Artificial Potential Fields

Constructing Artificial Potential Fields

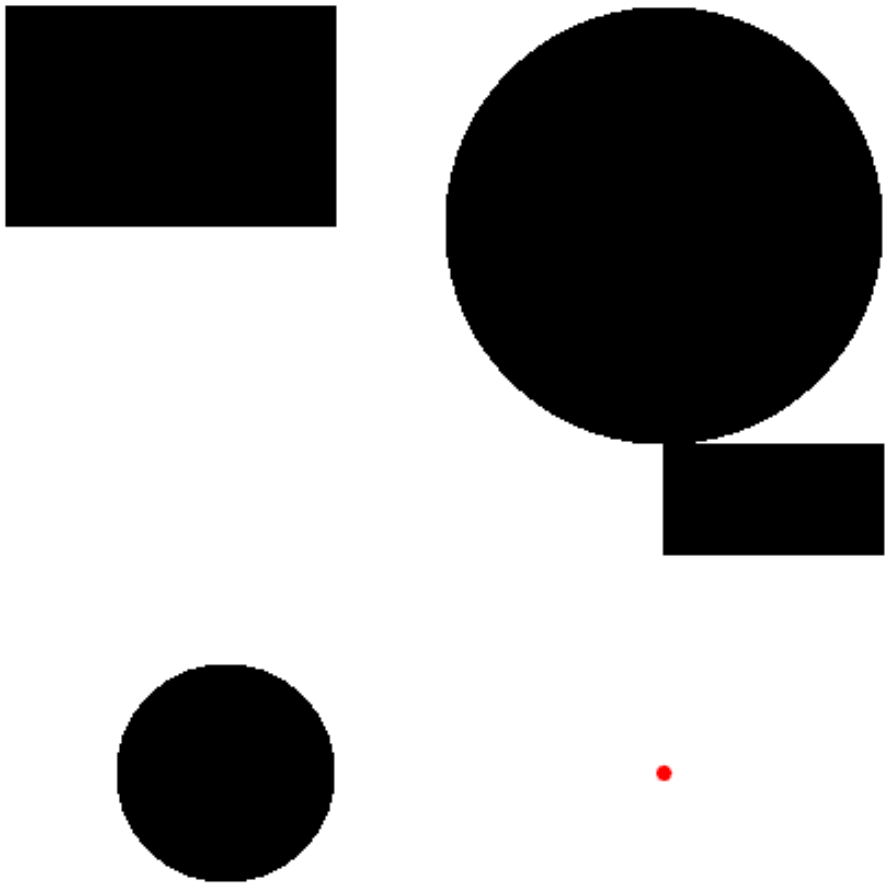
SECTION 4.1

Penn

- **The basic idea is to try to construct a smooth function over the extent of the configuration space which has high values when the robot is near to an obstacle and lower values when it is further away.**
- **We also want this function to have it's lowest value at the desired goal location and it's value should increase as we move to configurations that are further away.**

- If we can construct such a function we can use it's gradient to guide the robot to the desired configuration.
- As usual it's easiest to start with an example in a 2 dimensional configuration space where we can more easily visualize what is happening.
- This figure shows a typical 2 dimensional configuration space where the black regions correspond to configuration space obstacles and the red dot indicates the desired goal configuration.

Example 2D Configuration Space



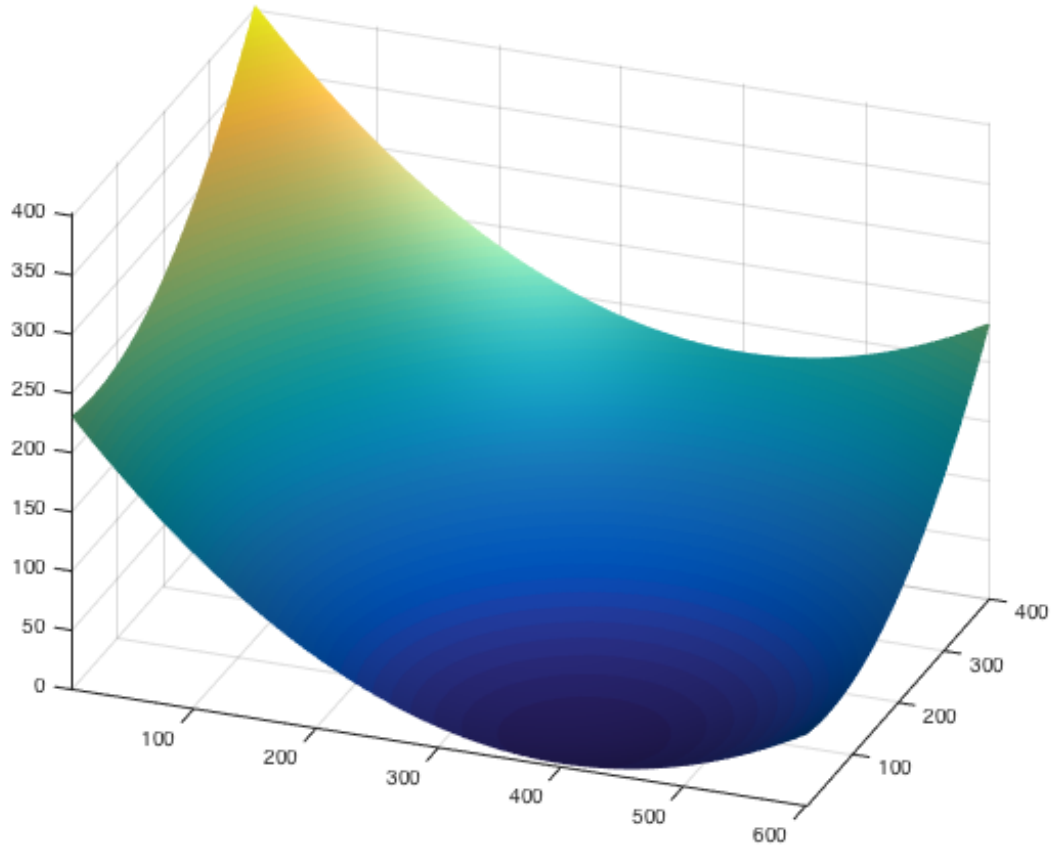
Constructing an Attractive Potential Field

- An attractive potential function, $f_a(\mathbf{x})$, can be constructed by considering the distance between the current position of the robot, $\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$, and the desired goal location, $\mathbf{x}_g = \begin{pmatrix} x_1^g \\ x_2^g \end{pmatrix}$, as follows:

$$f_a(\mathbf{x}) = \xi(\|\mathbf{x} - \mathbf{x}_g\|^2)$$

- Here ξ is simply a constant scaling parameter

Visualizing the Attractive Potential Field



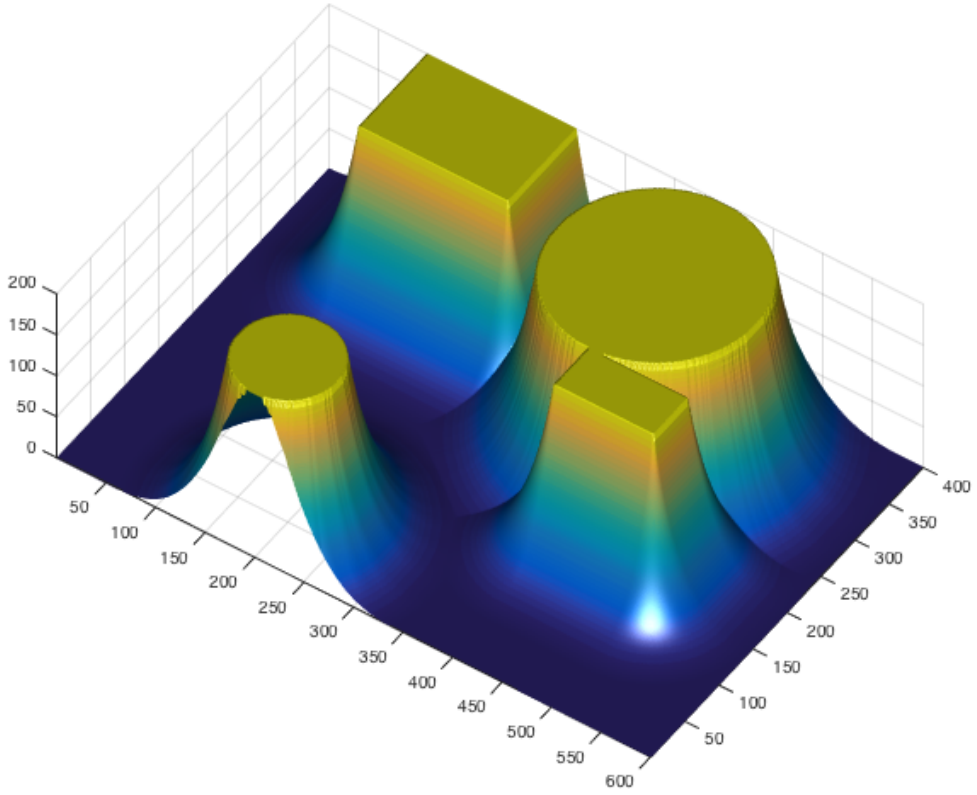
Constructing a Repulsive Potential Field

- A repulsive potential function in the plane, $f_r(\mathbf{x})$, can be constructed based on a function, $\rho(\mathbf{x})$, that returns the distance to the closest obstacle from a given point in configuration space, $\mathbf{x}$.

$$f_r(\mathbf{x}) = \begin{cases} \eta(\frac{1}{\rho(\mathbf{x})} - \frac{1}{d_0})^2 & \text{if } \rho(\mathbf{x}) \leq d_0 \\ 0 & \text{if } \rho(\mathbf{x}) > d_0 \end{cases}$$

- Here η is simply a constant scaling parameter and d_0 is a parameter that controls the influence of the repulsive potential

Visualizing the Repulsive Potential Field



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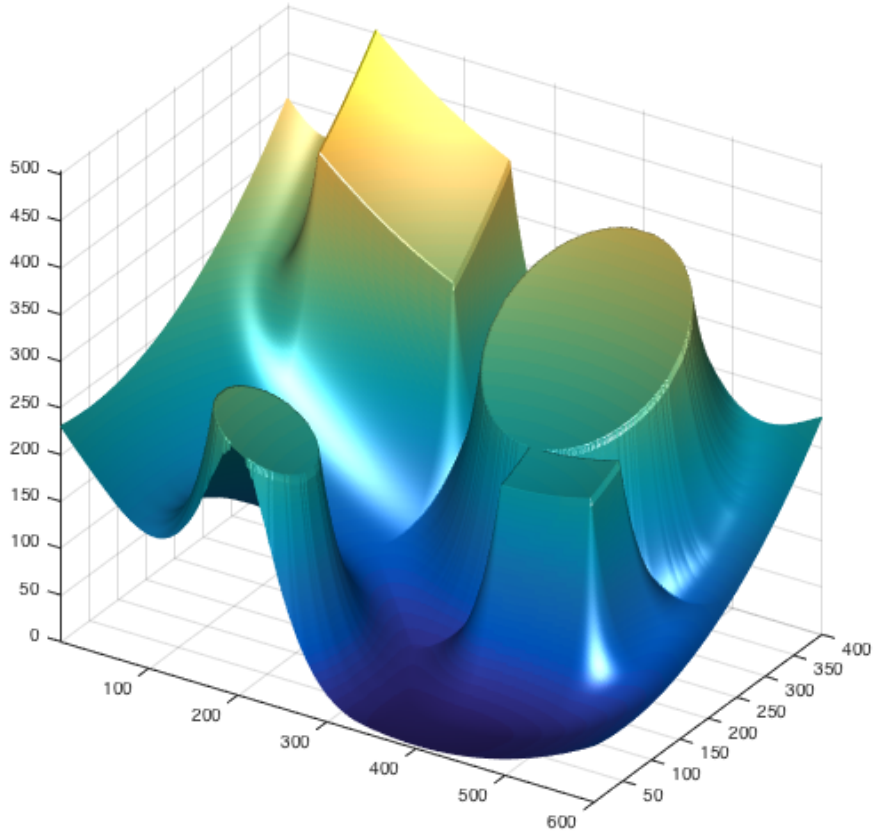
Visualizing the Combined Potential field



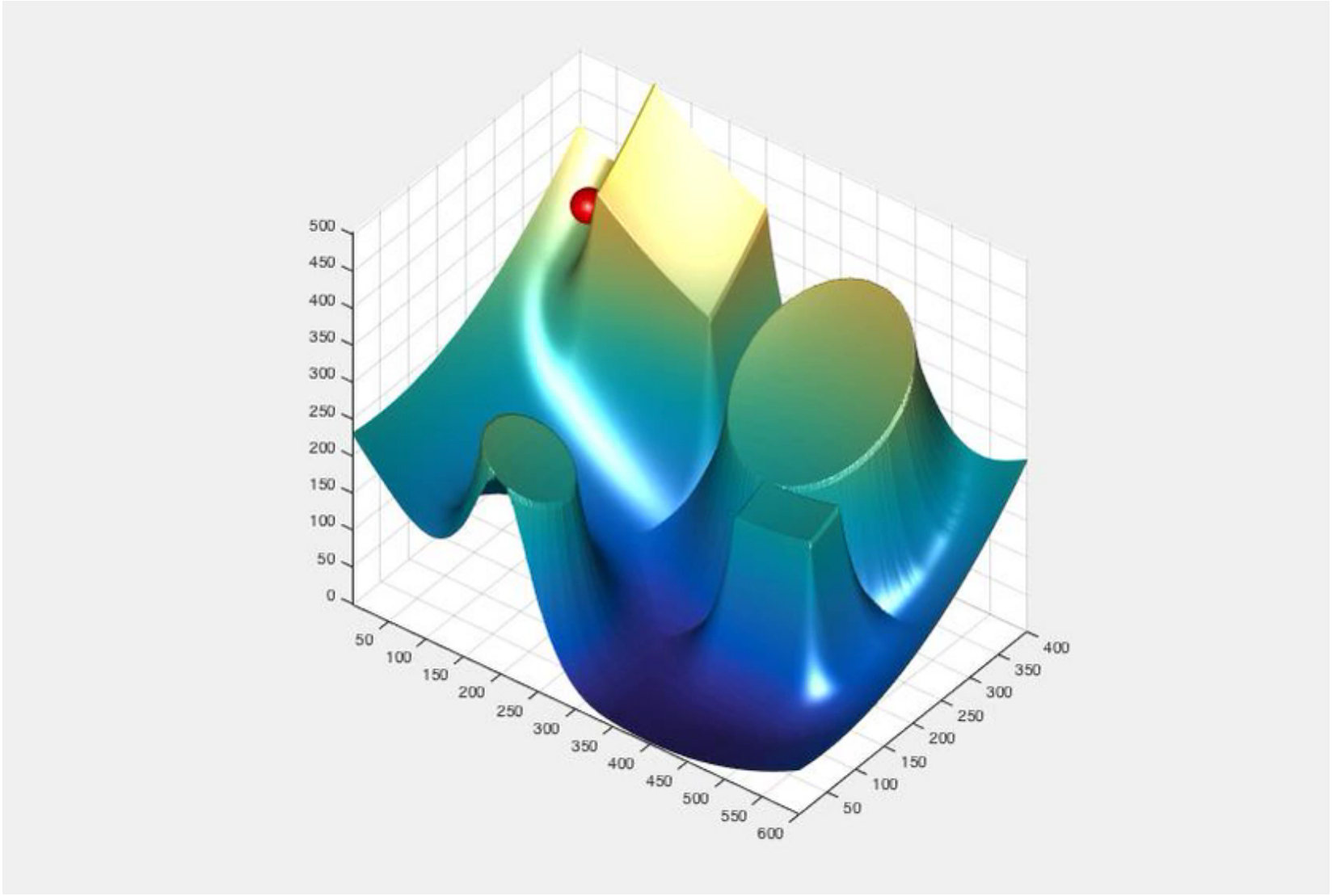
Gradient Based Control Strategy

- While robot position is not close enough to goal
  - Choose direction of robot velocity based on the gradient of the artificial potential field:

$$\mathbf{v} \propto -\nabla f(\mathbf{x}) = -\begin{pmatrix} \frac{\partial f(\mathbf{x})}{\partial x_1} \\ \frac{\partial f(\mathbf{x})}{\partial x_2} \end{pmatrix} \tag{1}$$

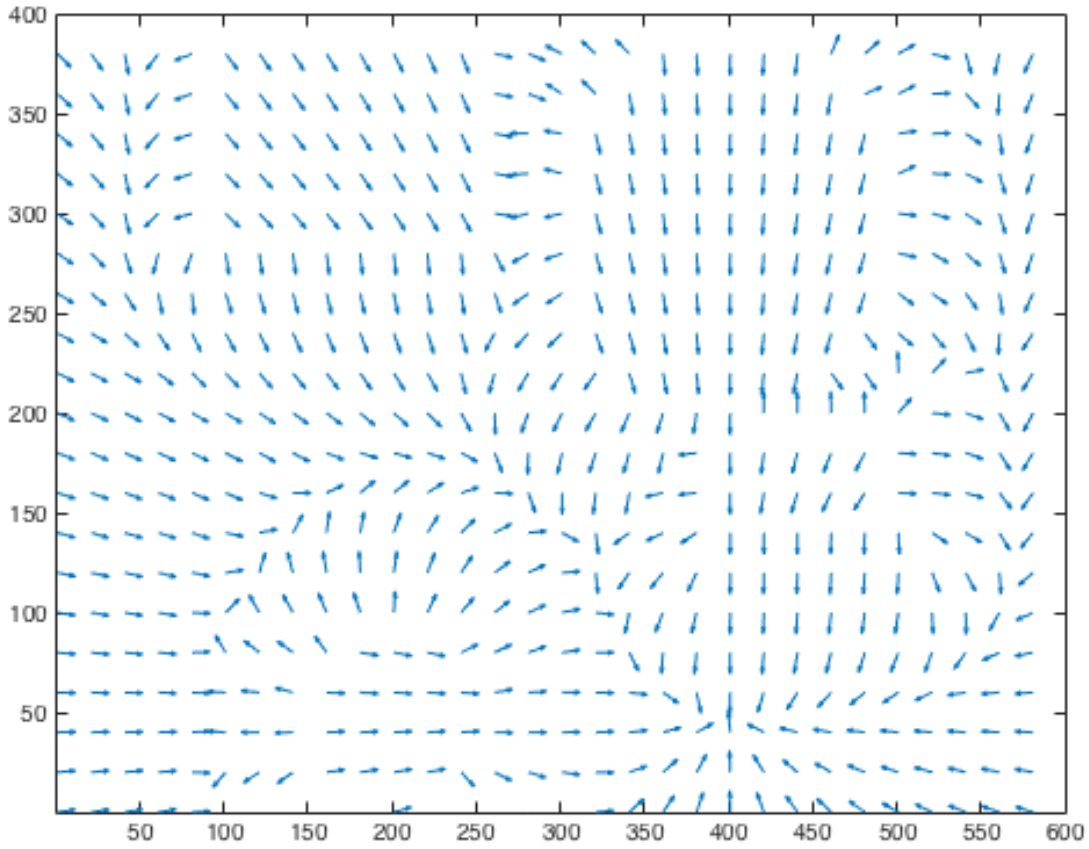
  - Choose an appropriate robot speed, $\|\mathbf{v}\|$

Animation of Gradient Based Control Scheme



Quiver Plot

- The arrows in this figure denote the direction of the gradient vector at various points in the configuration space.



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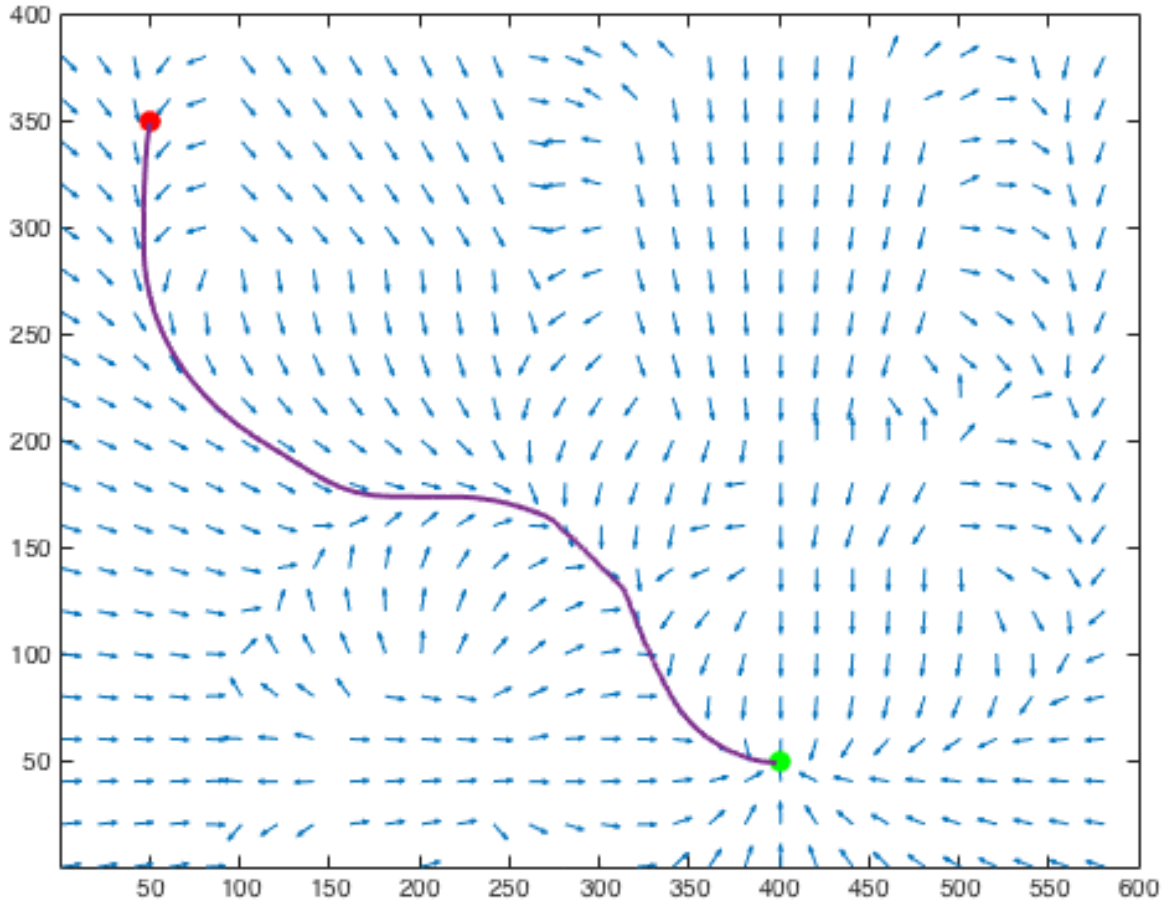
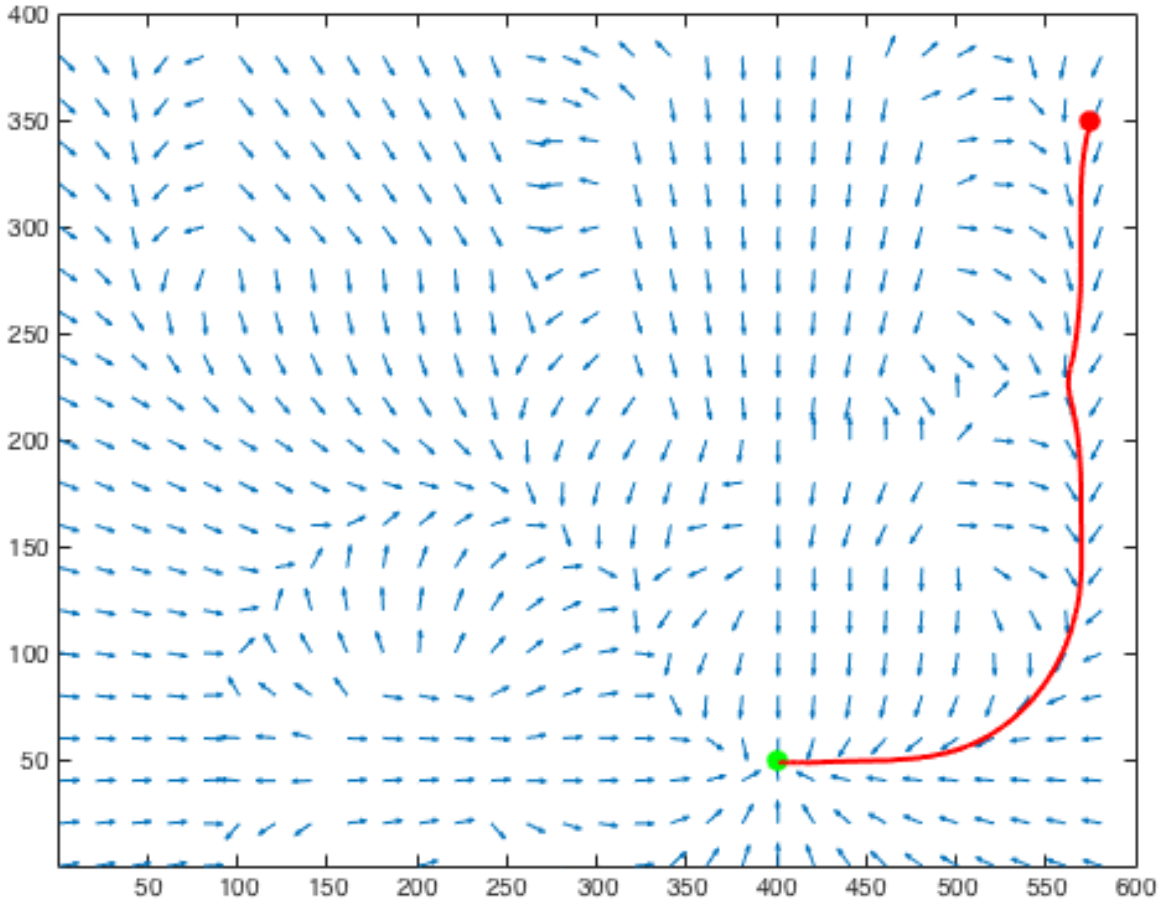
Trajectory Plot

- Example gradient based trajectory.



Trajectory Plot

- Example gradient based trajectory.



Trajectory Plot

- Example gradient based trajectory.