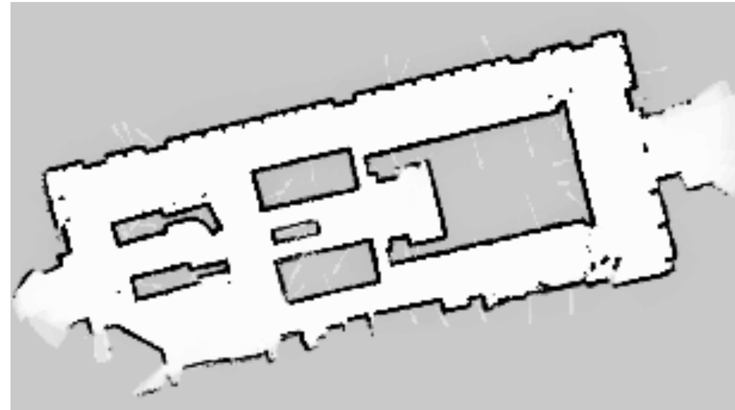
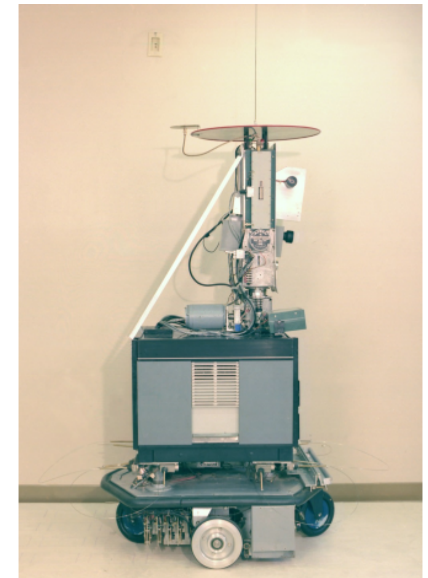
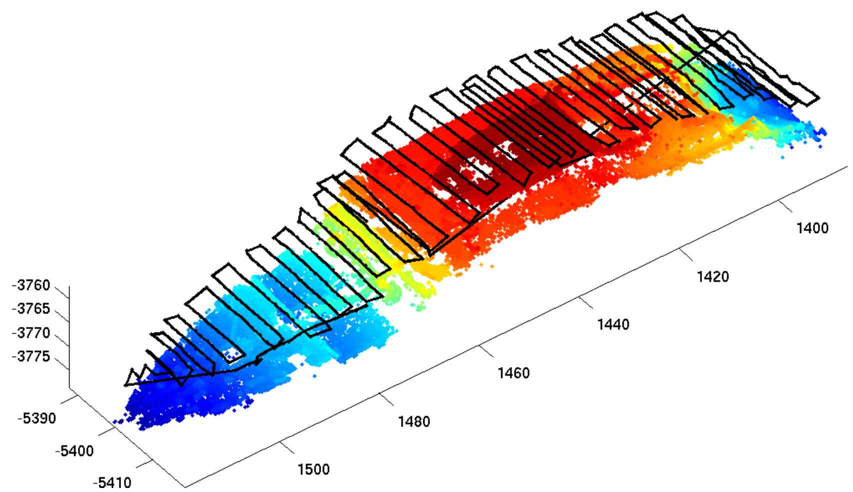
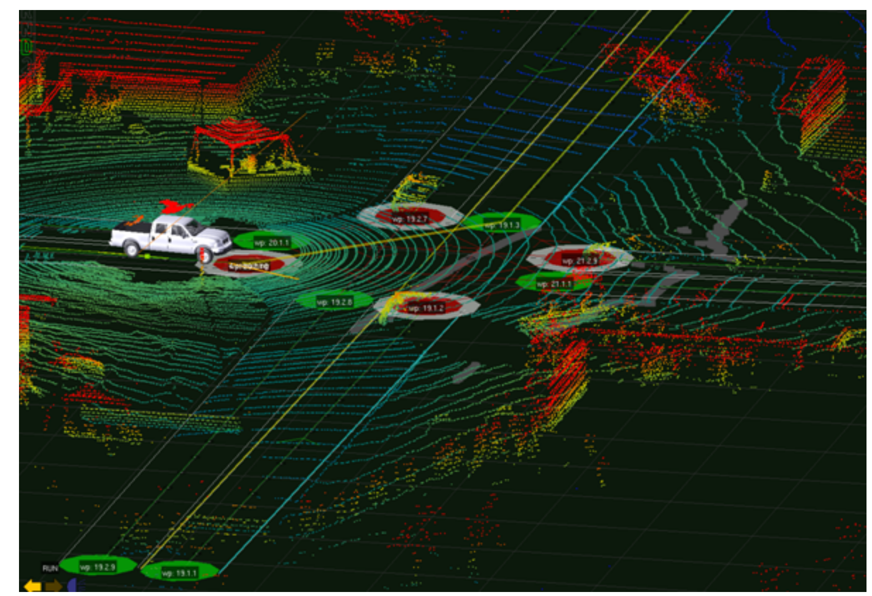








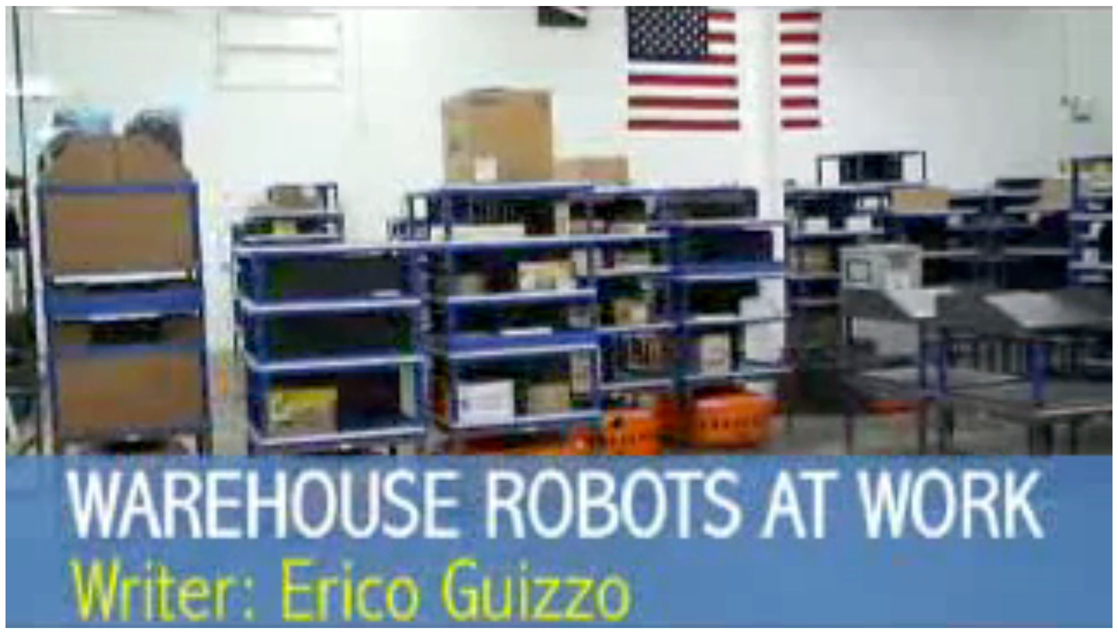
EECS568 Mobile Robotics: Methods and Principles

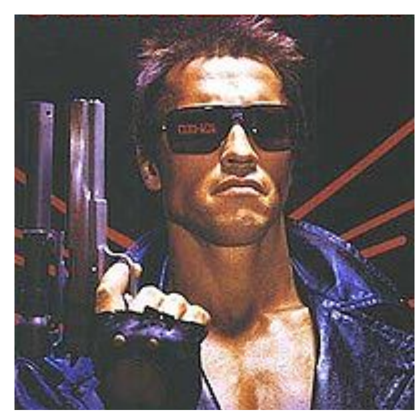
Prof. Edwin Olson

L01. Course Overview

What capabilities does a robot n

what kinds of tasks?
perception? (see next slide)





Robot Needs

- Actuator Design, compliance
- Physical system integration
- Low-level control systems
- Sensing/Perception
- State Estimation
- Motion Planning
- High-level planning
- Human/Robot interfaces

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Calibration
Segmentation
Object classification
Object recognition
Place recognition
Outlier rejection
Data association

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Pose Estimation
Tracking
Intent Estimation
Data fusion
Environment modeling
Mapping

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Obstacle avoidance
Which motions are useful?
Which motions are better than others?
Which will not result in the vehicle bursting into flames?

Robot Needs

- Actuator Design, compliance
- Physical system integration
- ...control systems
- ...eption
- ...ation
- Motion Planning
- High-level planning
- Human/Robot interfaces

Intra-Robot Communications
Inter-Robot Communications
Data logging/playback
Simulation
Visualization
Ground Truthing
Testing/Evaluation

Calibration
Segmentation
Object classification
Object recognition
Place recognition
Outlier rejection
Data association

Pose Estimation
Tracking
Intent Estimation
Data fusion
Environment modeling
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Obstacle avoidance
Which motions are useful?
Which motions are better than others?
Which will not result in the vehicle bursting into flames?

The point

- Robotics is hard and inter-disciplinary
  - Many subsystems have to come together to make things work
  - It's a hard subject to "dive in" to without getting stuck or frustrated.
- Hence, this course!

Course Objectives

- Get you over the “hump” of robot development
    - Develop a toolbox of essential algorithms
- Use real data as much as possible
    - Avoid toy problems
    - Experience real-world complications
- Prepare you for research in robotics
    - And/or building real systems

Topic Overview

- State Estimation
  - Vehicle state
  - Environment state (mapping)
- Perception
  - Lots of sensor modalities!
- Path Planning
  - Obstacle avoidance, kino-dynamic constraints
- Additional topics (time synchronization, system architecture, etc.)

State Estimation

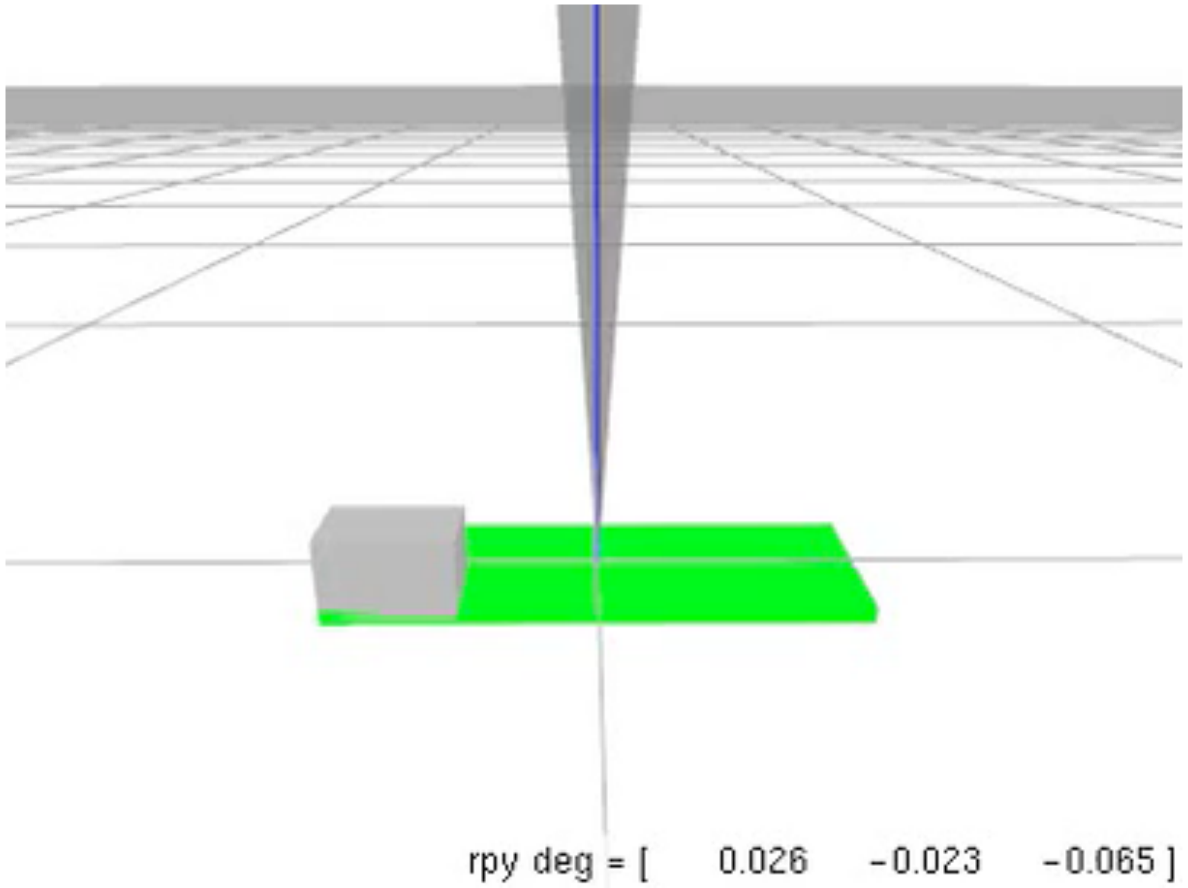
- Where am I?
  - (Estimate *my* state)

- What does the world look like?
  - (Estimate state of the world)

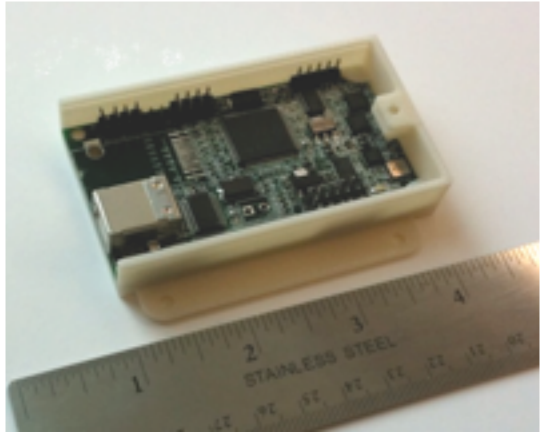
- What is the other guy doing?
  - (Estimate state and intent of other agent)

State Estimation

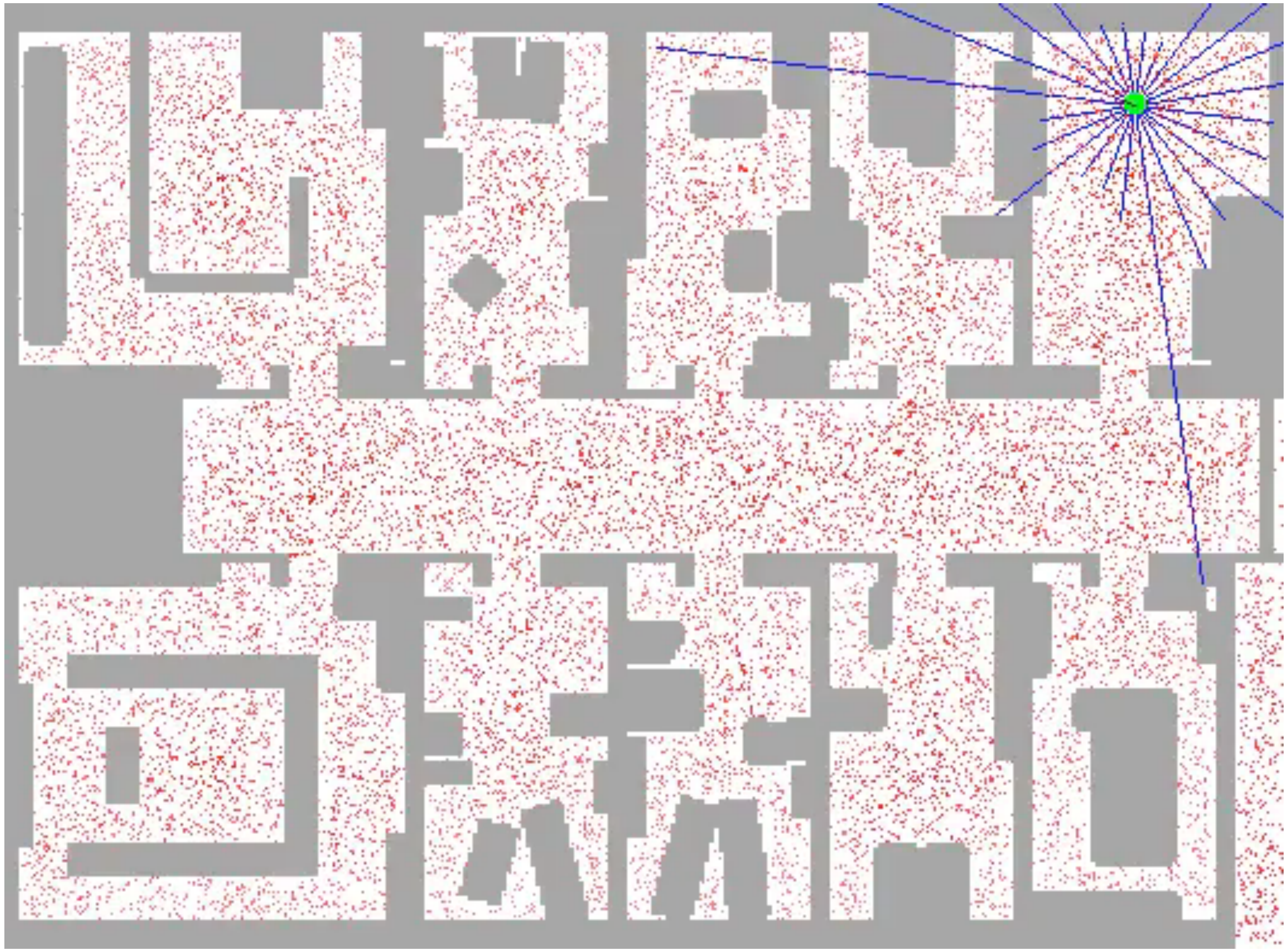
- What is my position?
  - Roll, pitch, yaw
  - x, y, z



- Estimate calibration parameters
  - e.g. Gyro offsets

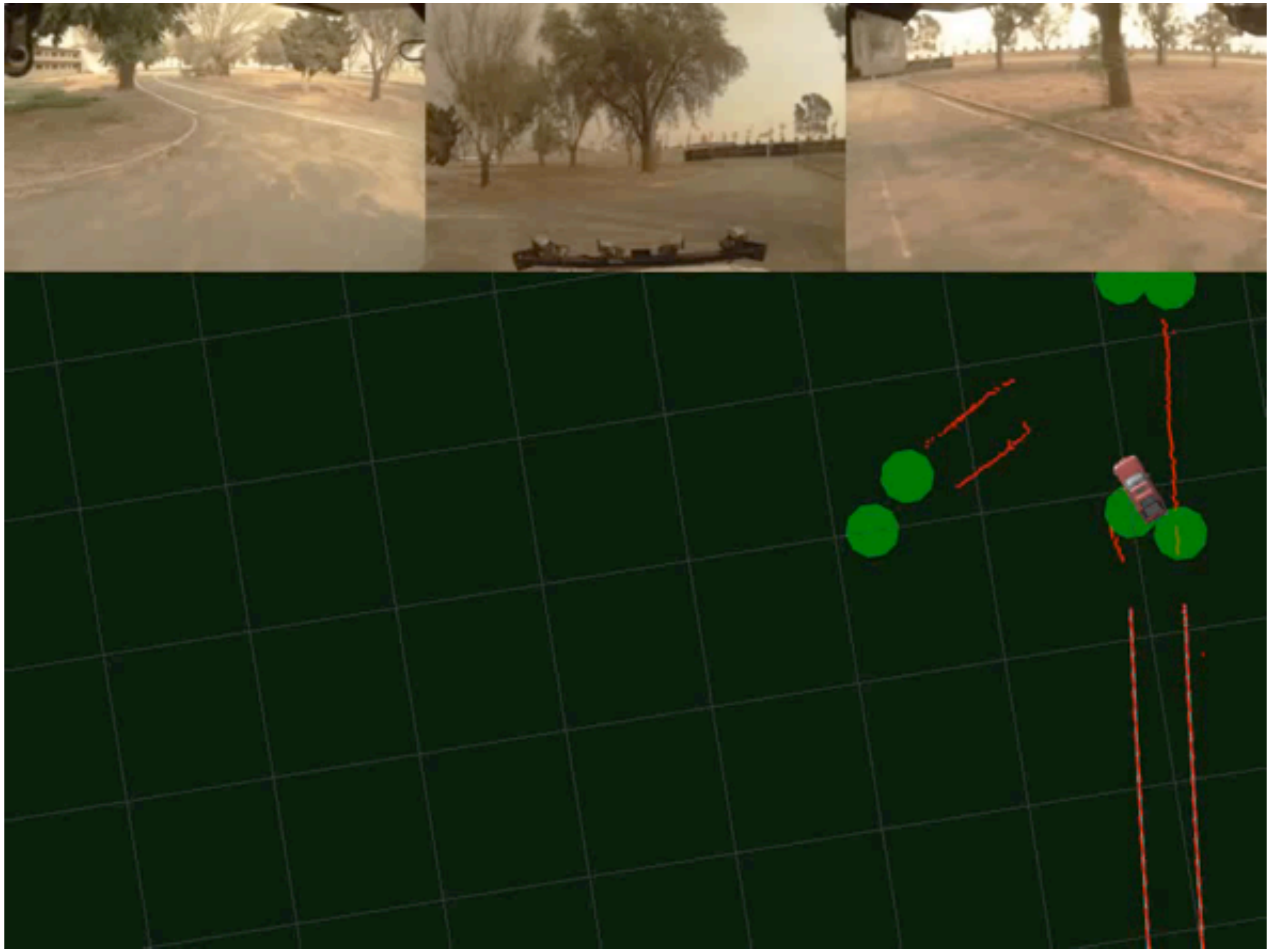


State Estimation: Localization



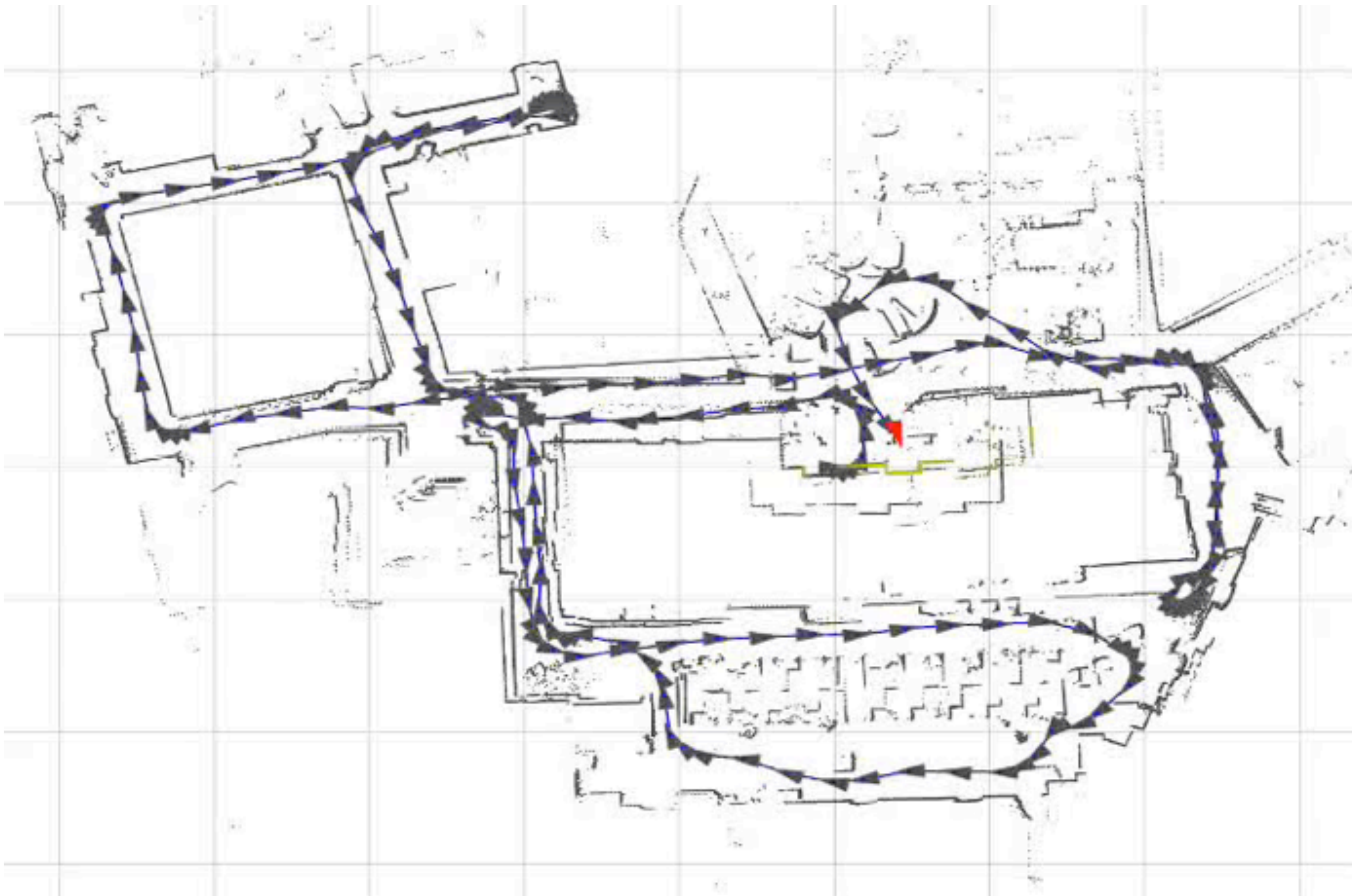
- Given a map of the world, where am I?

State Estimation: Localization



- Given a *prior* on the world (perhaps inexact), where am I?

State Estimation: SLAM



- Build a map and simultaneously estimate my position on that map.

Mapping: History

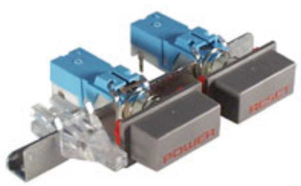
Gauss!

- Who is this?

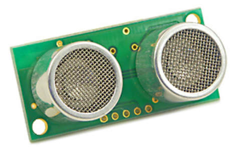
Mapping: History

- Heliotrope (invented by Gauss) and small map showing the triangulation of the Kingdom of Hanover

Robot Perception



$0.02

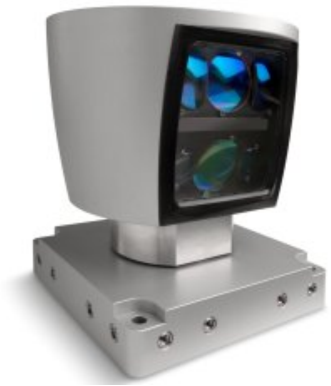


$5

$15

$100

$500



$75000

$5000

$2000

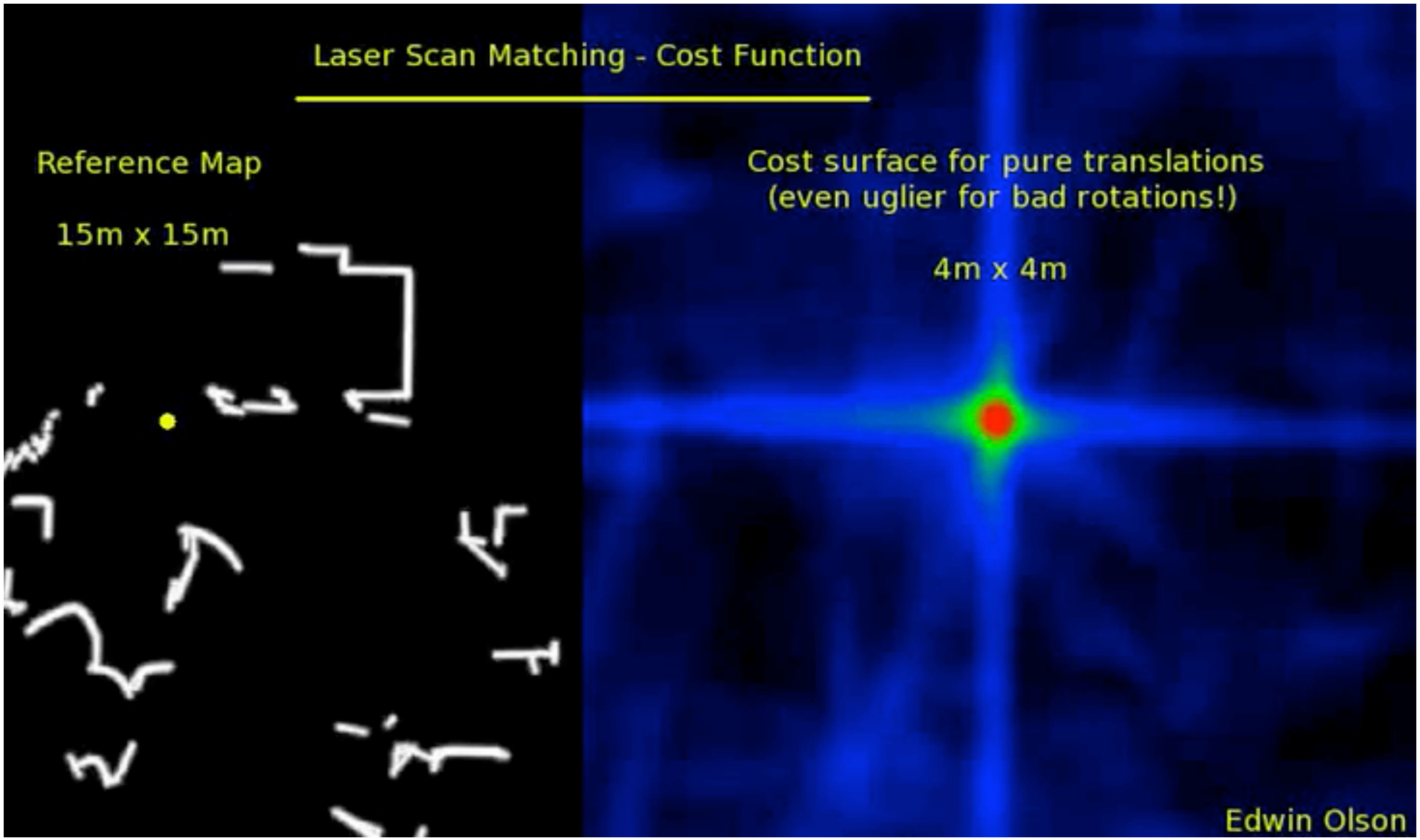
Robot Perception

They’re all framed “neatly”. A robot has to deal with occlusions, bad lighting, funny angles, distracting backgrounds.

- How is *Robot* Perception Special?

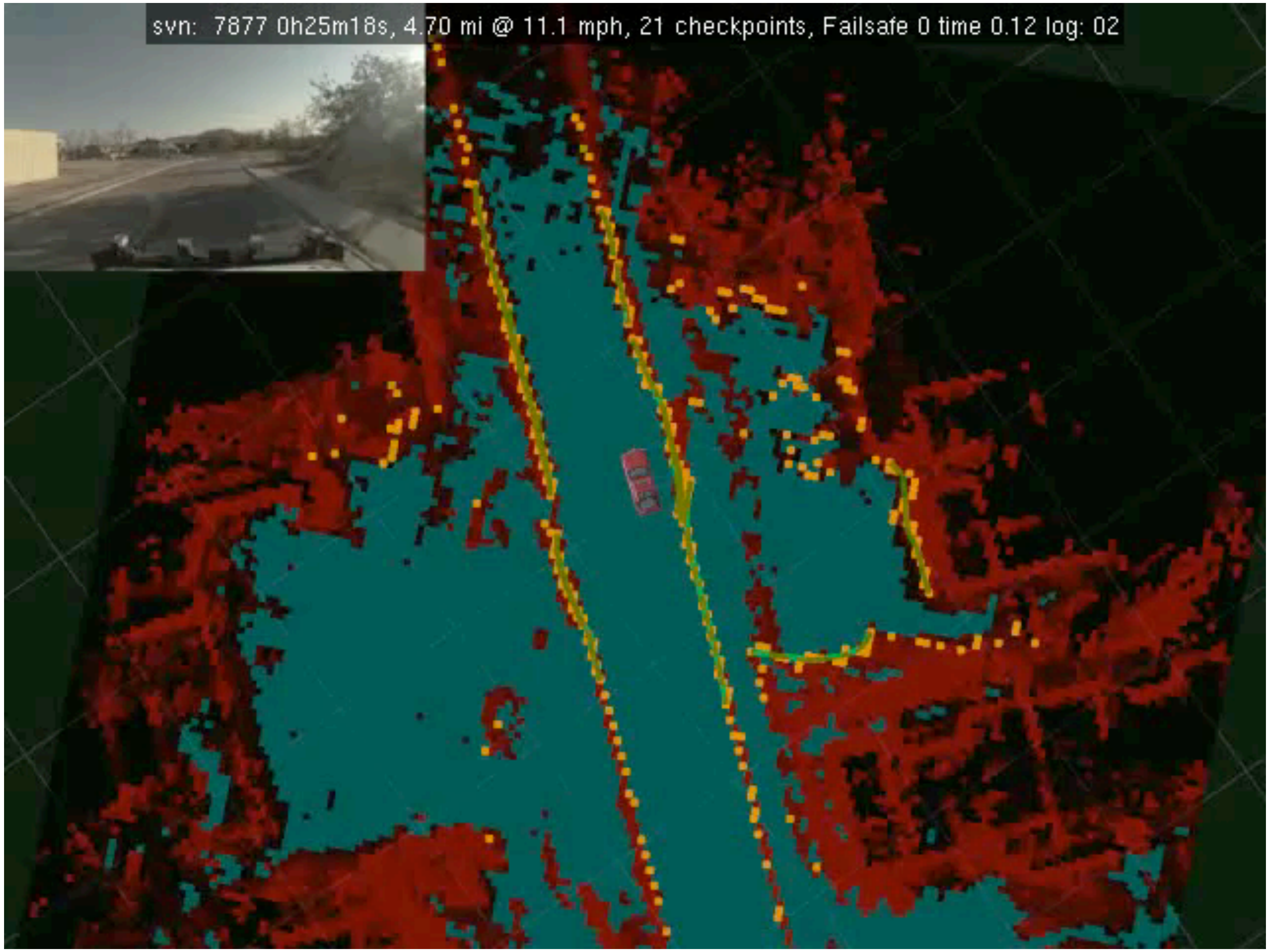
(Images from CalTech 101 Dataset)

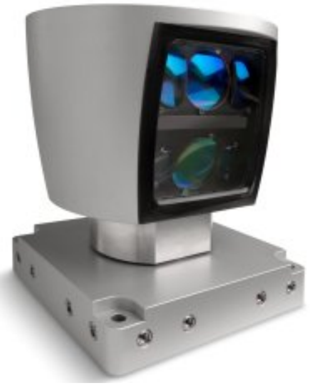
Lasers


Laser Scan Matching - Cost Function
Reference Map
15m x 15m
Cost surface for pure translations
(even uglier for bad rotations!)
4m x 4m
Edwin Olson

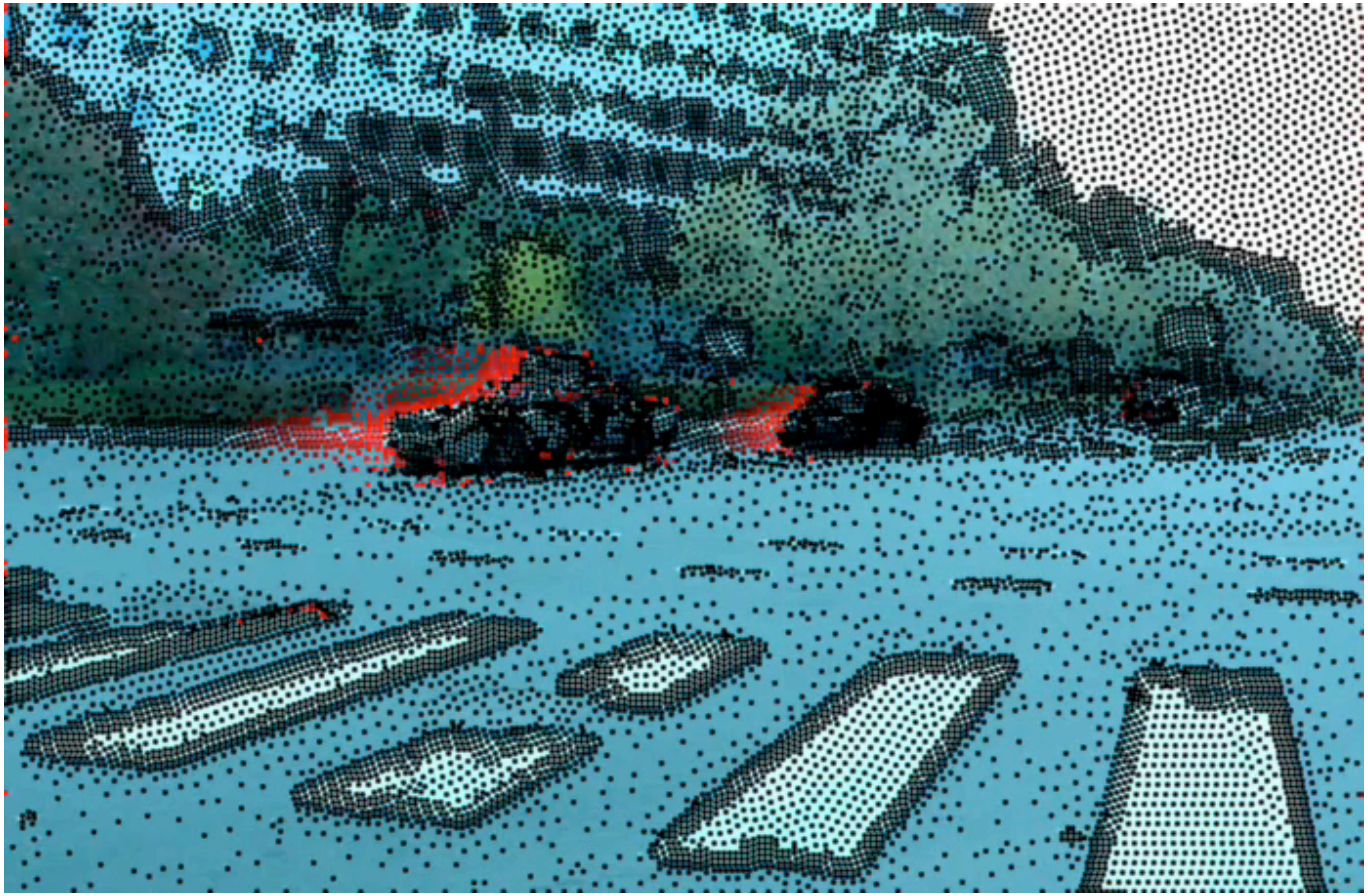

SICK

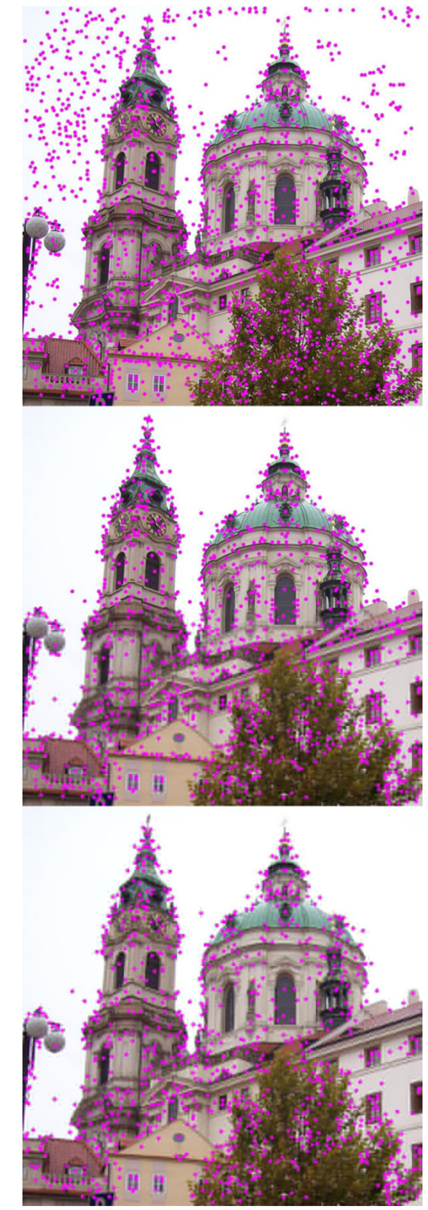
Laser Feature Extraction





Cameras



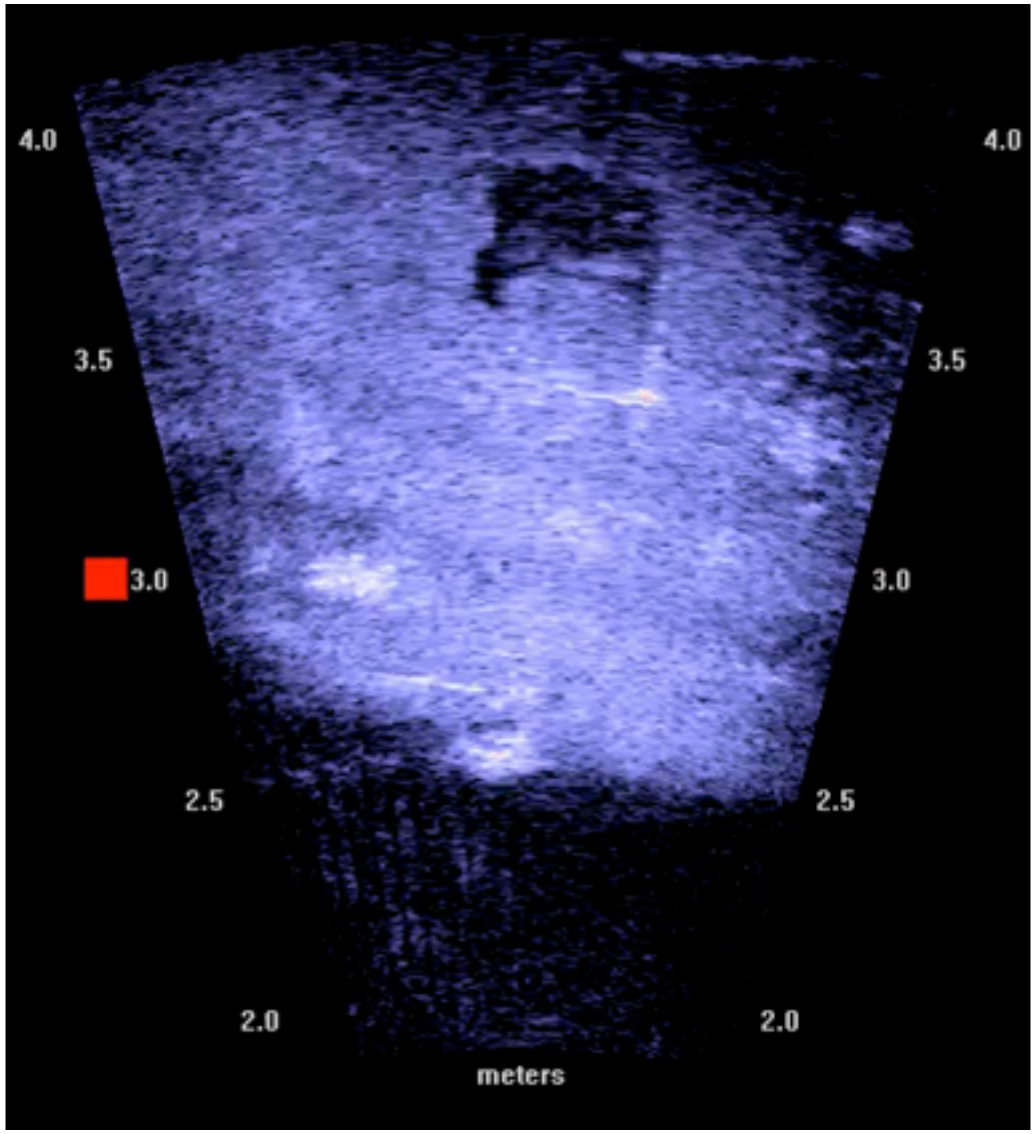


- Detection and tracking points

Cameras

- Artificial Features

Other Sensors



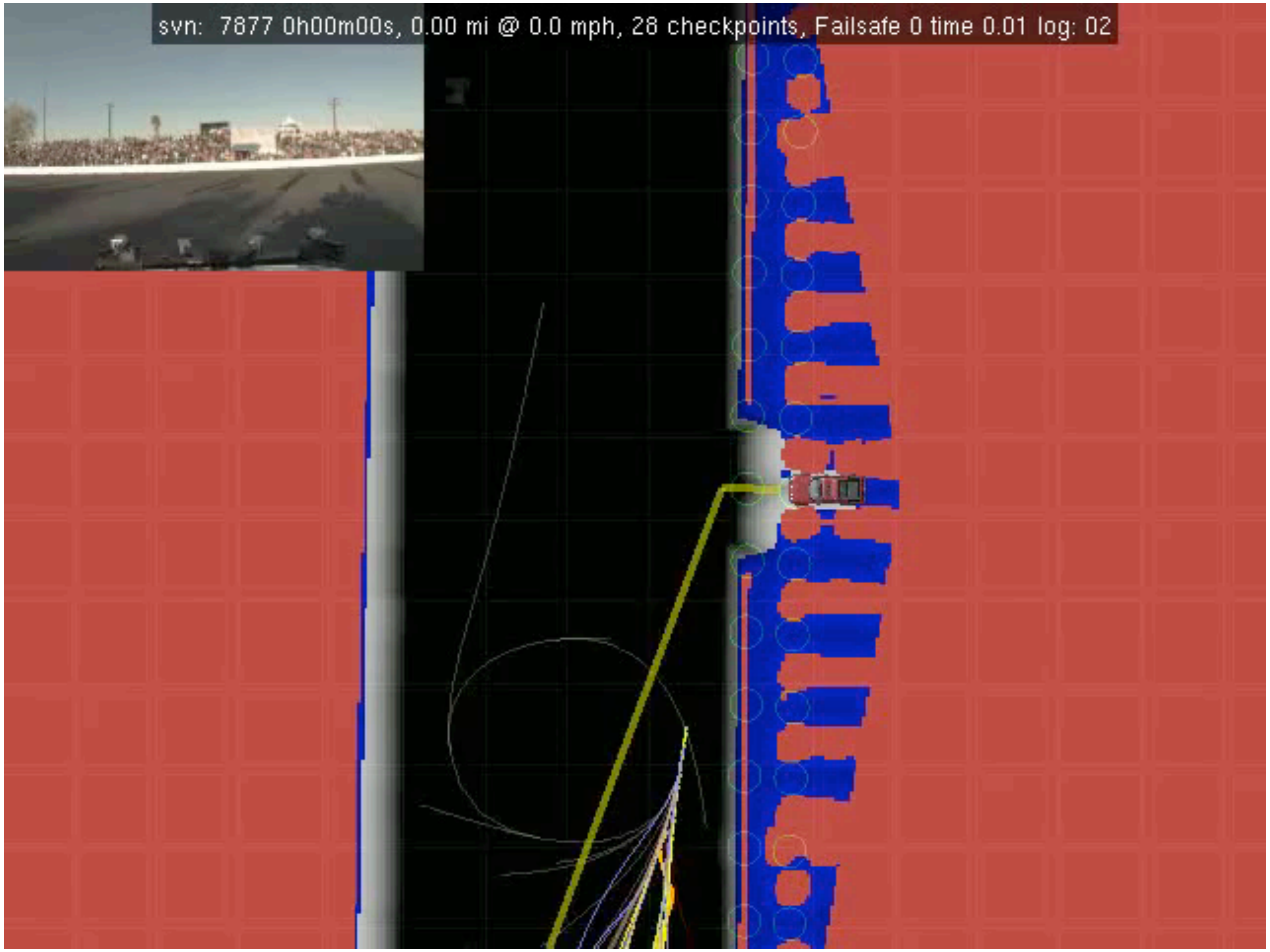
Motion Planning

- How does a robot get from point A to point B?
  - "Which route?"
  - Which path?"

"The key scientific and technological issue in robotics is that of coping with uncertainty ... In fact, the uncertainty is such that one of the most challenging activities for a mobile robot is simply going from point A to point B."
Tomas Lozano-Perez, 1990

Route Planning

Path Planning



Un-Topics

- Mechanical Design
- Control Systems
- Machine Learning
  - (well, mostly)

Un-Topics

break

Have everyone introduce themselves to four of their neighbors at one minute intervals....

they are to ask (and record) the names & how many siblings they have.

at the end:

* Can they compute mean/variance (both biased and unbiased) of siblings? Can they compute variance without computing mean first? If they can't, this is a warning sign for them.

* If we recorded the names of who talked to who, it would form a graph. Could we estimate a map of the world based on this graph? (Yes- Isomap... see Linear Algebra Lecture 3)

Course Administration

- Wiki: Calendar, Problem Sets, Policies, etc.
  - http://april.eecs.umich.edu/courses
- Mailing lists
  - eecs568@april.eecs.umich.edu
  - eecs568-staff@april.eecs.umich.edu
  - Subscribe yourself!
    - http://april.eecs.umich.edu/mailman/listinfo/eecs568

Pre-Requisites

- Officially: Graduate student status or instructor permission

- You need:
  - *Solid* Java/C/C++ programming
    - Java is the official language of the course.
    - Libraries and samples provided in Java
    - Unless specified otherwise, solutions must be in Java.
  - Basic probability background
  - Linear algebra*

Office Hours

- Prof. Edwin Olson
    - Monday 3-5p in CSE3737

- GSI Johannes Strom
    - Thursday 1-3p in TBD

Books

- There is no required textbook.

- A good reference for the first 40% of class:
  - Probabilistic Robotics, Thrun, Fox, Burgard

Evaluation

- 4 Problem Sets [32%]
  - Groups
- Two mid-terms [32%]
  - Individual
- Final Project [32%]
- Peer Evaluations and Participation [3%]
- Course evaluation [1%]

Groups

- Teams: 3 or 4 students; each lasts for two problem sets.
- PS1/2 Teams:
    - You pick them. Team memberships must be registered with staff by 5p on Friday.
- PS3/4 Teams:
    - Will be matched up by computer, guided by your preferences
- Team Bonuses: If everyone on your team scores well (B+ equivalent) on midterm, you get a one-grade increment! (A to A+).
- Peer evaluations

Collaboration Policy

- Your assignments must represent original work.
  - Use of external libraries limited to those explicitly identified by problem set writeup (e.g., Linear Algebra packages)
  - Use of external knowledge (academic papers-- not implementations) encouraged!
  - Problem sets must be done *collectively*, not divvied up.
    - Yes, this means you need to meet together.
    - (Why is this our policy?)

- Problem set certifications
  - "I participated and contributed to team discussions on each problem, and I attest to the integrity of each solution. Our team met as a group on [DATE(s)]."
  - Note any qualifications (we're reasonable).
  - Signatures

Late/Makeup Policy

- Problem set lateness
  - 10% per day *or fraction of*
  - After 3 days, no credit

- Exam makeup policy

Final Project and Demonstration

- Scope
  - Implement a more complicated algorithm
  - Implement a system of multiple algorithms
  - Develop a principled new algorithm
  - Develop a compelling real-world implementation
- Evaluation
  - 80% Write-up
  - 20% Interactivity and engagingness of presentation

Linear Algebra Review Sessions

- Many of you may lack an adequate Linear Algebra background.

- Linear Algebra Review Sessions
  - Thursday Sept 8, 7-9p
  - Friday Sept 9, 7-9p
  - Monday Sept 12, 7-9p

Last Thoughts

- Not registered?
  - We'll figure out how many of you we can accommodate.

- Teams
  - Identify team members.
  - Email to eecs568-staff@april.eecs.umich.edu (by 5p Friday)
    - SUBJECT
      - PS1/2 Team: gwashington, jadams, jjefferson
      - (either 3 or 4 members)
    - BODY:
      - What times did you identify during the week that you'll be able to meet?
      - Have you assessed the risk of dropping below two students?