

A Simplified Multi-Floor Classification-Based Indoor Positioning System Study

Optimizing Grid Size and Feature Selection for ML-Based IPS

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Problem, Approach & Contributions

Challenge: GPS fails indoors, need ML-based IPS using Wi-Fi fingerprinting

Research Gap: Limited understanding of grid size and feature selection impact

Our Contributions:

1. New evaluation metrics: AGT and ADT
2. Grid size vs. precision trade-off analysis ($1 \times 1\text{m}$ to $15 \times 15\text{m}$)
3. Feature filtering impact ($1,799 \rightarrow 378$ BSSIDs)
4. Verified local optimal grid size can be identified ($7 \times 7\text{m}$)

Research Overview

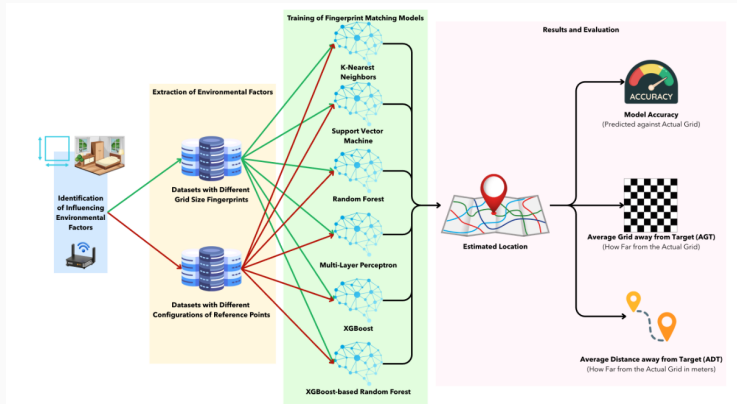


Figure 1: Four-part research methodology

Key factors identified:

1. Grid Size

- Larger grids → easier classification, lower precision
- Smaller grids → higher precision, more data collection effort

2. Low-Relevance BSSIDs

- Signals from distant access points
- Introduce noise and increase computational cost
- Need systematic filtering approach

New Evaluation Metrics

Average Grid from Target (AGT):

$$AGT = \sqrt{(x_{target} - x_{estimate})^2 + (y_{target} - y_{estimate})^2}$$

Average Distance from Target (ADT):

$$ADT = \sqrt{[w_g \times (x_{target} - x_{estimate})]^2 + [h_g \times (y_{target} - y_{estimate})]^2}$$

- AGT: Grid-based distance (adaptable to any grid size)
- ADT: Converts AGT to physical distance in meters using grid dimensions

Grid Interpolation Approach

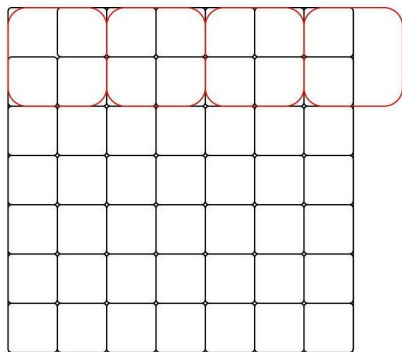


Figure 2: Grid aggregation visualization

Benefits:

- Avoid re-taping entire area
- Generate multiple grid sizes from $1 \times 1\text{m}$ base
- Reduce human measurement errors

Method:

- Average RSSI from 5 sampling points
- Test 8 grid sizes: $1 \times 1\text{m}$ to $15 \times 15\text{m}$

Dataset Overview

Table 1: Dataset metadata by grid size

| Floor | Grid Size | # Grids | # Data Points |
|-------|-----------|---------|---------------|
| 1st | 1 × 1m | 309 | 8,086 |
| 1st | 7 × 7m | 17 | 445 |
| 1st | 15 × 15m | 5 | 130 |
| 2nd | 1 × 1m | 174 | 4,554 |
| 2nd | 7 × 7m | 12 | 314 |
| 2nd | 15 × 15m | 4 | 105 |

- Total: 12,640 RSSI samples
- Filtered: 378 BSSIDs (from 1,799)

RSSI Heatmap Analysis

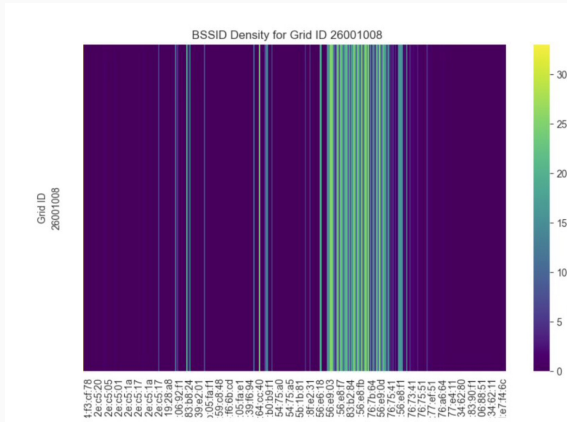


Figure 3: Heatmap showing RSSI values from different access points in a sample grid

- Darker colors = lower signal strength

Machine Learning Models

Models evaluated:

- k-Nearest Neighbor (kNN)
- Random Forest (RF)
- Support Vector Machine (SVM)
- Multi-Layer Perceptron (MLP)
- XGBoost
- XGBoost + Random Forest hybrid

Training approach:

- Standard process with hyperparameter tuning
- Consistent dataset across all models
- Comparison of filtered vs. unfiltered BSSIDs

Accuracy by Grid Size

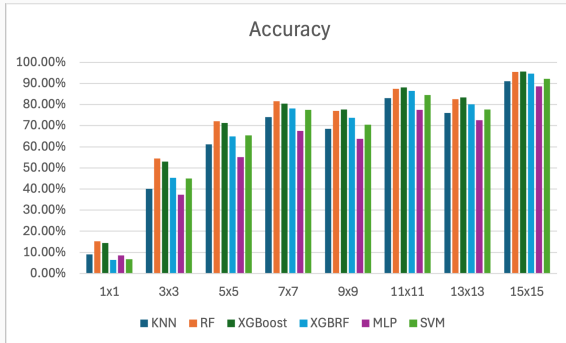


Figure 4: Model accuracy across different grid sizes (Filtered)

AGT Results

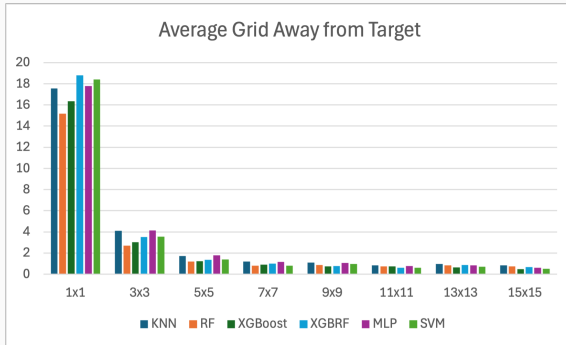


Figure 5: Average Grid from Target (Filtered)

ADT Results

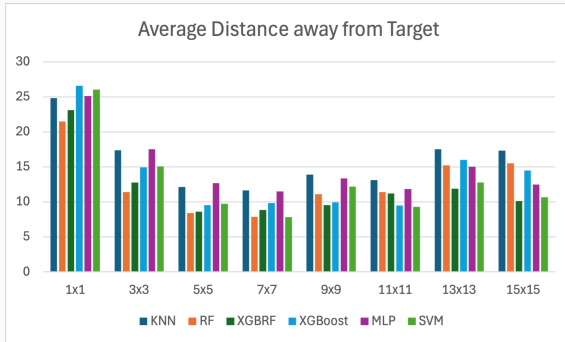


Figure 6: Average Distance from Target in meters (Filtered)

Feature Filtering Impact

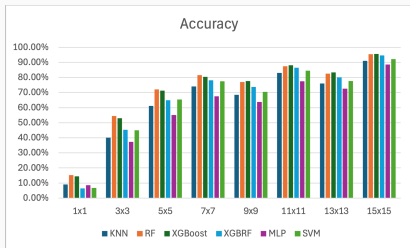


Figure 7: Filtered (378 BSSIDs)

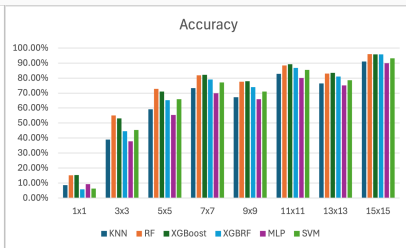


Figure 8: Unfiltered (1,799 BSSIDs)

Key Findings

1. Optimal Grid Size: $7 \times 7\text{m}$

- Best balance between accuracy and spatial resolution
- 80% accuracy with lowest AGT/ADT values

2. Feature Filtering Works

- 79% reduction in features ($1,799 \rightarrow 378$)
- Maintained performance, improved stability
- Significantly reduced training time

3. Best Models: RF and XGBoost

- Consistently outperformed other models
- Well-suited for fingerprint-matching tasks
- Better than complex deep learning in this setting

Practical Implications

For IPS Implementation:

- Don't assume bigger grids imply better accuracy - accuracy diminishes beyond optimal point
- Moderate grid sizes can be optimal
- Simple feature filtering is effective

Limitations:

- Site-specific results (university campus)
- Intensive data collection required (can be automated but still daunting)
- May need recalibration for different environments
- Architecture and materials affect performance

Future Directions

- Advanced deep learning models (attention-based, GNN-MLP)
- Real-time adaptive grid configurations
- Synthetic data augmentation and sensor fusion
- Transfer learning across buildings

Questions?

Implementation Challenges

Floor tiling variations:

- Different elevations and angles
- Addressed by reference-point-based grid construction

Edge grid effects:

- Corner vs. center RSSI variations
- Minimal impact on overall performance
- Misclassifications typically involve adjacent grids

Hardware constraints:

- RTX 3080 Ti struggled with unfiltered dataset
- Filtering made training feasible across all grid sizes