Trajectory optimization considering contrails

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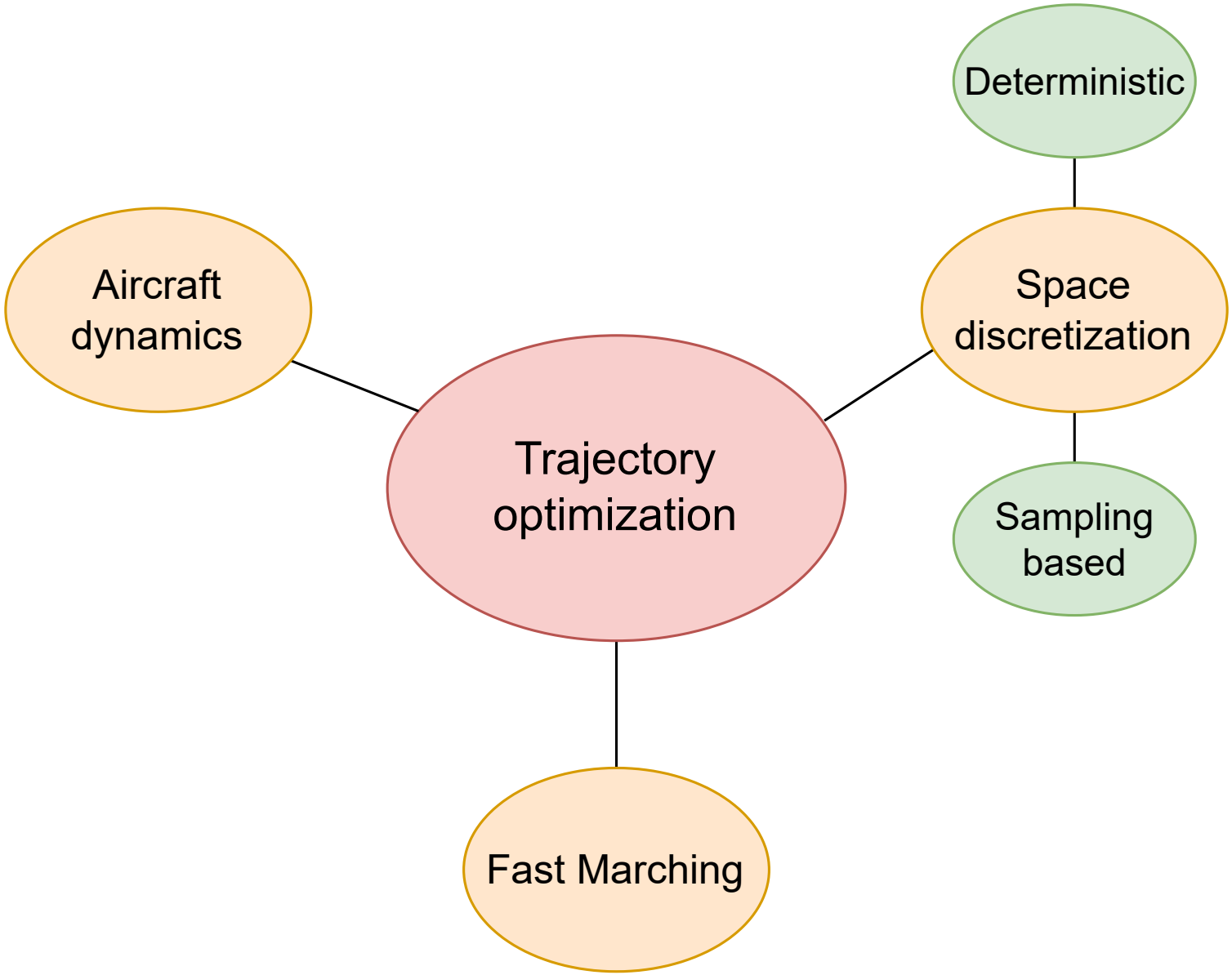
Related work



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Modeling

Model of the problem

$$\begin{aligned} \underset{\gamma}{\text{minimize}} \quad & \int_{t_0}^{t_f} C_t + C_r r(x,y)\,\mathrm{d}t \\ \text{subject to} \quad & \gamma \in \Gamma \end{aligned} \tag{1}$$

C_t is the cost coefficient of time, C_r the cost associated with contrails, $r(x,y)$ the penalty function and Γ the set of flyable trajectories.

$$r(x,y) = \begin{cases} \text{constant} & \text{if aircraft in penalty area} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

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FMT* Algorithm

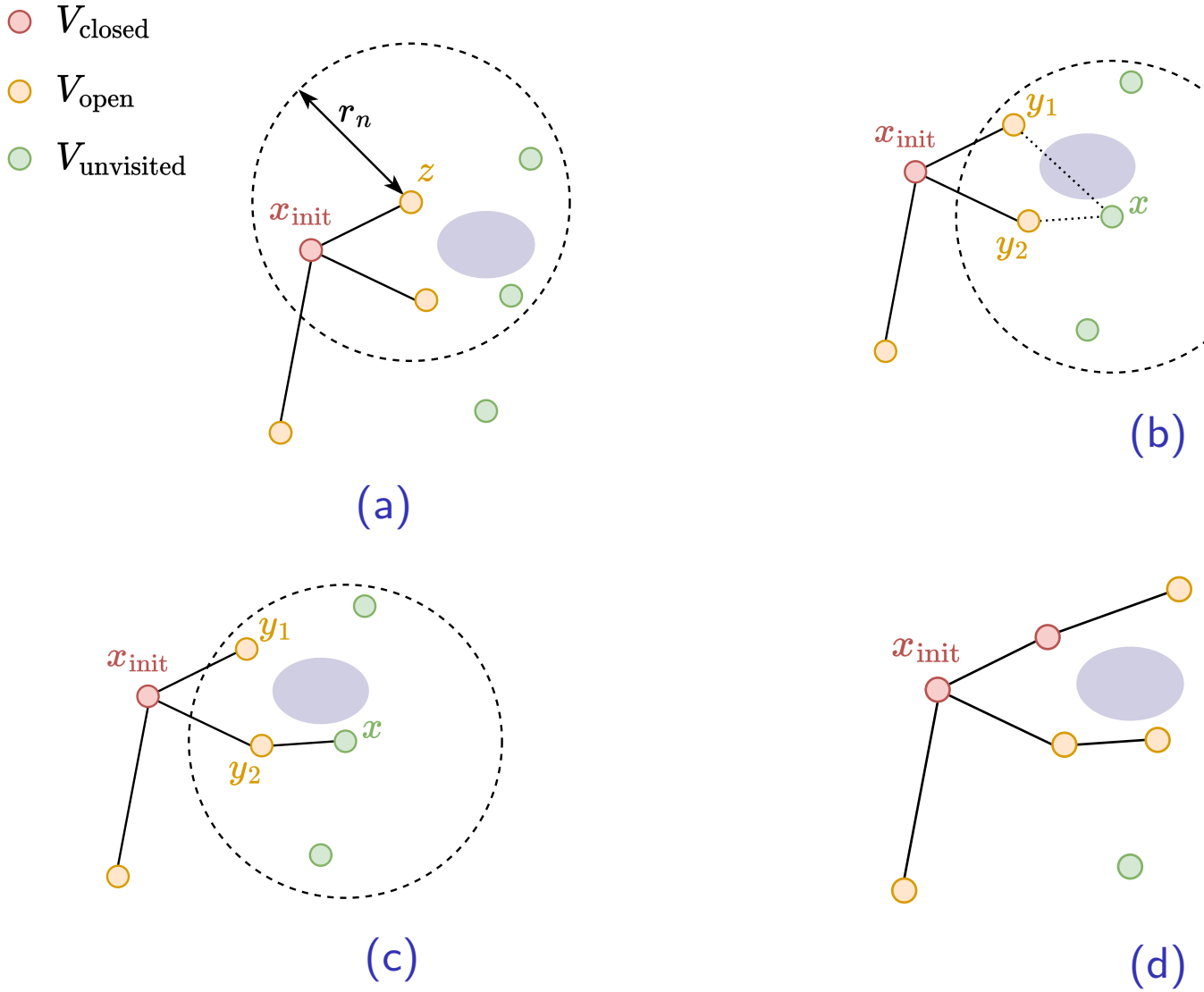
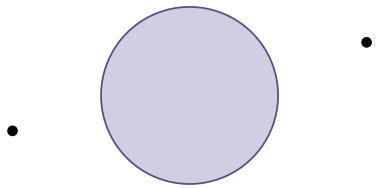
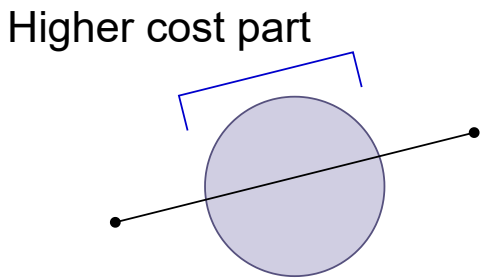


Figure: An iteration of the FMT* algorithm.

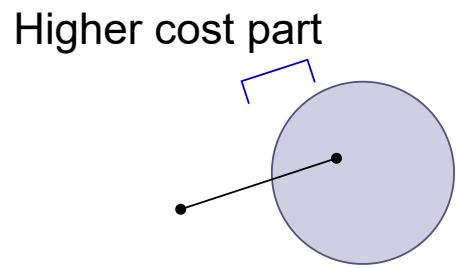
Ability to cross obstacles



(a)



(b)



(c)

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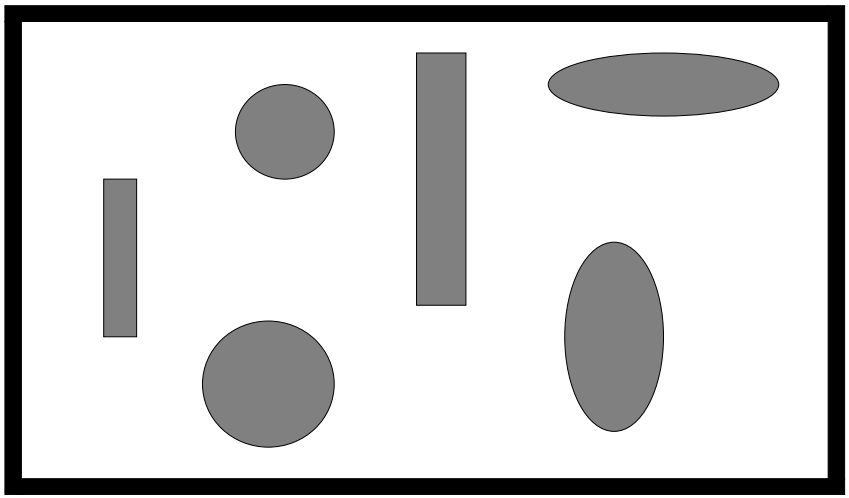
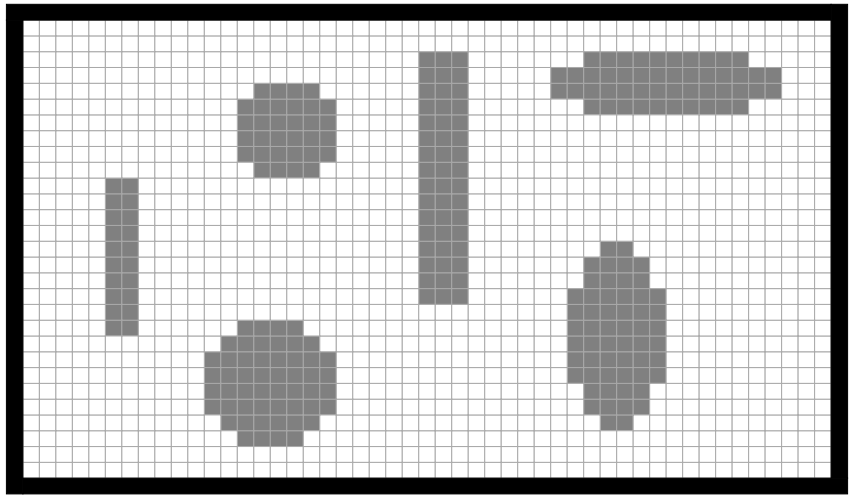
Discretization



(a) Initial environment



(b) Discretization of the obstacles

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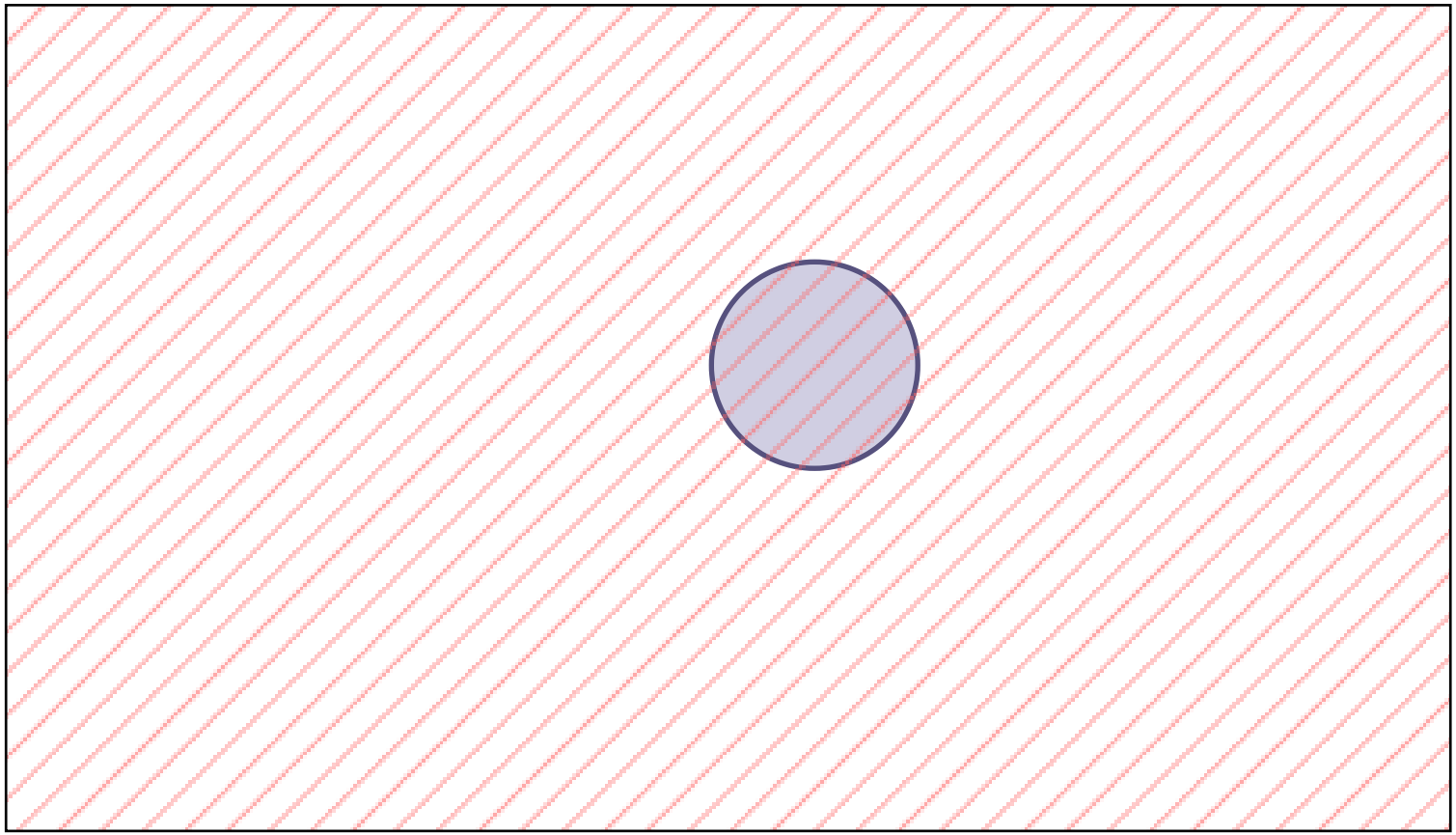
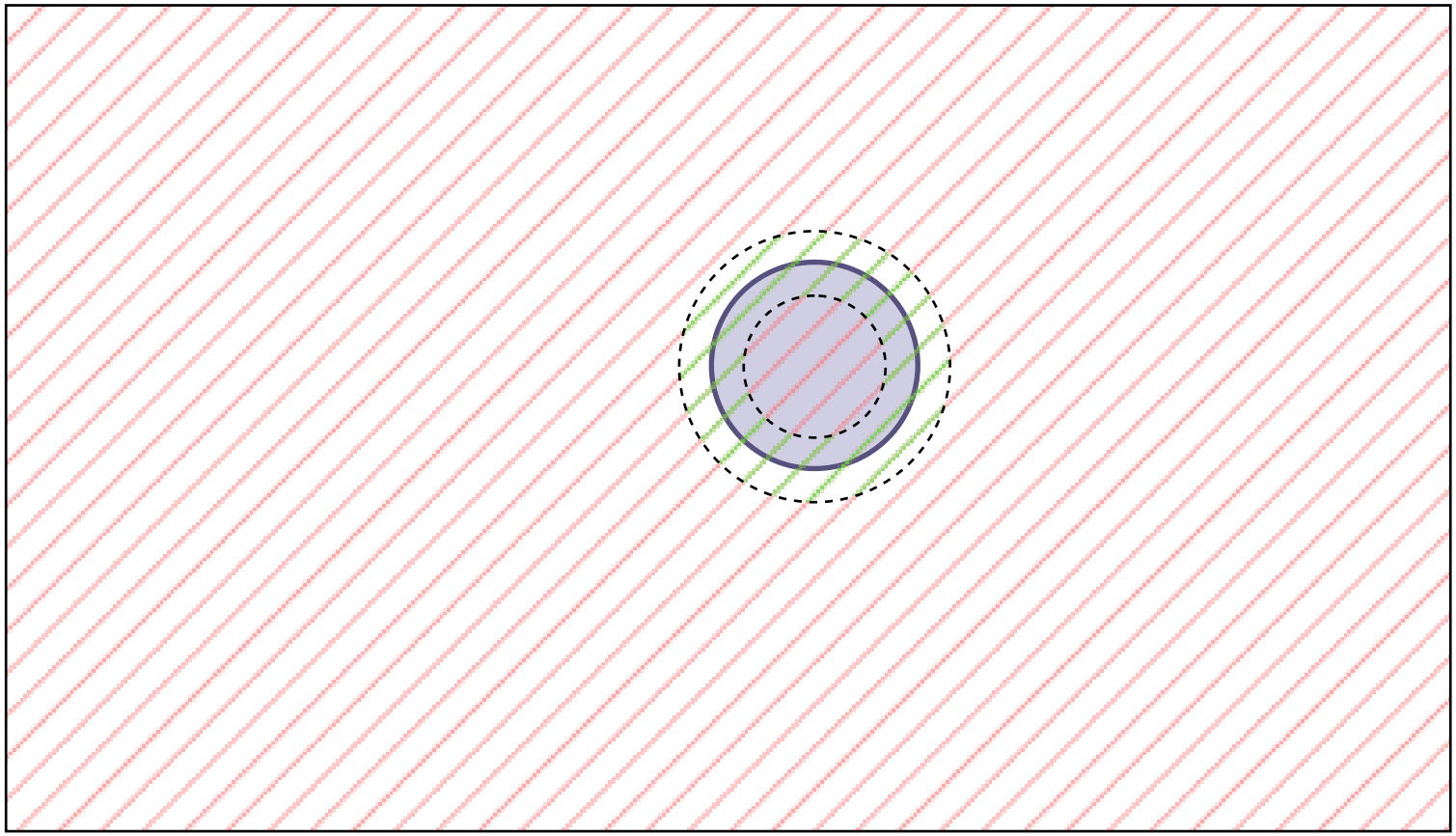
Uniform sampling



Obstacles sampling



Add a distribution for each obstacles to sample more around the boundary of the obstacles

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Uniform Sampling

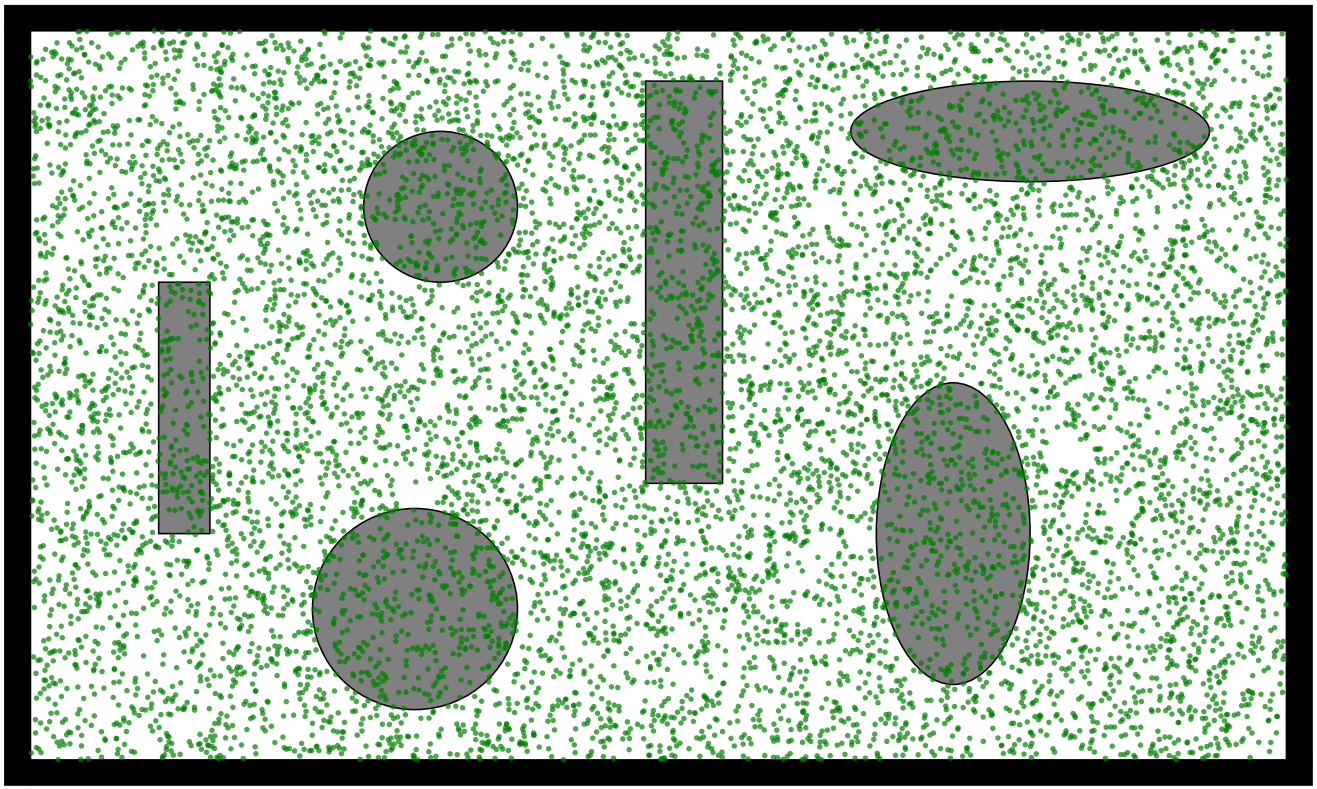

Figure: Sampling uniform obtained with 10 000 samples. The samples are represented by green dots.

Sampling considering obstacles

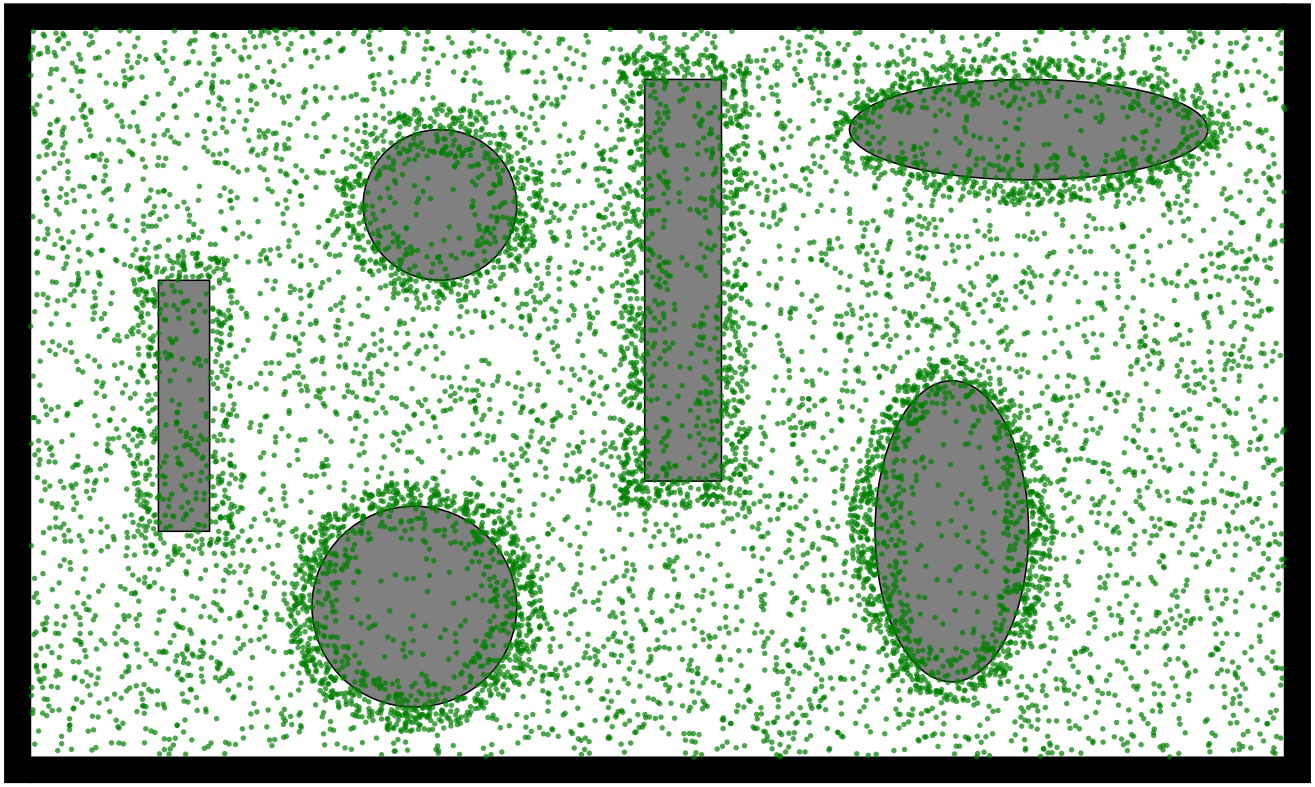

Figure: Sampling considering obstacles obtained with 10 000 samples. The samples are represented by green dots.

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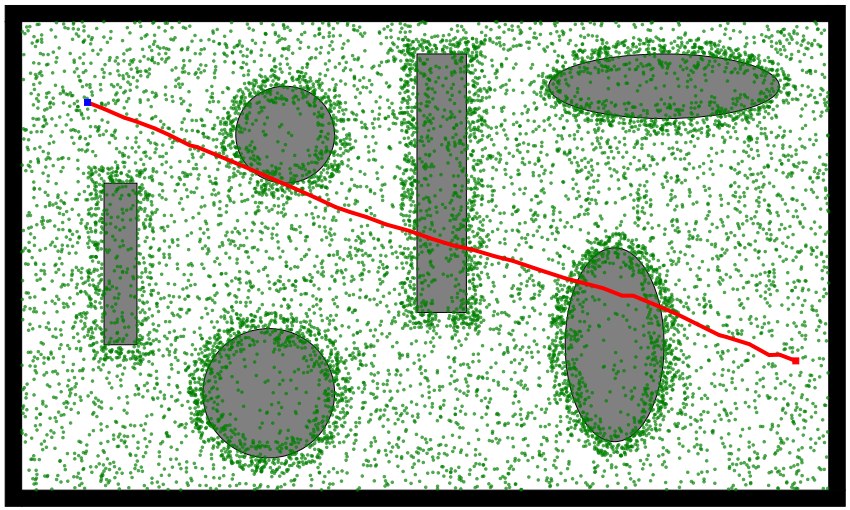
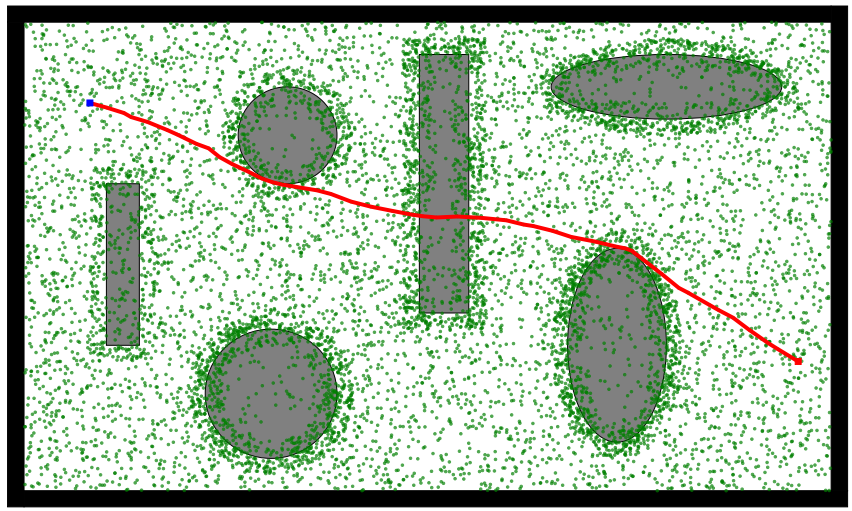
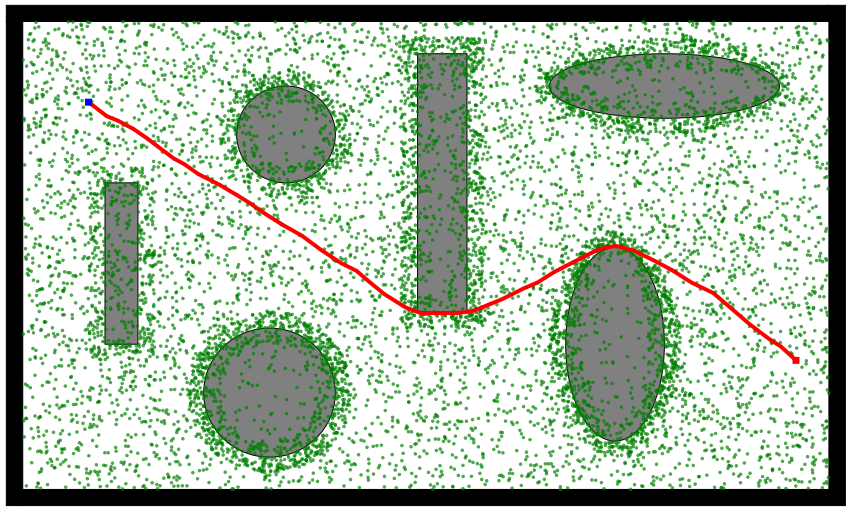
Euclidean distance



(a) $C_r = 0$



(b) $C_r = 1$



(c) $C_r = 2$

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Great-circle distance

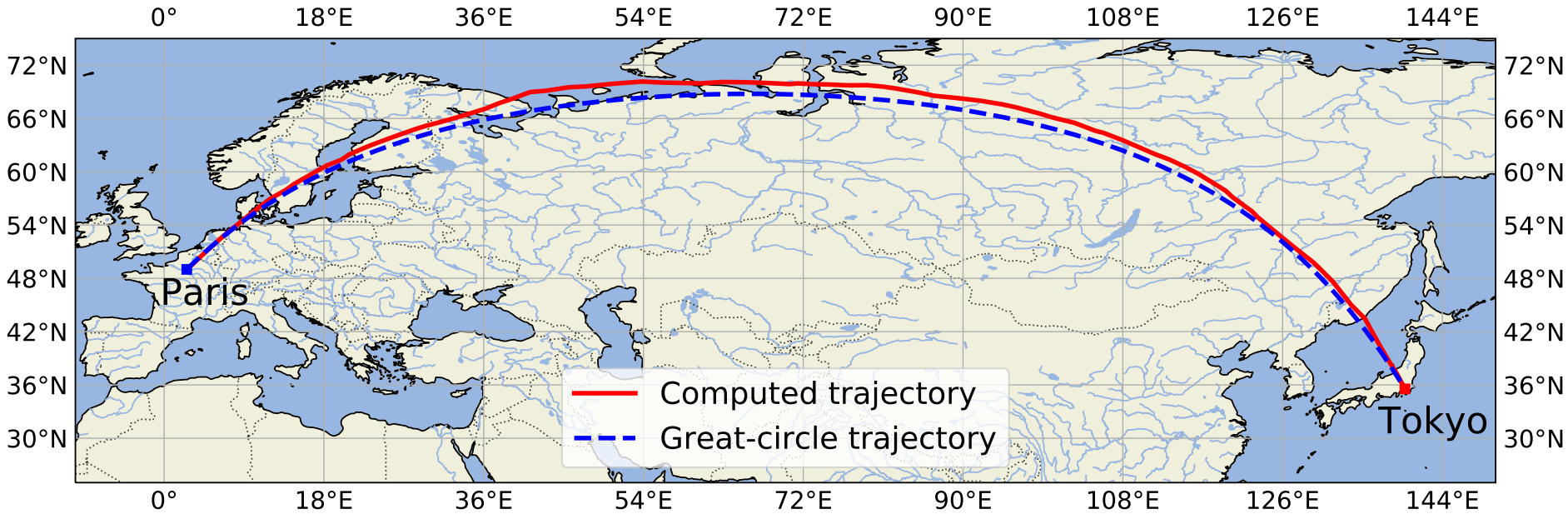

Figure: Comparison of the computed trajectory and the great-circle trajectory with longitude on abscissa and latitude on ordinate.

Great-circle distance with obstacles

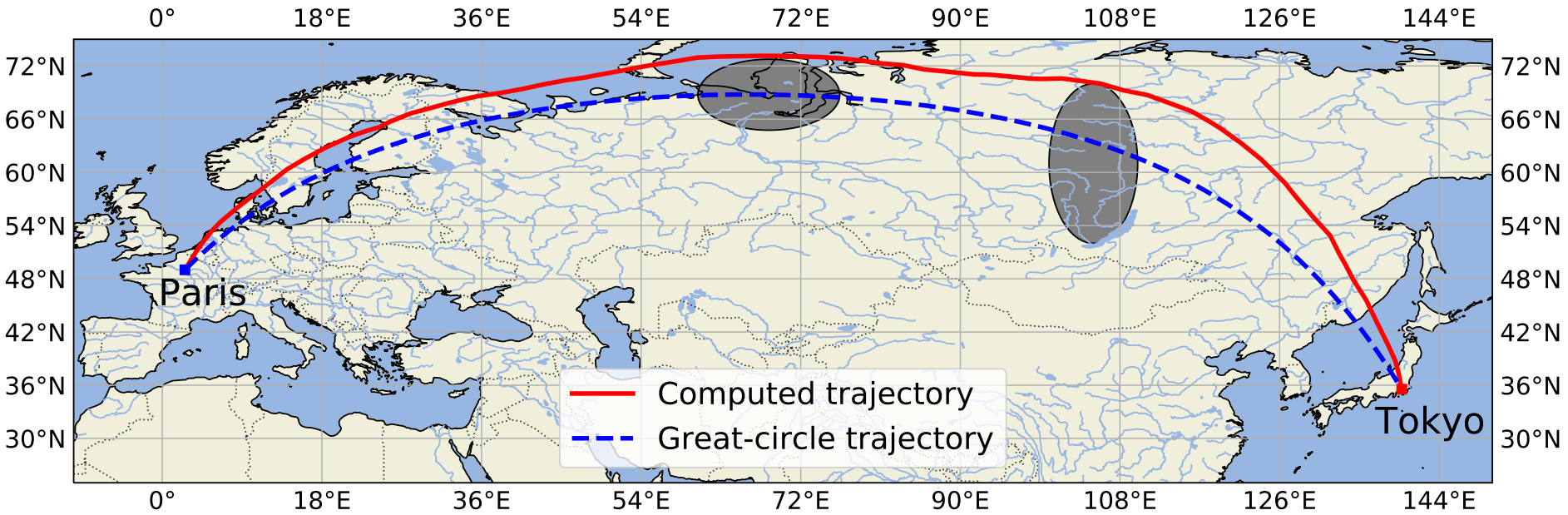

Figure: Using great-circle distance with obstacles.

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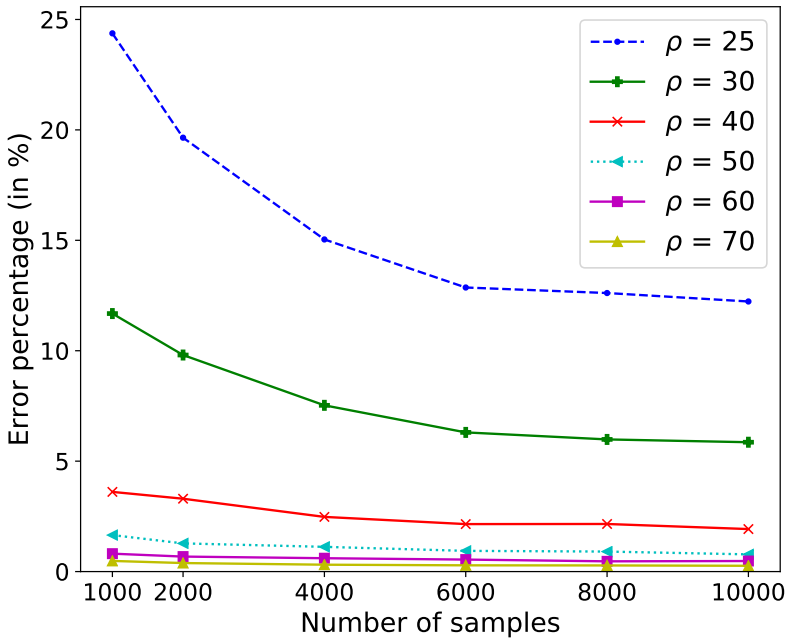
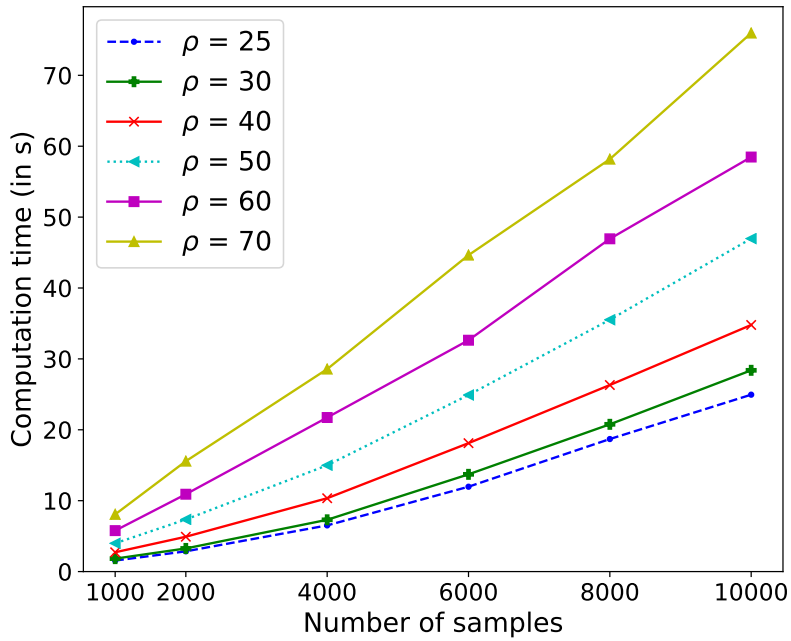
Comparison

$$r_n = \rho \sqrt{\frac{\log(n)}{n}}$$



(a)



(b)

Figure: Two graphs comparing the number of samples and the connection radius on a given environment.

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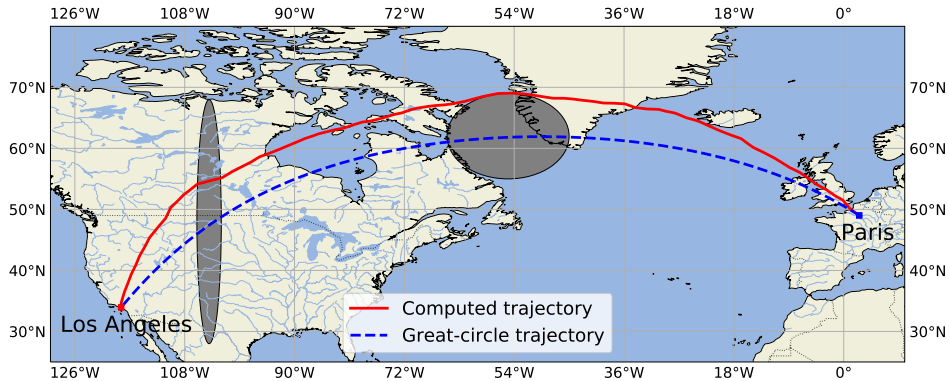
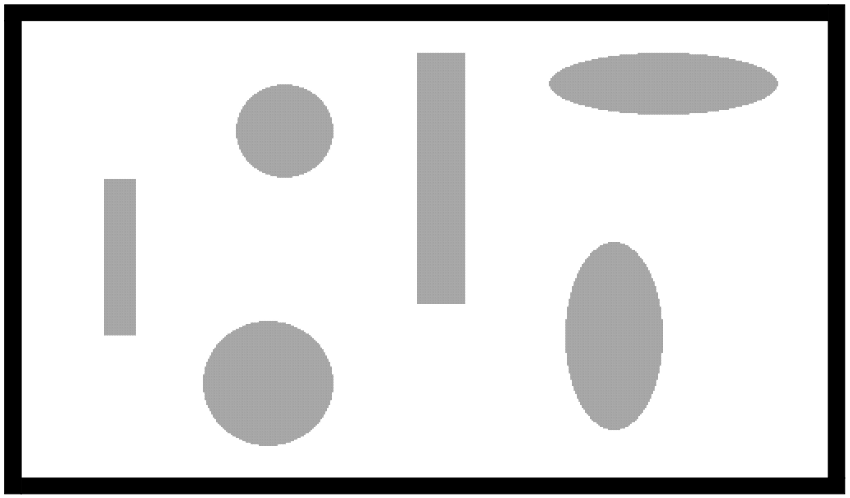
Conclusion

- Sample more around obstacles
- Soft obstacles
- Great-circle distance



Perspective



Upgrades :

- Use only a grid, bitmap
- Smooth the trajectories
- Add wind data
- Use real data