Olfactory Search in Turbulent Environments with Multiple Odor Sources

Project Description

- Motivation: Real world scenarios in turbulent environments often have particles scattered from several sources rather than just one.
- The authors in [1] describe a time-efficient search algorithm that utilizes counterturning within a parabolic trajectory.
- Goals: Assess the parabolic search algorithm in environments with more than one source to determine if it is still an effective method.

Scientific Challenges

- In flow regimes of high Reynolds number, the distribution of odor particles lacks uniformity.
- A complex strategy to find multiple sources, involving sense of smell and ability to determine wind direction, is needed.
- Can such a strategy work in a more nuanced flow with multiple sources?

Potential Applications

- A strategy for locating multiple sources of odor in turbulent flows would be useful for the design of robots used to find gas leaks or explosives.

$$P(\text{particle at x} \mid \text{fixed y} >> 1,\ p_R = p_L = 1/3, \text{sources at (-10,0) and (10,0)})$$

$$= 1 - \left(1 - \frac{1}{\sqrt{\frac{4}{3}\pi y}} e^{-\frac{3(x-10)^2}{4y}}\right)\left(1 - \frac{1}{\sqrt{\frac{4}{3}\pi y}} e^{-\frac{3(x+10)^2}{4y}}\right)$$

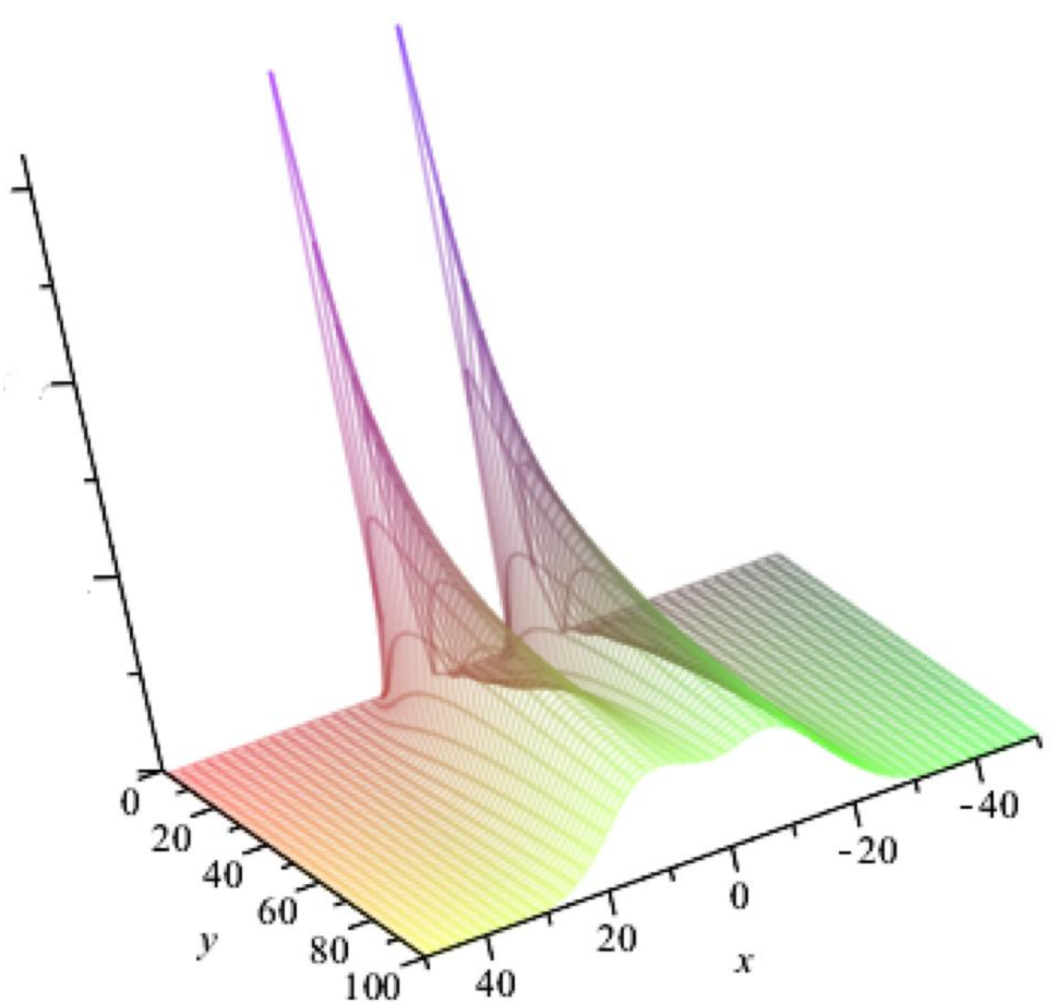

Figure 1. Graph of the probability distribution of the particles from two sources, plotted with Maple.

$$(x - x_i)^2 \le \frac{4}{3}(y_i - y)\ln\left(\frac{1}{0.05\sqrt{\frac{4}{3}\pi(y_i - y)}}\right)$$

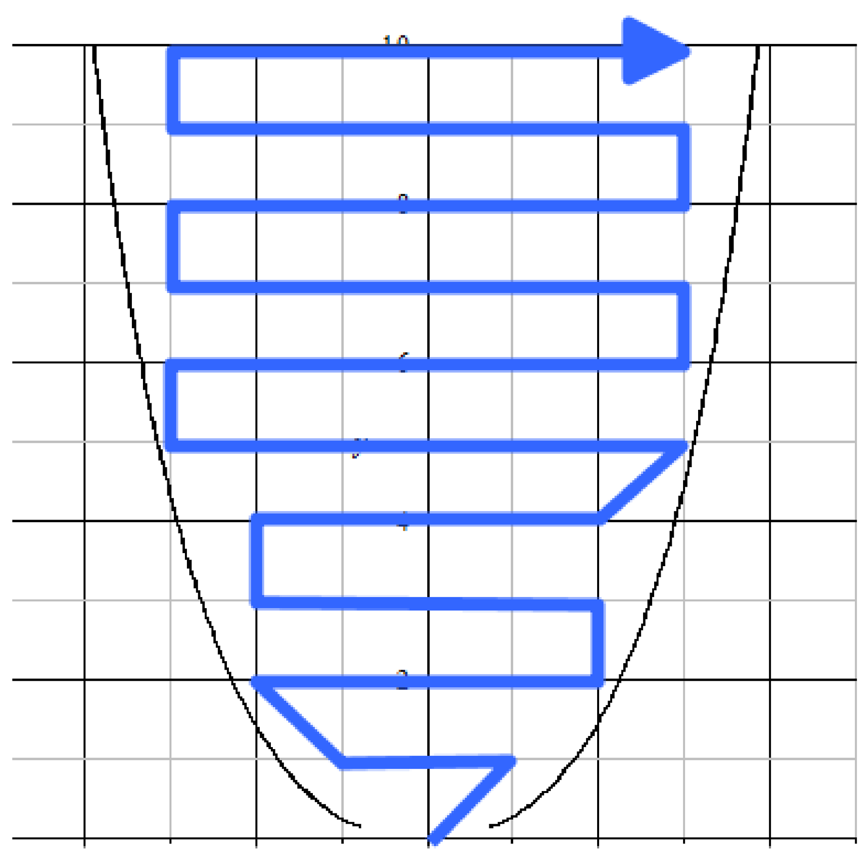

Figure 2. Depiction of the parabolic search trajectory for a fixed probability of 0.05, created with Maple.

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Methodology

1. The parabolic search algorithm described in [1] was reproduced in Python 2.7.
2. Four different simulations were performed with one seeker and two sources each releasing one particle per time step, and a simple simulation was performed with one source at the origin.
3. In the first two simulations, both sources were located at (0,0). For the first run, the initial robot position was (0,50) and in the second simulation the initial robot position was moved to (10,50).
4. In the final two simulations, the two sources were placed at (-10,0) and (10,0). Again, for one run, the initial robot position was (0,50) and in the other simulation the initial robot position was moved to (10,50).
5. To analyze the data, histograms were created for each simulation using Python 2.7.
6. The percentage of misses by the seeker was calculated for each of the four simulations.

Results

Simulation	Miss rate
(A) One source at (0,0); robot initially at (0,50)	5282 out of 100,000 5.282% misses
(B) Both sources at (0,0); robot initially at (0,50)	2588 out of 100,000 2.588% misses
(C) Both sources at (0,0); robot initially at (10,50)	10392 out of 100,000 10.392% misses
(D) Sources at (-10,0) and (10,0); robot initially at (0,50)	12160 out of 100,000 12.16% misses
(E) Sources at (-10,0) and (10,0); robot initially at (10,50)	5318 out of 100,000 5.318% misses

Table 1. Miss rate for four described simulations and simple case with one source at the origin. Separating the sources increases the percentage of misses, both when the source is directly in front of the robot initially, as when the robot is offset from the source initially.

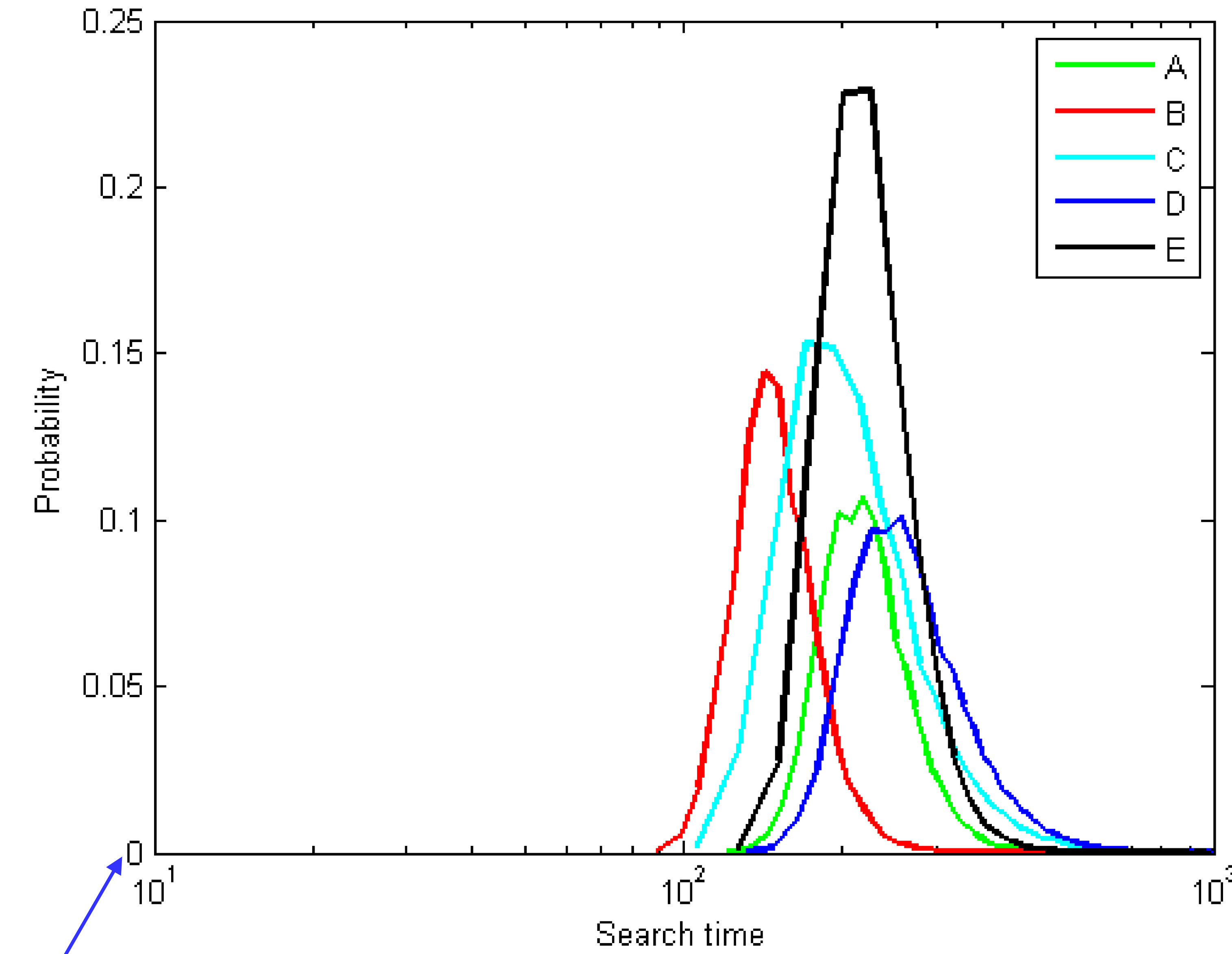

Figure 3. Histogram of search time distribution for each simulation and the simple case. Clearly, when the robot is initially between two separate sources the average search time is greater and there is greater variability in search times than when the sources are together. Furthermore, it appears that when one of two separate sources is directly in front of the robot initially, the search times are greater than when the two superimposed sources are directly in front of the robot initially.

Glossary of Technical Terms

Reynolds Number: ρvL/μ; where ρ is density of fluid, v is velocity of particles in the flow, L is characteristic length of the system, and μ is viscosity of the fluid.
Fixed probability: the probability that the particle originates from a source outside the parabolic region

References

1. E. Balkovsky and B.I. Shraiman, *Olfactory Search at High Reynolds Number*, Proceedings of the National Academy of Sciences of the United States of America **99**, 12589-12593 (2002).

Acknowledgments

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