Potential Field Path Planning

Reference:

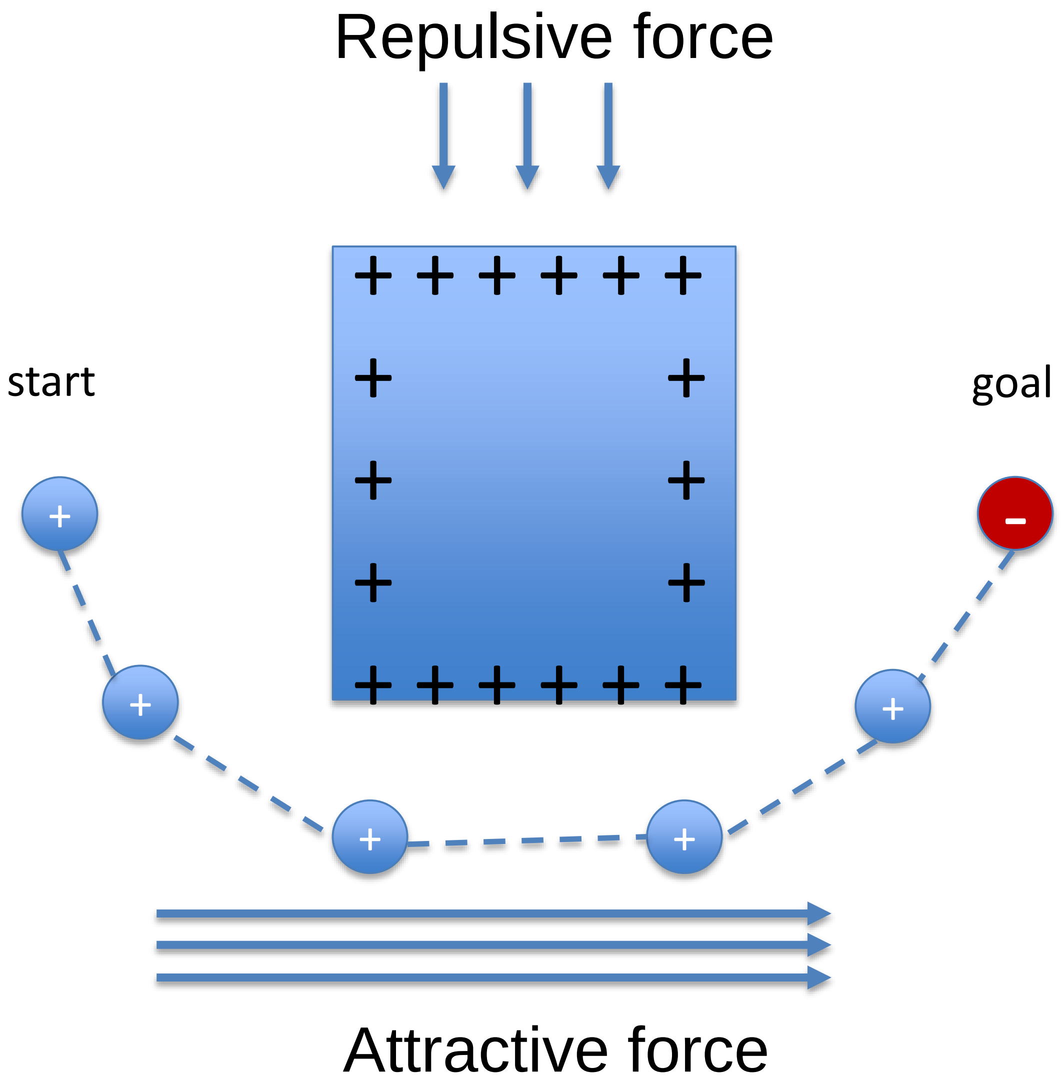
Principles of Robot Motion
H. Choset et.al.
Mit Press

Also: Siegwart text, section 6.3.2

Potential Field Path Planning

- Simple idea: Have robot “attracted” to the goal and “repelled” from the obstacles
- Think of robot as a positively charged particle moving towards negatively charged goal – attractive force
- Obstacles have same charge as robot – repelling force
- States far away from goal have large potential energy, goal state has zero potential energy
- Path of robot is from state of high energy to low (zero) energy at the goal
- Think of the planning space as an elevated surface, and the robot is a marble rolling “downhill” towards the goal

Potential Field Path Planning



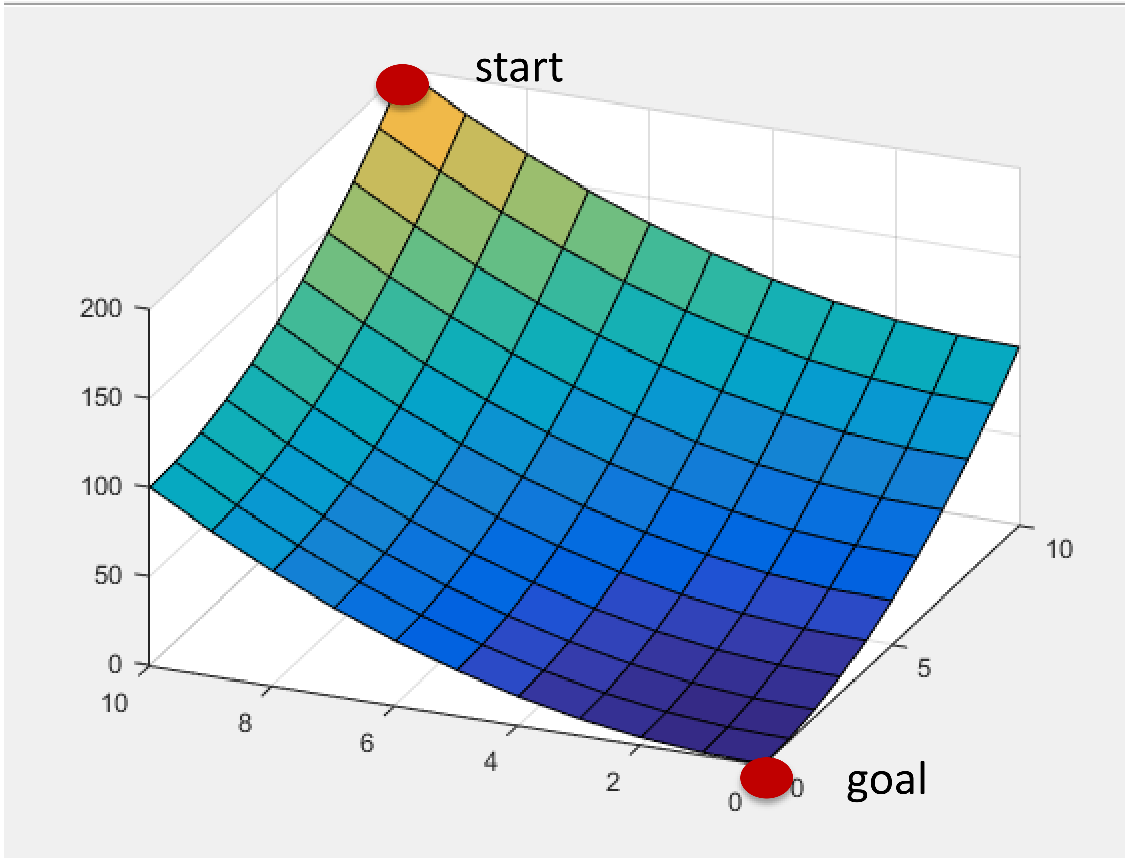
Potential Field Path Planning

- A potential function is a function that may be viewed as energy
- the gradient of the energy is force
- Potential function guides the robot as if it were a particle moving in a gradient field.
- Analogy: robot is positively charged particle, moving towards negative charge goal
- Obstacles have “repulsive” positive charge

- Potential functions can be viewed as a landscape
- Robot moves from high-value to low-value

  Using a “downhill” path (i.e negative of the gradient).
- This is known as gradient descent –follow a functional surface until you reach its minimum

Potential Field



- Attractive Potential Function is distance from goal
- High energy away from goal, Zero at goal
- Path is negative gradient, largest change in energy

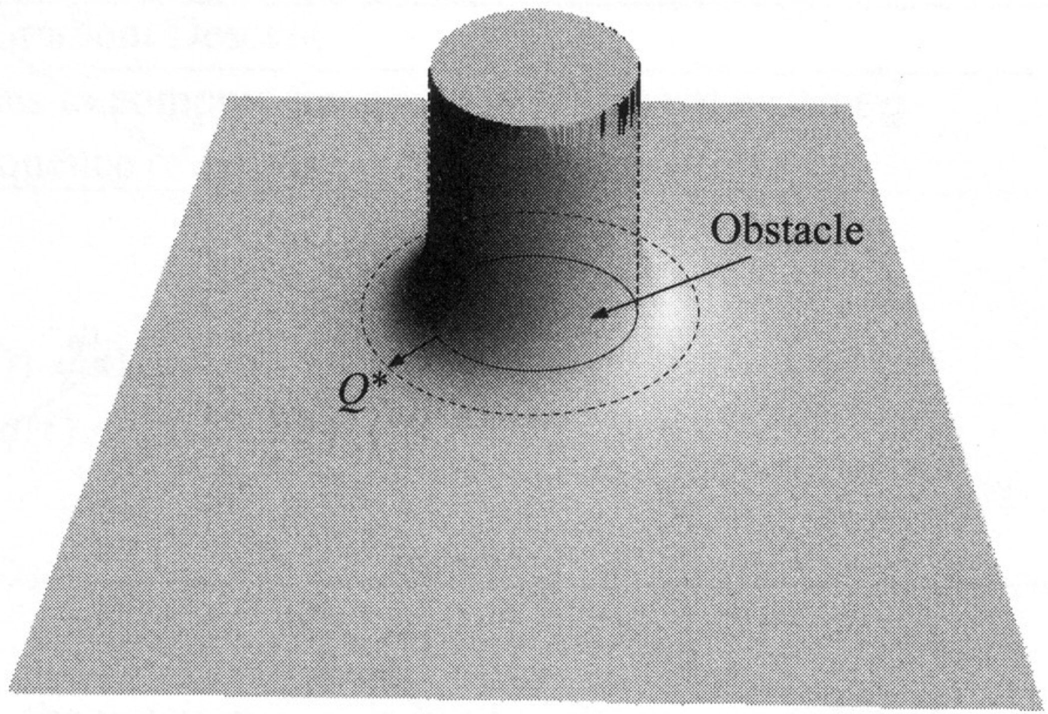


Figure 4.5 The repulsive gradient operates only in a domain near the obstacle.

Potential Field Path Planning

Attractive Energy: Distance to goal
Highly attractive farther away
Goes to zero at goal

$$U_{att}(q) \;=\; d^2(q, q_{goal})$$

Repelling Energy:
Inverse of distance to obstacles
Goes to zero as we move away

$$U_{rep}(q) \;=\; \frac{1}{d^2(q, Obstacles)}$$

Potential Function:
Sum of energy acting on robot
α weights + and - forces

$$U(q) \;=\; U_{att}(q) \;+\; \alpha\, U_{rep}(q)$$

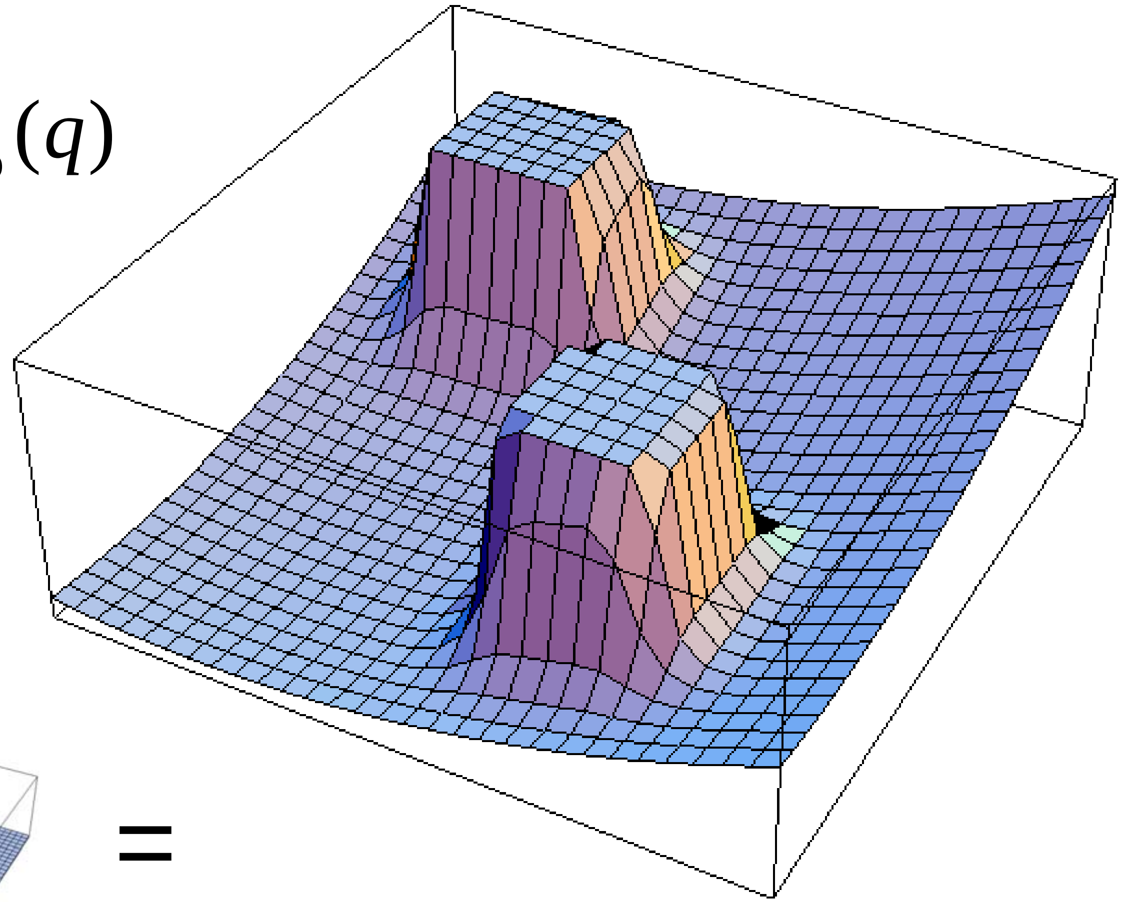
Robot moves along
negative gradient of F(q)

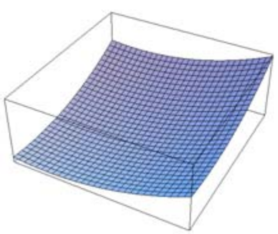
$$-\nabla U(q)$$

Total Potential Function

$$U(q) = U_{att}(q) + U_{rep}(q)$$

$$F(q) = -\nabla U(q)$$





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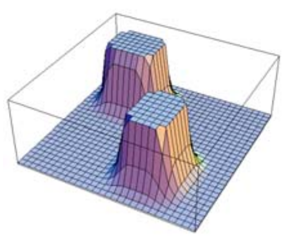

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Online Distance Computation

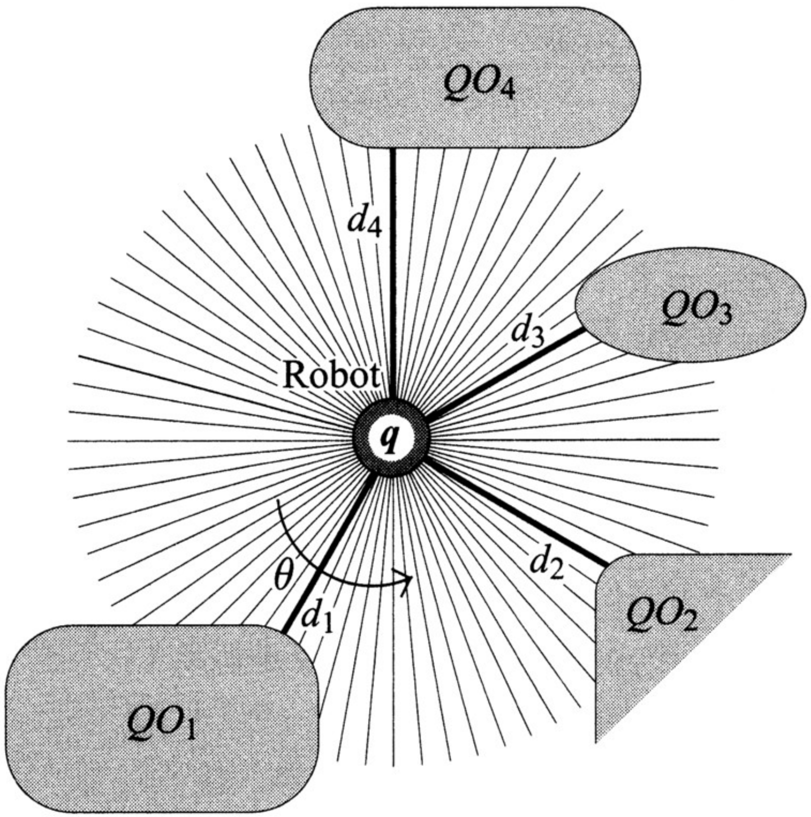
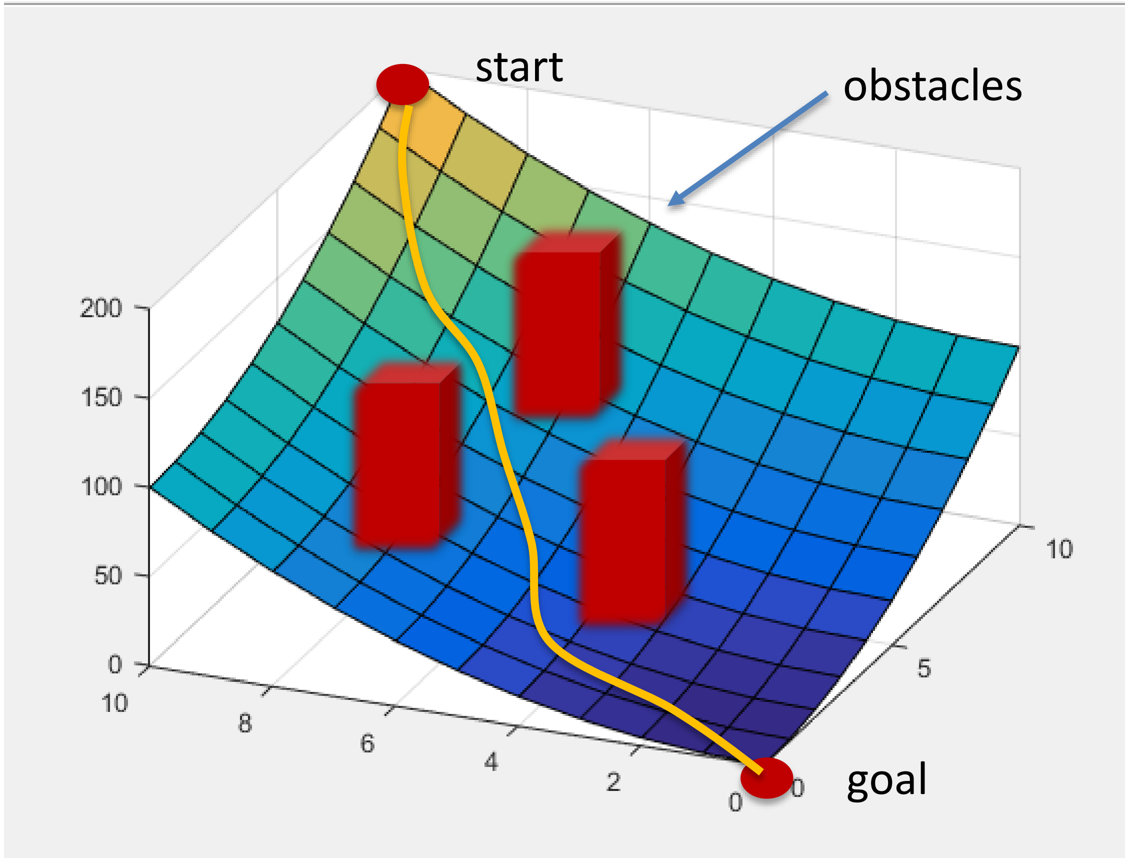


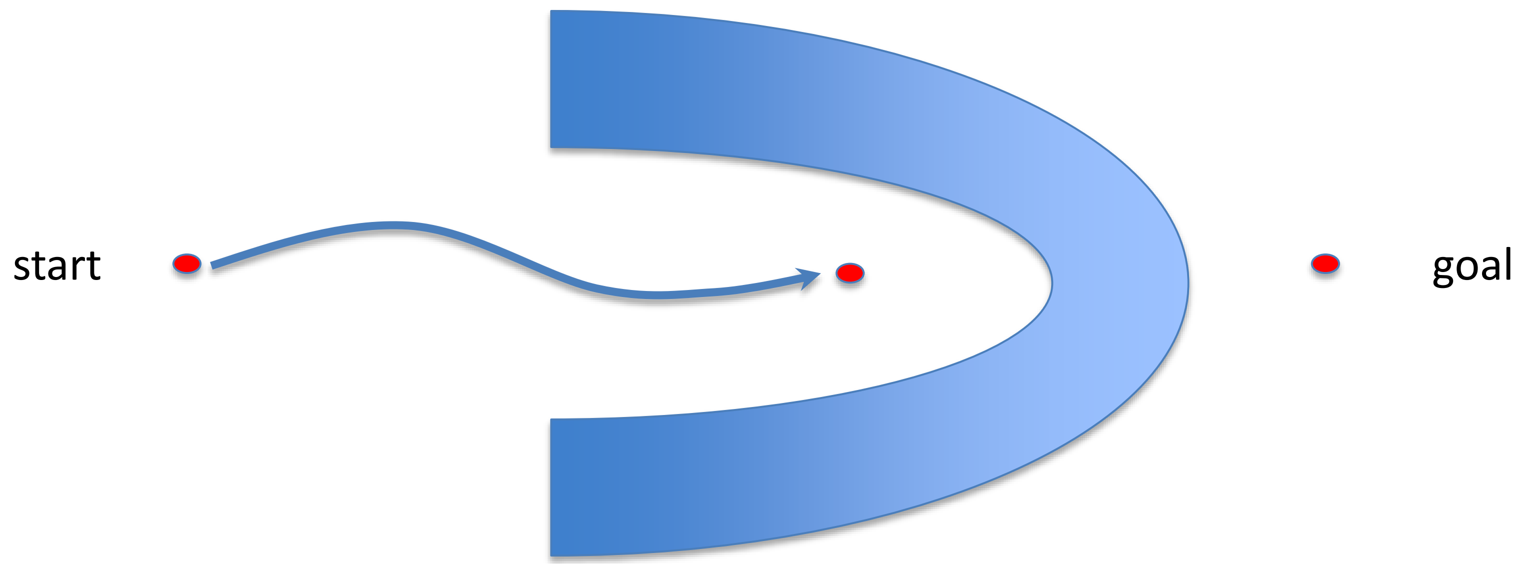
Figure 4.7 Local minima of rays determine the distance to nearby obstacles.

Potential Field



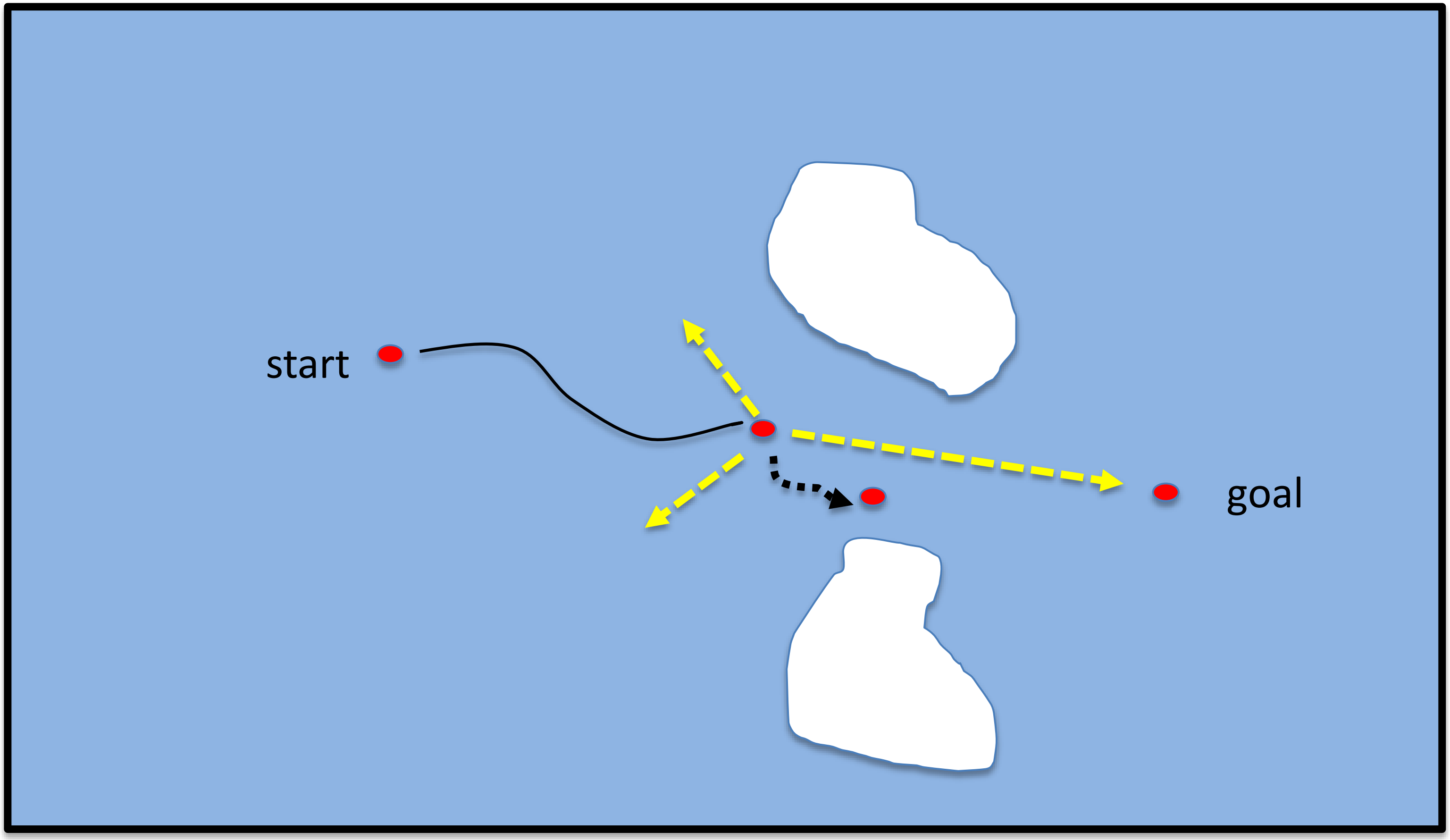
- Obstacles create high energy barriers
- Gradient descent follows energy minimization path to goal

Potential Field Limitations



Local minimum:
attractive force (goal) = repulsive force (obstacles)

Potential Field Methods



Local minimum: attractive force = repulsive force
Solution: Take a random walk – perturb out of minima
Need to remember where you have been!

Potential Fields Summary

- More than just a path planner: Provides simple control function to move robot: gradient descent
- Allows robot to move from wherever it finds itself
- Can get trapped in local minima
- Can be used as online, local method:
  - As robot encounters new obstacles v compute the Potential Function onlir
  - Laser/sonar scans give online distance to obstacles