Sequential Particle Filter Localization Algorithm for Locating Radioactive Sources

Abhishek P. Dahad

Sophomore, University of Michigan

Christopher C. Davis, Kimberlee J. Kearfott

University of Michigan

Introduction and Motivation

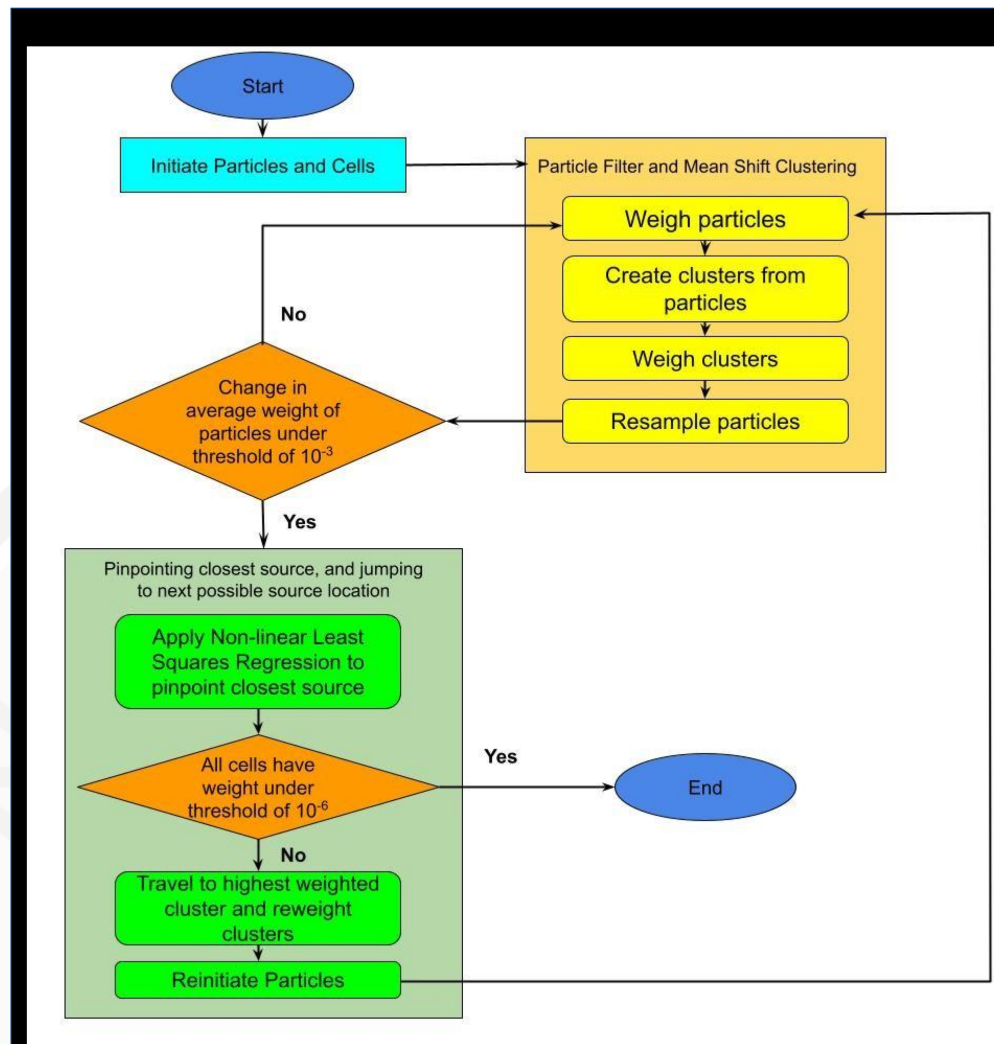
- Manual location of radiation sources in the field can be dangerous and inefficient.
- Autonomous devices with radiation detectors, such as ground-based robots or unmanned aerial vehicles, can solve both issues.
- Independent of platform, faster localization may be possible with algorithms to optimize navigation.
- Multi-source scenarios are difficult to navigate via previous methods due to local extrema, but Sequential Particle Filtering overcomes this.

Mission Relevance

- Improved response to radiological incidents
- Verification and monitoring of locations and strengths of radioactive sources for material management and recovery
- Improved background characterization by driving focus to areas of increased radioactivity

Technical Approach

- Multiple subroutines consisting of Monte Carlo localization algorithms, regression algorithms, and unsupervised clustering algorithms
- Greedy algorithm type chosen to sequentially locate multiple radioactive sources
- Tested with simulated radiation counts with a fixed number of sources with randomized coordinates
- Developed in Python using libraries such as NumPy, SciPy, and scikit-learn



▲ Algorithm control flow

Particle Filter $(\mathcal{X}_{t-1}, u_t, z_t)$:

$\bar{\mathcal{X}}_t = \mathcal{X}_t = \emptyset$

for n to N:

 sample $x_t^{[n]} \sim p(x_t \mid u_t,\, x_{t-1}^{[n]})$

 $w_t^{[n]} = p(z_t \mid x_t^{[n]})$

 $\bar{\mathcal{X}}_t = \bar{\mathcal{X}}_t + \left\langle x_t^{[n]},\, w_t^{[n]} \right\rangle$

end

for n to N:

 draw i with probability $\propto w_t^{[i]}$

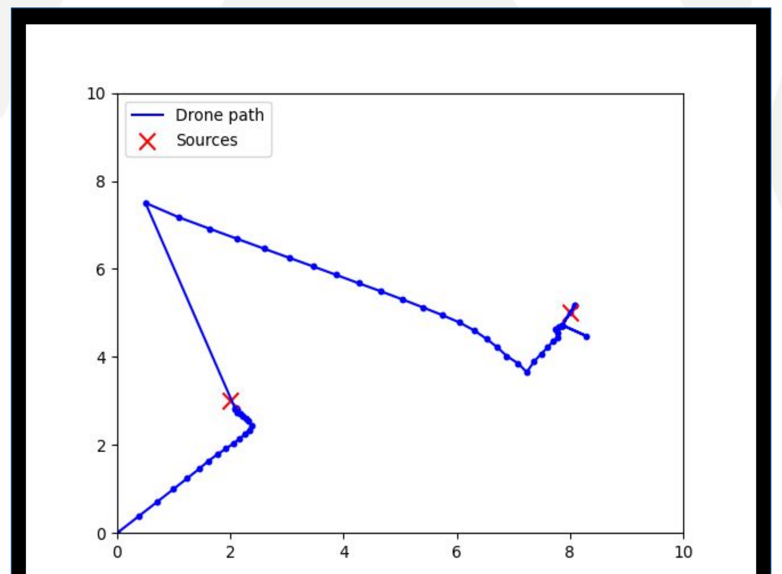
 add $x_t^{[i]}$ to $\mathcal{X}_t$

end

return $\mathcal{X}_t$

▲ Particle filter pseudocode

Results



▲ Two-source drone pathing with 1/√x step function

Function used for calculating step size for the drone:	Error in terms of sum of distance between prediction and actual source: (in arbitrary units)	Distance covered by the drone from start of algorithm to end: (in arbitrary units)	Number of steps:
Cube Root $f(x) = \frac{1}{\sqrt[3]{x}}$	0.0751	17.9	92
Square Root $f(x) = \frac{1}{\sqrt{x}}$	0.000150	18.0	59
$\log_{10}$ $f(x) = \frac{1}{\log_{10} x}$	0.383	12.7	19
Identity Function $f(x) = \frac{1}{x}$	1.52	10.4	193

▲Step-size performance

Expected Impact

- More rapid method of locating radioactive materials for radiological emergency response
- Need for direct human participation in manual surveys and searches potentially eliminated
- Additional tool for materials management and comprehensive background characterization

MTV Impact

- Practical introduction of students to robotics and algorithmic problem solving
- Undergraduate experience preparing and delivering scientific presentations
- Possible undergraduate journal publication

Conclusion

- Multiple source localization introduces a different type of paradigm from single source localization
- Locating singular sources in a multiple source situation can be done with noise resistant methods
- Square root function chosen for step size calculations as it offered the best accuracy for the least number of steps taken

Next Steps

- Expand weighting function criterion to reduce redundant movements and increase localization speed
- Consider radiation detector and platform limitations
- Validating through experimentation
- Account for attenuating obstacles

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