The Roomba 980: Computer Vision meets Consumer Robotics

iRobot®

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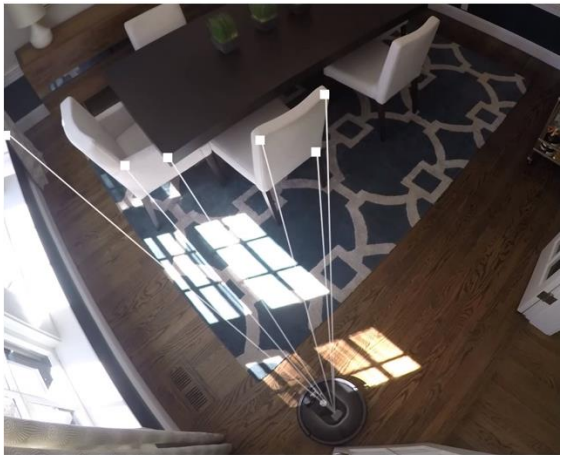
The Roomba 980

Navigation sensors:
- Odometry
- Gyro + Accel
- Mouse
- Camera
- Bumper (2 switches)
- Cliff sensors

Connectivity
- WiFi

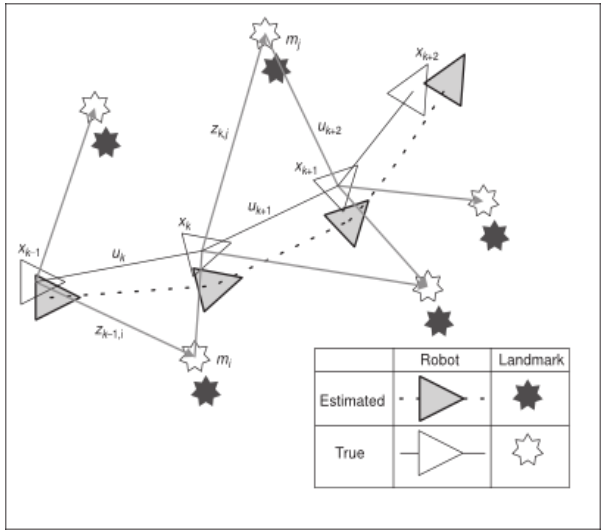
Vision vs. alternative technologies

- Cameras provide a large amount of information at an efficient cost
- Vision can be used for
  - Localization and mapping
  - Object recognition
  - Semantic understanding
  - User interaction
  - Pet detection
  - Obstacle avoidance
  - …



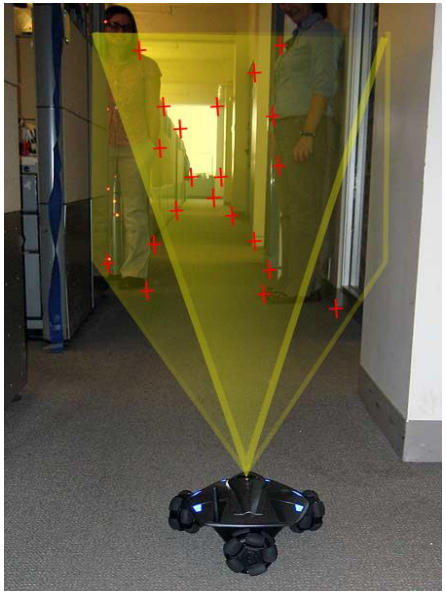
- Alternative technologies based on lasers (LRFs, LIDARs) are either less rich in terms of information or unaffordable

Challenge: SLAM w/ cameras



SLAM: Bailey & Durrant-Whyte, 2005

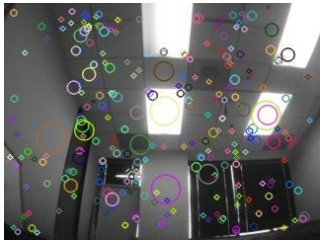
Pose graph encodes odometry and landmark observations to map and localize

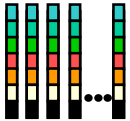


Landmarks:

SfM reconstructions over two frames

Challenge: SLAM w/ cameras





Scale Space Pyramid

Feature Detection

Feature Description

Land-marks

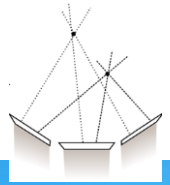
Pose

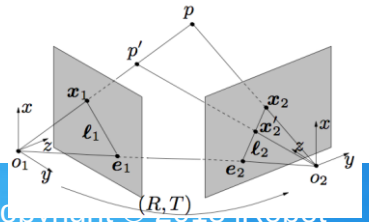
Landmark Creation and Recognition

Pose and Geometry

Feature Database

Database





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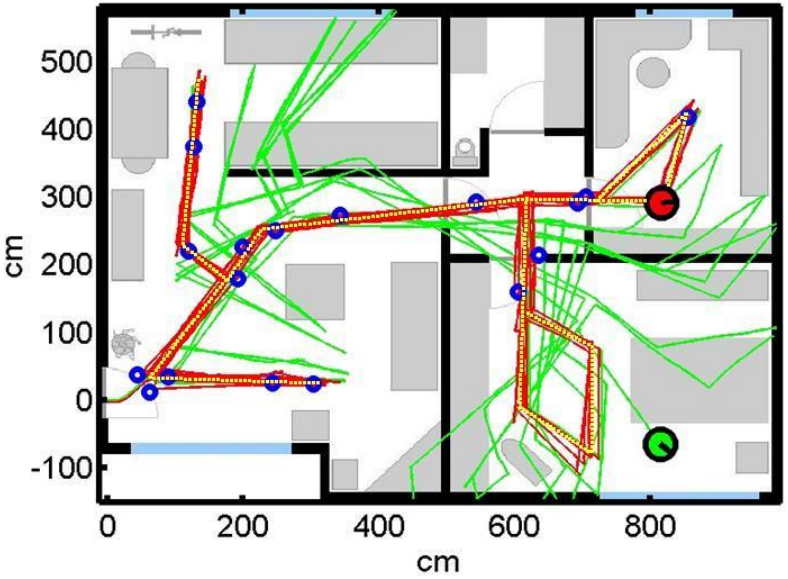


- vSLAM accuracy
  - 15 cm in position
  - 3 degrees in heading
- Robust in dynamic environments
- Kidnapping recovery

Niklas Karlson
Luis Goncalves
Enrico Di Bernardo
Jim Ostrowski
Phil Fong
Ethan Eade
Jason Meltzer
Dhiraj Goel
Vazgen Karapetyan
Paolo Pirjanian
…

vSLAM run on a PC

Karlsson et. al. ICRA 2005
Goncalves et. al. ICRA 2005

Challenge: Cost!

Goal: Enable intelligent navigation of consumer robotics products.

Rule of thumb in consumer electronics/toys:

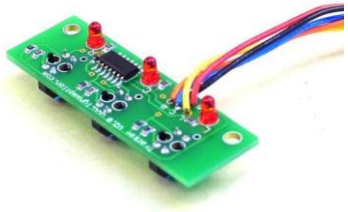
Production Cost: 20% – 30% retail price

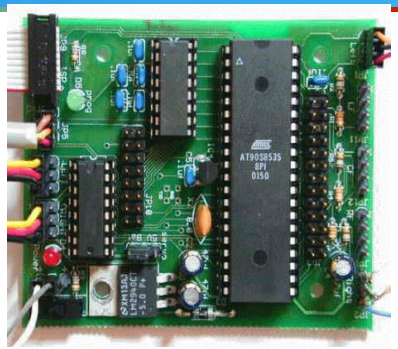
Example Retail Price: $300
Production Cost: $60-$90

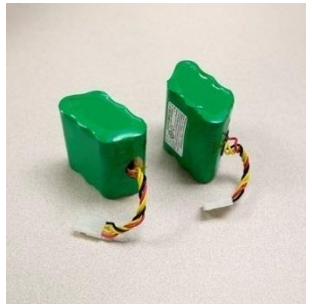
M**otors**, wheels, buttons, boards, CPU, memory, brushes, bins, plastic, sensors, **batteries**...

How much HW can you get for $60!!??

Challenge: Cost!







How much robot capability can you get for $60!!!????

Challenge: Efficient implementation

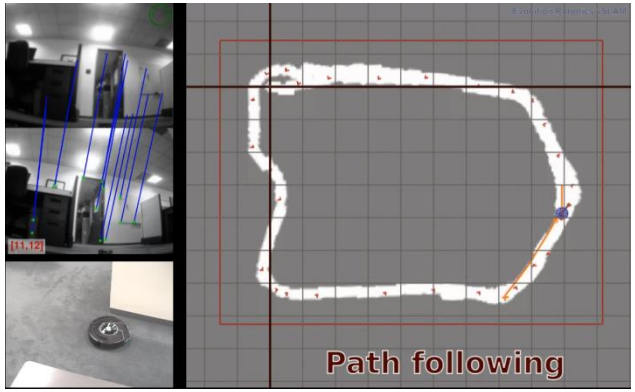
- Processor selection:
  - Image processing (integer) vs. optimization (floating point)
  - Image sensor interface
  - Clock rate
- Image sensor + lens subsystem:
  - Image size
  - FOV
- RAM:
  - Cost vs. space to map

Challenge: Efficient implementation

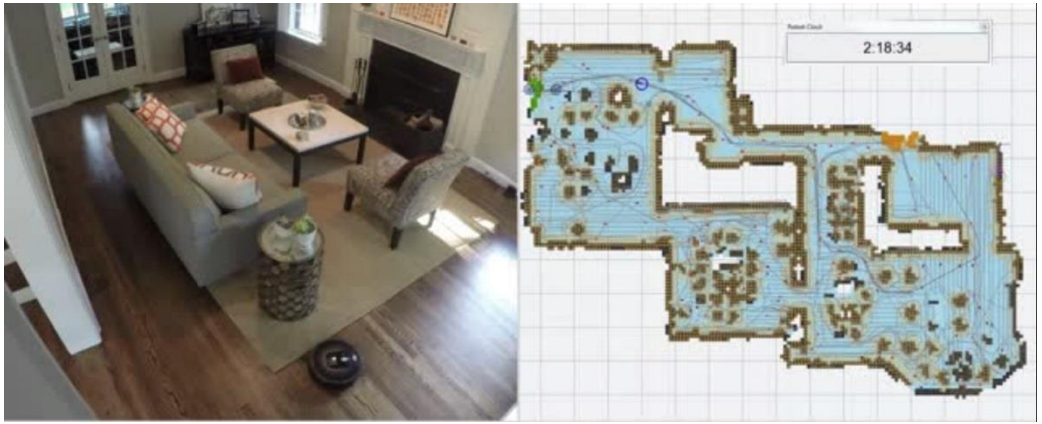
Computation profile, ARM9 @ 266 MHz Eade et. al. IROS 2010

95 ms	Detect and extract ~200 DoG/SIFT features
40 ms	Choose 3 candidate views
30-40 ms × 3	Perform view-local matching and pose estimation
40-60 ms (if recognition fails)	Attempt to create view
225-315 ms	Front end total

Challenge: From Technology to a Systematic Navigation System



vSLAM system works… on a demo…

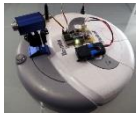


Need a systematic coverage system!
(Goel et. al. IROS 2013)

From Technology Demonstration to Technology Implementation in a System

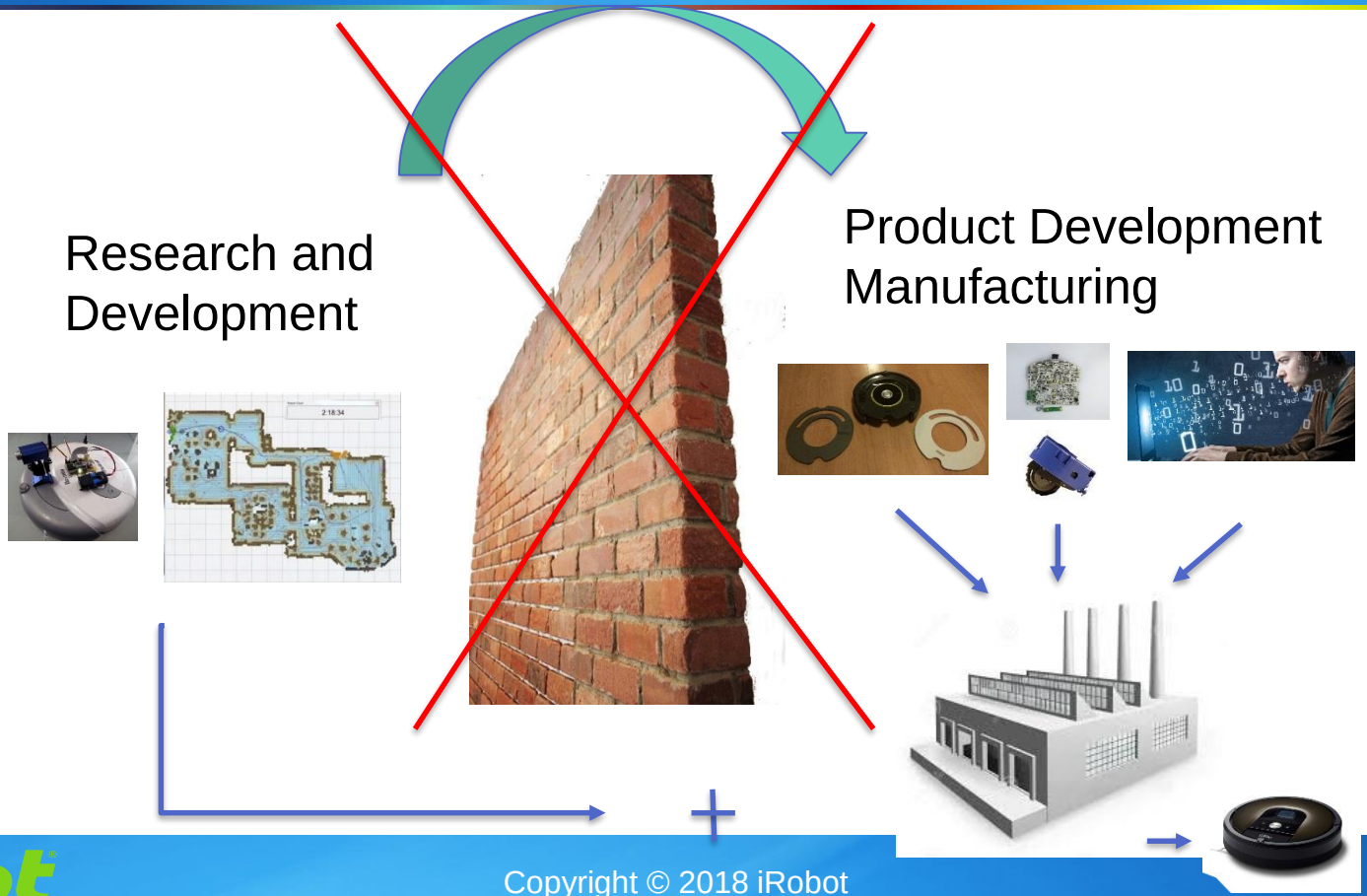
Challenge: Manufacturing

Research and Development



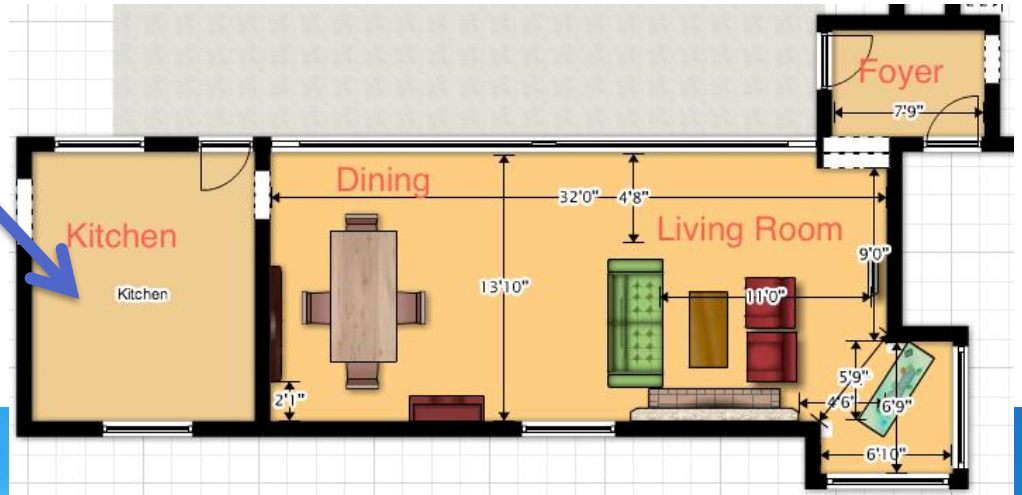
Product Development Manufacturing

Challenge: Manufacturing



Opportunity: Connected robots and the Smart Home

Future Challenge: Appearance Change (Long Term Mapping)



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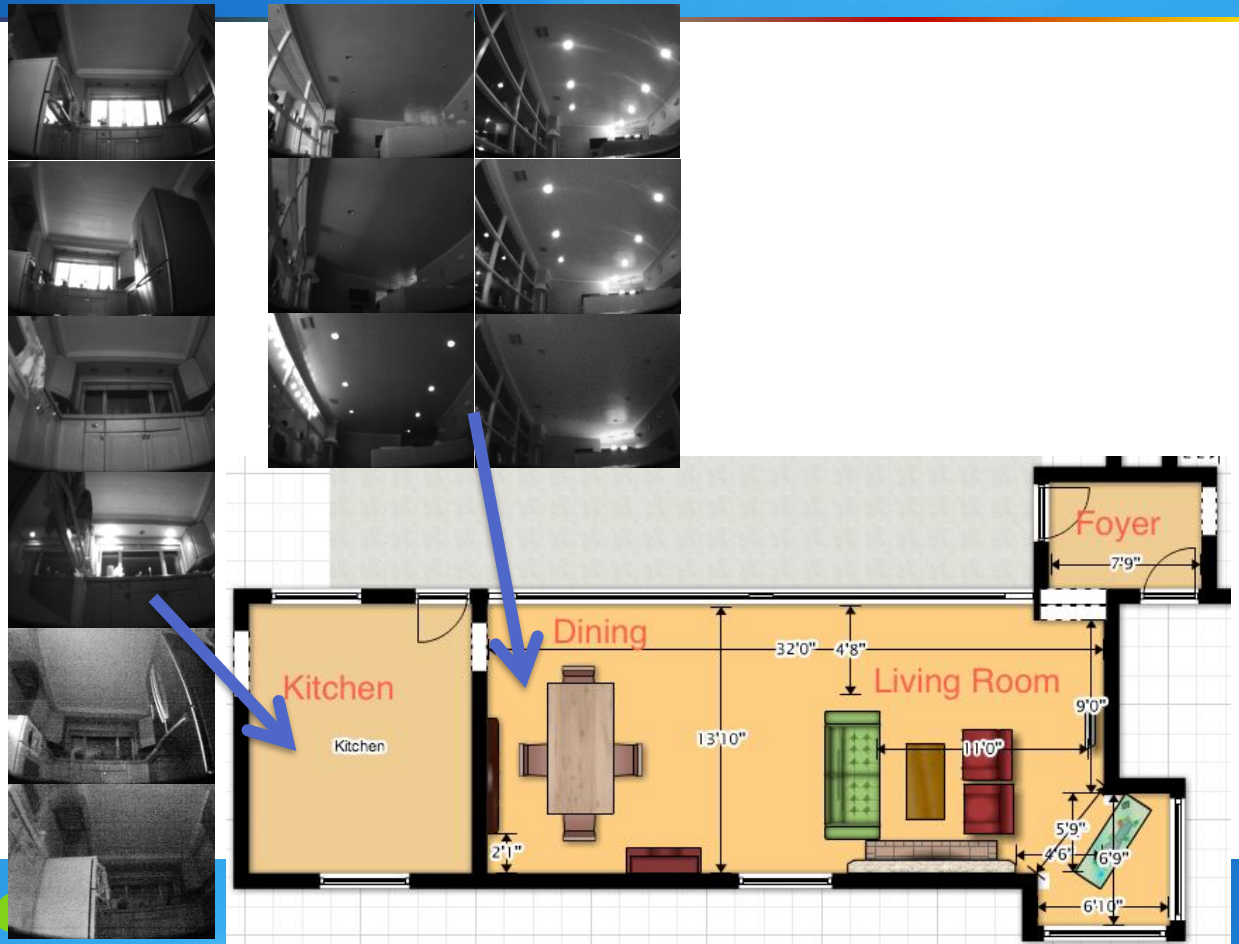

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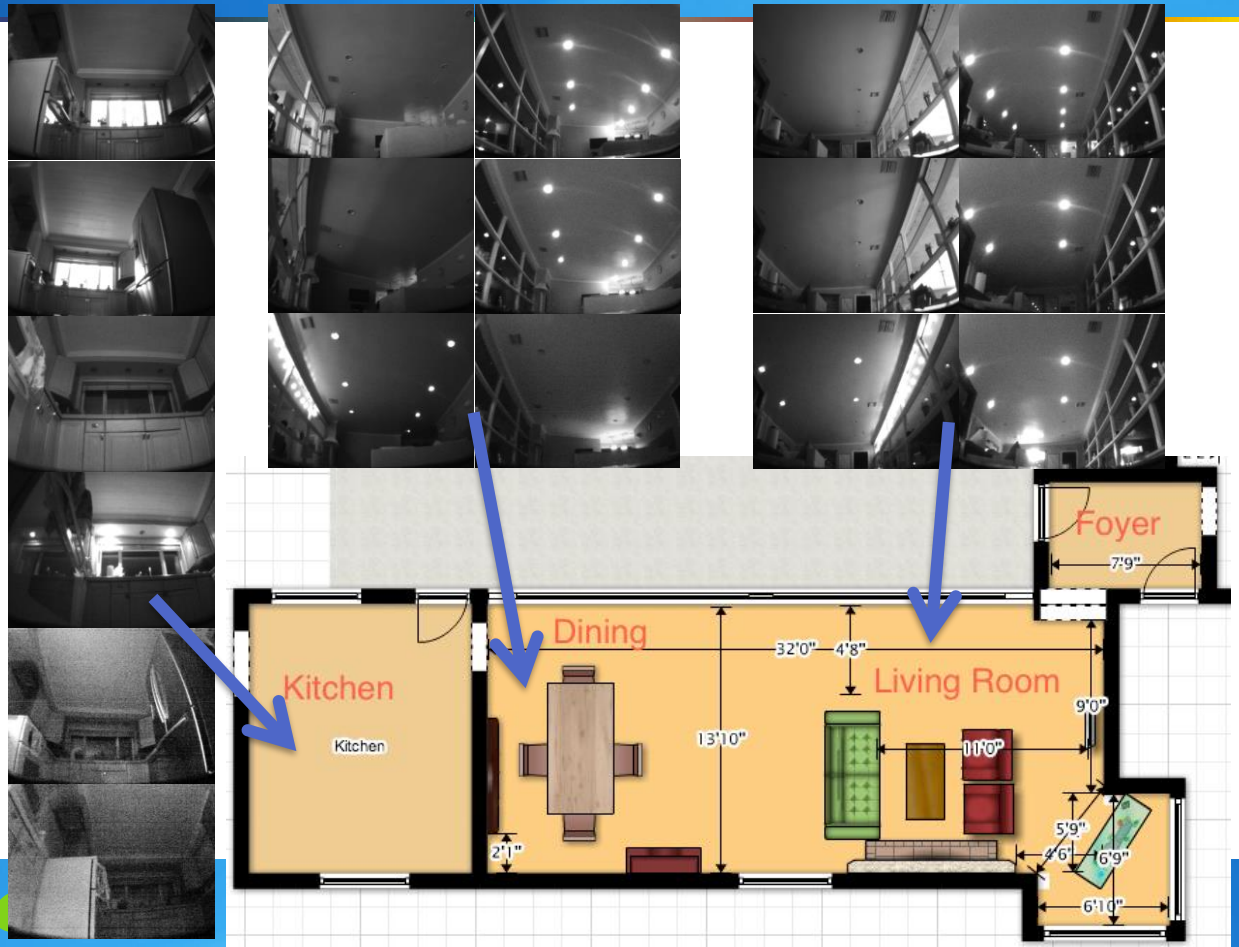

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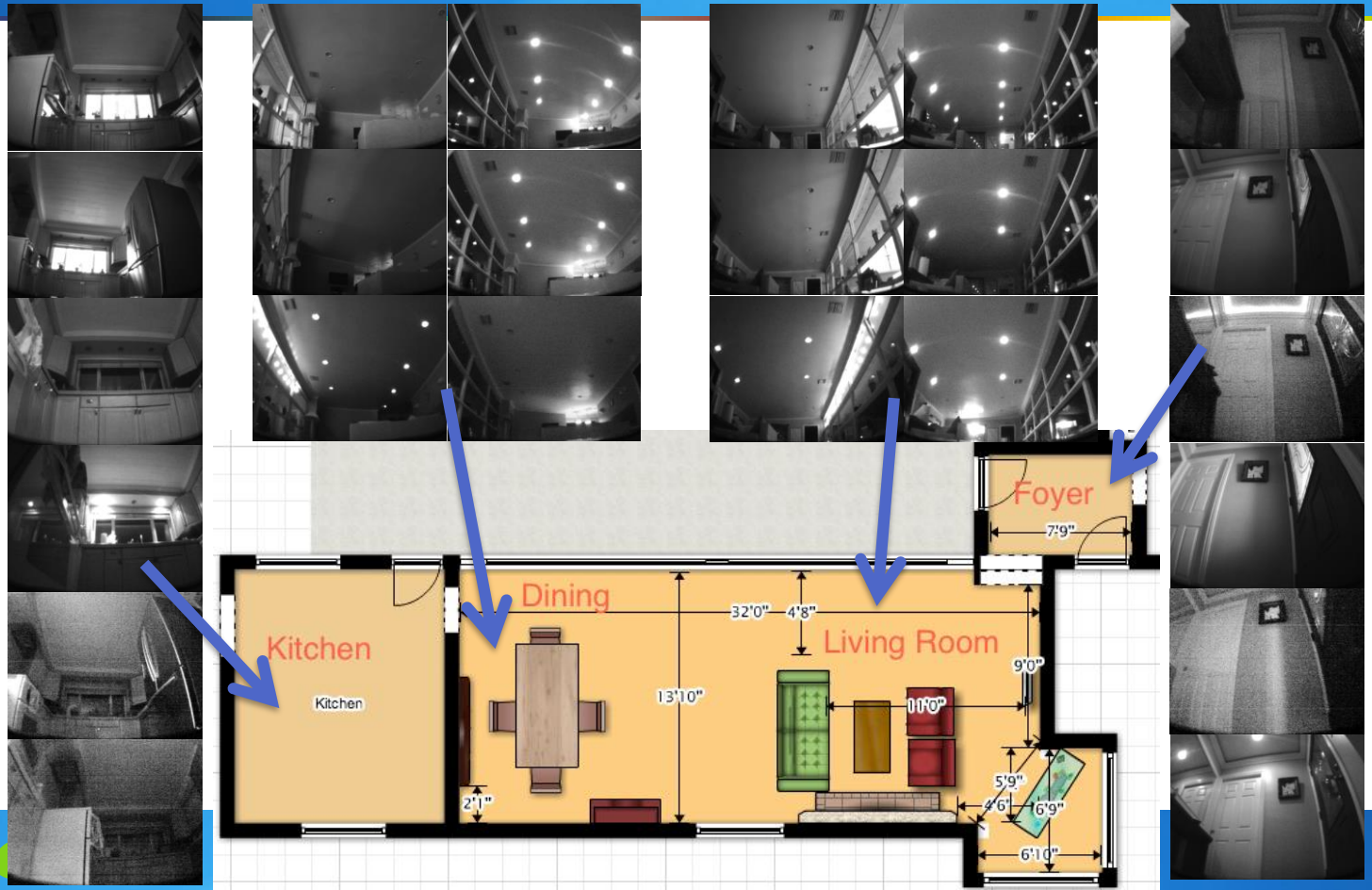

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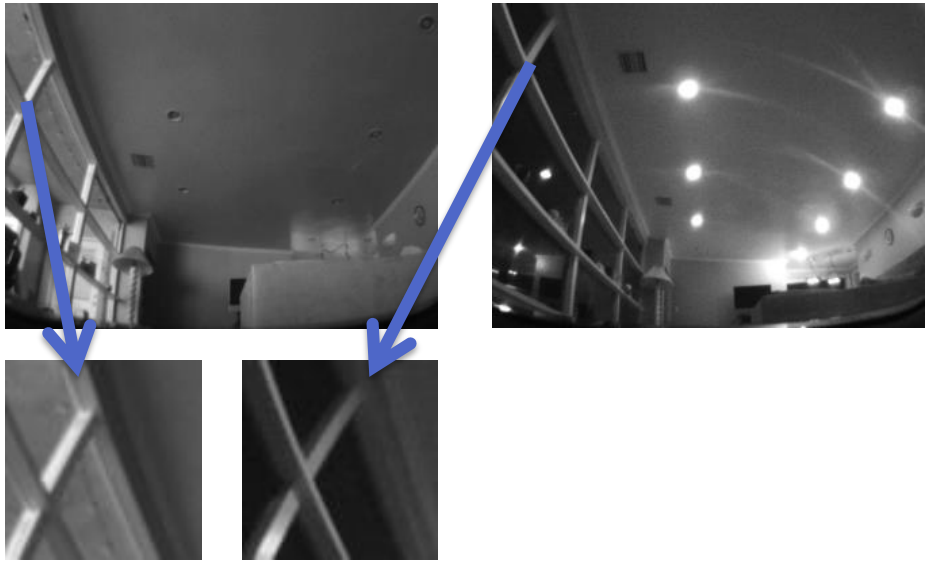

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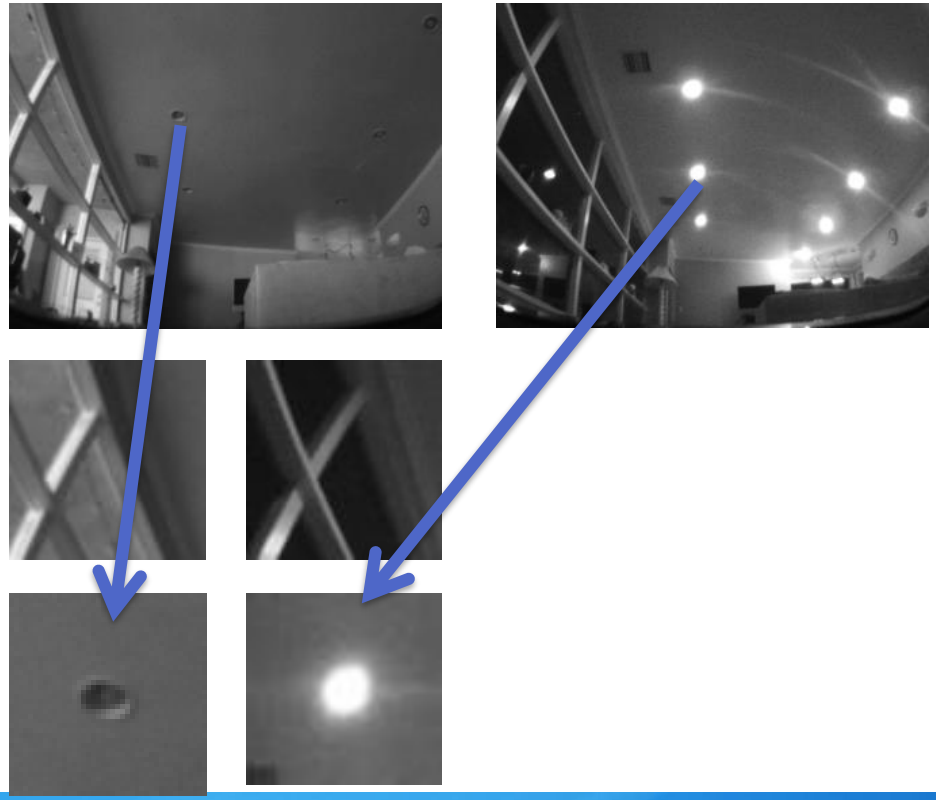

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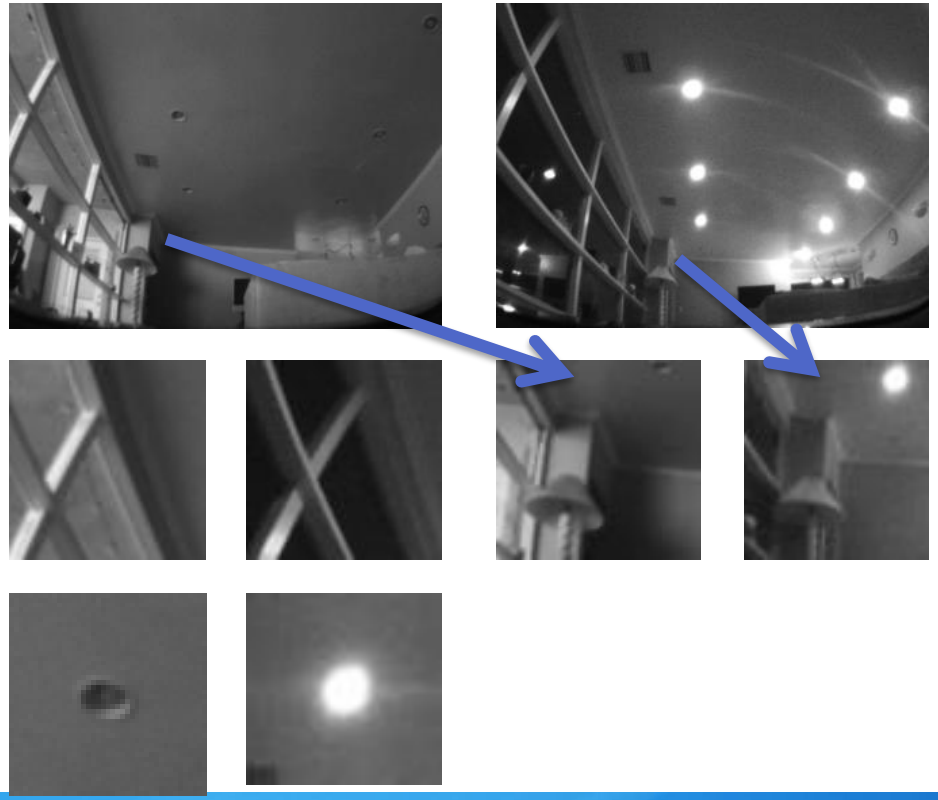

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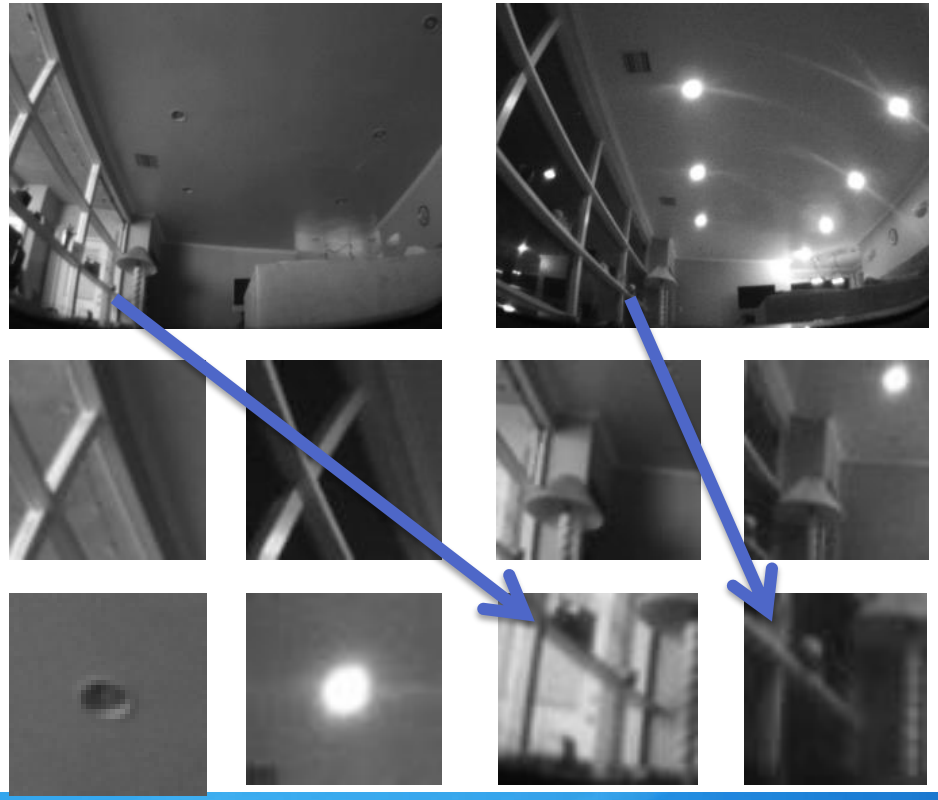
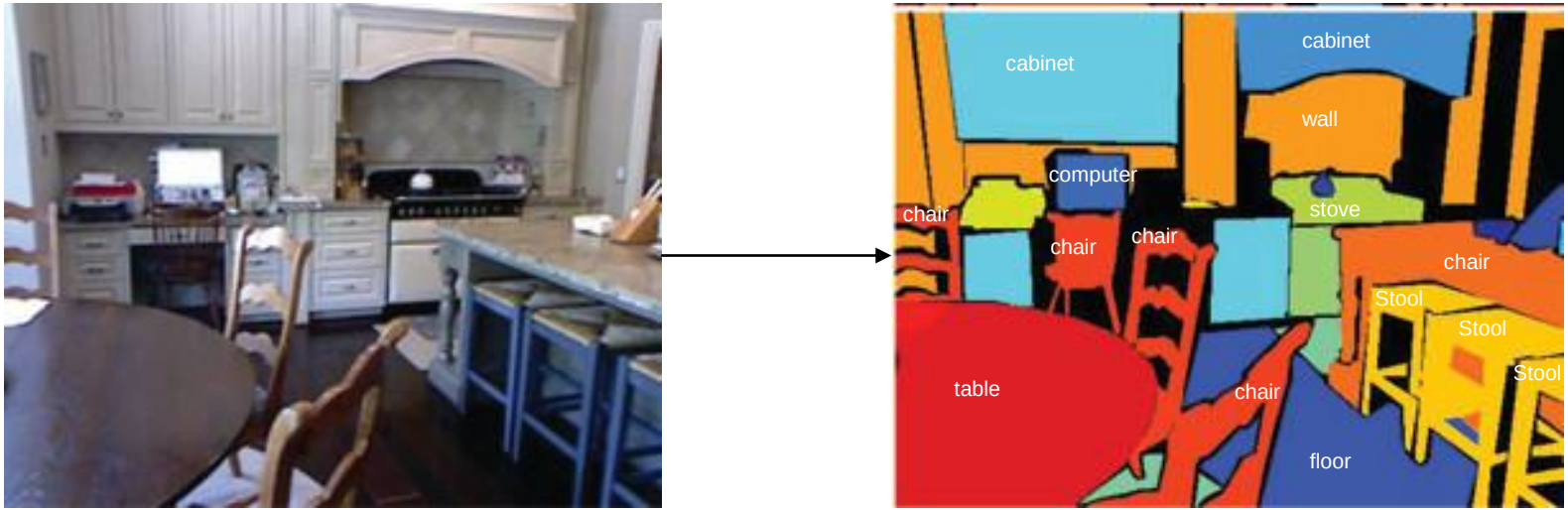
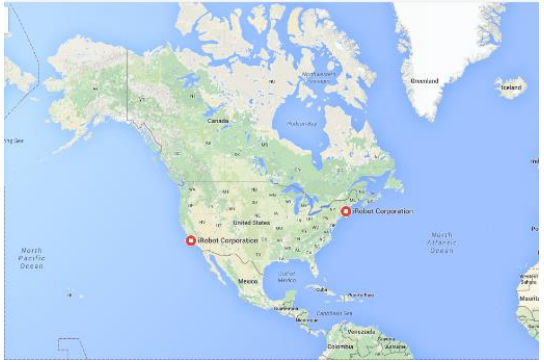


Future Challenge: Semantic Scene Understanding



We are Hiring!!!

- Looking for **Engineers** and **PhDs** interested in **Robotics** and **Vision**
- Pasadena, CA and Bedford, MA
- Contact: mmunich@irobot.com



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