

Programming Ubiquitous Things 2024/25 - Spring 2025 - UiO

Other Approaches and Conclusions

Prof. Paulo Ferreira
paulofe@ifi.uio.no
UiO/IFI/PT

© Paulo Ferreira

1



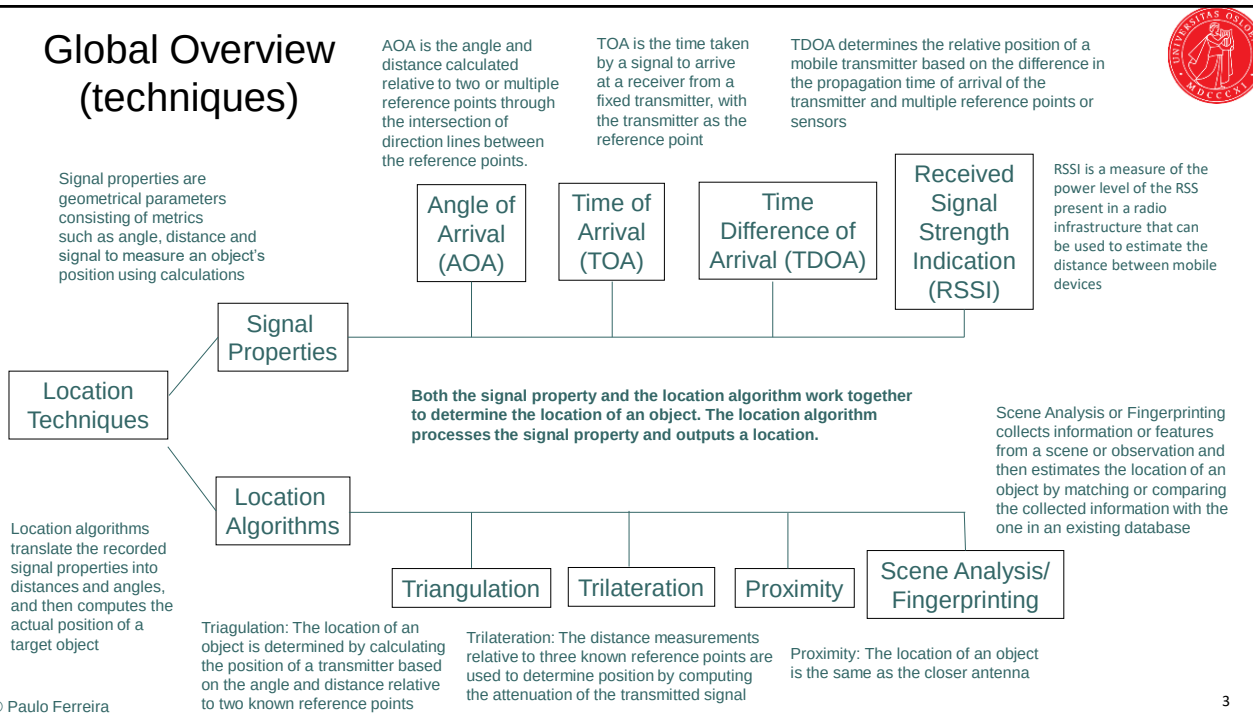
Contents

- Introduction and some basic definitions
- GPS and Differential GPS
- Infrared and Ultrasonic Location Systems
- Location Estimation with 802.11
- Cellular-Based Systems
- Other Approaches
- Location-Based Applications and Services
- Conclusions

© Paulo Ferreira

2

Global Overview (techniques)



© Paulo Ferreira

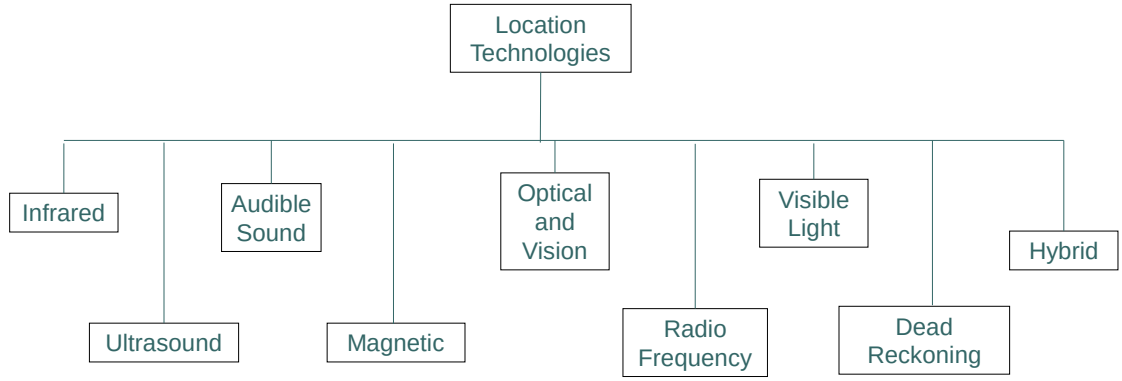
Global Comparison – signals properties and location algorithms

Signal property	Measurement metric	Pros	Cons
Angle of Arrival (AOA)	Angle-based	High accuracy at room level	Complex, expensive and low accuracy at wide coverage
Time of Arrival (TOA)	Distance-based	High accuracy	Complex and expensive
Time Difference of Arrival (TDOA)	Distance-based	High accuracy	Expensive
Received Signal Strength Indication (RSSI)	Signal-based (RSS)	Low cost	Medium accuracy

Positioning algorithm	Signal property	Pros	Cons
Triangulation	AOA	Simple, low-cost and high accuracy at room level	Complex, expensive and low accuracy at wide coverage
Trilateration	TOA/TDOA	High accuracy	Complex and expensive
Proximity	RSSI	High accuracy	Complex and expensive
Scene analysis/fingerprinting	RSSI	High performance	Complex, expensive, medium accuracy and time consuming

© Paulo Ferreira

Global Overview (technologies)



© Paulo Ferreira

5

Other Approaches

© Paulo Ferreira

6

Other Approaches – Introduction



- The location technologies we have described thus far:
  - vary in cost, coverage, and accuracy,
  - all are used in commercial location systems, and
  - all have reached wide-scale adoption in one or more application niches
- There are, however, **many other location technologies that have not gotten beyond the research laboratory or the prototype stage**
- There are **others**, too, that have been **largely perfected**, but due to **small coverage or exceptionally high cost** have not moved beyond a few highly **specialized niches**
- Some systems:
  - have 1 mm average error, and the least, with almost 100 km average error
  - eliminate the need for people to carry beacons or listeners and instead use a person's visual appearance, noise profile, or ground reaction forces to track them through an environment
  - in addition to the GPS, 802.11, and cell-phone-based system, there are many other radio-based systems based on both standard and custom protocols ranging in spectrum from 33 kHz up to 7 GHz

© Paulo Ferreira

7

Other Approaches – Systems



- Instrumented surfaces (base location estimation on something physical and fundamental):
  - Smart Floor, Magic Carpet
  - load sensors placed in the floor are likely to be robust, unobtrusive, and low-maintenance,
  - whereas some of these systems are **limited in their handling of multiple occupancy situations**, they can correctly detect occupancy and thus still work well for occupancy-based services
  - they **can be easily used into an existing home or office space** (assuming the elevated floor is OK)
- Vision:
  - it is one of the few approaches that **do not require instrumenting or tagging** the entity to be located
  - mobile (e.g., robotic navigation) / fixed cameras (e.g., track the location of the people that appear on camera),
  - visual tags (e.g., 2-D barcodes designed to be easily recognized by cameras)
- Laser range finders, Audible sound, Internet protocol measurement, Magnetic field strenght, Radio frequency identification tags, Radio from FM to ultrawide band, etc.

© Paulo Ferreira

8

Other Approaches - Comparison



Technology	Smart floors	Vision with fixed cameras	Vision + 2D tags	IP measurement
Accuracy	★★★★ 2D location with 10 – 20 cm accuracy (person may not be IDed)	★★★☆ 3D location with 10 – 100 cm depending on camera density	★★★★ 3D location with 1 cm accuracy when observed from < 2 m away	★☆☆☆ 2D location with 70-200 km accuracy
Coverage	★★☆☆ In rooms fit with in-floor sensors. Performs poorly with multiple users in room	★★☆☆ Indoor/outdoor in view of camera	★★☆☆ Indoor/outdoor in view of camera	★★★★ worldwide for any networked computer device
Infrastructure cost	★☆☆☆ Cost of retrofitting for load sensors prohibitive	★★☆☆ Requires networked cameras in each room	★★☆☆ Requires networked cameras in each room	★★★★ uses existing IP network
Per-client cost	★★★★ Requires no user instrumentation	★★★★ Requires no user instrumentation	★★★☆ Requires 2D tags on objects / people to be tracked	★★★★ Requires no extra hardware or software
Privacy	★★☆☆ User's location known, but identity often not	★☆☆☆ Video surveillance among worst intrusions on privacy	★☆☆☆ Video surveillance among worst intrusions on privacy	★★★★ No addition information released
Well-matched use cases	Assisted living, HVAC/smart home control	Asset and personnel tracking, security / surveillance	Asset and personnel tracking	National/regional information and advertisement delivery

© Paulo Ferreira

9

Other Approaches - Comparison



Technology	Magnetic field strength	RFID with fixed readers and mobile tags	Ultra-wide band radio TOF/AOA	TDOA from digital TV
Accuracy	★★★★ 3D location with 1 mm accuracy	★★★☆ Room (or area of room) with high accuracy	★★★★ 3D location with 15 cm accuracy	★★☆☆ 3D coordinates with 10-20 m median accuracy
Coverage	★☆☆☆ User must be within 3 meters of transmitter	★★☆☆ Indoor in room fit with readers	★★☆☆ Indoor in range of UWB listeners	★★★★ indoor/outdoor in range of TV towers
Infrastructure cost	★☆☆☆ transmitters cost $50k+ US	★☆☆☆ Long-range RFID readers required for each room	★★☆☆ Requires 2+ UWB listeners	★★★★ piggybacks timing info on existing TV signals
Per-client cost	★☆☆☆ Users fit with costly magnetic sensors	★★★★ Each object / person requires inexpensive tag	★★★☆ UWB badge required	★★★☆ antenna and chipset required
Privacy	Not a factor for such specialized systems	★★☆☆ Locations tracked by infrastructure. Opt-out by removing tag	★★☆☆ Locations tracked by infrastructure. Opt-out by removing badge	★★★★ Location is estimated passively on the local unit
Well-matched use cases	Motion capture for video games and animated media (cartoons)	Asset and personnel tracking, indoor mapping/ navigation/tour guides	Asset and personnel tracking, indoor mapping/ navigation/tour guides	Social networking, assisted living, activity tracking

© Paulo Ferreira

10

Location-Based Applications and Services

© Paulo Ferreira

11

Location-Based Applications and Services

- Navigation and way-finding
- Asset tracking
- Emergency response
- Geofencing
- Location-based content and search
- Social networking
- Health and wellness
- Gaming and entertainment










© Paulo Ferreira

12

Conclusions



- It’s a hot topic
- Much more is expected in the near future:
  - applications
  - security
  - technologies
  - behaviour changes
  - social impact
  - etc.
- Stay tuned !

© Paulo Ferreira