Lecture 6:

Hightower and Gaetano Borriello 2001
A Survey and Taxonomy of Location Systems for Ubiquitous Computing

COMP 30025J

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Abstract

- This paper is about how mobile computing apps can tell where they are physically located. This is now of crucial importance for AR applications
- Location sensing
- Taxonomy System on properties
- Reference Paper, written as a technical report(not peer reviewed) but its passed on a previous peer reviewed paper so its safe.

Conclusions

- Basic techniques on location sensing are examined
- Taxonomy is built and used to assess a case study app on ubiqutiious jukebox.
- Taxonomy range is complete so it points to an interest period of innovation
- This statement turned out to prophetic as 2002 onwards smartphones began using many of the techniques outlined in this paper.

Introduction

- Making Mobile Computing Application aware of their environment
- Section 2 : Basic Techniques
- Section 3: Taxonomy
- Section 4: Survey of current Systems
- Section 5 : case study to demonstrate the Taxonomy

Location Sensing Techniques / 2.1 Triangulation

- This section will outlin
  Three different autom
  location sensing
  techniques
  - Triangulation
  - Scene Analysis
  - Proximity

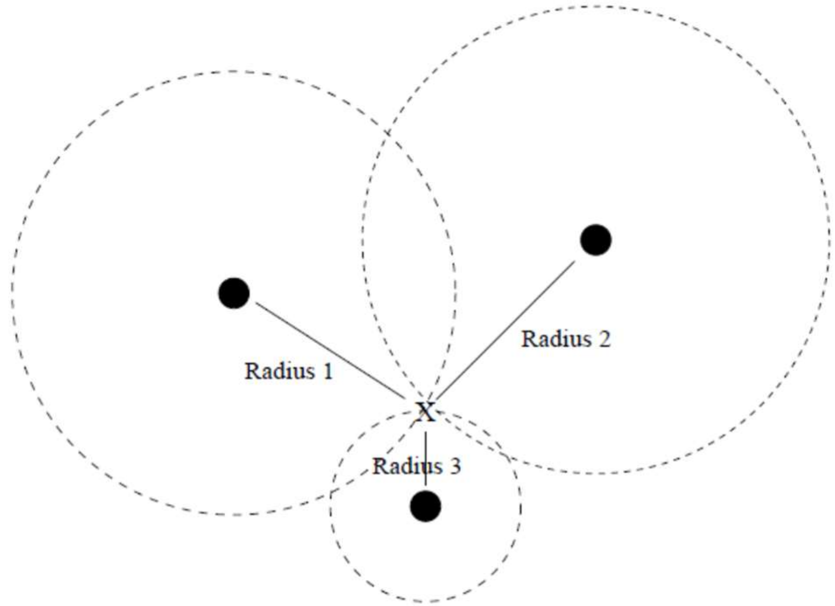


Figure 1: Determining 2D position using lateration requires distance measurements between the object 'X' and 3 non-collinear points.

2.1.1 Lateration

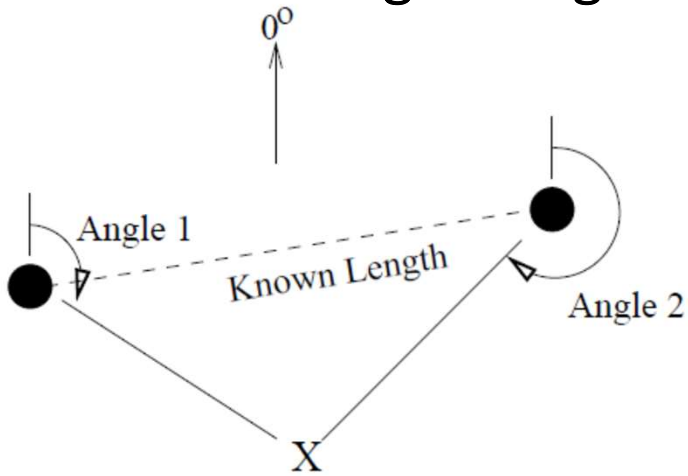
- Three approaches
- 1. Direct Measuring directly ,using physical mechanisms.
  - Still needed with many technique to find scale. For example you know the scale between objects but not their scale in the real world. Normally solved using a fixed measured object placed in the scene, e.g A metre stick
- 2. Time of Flight(Active)
  - Measuring the time a signal takes from the sensor to the target object and back again. If sound is used such as in an Ultra sound system it takes roughly 1.45 millisecond for the signal to travel a metre , while using a light pulse to track will take a 1.6 Nano seconds.

2.1.1 Lateration

- 2. Time of Flight (Passive)
  - GPS systems work using the same concept but the receiver is passive and does not emit the signal
  - GPS uses radio instead of Light or sound
  - All the Global position Satellites have clocks that are precisely synchronised.
  - The receiver must receive 4 different signals from 4 separate satellites.
  - They need 4 signals and not 3 as its getting an object in 3D space(Latitude , Longitude and elevation)
  - The receiver gets the different radio messages which are time stamp . It uses the differences in these times to work out distance.

2.1.1 Lateration

- 3. Attenuation
- Most signals , especially radio signals will loose power over distance.
- Radio signals as with most physical phenomena will attenuate proportion to the inverse square law. This can be used to calculate distance based on the priori knowledge of how strong the signal was originally
- $1 / R^2$



2.1.2 Angulation

- Using Angle to estimate distance , instead of distance
- More commonly used now with optical tracking systems.
- Phased Antenna arrays allows the device to figure out what angle a signal is coming from.
- Lighthouse system for the VIVE
- Remember Graphics when you used the implicit line, discovering distance using angles.

2.2 Scene Analysis

- Natural Feature Tracking
- Tracking the distance between successive scenes to estimate location
- Last week we explore how feature tracking could be used to generate 3D geometry, this can be similarly used to track the camera location.
- Scene analysis can also be done for different forms of the EM spectrum , not just light , but any signal can used to help track a scene

2.3 Proximity

1. Detecting physical contact
   - Pressure sensors , touch sensors and capacitive field detectors
   - Common on current mobile smart phones.
2. Monitoring wireless cellular access points
   - Mobile towers give an approximate location as if a phone signal can reach them it proves that the phone is within a set range. Used by police to find if a suspect phone was in an area
   - This can be used in an indoor sensors but requires multiple sensors so can prove costly.
3. Observing automatic ID systems
   - Smart cards like NFC tags
   - Tags read through optical tracking like Car licenses plates

3 Location System Properties

- Describes the factors that will be used to build up the taxonomy.
  - Physical Position and Symbolic Location
  - Absolute versus Relative
  - Localized Location computation
  - Accuracy and prediction
  - Scale
  - Recognition
  - Cost
  - Limitations

3.1 Physical Position and Symbolic Location

- Physical location gives you an exact position relative to some sort of coordinate system
- This can be like GPS , a longitude or latitude
- Alternatively you can have symbolic position , such as saying an object is at certain location like BJUT is in Beijing or UCD is in Dublin.

3.2 Absolute versus Relative

- When describing objects in a systems, we need to understand if they have an **absolute** position , meaning they have one shared reference such as an object described by a GPS system
- A **relative** position on the other hand is when each object has its own frame of reference. Such as one objects distance in relation to another.
- Thus if you have a number of relative positions , you can build up a map of the objects that would be considered an absolute position system.

3.3 Localized Location computation

- Two approaches to deciding whether the system or the devices devices within a tracked environment are the ones responsible for processing their location.
- A passive system like GPS reads signals , and the satellites providing that network do not know about the GPS reading devices. This guarantees privacy for the devices
- Other systems are probe the objects such as Radio tags , where the devices depend on the infrastructure to compute their location.

3.4 Accuracy and Precision

- Accuracy is the granularity of the position information a device can provide.
- Precision is how often you can trust that accuracy.
- Using multiple sensors , you can improve both these factors by adding more devices. This is considered a form of sensor fusion
- Beijing companies such Noitiom , create devices such as Perception Neuron , this devices takes several Inertial trackers and combines them to all for full body tracking.

3.5 Scale

- Each tracking system must be assessed on its scalability.
- GPS is world wide but most tracking system due to their technology are limited in range.
- Also different tracking systems scale not only in range but also scale in terms of then umber of objects that can be tracked at any given time.
- Outside of each using pulsars , an intergalactic pulsar-based GPS can be used through these natural sources. Giving you an accuracy of around 5 kilometres.

3.6 Recognition

- Systems that recognize objects directly within the system and track them with specific ID tags
- These Global Unique ID’s can then be used with other contextual information to allow a system to make an intelligent choice of how to process the object.
- System like GPS can allow the devices tracked to broadcast their position allowing the system to recognize that the objects within the system.

3.7 Cost

- An important factor in any real system is of course cost.
- Most tracking systems due to commercial pressure reduce in cost over time.
- Magnetic trackers that we used in UCD cost over 3000 euro but now only cost 100 euro
- GPS system used to cost 100's of euros but now the chip inside your smart phone less than euro .

3.8 Limitations

- Tracking always depends on the environment
- GPS for instance doesn't work well in built up environments as the radio wave gets bounced around and your receiver thus gets reflections as well as the real signal.
- In general system can have multiple sources of interference that must be taken into account.

4 A Survey of locations Systems

- This information is stored in two tables
- For your course you do not need to know much about these systems as many have been replaced with time.
- But it’s a good resource as if you had a project that need similar technology they would be an excellent starting point.

	lateration						
Active Badges	Diffuse infrared cellular proximity		•	•			√
Active Bats	Ultrasound time-of-flight lateration	•		•			√
MotionStar	Scene analysis, lateration	•		•			√
VHF Omnidirectional Ranging (VOR)	Angulation	•		•		√	
Cricket	Proximity, lateration		•	◦	◦	√	
MSR RADAR	802.11 RF scene analysis & triangulation	•		•			√
PinPoint 3D-iD	RF lateration	•		•			√
Avalanche Transceivers	Radio signal strength proximity	•			•		
Easy Living	Vision, triangulation		•	•			√
Smart Floor	Physical contact proximity	•		•			√
Automatic ID Systems	Proximity		•	◦	◦		√
Wireless Andrew	802.11 cellular proximity		•	•			√
E911	Triangulation	•		•			√
SpotON	Ad hoc lateration	•			•		√

Name	Accu & Prec	Scale	Cost	Limitations
GPS	1-5 meters (95-99%)	24 satellites worldwide	Expensive infrastructure, \$100 receivers	Not indoors
Active Badges	Room size	1 base per room, badge per base per 10 sec	Administration costs, cheap tags & bases	Sunlight & fluorescent interference with infrared
Active Bats	9cm (95%)	1 base per $10m^2$, 25 computations per room per sec	Administration costs, cheap tags & sensors	Required ceiling sensor grids
MotionStar	1mm, 1ms, 0.1° (nearly 100%)	Controller per scene, 108 sensors per scene	Controlled scenes, expensive hardware	Control unit tether, precise installation
VHF Omnidirectional Ranging (VOR)	1° radial (≈100%)	Several transmitters per metropolitan area	Expensive infrastructure, inexpensive aircraft receivers	30-140 nautical miles line of sight
Cricket	4x4 ft. regions (≈100%)	≈ 1 beacon per 16 sq. ft.	\$10 beacons & receivers	No central management, receiver computation
MSR RADAR	3-4.3m (50%)	3 bases per floor	802.11 network installation, ≈\$100 wireless NICs	Wireless NICs required

			sive hardware	ence
Avalanche Transceivers	Variable, 60-80m range	1 transceiver per person	≈$200 per transceiver	Short radio range, unwanted signal attenuation
Easy Living	Variable	3 cameras per small room	Processing power, installed cameras	Ubiquitous public cameras
Smart Floor	Spacing of pressure sensors (100%)	Complete sensor grid per floor	Installation of sensor grid, creation of footfall training dataset	Recognition may not scale to large populations
Automatic ID Systems	Range of sensing phenomenon (RFID typically ¡ 1m)	Sensor per location	Installation, variable hardware costs	Must known sensor locations
Wireless Andrew	802.11 cell size (≈100m indoor, 1km free space)	Many bases per campus	802.11 deployment, ≈$100 wireless NICs	Wireless NICs required, RF cell geometries
E911	150-300m (95%)	Density of cellular infrastructure	Upgrading phone hardware or cell infrastructure	Only where cell coverage exists
SpotON	Depends on cluster size	Cluster at least 2 tags	$30 per tag, no infrastructure	Attenuation less accurate than time-of-flight

5 Applying the taxonomy

- Case study of a personal ubiquitous jukebox
- Customized audio streams that are played on nearby speakers.

  - Physical versus **Symbolic** -> **Symbolic** as once the speakers know he is nearby and they are closest it does not matter the precise distance.
  - **Absolute** or Relative -> Absolute due to fixed speakers.
  - **Localized local Computation** -> needs to compute users location and maintain access controls for privacy.

5 Applying the taxonomy (continued)

- **Recognition** -> Need to separate out users
- **Accuracy and Precision** -> 4- 6 m and a 99% precision
- **Cost** -> low cost
- **Limitations** -> indoor

- The paper recommends, Active badge technology , only one thing I would disagree as Bluetooth with Attenuation (e.g. how strong the signal is) solves much of this problem.

6 Research Directions / 6.1 Sensor Fusion

- Lower cost, reducing infrastructure requirements, improving scalability and increasing the flexibility of potential systems.
- Sensor fusion research needed to connect all these different systems and use them to reduce error
- Huge Field of Robots has been using sensor fusion for the last 20 years and continues to do so.
- Many of those techniques have been brought into VR and AR tracking devices.

6.2 Ad Hoc Location Sensing

- Ad hoc mesh networks are becoming more common and using Attenuation , the strength of signally themselves can be used to self organise.
- Leads to a highly scalable approach.
- UCD projects in this area include SIXTH (which you can learn more about by searching our papers online)

6.3 Location-Sensing System Accuracy: A challenge

- One great challenge is configure a sensor network
- One solution to this is using Simulations to help define what system we need.
- The paper mentions a solution to this problem using game engines
- Game engines allow us to simulate in VR these sceanrios and the paer demonstrates how to make AR possible, Research into VR is essential
- Next week, Game Engines will be our topic

Re-sit paper for AR/ VR

- In the very unlikely event that someone does fail the course
- The re-sit exam will not be open book.
- This is important to note as it was last year so this slide is just to formal announce this now.
- As it will to be open book though I can make the questions a lot easier than I do the main exam paper.

References

- Lots of websites (with access times) but many maybe gone by the time the reader could access them.
- Mostly just naming different Location system so not much to be interested in
- Only two self references so the author is not over promoting himself.
- References Sebastin Thrun who he would later work with in Google.
- Thrun is responsible for a lot of google major projects

Next Papers

- Next week we are going to discuss Game engines. (This topic is wide so I have narrowed to three interesting areas using short papers)

- 10 pages in total.

- To help us I got 3 short papers to outline three important aspects
  - Game Engines for Research
    - GAME ENGINES IN SCIENTIFIC RESEARCH By Lewis and Jacobson 2002
  - Using a Game Engine in AR
    - ARQuake The Outdoor Augmented Reality Game System by Piekarski and Bruce Thomas 2002
  - First easy to use Game engine for VR
    - Alice: A Rapid Prototyping System for Building Virtual Environments Conway, Pausch, Gossweile and Burnette 1994