Algorithms for Rapid Radiation Source Location with a Drone

CC Davis, ME Trager, AJE Kent, LK Chung, JD Noey
University of Michigan
Prof. KJ Kearfott, kearfott@umich.edu
Consortium for Monitoring, Technology, and Verification (MTV)

Introduction and Motivation

- Manual location of radiation sources inefficient and dangerous
- Unmanned aerial vehicles (UAVs) allow remote operations
- Desire efficient navigation with real-time data collection
- Algorithms enable mapping and allow an optimal approach for a single UAV
- Works for any robotics platform, but UAVs allow line-of-sight, avoiding intervening attenuating materials, and do not have navigational paths restricted by roads and other infrastructure

Mission Relevance

- This project seeks to provide an efficient avenue of accurately and quickly localizing sources of radiation in an environment.
- The methods presented in this project would directly facilitate the location and recovery of any sources, let alone lost or stolen ones.

Technical Approach

- **Maximum a Posteriori Estimation** (MAP), **Least Squares**, **Recursive Bayesian Estimation**, and **Hill-Climbing**.
- MAP Estimation and Least Squares exploit Inverse-square Law
- The Recursive Bayesian Estimation method adapts particle filter
  - Monte Carlo Localization
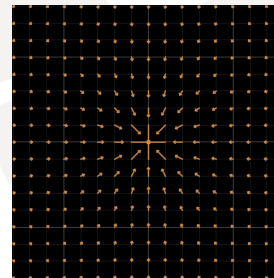- Hill-Climbing uses coordinate ascent to maximize each axis

$$\underset{x_s,y_s,z_s,k}{\mathrm{argmin}} \sum_{i=1}^{n} \left(\frac{k}{(x_i - x_s)^2 + (y_i - y_s)^2 + (z_i - z_s)^2} \right)^2$$
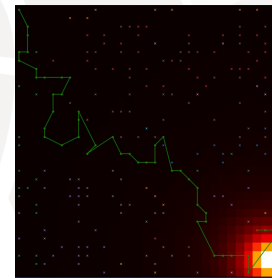
- Least Squares Optimization Formula
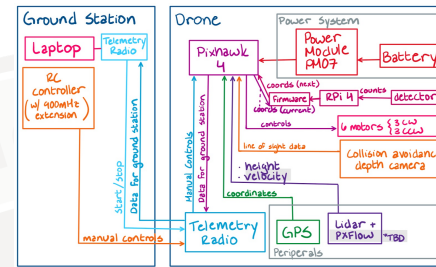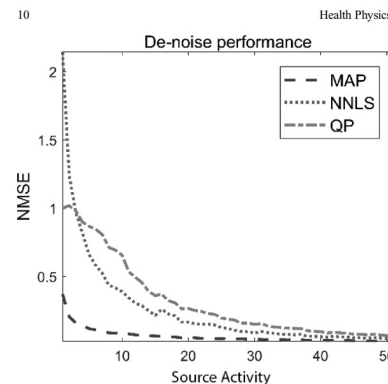

- Drone System Diagram

Results

- MCL Vector Field Map

- Recursive Bayesian Estimation

- MAP vs Least Squares Denoising and Accuracy

Liu T, Di Fulvio A, Chung LK, Kearfott KJ. Radiation mapping for unmanned aerial vehicle: development and simulated testing of algorithms for source mapping and navigation path generation. Health Phys 120(0):000-000; 2021.

Expected Impact

If successful, this project offers a more efficient approach to traditional surveying and detection techniques

MTV Impact

- Prepared for future UROP and Health Physics Society Presentations
- Early introduction to Particle Filtering, Kalman Filtering, and other statistical topics beyond current undergraduate level

Conclusion

- MAP Estimation requires suitable prior and sampling resolution
- Least Squares provides an efficient, but cumbersome, approach
- Recursive Bayesian Estimation's efficiency and efficacy controlled by point-cloud size
- Hill-Climbing requires minimal computations, so can be run on weaker systems

Next Steps

- Run trials on simulated data
- Integrate algorithms into UAV pipeline
- Run physical trials on UAV testbed, substituting with non-ionizing WiFi
- Compare time, calculations, accuracy, and efficiency of routes
- Multi-, and single-source trials