Pattern Recognition in Mobile Robotics

CSE 455/555 Introduction to Pattern Recognition

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Abstract/Lecture Overview

A more realistic set of motivating application examples based in Mobile Robotics

- Motivations for mobile robotics
- Challenges of mobile robotics
- Examples involving pattern recognition
- Not going to talk about Industrial/static robotics
  - Even thought there are many applications of pattern recognition in this area of robotics

What is Robotics?

- Definitions
  - Intelligent connection of perception to action
- Perception - Acquisition and interpretation of sensor data
- Intelligence?
  - Decision making
  - Learning
- Actuation - Effecting changes in the physical world
  - Locomotion
  - Manipulation
- Roles of pattern recognition in robotics
  - Pattern recognition also has a role to play in intelligence
  - Pattern recognition forms part of the interpretation

Robotics Areas

- Static
  - Industrial robotics
  - Controlled environments
  - More commercially successful
- Mobile
- Indoor Robotics
  - Personal robotics
  - Office robots
    - Remote telepresence
  - Domestic robots
    - Roomba - most successful consumer mobile robot?
- Field Robotics
  - Mining
  - Military
- Health care
  - Home care for the elderly (Especially Japan)
- Wherever it is Dirty, Dull or Dangerous

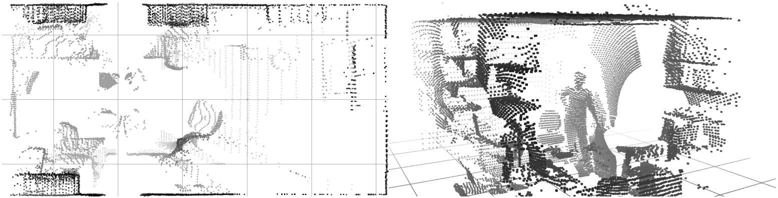
Willow Garage

- Long term funded company that does not need to make a profit
- Adheres to the open source development model
- Robot Operating System (ROS)
- OpenCV
  - Computer Vision
  - Machine Learning algorithms
- PR2 Robot
  - PR2 Beta Overview Video

Sensors

- Internal sensors
  - Global position system - GPS
  - Inertial Measurement Unit - IMU
- Vision based
  - Standard Cameras
  - Omnidirectional
- Range sensors
  - Time of flight
  - Triangulation based
    - Structured light
    - Stereo vision
  - Ultrasonic
- Kinect
  - Structured light 3D depth sensor
  - Returns RGBD - Red, Green, Blue and Depth
  - Inexpensive at 150$

Pattern Recognition in 3D Data versus Pictures



- More difficult for humans
- More suitable for computers?
  - 3D data is more independent of observer position
  - Many objects are rigid or articulated so 3D shape is important and invariant
  - For features invariant is good
    - implies reliable/repeatable extraction
- Camera images susceptible to
  - illumination changes
  - loss of information in conversion from 3D to 2D

Considerations specific to mobile robotics

- Autonomy
  - There can be no guarantee of continuous connection. Therefore a certain level of autonomy is required for reliable continuous operation.
- Power consumption
  - Restricted processing power
    - Especially for indoor and smaller robots that run on batteries
- Real-time constraints
  - Pedestrian recognition has to be fast and reliable for automotive applications
  - Batch algorithms not really suitable
    - For long term operation robot ultimately has to process data as fast as it receives it.

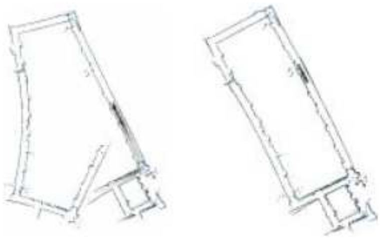
Localisation and Mapping

- Localisation
  - For most applications need to have an awareness of location
  - Augment the robots workspace with features
    - Possible but expensive for factories and other controlled environments
- Mapping
  - Learning a model of the operating workspace/environment
  - Aids localisation
  - Aids path planning
- Simultaneous Localisation and Mapping (SLAM)
  - The process of both inferring location from a map whilst simultaneously updating the map with new observed information.

Simultaneous Localisation and Mapping (SLAM)

- SLAM is vital for indoor robots
  - Interestingly not used for the iRobot roomba
- Outside not as necessary where GPS coverage is available
- Various flavours of SLAM
  - Metric
  - Topological
- Matching
  - 2D/3D scan matching
  - Image

Loop Closing



- Closing of an open loop in a large (80m by 25m) cyclic environment from Konolige and Gutmann (1999)
- Improving map accuracy through loop closing
  - Have I been here before?
  - Recognising previously visited locations

Scan matching

- Two scans taken from different poses
- Find features present in each scan
- Determine the correspondence between features
- Use this information to align the scans
- This gives the pose change between scans
- Much research done with 2D range scans
- Example with 3D scans or an indoor environment
  - Scan matching Ilustration

3D mapping indoors

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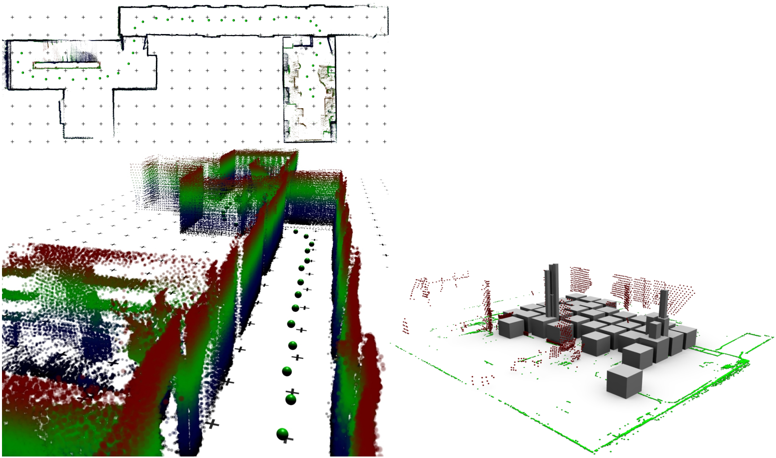


- 3D map fly around video

Probabilistic robotics

- Return not only an answer but some idea of the probability distribution
    - For example the pose distribution can be multimodal
    - Many ways of representing these probablity density functions
    - Thus you have some idea of how likely the result is to be correct
- Algorithms in robotics need to be robust
    - Robust statistics e.g. median
        - contrast with sufficient statistics
        - Insensitive to outliers
    - Sufficient statistics e.g. mean
        - Mathematically analytic
        - Computational convenient
        - Sensitive to outliers

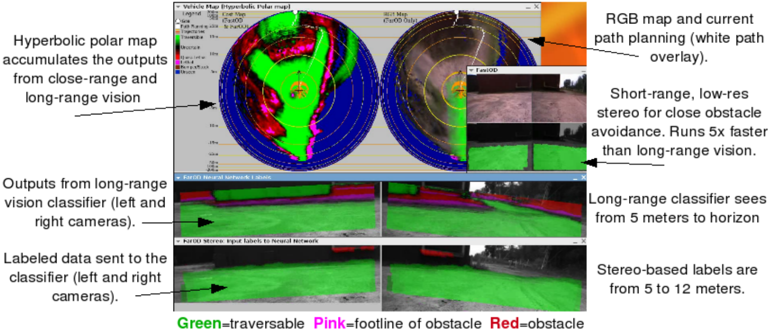
DARPA Grand and Urban Challenges

- Grand Challenge
  - $2 million Prize awarded to Stanford Racing Team
  - 132 mile desert course in just under 7 hours
- Urban challenge
  - Follow on from the easier grand challenge
  - Autonomous vehicle drive through an urban environment
    - Drive in traffic
    - Maneuvers merging, passing, parking, negotiating intersections
  - Featured the first autonomous car crash
  - Reliable perception and interpretation vital
  - Final highlights
    - DARPA Urban challenge highlights video
- Key Enablers
  - Velodyne 3D laser scanner
  - Near to far learning

Learning for mobile autonomous systems

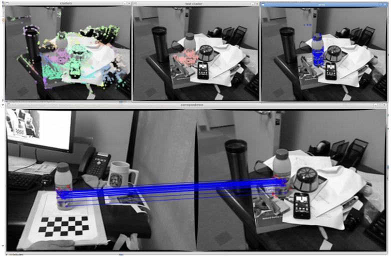
- Pattern recognition enables systems to learn and generalise from new data.
- Interaction with humans provides plenty of opportunity for supervised learning.
- Amazon's mechanical turk
  - Humans working for the robots!
- DARPA urban challenge videos
  - near to far learning in images e.g. using laser data and corresponding vision results to train and so classify far image pixels.
- Self supervised learning
  - Training data might arrives at a later time for some cases
  - Training data provided by others sensors
    - e.g. Near to far learning

Near to Far Learning



- Image and research from Raia Hadsell
- Online machine learning
  - Either laser or stereo provides reliable near range 5m classification (driveable or not based on smoothness)
  - Then used as training data for appearance based classifier for pixels beyond 5m

Solutions in Perception Challenge

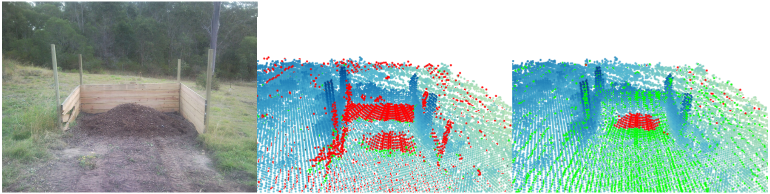


- Goal
  - Rigid objects recognized and their 6DOF pose determined with the Kinect sensor
- Kinect sensor
- Best solutions likely to combine conventional image information with depth information
- Ideal opportunity to put into practice what you learn in this course

Field robotics

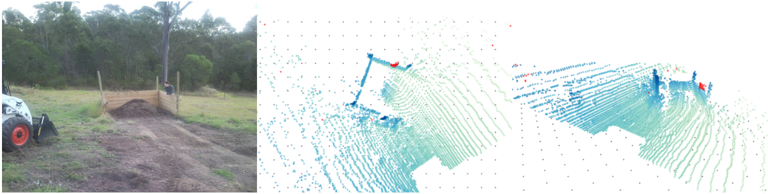
- Work undertaken at the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Autonomous earth moving

Autonomous Skid Steer loader (Bobcat)



- Earth moving task
  - Move soil material from one location to another
- Ultimate goal is the design the terrain you want in a CAD package and have it replicated in the physical world by autonomous excavation and earth moving machines

Reliable Human/Novelty Detection



- Learn the operational environment
- Highlight those areas that have changed
- Essential for safety reasons
  - If unknown objects detected or the environment has been tampered with need to potentially stop operation
- Handle noise, how much variation constitutes change?

Some active research questions related to Pattern Recognition

- SLAM
  - Monocular camera based visual SLAM
  - SLAM with RGBD sensors
- Correspondence problem
  - Finding corresponding points in multiple images
  - For stereo vision
- Object recognition in 3D data
  - 3D shape based retrieve and lookup
  - View and occlusion invariant hashing
  - Locality sensitive hashing
- Object recognition from a moving camera sensor
  - Different to object recognition in random images
  - Background subtraction for moving cameras

Recap

- What is (mobile) robotics?
- Example applications involving pattern recognition
  - Localisation
  - Mapping
    - Scan matching
    - Loop closing
  - Terrain classification for path planning
    - Near to far learning
    - Self supervised machine learning
  - Field robotics
    - Autonomous Earth moving
- Current work in the research community
- Solutions in Perception Challenge

Questions for consideration?

- What is holding back mobile robotics?
  - Was the lack of low cost depth sensors, but now with the Kinect?
  - Low cost manipulator platforms? The PR2 is $400,000
- Motivated by the recent debut of the Kinect how can existing computer vision pattern recognition algorithms be applied to RGBD data?