15-494/694: Cognitive Robotics

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Lecture 7:

The World Map

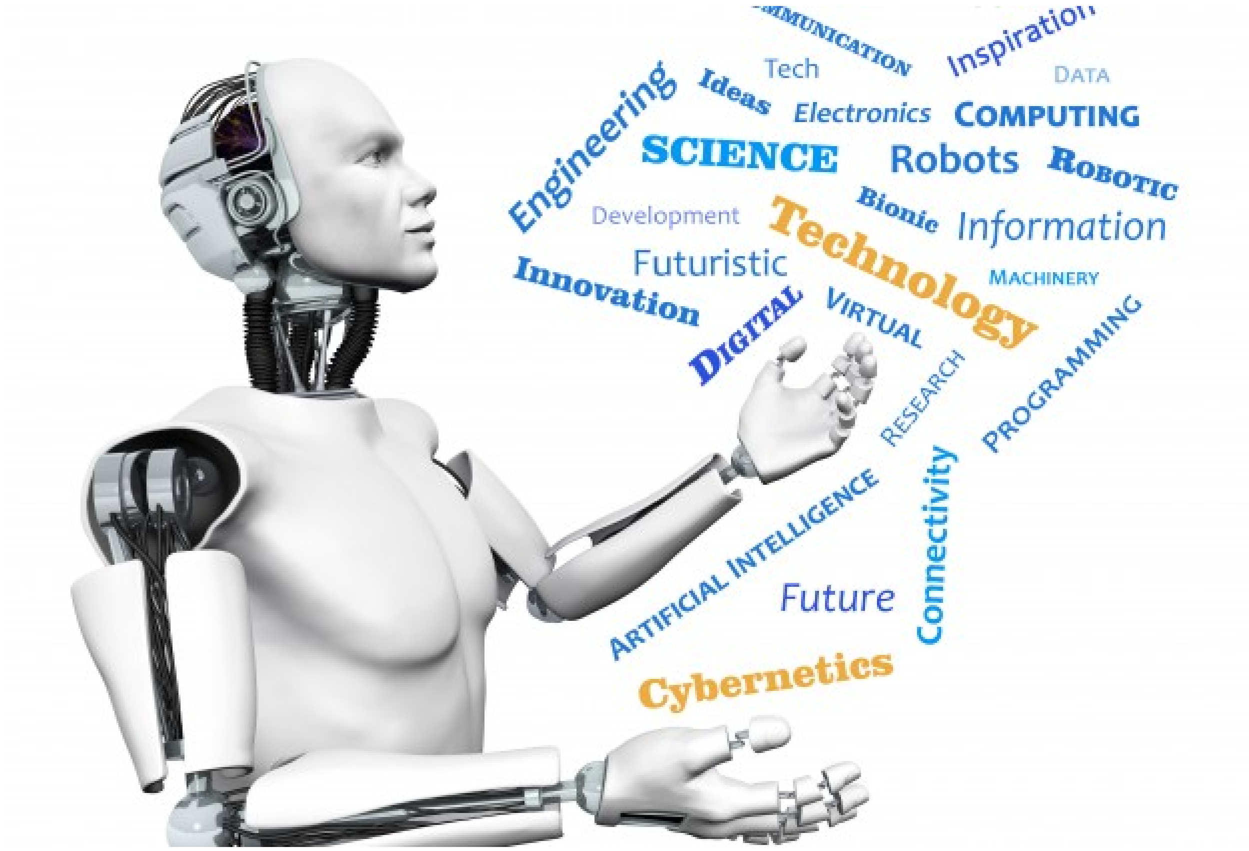


Image from http://www.futuristgerd.com/2015/09/10

Outline

- Why have a world map?
- What's in the vex-aim-tools world map?
- The data association problem
- The kidnapped robot problem
- Obstacle detection

Why Have A World Map?

- Represent objects available to the robot.
- Landmarks to be used for localization.
- Obstacle avoidance during path planning.

The vex-aim-tools World Map

- Barrels, balls, AprilTags from “aivision”
- Aruco markers from OpenCV
- Coming soon: walls / doorways
- Future: cliffs
- To access the world map:
    - robot.worldmap is a WorldMap object
- Objects are in:
    - robot.worldmap.objects

Object Pose

- A Pose is in (x,y,z,θ) coordinates.
  - Angles are in radians
- Pose is defined in utils.py.

- The robot and all world map objects have positions that instances of utils.PoseEstimate.
  - Uses a Kalman filter to estimate position

The Data Association Problem

- You see an orange barrel.
  - OrangeBarrel.a
- You move to another position.
- You see an orange barrel again.
- Is this the same barrel, or a new one?
  - Compare world (not camera) coordinates.
  - Requires accurate robot position info.
- Did someone move the first barrel?
- How many orange barrels are there?

Current vex-aim-tools Solution

1) For each new image, find all the objects and calculate their world coordinates.

2) Match new objects to world map objects if coordinates are “close enough”.

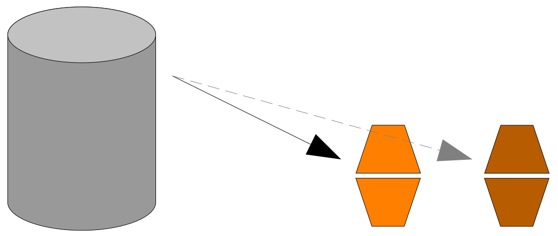
3) Calculate which world map objects *should* be visible given robot pose and note any that weren’t matched. Assume they moved somewhere; mark as “missing”.

4) If there are seen objects remaining, assign them to missing world map objects.

5) For any remaining seen objects, create new world map objects.

Future Improvements

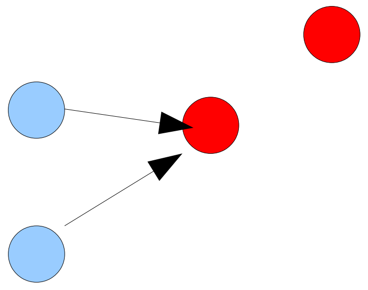
- Take occlusion into account when calculating which objects “should” be visible from current location.



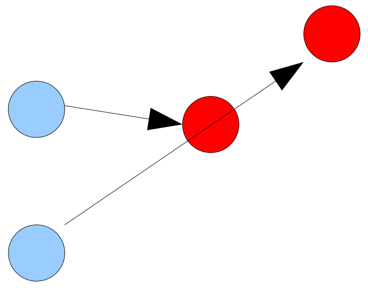
- Use a smarter algorithm to match new objects to world map objects, instead of current greedy algorithm.
  - The Hungarian algorithm (Munkres algorithm) does a better job.

Data Association

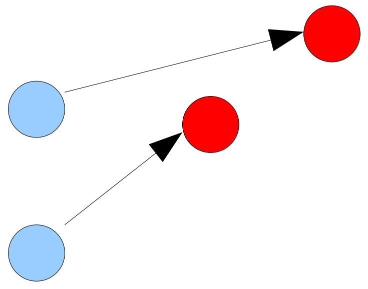
- Independent (greedy) closest match:



- Closest match without replacement:



- Hungarian algorithm:



The Kidnapped Robot Problem

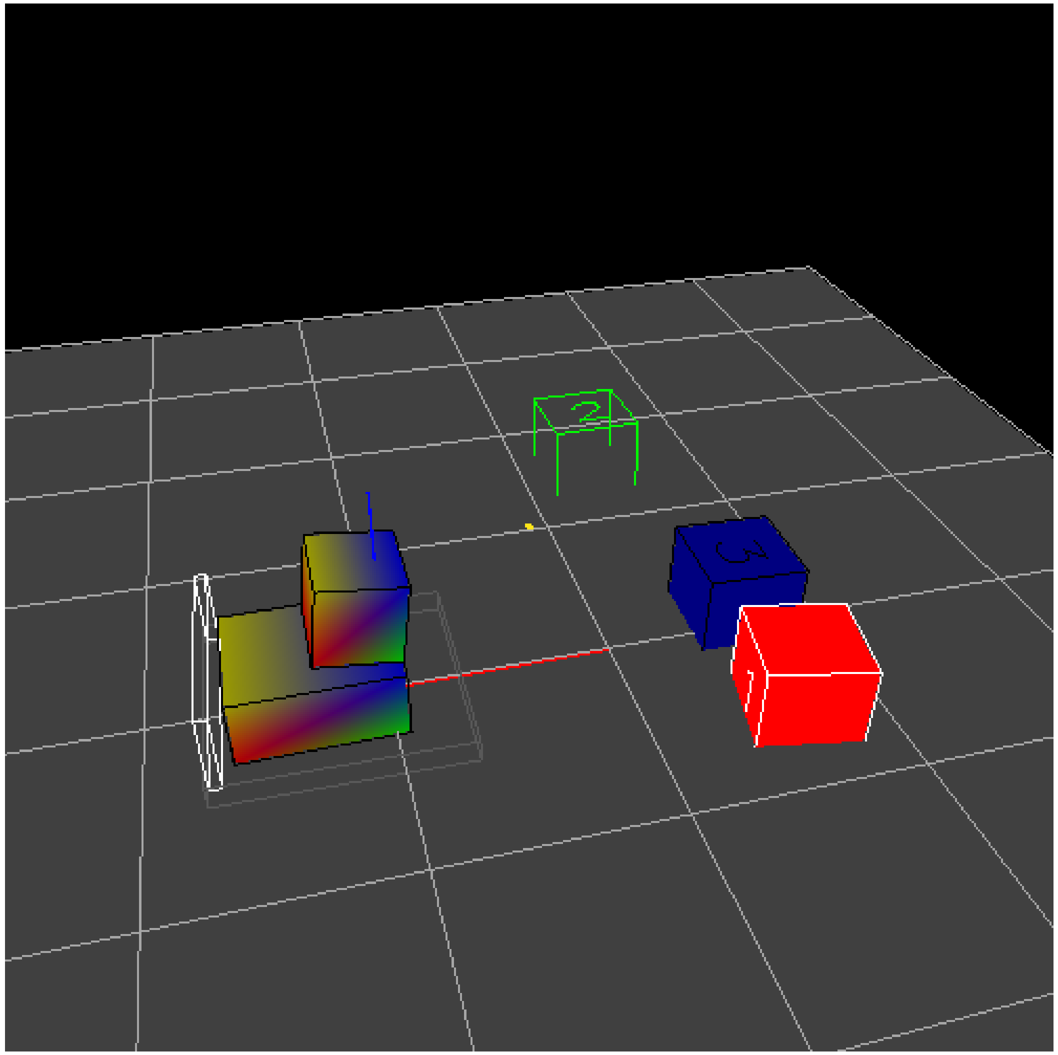
- What do we do when the robot is picked up and placed in an unknown location?
- If familiar landmarks are present, we can randomize the particles and relocalize.
- What if we don’t see any landmarks, but do see new objects?

Origin ID (Cozmo)

- The robot's origin_id starts at 1.
- Every time Cozmo is picked up and put down, he may get a new origin_id value.
- Landmarks can pull him back to an old id.

- Every time the robot sees an object, that object's origin_id is updated to match the robot's.
- Object poses are only valid if their origin_id matches the robot's.

show worldmap_viewer



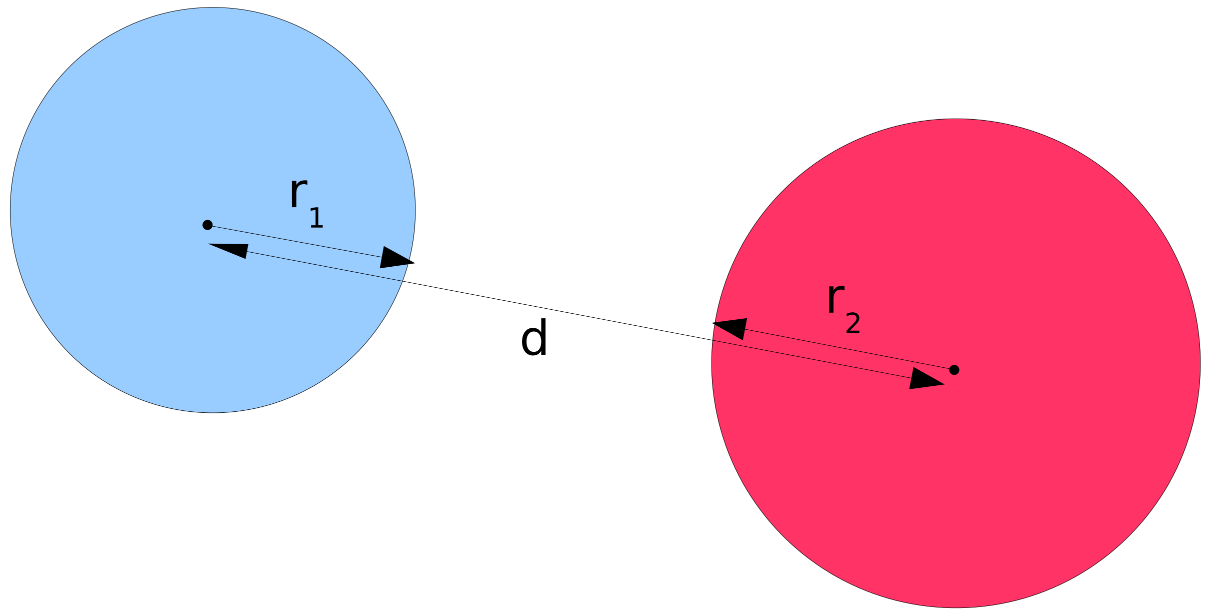
Obstacle Avoidance

- Having a world map allows us to do path planning to avoid obstacles.
- The path planner needs a way to detect when two objects would collide.
- How can we detect collisions?

Collision Detection

- Represent the robot and the obstacles as **convex polygons**.
- In 2D, use the Separating Axis Theorem to check for collisions.
  - Easy to code
  - Fast to compute
- In 3D, things get more complex.
  - The GJK (Gilbert-Johnson-Keerthi) algorithm is used in many physics engines for video games.

Collision Detection: Circles

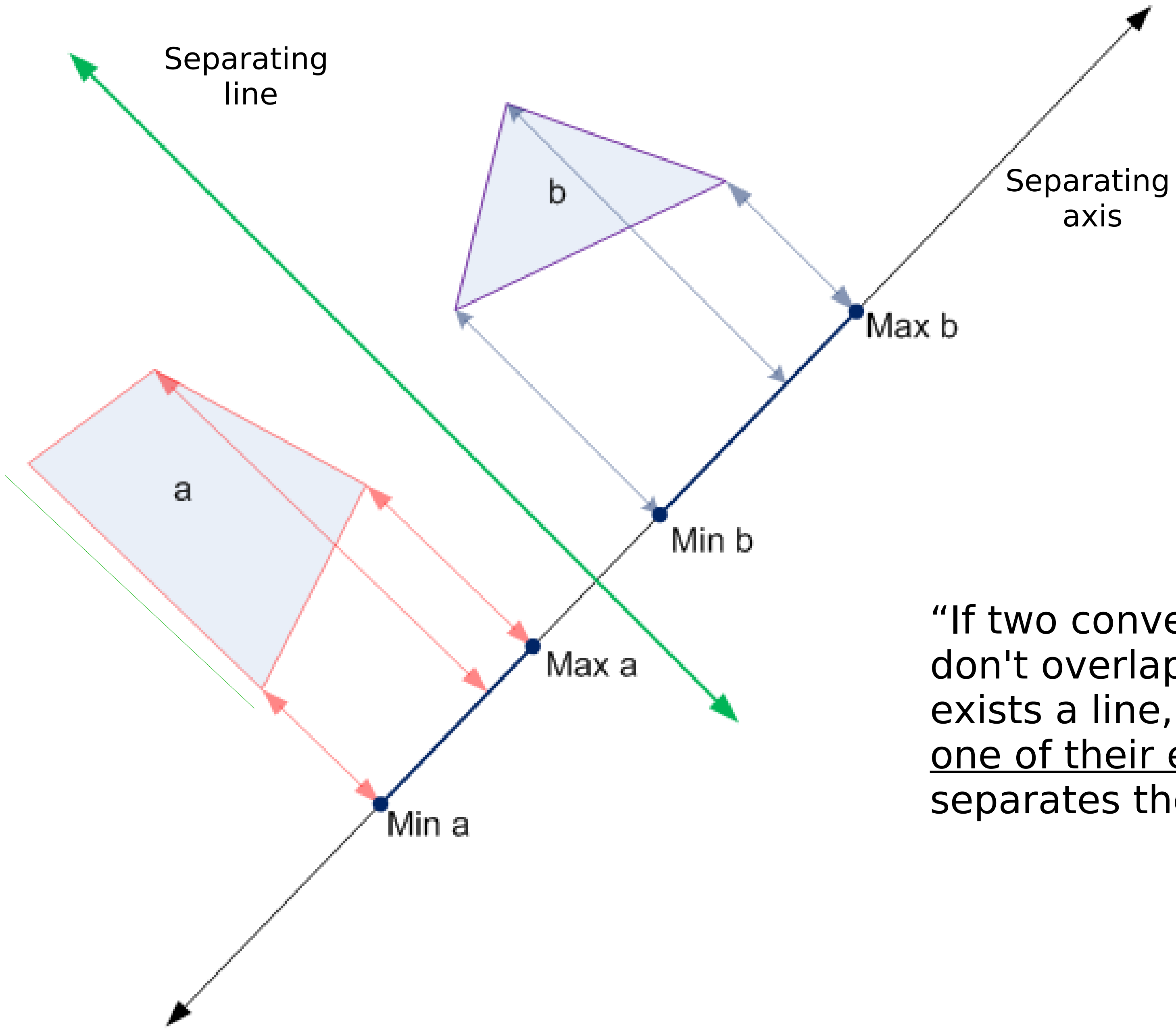


- Let d = distance between centers
- Let r_1, r_2 be the radii
- No collision if $d > r_1+r_2$

Collision Detection: Two Convex Polygons

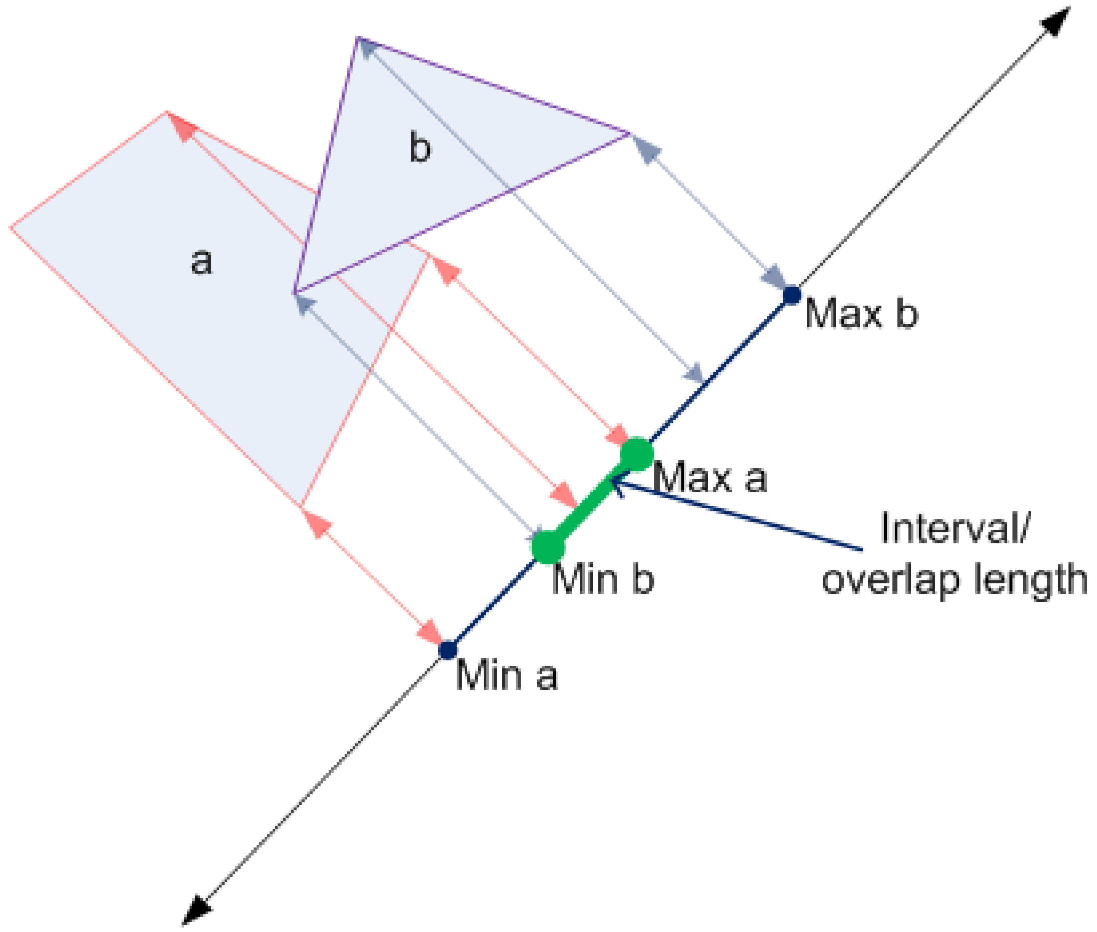
- The Separating Axis Theorem can be used to detect collisions between two <u>convex</u> polygons.
- Time is proportional to the number of vertices.
- To handle <u>non-convex</u> polygons, decompose them into sets of convex polygons and check for collisions between any two components.

Separating Axis Theorem

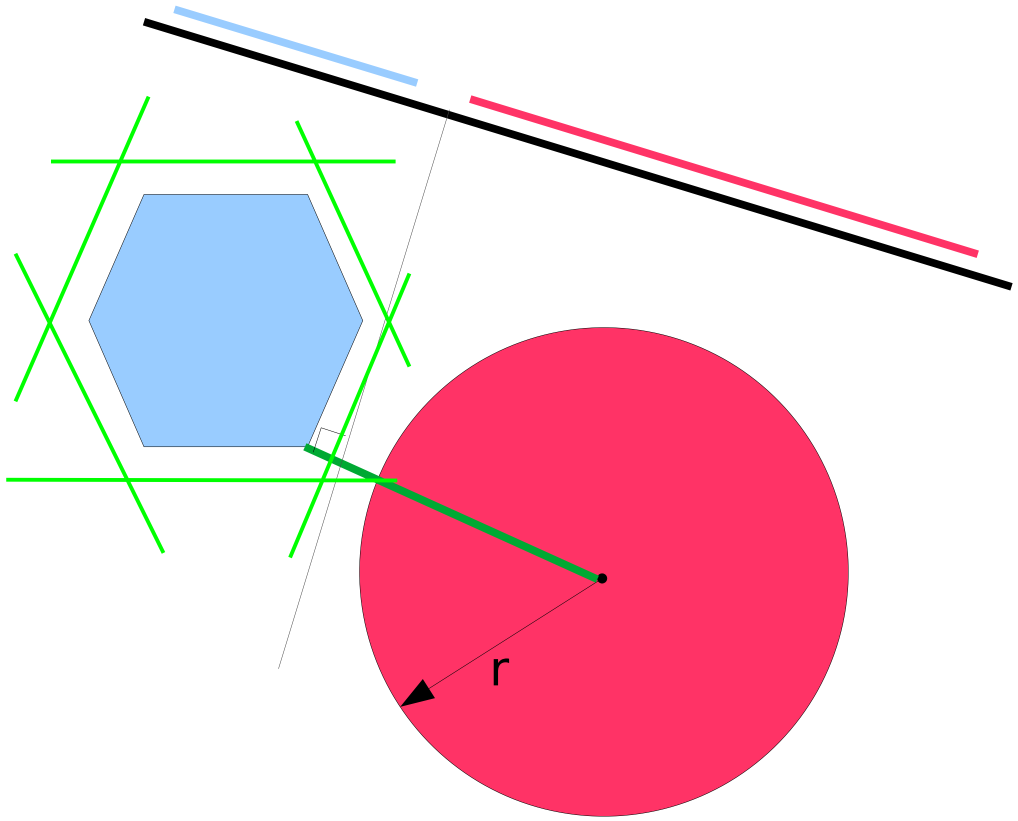


"If two convex polygons don't overlap, then there exists a line, parallel to <u>one of their edges</u> that separates them."

Separating Axis Theorem



Collision Detection: Circle and Convex Polygon



- Separating axes to check are parallel to the edges of the polygon or the line joining the nearest vertex to the center of the circle.

Collision Detection Algorithm

We only need to find one separating axis to be assured of no collision.

```
def collision_check(poly1,poly2):
  for axis in Edges(poly1) ∪ Edges(poly2):
     base = pependicular_to(axis)
     proj1 = project_verts(poly1, base)
     proj2 = project_verts(poly2, base)
     if not overlap(proj1,proj2):
        return False
  return True
```

How To Build A World Map

- SLAM: Simultaneous Localization and Mapping algorithm.
- Each particle stores:
  - a hypothesis about the robot's location (x,y,θ)
  - a hypothesis about the map, e.g., a set of landmark identities and locations: $\{ (i, x_i, y_i, \theta_i) \}$.
- Particles score well if:
  - Landmark locations match the sensor values predicted by the robot's location.