Computing with Location

- Navigation
- Global Location
  - All things GPS
- Model-based localization vs. fingerprinting
  - Localization beyond GPS
- Beyond localization
  - Nomatic*IM context
Intro to Location

Tools for Navigation

- Navigation Tools
  - Clocks
  - Odometer
  - Electronic Aids
  - Radio navigation aids
    - ground-based
    - space-based
Global Location GPS
Global Location GPS

• Latitude and Longitude
  • What are they?
  • Datum
Global Location GPS
Global Location GPS

- Current GPS
  - Fully operational
  - accurate, continuous, global 3-D position and velocity
  - also distributes universal coordinated time
- 24 satellites
- 6 orbital places
- 4 satellites per plane
- not geosynchronous
Intro to Location

Global Location GPS

• Current GPS

• Based on
  • Time Of Arrival (TOA)
  • knowledge of satellite orbits

• Satellites have atomic clocks on board

• 2 frequencies
  • L1 1575.42 MHz
  • L2 1227.6 MHz
Global Location GPS

- Current GPS
  - Receiver requirements
    - Must have local clock
    - 3-D position requires four satellites
      - time or height reduces this
Intro to Location

Global Location GPS

Thursday, February 9, 12
Global Location GPS

- Basic concept is based on the foghorn paradigm
- but in 3-D
Global Location GPS

- The current and future of GPS
  - WAAS
    - Additional satellites in geosynchronous orbit
  - DGPS assistance from a land based receiver
  - Galileo
    - European competitor
    - GPS compatible
  - GLONASS
Global Location GPS

- The current and future of GPS
  - BeiDou
    - Chinese competitor
    - centralized system
  - Japanese Quasi-Zenith System
Global Location GPS
Global Location GPS

- GPS accuracy
  - 13 m 95% of the time horizontal
  - 22 m 95% of the time vertical system
  - 40 ns 95% of the time
- How do you design for this?
Global Location GPS

- GPS accuracy
  - 13 m 95% of the time horizontal
  - 22 m 95% of the time vertical system
  - 40 ns 95% of the time
- How do you design for this?
- Urban canyons
  - What are they?
- Japanese response, European response
Global Location GPS
Representing Location
Representing Location

- Absolute
- In reference to an origin (e.g., GPS)
- Exact, Unambiguous, Machine friendly
Representing Location

- Absolute
  - In reference to an origin (e.g., GPS)
    - Exact, Unambiguous, Machine friendly
- Relative (e.g., laser range finder)
  - In reference to another position
Representing Location

- Absolute
  - In reference to an origin (e.g., GPS)
    - Exact, Unambiguous, Machine friendly
- Relative (e.g., laser range finder)
  - In reference to another position
- Symbolic
  - In reference to common knowledge
    - Inexact, Ambiguous, Human Friendly
Representing Location

• How can you transform between
  • Relative and Absolute?
  • Absolute and Symbolic?
Intro to Location

Tools for Navigation
Tools for Navigation

• Who calculates position?
  • Client based
  • Network based
  • Network assisted
Tools for Navigation

- Who calculates position?
  - Client based
  - Network based
  - Network assisted
- What’s the impact?
Categorizing Localization

Properties

Where is the computation done?

- GPS locally - private, scalable
- Cell-phone positioning - assisted, scalable to a degree, location is revealed
- Broadcast ID-badge systems - localization is in infrastructure
Localization beyond GPS
Approaches to Localization

Proximity

Knowing that you are near a fixed location

Typically based on non-localization technology

Cell-towers, Credit card usage, login information
Approaches to Localization

- Trilateration
  - GPS is an example
  - Multiple references to fixed locations which resolve position
  - Time of flight
  - Signal strength
Approaches to Localization

- Hyperbolic Lateration
  - Leverages the difference in signal arrival time
Approaches to Localization

- Triangulation
  
  Finds the intersection of multiple lines of sight
Approaches to Localization

Fingerprinting

- Surveys the world before hand to find what signals look like when you are there
- When you are at a place you find the closest match
Approaches to Localization

- Dead Reckoning
  - Start at one place you know
  - Keep track of time and odometry
Approaches to Localization

Scene Analysis

- Evaluating content from a fixed camera
- Color histograms from doorways
- Evaluating content from a mobile camera
- Tour guide scene matching
Sources of Error
Intro to Location

Sources of Error

- Incorrect Reference Points
Sources of Error

- Incorrect Reference Points
- Atmospheric delay
Intro to Location

Sources of Error

- Incorrect Reference Points
- Atmospheric delay
- Clock synchronization
Sources of Error

- Incorrect Reference Points
- Atmospheric delay
- Clock synchronization
- Multi-path propagation
Sources of Error

- Incorrect Reference Points
- Atmospheric delay
- Clock synchronization
- Multi-path propagation
- Geometry
Categorizing Localization

Properties

- Accuracy and precision
- GPS 15m - 95% of the time
- Sensor fusion tries to improve accuracy and/or precision by combining sensors
- Accuracy and precision may change to conserve battery life.
Categorizing Localization

Laser Feature
Categorizing Localization
Categorizing Localization

Properties

Scale

Global, Regional, Local

- GPS - Global
- RFID Readers - local
- Cell-phone localization - regional
Categorizing Localization

Properties

Recognition

GUID - globally unique identifier

Do we know who or what you are?

GPS - no

Sensor fusion - maybe
Categorizing Localization

- Properties
- Cost
- Deployment
- Infrastructure
- Maintenance
- Incremental Users or Improvements
Categorizing Localization

Properties

Limitations

Indoor/Outdoor

Battery Power

New Equipment
Examples

- Active Badge
  - GUID broadcast by infrared
  - symbolic proximity
  - absolute positioning
  - sunlight/fluorescent lighting
Examples

- **Active Bat**
  - GUID ultrasonic broadcast by radio request
  - Infrastructure computes absolute proximity
  - 9cm 95% of the time
  - Bad scalability, hard to deploy, maybe costly
Examples

- Cricket

- Object based ultrasonic localization

- Radio frequency control signal

- Triangulation base on time-of-flight

- Private, decentralized scalability

- Local computation -> power drain
Examples

- RADAR
  - building-wide tracking system
  - 2-D Wifi based localization
  - "scene analysis" through fingerprinting
  - local computation -> power drain
Examples

- RADAR
- building-wide tracking system
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- local computation -> power drain
Examples

- Smart Floor
  - local tracking
  - anonymous
  - no additional equipment for a person
  - poor scalability
  - costly
Examples

- Smart Floor
  - local tracking
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  - no additional equipment for a person
  - poor scalability
  - costly
Intro to Location

Summary

For instance, sometimes you might forget to Check In when

YouTube
Intro to Location

Summary

• No single location system is good everywhere
Summary

• No single location system is good everywhere
• Sensor fusion or combination systems are a solution
Summary

• No single location system is good everywhere
• Sensor fusion or combination systems are a solution
• Privacy vs Usability