EG-M42 Software for Smartphone: **Task Introduction: Indoor Wireless Localisation**

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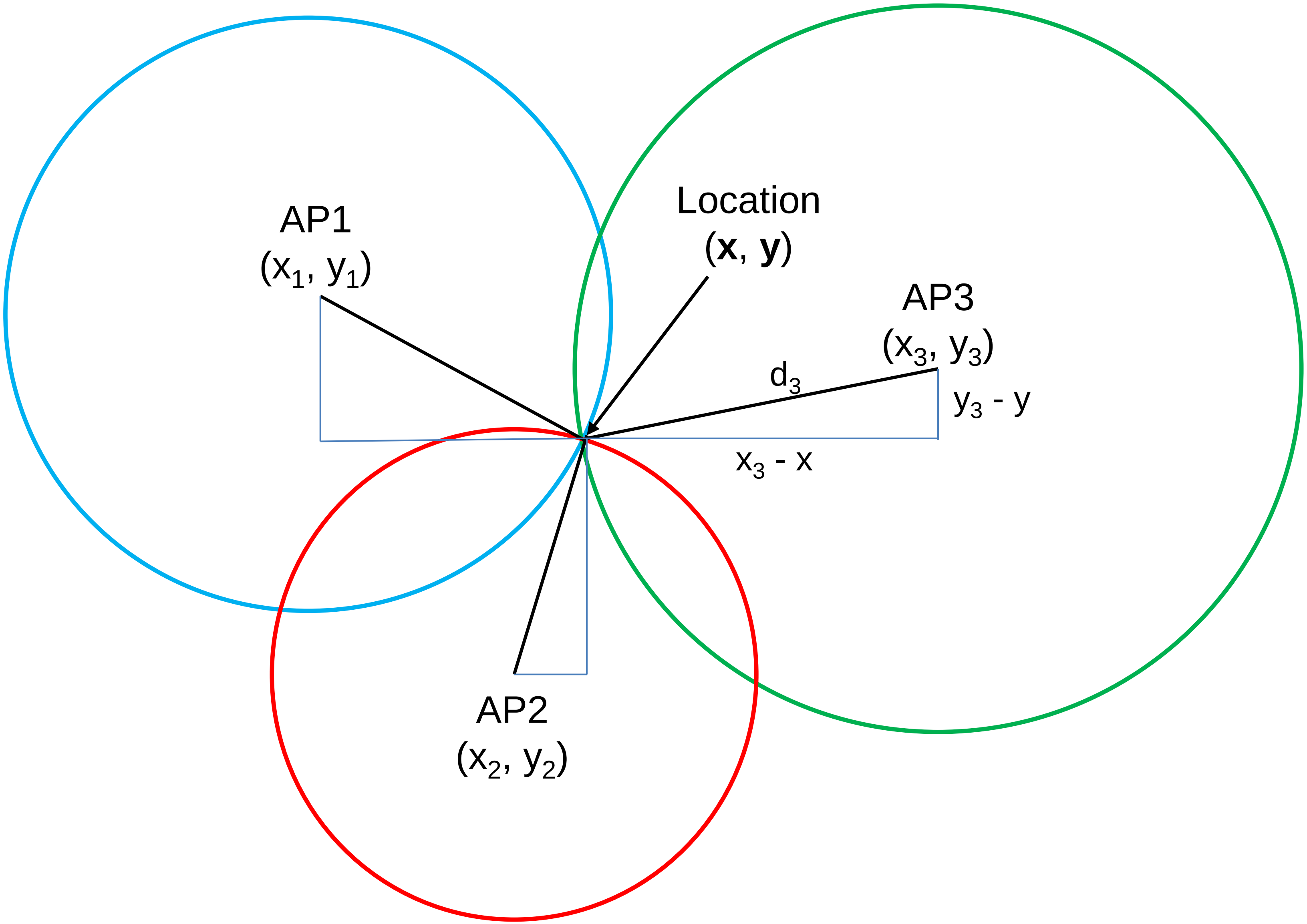
Outline

- Introduction
- Localisation Techniques
  - Geometric Approaches
  - Location Fingerprinting
- Android App for Indoor Localisation
  - Overview
  - Requirements

Geometric Approach: Trilateration



Geometric Approach: Trilateration

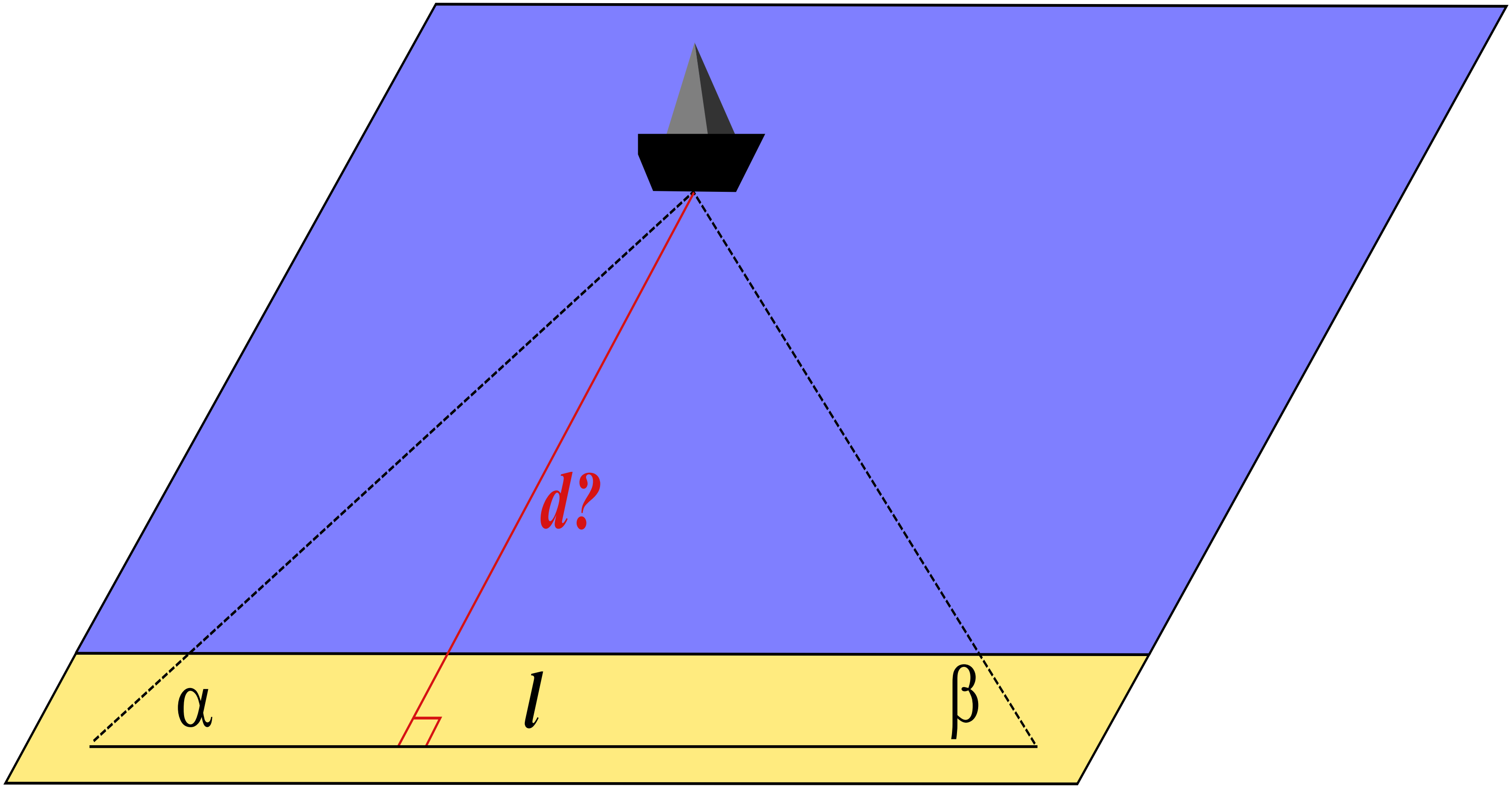
- 3 equations for 2 unknowns (i.e., x & y)

$$(x_1 - x)^2 + (y_1 - y)^2 = {d_1}^2$$
$$(x_2 - x)^2 + (y_2 - y)^2 = {d_2}^2$$
$$(x_3 - x)^2 + (y_3 - y)^2 = {d_3}^2$$

- Matrix form of equations after rearrangement

$$2\begin{bmatrix} x_3 - x_1 & y_3 - y_1 \\ x_3 - x_2 & y_3 - y_2 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \end{bmatrix}$$
$$= \begin{bmatrix} \left({d_1}^2 - {d_3}^2\right) - ({x_1}^2 - {x_3}^2) - ({y_1}^2 - {y_3}^2) \\ \left({d_2}^2 - {d_3}^2\right) - ({x_2}^2 - {x_3}^2) - ({y_2}^2 - {y_3}^2) \end{bmatrix}$$

Geometric Approach: Triangulation



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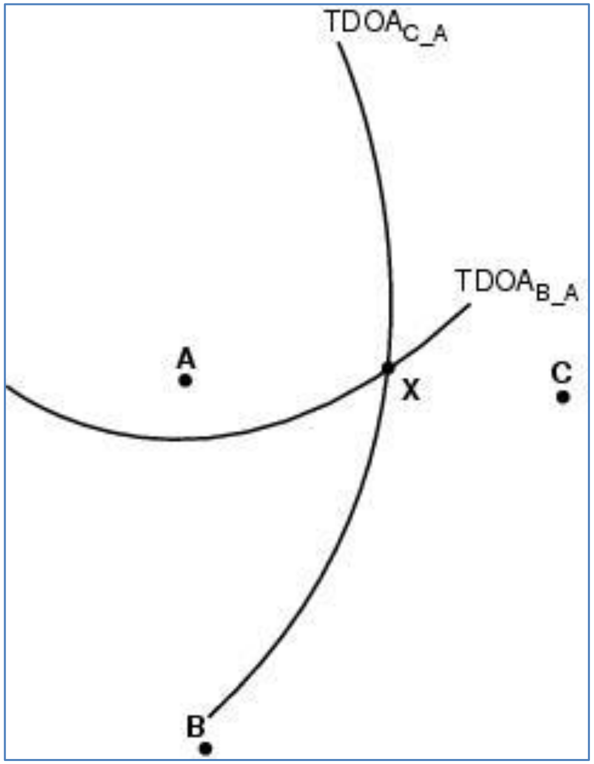
Geometric Approach: Distance Measurement Techniques

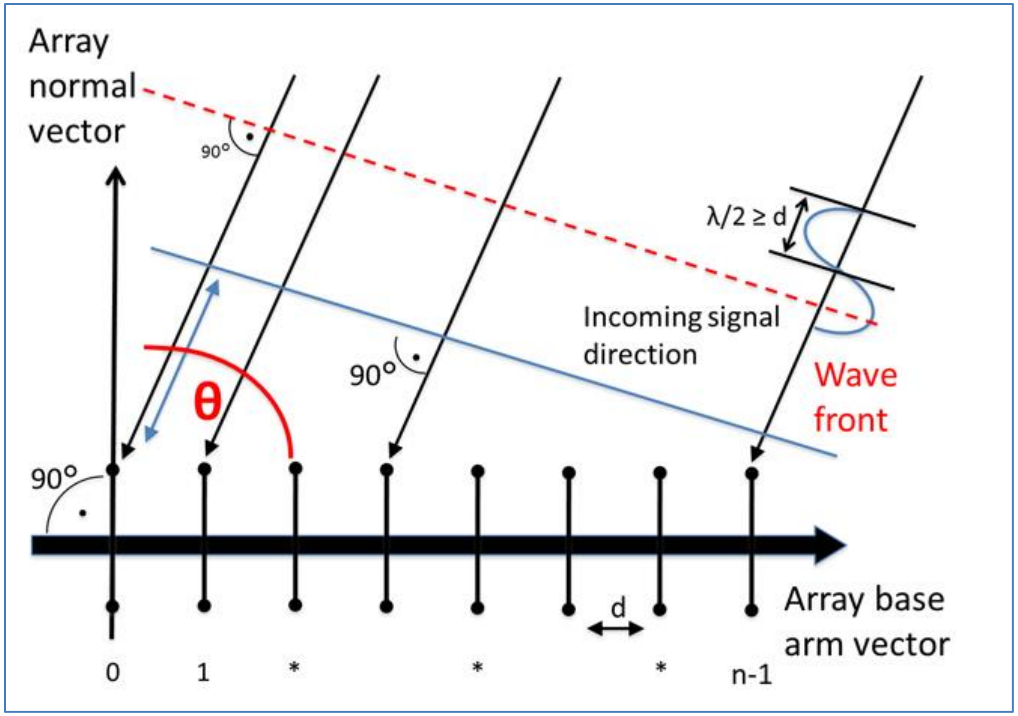
- Based on time delay
  - Time of Arrival (TOA)
  - Time Difference of Arrival (TDOA)
  - Example: GPS
  - Requirement: Synchronisation between RXs and TX (TOA) or among RXs (TDOA)



- Based on received signal strength
  - Based on path loss model
    - e.g. $P(d) = P(d_0) - \eta 10 log\left(\frac{d}{d_0}\right) + X_\sigma$

Geometric Approach: Angle Measurement Techniques

- Angle of Arrival (AOA)
  - Based on TDOA (i.e., phase difference) of array antenna



Location Fingerprinting: Example

- Indoor Navigation System - Positioning demo in hallway

Location Fingerprinting: Location Fingerprint

- Location fingerprint is denoted as a tuple of ($\mathcal{L}$,$\mathcal{F}$), where
  - $\mathcal{L}$ is location information like coordinates (e.g., (x,y,z)) and indicator variables (e.g., 'Talbot286');
  - $\mathcal{F}$ is a vector of received signal strengths (RSS), i.e., $(\rho_1, \cdots, \rho_N)^T$ where ρ_i is the average RSS from AP_i.
    - Optionally, we can add a vector of standard deviations to $\mathcal{F}$.
  - Alternative approach is the use of *conditional probability distribution* (i.e., *likelihood function*) as location fingerprint → Probabilistic methods.

Location Fingerprinting: Location Estimation

- Deterministic
  - **Nearest Neighbour Methods**
  - Neural Network Methods
- Probabilistic
  - Bayesian Inference
  - Support Vector Machine (SVM) technique
  - Gaussian Process Latent Variable Model (GP-LVM)

Nearest Neighbor Methods*

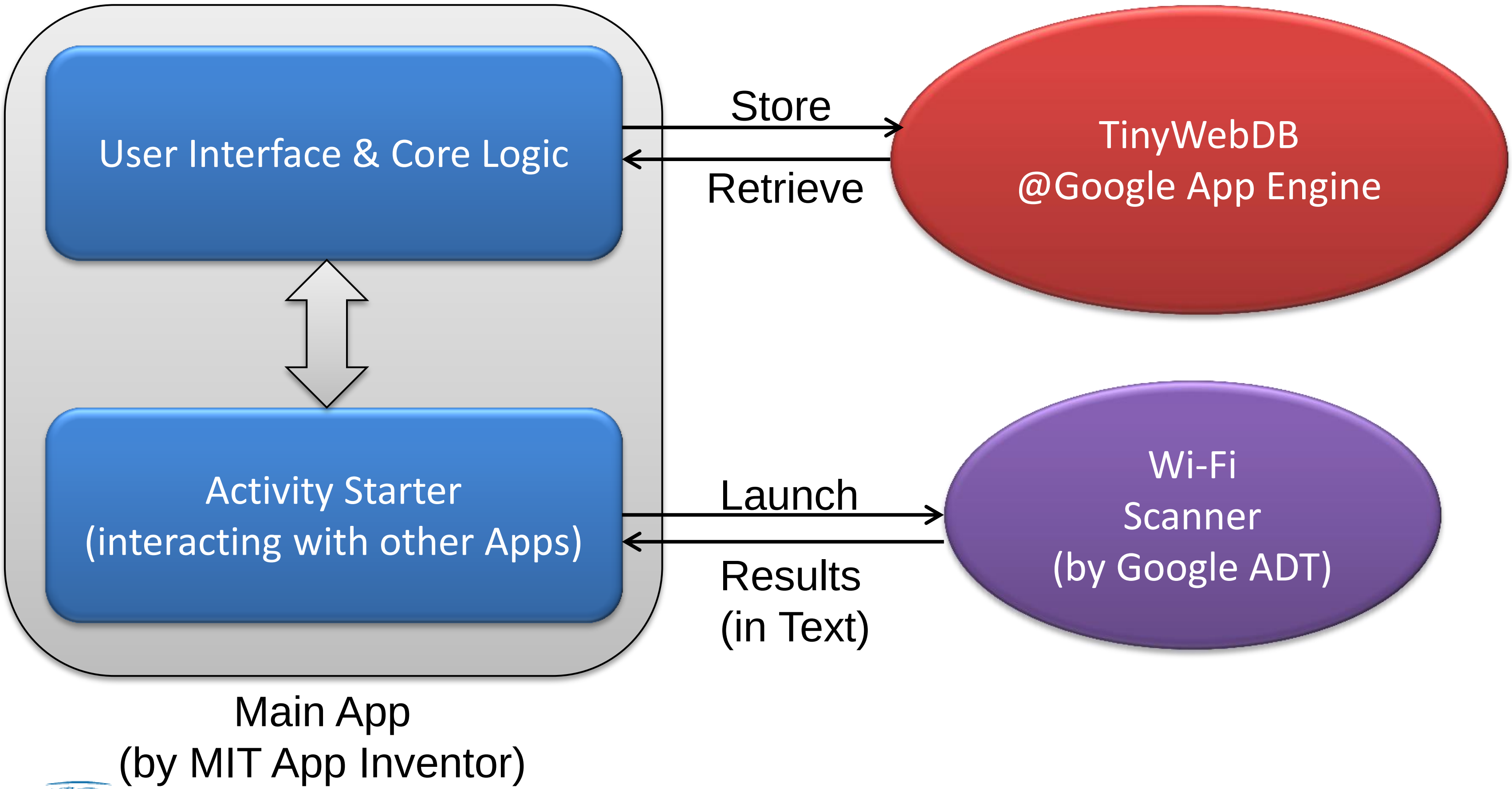
- A simple approach based on the notion of distance in signal space:
  - Given a fingerprint of $(\mathcal{L}, (\rho_1, \cdots, \rho_N)^T)$ and an RSS measurement of $(s_1, \cdots, s_N)^T$, the *Euclidean distance* measure is defined as

$$sqrt\left(\sum_{i=1}^{N}(s_i - \rho_i)^2\right)$$

  - Then, we find a fingerprint providing a minimum distance, $\mathcal{L}$ of which is the estimated location.

* P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system," Proc. of INFOCOM 2000, vol. 2, pp. 775-784, Mar. 2000.

Android Apps for Indoor Localisation: Overview



Android Apps for Indoor Localisation: Requirements

- Minimum 3 locations
  - Inside Talbot 286
  - (Just) outside Talbot 286
  - (Nearby) Corner
- Priority
  - Accuracy of estimation
  - User interface
  - Speed of response