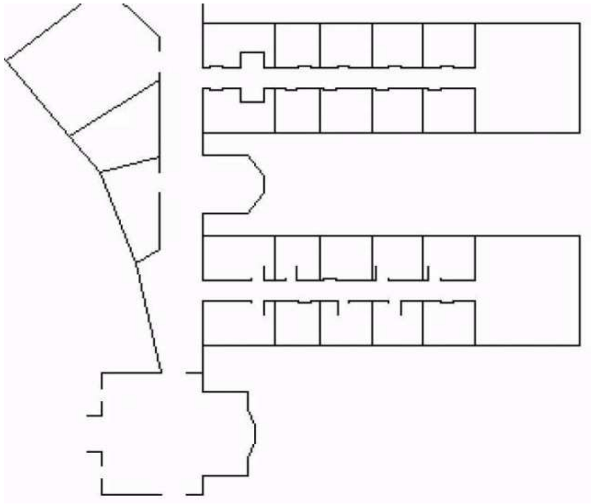
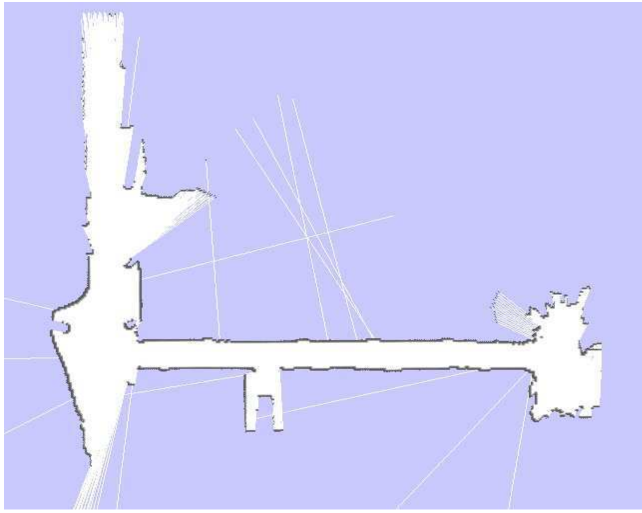
ECGR4161/5196 – Lecture 15 – August 7, 2012

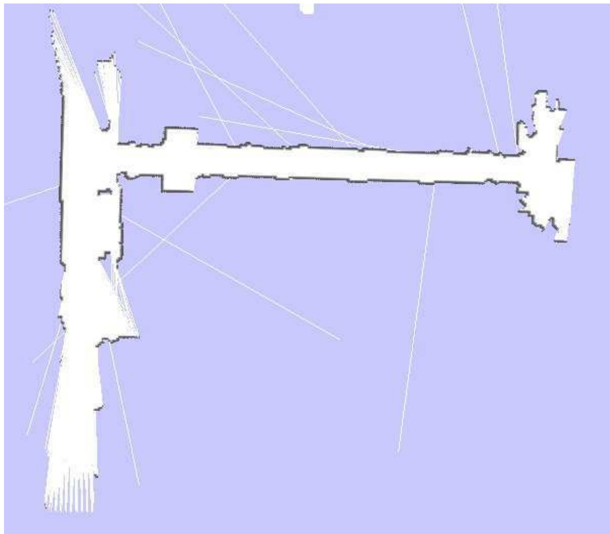
Today:

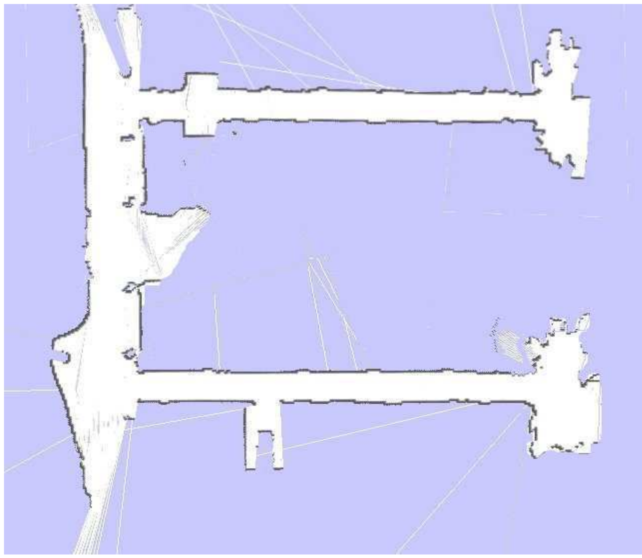
- Presentations – SLAM (recorded in two sessions, with a break in the middle).
- Quiz 13
- Discussion - Exam

Multi Robot SLAM and Map Merging



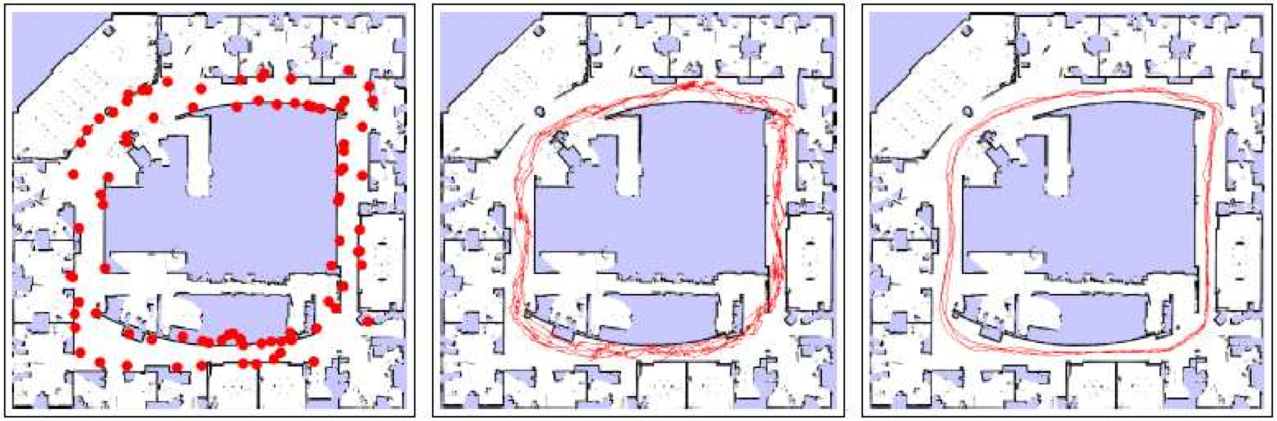






SLAM with RFID Technology

- Technique:
  - Laser range scanner and two RFID antennas.
  - Uses “map previously learned from laser range data.”
  - Estimate location of RFID tags.
  - Apply Monte Carlo localization to estimate location
- Benefits:
  - Reduces time required for localization of robot.
  - Accurately localize moving objects.
  - Low cost to implement.



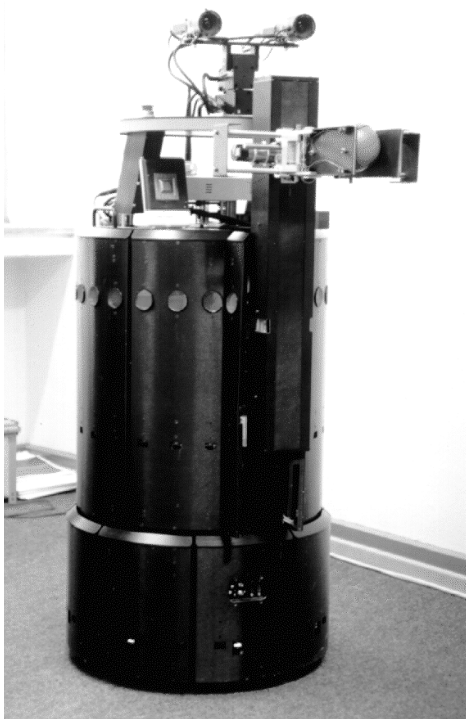
[1] Dirk Hahnel, Wolfram Burgard, Dieter Fox, Ken Fishkin, Matthai Philipose. “Mapping and Localization with RFID Technology.” Intel Research. December 2003. <http://edge.rit.edu/content/P12015/public/Referenca%20Materials/RFID%20READER%20SKYTEK%20M9%20Module/Mapping%20and%20Localization%20with%20RFIDs.pdf>

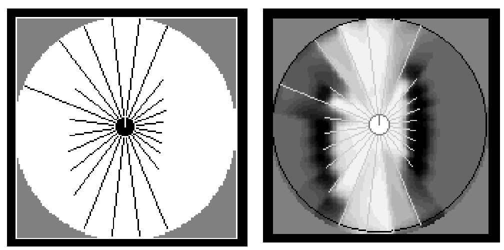
RHINO High-Speed Mapping and Navigation

Mapping
- Ø Grid-Based Maps
  - •Ultrasonic Sonar
  - •Stereo Camera
  - •Integration
- Ø Topological Maps

Localization
- Ø Wheel Encoders
- Ø Map Matching
- Ø Sonar Modeling
- Ø Maneuverability
- Ø Wall Orientation
- Ø Landmarks

Navigation
- •Global Planner
- •Collision Avoidance
- •Hard Constraints
- •Soft Constraints





(a) (b)

Figure 1: Bird's Eye View of
(a) Ultrasonic Sensor and
(b) Occupancy Mapping

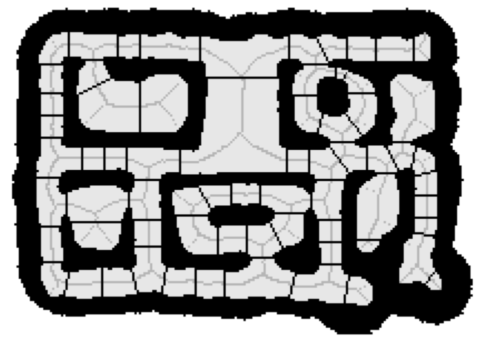


Figure 2: Example of Topological Mapping

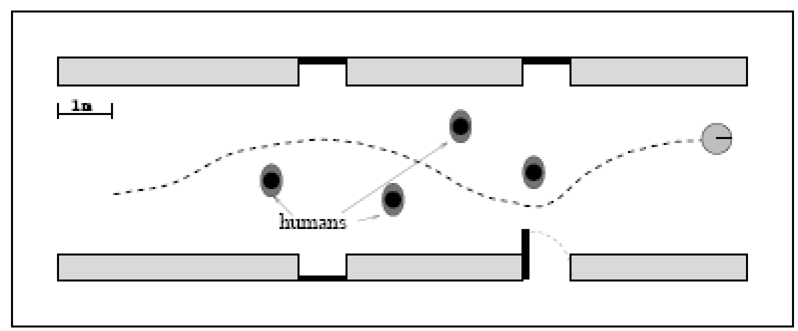


Figure 3: Example of Navigation

Reference

1. Thrun, Sebastian, et al. "Map Learning and High-Speed Navigation in RHINO." http://www-home.fh-konstanz.de/~bittel/robo/thrun_MapLearningAndNavigationInRhino.pdf (accessed July 7, 2012).

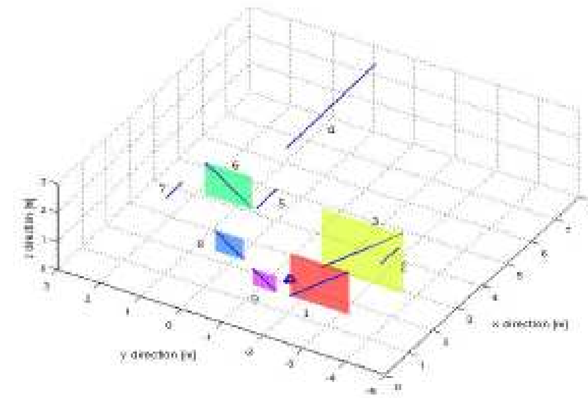
Stanley – Stanford University DARPA Challenge

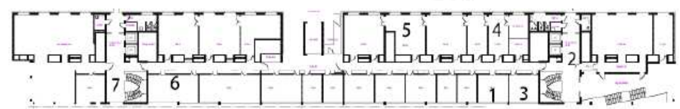
- Probabilistic Terrain Analysis Algorithm (Enabled High Speed Desert Driving).
- 5 LIDAR Units used for 3D Mapping.
- Inertial guidance system (3 gyroscopes and 3 accelerometers).
- GPS Waypoints.
- Color Video Camera.
- Output data from the 3D LIDAR was compressed into a 2D map divided into a grid of 30 x 30 cm cells.
- Cells are then designated as either: drivable, obstacle, or unknown.
- Software algorithm compares samples of video deemed to be "drivable" by the LIDAR map and uses this "knowledge" to determine the "drivable surface in the remainder of the video.

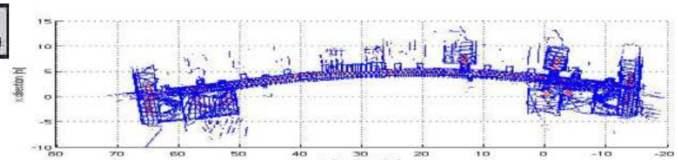
A Lightweight SLAM Algorithm for Indoor Environment

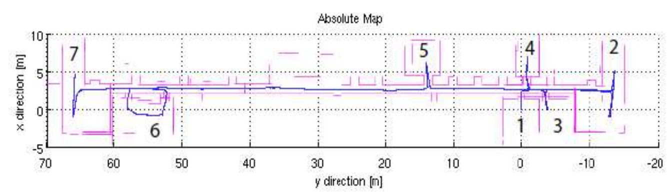
Assumptions: Orthogonality

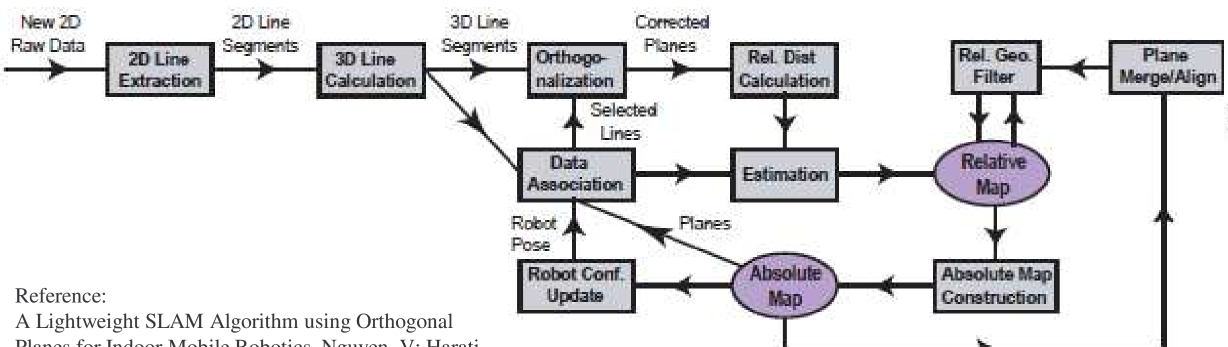
- Most indoor major structures can be represented by sets of parallel or perpendicular lines or planes. Only map planes verifying the Orthogonality constraint.
- Removes estimation of the robot's 3D orientation
- Reduces mapping of the orthogonal planes to a linear estimation with one parameter per plane
- Divides planes into three groups: X-Planes, Y-Planes and Z-Planes
- Within a group, the orientation of the planes is known. Only need to estimate the distance from the origin to the plane.
- Pros: Simple, fast and reduced processing power
- Cons: Orthogonality assumption, does not work well in outdoor environment or with complex surfaces











Reference:
A Lightweight SLAM Algorithm using Orthogonal Planes for Indoor Mobile Robotics, Nguyen, V; Harati, A; Siegwart, R. Autonomous Systems Laboratory. Swiss Federal Institute of Technology

Slam – Rapid 3D Mapping

SLAM is the problem of building a map of an unknown environment while at the same time navigating the environment, using the unfinished map

3D maps give you an overhead view of a location, like a traditional paper map. 3D maps give you a schematic, angled view of the route ahead of you, as if seen from the air above you.

http://www.saabgroup.com/Global/Documents%20and%20Images/Campaigns/Rapid%203D%20Mapping/Hoover_Dam_Rapid_3D_Mapping_small.jpg

3 Steps to Superior Awareness

1. Fly
2. Generate
3. View

http://www.saabgroup.com/Global/Documents%20and%20Images/Campaigns/Rapid%203D%20Mapping/SanFransisco_small.jpg

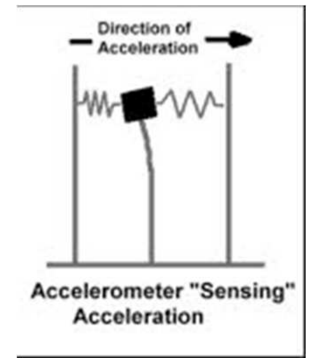
3D Mapping Applications Videos

http://www.youtube.com/watch?v=s6odzWGqi70&feature=player_embedded

http://www.youtube.com/watch?v=CNemPTHOKWg&feature=player_embedded

IMU and Lidar

1. IMU – Inertial Measurement Unit
   - 3 Gyroscopes
     - Measures the rotation around/about an axis.(Pitch, Roll, Yaw)
       - The rate of change of the angle.
   - 3 Accelerometers
     - Measure the acceleration indirectly through a force that is applied to one of its walls/springs.



2. LIDAR – Light Detecting and Ranging
   - Emits laser light and detects the light reflected back by objects. Based on the time to return distance can be determined.
   - Can scan up to 360 degrees continuously.

Videos:
http://youtu.be/cquvA_IpEsA - gyro
http://youtu.be/sieBqVxTz2c - IMU/LIDAR

References:
Livesay, Ed. "Accelerometer spring model." Drawing. *The Traffic Accident Reconstruction Origin* 6 Aug. 2012. <http://tarorigin.com.>
Kieff. From Wikimedia Commons. <http://en.wikipedia.org/wiki/File:Gyroscope_precession.gif.>http://absoluteastronomy.com
Tandy, Michael. From Wikimedia Commons.<http://upload.wikimedia.org/wikipedia/commons/c/c0/LIDAR-scanned-SICK-LMS-animation.gif.>
Gadget Gangster. "Accelerometer & Gyro Tutorial." Instructables. 6 Aug. 2012. <http://www.instructables.com.>

iRSP SLAM 3D Execution

This PowerPoint is about the demonstration of 3D SLAM capability of a robot using iRSP(intelligent Robot Software Platform). The map data for the demonstration is updated from the calculated position of the robot using simulated onboard range sensors.

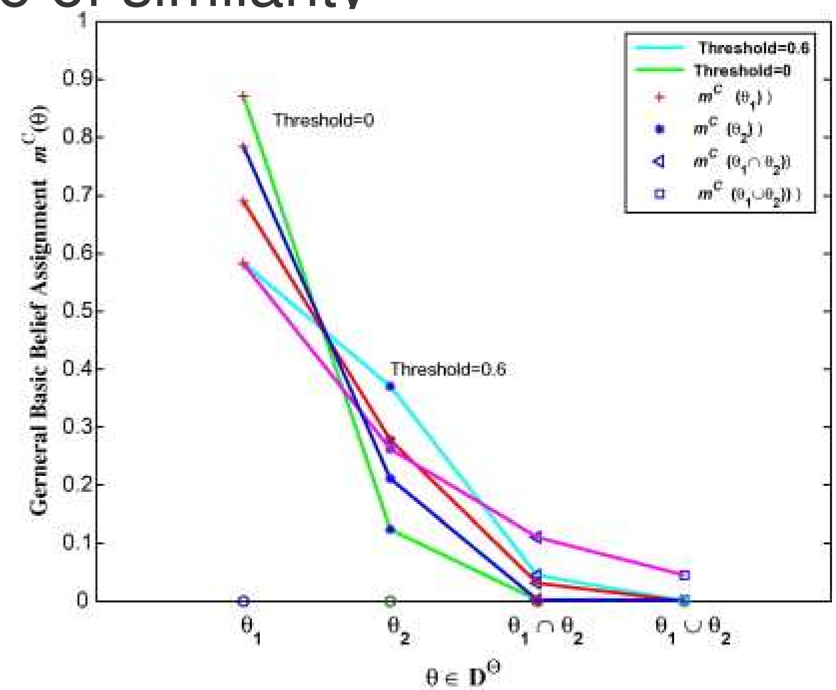
Simulated robot:

- Motor: 2 DC Motors
- Sensors:
  - 1D range sensor: 8 Sonar sensors
  - 3D range sensor: Xtion-Pro
  - Direction sensor: Absolute Compass Sensor

Video: http://www.youtube.com/watch?v=AByETaadky4

Intelligent Technologies for SLAM

- Spiking neural network human localization
- Mapping in unknown locations
- Neural gas
- Evidence supporting measure of similarity
- Unified fusion approach



http://www.sciencedirect.com/science/article/pii/S002002551000530X

Atlas – mapping of large-scale environments

Algorithm: Dijkstra Shortest Path

- Starts at a source vertex
- Creates a tree to other vertices
  - Ordered by distance

Method of Storage:

- Local Region SLAM
- Map-frame hypotheses
  - Juvenile
  - Mature
  - Dominant
  - Retired

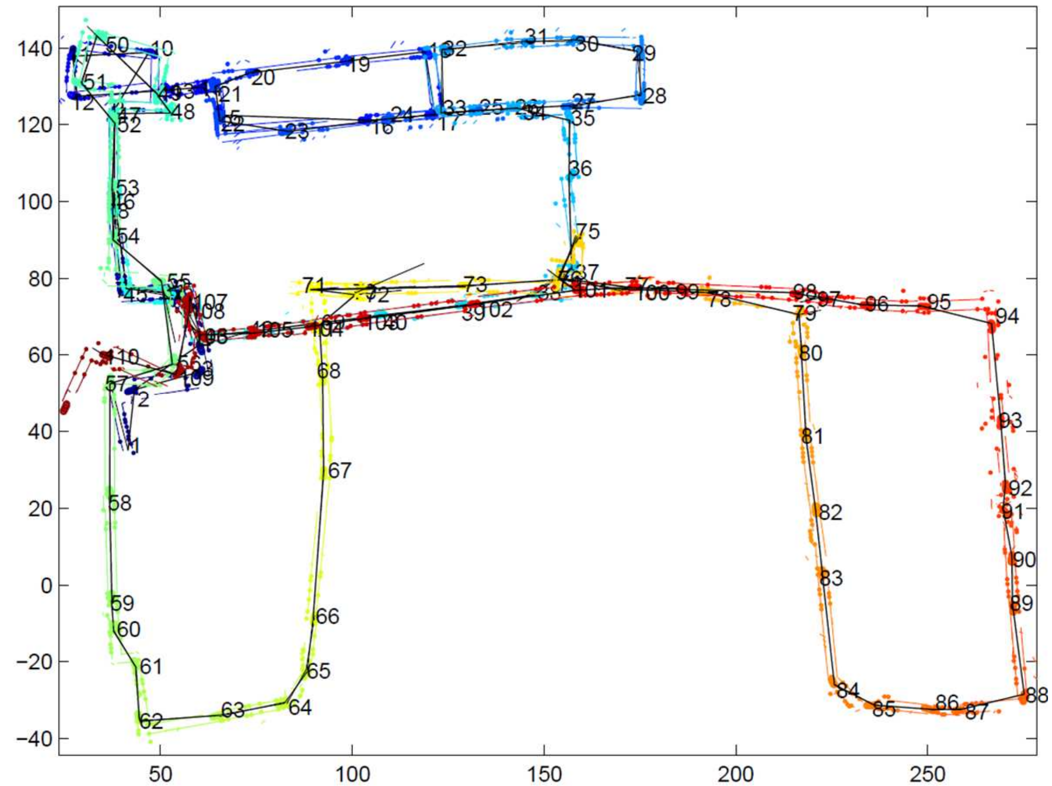
Visualization:

- Global Optimized Map
- Atlas graph

Bosse, Newman, Leonard, et al. International Conference on Robotics and Automation, TBipei, Taiwan, September 2003, pp. 1899-1906

Results:

- 101 map-frames
  - 15 mapped line segments



MITRE

-Improving design on UGA's and UAV's

-Now 2D Frames of video

-Moving to 3D Virtual Mapping on the move

-For use in Military situations

- -city streets
- -building interiors

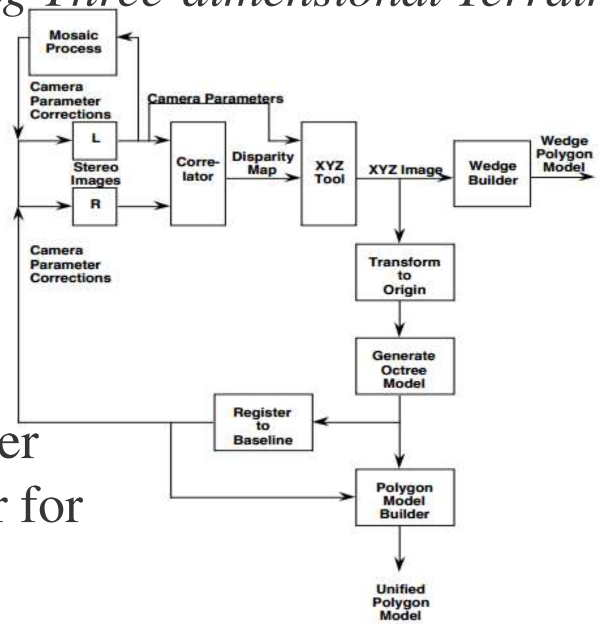
-Uses stereo vision and flash LIDAR

http://www.mitre.org/news/digest/advanced_research/06_08/a_situation.html

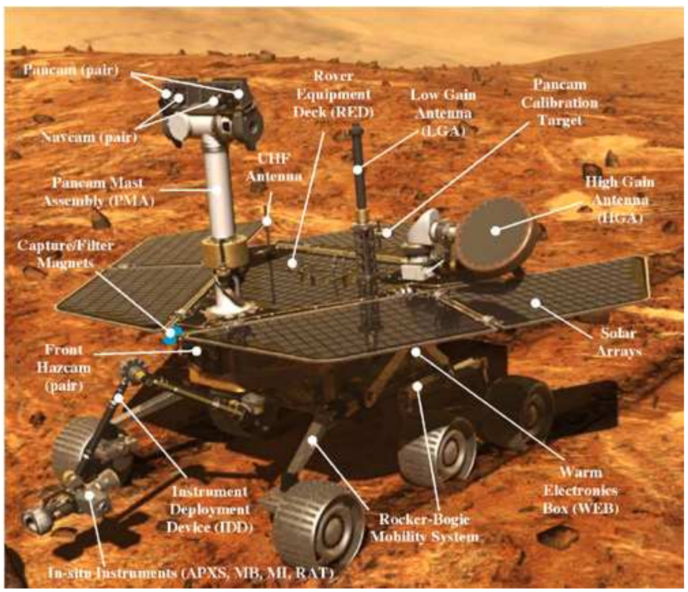
Mars Rover – SUMMITT/Waypoint and Frames

System for Unifying Multi-resolution Models and Integrating Three-dimensional Terrains

- Utilizes 3 sets of fixed cameras with each in stereo
- Each camera produces a disparity map that identifies matching features in each image
- Computes the range to a pixel in one image to its matching pixel in the other image
- Used to create XYZ point cloud model[2]



SUMMITT Flow Diagram [1]



MER [2]

- IMU and motor encoder
- Rover Motion Counter for vehicle moves
- RMC resets when a site frame is made
- Site frame created when the total localization error is at a point that targeting accuracy suffers
- Many site frames can be combined in order to form a comprehensive operational map[3]

[1]http://wwwdial.jpl.nasa.gov/public_html/john/papers/SMC_Hawaii/SMCpaper.pdf
[2]http://marsrover.nasa.gov/mission/spacecraft_surface_rover.html
[3]http://wwwrobotics.jpl.nasa.gov/publications/Mark_Powell/IEEE_IRI_06_Targeting.pdf

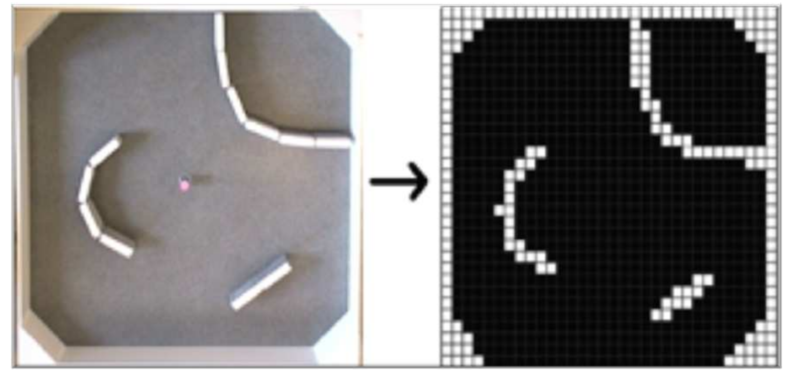
Online SLAM in Dynamic Environments

- Uses Kalman Filter to estimate robot position and landmarks
- Uses 3 occupancy grids static, dynamic, and location
- Static map is created first then dynamic
- Dynamic objects must move at least once
- Third map used for location of landmarks for localization

Source:http://cres.usc.edu/pubdb_html/files_upload/378.pdf

Occupancy Grid Mapping (OGM)

- Occupancy grids were first popularized by *Hans Moravec* and *Alberto Elfes* at CMU, Pittsburgh, PA.
- Maps the environment in a 2D array.
- The Robot knows its location at all times.
- Each cell holds a probability value that the cell is occupied.
  - **Bayes Law**: $p(A \mid B) = \frac{p(B \mid A) * p(A)}{p(B)}$
- Typical sensors: Sonar, Laser, IR, Bump, etc.



http://www.ikaros-project.org/articles/2008/gridmaps/

Map-Making Robots

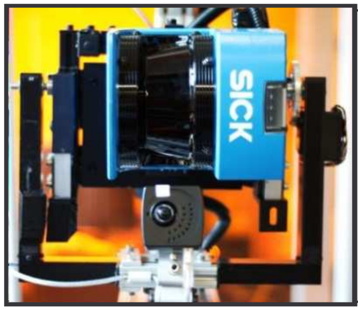
http://www.ikaros-project.org/articles/2008/gridmaps/

E-puck robot (www.e-puck.org)

R.O.A.M.S.

R.O.A.M.S. is an acronym for **R**emotely **O**perated and **A**utonomous **M**apping **S**ystem

- ROAMS uses a unique 3-axis rotary actuator to enable the LIDAR to be used both as 2D (Obstacle avoidance) and 3D (Mapping)



[1]

- Students at Stevens have developed their own software based Operator Control Unit (OCU) so anyone from any network connected PC can control the ROAMS robot

ROAMS is only capable of acquiring 3D LIDAR scans while it is stationary

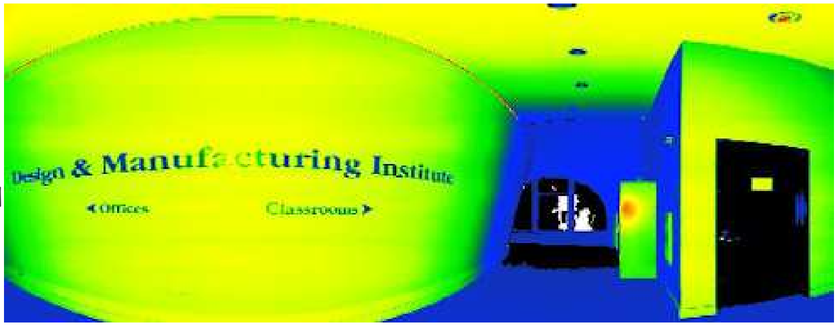

[2]

- Multiple Path Planning sensors are used such as IR, GPS, and real time video

Video registration is used for texturing of scan points to provide photo realistic 3D maps

What will this mean for the Future?...

[4]



[5]

- Ergonomically designed to fit into most commercial office/building spaces

- Reflection intensity panorama produced by ROAMS scanner. In complete darkness.

References:
[1] (2011). *Remotely Operated and Autonomous Mapping System (ROAMS)* (2011). [Web Photo]. Retrieved from http://www.ballos.com/tepraconnect_interface/TePRA09/335.pdf/
[2] (2012). *Remotely Operated Autonomous Mapping System*: (2012). [Web Photo]. Retrieved from http://www.dmi.stevens-tech.edu/index.php /
[3] (2012). *Stevens (Stevens IOT LOGO)*(2012). [Web Photo]. Retrieved from http://www.stevens.edu/sit/
[4] (2011). *The World OF Matrix* (2011). [Web Photo]. Retrieved from http://blogs.cornell.edu/newmedia11jz387/2011/04/13/the-world-of-matrix/
[5] (2011) *Reflection intensity panorama produced by ROAMS scanner. In complete darkness.*(2011). [Web Photo]. Retrieved from http://www.dmi.stevens-tech.edu/index.php

SLAM using DIDSON-Acoustic Imaging Sonar

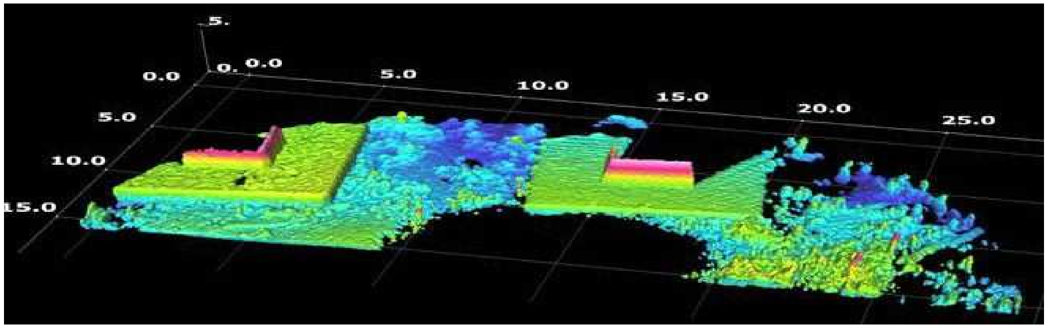


Figure 1: 3D Ocean Floor Mapping [2]

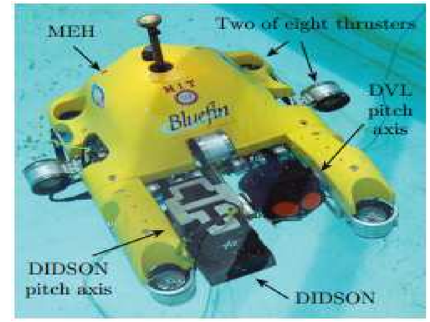


Figure 2: HAUV with DIDSON [1]

Applications: ship hull and infrastructure inspection, marine structure inspection, under water survey and navigational based mapping

Sensors:

•**DVL (Doppler Velocity Log)** – navigation "underwater GPS", under water current tracking

- **Depth Sensor**
- **DIDSON 1.8MHz (Dual frequency Identification Sonar)** – uses sound waves to map and create an image of the ocean floor or the hull of a ship

Procedure:

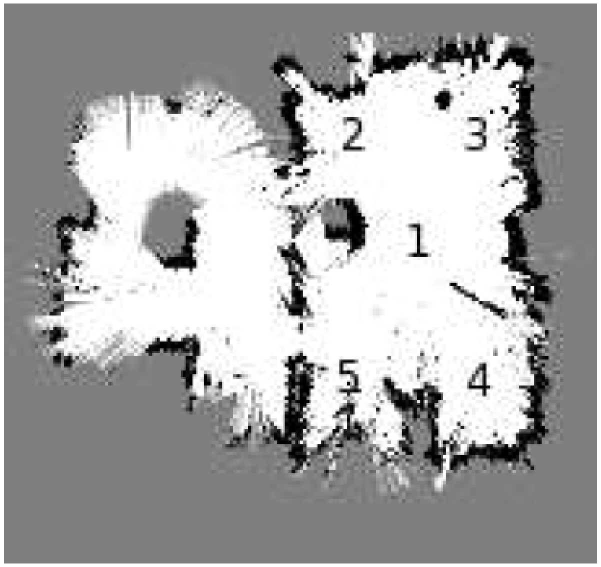
- SLAM uses the data and statistics acquired from the on board sensors and DIDSON
- Sensors and DIDSON combine to create 2D and 3D maps of unknown objects/environments
- Improves accuracy of existing maps by localization and not relying on external infrastructure

Works Cited:

[1] Publication: "SLAM for Ship Hull Inspection using ESEIF" Massachusetts Institute of Technology, Walter, M.; Franz, H.; Leonard, J. (pages 1-8). http://people.csail.mit.edu/mwalter/papers/walter08a.pdf
[2] http://www.oceanmarineinc.com/sonar-systems/didson-software_P1019

Real-Time Stereo Visual SLAM

-What is simultaneous localization and mapping?

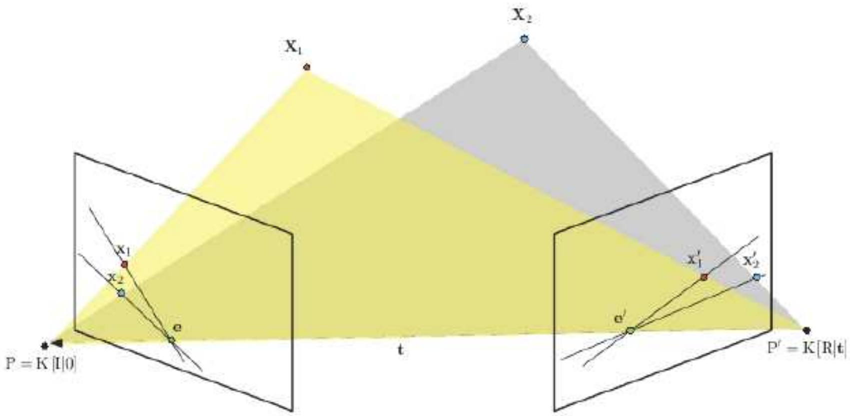


-Most common sensors used for SLAM:
- -Laser ranging
- -Sonar
- -Inertial
- -Vision

Why are vision based sensors superior in a SLAM application?

Why stereo visual slam?

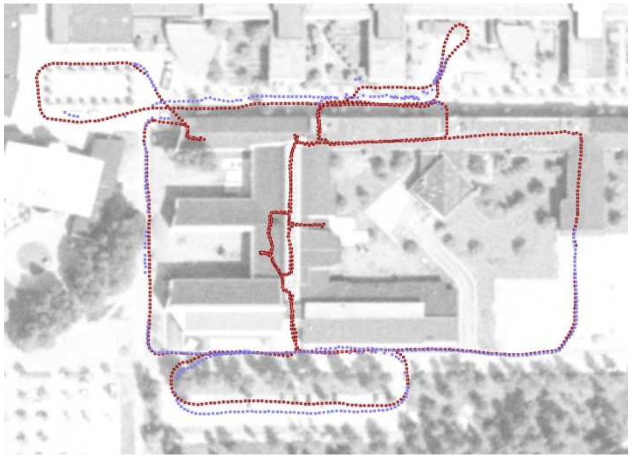
Processing stereo SLAM:
- -images are captured using two cameras
- -converted to gray scale
- -scale spaces are created
- -correspondences are estimated using camera projection matrixes
  - -based off of initial calibration of cameras

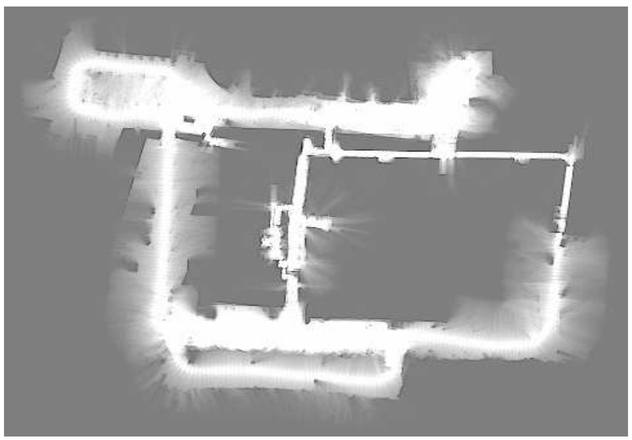


P. Elinas, J. Little, R. , " Stereo vision SLAM: Near real-time learning of 3D point-landmark and 2D occupancy-grid maps using particle filters.," *University of British Columbia*

S. Thomas, "Real-time Stereo Visual SLAM," *Heriot-Watt University*

Mini-SLAM





- Hardware uses odometry and an omnidirectional camera.
- The camera supplies information used by SLAM algorithm.
  - More consistent maps created.
- Map estimations done by a linear time SLAM algorithm using graph representation.
  - Scales better due to not estimating landmark locations
  - Instead, object similarity used to determine landmark locations.
- Uses Multilevel Relaxation algorithm to determine that objects in images are the same.

“Mini-SLAM: Minimalistic Visual SLAM in Large-Scale Environments Based on a New Interpretation of Image Similarity.” Henric Andreasson, Tom Duckett, and Achim Lilienthal. <http://aass.oru.se/~han/papers/icra07andreasson.pdf>.

Particle Filter Based SLAM

- 2 reference frames
  - Robots
    - •Sensor ex: Odometer
  - World
    - •Sensor ex: laser rangefinder

Example Algorithm Psuedo Code

For Each line in logfile

If logfile line = odometer entry

-predict particle

If logfile line = laser rangefinder

For Each particle in particle set

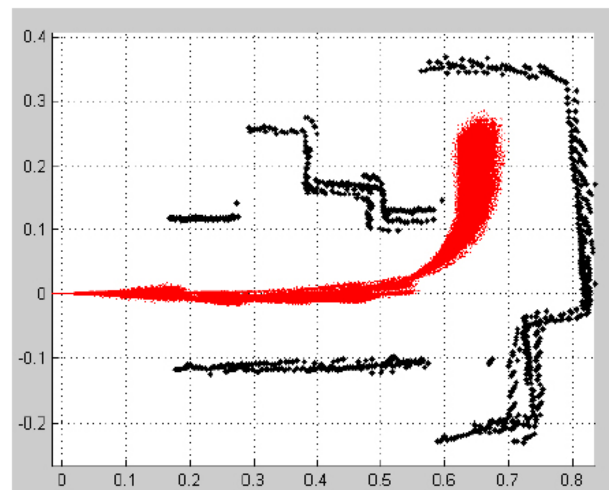
-Extract corners & decide if new

if corner has been seen previously

compute new weight of corner

else

add new corner to particles

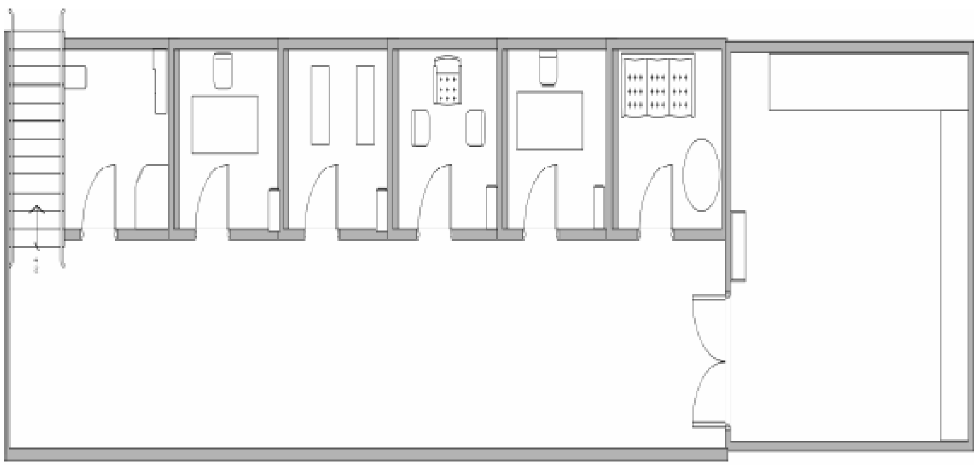


Top: Course Bottom: Particle filter calculations[1]

[1] Luciano, S. Xavier. P. Exercise 4: Particle Filter Based Slam, 2008, Autonomous Systems Lab Swiss Federal Institute of Technology, Zurich

SLAM Robot: Laser Range Finder and Monocular Vision

- Harbin Institute of Technology
- Autonomous Robot
- Weighted least square fitting
- Canny Operator
- Kalman filtering (KF): localization & grid map building simultaneously



Experiment Robot:
•CMOS camera and optic mica
•Radio Ethernet

Reference: SLAM for Mobile Robots Using Laser Range Finder an d Monocular Vision, Sheng, F.; Hui-ying, L.; Lu-fang, G.; Yu-xian, G.; 2007 IEEE