fields that are unknown before flight. Because wind information is available only along previously traversed paths, the environmental state must be inferred from partial, path-constrained measurements and incorporated into later routing decisions. A sequential signal-stitching strategy is developed to update edge traversal costs and improve future route selection. This framework is then extended to a two-dimensional verification setting, which shows that edge-dependent spatial flow structure must be incorporated once the wind field is resolved over a realistic urban geometry.

Together, these results show that near-optimal navigation can be achieved without complete prior environmental knowledge when sensing, estimation, and planning are explicitly coupled during mission execution. More broadly, the dissertation demonstrates that in partially observable dynamic environments, successful autonomy depends less on full-state reconstruction than on estimating the environmental structure most relevant to the decision at hand.