Search of Scent Source in Turbulent Flows

Project Description

- Motivation: Analysis of odor distribution in a city grid is essential to ensuring the safety and wellbeing of the public.
- Article [1] discovered that odor distribution in an open field is concentrated in a parabolic region, developed probability density functions for active and passive search and found that an active search method significantly reduced typical search time
- Goals: Develop an analytical model for odor dispersion in a turbulent urban setting, and determine the most efficient search algorithm to find the scent source

Scientific Challenges

- In a city grid, buildings can affect the propagation of wind and therefore make detecting a scent source more difficult.
- The distribution of the odor patches is no longer Gaussian due to wind obstructions
- Turbulent flow characterized by a high Reynold's number complicates scent gradient detection.

Potential Applications

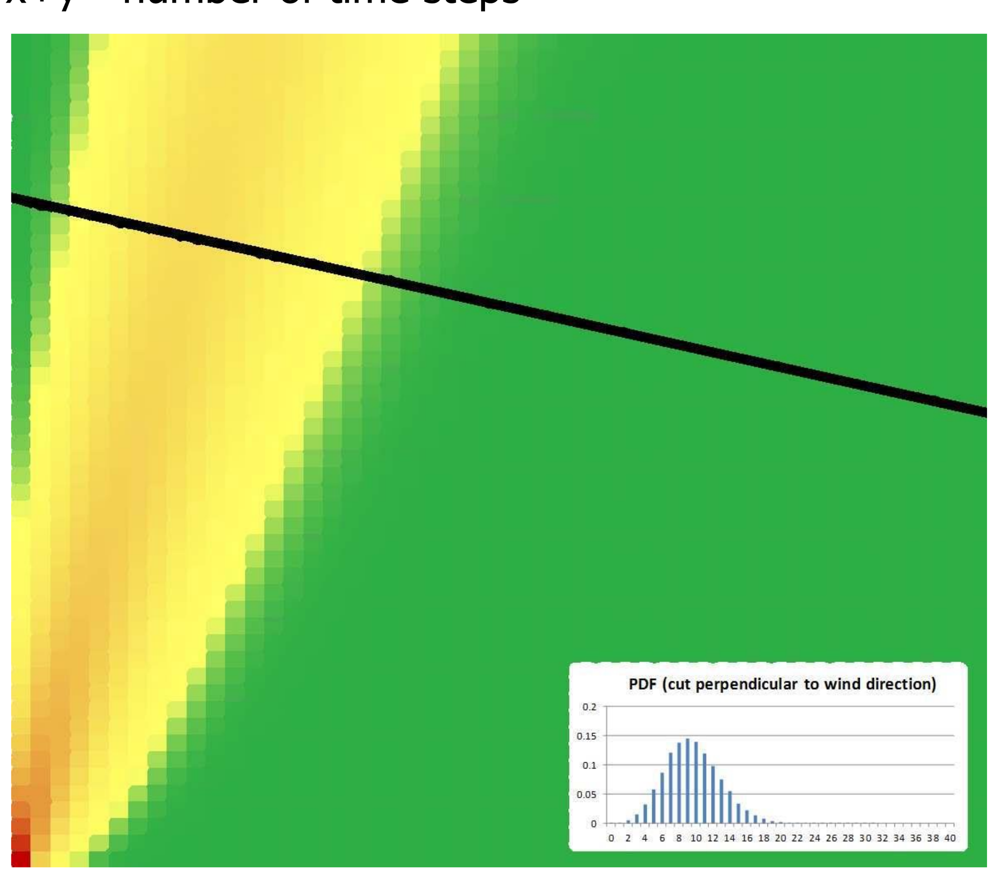
- Military applications involving the search for explosives
- Search for drugs or chemical leaks
- Better understanding of animal search patterns with obstacles

Binomial PDF :

$$P_p(n|N) = \binom{N}{n} p^n q^{N-n} = \frac{N!}{n!\,(N-n)!} p^n (1-p)^{N-n}$$

$$f(x,y) = \binom{x+y}{x} p^x (1-p)^y = \frac{(x+y)!}{x!y!} p^x (1-p)^y$$

p = probability of moving to the right
q = 1-p = probability of moving up
N = x+y= number of time steps



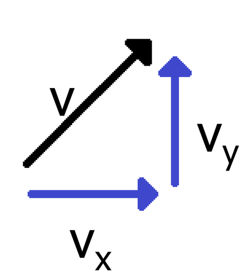


Figure 1: The odor plume with wind direction at 75° North of East and cross section of the distribution.

Team Members:

Craig Thompson,
Cristina Retamoza
Laura Nakolan
Steven Smith
Noah Hammer

Methodology

1. Researched olfactory search in turbulent flow by reading journals
2. Spoke to professors to analyze the behavior of the odor plume in a city grid
3. Ran Monte Carlo simulations to create a distribution map
4. Researched probability distribution types (Gaussian, Binomial, et cetera)
5. Used Microsoft Excel to visualize the probability density and the cross section of the odor distribution
6. Developed passive and active search algorithms in Python
7. Analyzed most efficient search method based on typical search times

Results and Conclusions

2. The "Comb" search is the most efficient strategy because it actively moves towards the source regardless of detection of odor patches.

Search Type	Wind Vector	Average Search Time (50,000 Runs)	Failures (Out of 50,000)
Passive Search	45°	813.0 Time steps	116
	75°	353.6 Time steps	8
Active "Comb" Search	45°	208.2 Time steps	0
	75°	114.6 Time steps	0
Active "Center" Search	45°	822.3 Time steps	0
	75°	848.8 Time steps	55

Table 1: The typical search times at varied wind vectors using different search strategies and the initial position in the center of the plume. The typical search time only considers successful searches.

2. The center method moves towards the source at a slower rate and is more likely to fail at near horizontal or vertical wind directions.

3. Passive method will eventually find the source, but often takes an unreasonably large amount of time, especially when wind is hitting the buildings at a near 45° angle.

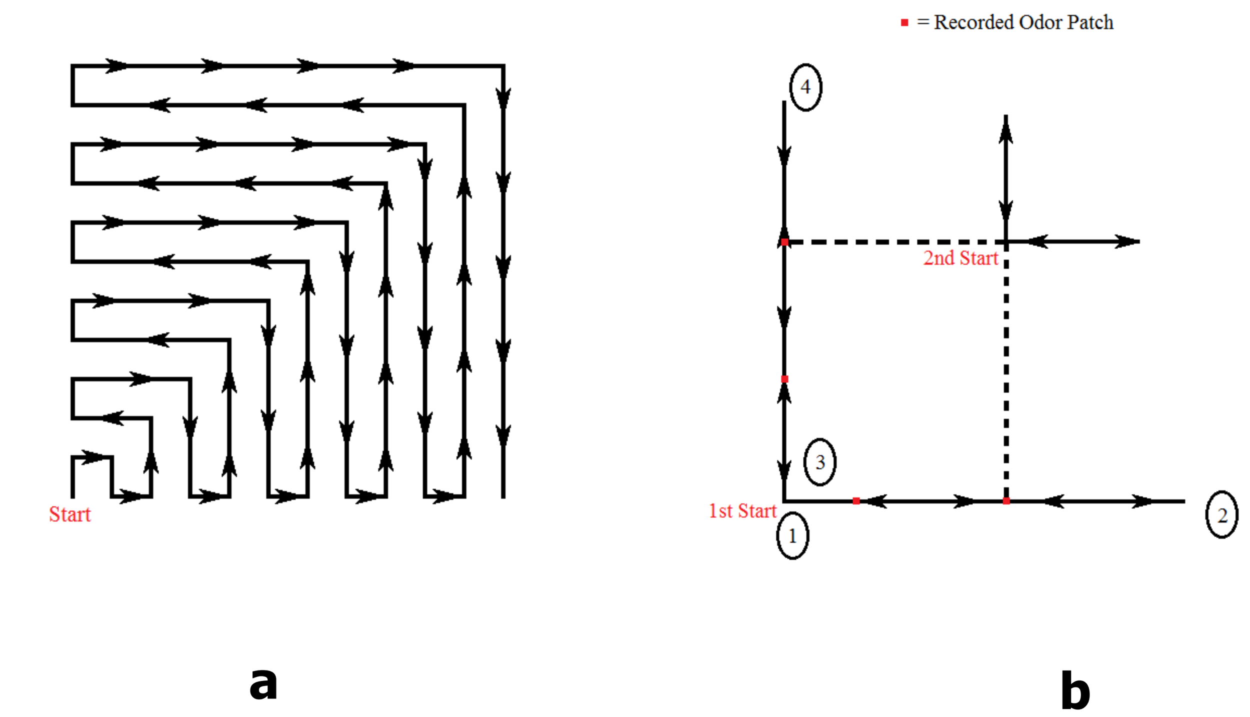


Figure 2a: The "comb" search strategy with the wind at a 45° angle
Figure 2b: The "center" search strategy with the wind at a 45° angle

Glossary of Technical Terms

Monte Carlo Simulation: (probability simulation) Computational algorithms that rely on generation of random variables in order to obtain the distribution of an unknown probability entity.

Binomial PDF: Probability density function of the discrete Binomial distribution, gives probability of getting *n* success in *N* trials.

Reynold's Number: The ratio of inertial force and viscosity force.

References

1. Balkovsky, Eugene and Boris, I. Shraiman, *Olfactory Search at High Reynold's Number*, Proceedings of the National Academy of Science in the United States of America.**99.20**, 12589 – 12593 (2002).

Acknowledgments

1. This project was mentored by Ildar Gabitov, whose help is acknowledged with great appreciation. And special thank you to Misha Stepanov for his advisement.