Indoor positioning using smartphones

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  - Targeted advertisement and analytics.
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- *Internet-of-things (IoT):*
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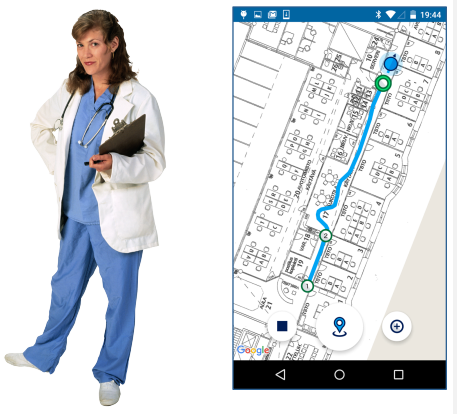
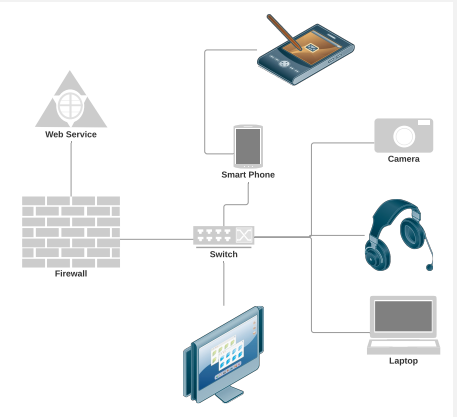
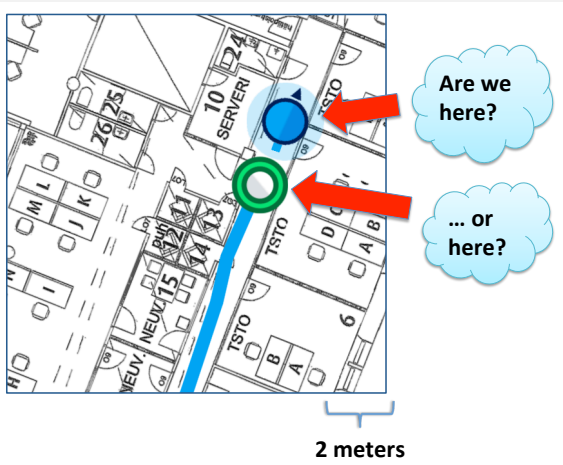
  - Ad-doc network formation.
- *Safety and security:*
  - Navigation in burning buildings.
  - Security personnel tracking.

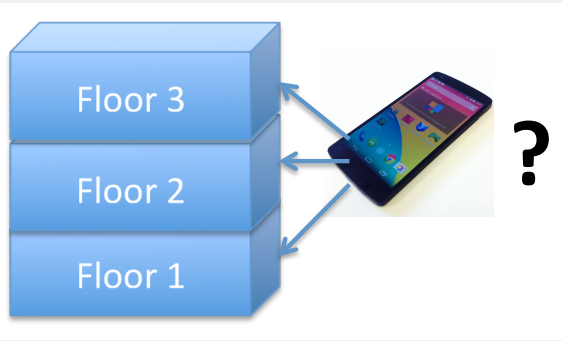




Why indoor positioning is hard

- GPS does not work indoors – nor any other satellite navigation system.
- The accuracy requirement is often 1 meter.
- Mobile phone network positioning is not accurate enough.
- Accurate height information is important (which floor).
- Indoor maps can be challenging to obtain.



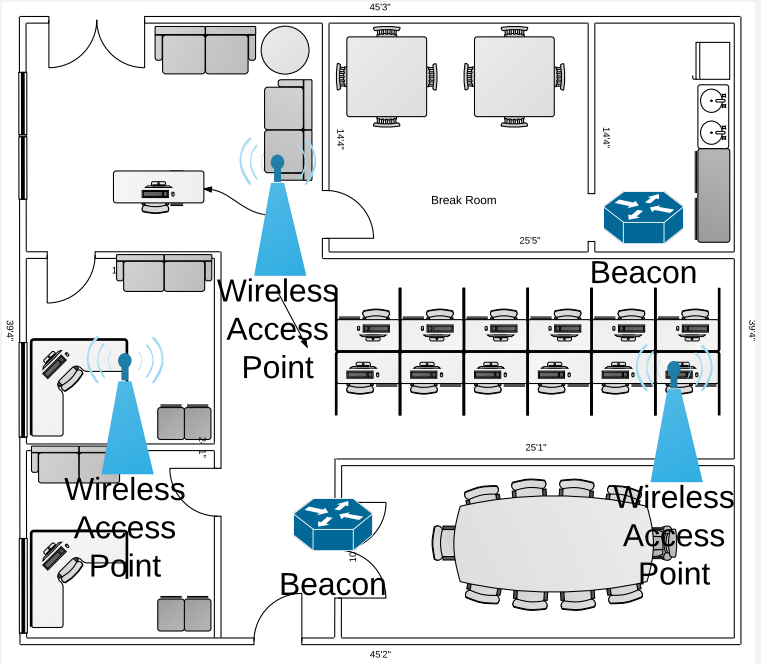


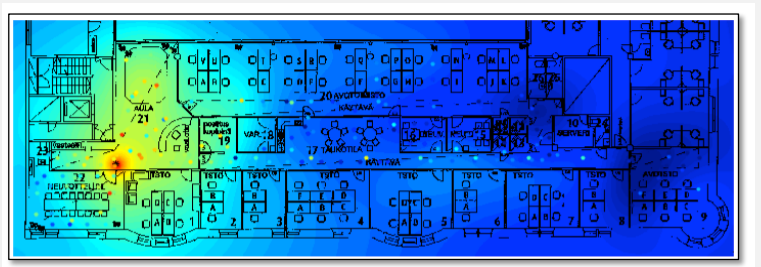
Sensors in modern smartphones

- GPS/GNSS receiver for (outdoors) satellite positioning.
- Accelerometer and gyroscope measure the local moment and rotation.
- WiFi, Bluetooth, and 3G/4G/5G measure radio signals.
- Magnetometer (compass) measures the local magnetic field direction.
- Barometer measures the local pressure (gives information on height).
- Camera measures the optimal properties of the environment (i.e. takes pictures).

WiFi and beacon-based positioning

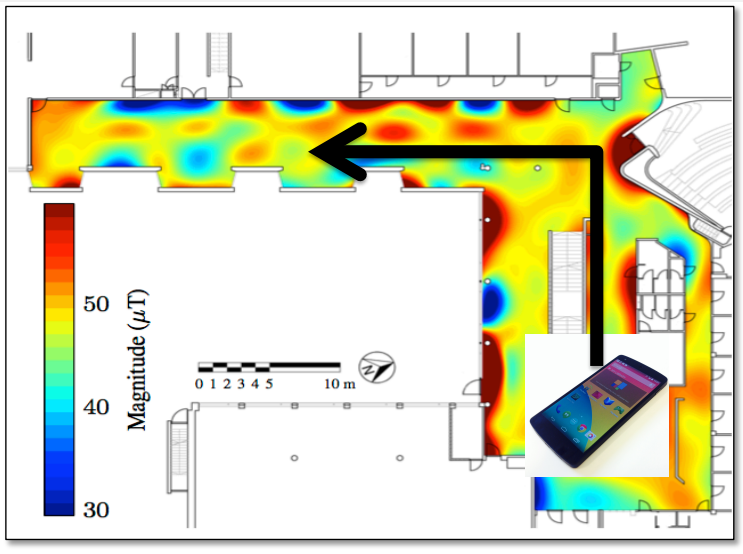
- WiFi and (Bluetooth) beacons are often used for indoor positioning.
- Based on measuring strengths of radio transmitters in known locations.
- Requires building a map of the radio environment.
- Accuracy is limited by local attenuation and device differences.
- Radio maps need to be updated continuously – can be labour-intensive.





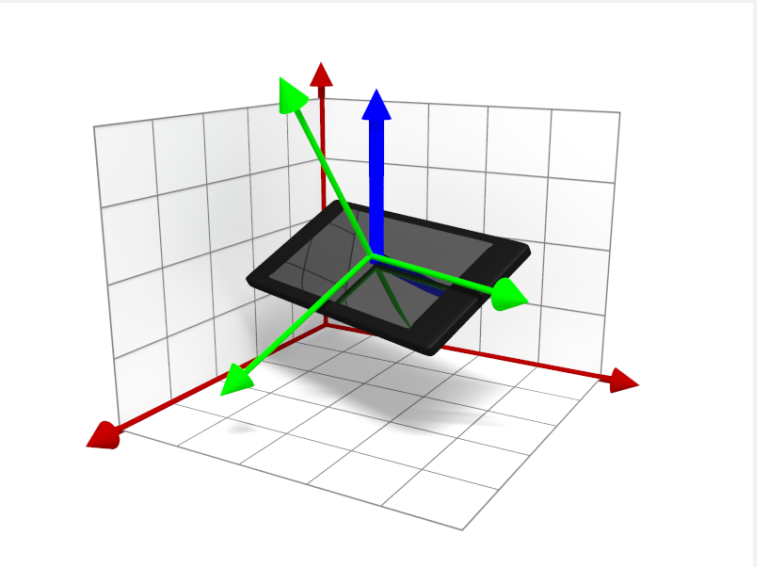
Magnetic positioning

- Magnetic positioning utilizes local magnetic field variations in buildings.
- Requires creating a map of the magnetic field variations.
- Due to field ambiguity, needs to combined with inertial navigation and orientation tracking.
- Locally accurate, benefits from combining with WiFi/Beacon positioning.



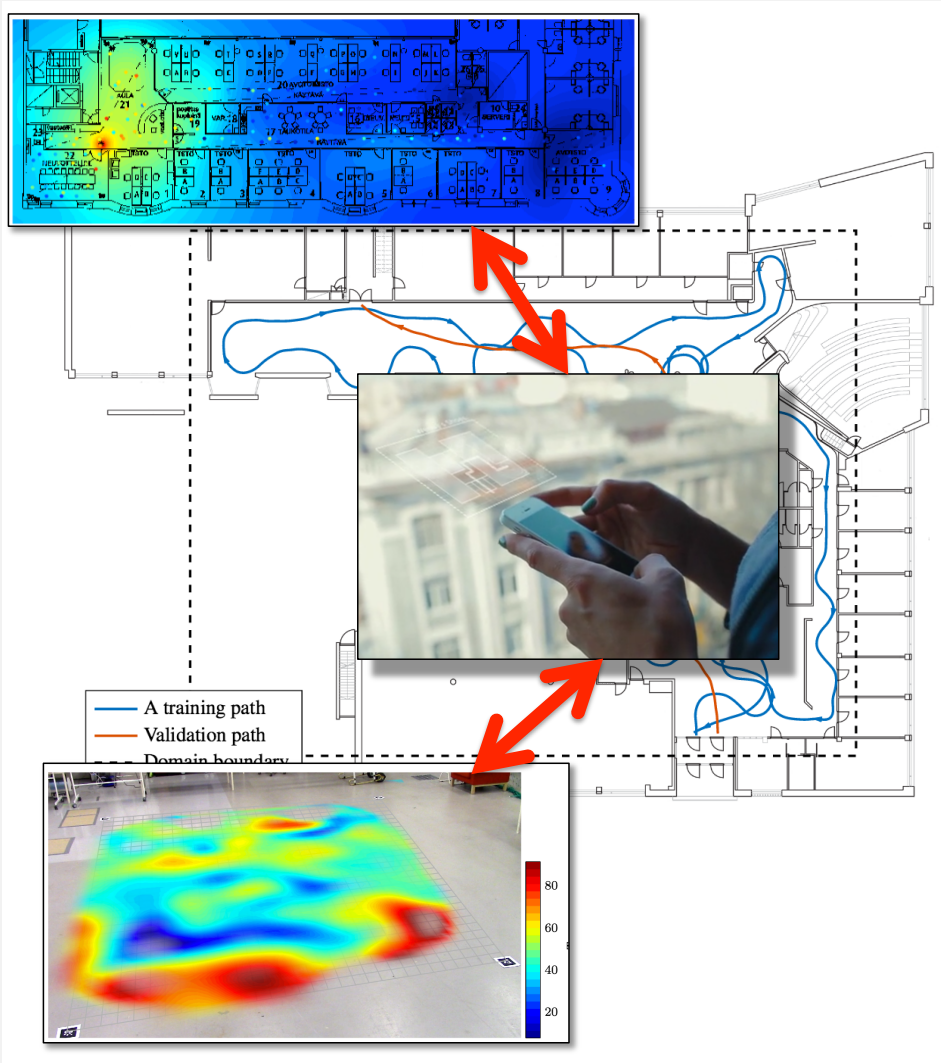
Inertial navigation, PDRs, and orientation tracking

- Acceleration and angular velocity can be integrated to give position and orientation.
- Unknown initial conditions and sensors drifts cause problems.
- The known gravitation direction helps in orientation tracking.
- Accelerometer can also be used to detect steps – gives a measurement of speed/distance.
- Barometer can be used to for local height tracking.
- Best when combined with radio and magnetic positioning methods.



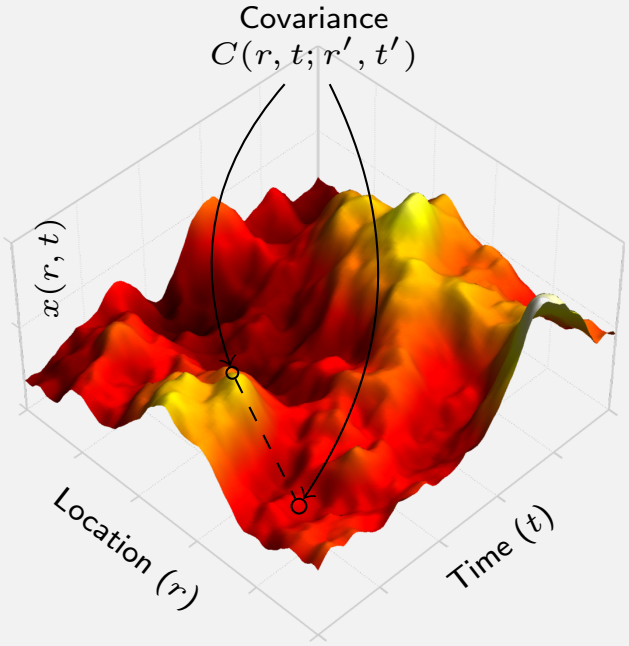
Simultaneous localization and mapping (SLAM)

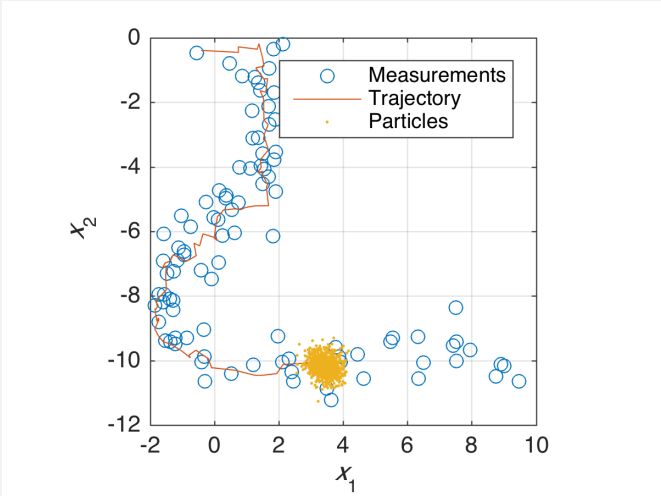
- In simultaneous localization and mapping (SLAM) the radio/ magnetic map is created while positioning.
- Considerably harder than separate mapping and positioning.
- Typically based on detecting a return to known location:
  - We can do a loop closure to confirm the traveled path.
  - Inertial navigation can be used to map a small unknown area at a time.
  - Known wall locations provide constraints.



Gaussian processes, Kalman and particle filtering

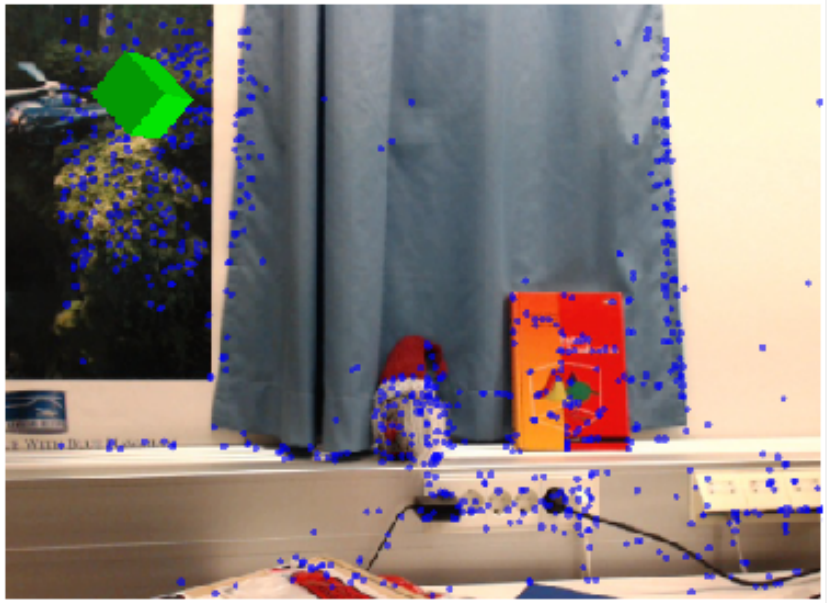
- WiFi, beacon, and magnetic maps typically estimated using Gaussian processes (GPs).
- GPs are machine learning tools for learning the field from noisy observations.
- Inertial sensor fusion is often done using (extended) Kalman filters.
- Sensor fusion with radio and magnetic often done with particle filters.
- When combined, can be used for simultaneous localization and mapping (SLAM).
- Generally, multi-sensor processing is treated as a (Bayesian) statistical inverse problem.

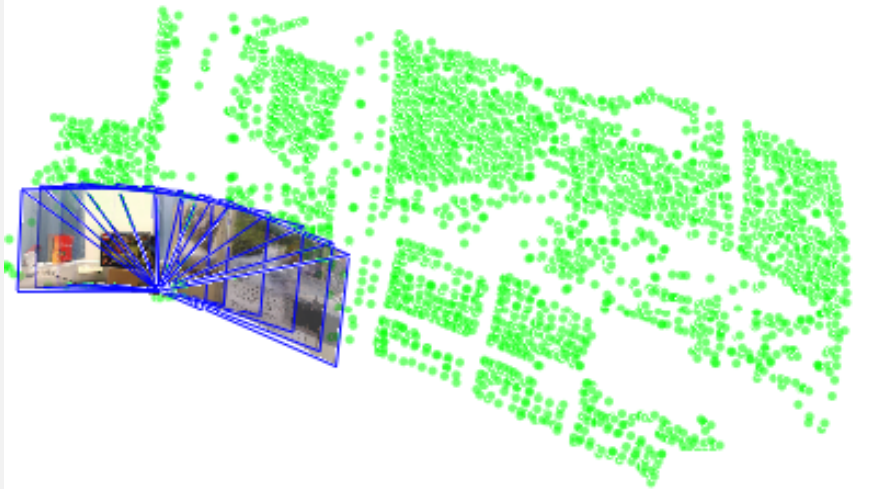




Computer vision, future insights

- Smartphone camera can be used for determining the 3D structure of indoor environment.
- When combined with SLAM, eliminates the need for floorplans – and eases SLAM.
- Even better is to use a depth-camera, laser, or miniature radar.
- Other improvement possibilities:
  - Cooperative positioning.
  - Other signals of opportunity.
  - Modeling of human behaviour.





Summary

- Indoor positioning has applications, e.g., in shopping malls, hospitals, internet-of-things, and security.
- Hard, because GPS does not work indoors and the accuracy requirements are tight.
- Smartphones have a number of sensors: radio, inertial, magnetic, and barometer sensors (among others).
- Indoor positioning typically use WiFi, beacons, or magnetic field variations.
- Inertial navigation, step counting, and barometer can be combined with the methods.
- Simultaneous localization and mapping (SLAM) methods build maps while positioning.
- Computational methods include Gaussian processes together with Kalman and particle filters.