Robotics
Enabling Autonomy in Challenging Environments

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CSCE 190

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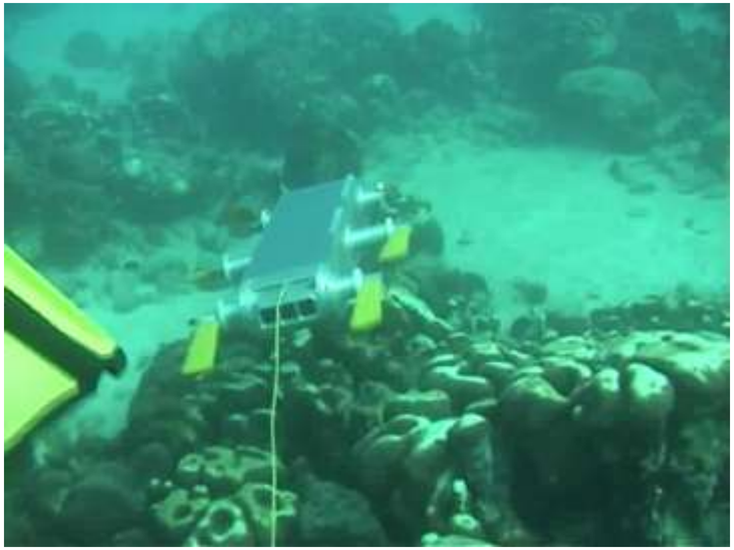
Why Robotics?

Mars exploration rover (MER) animation



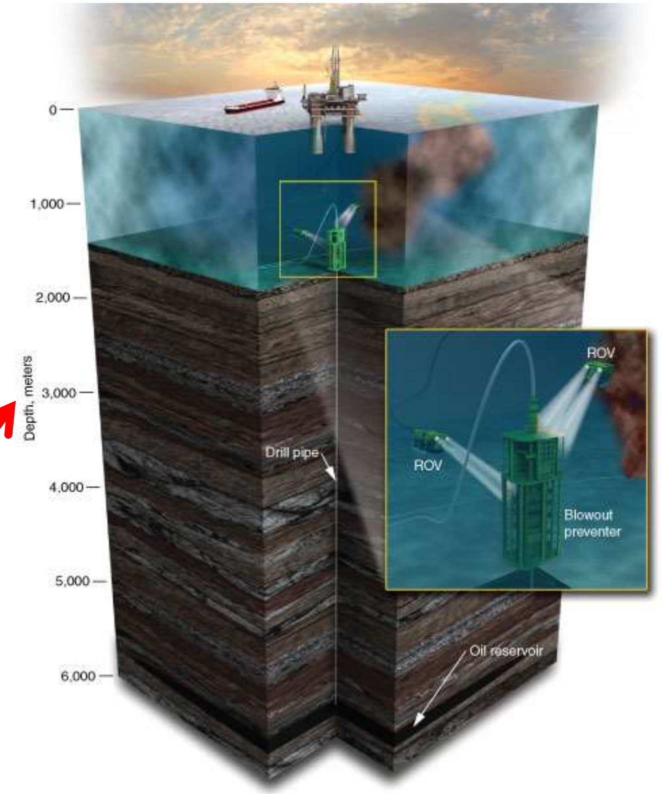
Underwater exploration, Barbados

Roomba® vacuuming robot in action

Driverless Car
TED talk: S. Thrun

Present Everywhere

- At home
- On the road
- In the sky (drones)
- In the fields (agricultural robotics)
- In resource utilization (**ROV in the oil industry**)
- Along power lines
- Education



Robotics becomes affordable

TurtleBot 2

AR.DRONE

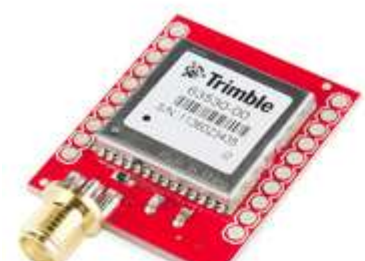
Kinect

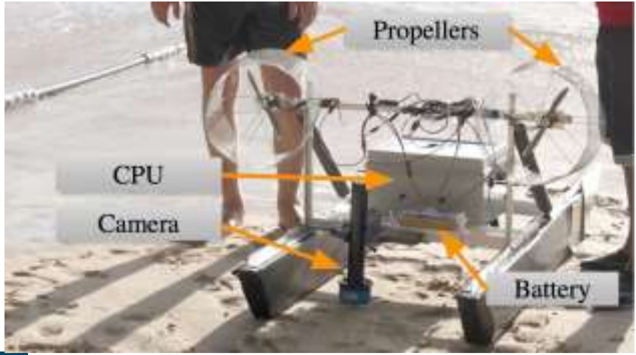
IMU

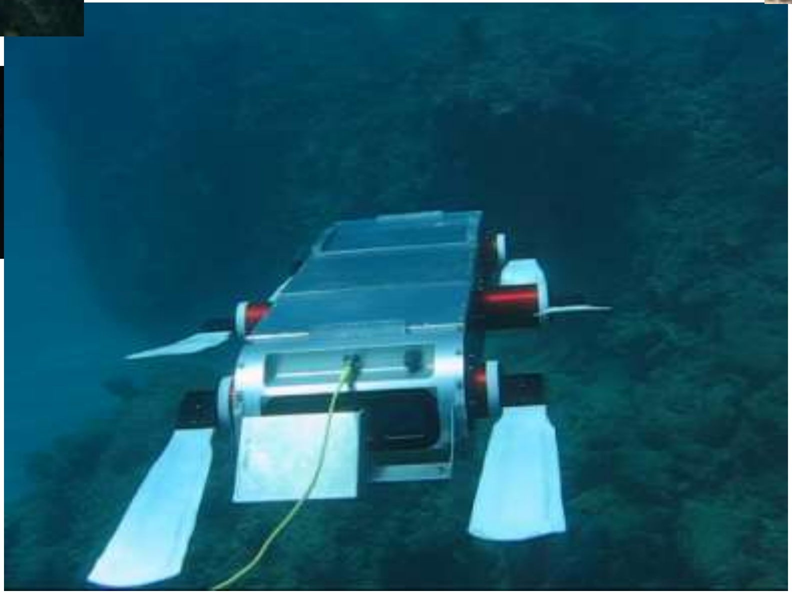
Raspberry Pi

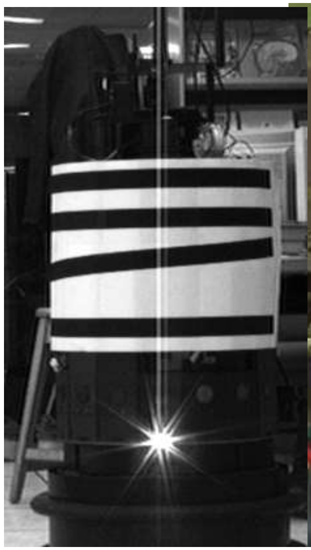
Lego Mindstorm

GPS

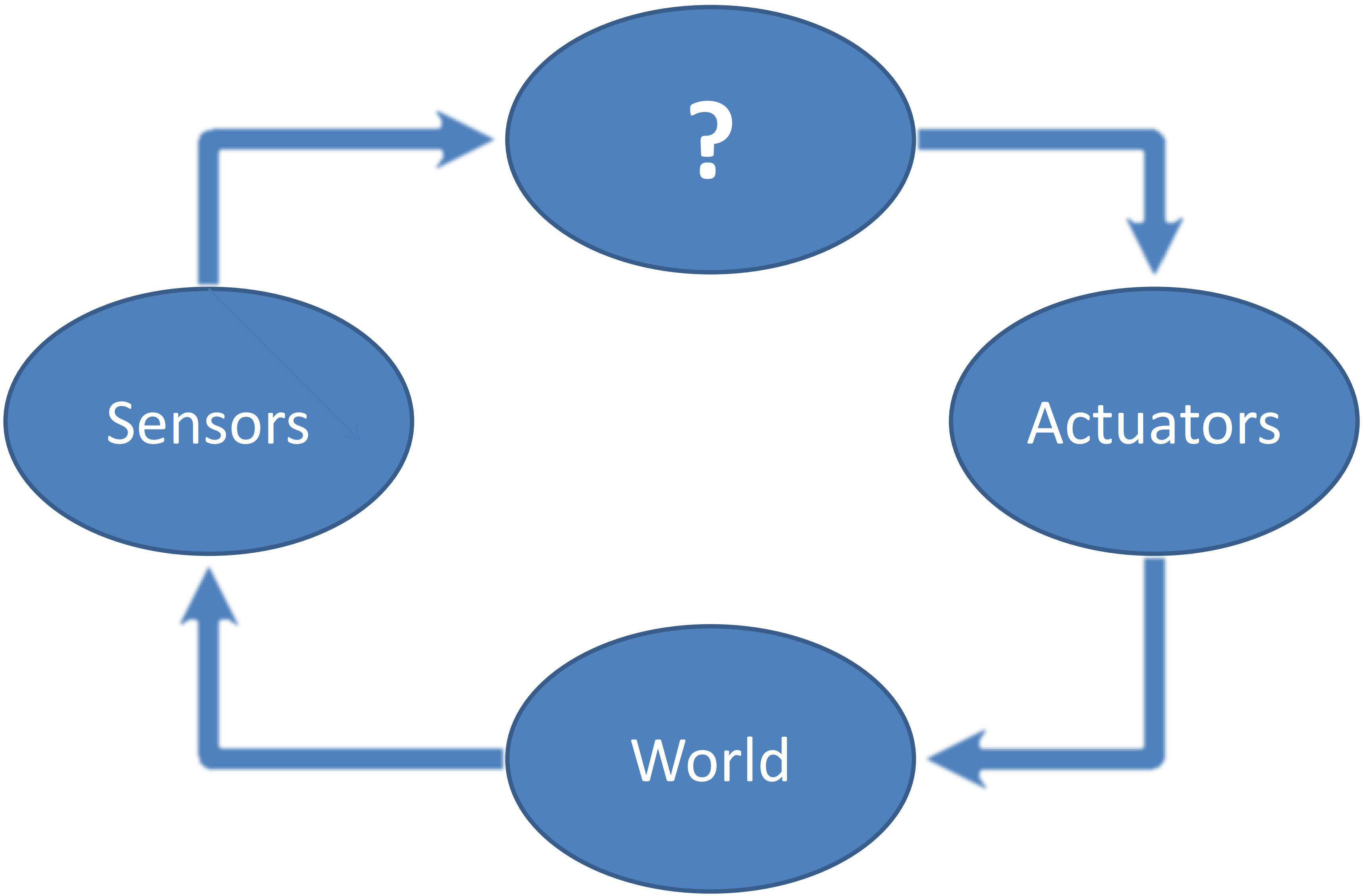



Propellers
CPU
Camera
Battery

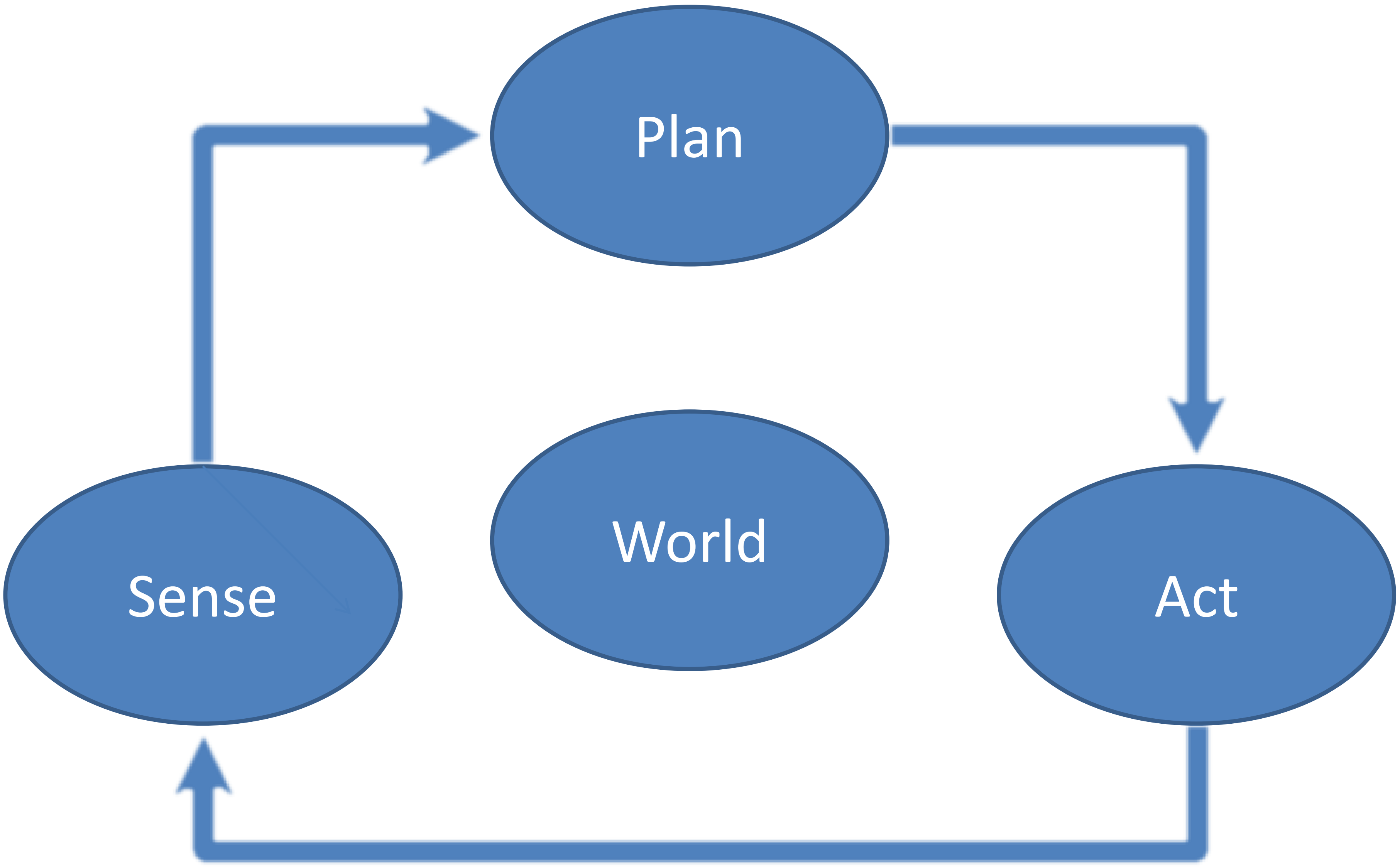




Robotic System



Robotic System



Sensors

- **Proprioceptive Sensors**

  (monitor state of robot)
  - Battery Voltage
  - IMU (accels & gyros)
  - Wheel encoders
  - Doppler radar
  - GPS …

- **Exteroceptive Sensors**

  (monitor environment)
  - Cameras (single, stereo, omni, FLIR, RGB-d, …)
  - Laser scanner
  - MW radar
  - Sonar
  - Tactile
  - Chemical
  - Olfactory…

Perception

Sensing the world

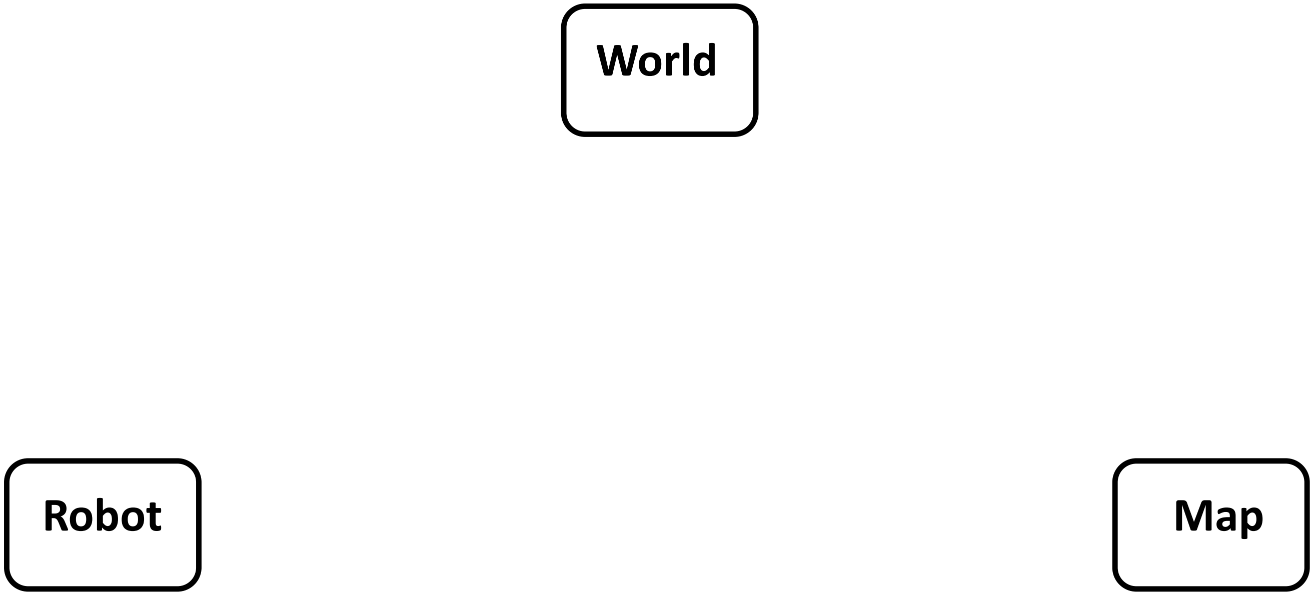
versus

Understanding the world

Three Main Challenges in Robotics

- How to Go From A to B ? (Path Planning)
- What does the world looks like? (mapping)
  - sense from various positions
  - integrate measurements to produce map
  - **assumes perfect knowledge of position**
- Where am I in the world? (localization)
  - Sense
  - relate sensor readings to a world model
  - compute location relative to model
  - **assumes a perfect world model**
- Together, the above two are called SLAM
  (Simultaneous Localization and Mapping)

Stage, Actor, and Representation



Stage, Actor, and Representation

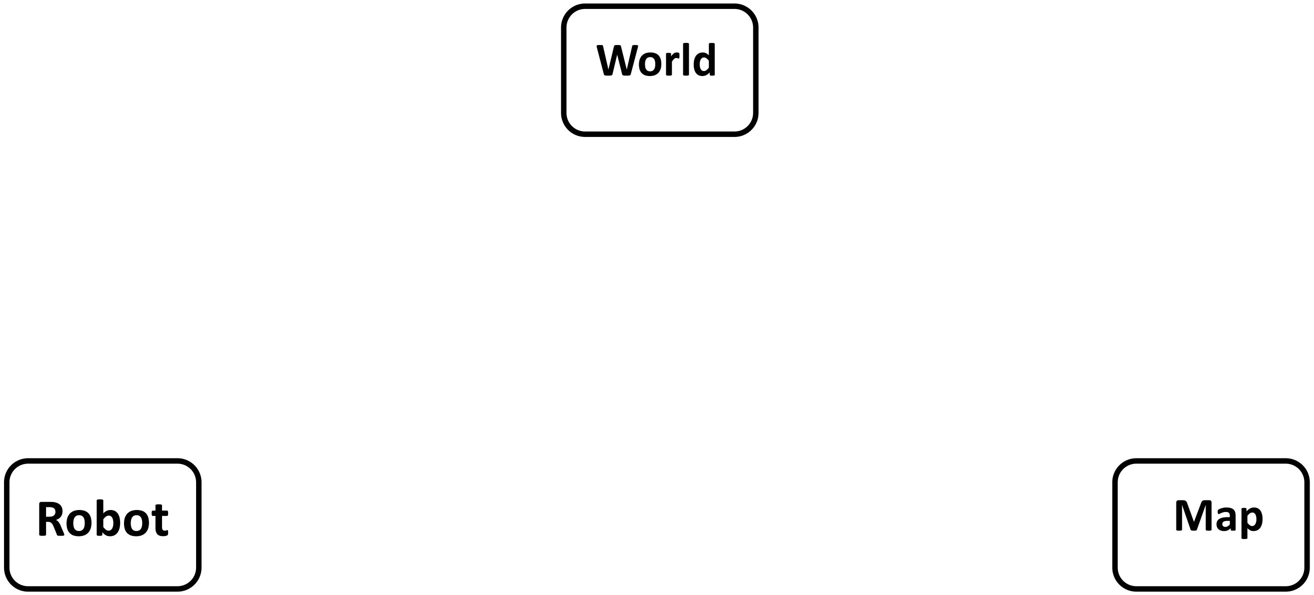
World

- Indoor/Outdoor
- 2D/2.5D/3D
- Static/Dynamic
- Known/Unknown
- Abstract (web)

Robot

Map

Stage, **Actor**, and Representation



- Mobile
  - Indoor/Outdoor
  - Walking/Flying/Swimming
- Manipulator
- Humanoid
- Abstract (web-bot)

Stage, Actor, and **Representation**

World

Robot

Map

- Topological
- Metric
- Feature Based
- 1D,2D,2.5D,3D

Stage, Actor, and Representation

World

- Indoor/Outdoor
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Robot

- Mobile
  - Indoor/Outdoor
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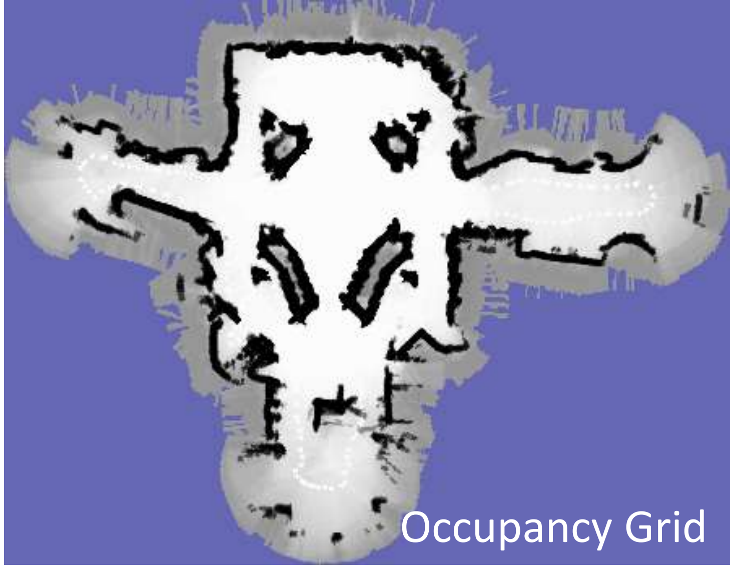
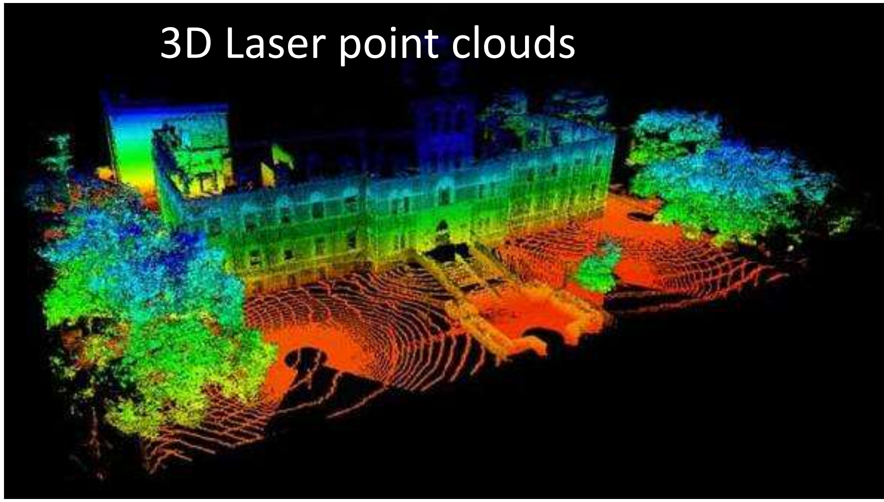
Map

- Topological
- Metric
- Feature Based
- 1D,2D,2.5D,3D

Mapping

- What the world looks like?
- Knowledge representation
  - Robotics, AI, Vision
- Who is the end-user?
  - Human or Machine
- Ease of Path Planning
- **Uncertainty!**

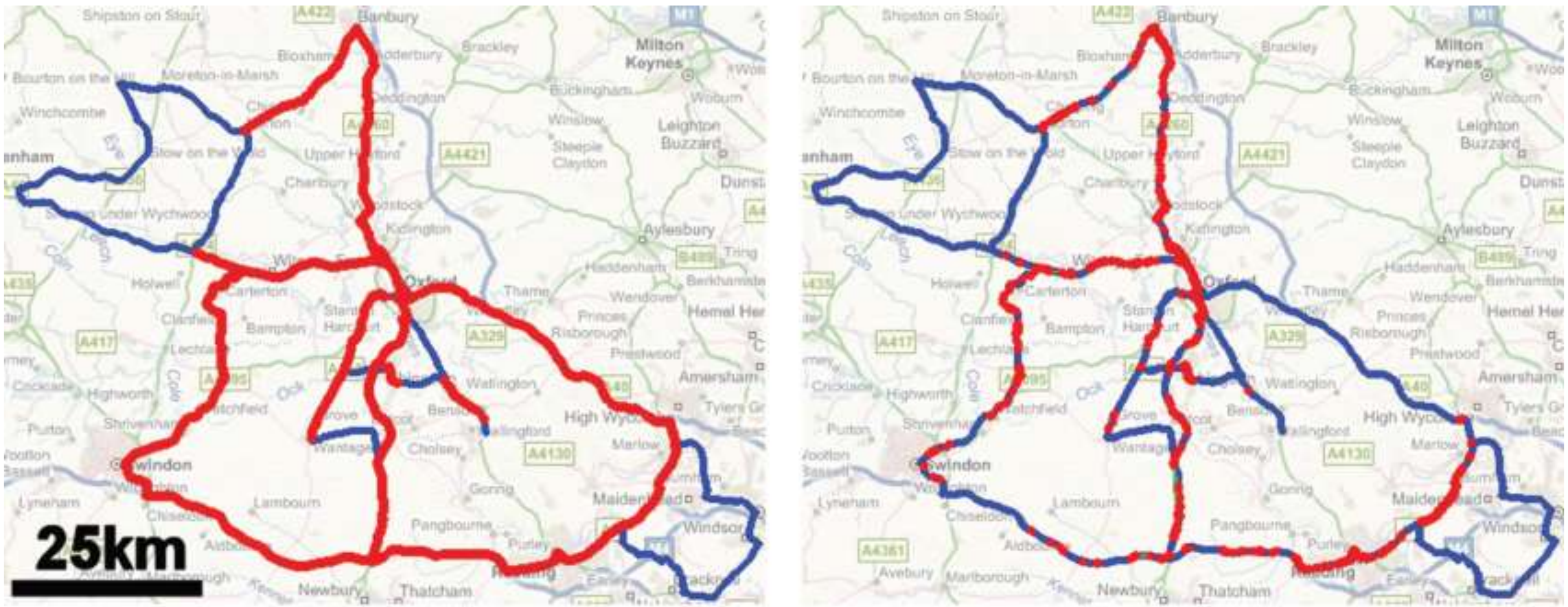




Appearance based

Appearance based Mapping

- 1000Km Trajectories



(a) (b)

Mark Cummins and Paul Newman. ``*Appearance-only SLAM at Large Scale with FAB-MAP 2.0".* The International Journal of Robotics Research. November 2010

Appearance based Mapping

Successful Loop Closures

False Loop Closures

Where am I? Localization

- Tracking: Known initial position
- Global Localization: Unknown initial position
- Re-Localization: Incorrect known position
  - (kidnapped robot problem)

Localization

Initial state
detects nothing:

Moves and
detects landmark:

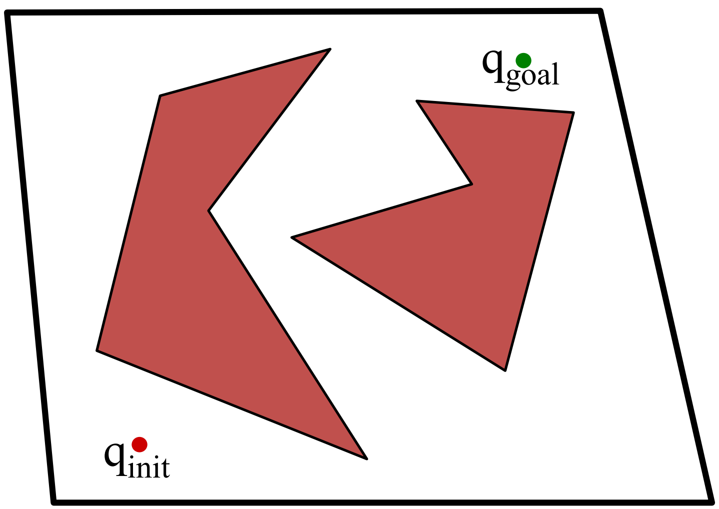
Moves and
detects nothing:

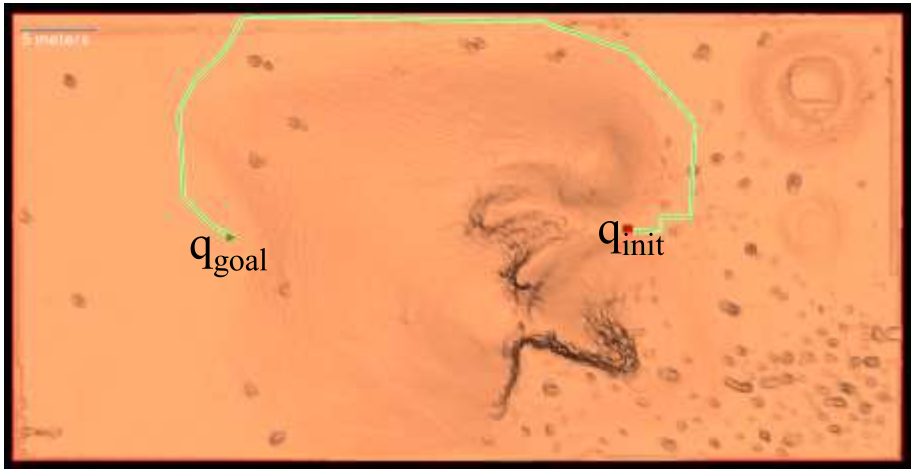
Moves and
detects landmark:

Motion Planning

- The ability to go from **A** to **B**
  - Known map – Off-line planning
  - Unknown Environment –Online planning
  - Static/Dynamic Environment

q_{init} q_{goal}



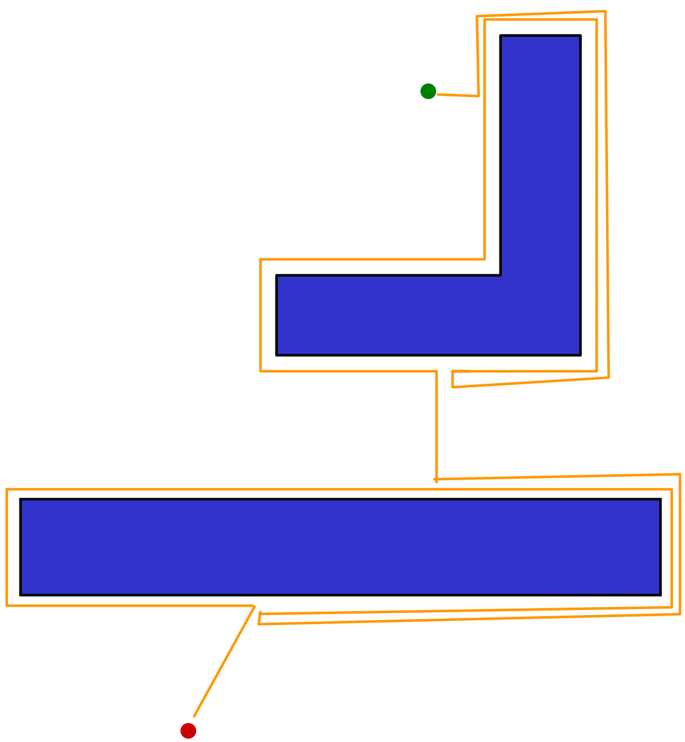


Bug Strategy

Insect-inspired "bug" algorithms

- known direction to goal
- otherwise only local sensing

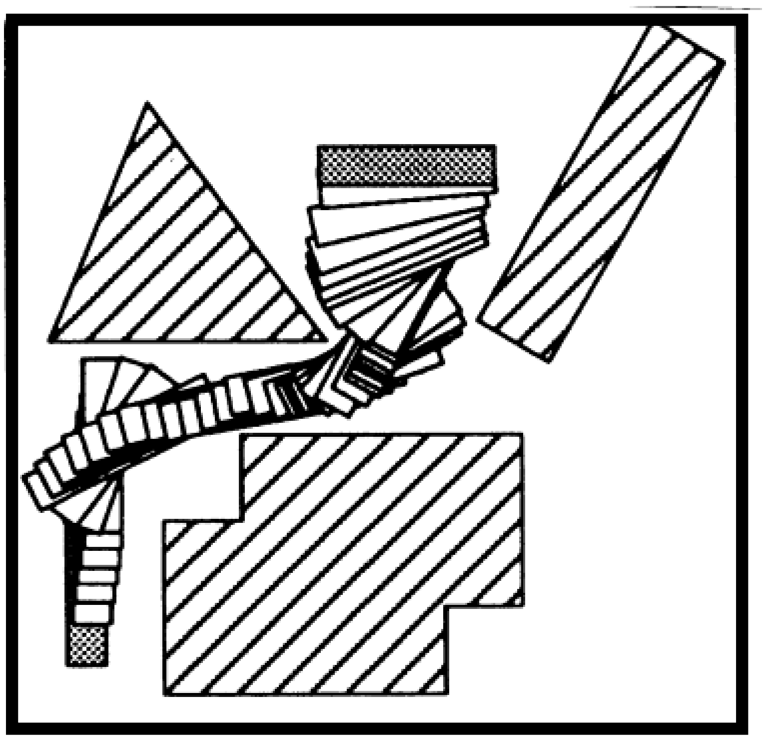
walls/obstacles encoders

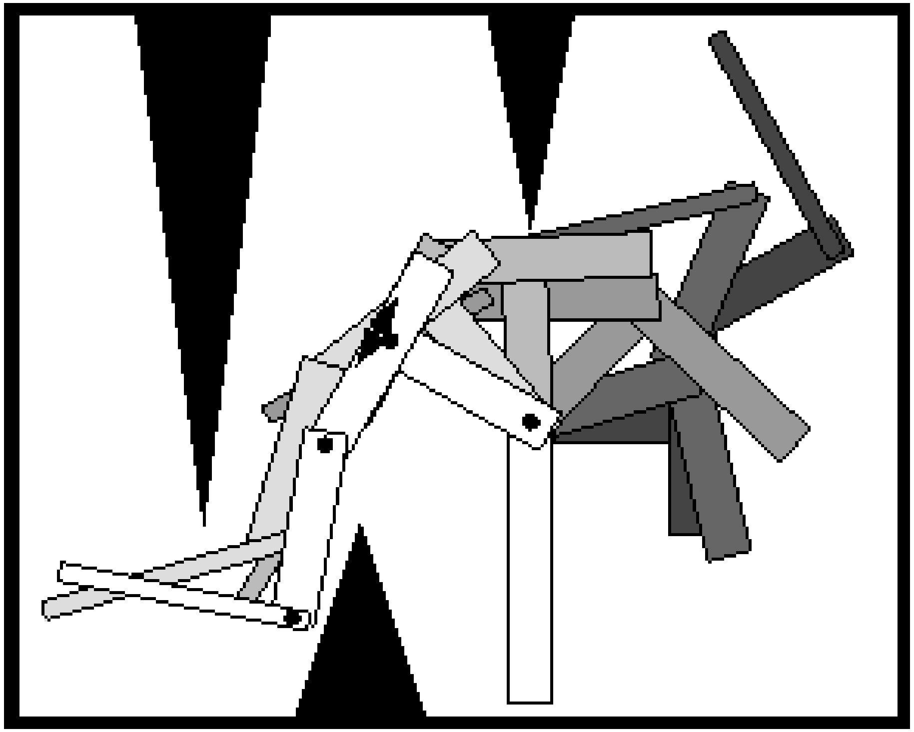


"Bug 1" algorithm

1. head toward goal
2. if an obstacle is encountered, circumnavigate it and remember how close you get to the goal
3. return to that closest point (by wall-following) and continue

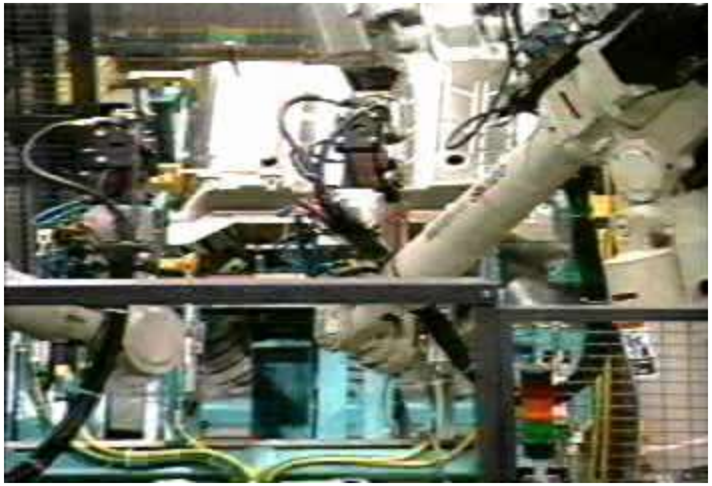
More Complex Path Planning





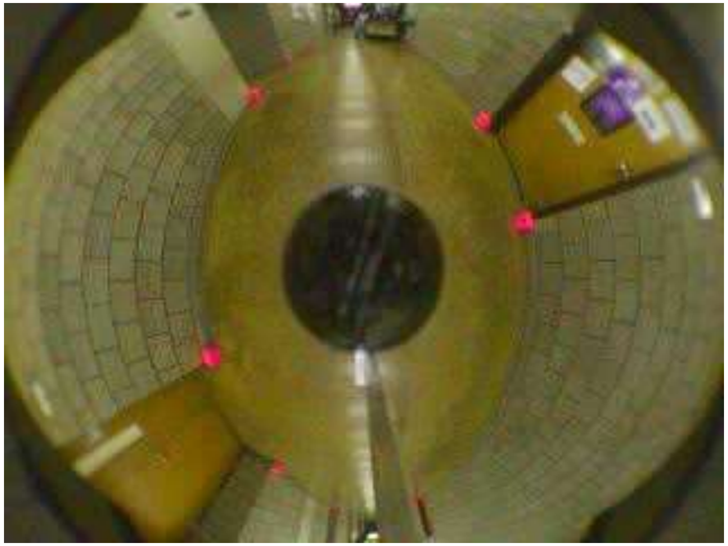
Historical Overview

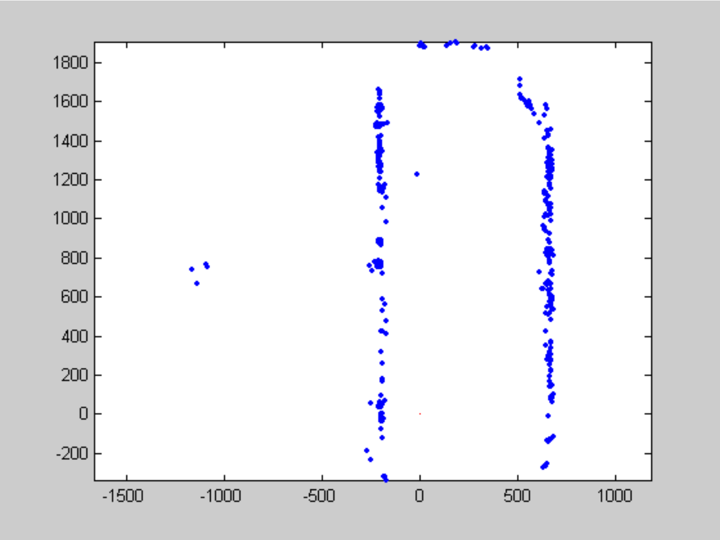
- Factory automation
  - (1950-now)



Historical Overview

- Factory automation
- Indoor environments
  - 1990-2005



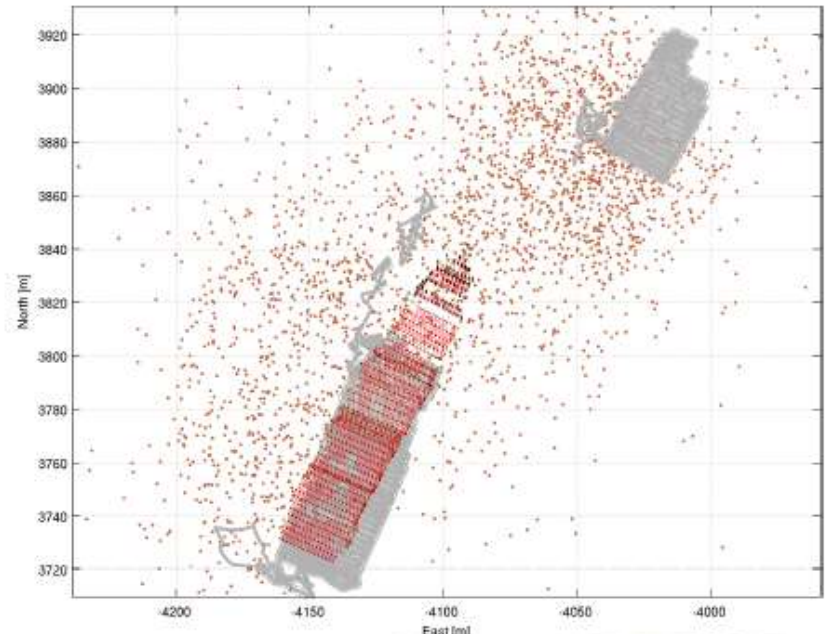


Historical Overview

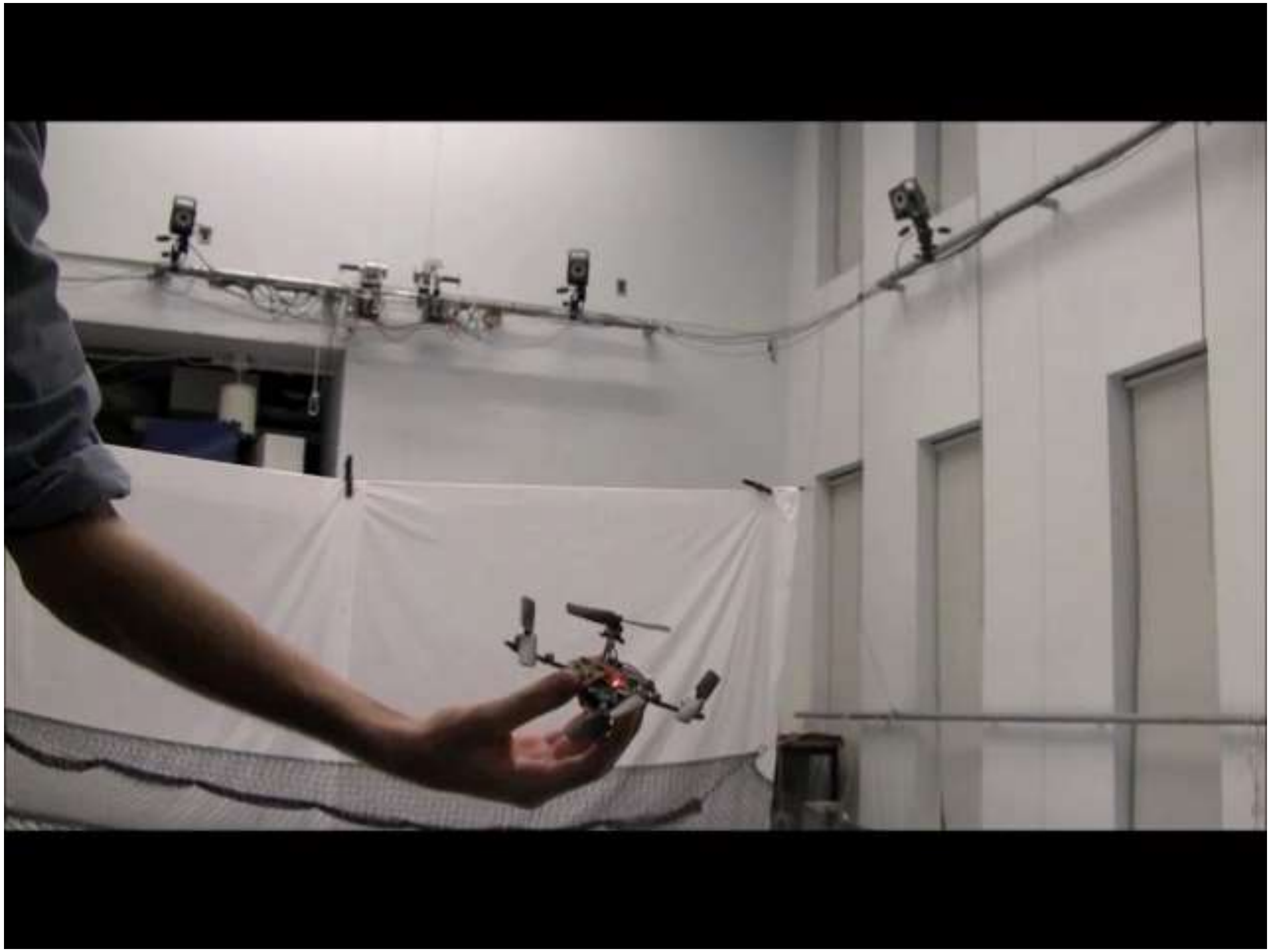
- Factory automation
- Indoor environments
- Field Robotics
  - 2005-future

Highlights: Mapping the Titanic

Ryan Eustice, Hanumant Singh, John Leonard, Matthew Walter and Robert Ballard, *Visually navigating the RMS Titanic with SLAM information filters*. In Proceedings of the Robotics: Science & Systems Conference, pages 57-64, June 2005.



Highlights: Many Quadrotors



V. Kumar, GRASP Lab,
University of Pennsylvania

Highlights: Legged Locomotion

Highlights: DARPA Grand Challenge

- 2004: Mojave Desert USA, 240 km
  - CMU Sandstorm traveled the farthest distance, completing 11.78 km

- 2005: Mojave Desert USA, 240 km
  - **Stanford's Stanley, first place 6h54m**
  - CMU's Sandstorm, second place 7h05m

Highlights: DARPA Urban Challenge 2007

- George Air Force Base, California. 96 km urban area course

CMU's BOS,
first place 4h10m

Stanford's Junior,
second place 4h29m

Driverless Car

- Safer
- More efficient
- Enable people

- The Nevada law went into effect on **March 1, 2012**, and the Nevada Department of Motor Vehicles issued the first license for a self-driven car in **May 2012**. The license was issued to a Toyota Prius modified with Google's experimental driverless technology.
- Google driverless car, with a test fleet of autonomous vehicles that as of May 2012 has driven **282,000** km.

Another trend
Mobile Manipulation

The robots have only interpreted the world, in various ways; the point is to change it[1].

[1]Paraphrasing a philosopher of the 19th century.

Human-Robot Interaction

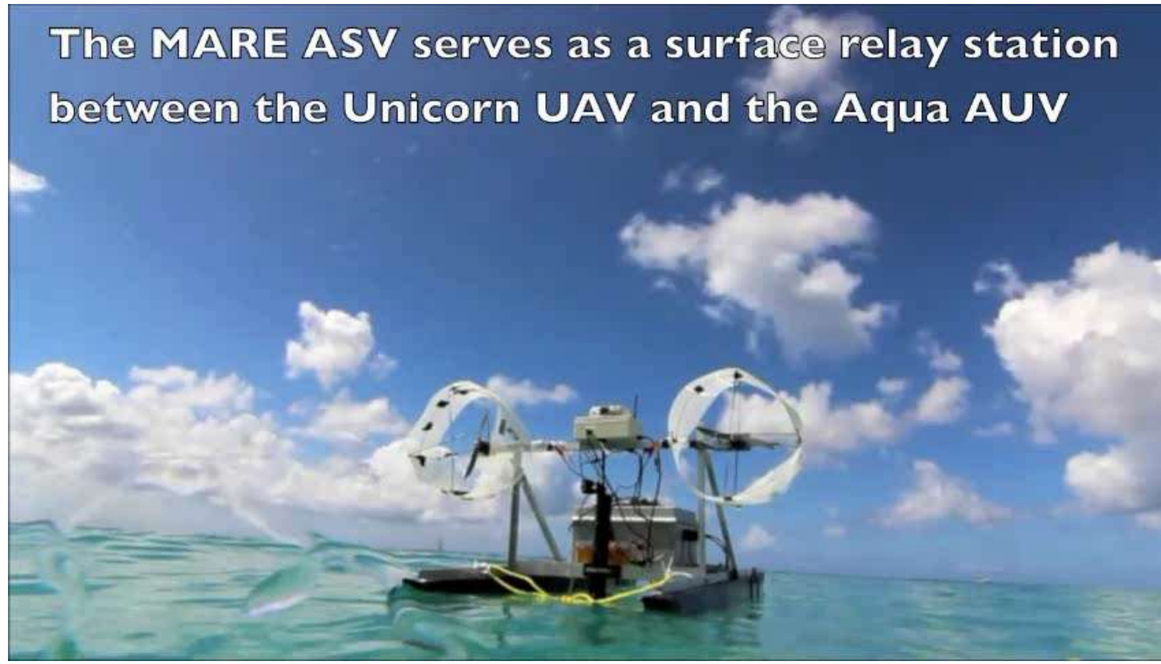
Conclusions

- It has been an exciting learning/working experience
  - "My robot is misbehaving today!"

- **I like what I am doing**
- Computer Science
  - New and Dynamic Science
  - Combines Theory and Practice
  - Results are visible
  - Changes the way we live (Robotic Technology everywhere)
- More Intelligence and Autonomy required
  - In Space
  - In Production
  - At Home
  - On the road

CSCE Courses in Robotics

- CSCE 274
- CSCE 574
- CSCE 774



Questions?

Halifax, Nova Scotia, Canada **Fisherman’s Reef, Barbados**