ETH Zürich

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Robotics Programming Laboratory

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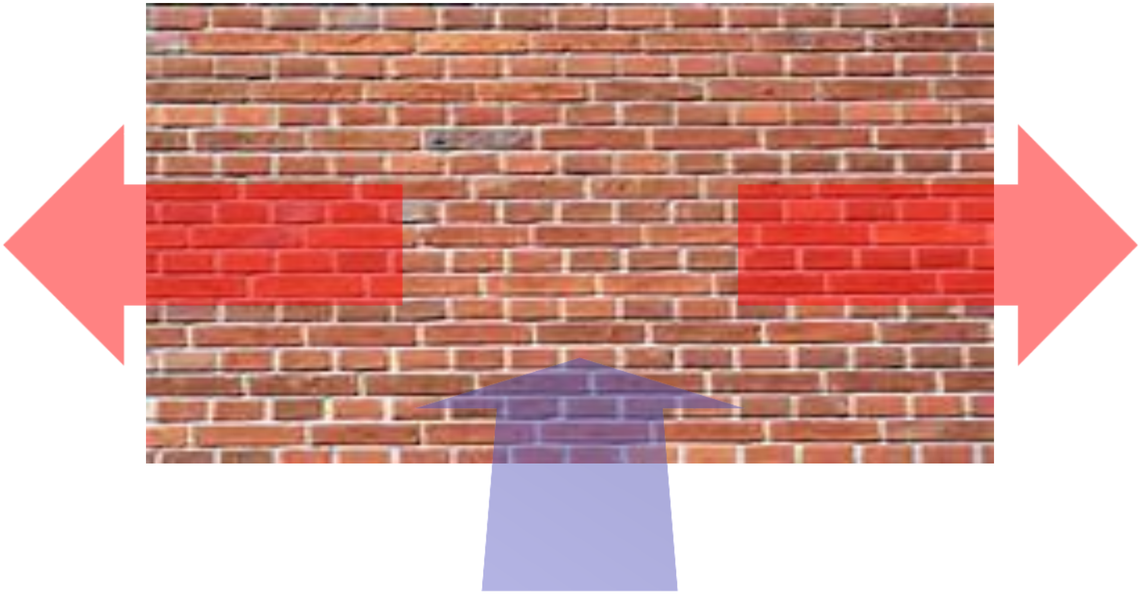
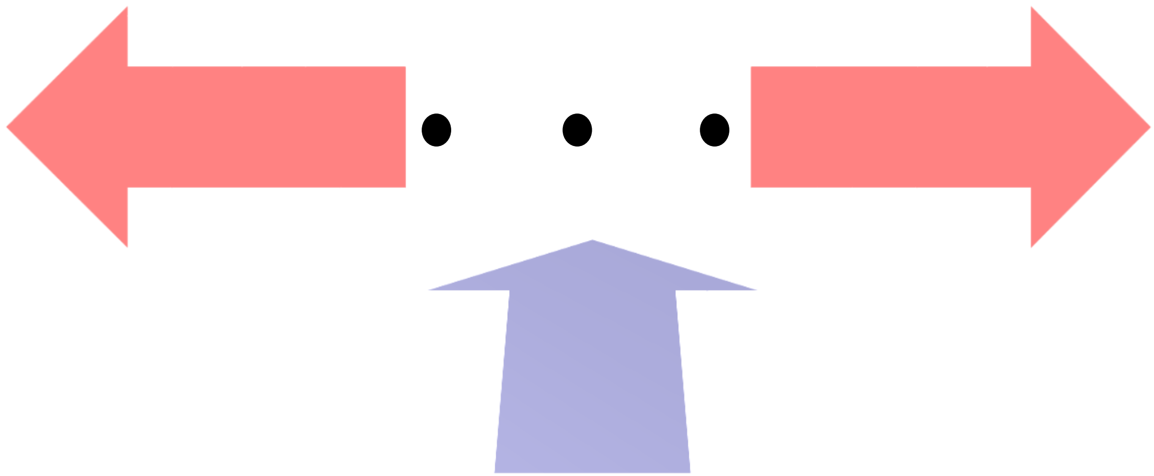
Lecture 5: Obstacle Avoidance

Obstacle avoidance: our perspective



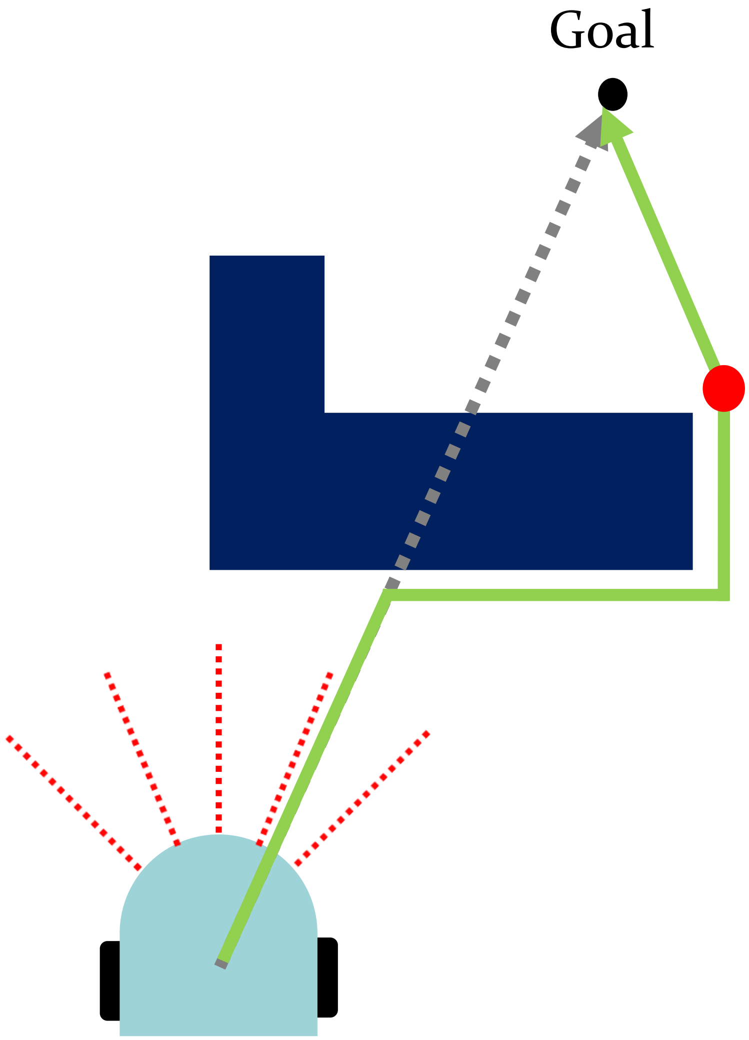
Obstacle avoidance: robot's perspective



Bug algorithms

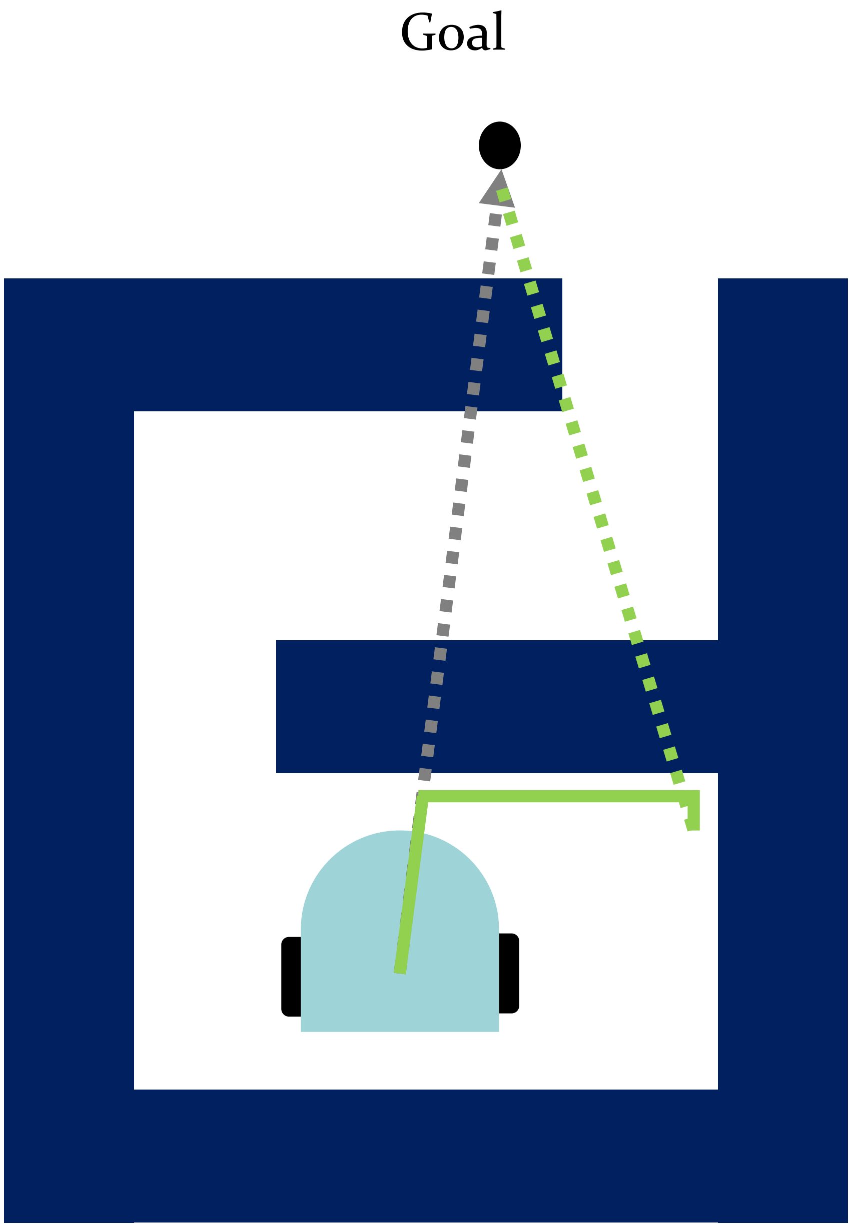
- Known:
  - Goal position
  - Current position
  - Sensing ability to detect nearby obstacles
- Sense -> Act: does not store any past information
- Sensor:
  - Bug 0, Bug 1, Bug 2: tactile sensor
  - Tangent Bug: range sensor

Bug 0

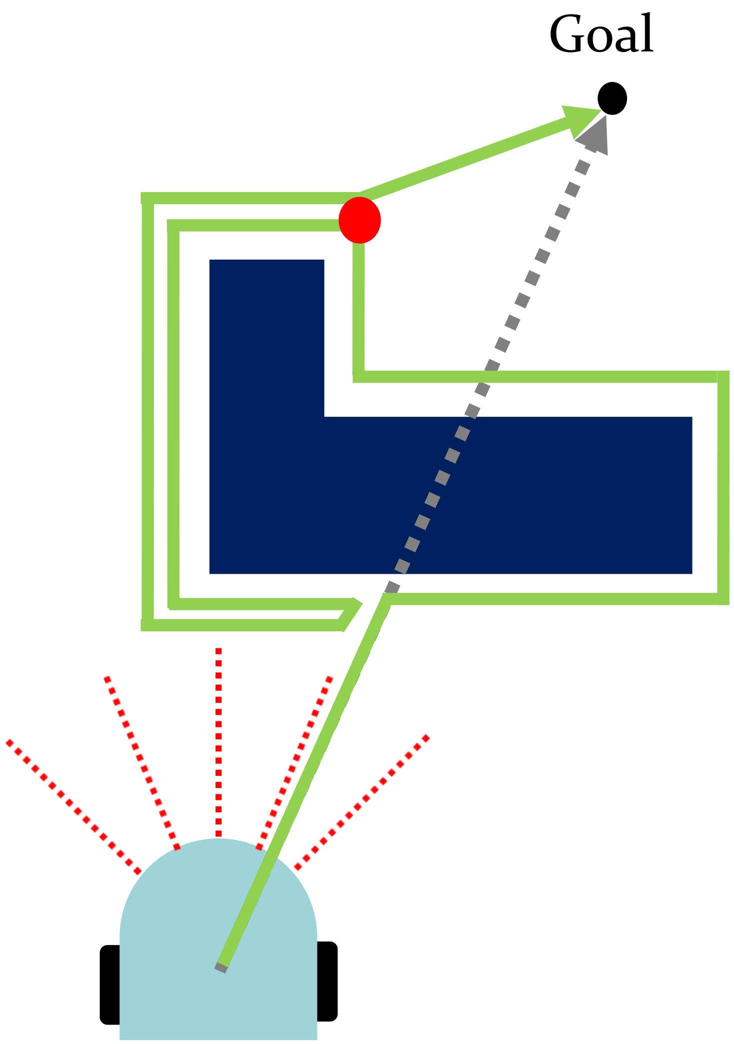


1. Move toward the goal:
   1. If the goal is reached: Stop
   2. If an obstacle is in the way: Go to step 2
2. Follow the obstacle boundary:
   1. If no obstacle in the way, go back to step 1.

When does Bug 0 fail?



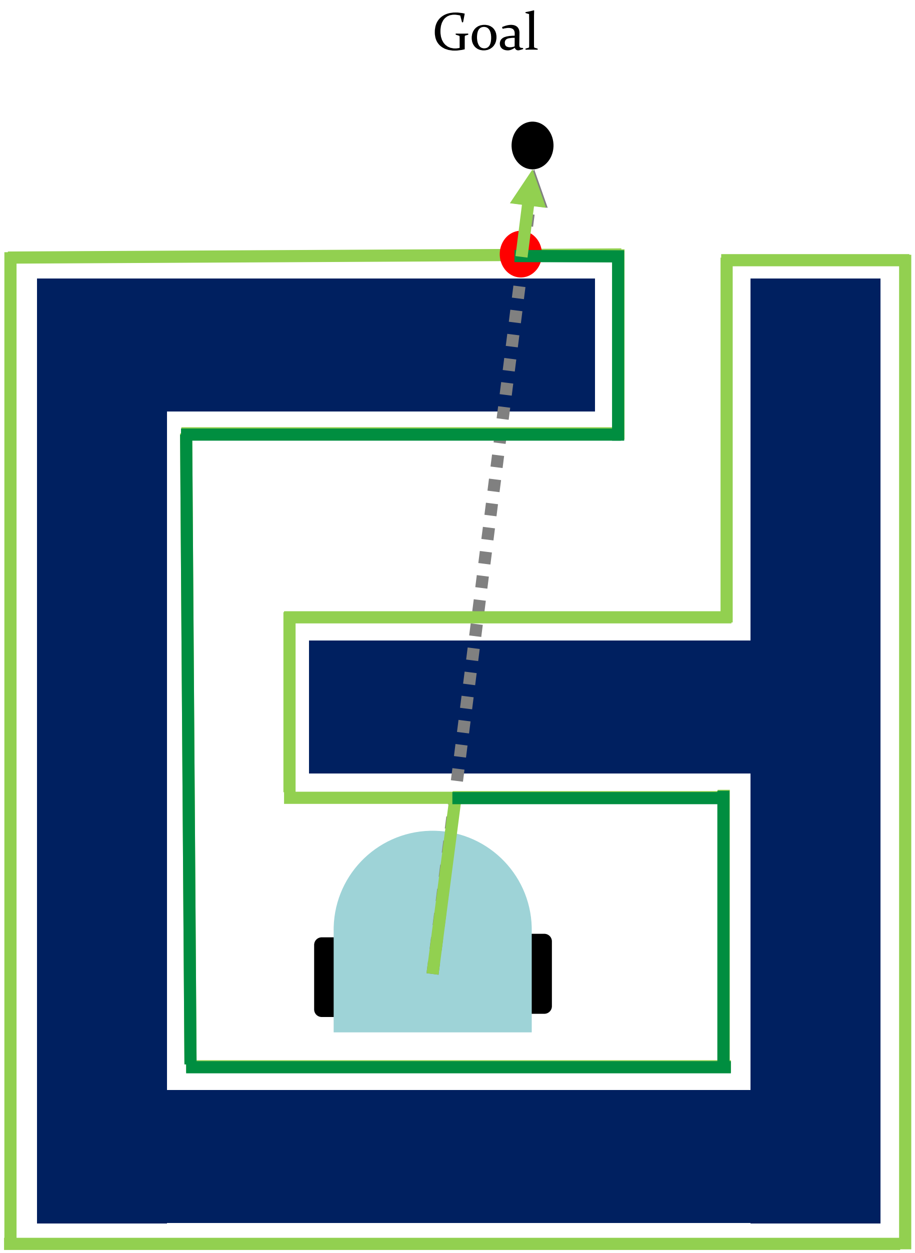
Bug 1



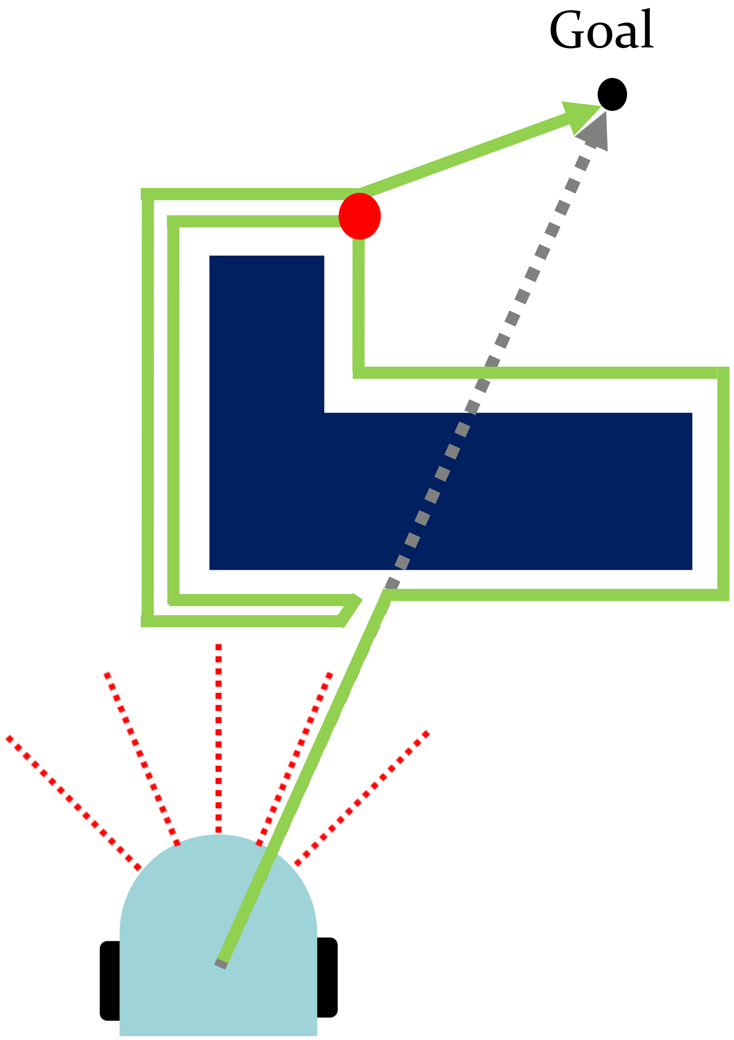
1. Move toward the goal:
   1. If the goal is reached: Stop
   2. If an obstacle is in the way: Go to step 2
2. Follow the obstacle boundary:
   1. Mark the closest
   2. After a complete loop: Go to the closest point to the goal then go back to step 1.

Lumelsky , V. & Stepanov, A. "Path-planning strategies for a point mobile automaton moving amidst unknown obstacles of arbitrary shape," . Algorithmica 2:403-430. 1987

Will Bug 1 fail?



How much would Bug 1 travel?



Given

- D: distance between start and goal
- P_i: Perimeter of i'th obstacle

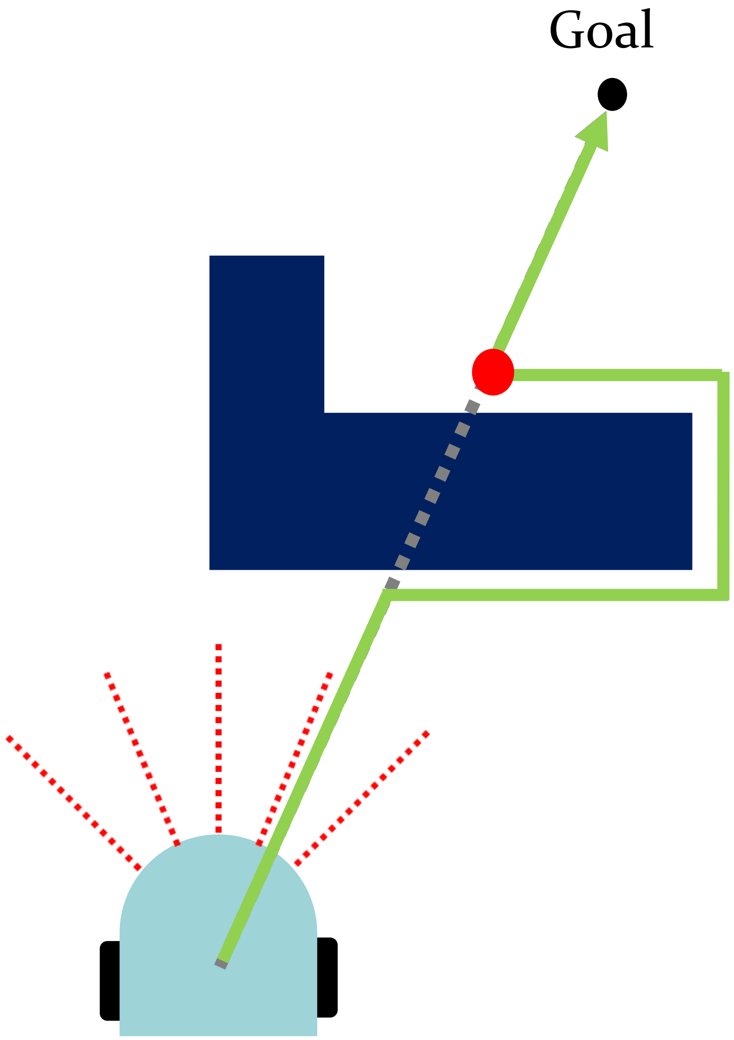
Shortest travel distance?

- D

Longest travel distance?

- $D + 1.5 \sum_i P_i$

Bug 2

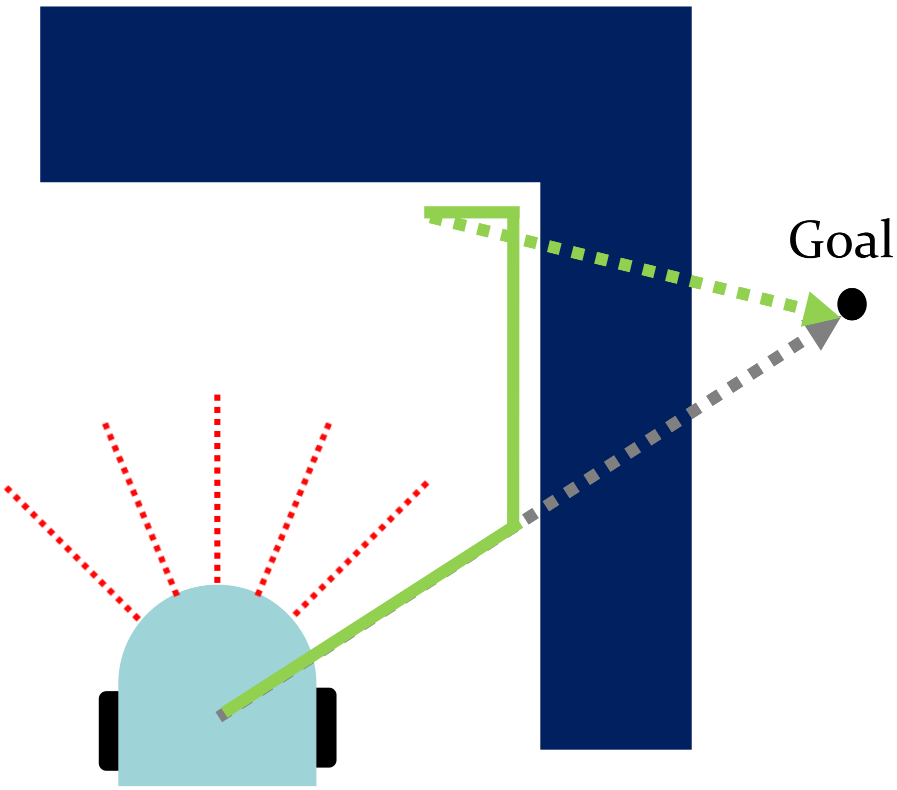


1. Move toward the goal:
    1. If the goal is reached: Stop
    2. If an obstacle is in the way: Go to step 2
2. Follow the obstacle boundary:
    1. If the goal line is crossed and is closer to the goal: Go to step 1.

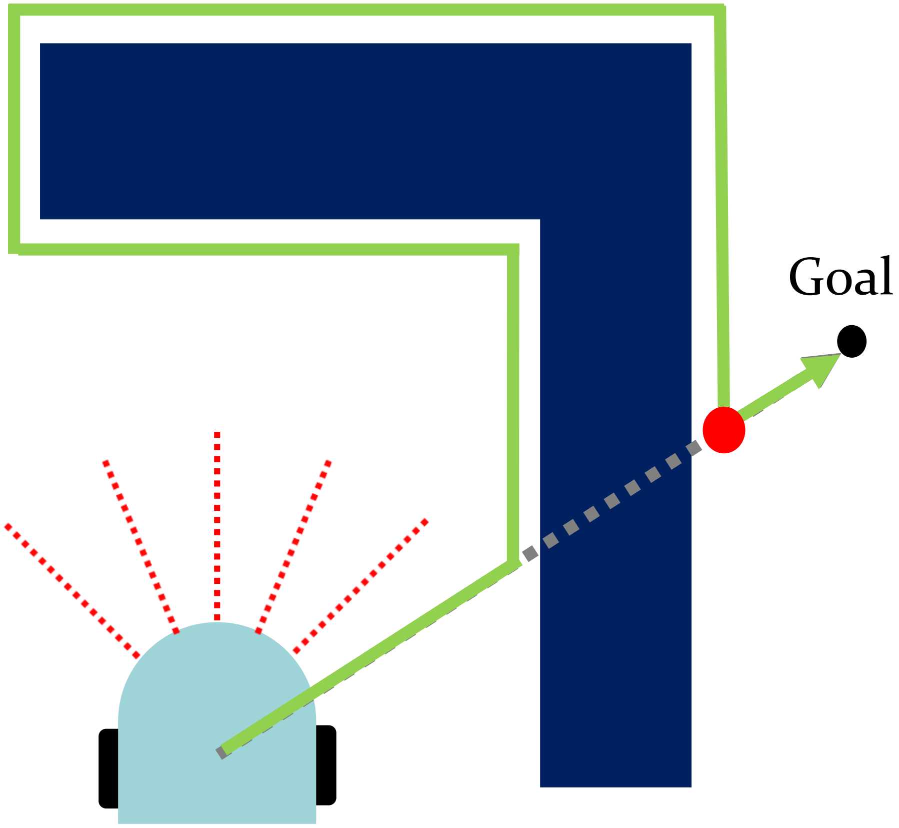
Lumelsky , V. & Skewis, T. "Incorporating range sensing in the robot navigation function," IEEE Transactions on Systems, Man, and Cybernatics 20(5): 1058-1068, 1990.

Is crossing the goal line important?

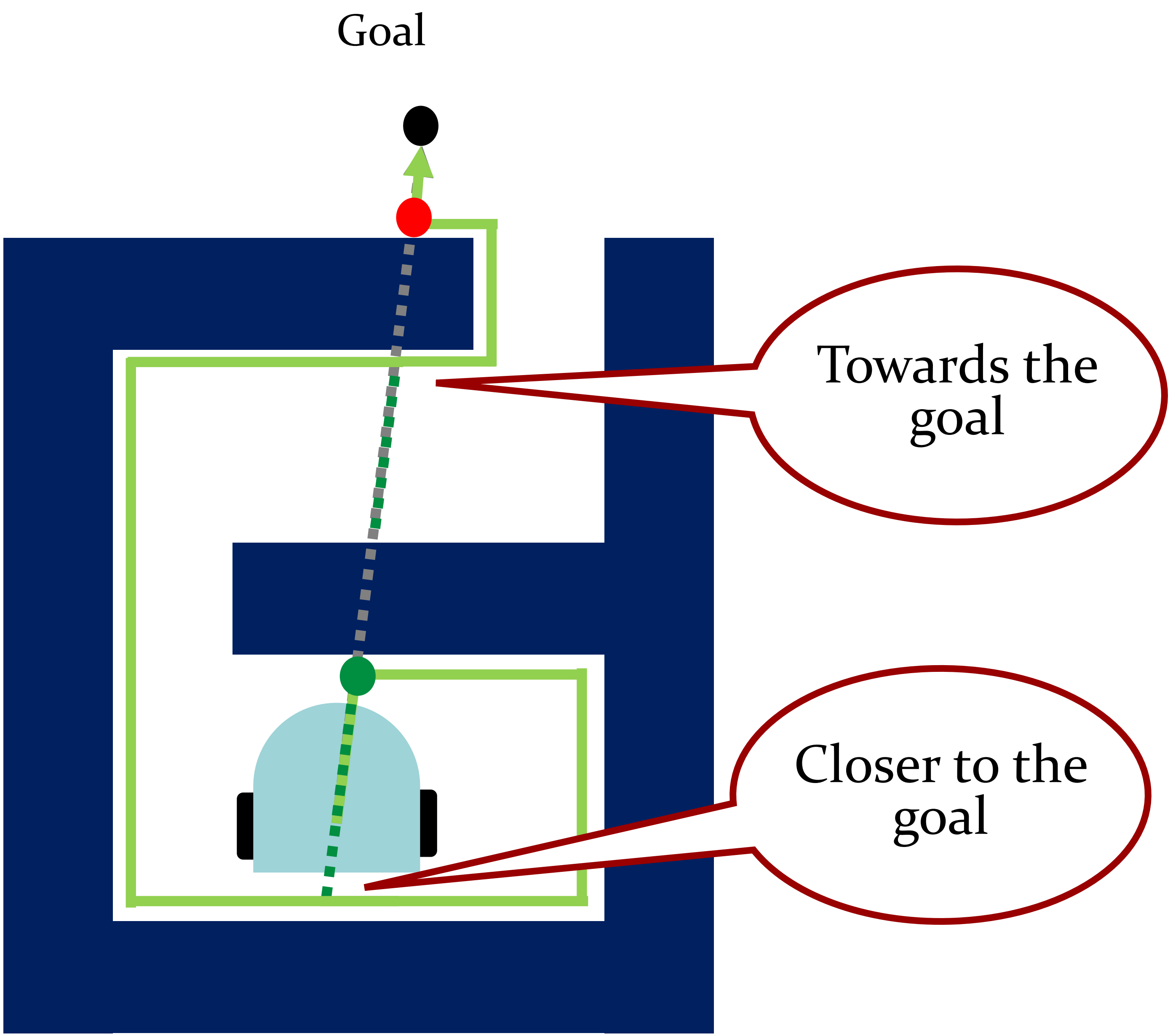
Bug 0



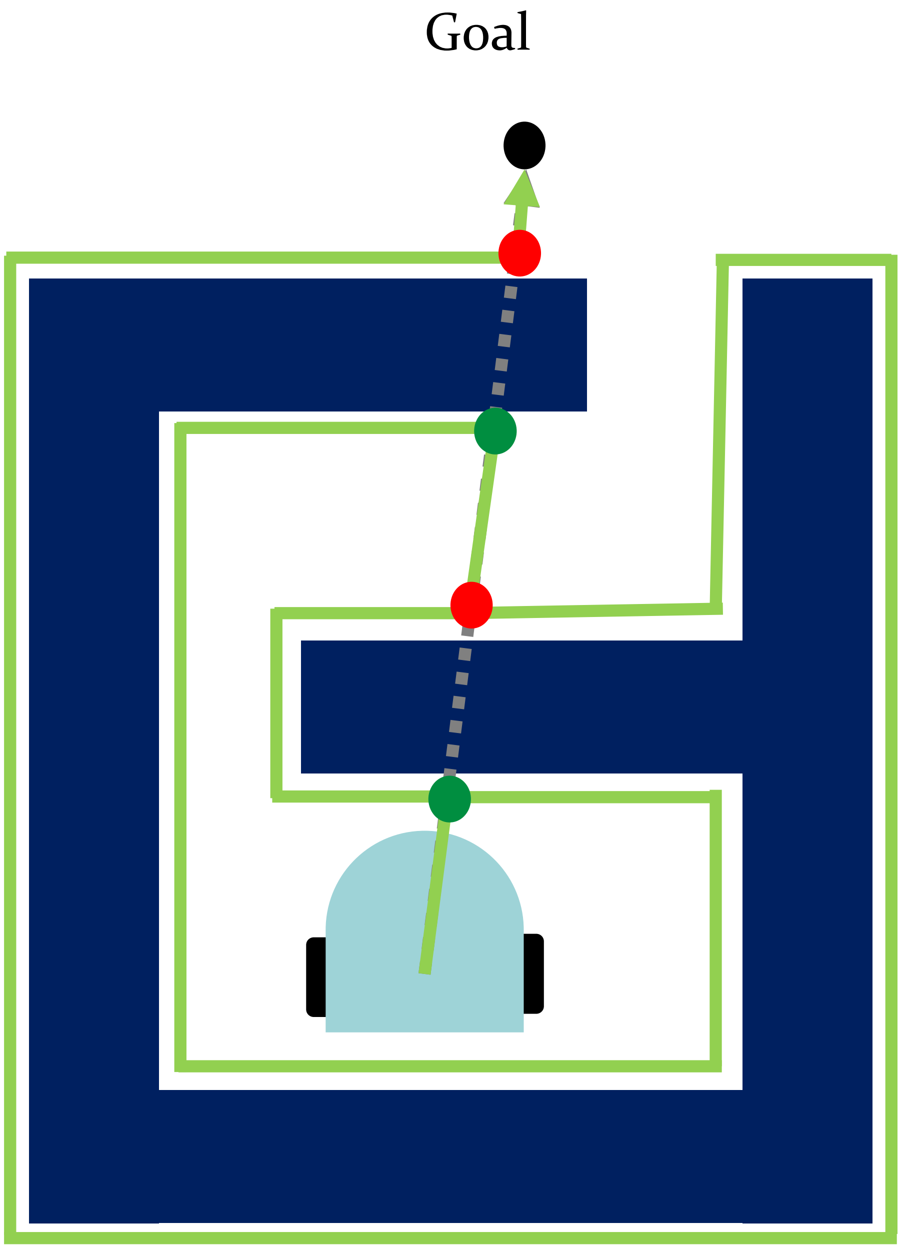
Bug 2



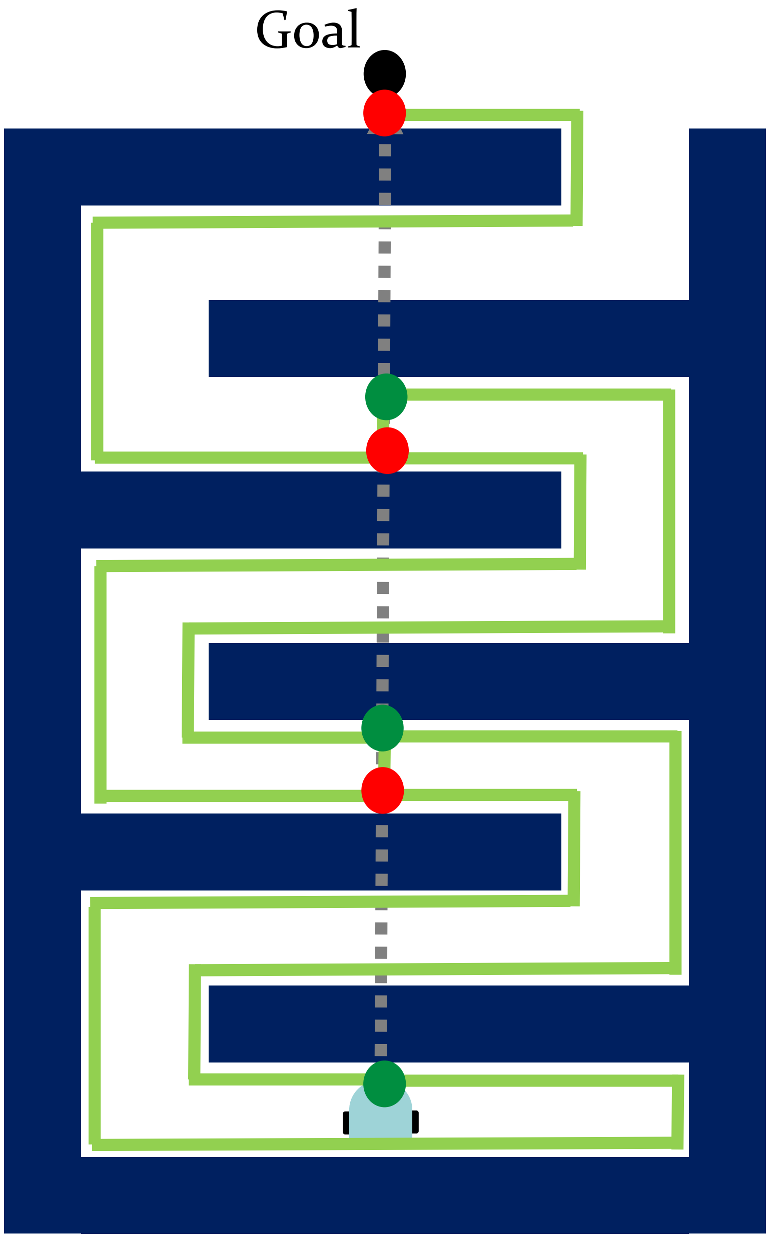
How well does Bug 2 work?



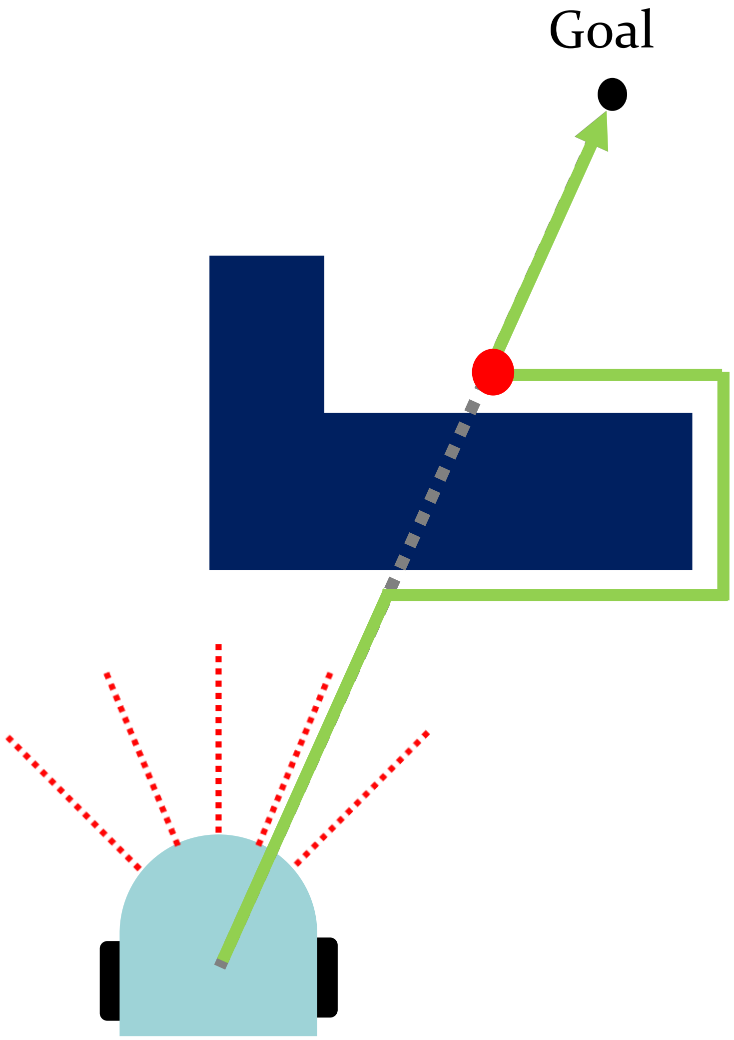
How well does Bug 2 work?



How well does Bug 2 work?



How much would Bug 2 travel?



Given

- D: distance between start and goal
- P_i: Perimeter of i'th obstacle
- n_i: number of times i'th obstacle crosses the goal line

Shortest travel distance?

- D

Longest travel distance?

- $D + 1/2 \sum_i n_i P_i$

Bug 1 vs Bug 2

Bug 1

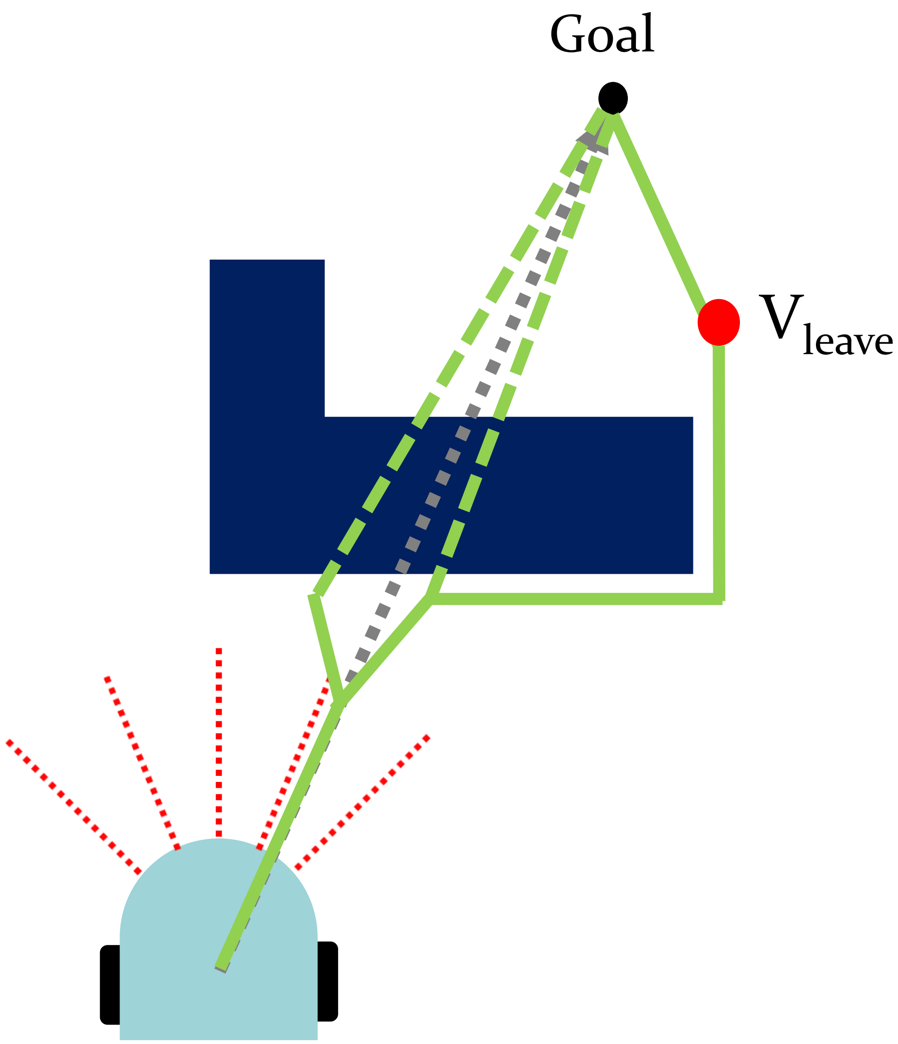
- Exhaustive search: analyze all choices before committing
- More predictable performance

Bug 2

- Greedy search: take the first viable choice
- Generally outperforms Bug 1 but could be worse if the obstacles are complex

Can we do better if we can see more?

TangentBug

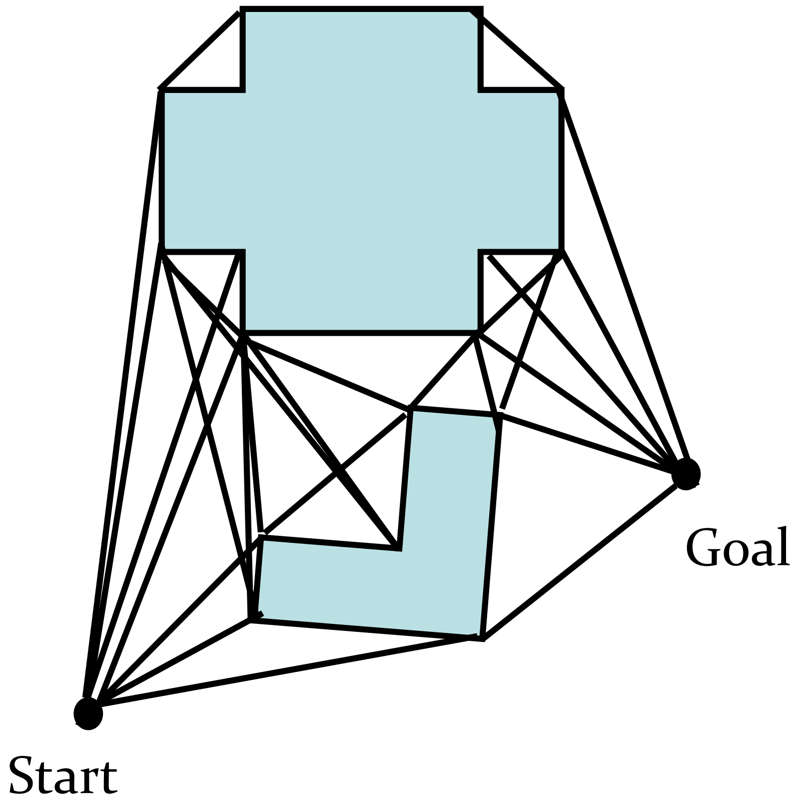


1. Move toward the goal:
   1. If the goal is reached: Stop
   2. If a local minimum is detected: Go to step 2
2. Move along the boundary marking d_{min}:
   1. If the goal is reached: Stop
   2. If $d(V_{leave}, goal) < d_{min}$: Go to step 3
3. Perform the transition phase:
   1. Move directly towards V_{leave} until Z, where $d(Z, goal) < d_{min}$: Go to step 1

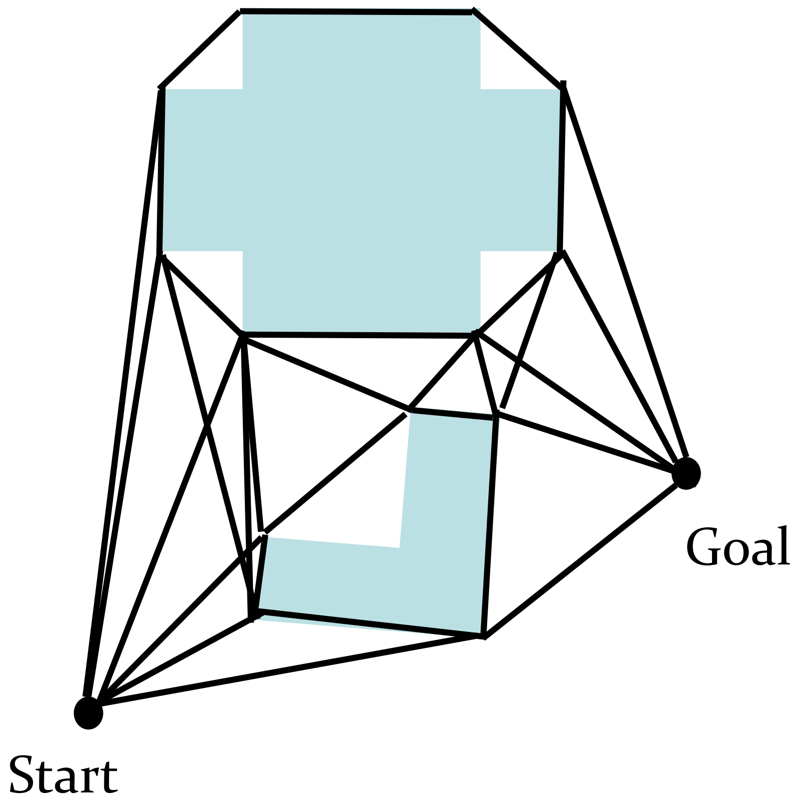
Kamon, I., Rimon, E. & Rivlin, E. "TangentBug: A Range-Sensor-Based Navigation Algorithm," The International Journal of Robotics Research. 17(9): 934-953, 1998.

Visibility graph & tangent graph

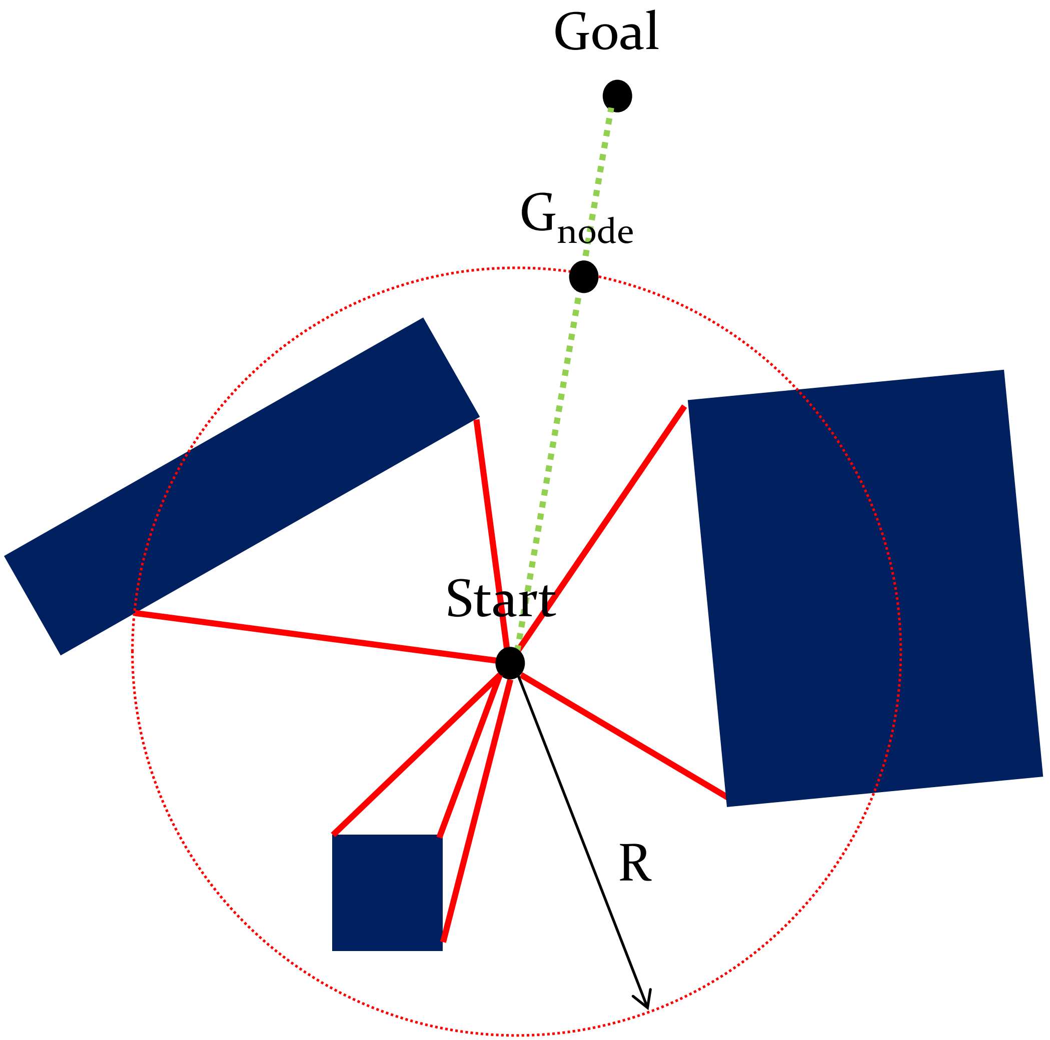
Visibility graph



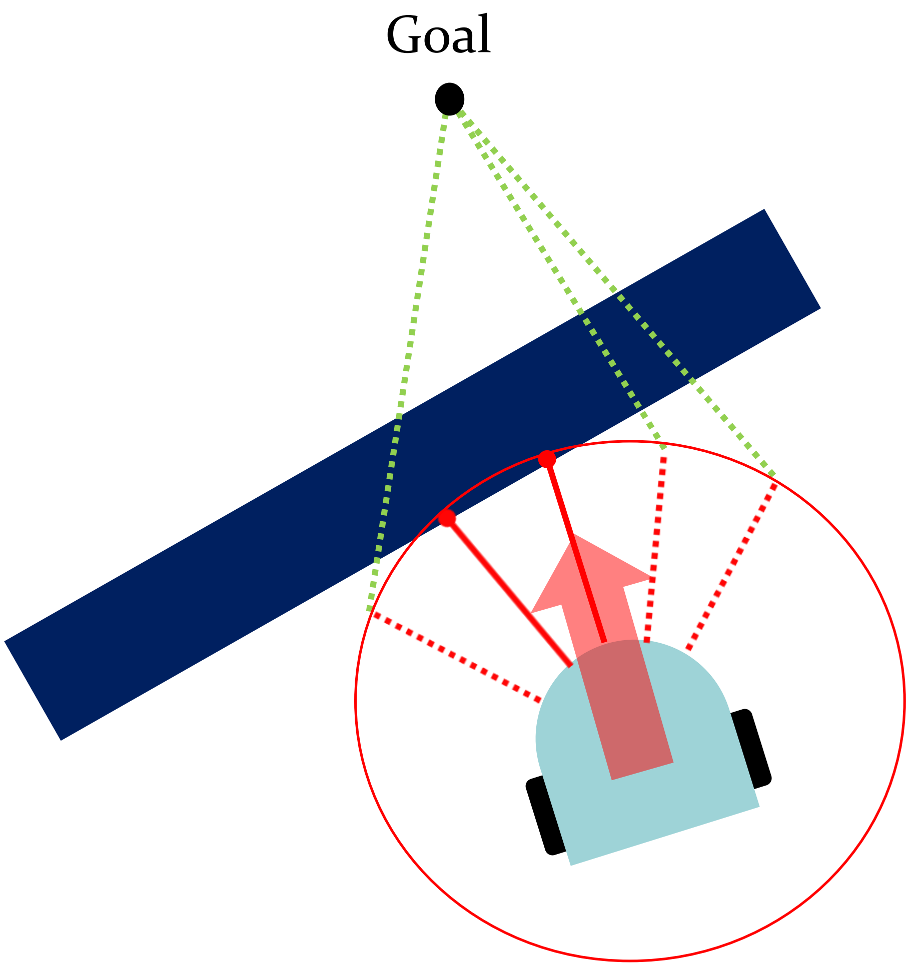
Tangent graph



Local tangent graph

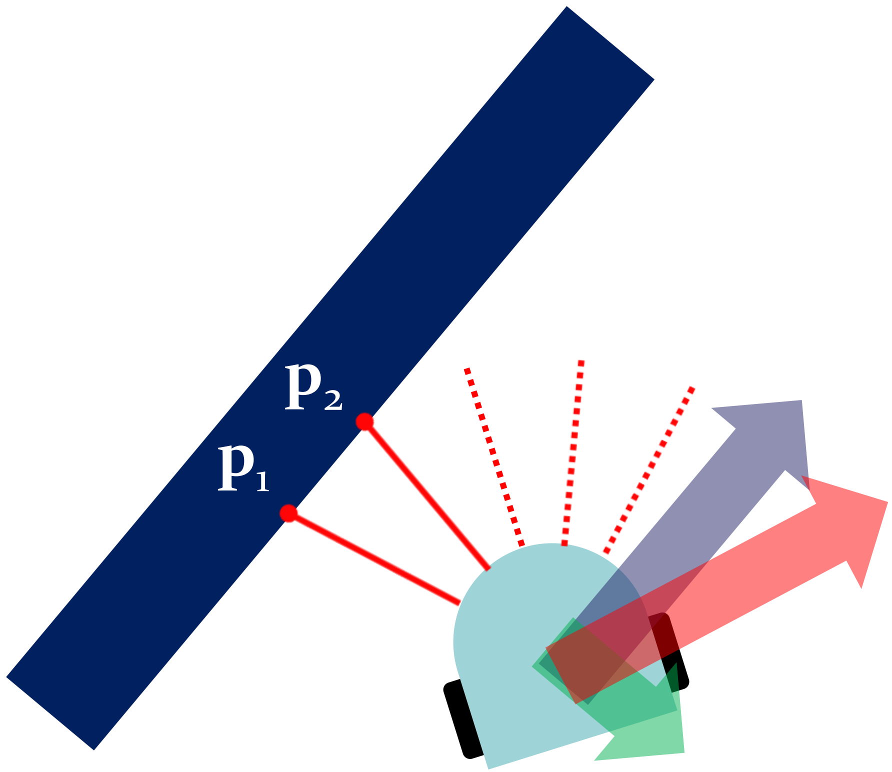


Local minimum detection



$d(x, goal) \leq d(V, goal)$ for all V

Wall Following

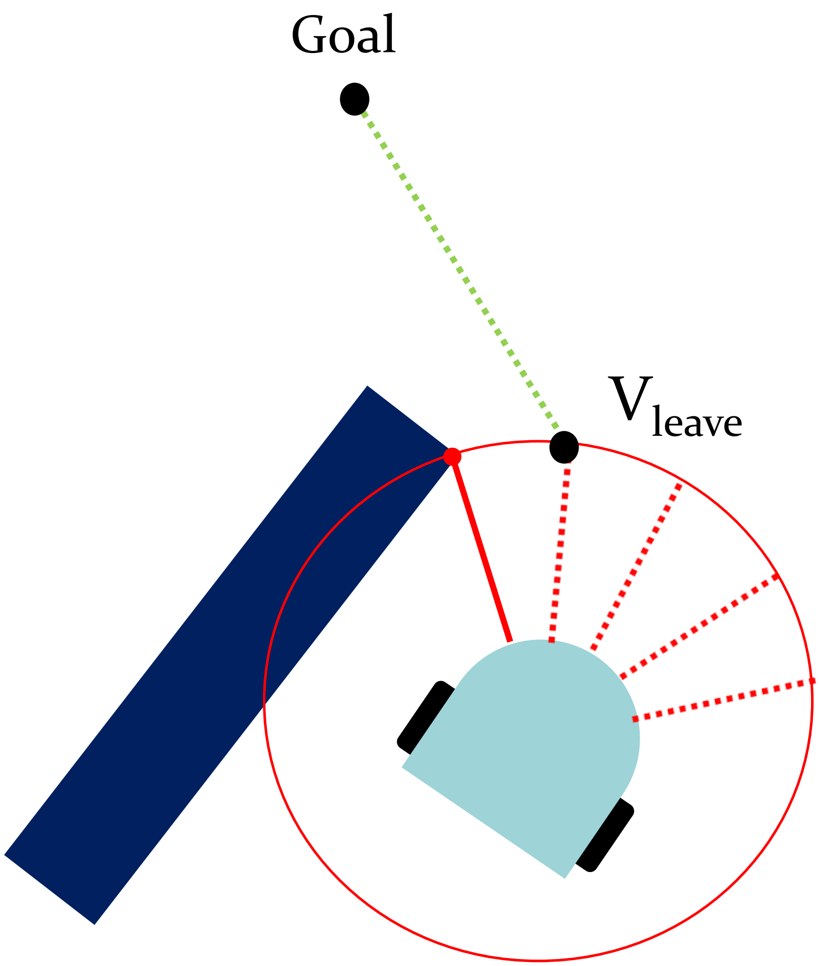


$$\mathbf{v}_{wall} := \mathbf{p}_2 - \mathbf{p}_1$$

$$\mathbf{v}_{distance} := (d_{current} - d_{desired}) * \mathbf{v}_{perpendicular}$$

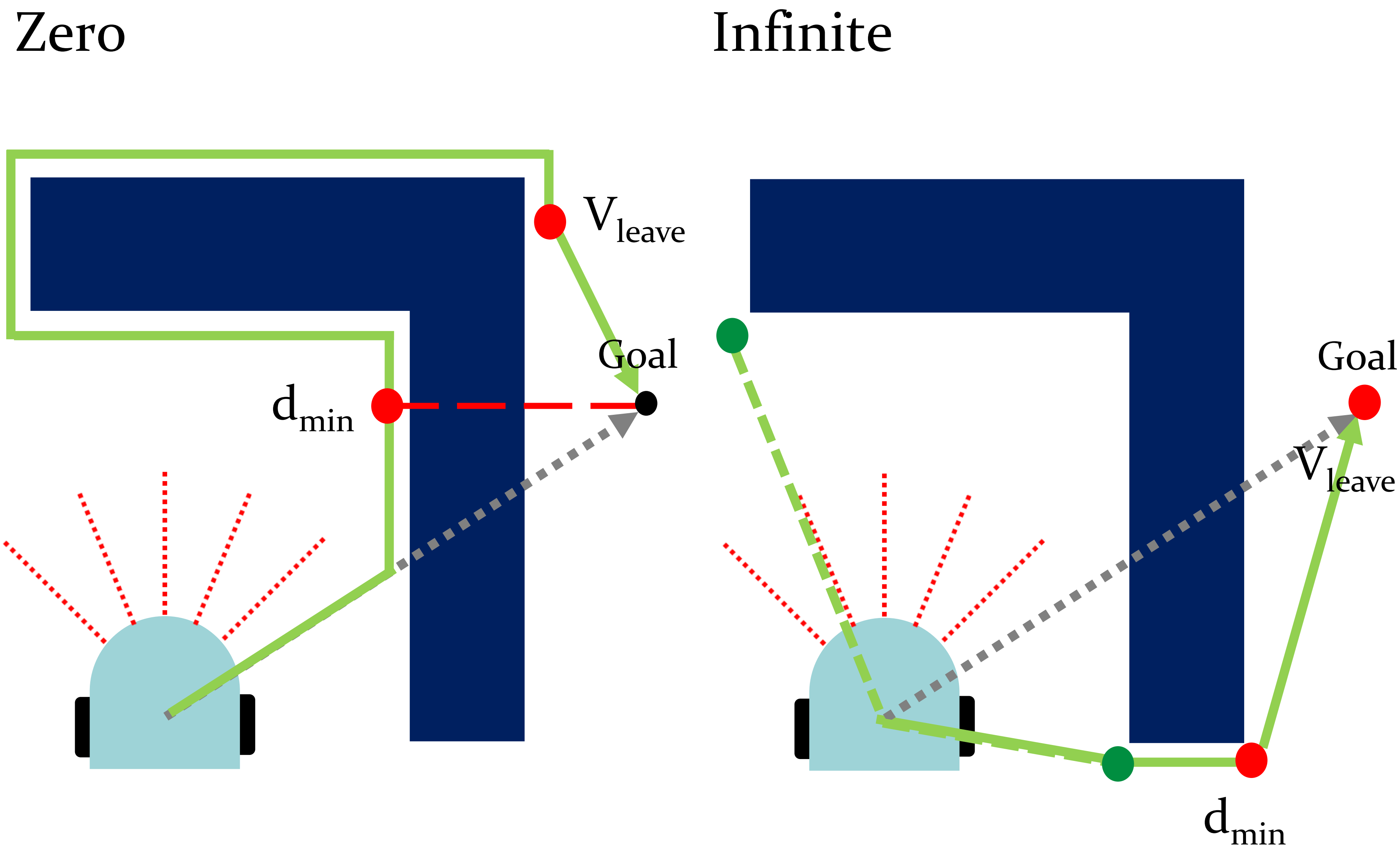
$$\mathbf{v}_{robot} := d_{desired} * \mathbf{v}_{wall} + \mathbf{v}_{distance}$$

Leave condition detection

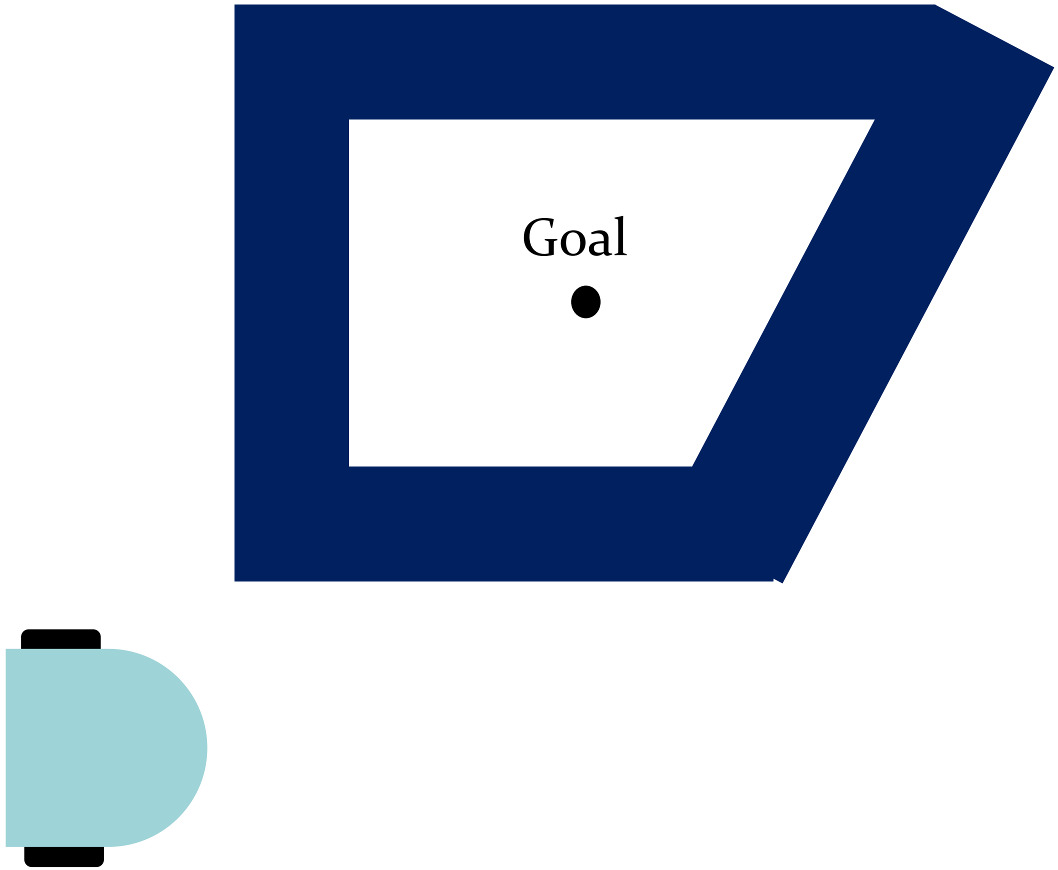


$$d(V_{leave}, goal) < d_{min}$$

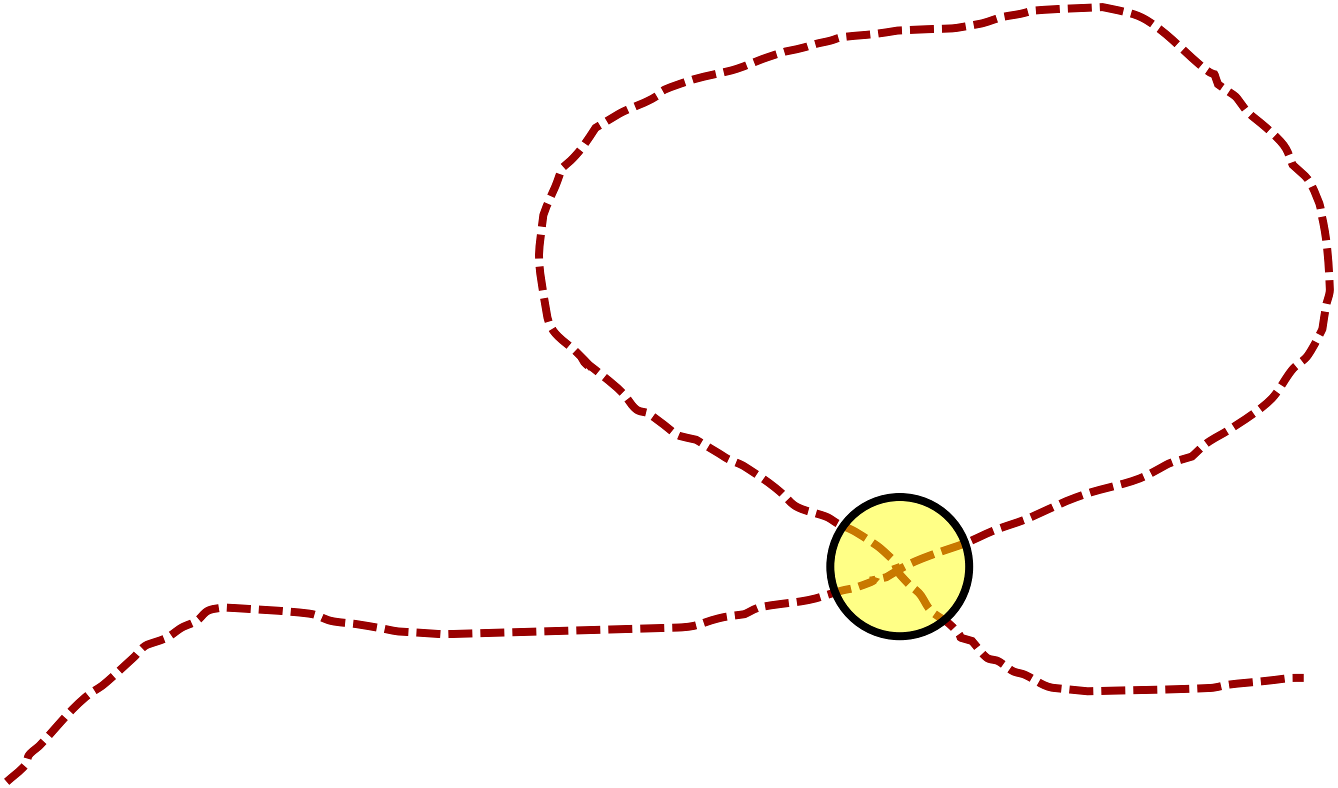
Sensor range



Unreachable goal



Loop closure



Challenging!

- Drift
- Limited sensor information

Software engineering tips

```
class
  TANGENT_BUG
feature
  update_velocity ( ... )
    do
        if state = go_to_goal_s then
          go_to_goal ( ... )
        elseif state = wall_following_s then
          follow_wall ( ... )
        elseif state = transition_s then
          transition_to_goal ( ... )
        ...
    end
```

```
class
  TANGENT_BUG
feature
  update_velocity ( ... )
    do
        current_state.update_velocity ( ... )
        ...
    end
current_state: STATE
```

```
deferred class
  STATE
feature
  update_velocity ( ... )
```

```
class
  GO_TO_GOAL_STATE
inherit
  STATE
```