AI for Mobile Robots
- CSIP5202 -

Environments & Simulation

Overview

- Environment types
- Elements of navigation
- Localisation
- Path planning
- Simulation

Environments

- Question 1: *what tasks would a robot need to complete?*

- Question 2: *what would a robot operate?*

- Question 3: *what characteristics of the environment would we need to design for?*

Environment Types

- There are many different types of environments in which a robot may be required to operate
- Environments are typically categorised by their degree of structure
- Although there is no solidly accepted definition of structures, environments can be split into one of the following categories:
  - Structured
  - Partially Structured
  - Unstructured

Structured

- A structured environment has been specially designed for the robot to operate in
  - A factory floor with track to follow
- An exact description of the environment can be supplied to the robot during its design phase
  - Very little or perhaps no sensor data may be required
- There are usually no unexpected or unplanned dynamic aspects to the environment
  - The environment does not change
  - The robot can be told in advance of how and when the environment will change and how to deal with it

Partially Structured

- Somewhere between the previous two extremes!
  - An environment which may be modelled to a certain extent, but with insufficient model detail to fully support task completion
- Possibly, the static component of the environment has been modelled, but the dynamic changes are unpredictable and must be sensed.
  - E.g. a factory floor with in-built ‘tracks’ to follow, but with unpredictable (e.g. human) obstacles to avoid
  - The streets in a city

Unstructured

- Complex environments
  - Robots generally operate purely in response to real-time sensor data
- Robots cannot rely on complete knowledge about their surroundings
- Robots cannot assume that their actions succeed reliably
- Such environments usually have significant dynamic changes
  - Real-world as opposed to artificially created
  - May have unknown attributes
  - May be almost entirely unknown

Unstructured

- Robot motion and manipulation
  - Object properties required for manipulation cannot be known beforehand
  - Information about objects has to be acquired through sensors
  - Need to manipulate an object in a timely fashion in a rapidly changing world
  - The number of configurations (movements) is too large
  - It is difficult to design a robot that’s robust in an environment if we don’t know the surface or space affecting what actuator we use.
  - Path planning is highly-dimensional

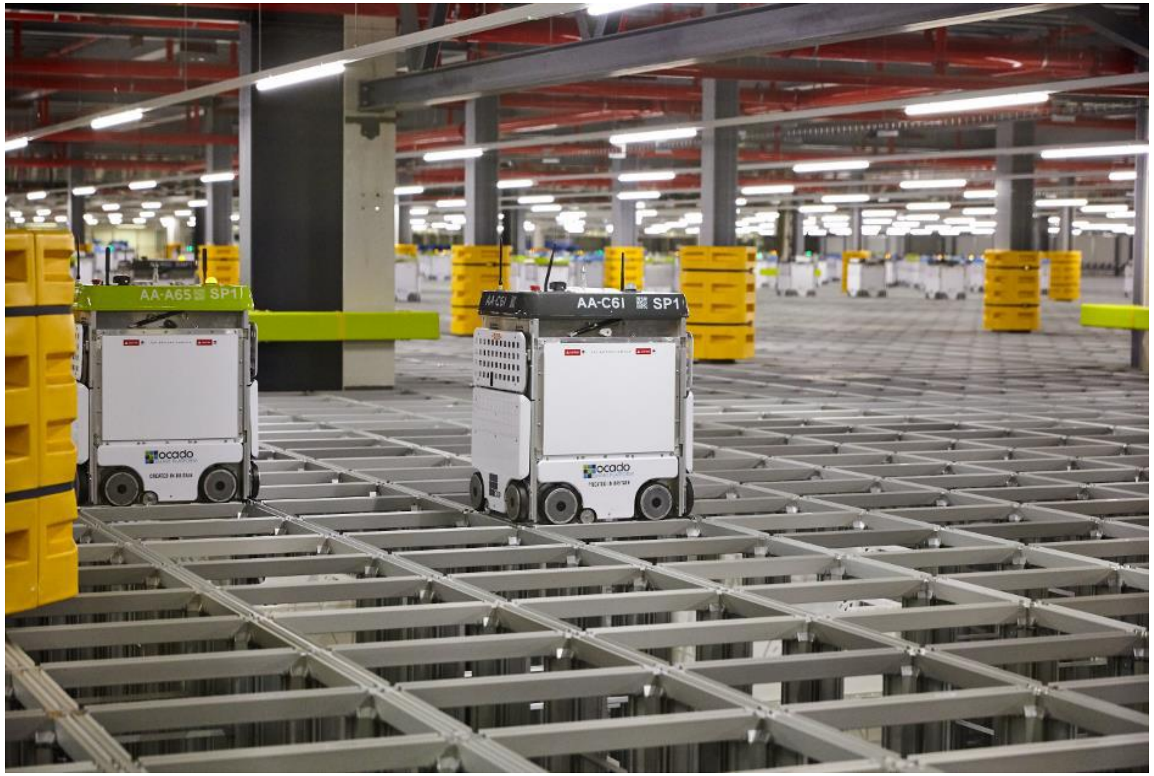
Unstructured

- Perception
  - Design of the sensors not knowing the environments means that we may not be sensing what we need to sense
  - Object Recognition how do we understand the objects in the environment
    - What sensors to use?
    - How to represent the data?
    - Do we understand what the object is based on prior observations
    - Is the object dynamic?
    - Obstacle Avoidance we need to distinguish between objects and free space and path plan accordingly

Possible Details

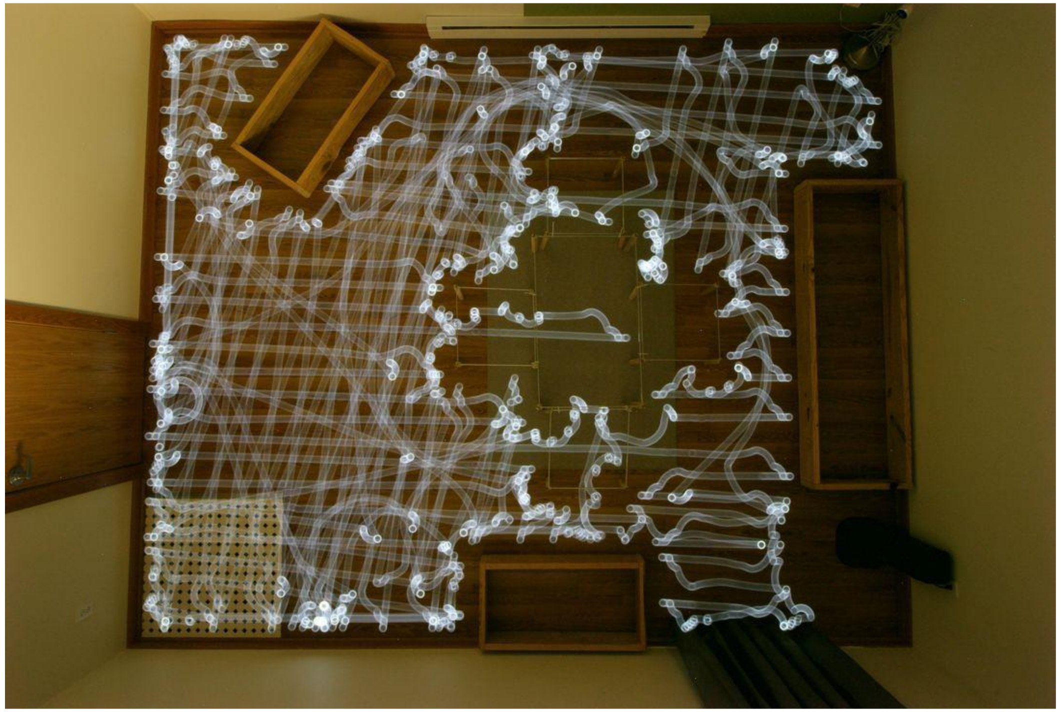
- More information/details about the environment beforehand
- Example (in a factory):
    - Physical structure
    - Lighting
    - Employees
    - Fixtures
    - Variable conditions
    - Hazards

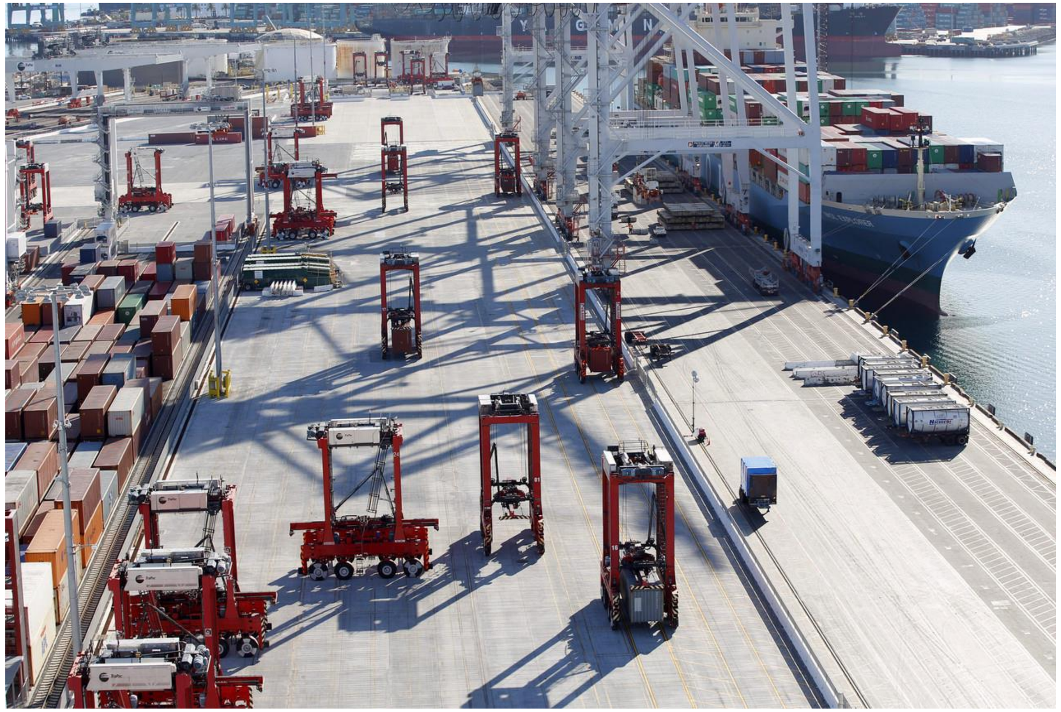
Examples



https://www.aboutamazon.com/news/operations/10-years-of-amazon-robotics-how-robots-help-sort-packages-move-product-and-improve-safety
https://www.theengineer.co.uk/ocado-online-grocery-robot/

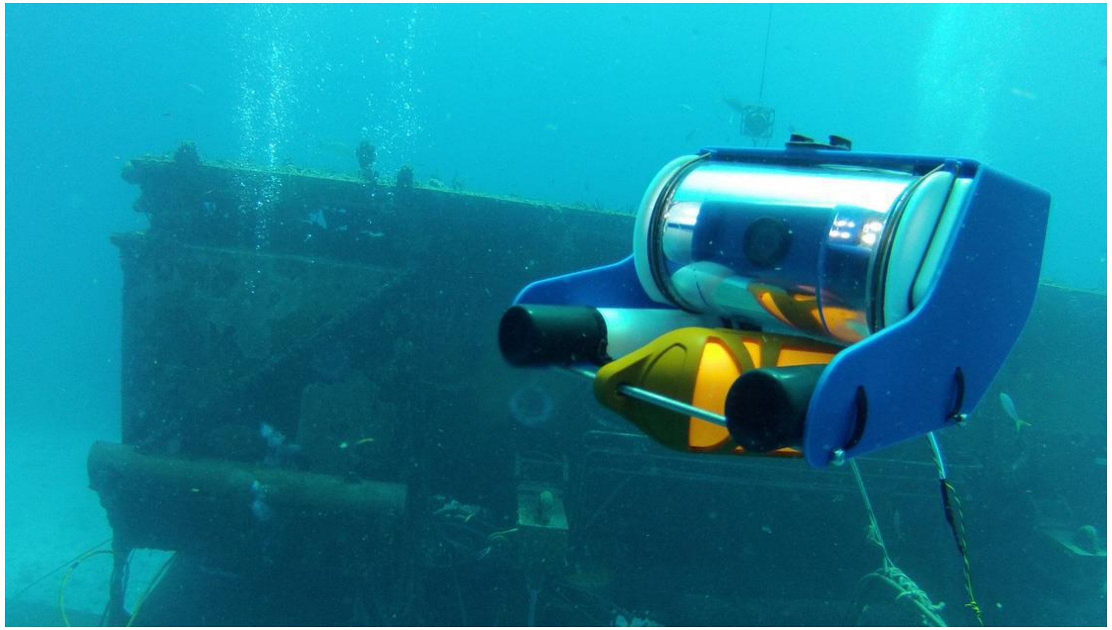
Examples





https://www.cnet.com/news/how-to-choose-the-best-robot-vacuum-for-your-home-roomba-neato-ecovacs-2019/
https://www.wsj.com/articles/massive-robots-keep-docks-shipshape-1459104327

Examples



https://www.afcea.org/content/dhs-nist-standards-rescue-robots-gain-momentum
https://www.tested.com/art/makers/455670-openrovs-eric-stackpole-talks-year-open-source-progress/

Elements of Navigation

- A good understanding of the environment is important for navigation tasks
- To successfully navigate, we need to look at the following:
  - Base and sensor control
  - Obstacle avoidance
  - Localisation and planning
  - Path planning

Base and Sensor Control

- A mobile robot needs:
  - Information about its environment (implicit or explicit)
    - Model-based or reactive
  - Sensors to measure their own movement and the environment
    - Odometry and external cues detection
  - Actuators to be able to move

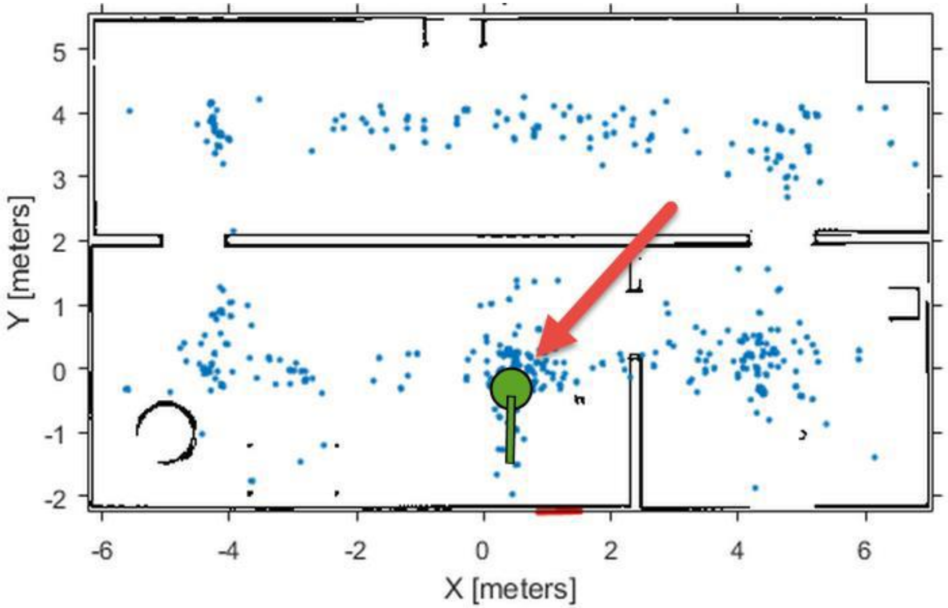
Obstacle Avoidance

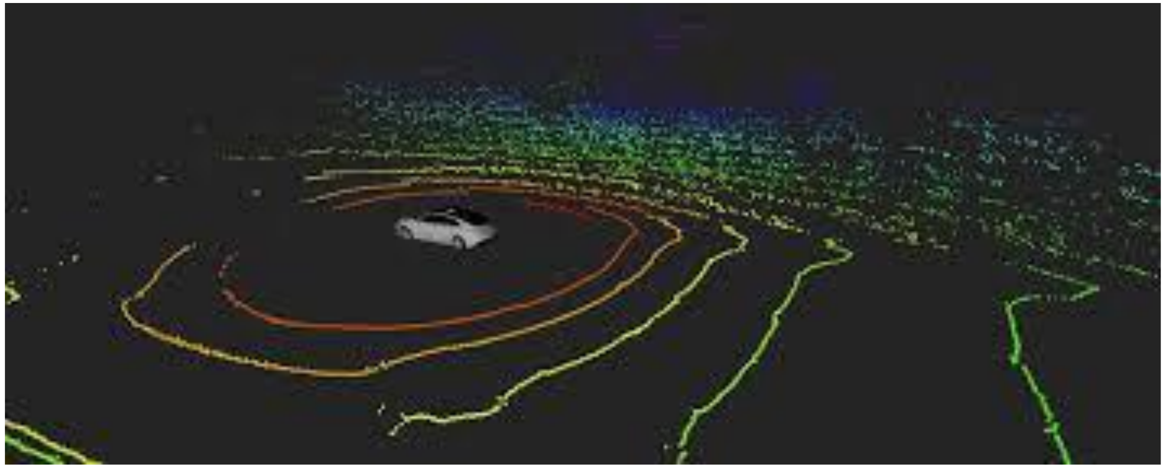
- The simplest way is using a reactive behaviour to navigate, i.e. move forward until an obstacle is found
- Though different schemes can be used:
  - Reactive: moving back and changing direction
  - Planning: following the edge of an obstacle
  - Planning with a model update: changing the target

Localisation

- Localization in robotics involves being able to determine the robot’s position and orientation
  - Odometry and Dead Reckoning are based on the model and internal state sensors alone
  - Active Beacons can be used to confirm stages in the models and increase accuracy and/or reliability
- Once a robot has acquired and processed its sensor data, it needs to match this information to the environmental model (map) to be able to determine where it is
- This implies memory and a model-based approach

Localisation

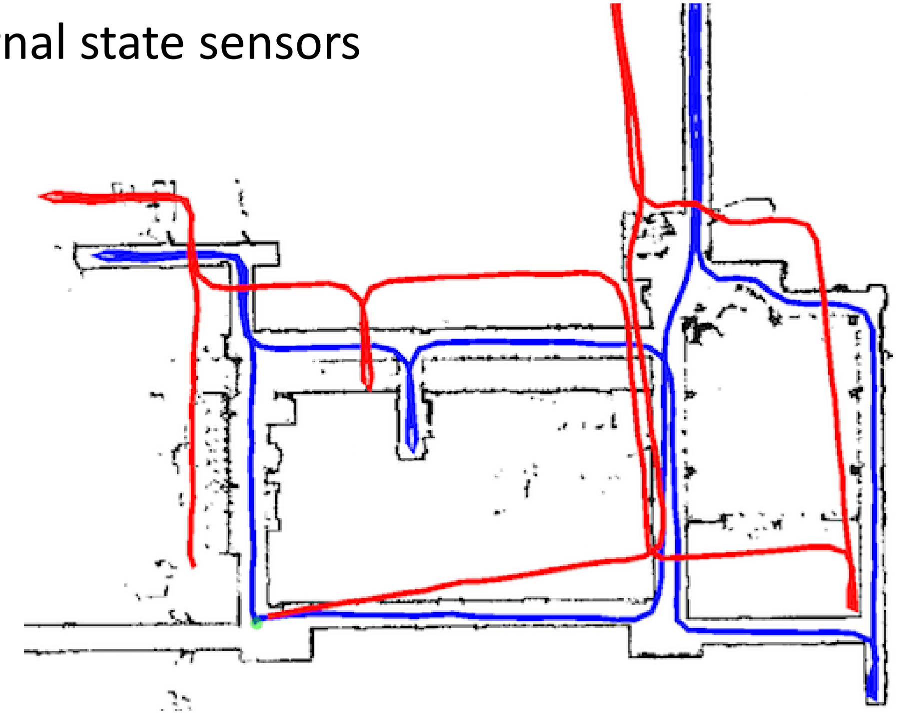




https://uk.mathworks.com/help/nav/ug/monte-carlo-localization-algorithm.html;jsessionid=499d2c523d91a3f0b8fda8a9ae64
http://pro.hw.ac.uk/

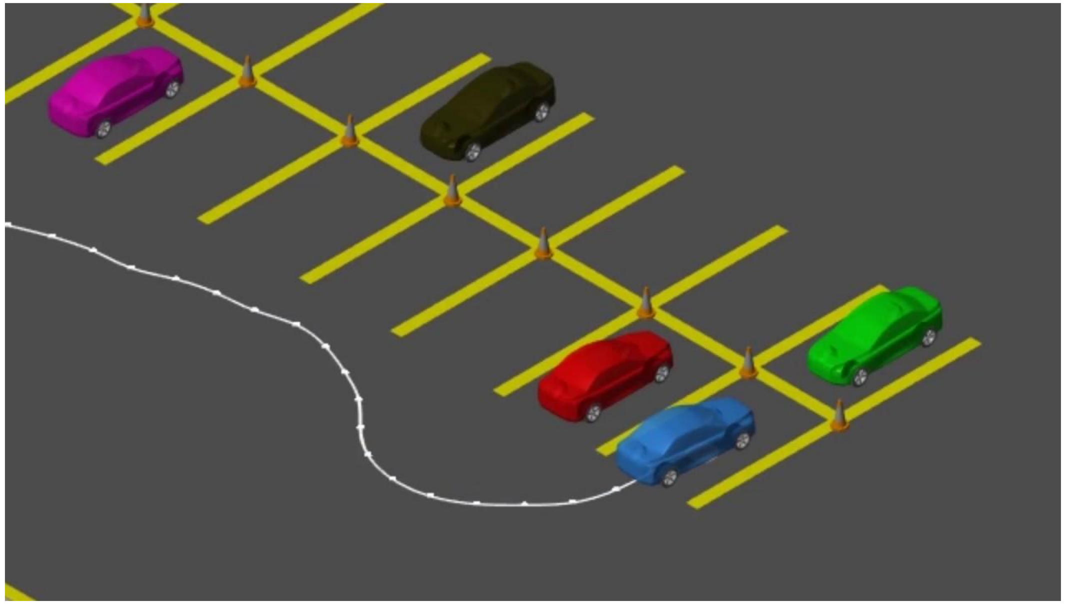
Localisation

- Odometry and Dead Reckoning
  - Measuring how much it thinks it has moved using internal state sensors
  - Measuring the actual movement of its traction system
  - But both intrinsic and external Errors accumulate



Path Planning

- Having a model-based system (inc. a map)
  - Enables the robot to plan ahead
  - Planning ahead means paths can be determined beforehand rather than wandering randomly
  - Planning a path means it can also be optimized in relation to a given criteria
    - Simplest objective: to reach a position
    - Additional aspects can be achieved such as to optimize the path to minimize distance:



https://www.youtube.com/watch?v=Yse_YDpmsBM

Simulation

- Simulation involves creating, executing, and analysing models of physical systems.
- Common in understanding reality, simulations involve constructing artificial objects for role-playing.
- Facilitates extensive robot testing, surpassing physical testing frequency.
- Benefits include injury prevention, avoiding design changes post-production, reducing manufacturing cycle times, and minimizing paperwork

Simulation

- While abstract models prove valuable for examining facets of autonomous agents' control issues, caution is imperative when extrapolating conclusions regarding real-world behaviour from such models
- Unless their limitations are recognised, they can lead to both the study of problems that do not exist in the real world, and the ignoring of problems that do

Lab Work

- Your task:
  - You’ve seen two examples of simulators
  - You should have seen a brief overview of how to program the robots in the simulator
  - For the rest of the module, choosing which simulator to use is up to you for the labs. The work can be completed with both.

Simulation

- Wide range of choices for software:
  - MATLAB/Simulink
  - ARIA/iRobot
  - CoppeliaSim
  - Webots
  - LabVIEW
  - RobotStudio
  - Workspace

Questions?