Smartphone-based User Location Tracking in Indoor Environment

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Overview

- The whole path is split into:
  - Find Building ID
  - Find Floor ID
  - Path Approximation
  - Smoothing
  - What next?

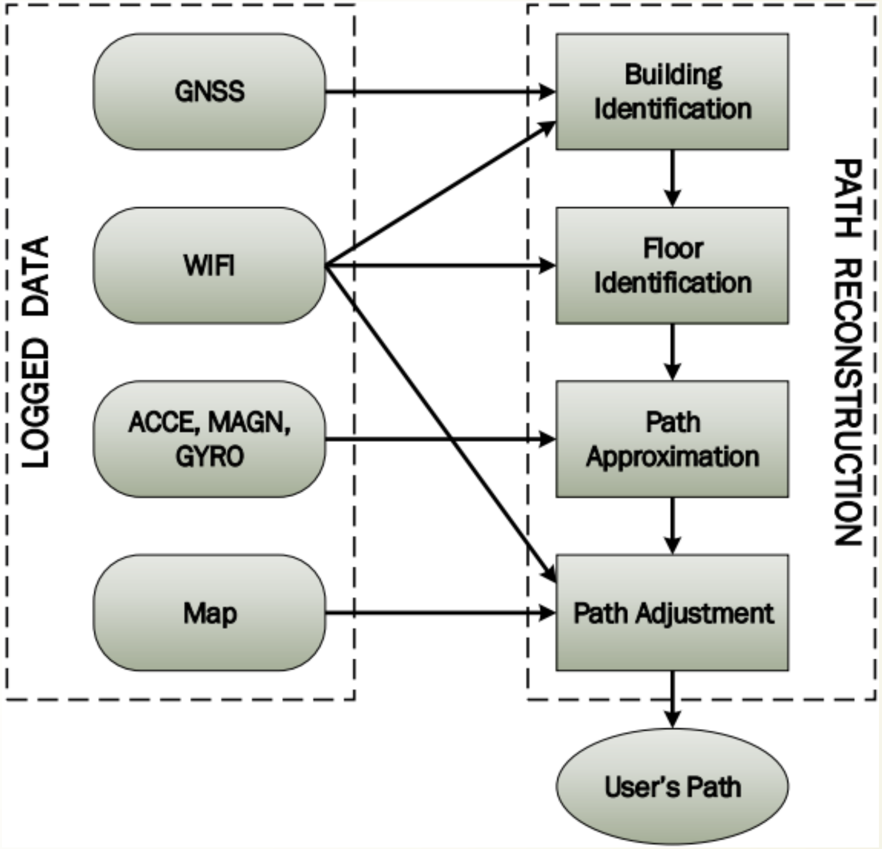

Figure 1: Subtasks and sensors are used

Building Identification

- Use GNSS is enough
- If not, we can look into the BSSID of the WIFI

	UAH	**CAR**	**UJITI**	**UJIUB**
UAH	0.	24.9	285.0	284.6
CAR	24.9	0.	292.7	293.1
UJITI	285.0	292.7	0.	0.4
UJIUB	284.6	293.1	0.4	0.

Table 1: Distance between buildings in km

Floor Identification

- Use WIFI data, by finger-printing approach.
  - Group “closed” WIFI data into one complete scan
  - Sparse data
- Feature set:
  - Raw feature: D = 353 in case of UAH building
  - K-filter feature[1] : used K = 2
  - Hyperbolic Location Features (HLF)[2]

[1] A. Moreira, M. J. Nicolau, F. Meneses, and A. Costa. Wi-fi fingerprinting in the real world – rtls@um at the evaal competition. In Indoor Positioning and Indoor Navigation (IPIN), 2015 International Conference on, pages 1–10, Oct 2015

[2] M.B. Kjaergaard and C.V. Munk. Hyperbolic location fingerprinting: A calibration-free solution for handling differences in signal strength (concise contribution). In Pervasive Computing and Communications, 2008. PerCom 2008. Sixth Annual IEEE International Conference on

Floor Identification

- Learning models: KNN, Random Forest (RF), Extreme Gradient Boosting (XGB) [3]
- Results in cross-validation testing, with 5-fold:
- End up with two assumptions:
  - Floor is well-separated
  - Entrance/leaving points are at the stairs

	RAW	2-filters	HLF
KNN	91.47%	91.30%	91.47%
RF	95.52%	94.28%	92.70%
XGB	**98.24%**	97.80%	97.36%

Table 2: Accuracy on floor identification sub-tasks (use classifiers only)

[3] Tianqi Chen and Carlos Guestrin. Xgboost: A scalable tree boosting system. CoRR, abs/1603.02754, 2016.

Path Approximation within a Floor: WIFI

- Use WIFI fingerprinting approach:
  - The same feature set and learning models as floor.
  - Change the target: regression and classification.
- An average of error at 3rd-quarter is around 6.5m with cross validation

Method	Raw	2-filters	HLF
KNN regression	9.7m	9.4m	9.1m
KNN classifier	10.3m	10.3m	10.3m
RF classifier	10.6m	11.5m	12.9m
XGB classifier	6.6m	**6.0m**	6.2m

Table 3: 3rd-quarter error of several learning models

Path Approximation within a Floor: Speed

- For speed:
  - Moving and standing patterns are well separated.
  - From the log file, calculate the average speed.
- Use simple rule:
  - If std ≥ 1.0, use average speed
  - Otherwise, 0

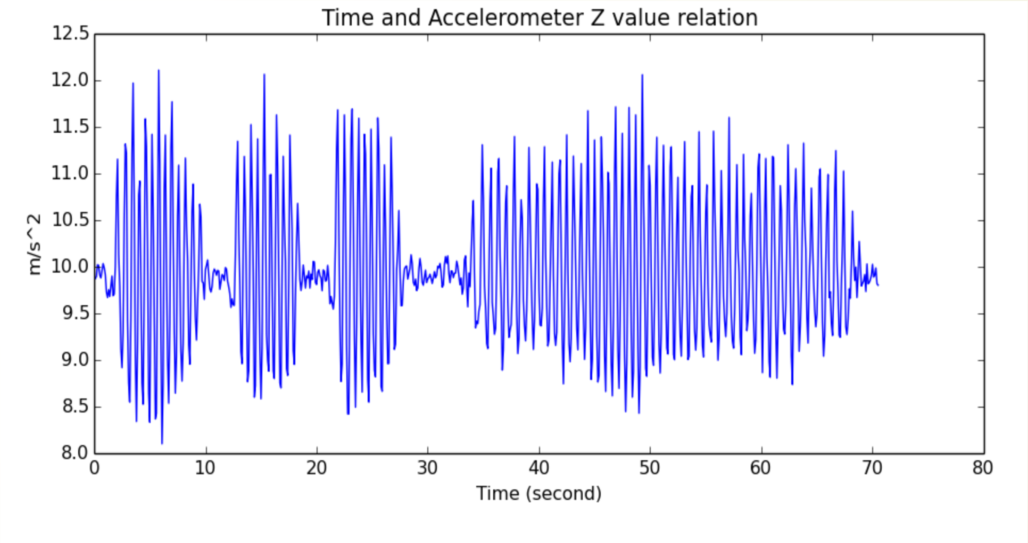

Figure 2: Z-axis of accelerometers

Path Approximation within a Floor: Direction

- Direction is calculated in a numerous way:
  - By rotation matrix from ACCE and MAGN
  - By integrating of GYRO data
  - By Madgwick filter[4]
  - By AHRS data
- The path is constructed by using Particle Filter[5]
- Affect by errors drifting seriously

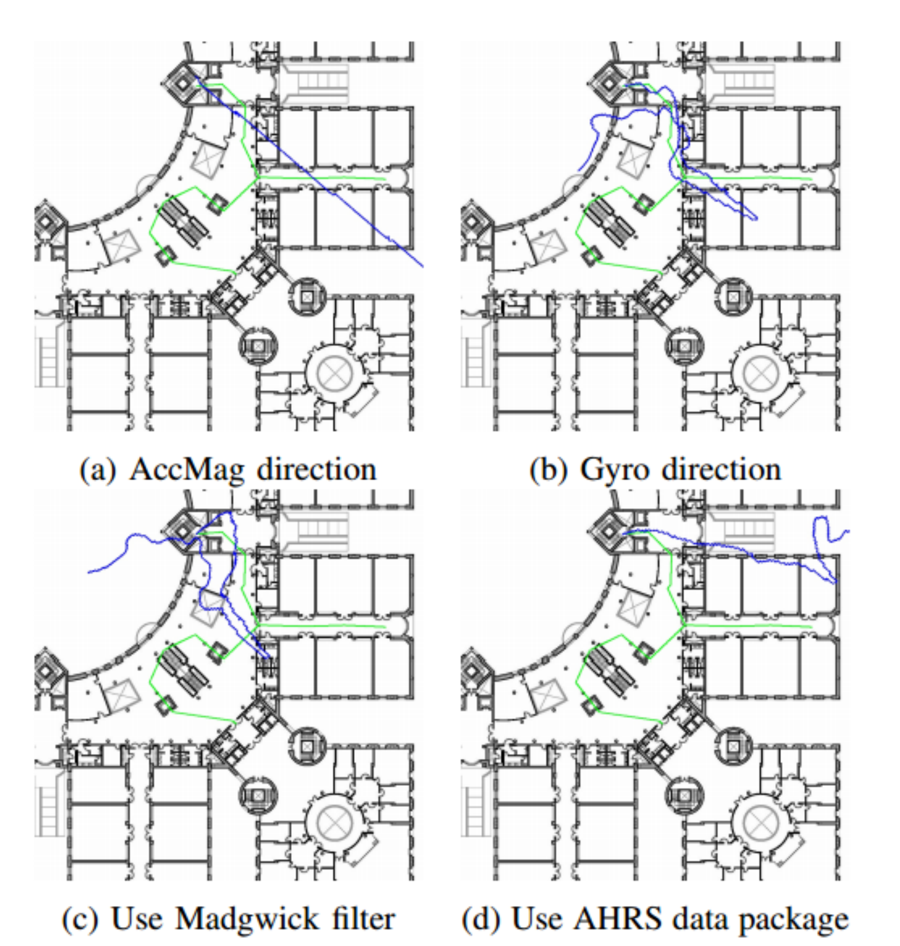

Figure 3: Four different methods for computing direction

[4] Sebastian Madgwick. An efficient orientation filter for inertial and inertial/magnetic sensor arrays. Report x-io and University of Bristol (UK), 2010
[5] Nisarg Kothari, Balajee Kannan, Evan D Glasgwow, and M Bernardine Dias. Robust indoor localization on a commercial smart phone. Procedia Computer Science, 10:1114–1120, 2012

Path Approximation within a Floor: Combination

- Combining with WIFI
  - It takes around 4s to get a new completed WIFI scan
  - Use local adjustment from the classifier results

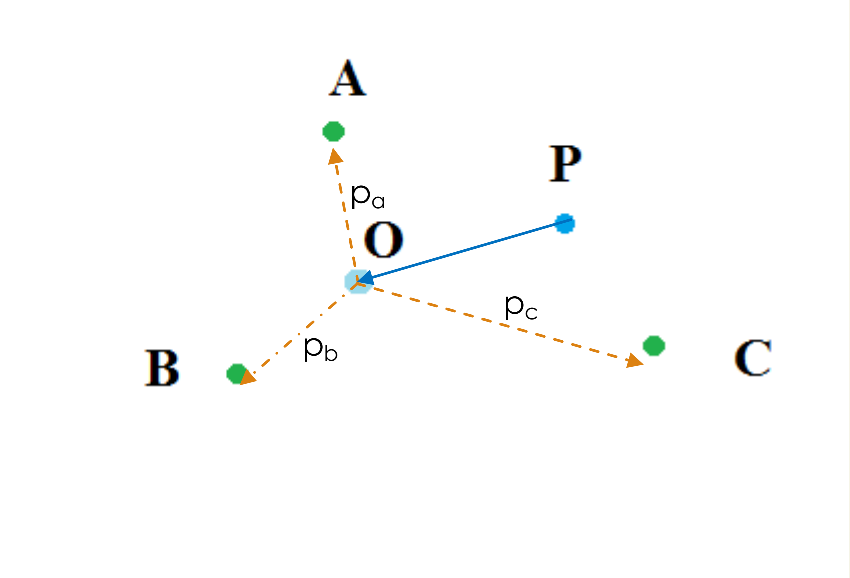

Figure 4: Adjusting particle P based on output of WIFI fingerprinting classification model

Path Approximation within a Floor: Wall-crossing check (1)

- Wall crossing adjustment:
  - Assign the direction to go parallel with the wall

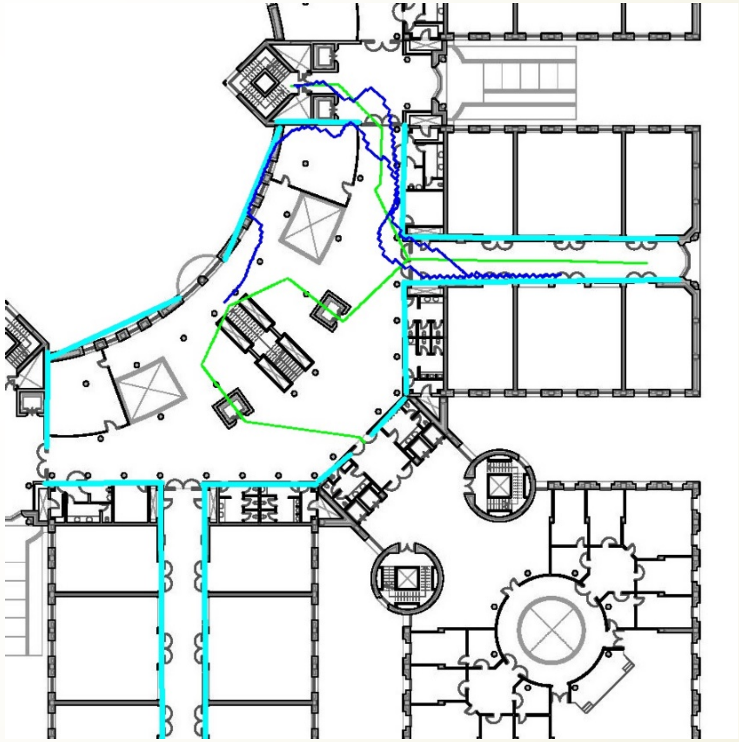

Figure 5: Avoiding to cross the wall by adjusting the local direction

Path Approximation within a Floor: Wall-crossing check (2)

- Optimizing wall crossing:
  - Use 2 operators: rotation and local speed adjust.
  - Greedy algorithm: apply to avoid first cross wall.
  - Can be solved by dynamic programming but difficult

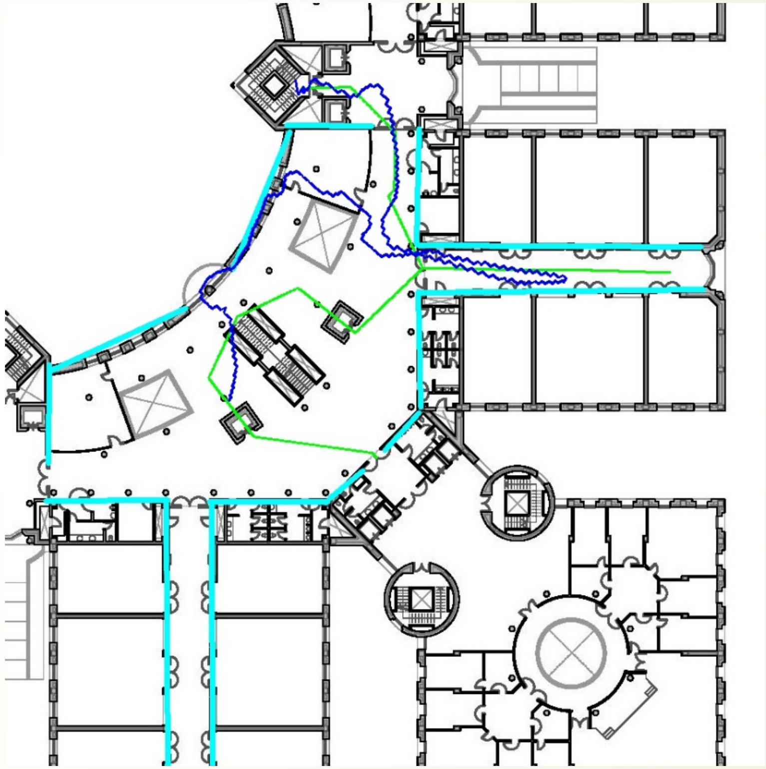

Figure 5: Results of applying greedy algorithm for adjusting speed and direction

Path Approximation within a Floor: Results

- Results on 3 minutes and 7 minutes approximation:

Increasing chances of overfitting

	3 minutes	7 minutes
WIFI	16.4m	29.8m
Wall adjust + WIFI	14.2m	28.1m
Optimize + Wall adjust + WIFI	10.1m	24.5m

Table 4: 3rd-quarter error of three combining methods

Path Approximation within a Floor: Results

- Best approximation results (after submitting the paper):
  - Use rotation matrix only with normalization to 0-mean MAGN (from our paper's reviewers).
  - Only use local adjust with WIFI
  - Do forward and reverse approximation then take weighted average position.
- Error 3rd-quarter is around 13.0m

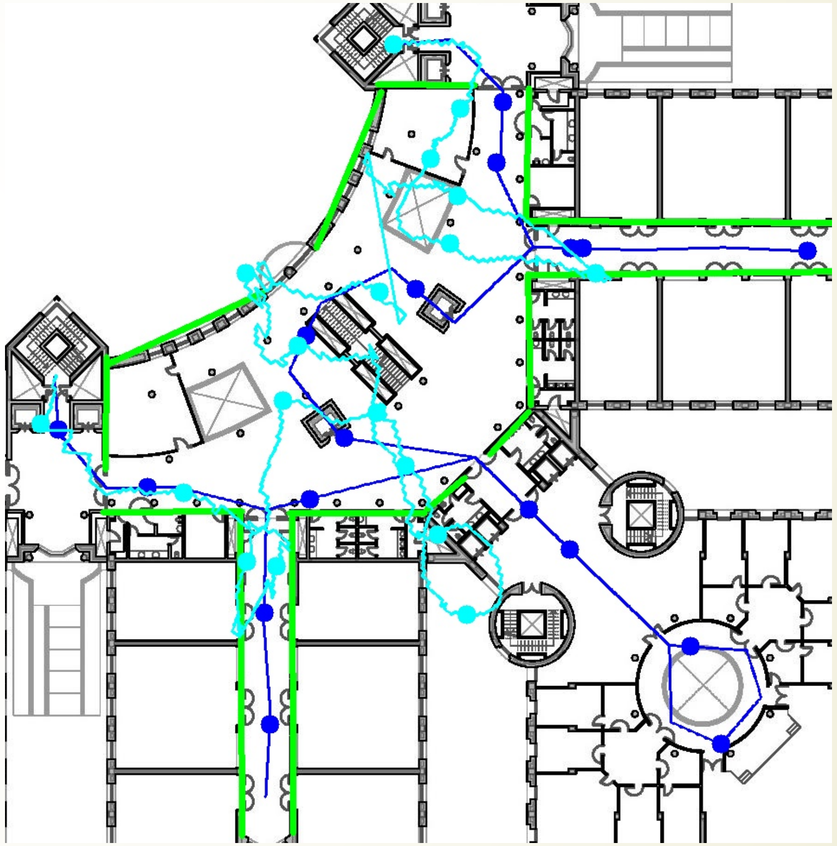

Figure 6: Best approximating results on Floor 1, Route 1, S3 phone, UAH building.

Discussion and Future Works

- The test data is the real challenge.
- The problem is not solved yet:
  - Floor is not well separated enough on test data: cannot identify entrance/ leaving points. Proposed solutions:
    - Moving patterns can be used here (turning around in the stairs/standing in elevators)
    - Depend largely on WIFI at first step
    - Looking for big changes in MAGN
  - If the phone is in the pocket? Proposed solutions:
    - Use WIFI only.
    - Use other axis, however when?

THANK YOU FOR LISTENING!

and Wish You Have A Good Accuracy