

LOCATION AWARENESS

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Topics to be covered ...

- Survey and taxonomy of location systems
- Probabilistic room location service – Nibble
- Cricket Location Support System

Location Systems

- Need for location systems
 - Applications need to be location-aware
- Techniques
 - Triangulation, Scene analysis, Proximity

Triangulation

- Uses the geometric properties of triangles to compute object locations.
- Further subdivided into
 - Lateration (distance)
 - Angulation (angles)

Lateration

- Computes the location of an object by measuring its distance from multiple reference positions.
- A 2 dimensional location requires distance measurements from 3 non collinear points
- A 3 dimensional location requires distance measurements from 4 non coplanar points
- Domain specific knowledge may reduce the number of required measurements

Lateration ...

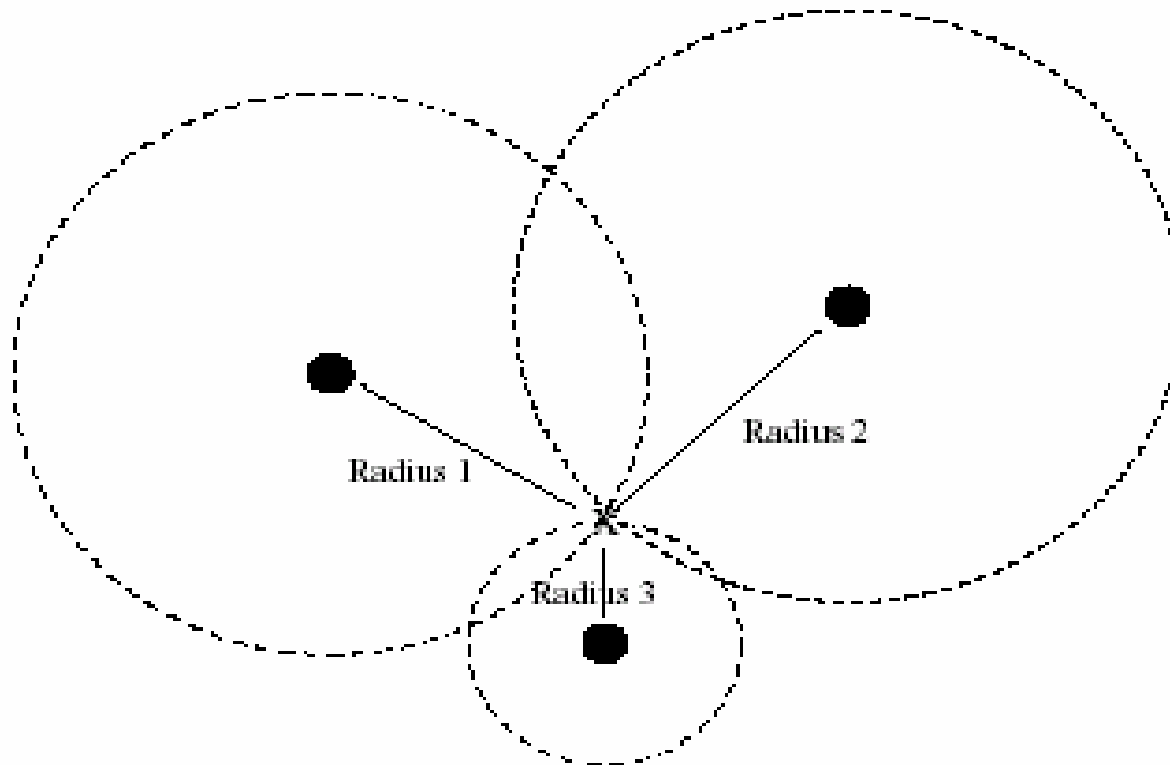


Figure 1: Determining 2D position using lateration requires distance measurements between the object 'X' and 3 non-collinear points.

Lateration ...

- There are three techniques to measure distances:
 - **Direct** (eg tape measure)
 - **Time-of-Flight** : Distance is measured by the time taken to travel to a point.
 - **Attenuation** : Correlate attenuation and distance for a specific type of emission and the original signal strength to obtain distances.

Angulation

- Similar to lateration except that it uses angles along with distances to compute location.
- A 2 dimensional angulation requires 2 angle measurements and 1 length measurement.
- A 3 dimensional angulation requires 2 angle measurements, 1 length measurement and 1 azimuth measurement
- Ex. Phased antenna arrays

Angulation ...

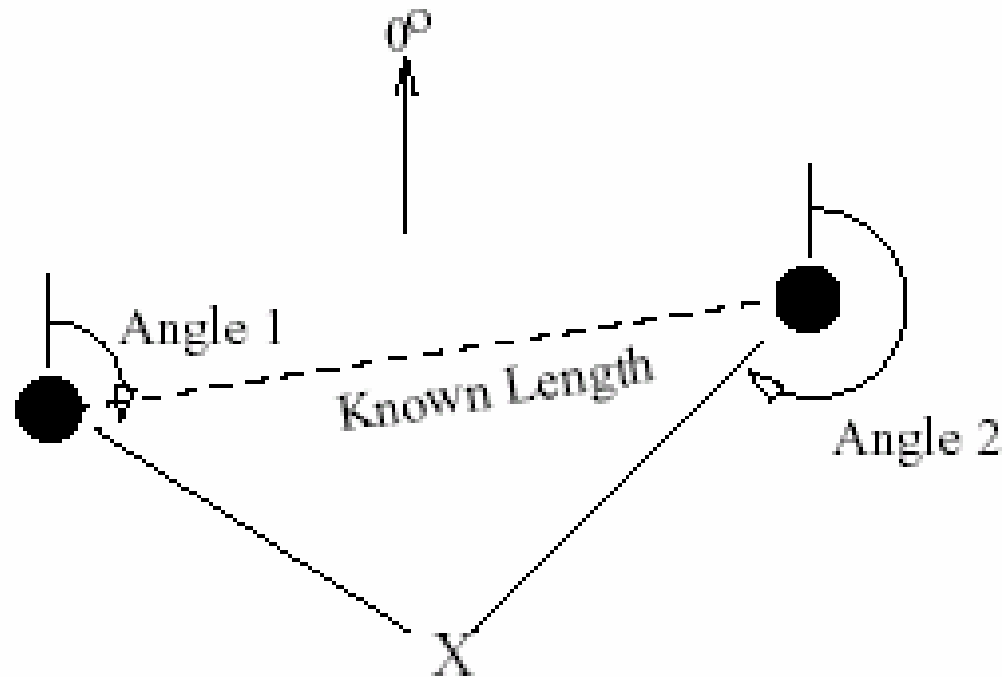


Figure 2: This example of 2D angulation illustrates locating object 'X' using angles relative to a 0° reference vector and the distance between two reference points. 2D angulation always requires at least two angle and one distance measurement to unambiguously locate an object.

Scene Analysis

- Uses features of an observed scene to draw conclusions about the observer or objects
- Scenes are usually simplified in order to easily represent and compare features
- It can be divided into 2 types:
 - **Static** : Observed features are looked up in a predefined dataset that maps them to locations
 - **Differential** : tracks the difference between successive scenes to estimate the location.

Scene Analysis



Figure 3: Horizon shapes extracted from a visual scene can be used statically to look up the observer's location from a prebuilt dataset or dynamically to compute movement of the vehicle mounted camera.

Scene Analysis

- Advantages
 - Location can be inferred using passive means and without resorting to geometric methods.
- Disadvantages
 - Observer needs to know the features of the environment.
 - Changes to environment may require database overhaul.

Proximity

- This entails determining when an object is “near” a known location.
- Objects presence is sensed using a physical phenomenon with a limited range.
- There are 3 approaches:
 - Detecting physical contact
 - Monitoring wireless cellular access points
 - Observing automatic ID systems

Location Sensing Properties

- **Physical position and Symbolic location**
 - GPS is an example of physical positioning technology
 - Symbolic locations encompass abstract ideas of where an object lies
 - Resolution of physical positioning systems can have implications for the definitiveness of the symbolic information they derive

Properties ...

- **Absolute versus Relative**
 - An absolute location system uses a shared reference grid for all located objects.
 - In a relative system, each object has its own frame of reference.
 - Absolute locations can be transformed into a relative location – relative to another reference point.

Properties ...

- **Localized location computation**
 - Some systems insist that the objects being located actually compute their own position.
 - Other systems require the located object to periodically emit telemetry to enable the infrastructure to detect it. Such systems have lesser power and computational requirements.

Properties ...

- **Accuracy and Precision**
 - A location system should report positions accurately and consistently for every measurement.
 - Techniques like Sensor Fusion seek to improve accuracy and precision by having overlapping levels of resolution.
 - Adaptive fidelity systems

Properties ...

- **Scale**

- The scale of a system is assessed by considering its coverage area per unit infrastructure and the number of objects the system can locate per unit infrastructure per time interval.
- Time is important due to bandwidth limitations.
- Systems can generally expand to a larger scale by increasing the infrastructure.
- Cost and middleware are important factors

Projects ...

- **Recognition**

- Some applications need to recognize located objects to take a specific action based on their location. Automatic identification mechanisms are needed here.
- One way to achieve this is by assigning a unique ID to each object.

Properties ...

- **Cost**

- Time costs for installation and administration of the location system.
- Space costs for infrastructure and hardware costs to set up the system
- Capital costs for equipment and personnel

Properties ...

- **Limitations**

- Some systems may not work under certain environmental conditions
- Functional limitations are the characteristics of the underlying technologies
- Future work should focus on lowering costs, reducing infrastructure, improving scalability and building flexible systems.

Nibble – Probabilistic Room Location Service

- It is a unique application for a wireless network based on the IEEE 802.11 standard.
- It infers the location of a wireless client from signal quality measures using Bayesian networks
- Needs no extra hardware. Only software.

Nibble

- The UCLA Multimedia Systems Lab devised and implemented the Multi-use Sensor Environment (MUSE)
- It is a middleware architecture for sensor smart spaces using Bayesian networks.
- Nibble is built on top of this setup.

Nibble - Basics

- The 802.11 Wi-Fi network consists of several wireless clients and access points.
- Clients use the access point that gives them the strongest RSSI
- Mobile clients periodically survey the signal quality to determine the best access point.
- Nibble relies on a fusion service to infer locations from signal strength measures between the object and the access points

Nibble – Fusion Service

- Has 2 components
 - Evidential reasoning model that collects and interprets information from the sensors
 - Resource optimization model for minimizing the cost of gathering data
- The sensor data is characterized probabilistically and fed as input to the fusion service. The output is a probability distribution that represents context data.

Nibble ...

- In Nibble, the interpretive part of the fusion service is the Bayesian network
- It is a graphical representation of a joint probability distribution that explicitly declares dependency relationships between random variables.
- Computation on this is feasible since the relationships are declared.

Nibble

Bayesian Network Framework for Inferring Location

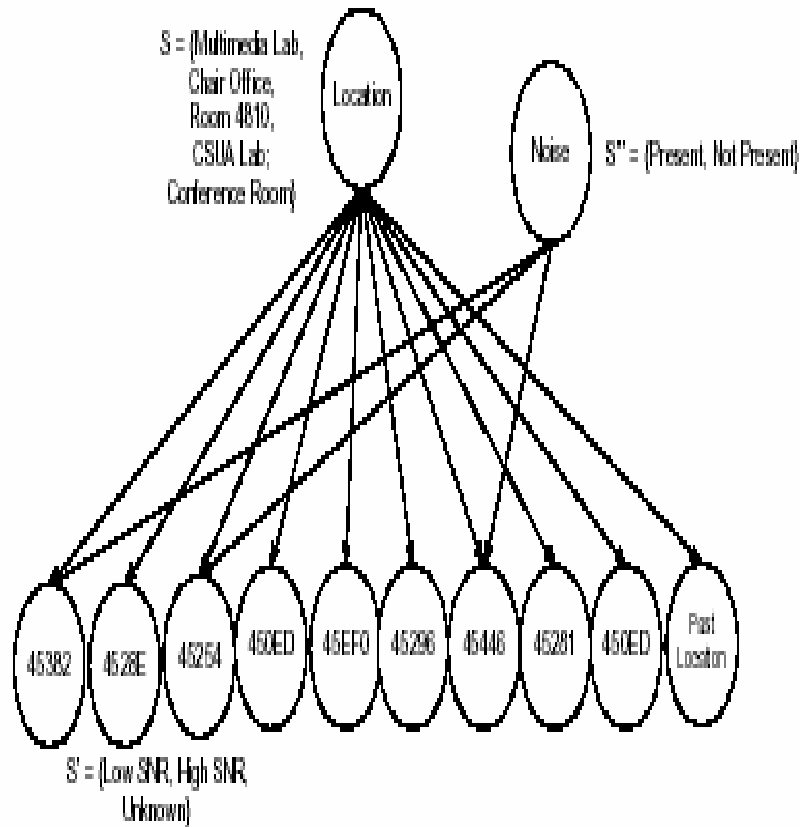


Fig. 1. Example Bayesian network for inferring location in a Wi-Fi network

- The network is a rooted tree with directed arcs from the root to the terminal nodes signifying a dependency relationship.
- The root is a query variable that describes $p(L)$.
- Terminal nodes represent observable variables that describe $p(E|L)$
- From this we can calculate $p(L|R)$

Nibble

- In the Bayesian network for determining location, L and E are quantized into discrete values.
- Nibble can theoretically distinguish $n^{**}s$ different locations.
- To infer location, we need to provide values for $p(L)$ and $p(E|L)$ for each access point.
- L can be built incrementally and locations can be added and deleted anytime.
- Profiles for people's preferences of locations can be easily incorporated

Nibble - QoI

- A quantifiable measure of quality for a fusion service allows applications to choose between services based on “cost”.
- QoI characterizes the performance of a fusion service in terms of the accuracy of the inference and the level of confidence in the measure.
- The optimization problem would be to achieve a high QoI at minimal “cost” (consultation of an access point).

Cricket - Location Support System

- It is a location support system that allows applications to learn their physical location by using *listeners* that hear and analyze information from *beacons* spread throughout a building.
- It does not rely on centralized management and there is no coordination among beacons.

Cricket

- The goal was to develop a system that allows applications to learn their physical location and then advertise themselves to a resource discovery service.
- They learn about services in their vicinity via an active map that is sent from a map server.
- Cricket is a building-wide deployable location support system in the context of Project Oxygen.

Cricket Design Goals

- **User privacy**
 - It is not a tracking system that keeps track of all the objects' locations.
- **Decentralized administration**
 - There is no central entity since centralized control can be a hindrance to scalability
- **Network heterogeneity**
 - Cricket is decoupled from data communication mechanisms to achieve technology independence.

Design goals ...

- **Cost**
 - It uses commercial off the shelf products and costs about \$10 per beacon and receiver
- **Room sized granularity**
 - The system should be able to determine spatial regions to within 1 – 2 sq. feet

Basic Operational Idea

- Beacons publish information on a RF signal. With each RF signal, the beacon transmits a concurrent ultrasonic pulse.
- The listeners receive these, correlate them to each other, estimate distances to different beacons and infer the space they are currently in.
- The beacons use a decentralized randomized algorithm for transmission

Specific details ...

- Cricket uses beacons to distribute information about a geographical space. It is a small device attached to some location.
- Listeners are small devices that listen to messages from beacons and use them to infer the space they are currently in.
- When a mobile device has a listener on it, it constantly listens to beacons to infer its location. As the device moves, the navigation S/w uses the *listener* API to update its current location.
- The only configuration needed is defining the message broadcast by a beacon to indicate a space.

Specific details ...

- The precision is determined by how well the listener can detect the boundary between 2 spaces.
- The granularity specifies the smallest possible size for a space such that boundaries can be detected with a high degree of precision.
- Accuracy is the degree to which the distance from a beacon, estimated by a listener matches the true distance.

Determining Location

- A combination of RF and ultrasound is used to enable a listener to determine the distance to beacons, from which the closest beacon can be determined.
- This is done by measuring one way propagation time of the ultrasonic signals emitted by the beacon.
- When the listener gets the RF signal it turns on its ultrasonic receiver and uses the time difference to determine the distance to the beacon.

Reducing Interference

- The decentralized beacon network comes at the absence of explicit coordination. This lack of coordination can cause RF transmissions from different beacons to collide and lead to false results.
- Ultrasound also suffers from multipath effects due to reflections.
- The listener has to gather various RF and US samples and correlate the {RF,US} pairs.
- The collision problem is handled by randomization

Reducing interference ...

- **Proper selection of system parameters**
 - In addition to space information, each beacon also transmits a unique identifier. This allows the listener to correlate the RF and ultrasonic beacon signals correctly
- **Listener interference algorithms**
 - *Majority*
 - *Min mean*
 - *Min mode*

Beacon Positioning

- This is a non trivial problem because it is instrumental in enabling listeners to make the right choice.
- Whenever a beacon is placed to demarcate a boundary for a space, it should be placed at a fixed distance away from that boundary.
- Ultrasonic interference can lead to misleading data and hence it is important to reduce ultrasonic leakage. We align the ultrasonic transmitter at 45 degrees to the direction of peak signal strength.

Summary

- The primary goals of user privacy and decentralized control were achieved.
- The Cricket system can be incorporated into applications like active map and location based services with relative ease.
- The emphasis is on the object to determine its own location.