***Department of Mechanical and Aerospace Engineering***

***Doctoral Dissertation Defense***

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**GWU SEH – Room 2990**

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***"Multi-Robot Probabilistic Mapping and Exploration"***

**Abstract**

This dissertation focuses on robotic mapping and exploration of uncertain environments. Computational algorithms are developed to provide complete stochastic information of the environments. These algorithms are designed for real-time implementation for robotic autonomy. First, probabilistic occupancy grid mapping is developed according to Bayesian framework. A novel approach to this problem is explored, which uses important physical properties of the environment and stochastic properties of depth sensors. We develop an exact solution to occupancy grid probability that can be achieved in real-time using sensor properties and conventional assumptions of an occupancy grid. The rapid computation allows the algorithm to consider large scans of measurements in 2D and 3D environments. The mapping algorithm is demonstrated with several numerical examples and experiments. The next topic is autonomous exploration, where a robot selects actions to maximize its knowledge about the probabilistic map. We select Shannon's entropy as a metric that represents grid cell uncertainty. Using the earlier contributions on probabilistic occupancy grid mapping, we determine the expected value of entropy change from possible future measurements. This entropy change provides important insights for where a robot should move to maximize its mapping information gain. Dijkstra's search is integral to the algorithm to account for collision-free distances during motion planning. This algorithm is designed for 2D and 3D, where computation time is carefully considered to ensure real-time algorithm performance. Several versions of the exploration algorithm are applied to simulations and experiments. The final topic of this dissertation relates to multi-vehicle cooperative scenarios. The mapping algorithm is revised to accept measurements from multiple sources with differing sensor properties. More importantly, the exploration algorithm structure is modified with a bidding-based framework. A series of auctions determines where robots should travel such that the members act together as a team. This solution is further extended to multi-vehicle patrol, where robots begin with an uncertain map, autonomously explore the space, and periodically revisit regions. Autonomous multi-vehicle patrol is accomplished through map degradation, where the probabilistic map becomes more uncertain over time, and the robots must revisit these spaces. These complex algorithms are demonstrated with numerical simulations. In short, this dissertation proposes novel solutions to probabilistic occupancy grid mapping, autonomous exploration, and patrol in single-vehicle and multi-vehicle scenarios. Real-time implementation is paramount to ensure autonomy during a task. The efficacy of the approaches are shown with several experiments and numerical examples.