ECGR4161/5196 – July 28, 2011

Read Chapter 5

Exam 2 contents:

- Labs 0, 1, 2, 3, 4, 6
- Homework 1, 2, 3, 4, 5
- Book Chapters 1, 2, 3, 4, 5
- All class notes

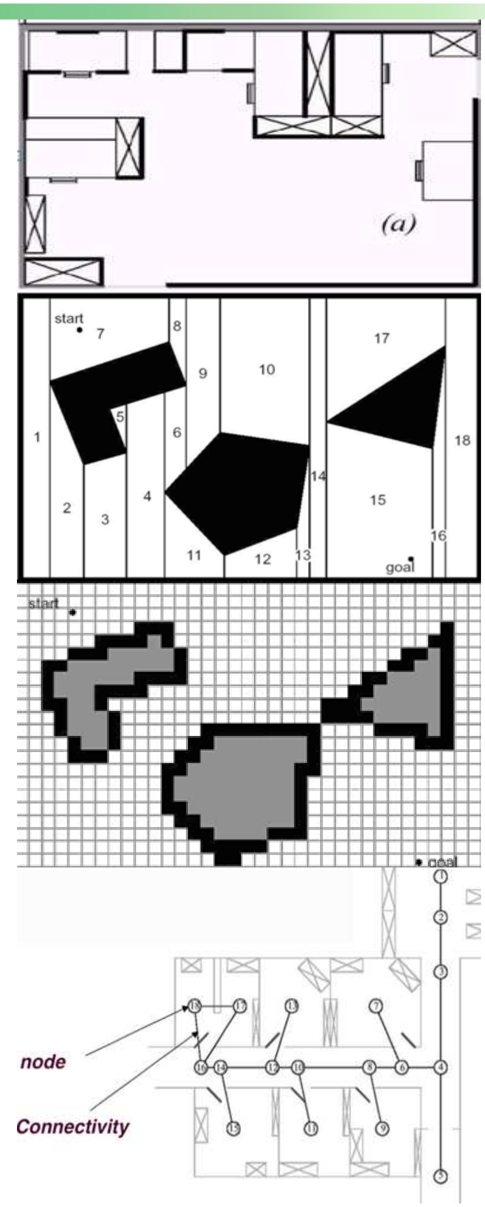
Varieties of Map Representation

Types of representation:

1. Continuous
   - continuous valued coordinate space (closed- world assumption, total area of map proportional to object density)
   - high accuracy and fidelity
   - computational costly (alleviated with abstraction)
2. Decomposition
   - breaking down continuous representation mapping to extract the most pertinent information
   - loss of fidelity and most likely movement precision
   - computational superiority along with better reasoning and planning

Forms of Decomposition:

1. Opportunistic – nodes of free space
2. Fixed – discrete approximation (Occupancy Grid)
3. Topological – connectivity of nodes through arcs



References:

Siegwart, Roland. Autonomous Mobile Robots. Cambridge, Massachusetts. The MIT Press, 2011, 284-296.

Waypoint Mapping – A Topological System

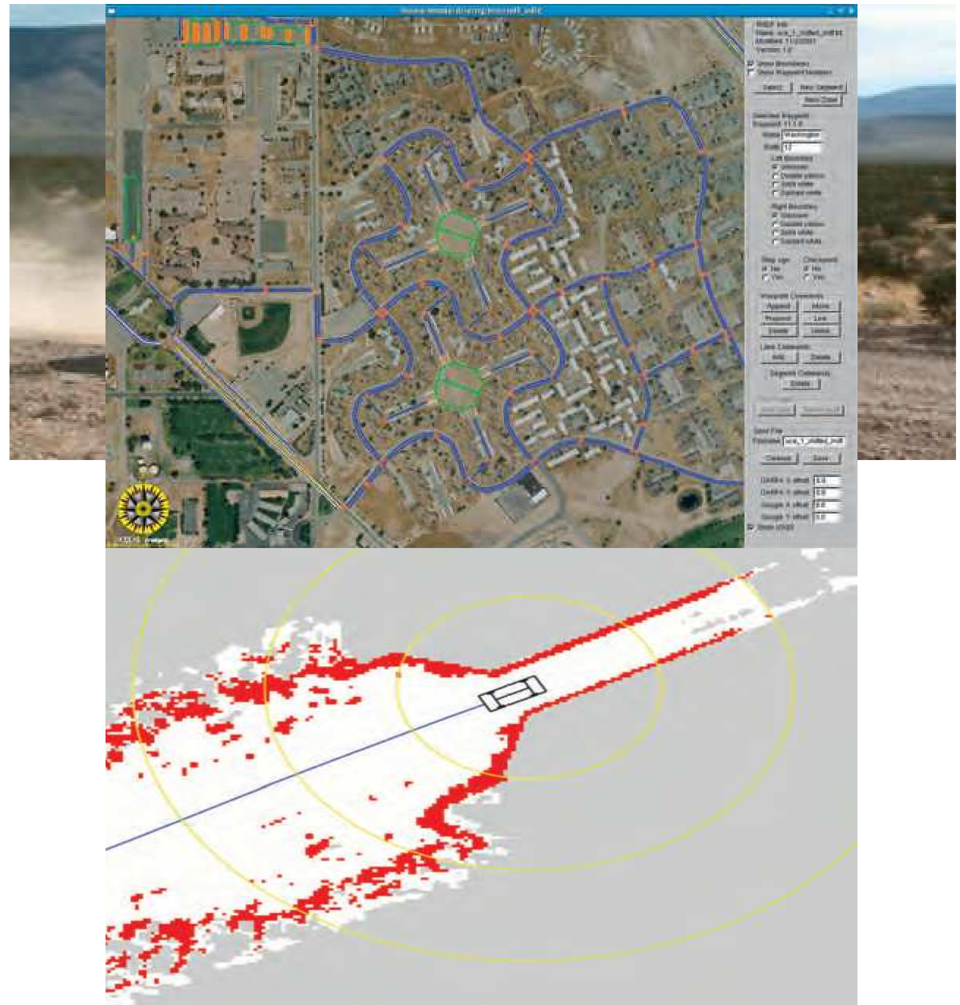
- **Waypoint mapping is a high-level mapping strategy to ensure that a mobile robot arrives at its ultimate goal efficiently.**

- **Waypoint mapping typically requires some form of Global (or Localized Global) coordinate localization**

- **May operate independently of obstacle avoidance algorithm, or in coordination with other mapping strategies (A* occupancy for example)**

- **Analogous to the Topological map representation in section 5.5.2 of <u>Introduction to Autonomous Mobile Robots</u>**

- **Can be reduced to very simple form**



Refs:

1) Introduction to Autonomous Mobile Robots, Siegwart Roland, Nourbakhsh, Illah Reza
2) Toward Robotic Cars, Trun, S.
3) A waypoint-tracking controller for a biomimetic autonomous underwater vehicle Jenhwa Guo

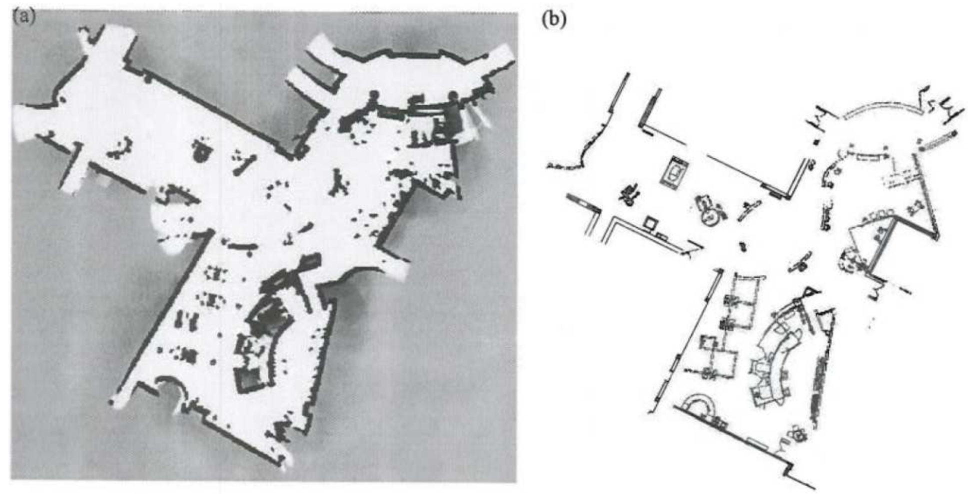
Occupancy grid maps (OGM) a mapping Algorithm

The best application of the OGM require robots with sonar or laser range finder sensors, both sensors are sensitive to absorption and dispersion which is a problem that OGM resolves by generating a probabilistic map.

The posterior of a map is approximated by
Factoring it into this equation

$$p(m \mid z_{1:t}, x_{1:t}) = \prod_i p(m_i \mid z_{1:t}, x_{1:t})$$

from reference [3]
Due to this factorization a binary Bayes Filter can
Be used to estimate the occupancy
probability for each grid cell [3].



(a) Occupancy grid map and (b) architectural blueprint of a recently constructed building.

From ref [1 ,fig 9)] and ref [2 fig 5.17]

Uncertainty	merging	Map dimension	Incremental	Dynamic setting	Handle raw data	Require poses
Posterior map	strong	unlimited	yes	limited	yes	yes

Table 1 Occupancy Grids algorithm summary of features

References: 1. Robotic Mapping by Sebastian Thrun February 2002 Carnegie Mellon
2. Chapters 5 of the introduction to Autonomous Mobile Robots
3. Wikipedia

Kalman Filters

Statements:

- The robot must explore and determine the structure of the space it is in
  - Simultaneous Localization and Mapping (SLAM)
- Each belief is uniquely characterized by its mean and covariance matrix
- This filter uses unimodal distribution and linear assumptions

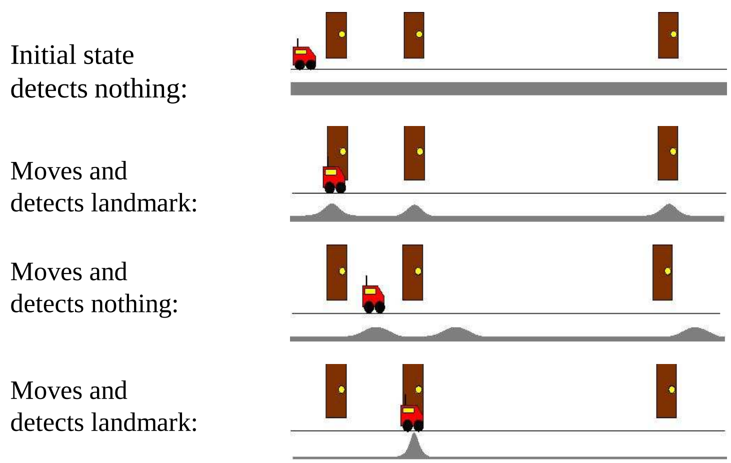


Figure 1: *Kalman Filter Sensor Processing [2]*

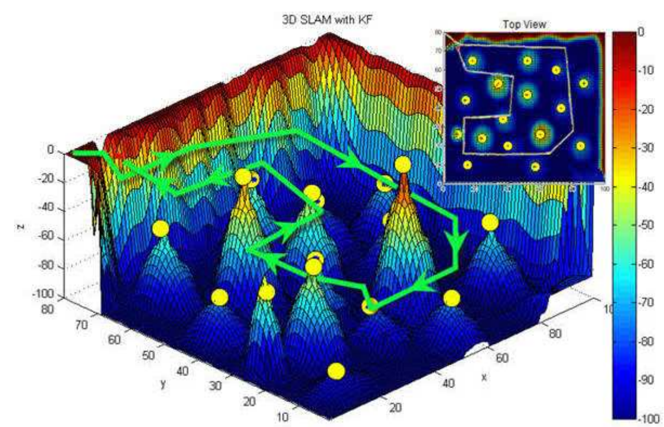


Figure 2: *Kalman Filter SLAM*

Problems:

1. A linear process model must be generated
2. Linearization will increase the state error

Sources:
[1] Robot Localization and Kalman Filters (http://www.negenborn.net/kal_loc/thesis.pdf)
[2] Mobile Robot Localization and Mapping Using the Kalman Filter (http://www.cs.cmu.edu/~robosoccer/cmrobobits/lectures/Kalman.ppt)

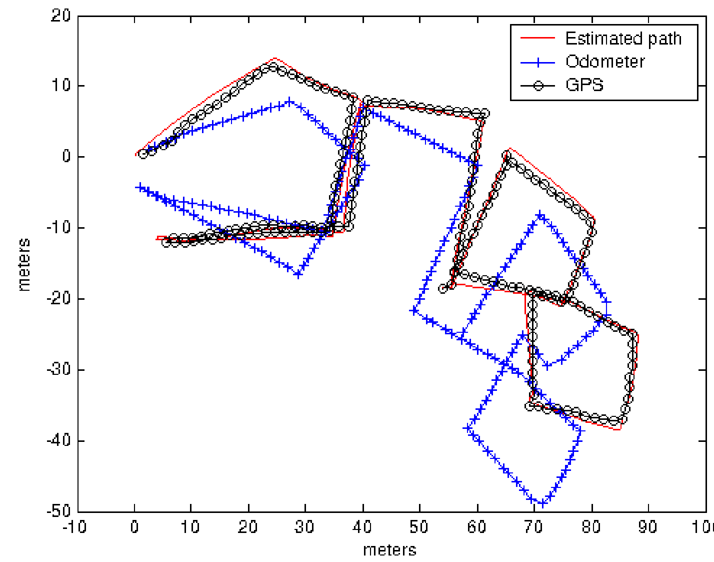
3D Mapping of Outdoor Environments

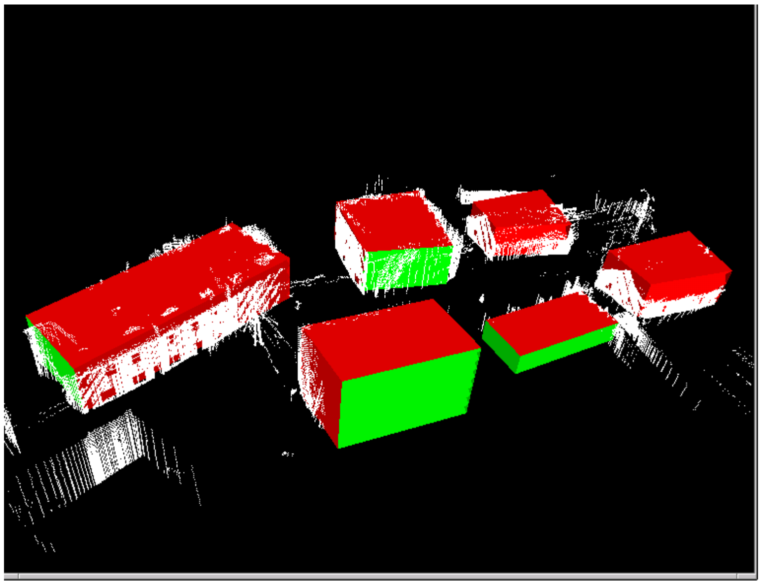
The algorithm focuses on efficiency and compactness of the representation rather than a high level of detail.

Mapping Algorithm has 3 steps:
Generating a point cloud map based on odometry, inertial measurement unit, GPS, and range information.
Point cloud are very memory inefficient.

Extracting planes from the point cloud map, Hough transform is used to extract planes from point cloud.

Associating planes and geometrically represent buildings.





[Ref - http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1545152](http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1545152)

3D Robot Mapping of Underground Mines

SLAM (simultaneous localization and mapping)

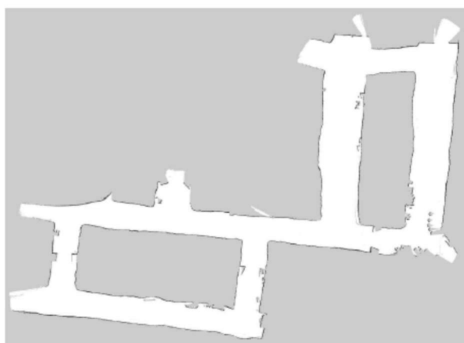
Prototype 1: Modified Pioneer AT Robot

Equipped with 2 SICK laser range finders, one pointing forward parallel to the floor, and one pointing upward perpendicular to the robot's heading direction

Equipped with 2 wheel encoders to measure approximate robot motion

Forward laser used for SLAM

Upward laser used to construct 3D shape of the walls

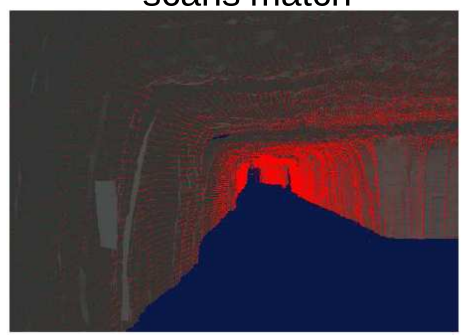


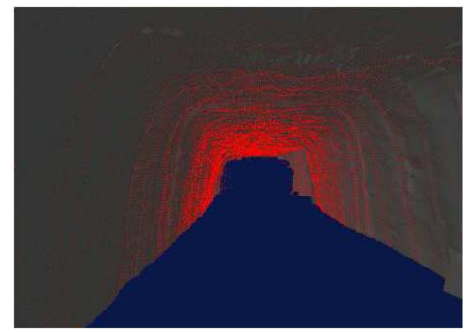
Prototype 2: Additional Sensors

2 more SLAM sensors added 90 degrees offset to the forward pointing sensors to add 3D (one pointed to the left and to the right)

3D reconstruction not achieved merely by adding vertical cross sections, as real time sensing can cause quite a bit of error

Using the first two lasers, errors are removed by interpolation between adjacent sensor scans, and adding cross sections of the two scans match





Jeffrey Skelnik jbskelni@uncc.edu

http://robots.stanford.edu/mines/mine-mapping/papers/thrun.mine-mapping.pdf

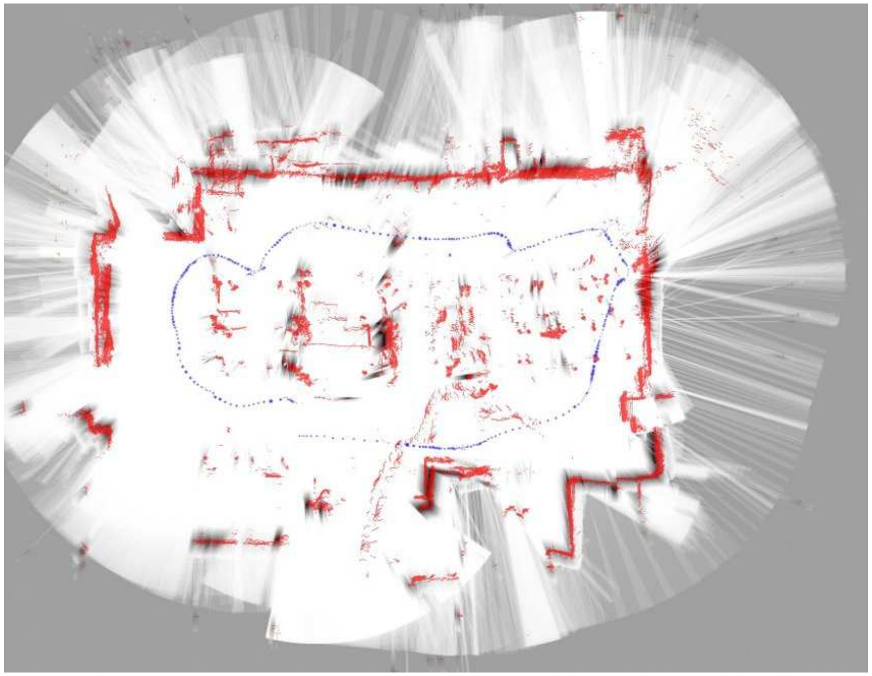
visual Simultaneous Localization and Mapping (vSLAM)

SLAM Algorithm

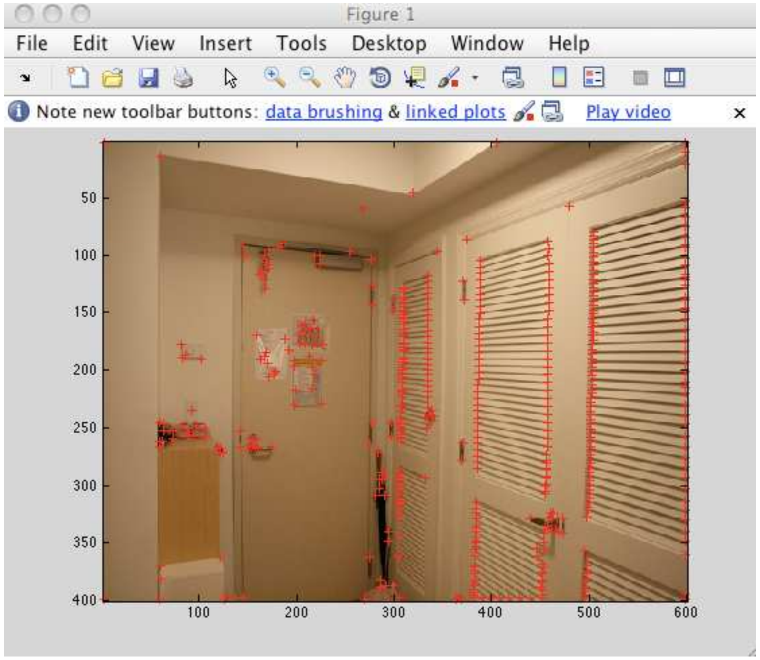
-Sensor Fusion (odometry, ranging, imaging)

-Find Features/Landmarks (application dependent)

-Merge with previously recorded data (landmark database)



[3] SLAM representation



[1] Harris Corner Detector

[1] http://www.flickr.com/photos/hnam/4074588812/in/photostream

[2] http://www.youtube.com/watch?v=DUmLJapio7o&feature=related

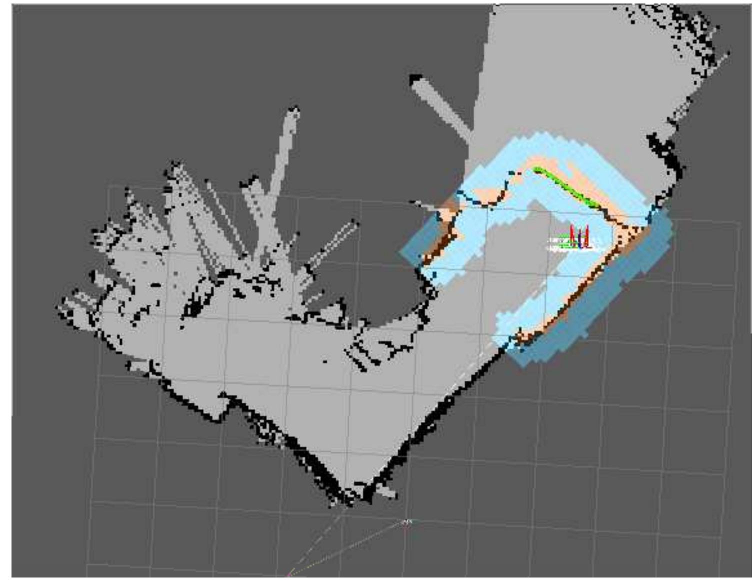
[3] http://www.morengi.com/infotrick/tinySLAM/total_color.jpg

[4]http://www.google.com/url?sa=t&source=web&cd=1&sqi=2&ved=0CBoQFjAA&url=http%3A%2F%2Fciteseerx.ist.psu.edu%2Fviewdoc%2Fdownload%3Fdoi%3D10.1.1.87.4010%26rep%3Drep1%26type%3Dpdf&rct=j&q=the%20vslam%20algorithm%20for%20robust%20localization%20and%20mapping&ei=nYQxTqiYIsry0gHTuvSUDA&usg=AFQjCNFtGCNErTWWlpPsDIccr25WXmGZAQ

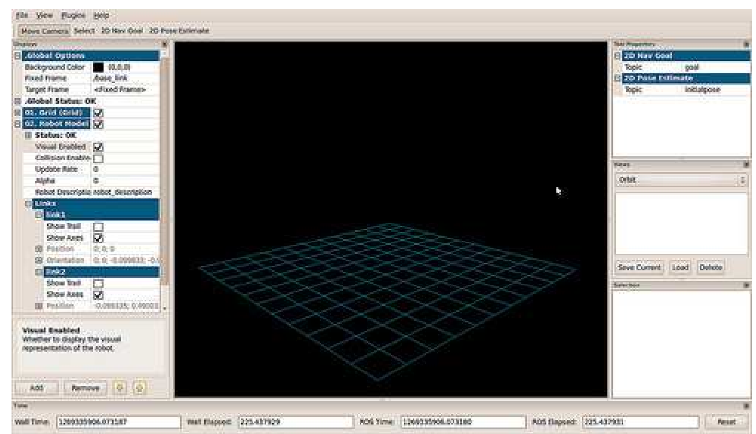
TurtleBot Mapping Using Kinect Sensor Bar

The TurtleBot uses information from the Kinect IR sensor bar and internal Gyro and encoders to build a map of its environment.

Using the GUI loaded in linux you must start the mapping program and then teleoperate the robot via an adhoc network and drive it around the area. The robot will then create the map based on its position given by the gyro and encoders, as well as any objects/walls given by the kinect sensor.



Navigation and Mapping

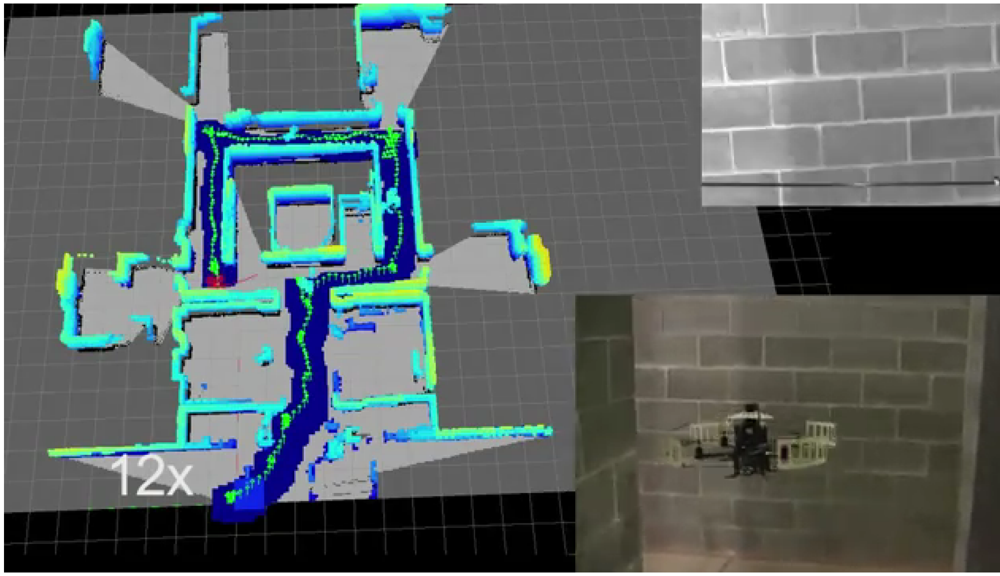


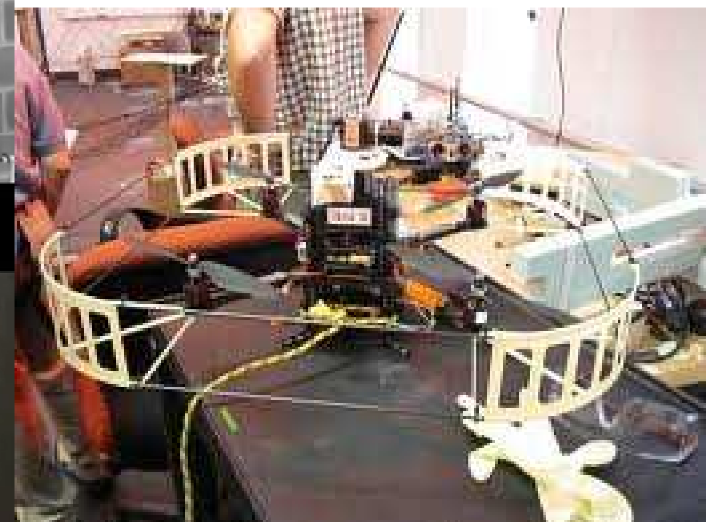
Map GUI

Sources/Videos
http://www.ros.org/wiki/Robots/TurtleBot (Video and Info)
http://profmason.com/?s=TurtleBot (Images/Video and Info)

http://www.youtube.com/watch?v=VIQChgUacJI&feature=player_embedded
http://www.youtube.com/watch?v=fljcaI4MDfA&feature=player_embedded

Mapping: IMU Combined with LIDAR



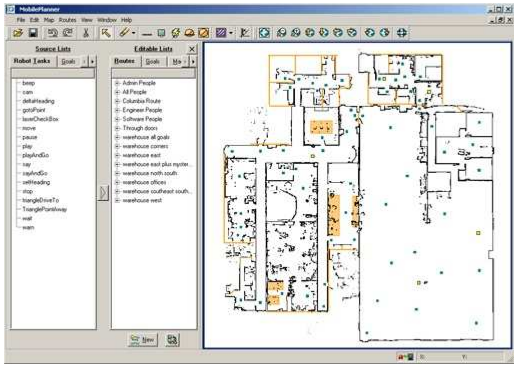


- Integration about the three axes to determine telemetry
- Must have a known starting point (or create a way-pointe)
- A sparse 3D map is generated on the robot based on sensor data, enabling high-level planning and visualization
- Planning and Mapping done onboard then sent to a home-base
- Allows for object avoidance in real time example

1) "Autonomous Aerial Navigation in Confined Indoor Environments - YouTube." *YouTube - Broadcast Yourself.* Web. 28 July 2011. <http://www.youtube.com/watch?v=IMSozUpFFkU>

Motivity™ Software Mapping

- Motivity Robot Core runs Mapping software
  - MobilePlanner allows creation of mission and tasks appropriate for the workplace
  - The software allows robots to learn room layout changes in minutes
  - No need for reflective tape or lines on the floor



- MobileEyes can be used for monitoring or manual control

"Million-mile Proven Motivity Robot Autonomy." *Intelligent Mobile Robotic Platforms for Service Robots, Research and Rapid Prototyping*. Web. 28 July 2011. <http://mobilerobots.com/Autonomous_Robotic_Platforms.aspx>.

ROAMS (Remotely Operated and Autonomous Mapping System)

- Maps an environment while returning a real-time, detailed 3D view of the location
- 2D LIDAR mounted on an adaptive three-degree of freedom rotating platform
- Integration of a 2D LIDAR, video camera, 3 servo motors and 3 angular position sensors are used to produce 3D color scans

Challenges: - Imprecise position and pose

- Non-unique solutions

The partial solution utilizes hue and texture information from video

Advantages: - Cheaper than other solutions

- Greater autonom

http://www.youtube.com/watch?v=Z_pWJxv3D5g

1- http://research.stevens.edu/index.php/remote-robotics-and-innovative-mapping-t-1
2- http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5339624

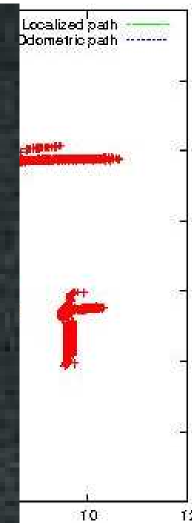
Mapping with the iRobot Roomba

Hardv

-
  v
-
-
- T

Playe
and se
tutori

- R
- u
- v
- L
- S
- lo



[1]SRI I
http://www.ai.sri.com/~gerkey/roomba/