Application for the Doctoral Contract 2025

Indoor Localization System for Patient Behavior Analysis in the Context of Connected Healthcare

Ph.D. Candidate:

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Dr. Huaqiong LI UCAS

11 / 09 / 2025

Outline

Personal

- Academic Background
- Research Experience
- Graduation Internship

Research

- Research Context
- Research Objectives
- Challenges
- Roadmap

Summary

- PhD Timeline
- Key Strengths
- Research Fit

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Academic Background

isep
École d'ingénieurs du numérique

UNIVERSITÉ Clermont Auvergne

- **Engineering Diploma in Wireless Communication & IoT Systems** 2022-2025

  ISEP – École d'ingénieurs du numérique, Paris, France

  - IoT & Wireless Networking, AI/ML for communications, Wi-Fi Systems, Embedded Sensors

- **Bachelor's Degree in Computer Science** 2018-2022

  - *With Honors (Mention Très Bien)*

  Université Clermont Auvergne, Clermont-Ferrand, France

  - Machine Learning, Signal Processing, Programming, Path Recognition, Sensor Integration

Research Experience

1. Performance Evaluation of Wi-Fi Networks with TDMA Coexisting with CSMA/CA

Xiaofan Guo et al. *Wireless Personal Communications*, Springer, 2020

- Introduced TDMA into Wi-Fi to enhance real-time performance and reliability.
- Results: **Reduced delay**, **improved reliability** with minimal impact on CSMA/CA throughput.

2. Indoor Localization in IoT Networks Based on Graph Neural Networks

Xiaofan Guo, Wafa Njima. *Article under preparation*, 2025

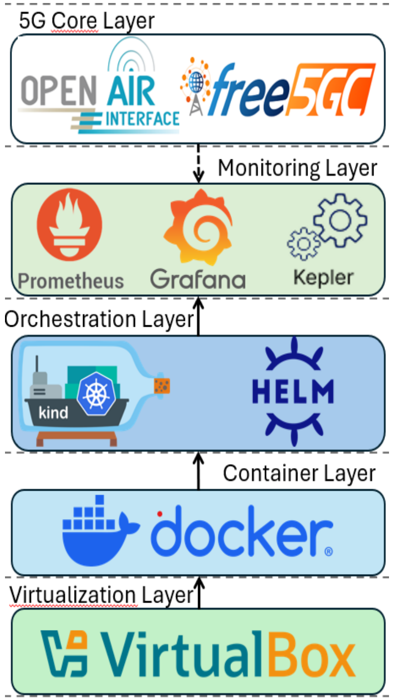
- Compared DNN vs GNN for Wi-Fi RSSI fingerprint localization.
- Results: GNN achieved lower localization error and faster runtime, showing greater robustness.

Graduation Internship

Energy Optimization in 5G Core Networks – Orange Innovation (24 Mar – 22 Sep 2025)

- ## Objective
  - Analyze and optimize the energy consumption of open-source 5G cores (free5GC vs OAI).
- ## Key Findings
  - Contrary to theoretical expectations, OAI consumed more energy than free5GC.
  - Frequent **heartbeat signaling** identified as the main cause of high energy consumption.
- ## Results
  1. Extending heartbeat **reduced OAI's energy consumption** without affecting stability.
  2. Findings were integrated into Orange's AI assistant to guide future deployments.

Testbed Architecture for 5GC



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Research Context

- **Hospitals Needs**
  - Patient safety
  - Efficient resource management
  - Behavior monitoring & analysis *(Smart hospitals)*

- **Current Methods**
  - GNSS unusable indoors
  - Wi-Fi RSSI / BLE = low accuracy, unstable
  - Focus mainly on localization, not behavior

- **Gap**
  - Lack of integrated approach combining real-time localization and patient behavior analysis

Figure Source: J. Lachmann, *Indoor Tracking of Patients in Hospitals*, July 12, 2018.

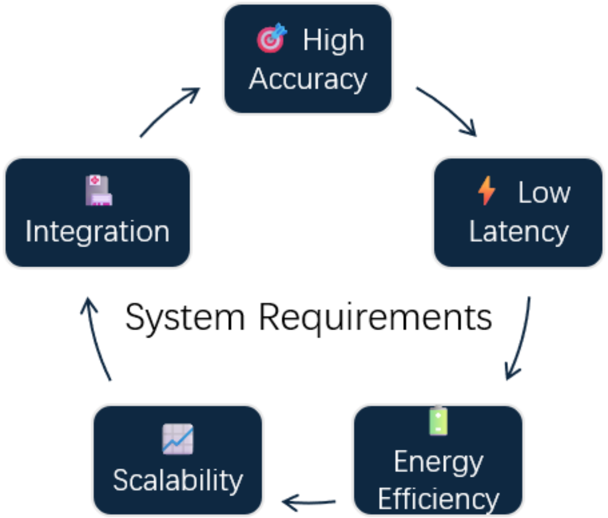
Research Objective

Objective:

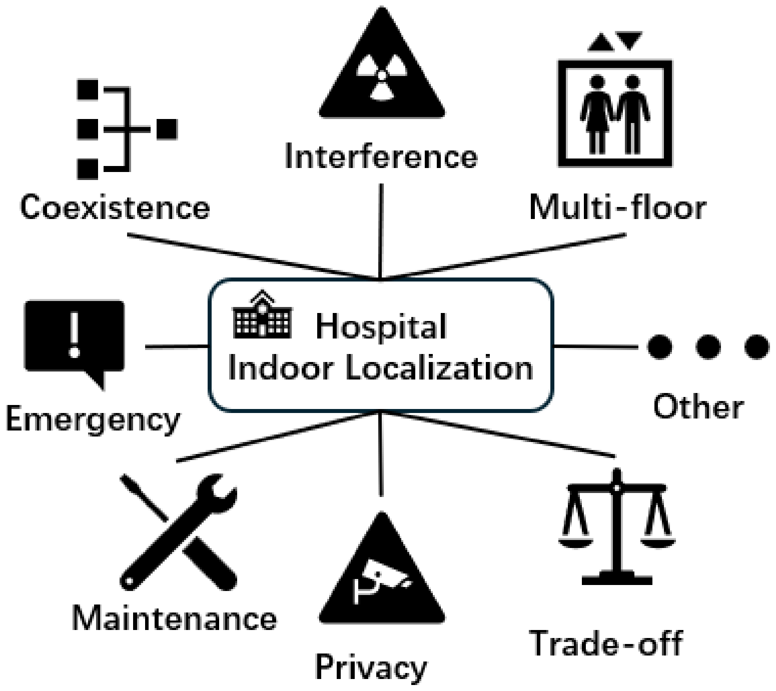
Enable real-time localization, monitoring, and behavior analysis

Response:
develop a multimodal
indoor localization system for hospitals

Hight Constraint:
achieve a balance between
accuracy, latency, and energy efficiency



Challenges



- **Technical Challenges**
  - Multi-technology coexistence
  - Dynamic hospital environment
  - Multi-floor & 3D localization
  - Accuracy–latency–energy trade-off
- **Operational Challenges**
  - Calibration & database updates
  - Scalability & robustness in large hospitals
  - Integration with existing IT systems
- **Security & Safety Challenges**
  - Patient privacy
  - Emergency reliability

Proposed Roadmap

1) Define application scenarios & key metrics
2) Technology & Sensor Selection
3) Data Acquisition (Wenzhou Hospital)
4) System Pipeline Design
5) Model Development
6) Validation & Evaluation
7) Optimization & Deployment

Proposed Methods

- ⭐2 Adaptive Sensor
- ⭐3 Multimodal Fusion
- ⭐4 Cross-modal Alignment
- ⭐4 Drift Compensation
- ⭐5 Transformer Fusion
- ⭐5 Edge Lightweight Inference
- ⭐6 Interference/Stress Testing
- ⭐7 Behavior Analysis
- ⭐7 Resource Management

Build an intelligent healthcare indoor localization system with behavior analysis

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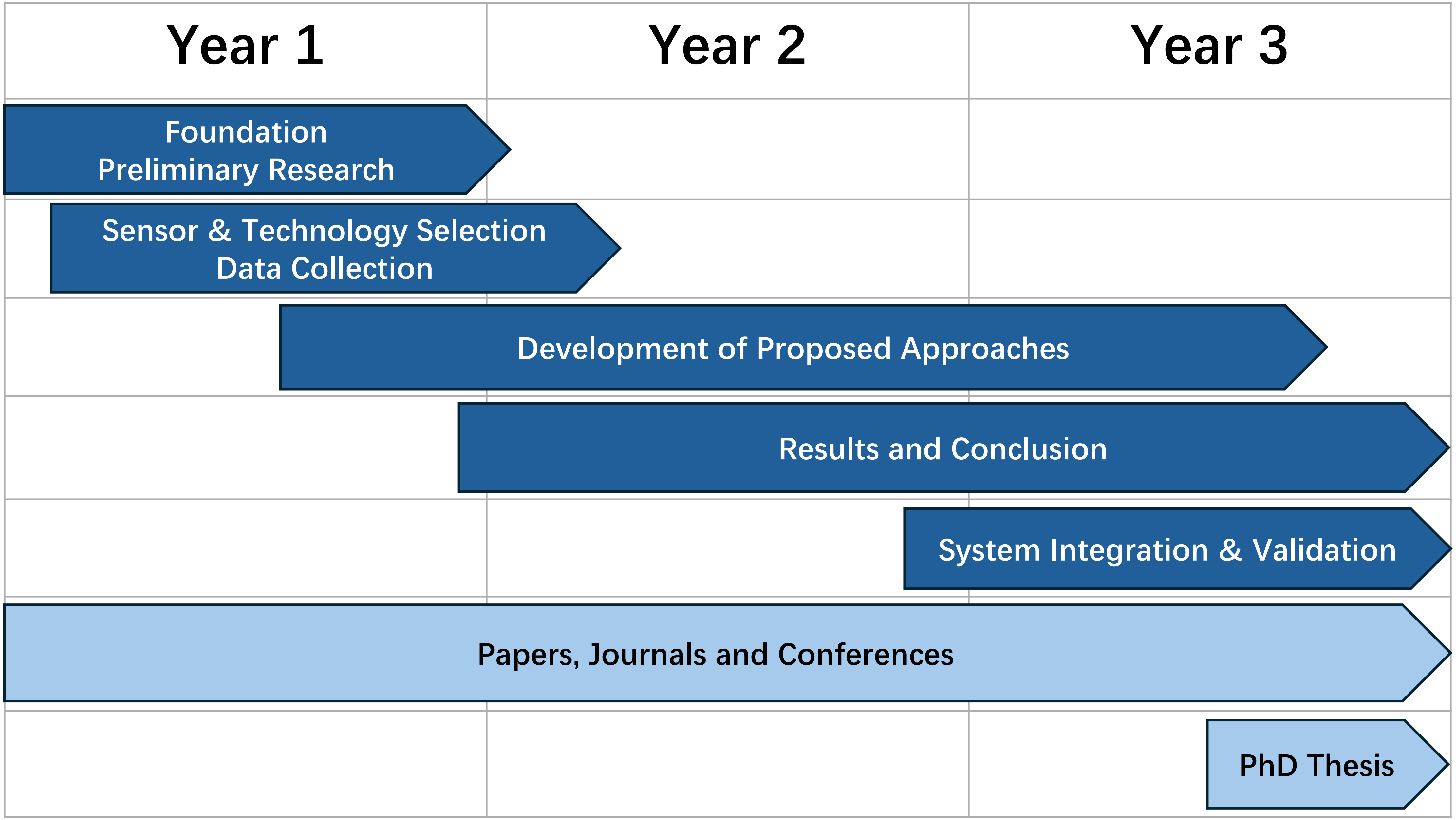
PhD Timeline



Key Strengths

Wireless & IoT	· Wi-Fi, 5G Core; Indoor Localization, Energy-efficient Systems
AI & Data	· DNN / GNN; Data modelling; Matlab-Signal processing; Python
Hardware & Sensors	· IoT devices; Health Data (temperature, fall detection)
Research & Innovation	· Publications; Problem-solving; Experimentation Skills
Collaboration	· Multilingual (EN/FR/中文); Academic & Industrial Teamwork
Soft Skills	· Analysis; Taste for Innovation, Research and Challenges

Research Fit

Orange Internship
- Reduce 5GC energy

Final Year Project
- Indoor localization

Wearable Sensors
- Health monitoring system

Multilingual
- EN, FR, 中

Energy-Efficiency | **Localization** | **Healthcare** | **Collaboration**

Indoor Localization System for Patient Behavior Analysis in the Context of Connected Healthcare

Behavior Analysis | **Integrated** | **Incentive**

Undergraduate Projects
- Path & image recognition

Interdisciplinary
- AI, Wireless, IoT, Healthcare, Energy Efficiency, Signal

Motivation
- Strong interest in Wireless & IoT and Research

Thank you for your attention.

I would be happy to answer any questions.

Appendix

1. Research Experience-Published Article
2. Research Experience-Article Under Preparation
3. Graduation Internship
4. Methods & Contributions
5. Future Goals

Research Experience-Published Article

Performance Evaluation of the Networks with Wi-Fi based TDMA Coexisting with CSMA/CA

Wireless Personal Communications, Springer, 2020

➢ **Objective**:

- Introduce TDMA (Time Division Multiple Access) into Wi-Fi to improve real-time performance and reliability when coexisting with CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)

➢ **Method**:

1. **Canceling Carrier Sensing**: TDMA devices transmit directly in allocated slots without checking channel availability.
2. **Priority Mechanism**: TDMA devices gain priority over CSMA/CA devices on the shared channel.
3. **Collision Handling**: TDMA devices immediately retransmit data until an ACK is received, ensuring reliability.

➢ **Result**:

- The TDMA mechanism significantly reduced delay for real-time applications and improved reliability through retransmissions.
- As frame length and duty cycle increased, CSMA/CA throughput slightly decreased but the impact remained manageable.

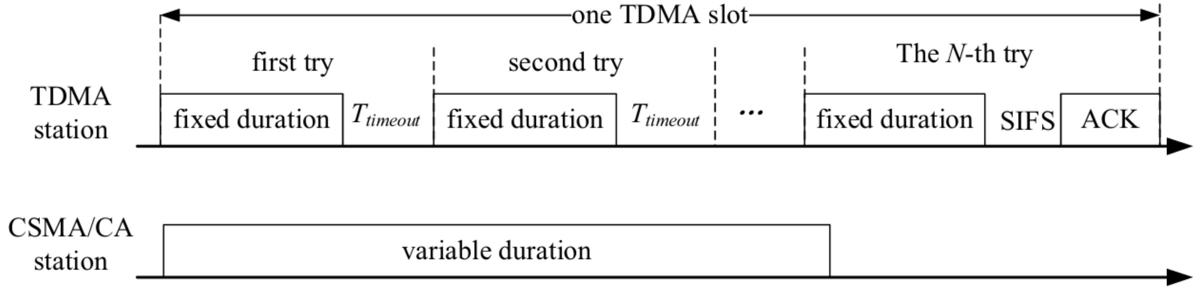


Fig. 2 Preemptive TDMA scheme

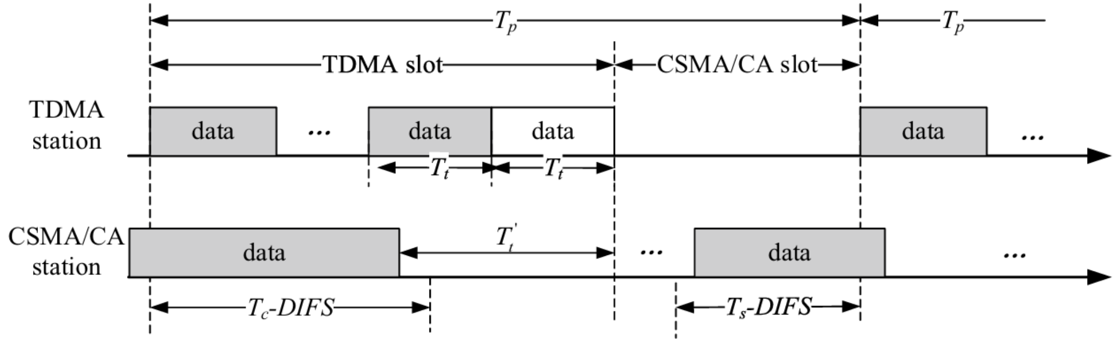


Fig. 4 The interference a CSMA/CA frame suffered from the Wi-Fi TDMA station

Research Experience-Article Under Preparation

Indoor Localization in IoT Networks Based on Graph Neural Networks

2025

- **Objective**:
  - Compare the performance of DNN and GNN in Wi-Fi RSSI fingerprint-based localization, Including predictions for longitude, latitude, floor and predicted time.
- **Method**:
  1. **DNN Encoder–Decoder**: Built an encoder–decoder baseline model with multi-task regression to jointly predict.
  2. **GNN with k-NN Graphs**: Constructed graphs using k-NN and applied GCN layers with message passing to capture spatial topology.
  3. **Evaluation Metrics**: valuated models by comparing hidden layer configurations, localization error, and runtime performance.
- **Result**:
  - GNN achieved lower localization error and shorter runtime with fewer hidden layers, improving accuracy and robustness.

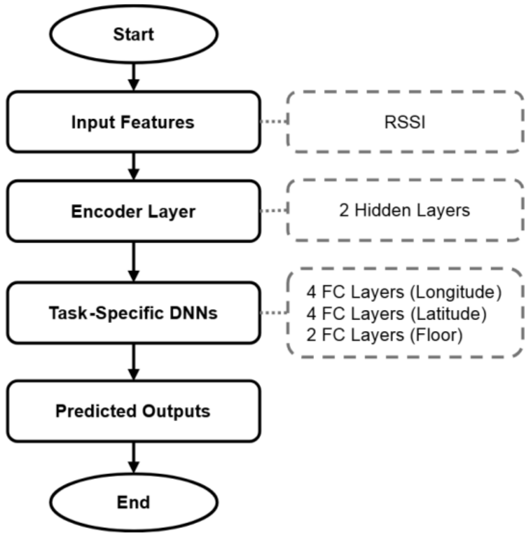


Fig. 1. Overall data preprocessing and prediction workflow of the DNN-based localization model. (FC: Fully Connected).

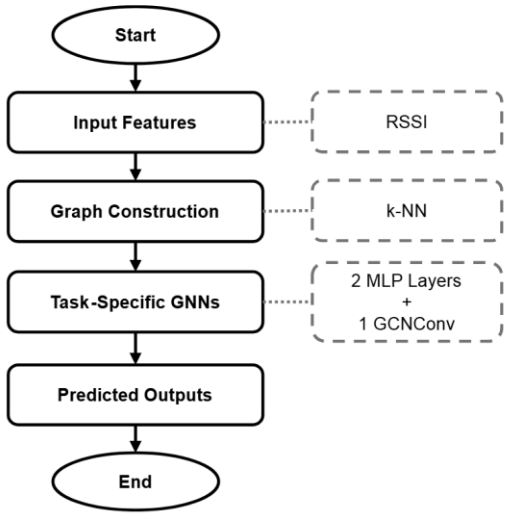
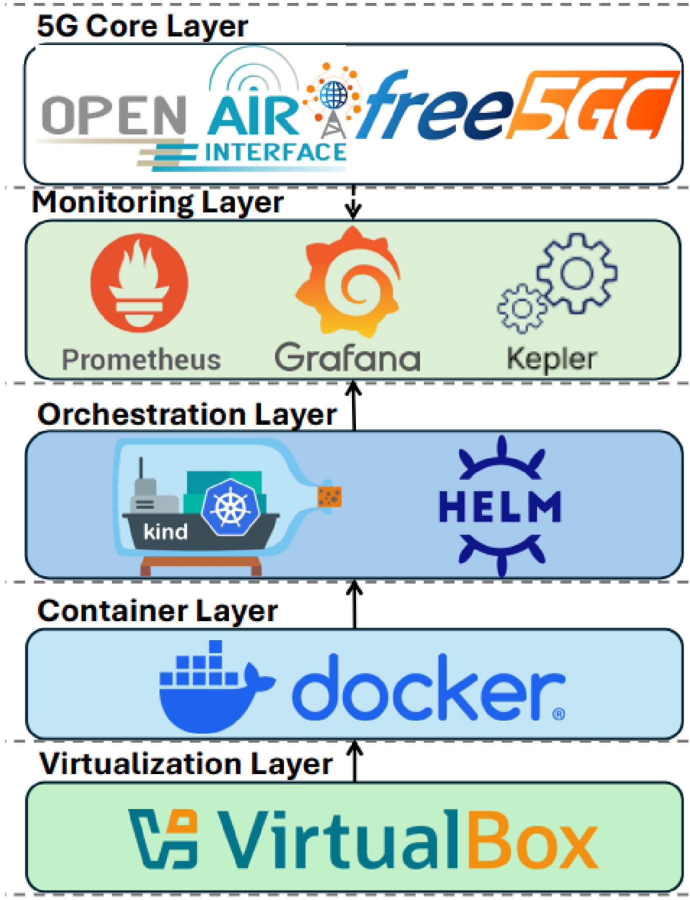


Fig. 2. Overall data preprocessing and prediction workflow of the GNN-based localization model. (MLP: Multi-Layer Perceptron, GCNConv: Graph Convolution layer).

Graduation Internship (24 Mar – 22 Sep 2025)

Energy Optimization in 5G Core Networks – Orange Innovation

- **Objective:**
  - Analyze the energy consumption of open-source 5G Core (free5GC and OAI) and explore methods to reduce it.
- **Method:**
  1. **Deployed** an energy monitoring framework (Kepler + Prometheus + Grafana on Kubernetes).
  2. **Installed and compared** free5GC and OAI; experiments revealed OAI consumed significantly more energy.
  3. **Proposed three hypotheses**: database implementation differences, residual container processes, and frequent inter-Pod signaling.
  4. Identified **frequent AMF heartbeat** signaling as the main cause, **modified** the source code, and extended the cycle from 10s to 100s.
- **Result:**
  1. Extending the heartbeat cycle significantly reduced OAI's energy consumption while maintaining system stability.
  2. The achievements were integrated into an AI assistant at Orange to support rapid future deployment.



Methods & Contributions

Multi-floor

Multi-floor · Fixed Localization

Possible Approaches

- Multimodal input: combine Wi-Fi, BLE, UWB.
- Add a floor classification module in DNN.

Possible Challenges

- Complex data synchronization.
- Strong floor-to-floor signal variation.

Multi-floor · Mobile Localization

Possible Approaches

- Fuse Wi-Fi, BLE, UWB, and sensor data.
- Use GNN combined with temporal models for cross-floor trajectory modeling.

Possible Challenges

- Cross-floor attenuation & dynamic interference.
- High computational and scalability requirements.

Fixed **Mobile**

Single-floor · Fixed Localization

Possible Approaches

- Use Wi-Fi or BLE RSSI fingerprinting.
- DNN regression model for (x, y) prediction.

Possible Challenges

- Signal interference from walls and devices.

Single-floor · Mobile Localization

Possible Approaches

- Use BLE/UWB with IMU sensors.
- GNN (k-NN graph) for trajectory modeling.

Possible Challenges

- Dynamic interference sources.
- High real-time computational cost.

Single-floor

Future Goals

Short-term (3 years)

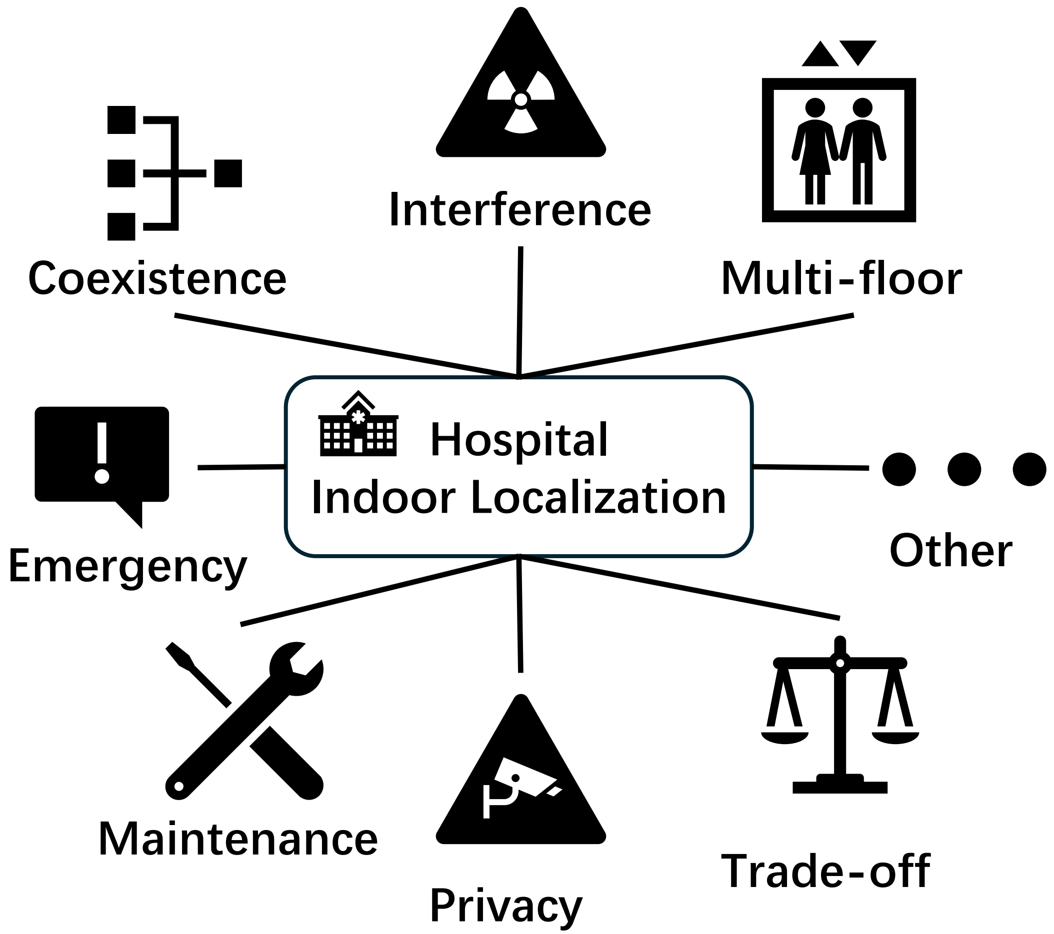
Develop a multimodal AI indoor localization system with high accuracy, low energy cost, and scalability in smart hospitals.

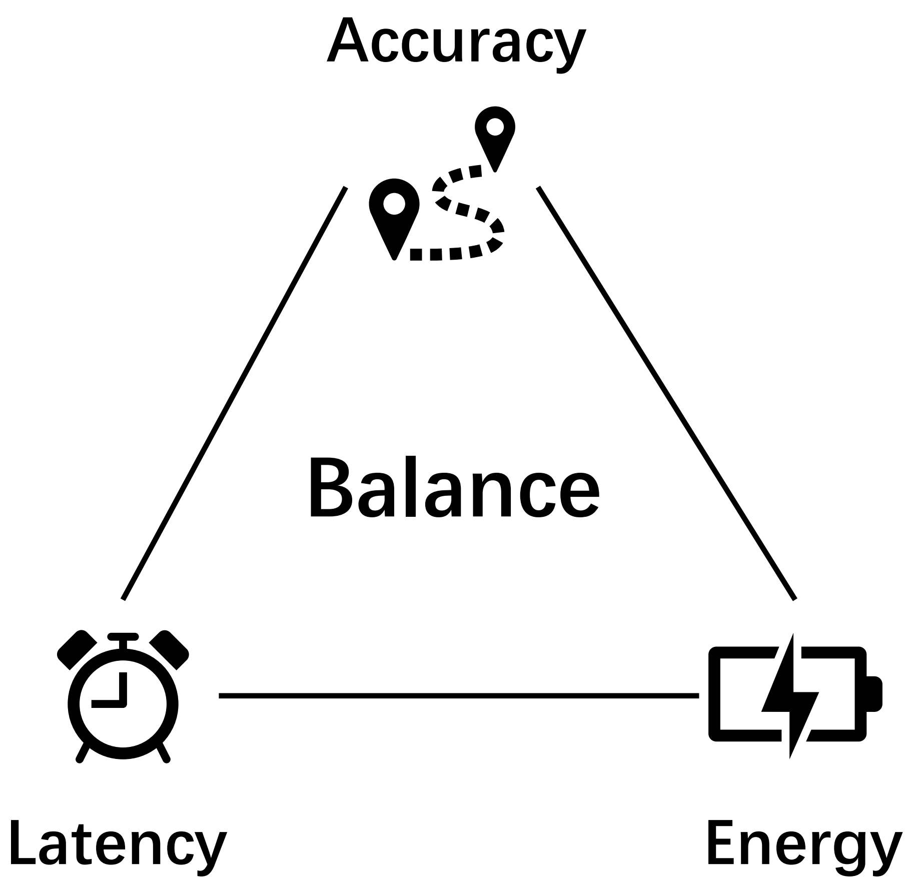
Mid-term (5 years)

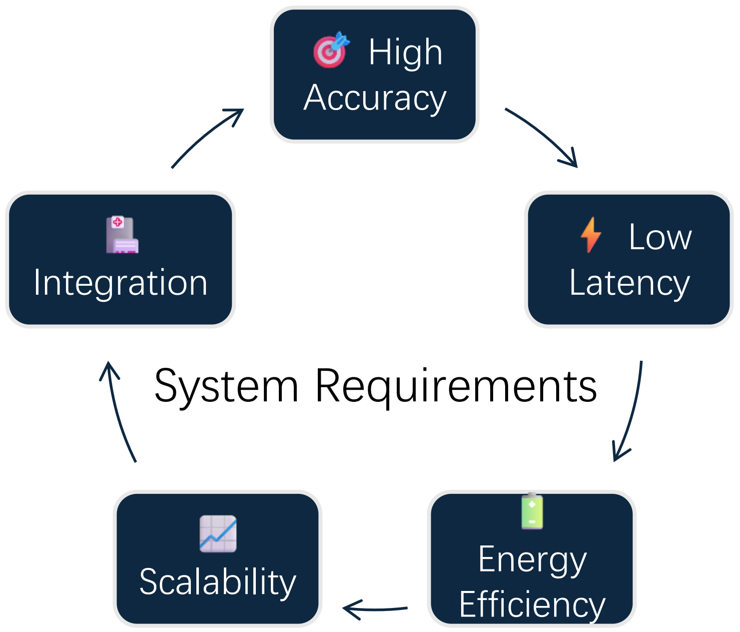
Promote the deployment and standardization of AI-based indoor localization and behavior analysis in healthcare.

Long-term (10 years)

Explore the integration of 6G networks and smart healthcare.


Interference
Coexistence
Multi-floor
Hospital
Indoor Localization
Emergency
Other
Maintenance
Privacy
Trade-off


Accuracy
Balance
Latency
Energy


High Accuracy
Low Latency
Energy Efficiency
Scalability
Integration
System Requirements