A Context-enhanced Sector-based Indoor Positioning Library

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Presenter

Jens Krösche is a professor in the Department of Mobility & Energy at the University of Applied Sciences Upper Austria. His research interests lie in the fields of context-aware computing, geographical information systems, navigation and positioning systems, and mobile information systems. The presented work is based on the results of a student's master's thesis.

Agenda

Introduction

Motivation

- Location is one of the most important context features
  - Real-time navigation
  - Locating specific items in warehouses
  - Orientation in a large building complex (hospital, airport, …)
  - …

- Localization outdoors thanks to multiple existing GNSS no problem, but

  → requires non-obstructed line of sight

  → not usable for indoor localization

  → complex algorithms necessary to achieve the same indoors

Is the **same accuracy and precision required indoors** as it is outdoors?

Goals

- Purely sector-based **context-aware indoor positioning** system
- Trade high accuracy for **robust and cheap positioning**
- **No machine learning**, artificial intelligence, or any form of data-based learning
- System is **applicable to any building**

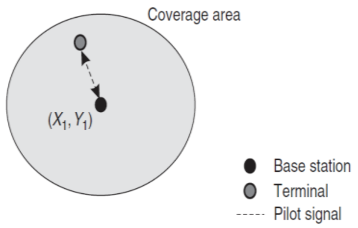
Fundamentals & Related Work

Basic Positioning Methods

- Proximity Sensing
- Lateration
- Angulation
- Pattern Matching/Fingerprinting
- Dead Reckoning

Basic Positioning Methods

- Proximity Sensing
  - **Exploits** the **limited range** of coverage of their pilot signals
  - Position of target **derived from base stations**



Omnidirectional proximity sensing

- Fingerprinting
  - Position of target **based on previously collected observations** of the site
  - Two phases:
    - **Off-line phase**: collect RSS values at pre-defined positions to create a database
    - **On-line phase**: match real-time RSS values to database

Related Work

- RADAR

  one of the first approaches to exploit existing WiFi infrastructure

- Horus

  applying probabilistic methods to fingerprinting

- Sectjunction

  partitions the site according to RSS values to narrow the search space

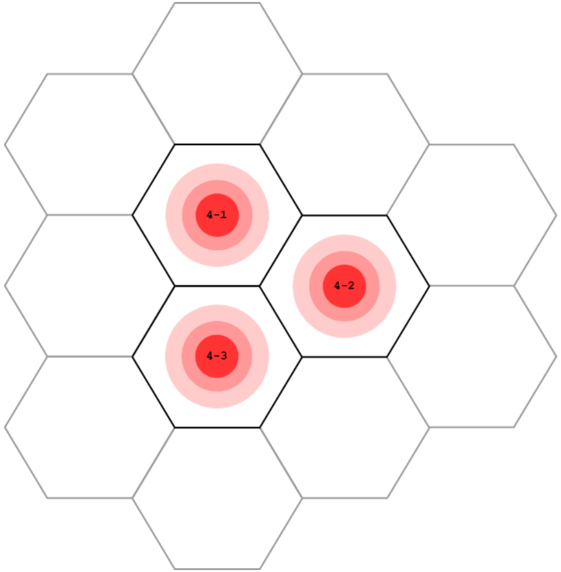
Concept

Overview

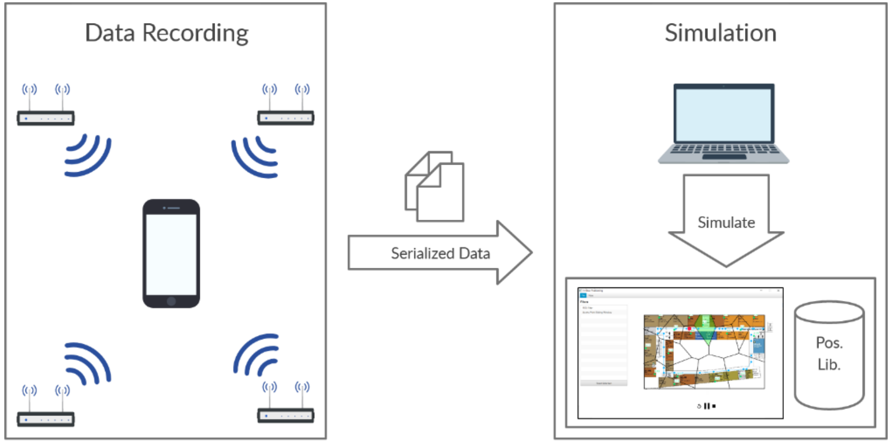
- **WLAN-based** indoor positioning system
  → follow the principles of proximity sensing
  → use existing network infrastructure

- Divide building into **sectors**
  → each access point inside a single sector
  → reduce complexity

- Utilize **filter pipeline** to derive position estimate



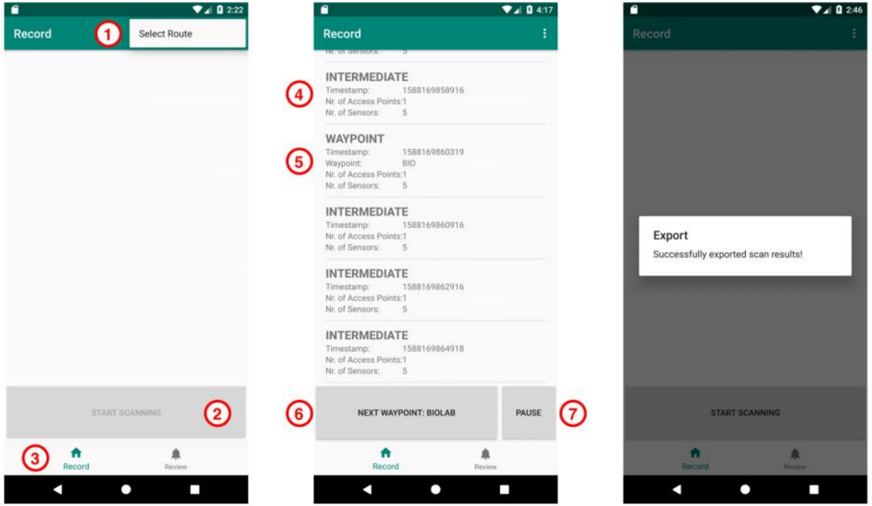
System Overview



- Components
    - Recording application
    - Simulation environment
    - Positioning library based on a filtering pipeline

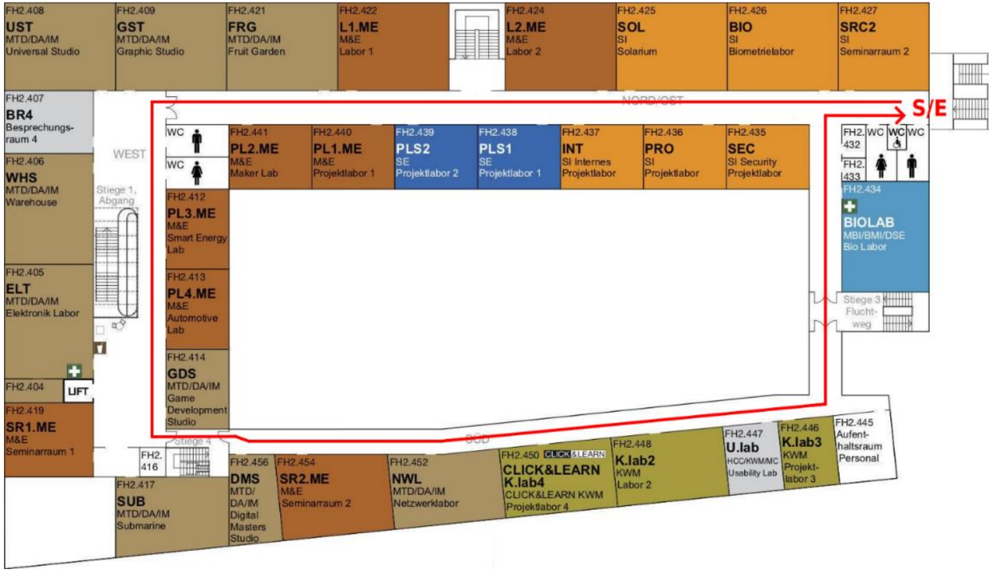
Data Recording

- Features
  - Records various WiFi properties and sensor values
  - Predefined **routes** to establish calibration points
  - **Waypoint** scans at calibration points and **Intermediate** scans in regular intervals
  - **Record/Pause** and **export** features



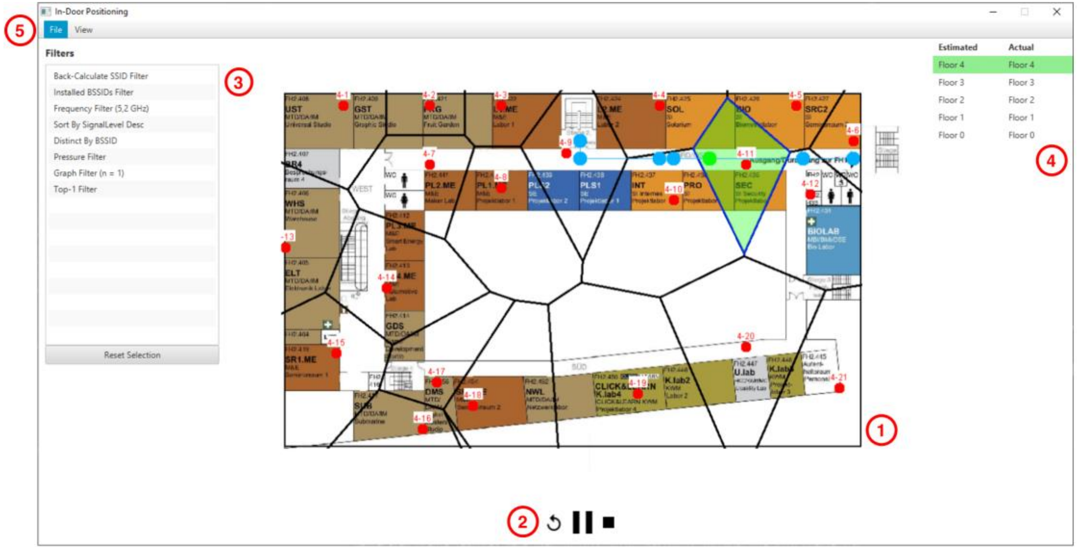
Recording Routes

- Background
  - Enable walkthrough simulation
  - Handle different scenarios
  - Based on building blueprints



Route Simulation

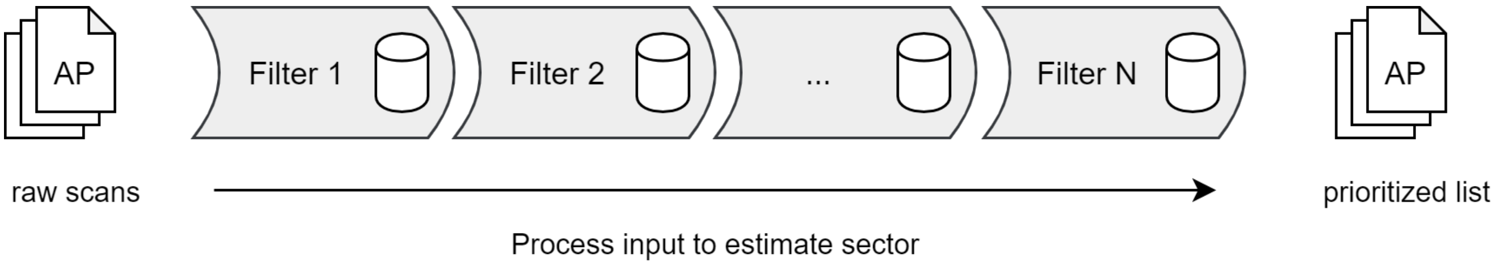
- Features
  - Visualize level-based floor blueprints
  - Choose route to simulate
  - Visualize simulation data based on calibration points
  - Configure filtering pipeline
  - Visualize localisation sectors and positioning results
  - Manage simulation



Filter Pipeline

- Input
  - **Scanned access points** in near proximity
  - **Sensor measurements** of environment
- Output
  - **Prioritized** list of **access points**

Filter Pipeline



Implementation

Iterations of Filter Pipeline

- Basic Pipeline
- Pressure Pipeline
- Graph (n = 1) Pipeline
- Blacklist Pipeline
- Graph (n = 2) Pipeline

Basic Pipeline

Installed BSSIDs Filter

↓

Frequency Filter

↓

Sort-By Filter

↓

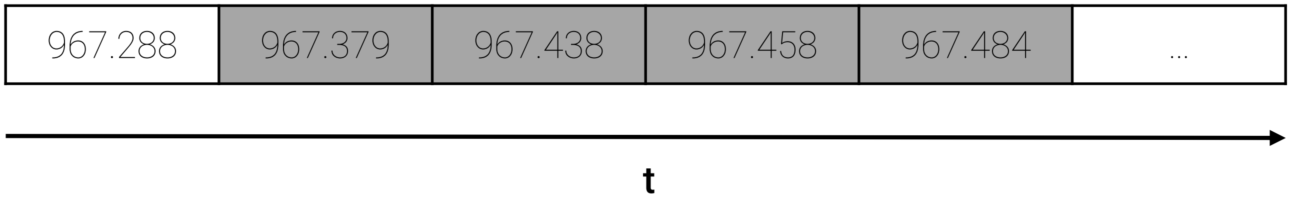
Distinct-By Filter

↓

Top-N Filter

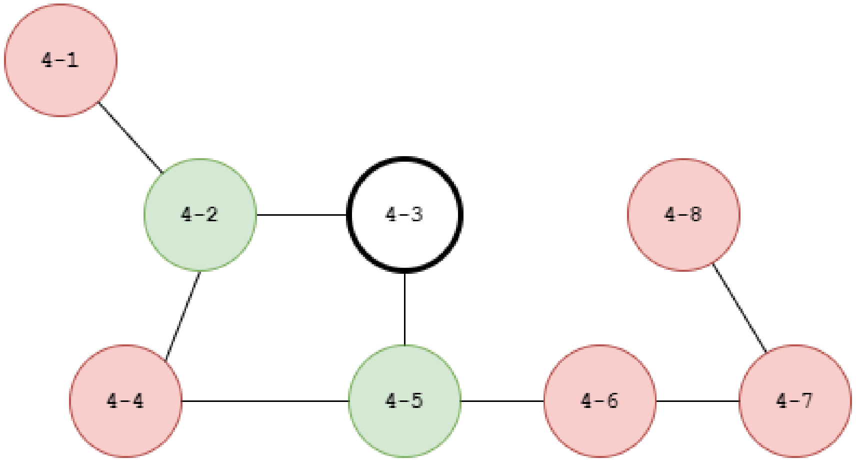
Pressure Filter

- Track four most recent barometer measurements
- Derive type of movement from ambient air pressure
  - air pressure going down → target moving up
  - air pressure going up → target moving down



Graph (n = 1) Filter

- Limits involuntary sector jumps
- Limit estimates to be within 1 hops of previous estimation



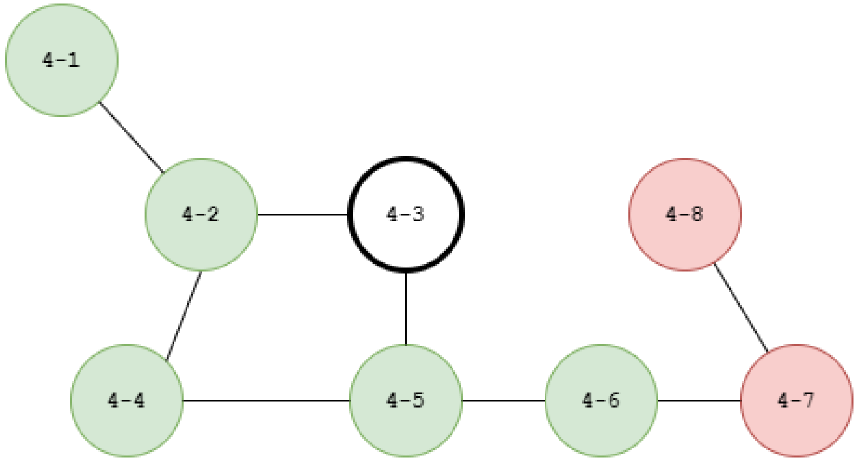
Blacklist Filter

- maximumNumberOfSuggestions: limit consecutive suggestions of a certain sector
- numberOfScansBlocked: limit number of times a certain sector is blocked

Sector	Number of consecutive suggestions	Remaining blocks
4-1	1	0
4-2	2	2
4-3	2	1
3-19	0	0

Graph (n = 2) Filter

- Limits involuntary sector jumps
- Limit estimates to be within 2 hops of previous estimation



Evaluation

Scenarios

- Scenario #1: **Change of Direction**

  At a certain point on the route, the target turns around and follows the route back

- Scenario #2: **Change of Floors**

  Two different flight of steps are used on this route to change from a higher to a lower floor and back

- Scenario #3: **Standing Still**

  The target standing still for an arbitrary amount of time at a certain point on the recording route

- Scenario #4: **Round Trip**

  The target follows a regular round trip, starting from a distinct location and arriving at the same location again

Metrics

- Number of Correctly Estimated Sectors (NCES)
  - Parameterized → tolerated distance

$$d_{acc} = \frac{n_{corr}}{n_{total}}$$

- Average Distance to Correct Sector (ADCS)
  - Non-parameterized

$$d_{avg} = \frac{\sum_i^n distance(pos_{est}, pos_{corr})}{n_{total}}$$

Performance Matrix

		Pressure	*Blacklist*	*Graph (n = 2)*
Scenario 1: Change of Direction	NCES (td = 0)	0.640	0.640	0.640
	NCES (td = 1)	0.980	1.000	0.980
	ADCS	0.380	0.360	0.380
Scenario 2: Change of Floors	NCES (td = 0)	0.479	0.535	0.479
	NCES (td = 1)	0.930	0.944	0.986
	ADCS	0.662	0.493	0.535
Scenario 3: Standing Still	NCES (td = 0)	0.718	0.590	0.744
	NCES (td = 1)	0.974	0.872	1.000
	ADCS	0.462	0.487	0.256
Scenario 4: Roundtrip	NCES (td = 0)	0.580	0.470	0.580
	NCES (td = 1)	0.960	0.920	0.950
	ADCS	0.470	0.610	0.470

NCES … Number of Correctly Estimated Sectors
ADCS … Average Distance to Correct Sector

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Conclusion & Future Work

Conclusion

- Best results achieved with Graph (n = 2) Pipeline
- Almost perfect results according to NCES with tolerated distance of 1

  → most results off by only 1 sector

- Overall performance favorable
- **HOWEVER:** Cell approximation is not realistic enough

Future Work

- Alternative cell approximation algorithms

  → signal propagation model

- More sophisticated filters

  → use more contextual information

  → analyze existing contextual information in detail

Q & A