Indoor Localization and Applications
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MICA overview

- **Some numbers**
  - 4 profs, 18 doctors

- **Research axes**
  - Localization in indoor and complex environments
  - Location-based services
  - Image & video processing
  - Audio processing, speech recognition, natural language processing
  - Multimodal human-system interaction

- **Further information**
  - [http://mica.edu.vn](http://mica.edu.vn)
  - [http://mica.edu.vn/perso/kiendt](http://mica.edu.vn/perso/kiendt)
Outline

- Introduction
- Multimodal Localization
- Pervasive Application Platform
- Conclusion
Location-based services

- Information customization based on user location
- Human/robot navigation guidance
- Location-based resource allocation
- 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, high deployment price,…
GPS, GALILEO

- **Principle:**
  - TOA $\rightarrow$ distance to satellites
  - Least square solution

- **Accuracy:** 30m

- **Advantage:** global

- **Problems:**
  - Obstruction $\rightarrow$ 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

- **Accuracy:** 5m

- **Advantage:**
  - No occlusion

- **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
Cameras

- **Approach:**
  - Mobile or fixed camera

- **Advantage:**
  - High accuracy

- **Problems:**
  - User identification
  - Limited view, non line of sight (NLOS)
  - Privacy
→ **Combination of multiple technologies** to overcome the limitation of individual ones
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System architecture

LOCALIZATION PLATFORM

- WIFI
- GPS
- RFID
- Pedometer

API → Database → Information Extraction Module → Calculating Module

precision limitation

results

Applications

results
Aggregation approach

- **Probability based**
  - For each point \((x, y, z)\), calculate aggregation probability \(\rho_\Sigma\)

- **Maximizing**

\[
\rho_\Sigma (x, y, z) = \bigg\{ \Omega \rho_i (x, y, z) e^{-\lambda_i t}, R_i \bigg\}_{i=1..n}
\]

- \(\Omega\): probability aggregation function
- \(n\): number of technologies
- \(\rho_i\): probability of technology \(i\) (sum, product,…)
- \(R_i\): reliability constant of technology \(i\)
- \(\lambda_i\): time decay constant of technology \(i\)
GPS

- Gaussian probability

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

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

- Fixed reader

- Gaussian probability

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

- \((x_0, y_0, z_0)\): reader location
- \(\sigma\): 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
- \( \sigma \): function of \( r_0 \)
Pedometer

- **Gaussian probability**

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

- \((x_0, y_0, z_0)\): nominal user location
- \(\sigma\): function of \((\text{step-length} \times \text{step-count})\)
- \(d\): 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
- \(\sigma\): function of user speed by 3-sigma rule
- \(d\): distance function with environment map awareness
  - Shortest-path based
  - Impossible location avoidance
Test scenario: user 1
Test scenario: user 2
Localization results

- WiFi only:
  - [video]
- WiFi + RFID + pedometer:
  - [video]
- WiFi + RFID + pedometer + historical & environment info:
  - [video]
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Introduction

- **Pervasive computing has a major impact on the ways that people work, learn, entertain and interact**
  - Interconnected devices
  - Handheld devices
  - Wireless communications
  - User at the center of the interaction cycle

- **Every devices on the market nowadays**
  - are wirelessly controllable
  - have a wireless communication
  - small yet powerful
System architecture

- Environment modeling
- Visualization
- User/robot localization, tracking & navigation
- Device management
- User information collection
Device management

- Abstract layer for devices
- Allowing 2 modes
  - Physical mode with real devices
  - Simulation mode with virtual devices

Legends:
- Bulb, lamp
- Air conditioner
- Ceiling fan
- Television
- Security camera
- Wifi access point
- Central server
Environment modeling

- Unified environment model for
  - Localization
    - Signal attenuation for WiFi, RFID,…
    - Range information for cameras
    - Result validation
    - Result filter with map information
  - Path-finding and navigation
  - Visualization

- Using XML
Visualization using Google Maps (2D)

Wifi Access Point
ID: 1
SSID: MICA
Power: 5
MAC: 68:7f:74:e7:76:c9
Address: 172.16.120.81
Long: 105.84666721523
Lat: 21.004215717493
Alt: 31
Floor: 8th
Active: yes
Visualization using Google Earth (3D)
Visualization using standalone app (3D)
User/robot localization

- **Integration of multiple technologies**
  - WiFi
  - RFID
  - Camera
  - Bluetooth
  - Pedometer
  - Multimodal (combination of above technologies)

![Localization Platform Diagram]

- **LOCALIZATION PLATFORM**
  - WIFI → API → Database → Information Extraction Module → Calculating Module → Applications
  - GPS
  - RFID
  - Pedometer
  - precision limitation
  - results
  - results
  - results
User/robot navigation

- **Optimal path finding**
  - Shortest path
  - Aware of walls, floors, stairs,…
  - Personalized on the basis of user context
  - Collision avoidance in dynamic environment
Application: Smart Remote Control

- Based on
  - User location
  - Phone orientation

Legends:
- Bulb
- Air conditioner
- Television/screen
- Security camera
- Projector
- User location
User-Adaptive Device Control
► Video
Interaction with Drone

► Video
Summary

- **Probability based multimodal localization approach**
  - Indoor environment
  - To do:
    - Integration of camera-based technology
    - Extension to complex environments

- **Platform for development of pervasive applications**
  - Environment modeling and visualization
  - Integration of localization techniques and navigation
  - Sensor/device management and control: highly extensible with heterogeneous technologies
Thank you for your attention!