Algorithms for Radio Networks

Localization
Localization

- Localization in an empty environment?
  - Requires some “stuff” around
  - Determine the physical position or logical location
- Reference points (“landmarks”)
  - Natural: Trees, mountains, river bend, earth’s surface, sun, stars, ...
  - Artificial: Road signs, Surveyor’s mark, Retro-reflector, buoys, lighthouse, radio beacon, ...
- Coordinate systems
  - Global coordinate frame, Earth coordinates
  - Local reference frame: Cartesian grid, floor tiles
  - Absolute or relative coordinates
Localization

› Applications
  • Surveying, geodesy
  • Naval navigation, aviation, space flight
  • Navigation of people inside buildings in urban areas
  • Cars on roads, logistics
  • Navigation of robots: Autonomous mobile units
  • Industrial machines, tools: Drills, rivet hammers
  • Networks: Routing algorithms, sensor networks
  • ...and many more!
Localization

- Parameter
  - Centralized or distributed computing
  - Availability of position information: Active vs. passive localization
  - Application
    - Indoors, outdoors, global
  - Sources of information: Sound, light, radio signal, magnetic field, ...

- Metrics
  - accuracy
  - precision
  - other costs
Sources of Information

- Neighborhood information
  - Range provides coarse location information
    - e.g. GSM / UMTS cell, wireless IDs
- Triangulation and trilateration
  - Angle differences
  - distance measurement
- Analysis of the environment
  - Characteristic "signature" by radio conditions in the environment
- Inertial navigation systems
  - Measurement of acceleration and rotation
Received Signal Strength Indicator

- Using the path loss at a known transmission power
- Measurement of the received signal

\[ P_{\text{recv}} = c \frac{P_{\text{tx}}}{d^\alpha} \iff d = \sqrt[\alpha - 1]{\frac{cP_{\text{tx}}}{P_{\text{recv}}}} \]

- Path loss exponent \( \alpha \)
- Transmission power \( P_{\text{tx}} \)
- Problem: High error rate

\[ \alpha < 2 : \text{hurkels} \]
\[ \alpha > 2 : \text{obstacles} \]

[Sichitiu and Ramadurai, MASS 2004]
RSSI

- Problem: high error rate
  - Probability distribution for RSSI and given transmission power

 ‣ Problem: high error rate
   • Probability distribution for varying RSSI and distance

Problem: high error rate

- Probability distribution for varying RSSI and distance

[Sichitiu and Ramadurai, MASS 2004]
Time of Arrival

› Time of arrival (TOA)
  • Transmission time ("Time of flight") is measured
  • Transmission time = Reception time – Send time
  • Results from the quotient:
    - Transmission time = distance / speed signal

› Problem
  • Positions of measurement points (anchors) must be known (usually...)
  • Accurate time measurement
  • Clock synchronization
  • Relative ranges require more anchors
Time *Difference* of Arrival (ToA)

- Two different signals with different transmission speeds
  - E.g. ultrasound and radio signal, “thunderstorm”
  - Main component of the speed of sound
  - Calculate the different arrival times is distance
  - If one signal is very fast (e.g. “light”), eliminate it

- Problems:
  - calibration (hardware delay)
  - special hardware is required
Round Trip time (ToA)

- Two way communication, send a signal back and forth between two transceivers
  - E.g. radio signal, sound signal
  - Distance = 1/2 * Round trip time / c
- Problems:
  - Again: calibration (hardware delay)
  - Requires two transmitters and two receivers
- Similar: Measure distance to an obstacle (reflection)
  - Distance measurement by Laser or ultrasound
Algorithms for Radio Networks

Localization

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