M2M Perception for Driving Safety

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M2M Perception

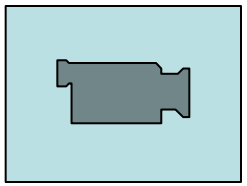
- **Driving Safety** is still Infeasible with perfect M2M communications

Dreams

Intelligent Transportation Systems

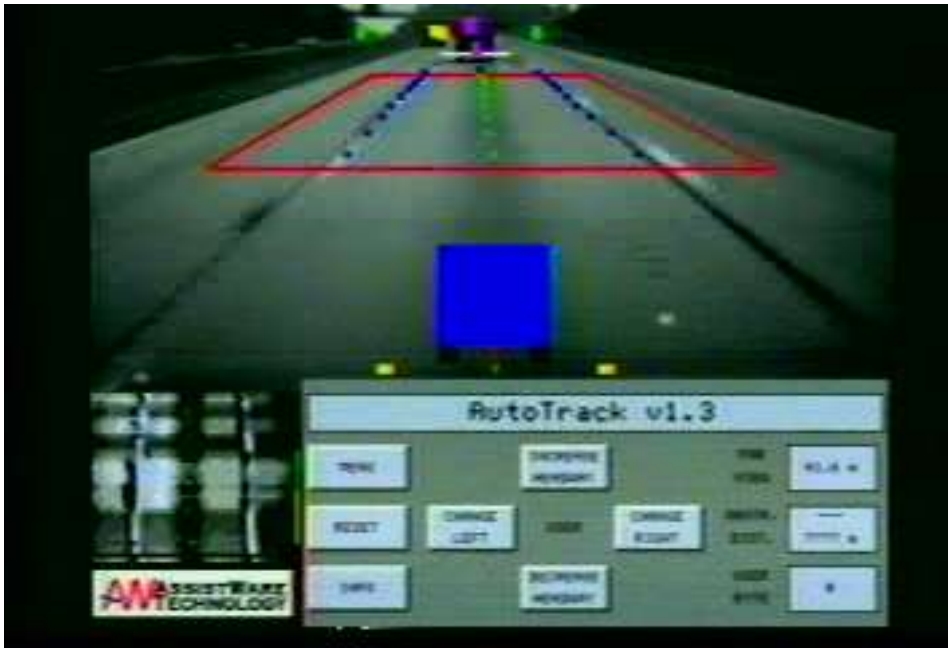
Knight Rider 1982-1986

A super intelligent robotic car



CMU Navlab (1985~1997)

From Highways to Urban Areas



- A wide variety of moving/stationary objects
- GPS/DGPS may fail. IMU/IMS is expensive

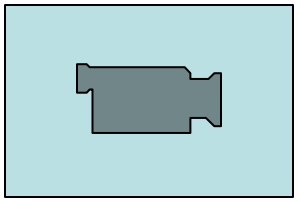
DAPRA Urban Challenge 2007

- Build an autonomous vehicle capable of driving in traffic,
- performing complex maneuvers such as merging, passing, parking and negotiating intersections.

Google Driverless Car 2010

Radar and Cameras

- Volvo 2011
  - Pedestrian Detection with Full Auto Brake
  - Adaptive Cruise Control with Queue Assist
- Sensing for Simple Events/Scenes
- Still Insufficient in Crowded Urban Areas



Science & Systems

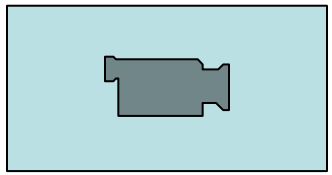
M2M Perception

- Sensor fusion to cope with **highly uncertain data** from **heterogeneous sensors**
- Recursive Bayesian Estimation:
  - Kalman filter,
  - Particle filter, etc.
- Fusion
  - **Multiple Tasks**
  - **Multiple Machines**

Multiple Tasks

- Localization
  - Given: an environment map, sensor measurements
  - Problem: Where is the robot?

$$p(x|M,U_k,Z_k)$$



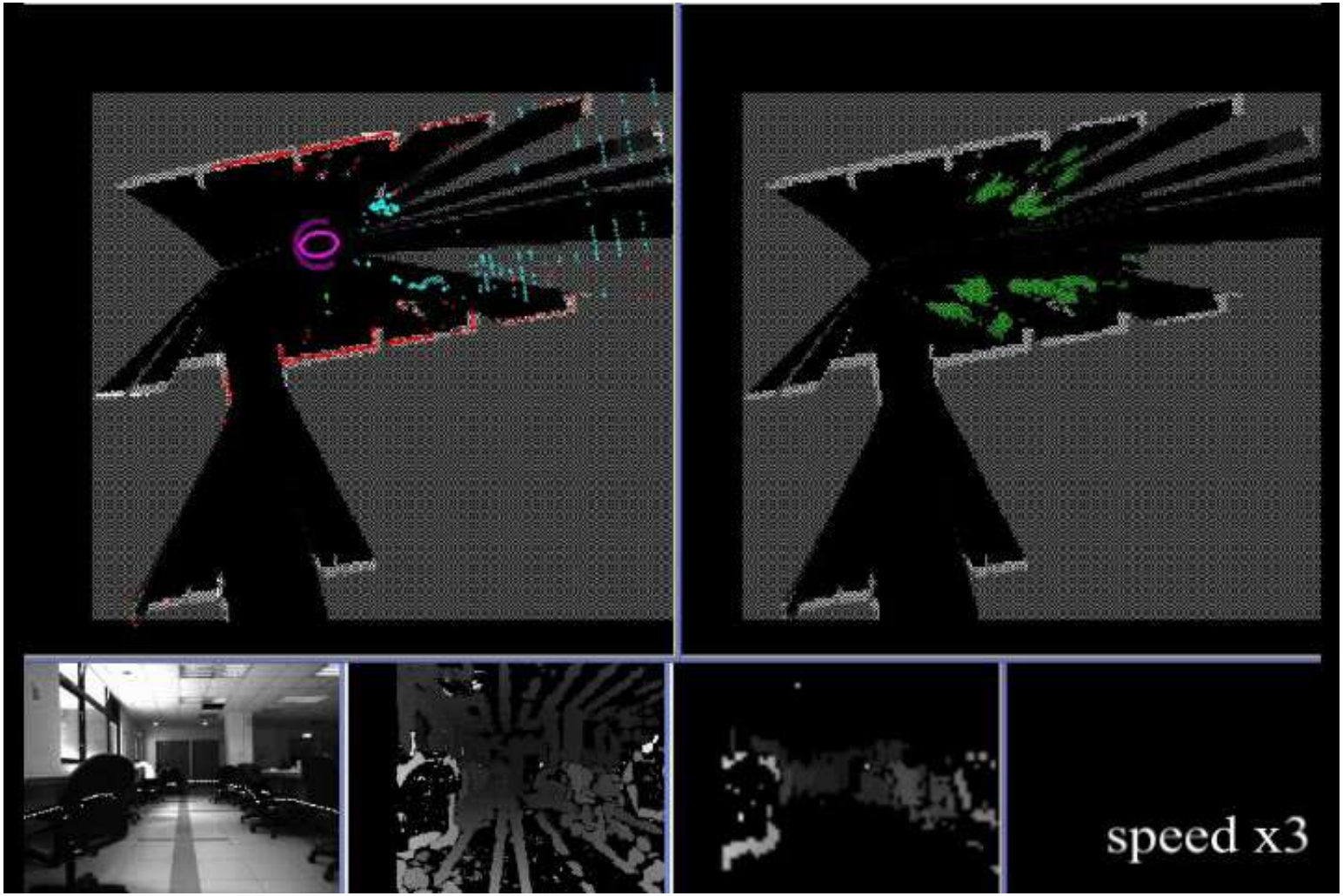
- Mapping
  - Given: the robot state, sensor measurements
  - Problem: Can we build a map of the environment?

$$p(M|X_k,Z_k)$$

Simultaneous Localization and Mapping

$$p(x,M|U_k,Z_k)$$

Sensor Fusion & Task Fusion



SLAM in Dynamic Environments

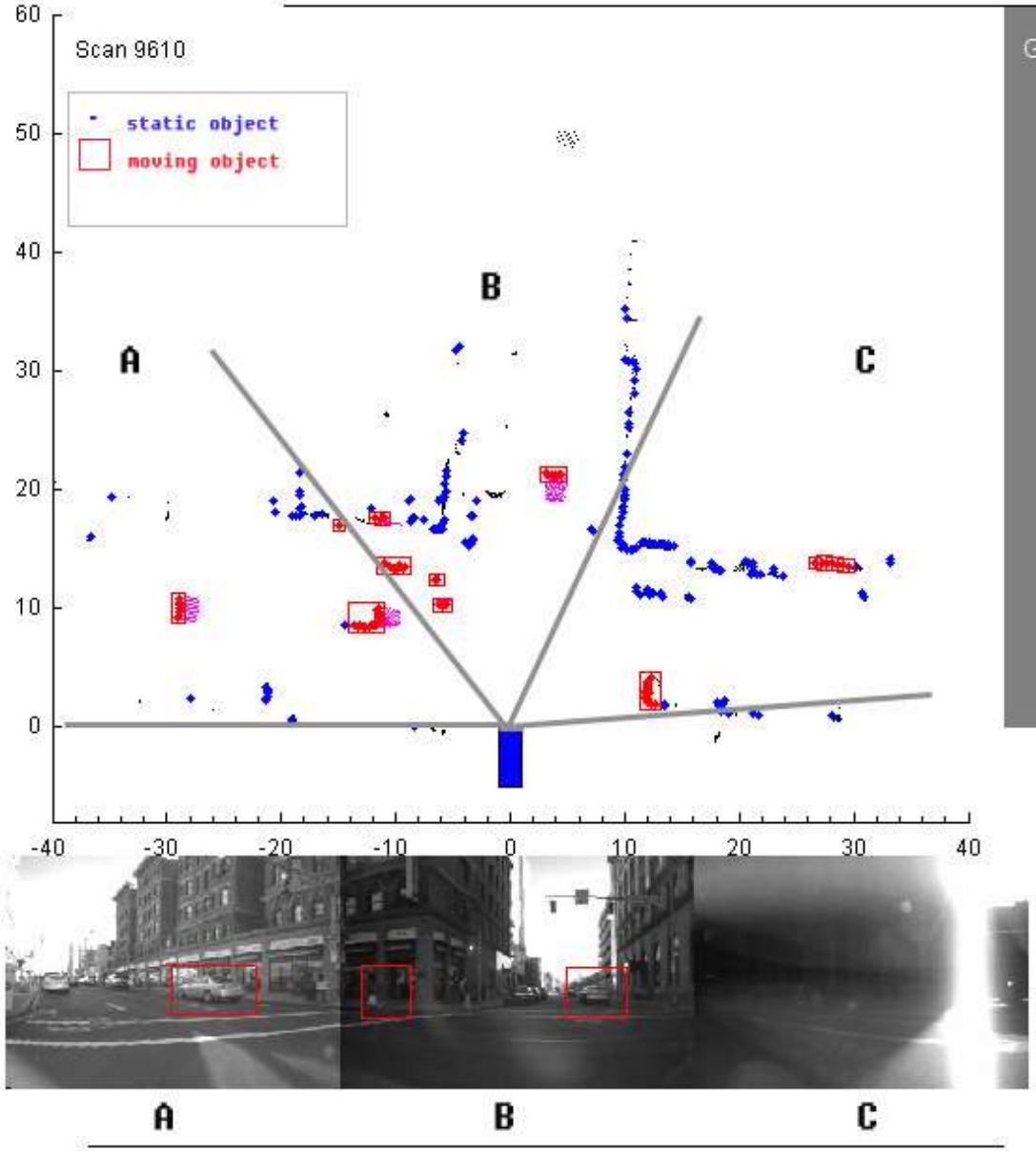
- Effects of Moving Objects

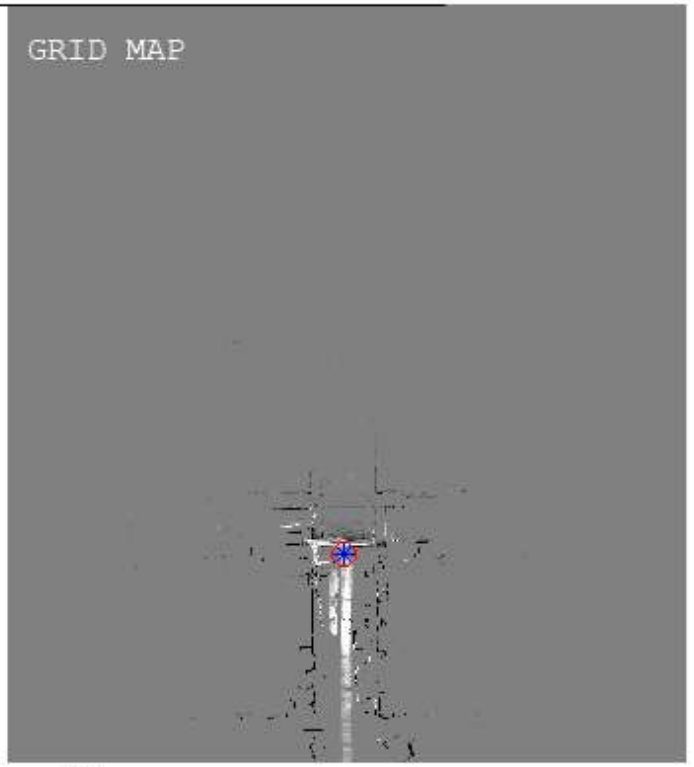
- One more task: Moving Object Tracking

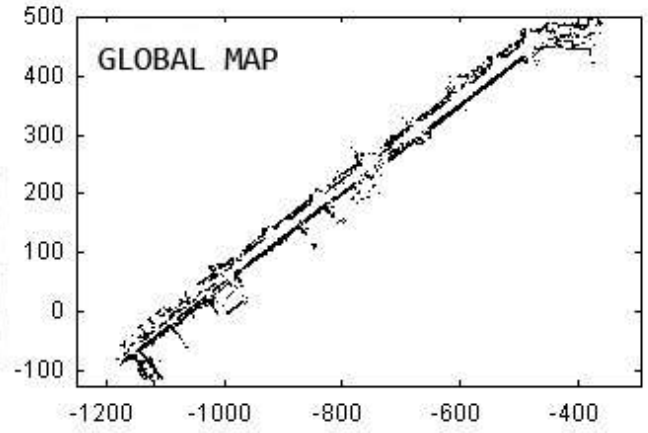
$$\mathbf{p(o,s|Z_k)}$$

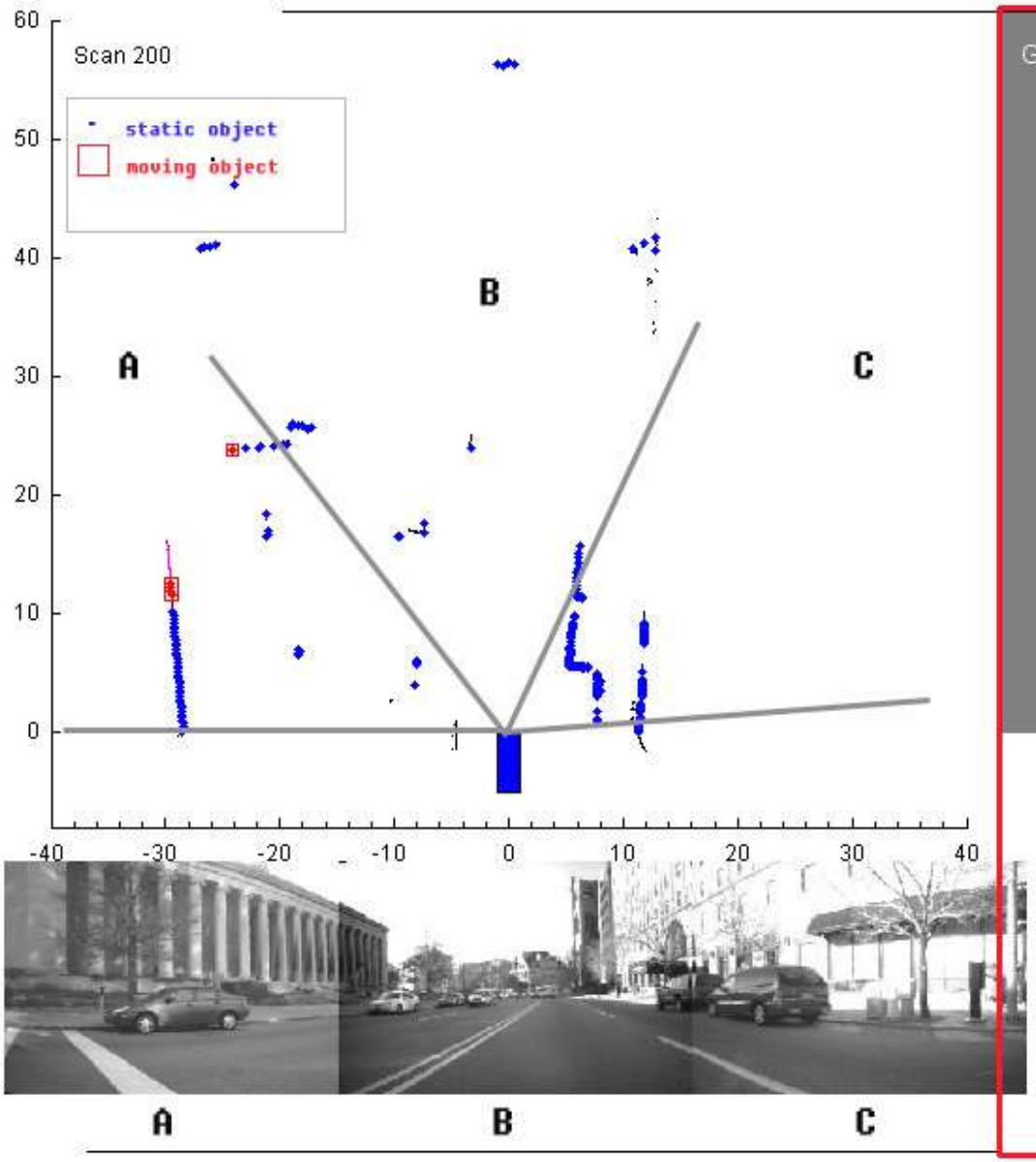
- Simultaneous Localization, Mapping & Moving Object Tracking (SLAMMOT)
  - IEEE ICRA 2003 Best Paper Award
  - IJRR 2007 (Rank 1 in Robotics)

$$\mathbf{p(x,M,O,S|U_k,Z_k)}$$

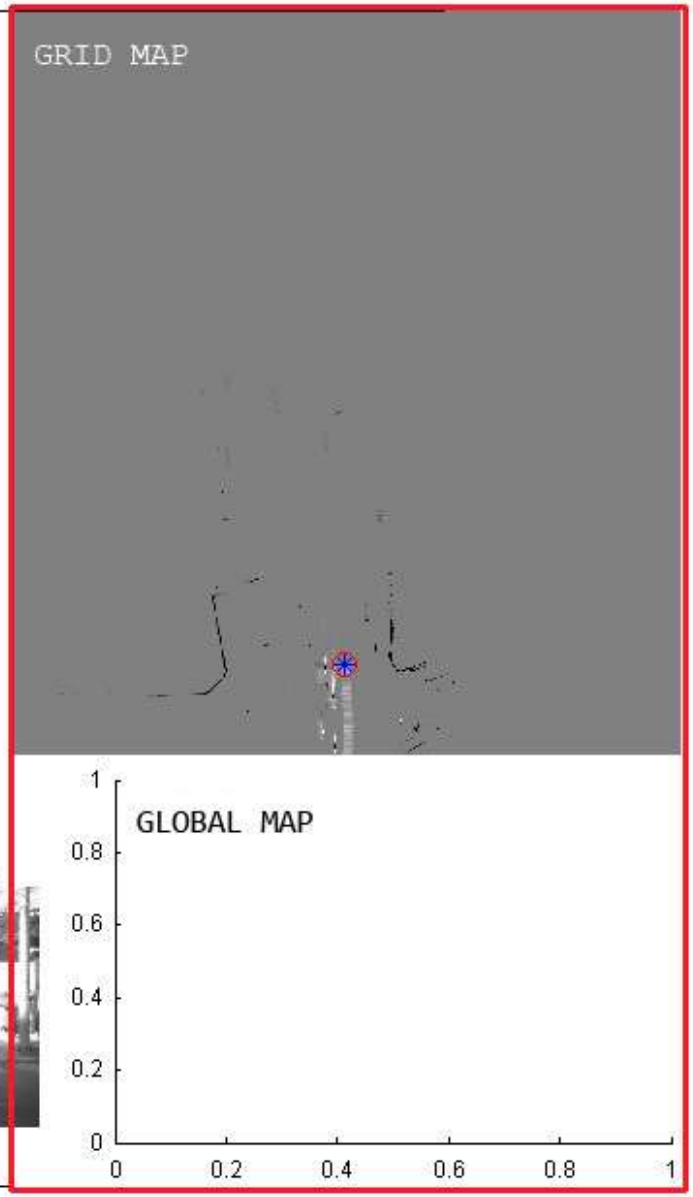

Scan 9610
static object
moving object
A
B
C
60
50
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
40


GRID MAP


GLOBAL MAP
500
400
300
200
100
0
-100
-1200
-1000
-800
-600
-400


Scan 200
static object
moving object
A
B
C
60
50
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
40

A
B
C

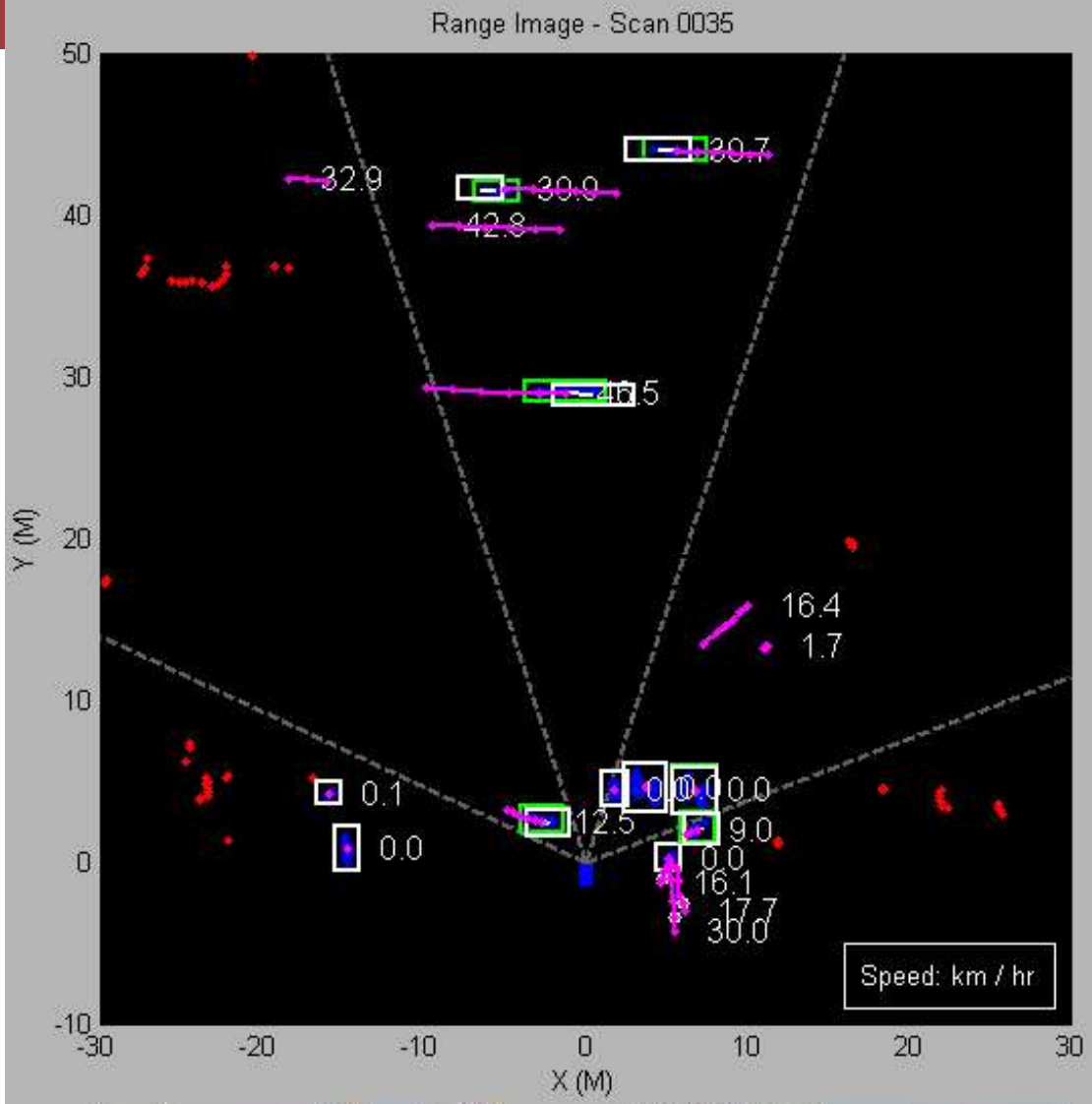

GRID MAP
GLOBAL MAP
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1

More In-Depth Contributions

- Simultaneous Ego-Motion Estimation, Segmentation and Moving Object Detection
  - JFR 2011 (Rank 2 in Robotics)
- The Annotated Laser Data Set for Navigation in Urban Areas
  - IJRR 2011 (Rank 1 in Robotics)
- Feasibility Grids for Localization and Mapping in Crowded Urban Scenes
  - ICRA 2011

Highly Dynamic Environments

- **IEEE ICRA 2007, IEEE ARSO 2008**



Traffic Pattern: 直行亲客路

From Multi-Task to Multiple Machines

RoboCup

Connected Vehicles

- By 2050, fully autonomous humanoid robot soccer players shall win the soccer game against the winner of the most recent World Cup.

- Standard Platform League (1999~today)
  - USA: CMU, UT Austin, U Penn, WPI, etc.
  - Team NTU Robot PAL(Since 2009)
    - 2009: Top 8, 2010: Top 16, 2011: 3rd place

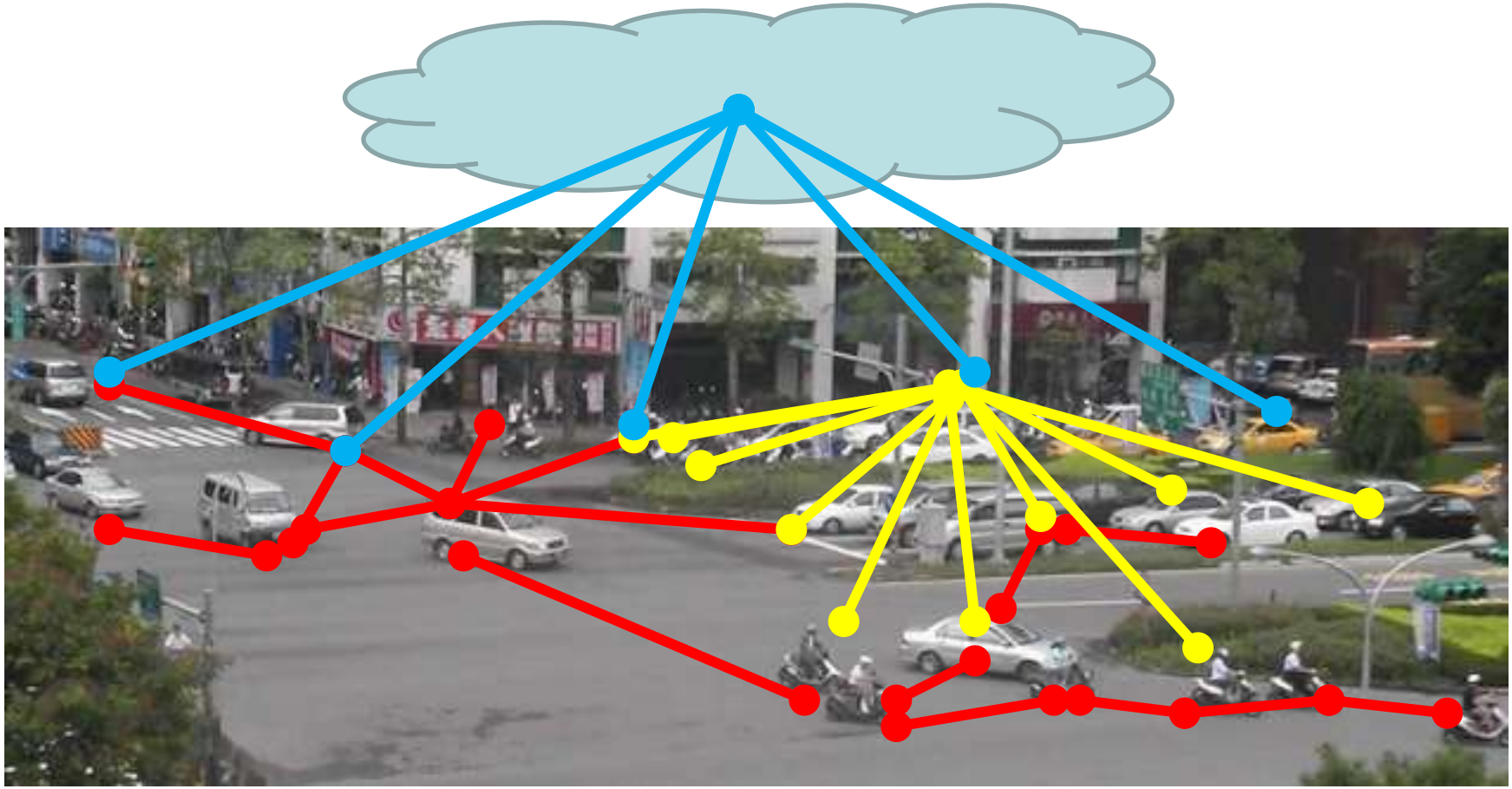
Cooperative Localization & Tracking

- IEEE ICRA 2011 paper
- Heavily used at RoboCup 2011

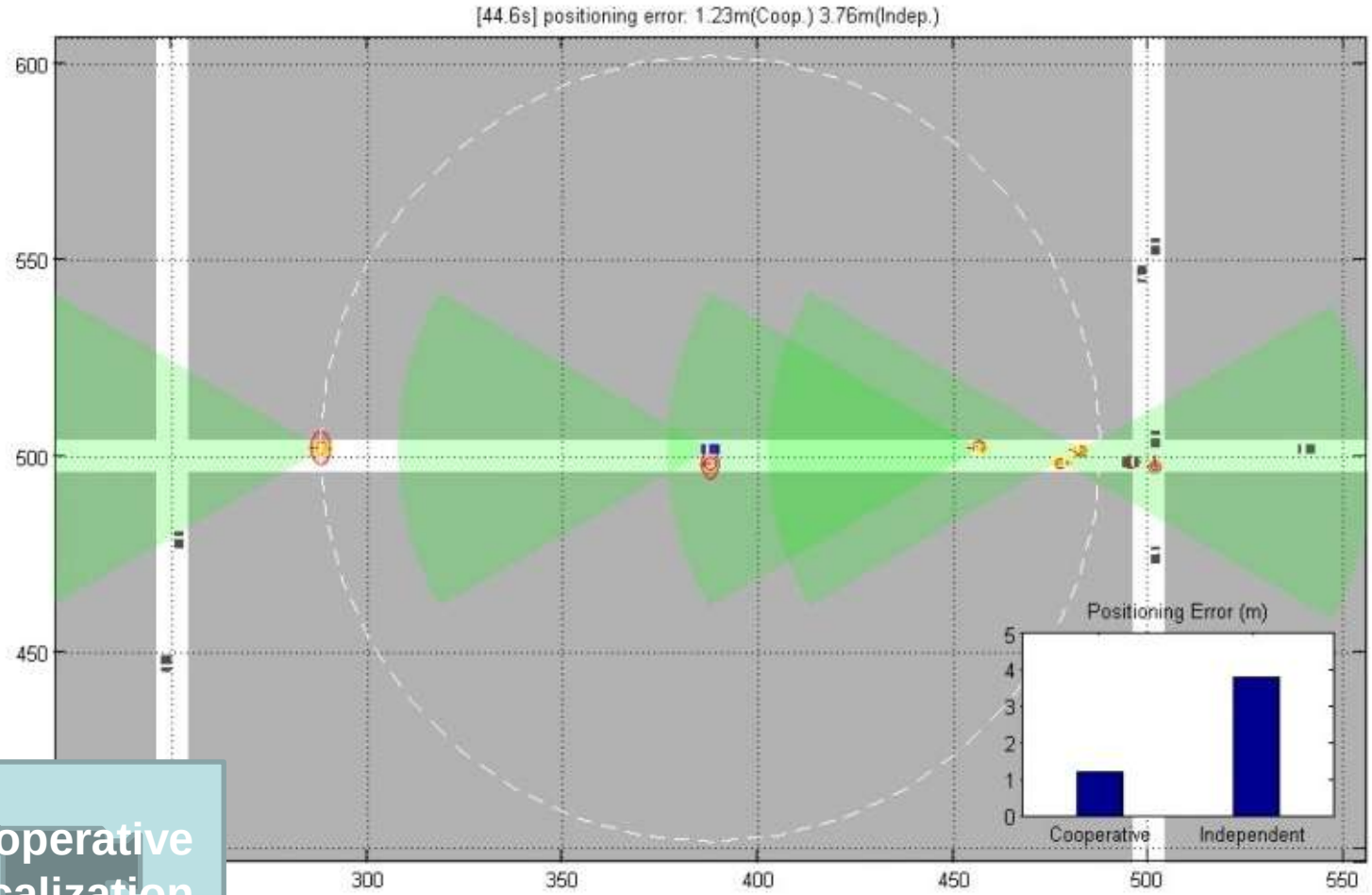
RoboCup 2011
NTU vs. CMU

RoboCup 2011
NTU vs. HTWK

Highly Dynamic Environments



Cooperative Localization and Tracking in M2M Transportation



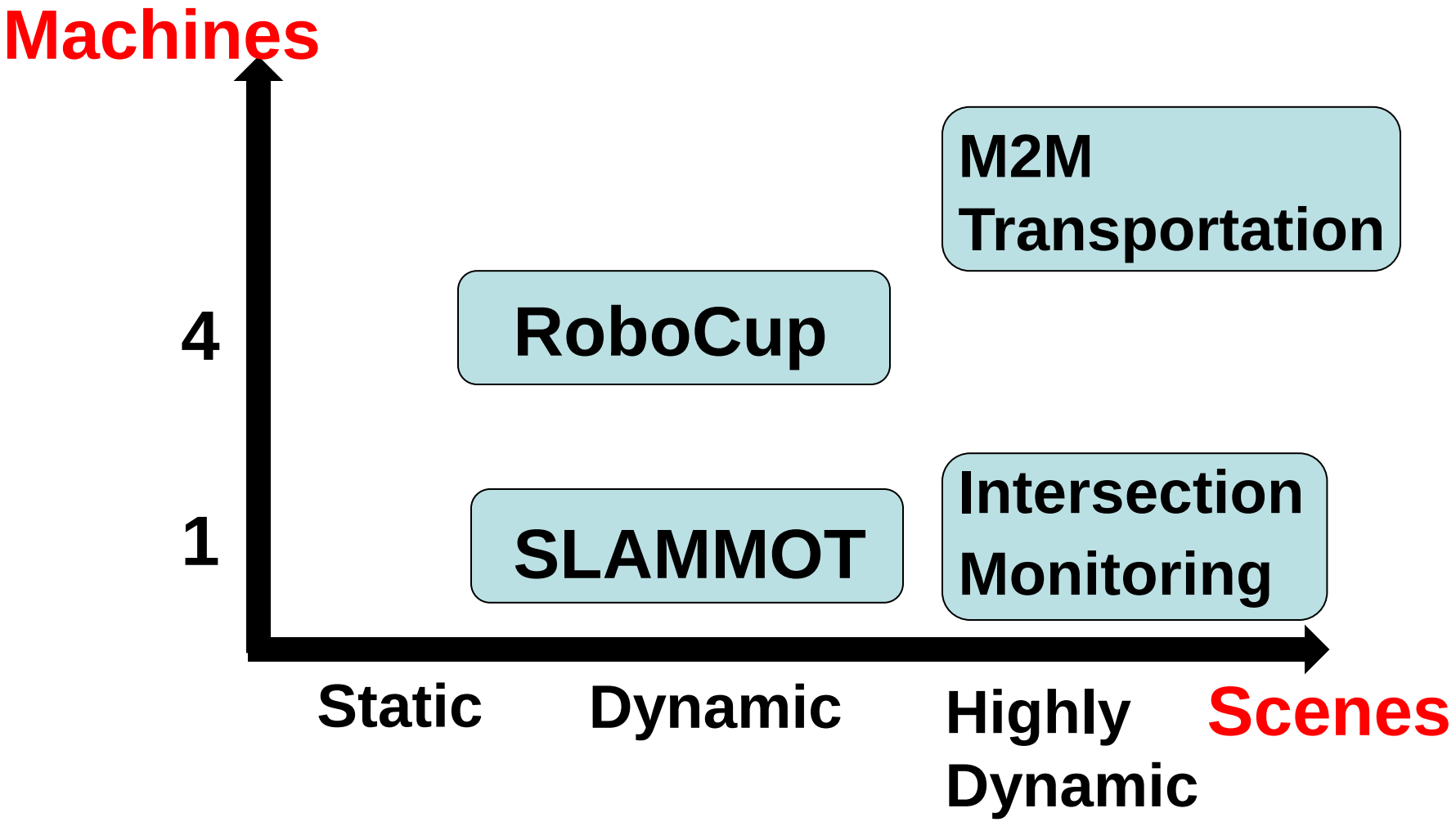
Cooperative Localization

Solutions for High-end and Lower-cost Vehicles

- 2D laser scanners, Cameras

Stereo Camera

M2M Perception Summary



Thanks for Your Attention!