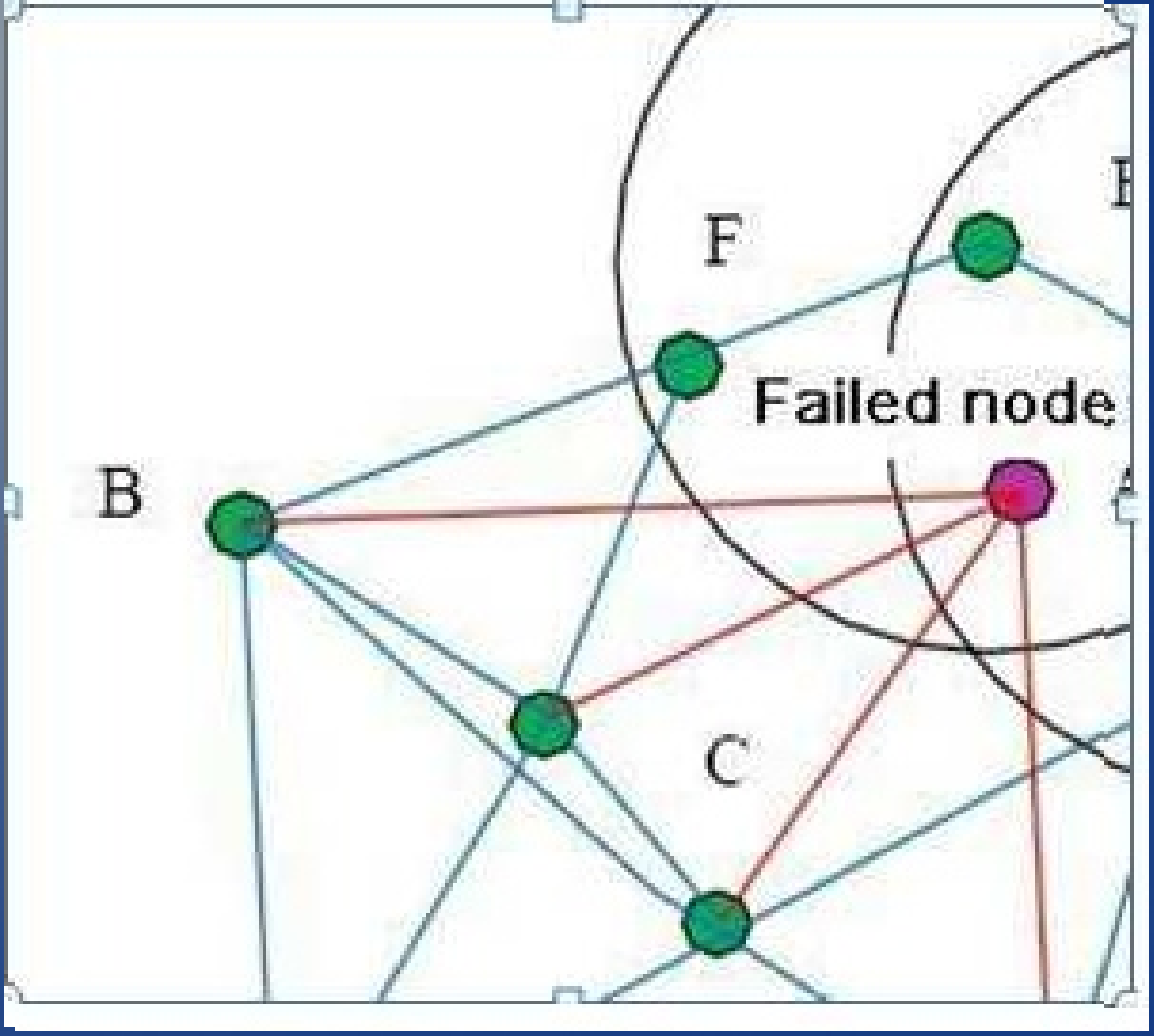
Robot Navigation Using Radio Signal in Wireless Sensor Networks

Ju Wang, Mohammad M Tabanjeh, Tariq Qazi, Brian Bennett, Cesar Flores-Montoya, Eric Glover, Meesha Rashidi
Virginia State University, 2014

Outline

- Background Robot RF localization
- RF Profile
- Distributed RF sensing
- Particle filtering
- Beacon set selection strategies
- Use of directional RSS measurements
- Test results

WSN Maintanenence problem



RF based locating technique

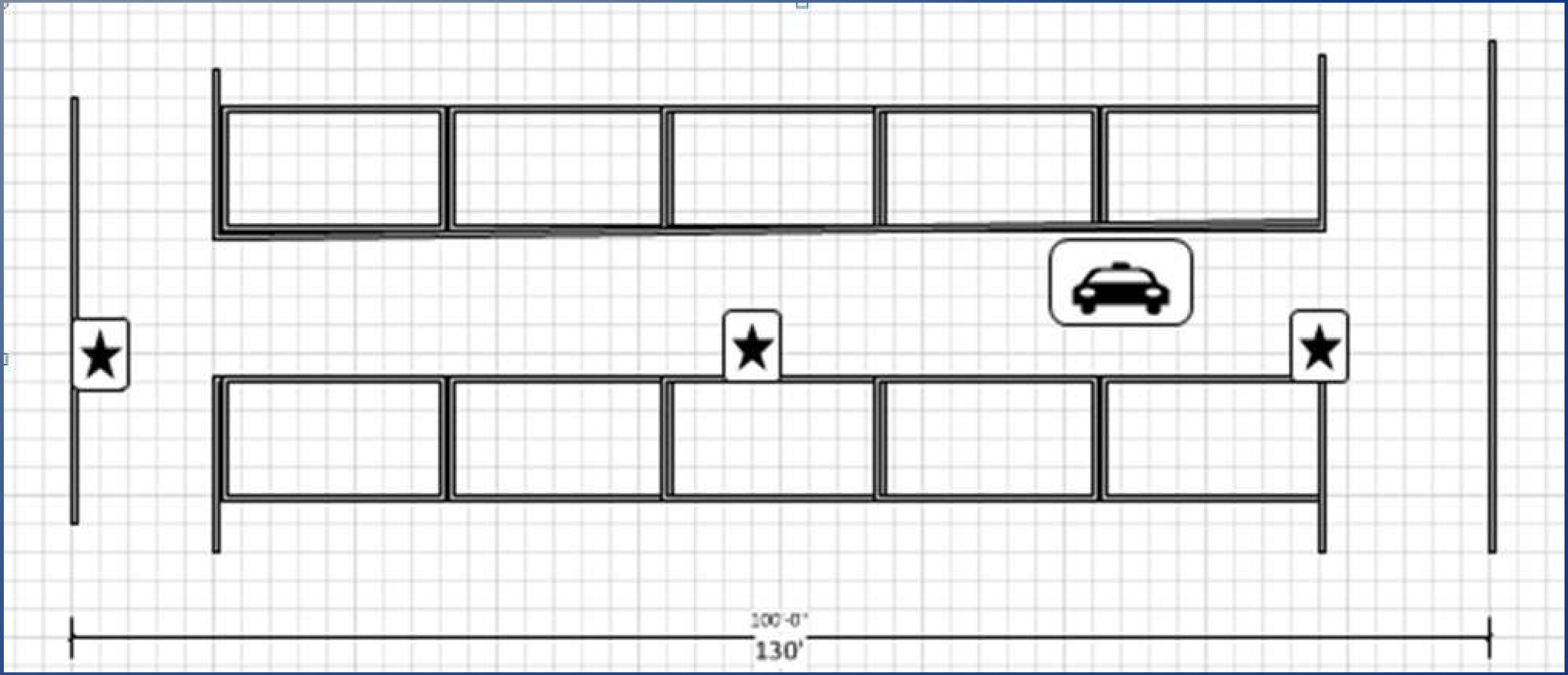
- Radio Signal Strength is inversely proportional to the distance between T-R
  - $$RSS = C P_s / D^n$$
- RSS localization has been proven difficult

  to use due to
  - the high complex and nonlinear radio channelmodel in real deployments.
- RF sensing remains to be a low accuracy positioning tool
- For decent results, good (detail) RF profile of the environment must be established

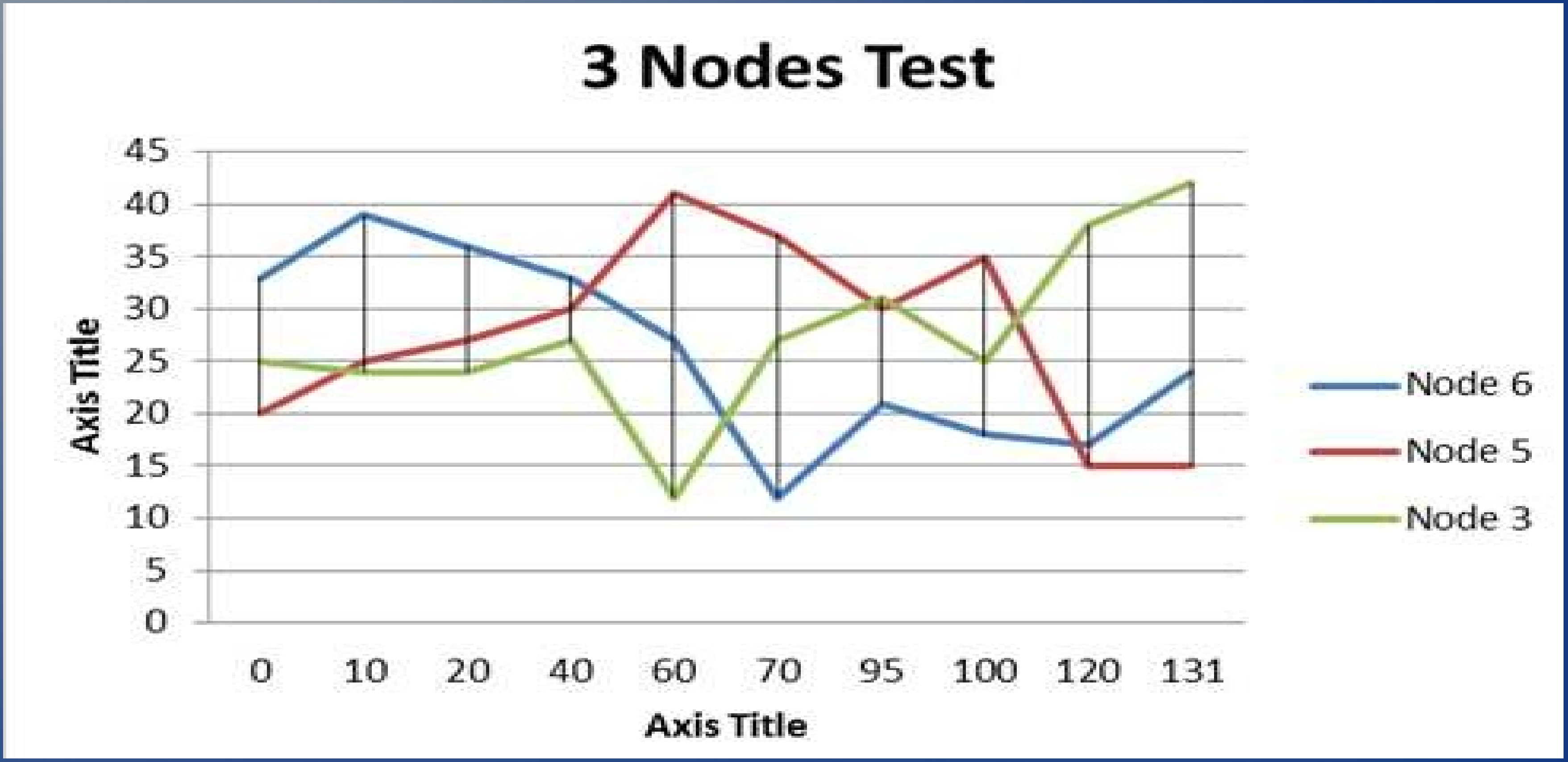
Indoor radio profiling

- Three wireless sensor nodes broadcast beacon packets
- ZigBee 0x0B (2405 MHz)
- Beacon packet contains a local SEQ # and a sensor node ID (unique)
- BEACON frequency programable (default 200 ms).
-

Indoor setting



Indoor RF profiles



Indoor RF profile data

- The RSS measurement result also shows a strong multi-path
- effect as the RSS is not monotonic of distance.
- strongest signal strength is in the range of 40 (-51 dBm).
- The lowest RSSI observed is 12 (-79 dbm)

Maximum-Likelihood estimation

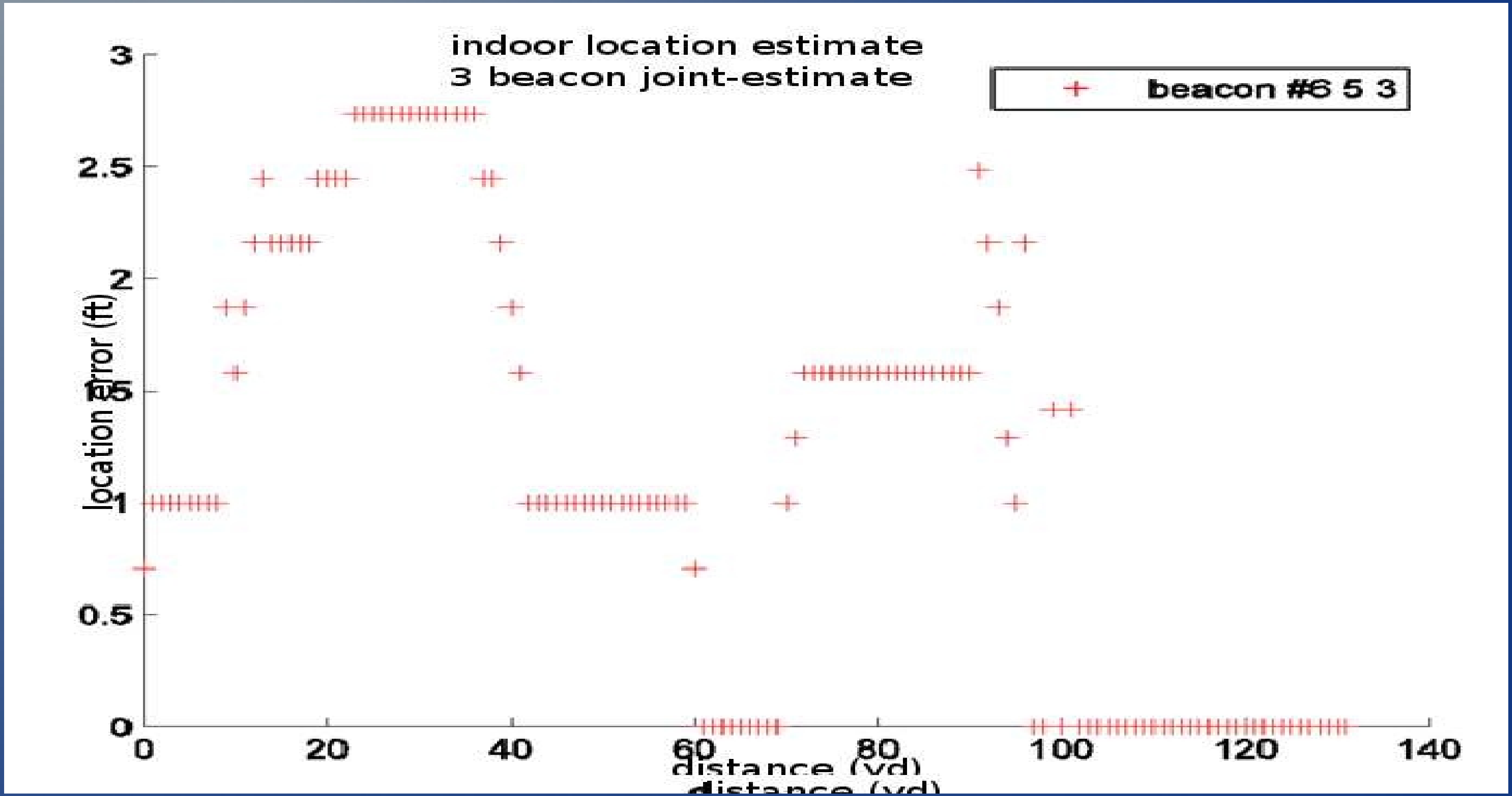
- P_{ri} conditional probability for all observable beacon nodes.
- R: The active beacon set, defined by
- $$R = i : SS_i > \zeta$$
- ξ is the tolerance margin of radiosensor.
-

$$\hat{d} = argmax_{d \in P}\{\sum_{i \in R} Pr_i(S\hat{S}_i|d)\}$$

Beacon Set Selection

- Fixed one: one particular beacon node is fixed and not changed during the navigation course.
- Strongest RSS first: R only contain the beacon nodewith the highest RSS reading.
- Closest to Target first: here R will contain the beacon node that is closest to the target sensor.
- Highest gradient first: here R will contain the beacon node whose RSS at the estimated robot position is the steepest

Indoor location errors



OUTDOOR 2D NAVIGATION

- RF profile is established in a 2-D grid
- indirect matching: If the target node can’t be heard, the robot is guided by matching the RSS reading of the beacon nodes between the robot and the target node.
- The RSS measurement at the robot is denoted by SS = (ssr (θ1), ssr (θ2), ...ssr (θn)).
- Directional antenna Measurement angle: 270 degrees and the resolution is 270/4096
-

Directional antenna profile

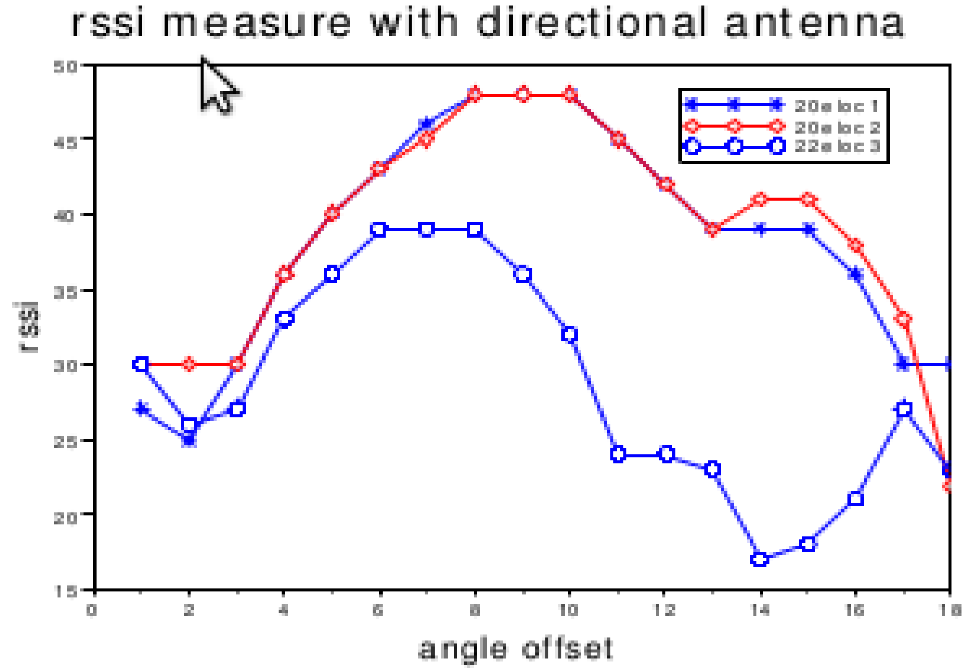


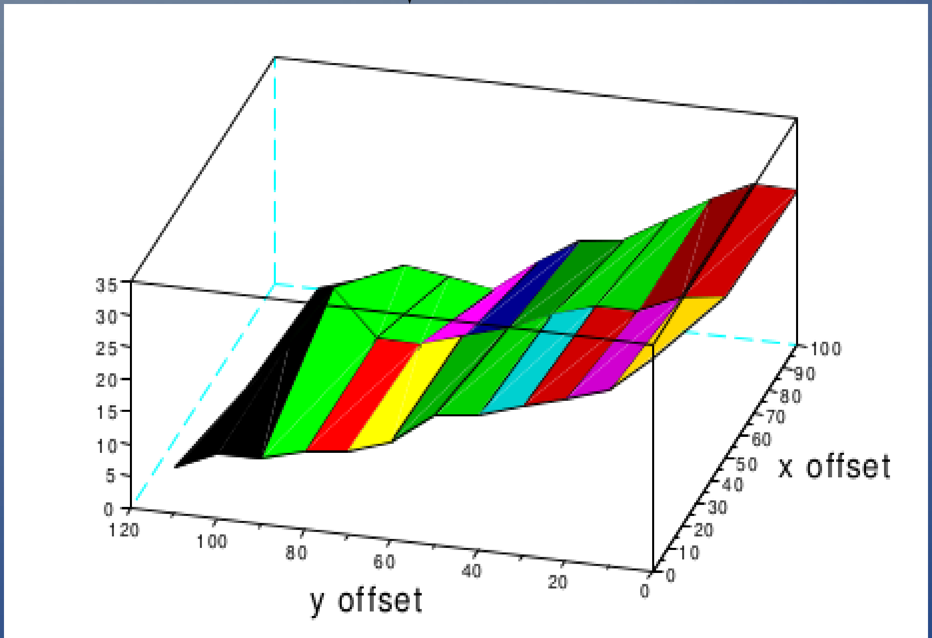
Fig. 7. RSS vs Angular offset measured by Directional antenna in room HM22E, target-robot distance: 3 feet.

Navigation Algorithm

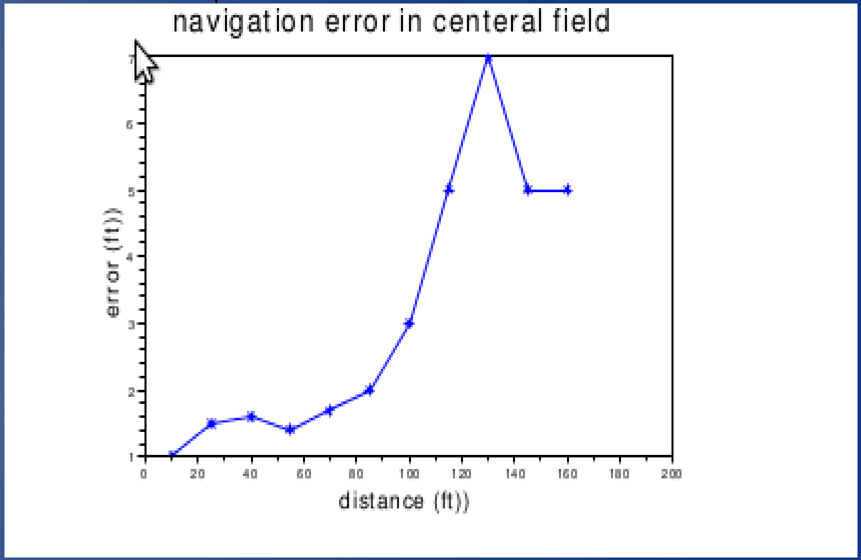
- Estimate the location of the target
- $$(\hat{x_t}, \hat{y_t}) = argmax_{(x,y)}\{\sum Pr_i(ss_i^t|(x,y))\}$$
- the location of the robot itself
- $$(\hat{x_r}, \hat{y_r}) = argmax_{(x,y)\in P}\{\sum Pr_i(ss_i^t|(x,y))\} \quad (7)$$
-
- an optimum movement direction θ∗ is calculated such that the RSS discrepency δSS will be reduced the most.

Results

- Grid RF profile



Navigation error



Thanks for listening