Multimodal Indoor Localization using Heterogeneous Technologies

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Outline

- Introduction
- Heterogeneous Localization Technologies
- Combination Approach
- Experiment Results
- Conclusion

Location based services

- Information customization based on user location
- Navigation guide
- Location-based advertising
- Security surveillance, alert, notification, warning,…
- …

Indoor localization

- **GPS generally works only outdoor ➔ search for indoor localization schemes**
- **Many approaches proposed for indoor localization: cellular networks, infrared, ultrasonic, computer vision, RFID…**
  - All suffer either from the limited accuracy, range, lacking of the infrastructure, or high deployment price

➔ **Combination of multiple technologies to overcome the limitation of individual ones**

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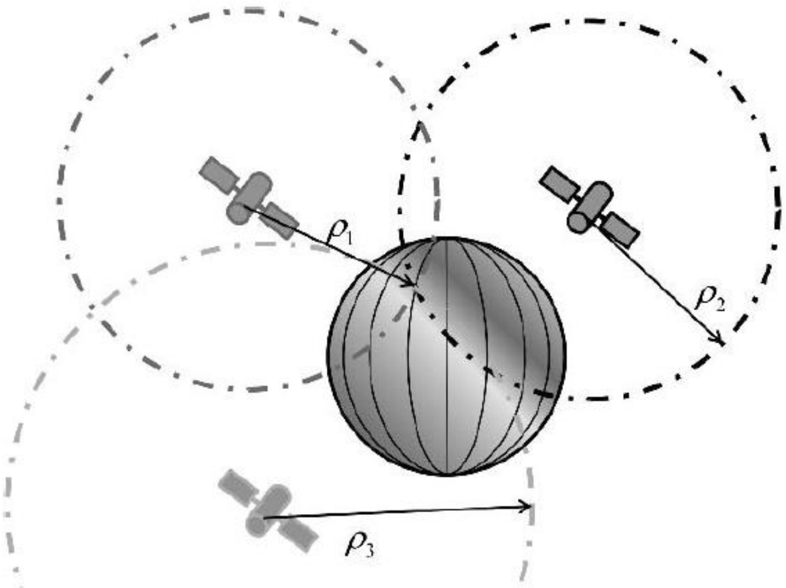
GPS, GALILEO

- **Principle:**
  - TOA → distance to satellites
  - Least square solution



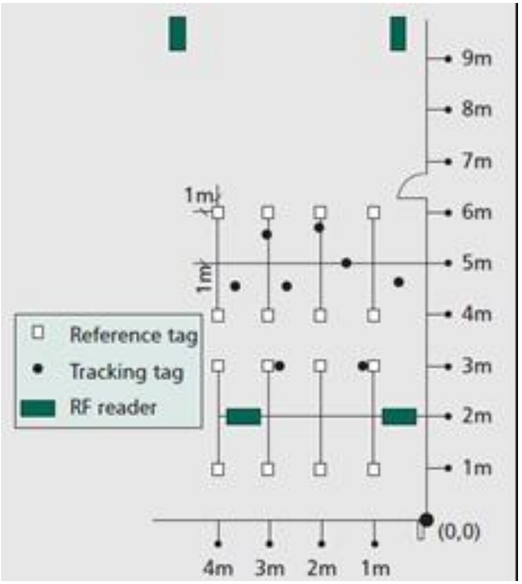
- **Accuracy: 30m**

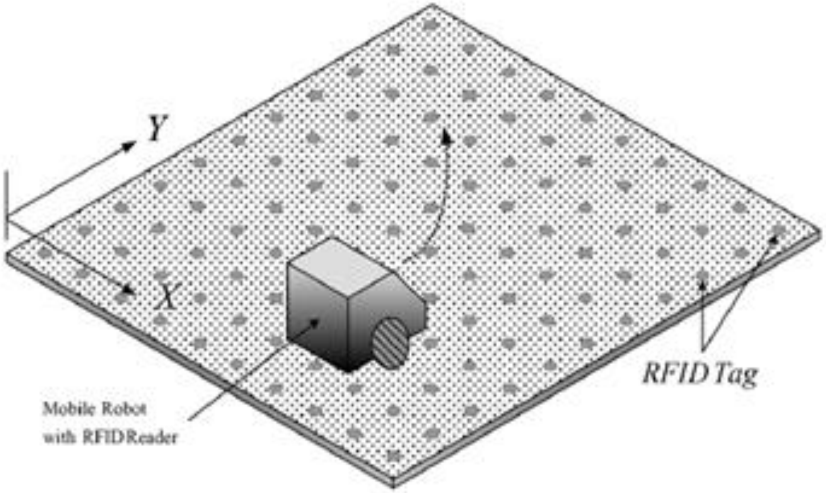
- **Advantage: global**

- **Problems:**
  - Obstruction → only outdoor
  - Multipath propagation
  - Signals weakened through atmosphere, walls, trees

RFID

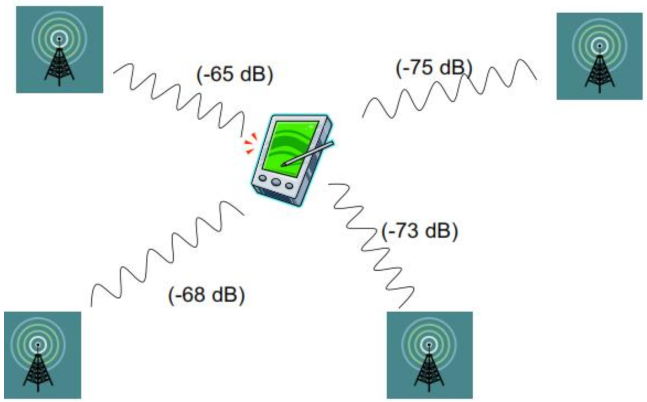
- **Main approaches:**
  - Fixed readers, mobile tags
  - Fixed tags, mobile readers
- **Accuracy: 1m**
- **Problems:**
  - Proximity localization
  - Scalability

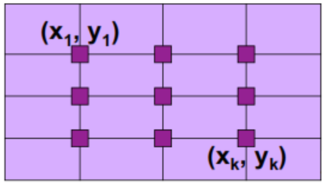




WiFi signals

- **Two main approaches:**
  - Geometrical calculation: angulation, lateration,…
  - Fingerprinting

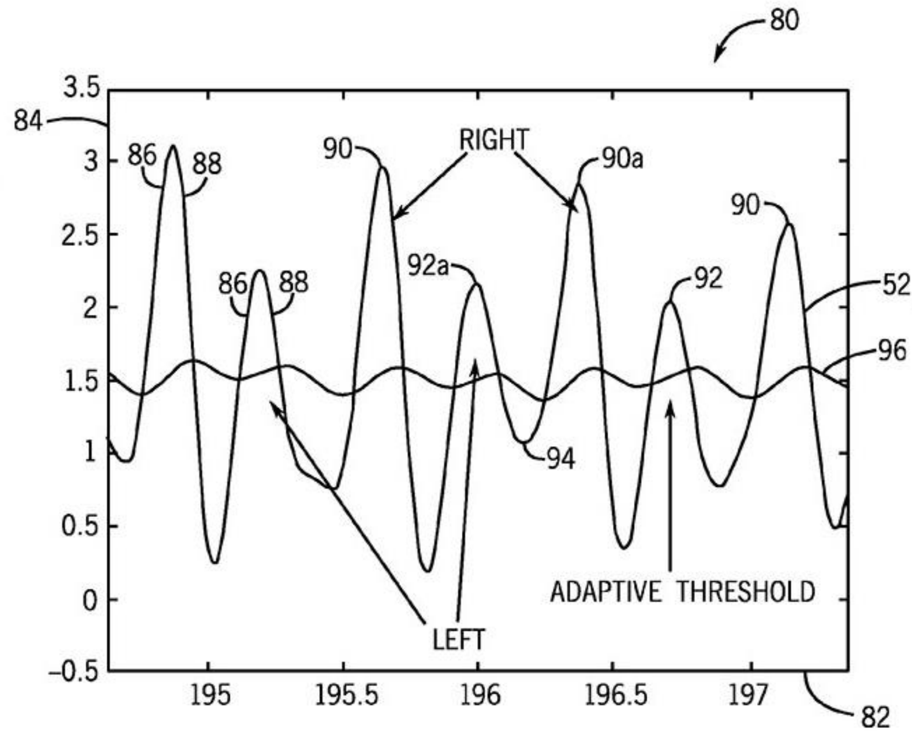




X	Y	AP_1		AP_n
x_1	y_1	ap_{11}		ap_{1n}
	…		…	
x_k	y_k	ap_{k1}		ap_{kn}

- **Accuracy: 5m**
- **Problems:**
  - Complex propagation characteristics (low stability)
  - Pre-deployment efforts required

Pedometer



- **Approach:**
  - Accelerometer
  - Pattern recognition
- **Advantage**
  - Self localization mechanism
- **Problems**
  - Additional orientation sensor required
  - Calibration needed
  - Inapplicable to robots

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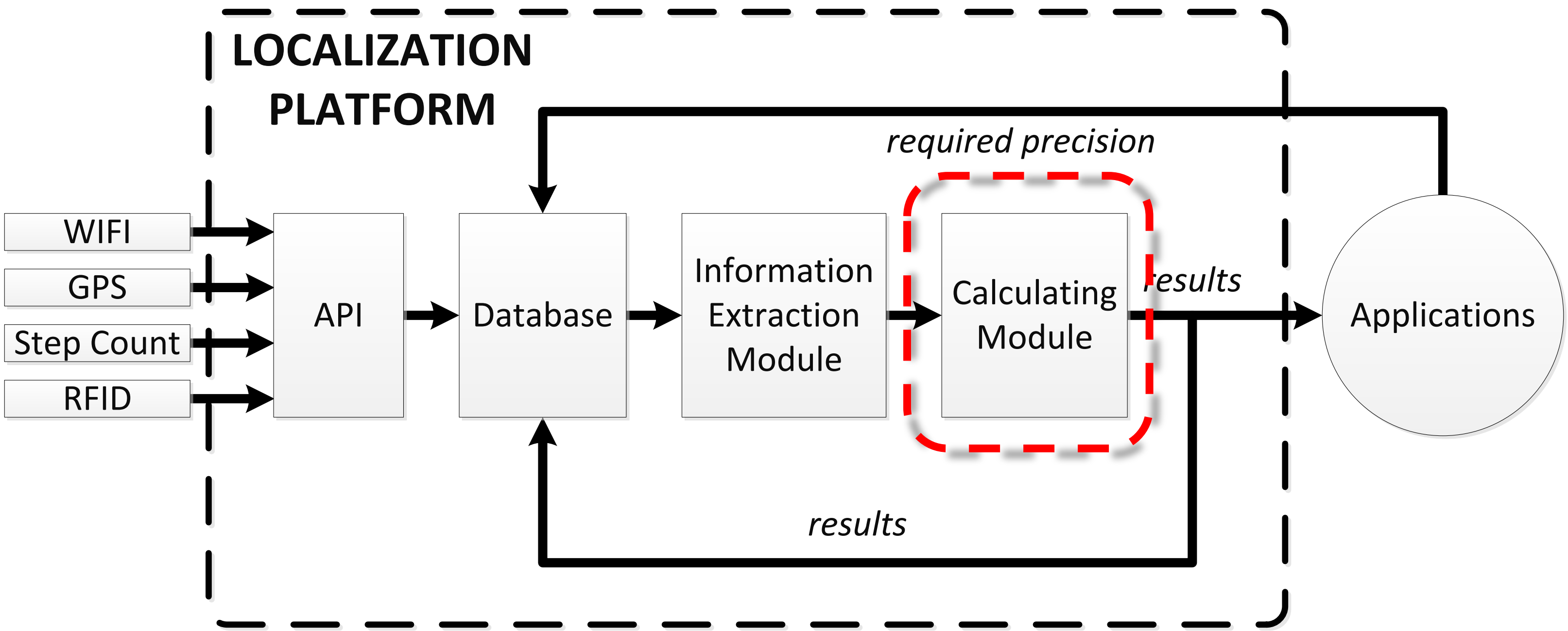
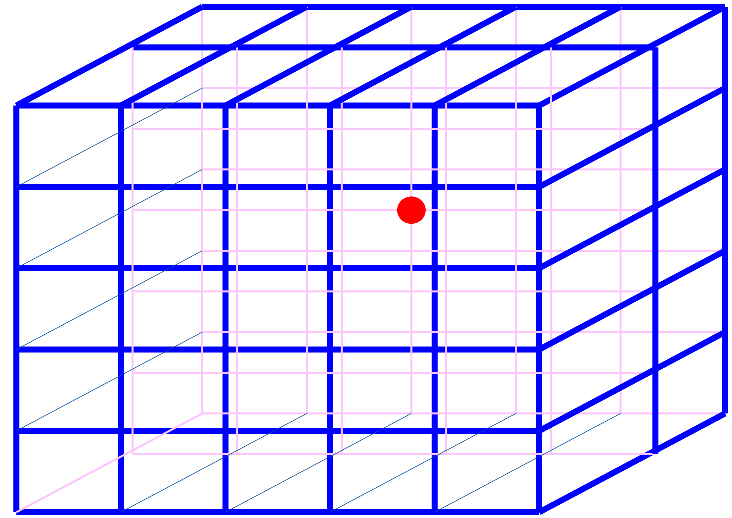
System architecture



Aggregation approach



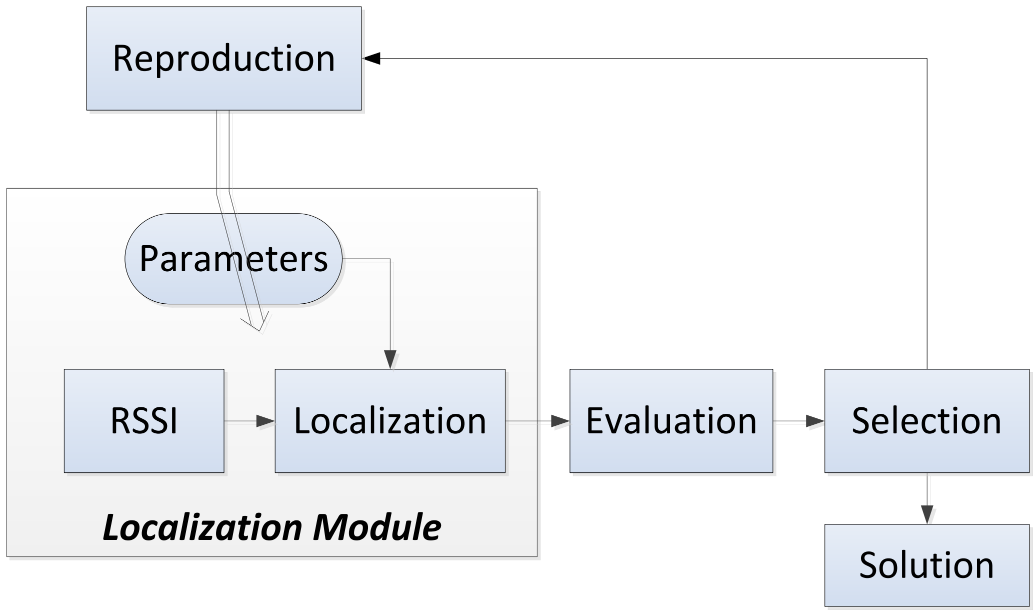
- **Probability based**
  - For each point (x,y,z), calculate aggregation probability ρ_Σ
- **Maximizing**

$$\rho_\Sigma(x,y,z) = \underset{i=1..n}{\Omega}\left(\rho_i(x,y,z)e^{-\lambda_i t}, R_i\right)$$

  - Ω: probability aggregation function
  - n: number of technologies
  - ρ_i: probability of technology i (sum, product,…)
  - R_i: reliability constant of technology i
  - λ_i: time decay constant of technology i

Parameter estimation

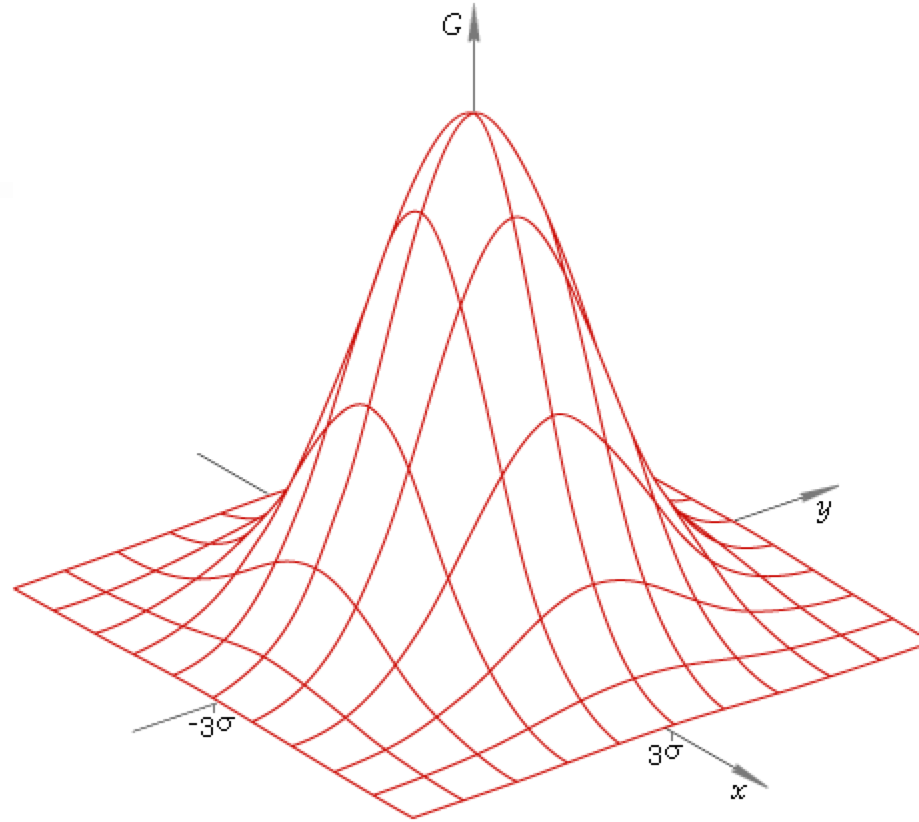
- **Parameters: λ_i, R_i**
- **Using genetic algorithms**



- **Cost function: RMS of localization error**

$$\Phi = \left(\frac{1}{N} \sum_{i=1}^{N} (\hat{x}_i - x_i)^2 + (\hat{y}_i - y_i)^2 + (\hat{z}_i - z_i)^2 \right)^{1/2}$$

GPS



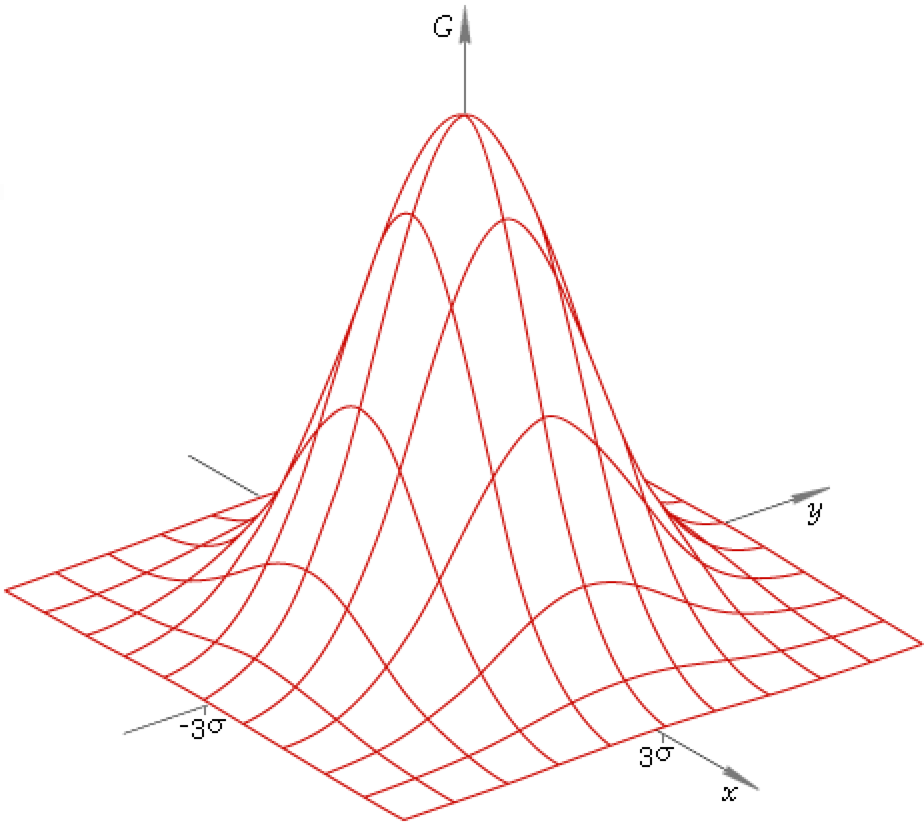
- **Gaussian probability**

$$\rho_i\left(x,y,z\right)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{\left(x-x_0\right)^2+\left(y-y_0\right)^2+\left(z-z_0\right)^2}{2\sigma^2}}$$

  - (x_0,y_0,z_0): returned location by GPS
  - σ: function of accuracy by 3-sigma rule

RFID

- **Fixed reader**



- **Gaussian probability**

$$\rho_i\left(x, y, z\right) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\left(x-x_0\right)^2+\left(y-y_0\right)^2+\left(z-z_0\right)^2}{2\sigma^2}}$$

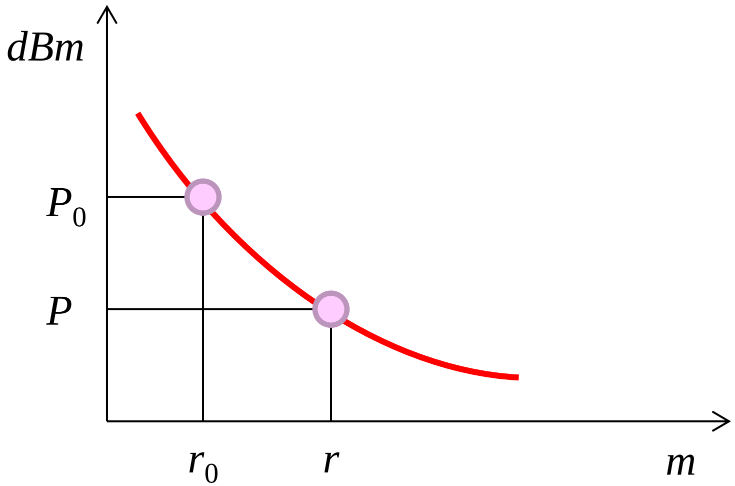
  - (x_0,y_0,z_0): reader location
  - σ: function of reader range by 3-sigma rule

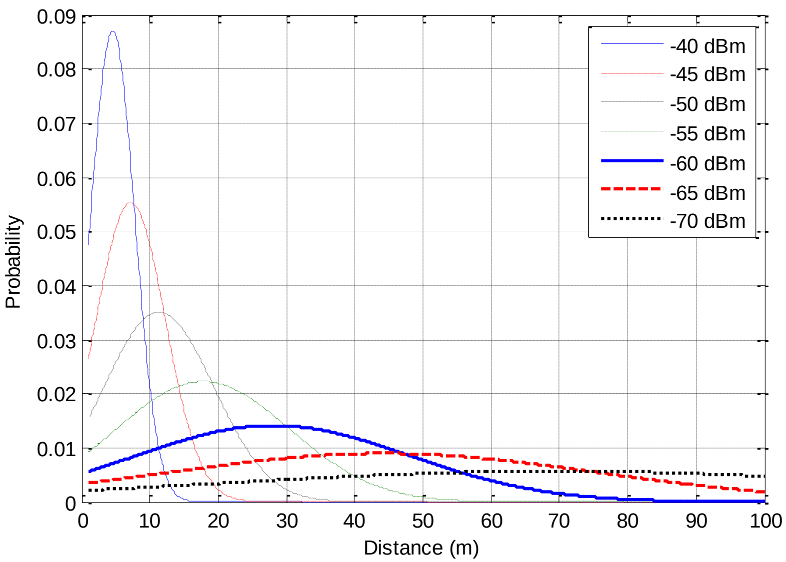
WiFi

- **Gaussian probability**

$$\rho = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(r-r_0)^2}{2\sigma^2}}$$

  - r_0: nominal distance from empirical propagation model
  - σ: function of r_0

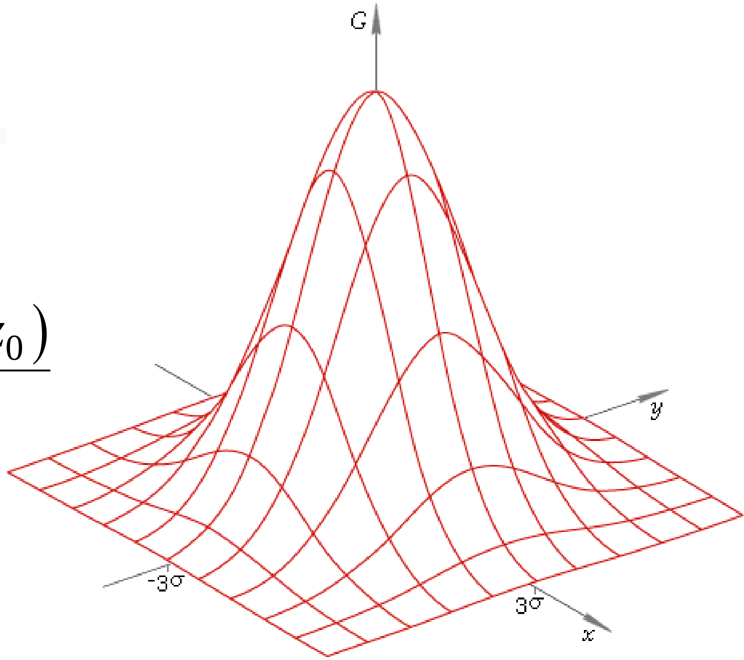




Pedometer

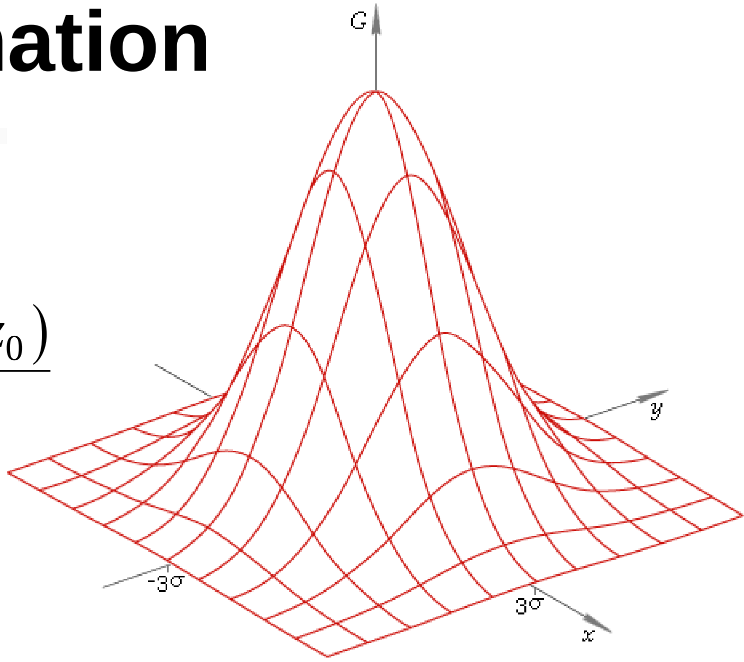
- **Gaussian probability**

$$\rho_i\left(x,y,z\right)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{d^2\left(x,y,z,x_0,y_0,z_0\right)}{2\sigma^2}}$$



  - (x_0,y_0,z_0): nominal user location
  - σ: function of (*step-length x step-count*)
  - *d*: Euclidean distance function

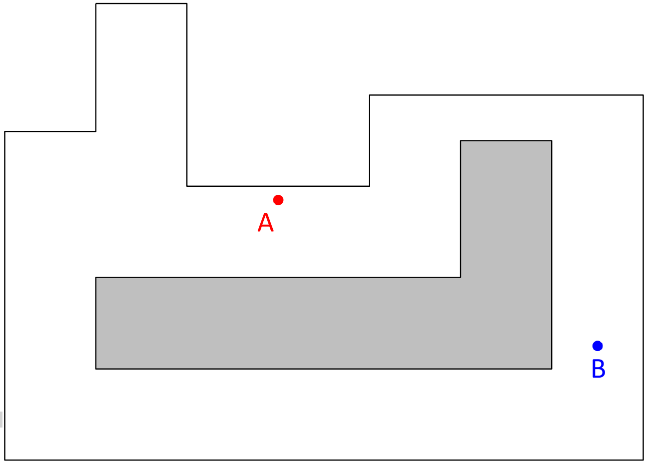
Historical & map information



- **Gaussian probability**

$$\rho_i(x,y,z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{d^2(x,y,z,x_0,y_0,z_0)}{2\sigma^2}}$$

  - (x_0,y_0,z_0): previous user location
  - σ: function of user speed by 3-sigma rule
  - d: distance function with environment map awareness
    - Shortest-path based
    - Impossible location avoidance



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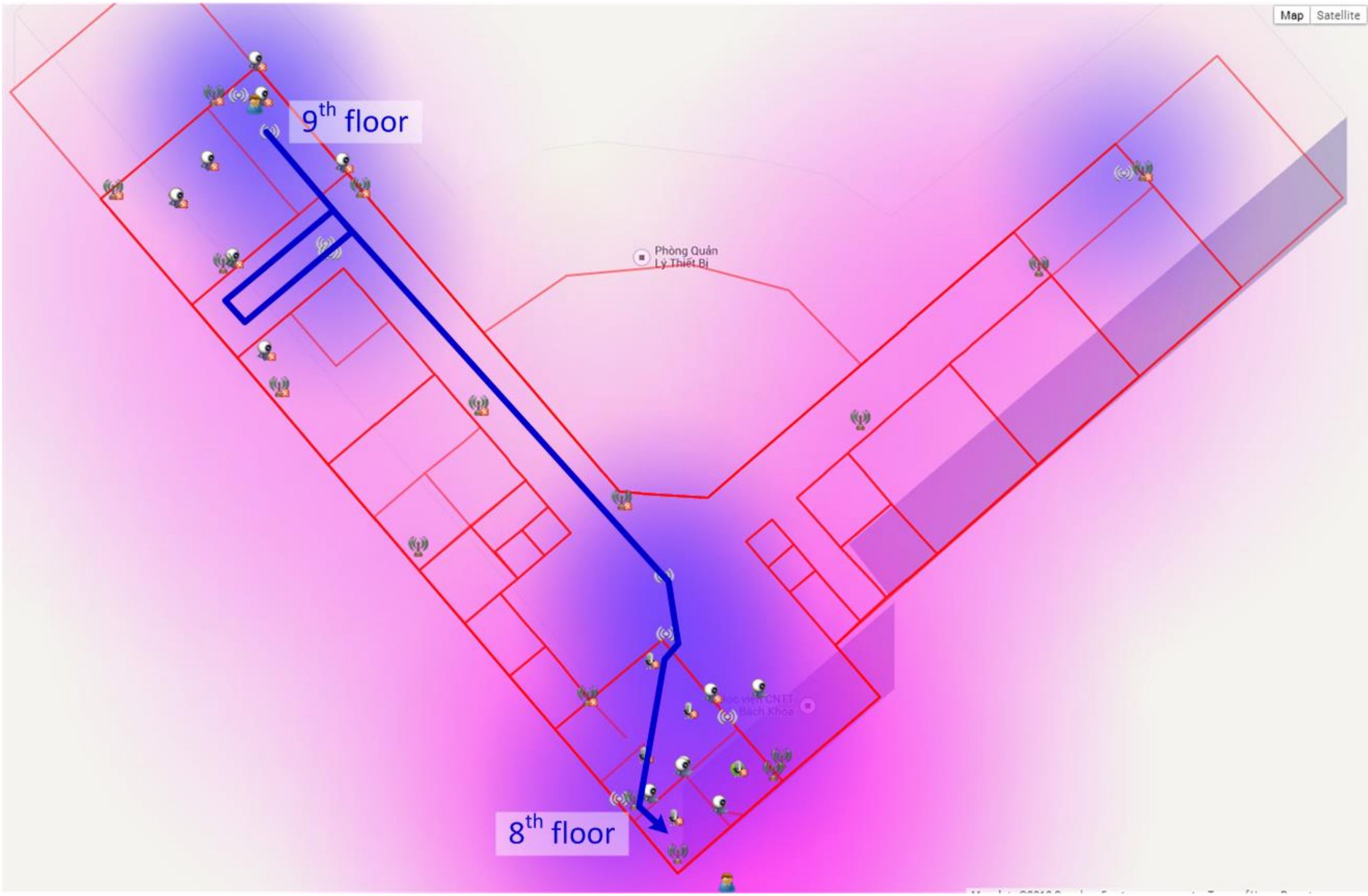
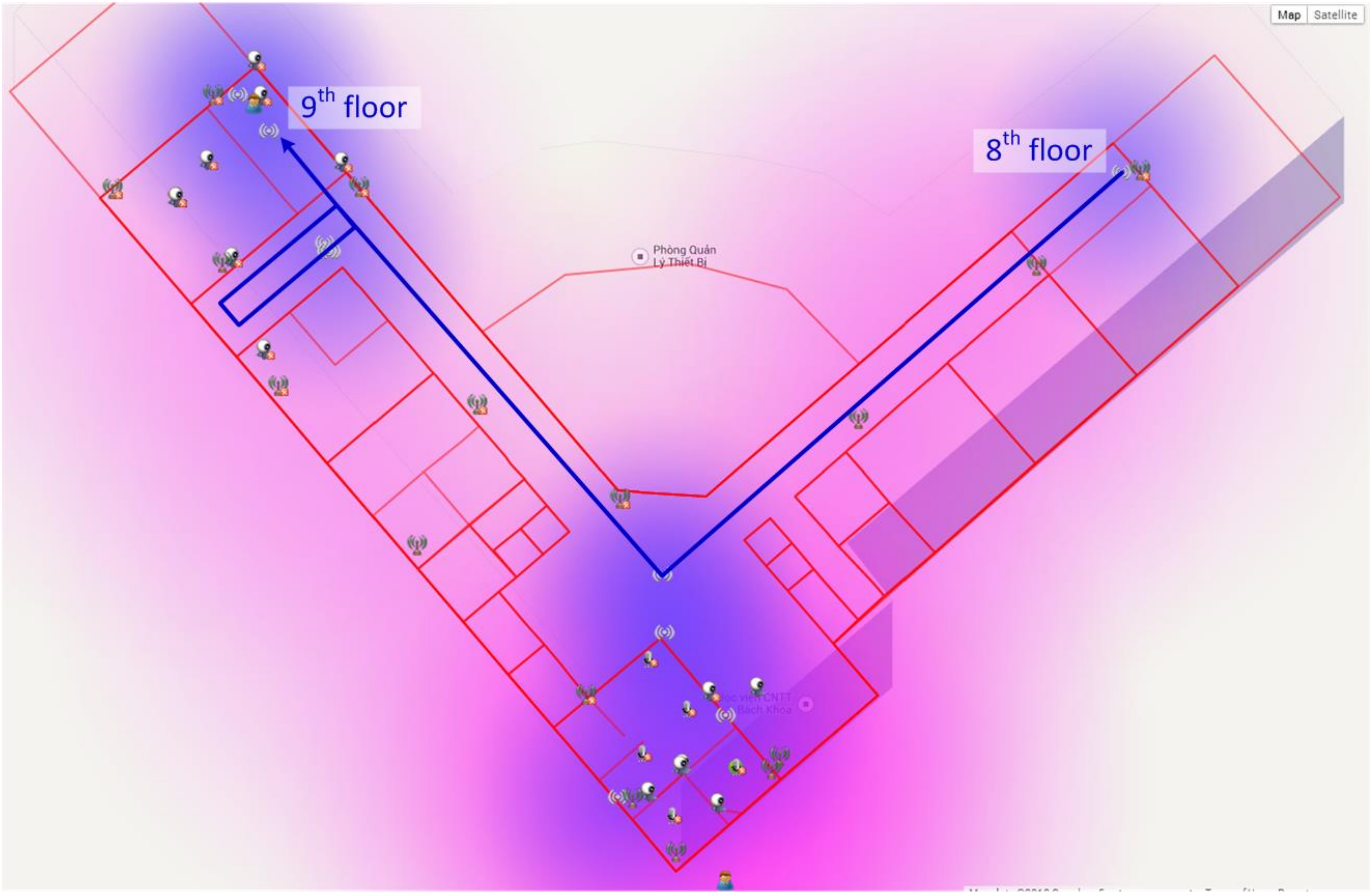
Test scenario: user 1

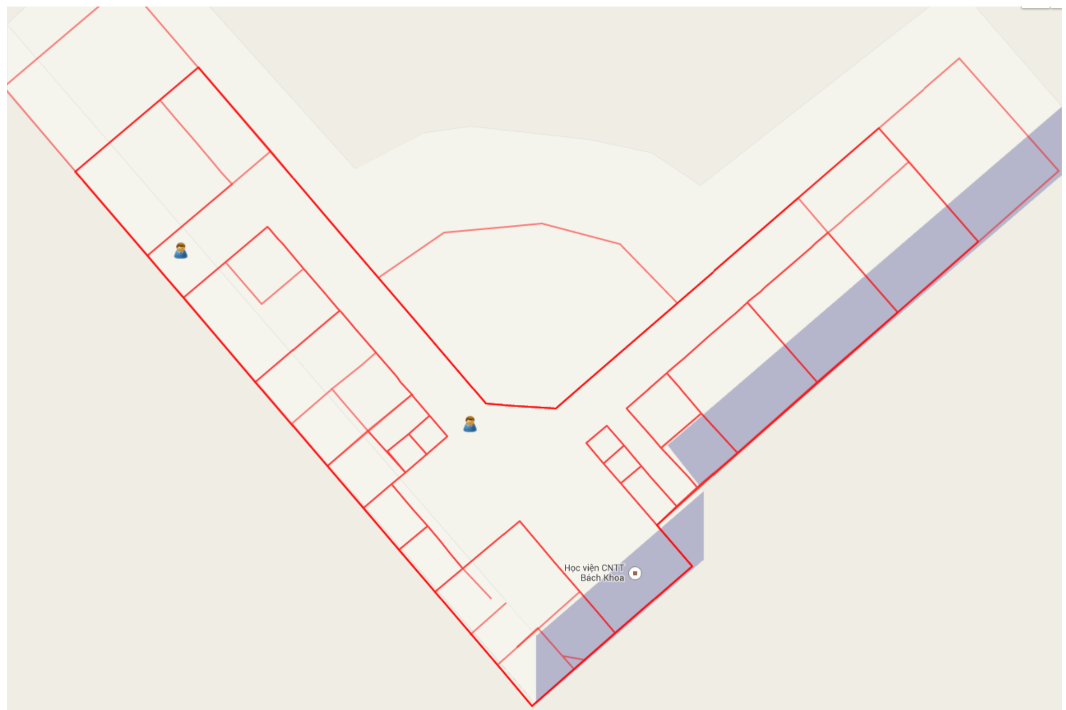


Test scenario: user 2



Results

- WiFi only:
  - video
- WiFi + RFID + step count:
  - video
- WiFi + RFID + step count + historical & environment info:
  - video



Conclusion

- **Probability based Multimodal localization approach**
- **System parameters tuned by using genetic algorithms with collected training data**
- **Highly extensible with heterogeneous technologies**
- **Significantly high accuracy of user localization is achieved**

- **Perspectives**
  - Integration of other technologies: camera (fixed or mobile)
  - Calculation speed

Thank you

for your attention!