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RSSI based indoor target locating and tracking

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0 Overview

Why to locate object

Background/Methology

- Wireless Sensor Network (WSN)
- Received Signal Strength Indicator (RSSI)
- Trilateration
- Evaluation of results
- Result for trilateration
- Kalman Filter (KF)

How produce synthetic data



1

Why to locate objects

1 Why to locate object

- Sailors all over the time have tried to locate themselves using stars
- Good to know where valuables are
- Popularity of Apple Airtag network

1 Why to locate object

- US military might start to locating their aircrafts

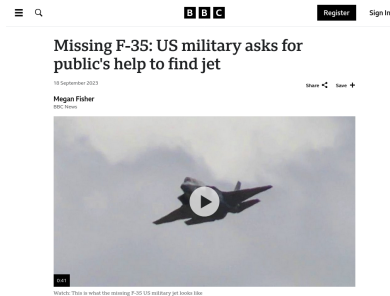


Figure 1: Fighert Jet got lost [1]

1 Why to locate object

Locating targets is easy. Mount a GPS chip on every target

Few problems

- GPS chips cost money
- Takes space on the target device
- Doesn't work indoors

2

Background

2 Wireless Sensor Network (WSN)

Wireless sensor network (WSN) are large self organizer networks of computing nodes gathering data from their surroundings [2, p 1].

Use cases

- Forest fire detecting
- Earthquake detecting
- Research

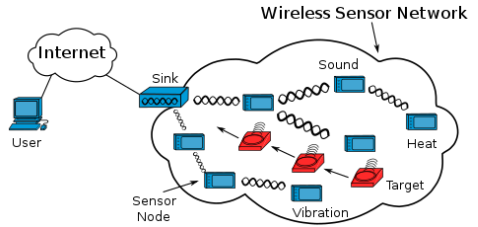


Figure 2: Simple WSN

2 WSN node

Small – About the size of a watch
[2, p 5]

Required component

- Central Processing Unit (CPU)
- Communicating unit
- Battery

Measurement node (Node)

- Lot of sensors
- Unknown position

Anchor nodes (Anchors)

- Estimates own location
- Specialized locating chip
- Mounted on known location

2 Received Signal Strength Indicator (RSSI)

One can calculate the distance between the node and anchor

Strength is inverse proportionality to the distances square [2, p 26]

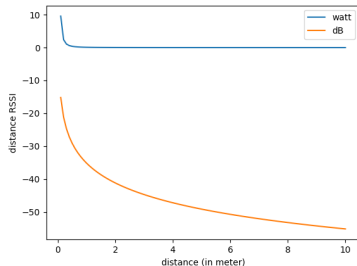


Figure 3: RSSI vs Dist

2 Friis equation and Log normal shadowing [2, p 32]

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi d} \right)^2$$

- P_r is recieved power
- P_t is transmitted power
- G_r is reciever gain
- G_t is transmitter gain
- λ is wavelength of signal
- d is distance between antennas

$$P_r^{[dB]} = P_{r0}^{[dB]} - 10\eta \log \left(\frac{d}{d_0} \right)$$

- $P_r^{[dB]}$ is recieved power at distance d
- $P_{r0}^{[dB]}$ is recieved power at distance d_0
- d_0 is reference distance
- d is distance between antennas
- η is path loss exponent

2 Trilateration

From three known points and known distances, the intersecting point can be computed [2, p 36]

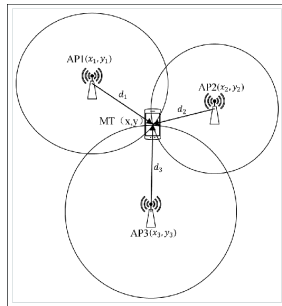


Figure 4: Illustration of trilateration [3]

2 Evaluation of results

Root Mean Square Error [2, p 69]

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2}{2N}}$$

- \hat{x}_i is the i :th measurement in the x-axis
- \hat{y}_i is the i :th measurement in the y-axis
- x_i is the i :th actual point in the x-axis
- y_i is the i :th actual point in the y-axis
- N is the count of all points

2 Result for trilateration – 4 anchors

With four nodes positioned into the corners of our room the RMSE is 10.01 meters

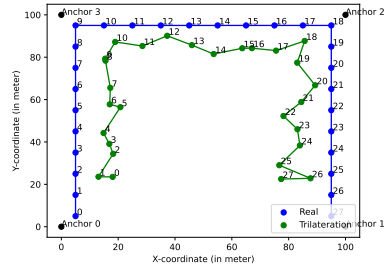


Figure 5: Trilateration with four nodes

2 Result for trilateration – 8 anchors

One easy way to increase the accuracy it to increase the number of nodes. With eight nodes positioned as shown in the picture the RMSE is 4.55 meters

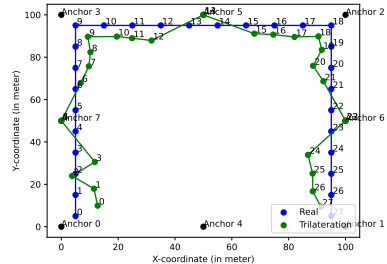


Figure 6: Trilateration with eight nodes

2 Kalman Filter (KF) [4]

- R. Kalman published a revolutionary paper in 1960
- Recursive solution to a discrete-time linear optimization problem
- Recursive → No huge memory consumption

Works as a sequence of two different phases

- 1st phase is the prediction phase
- 2nd phase is the update phase

2 Result of Kalman Filter – 4 anchors

With Kalman Filter the RMSE drops down to 8.29 meters

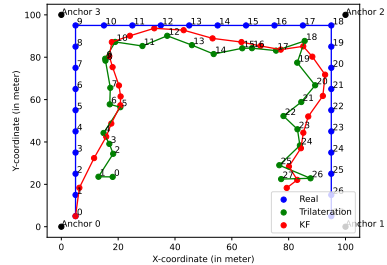


Figure 7: Improvements with Kalman Filter

3

How produce synthetic data

3 How produce synthetic data

- Hopefully a whole testing lab – unfortunately not
- Need to produce it synthetically.
- Five step process

3 How produce synthetic data

Generate simple trajectory.

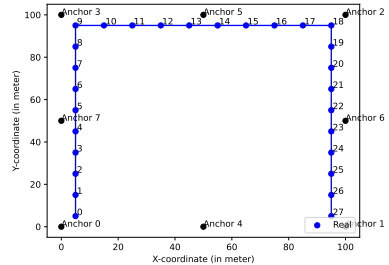


Figure 8: Simple path

3 How produce synthetic data

Calculate distances between each step and anchor

$$d = \sqrt{(x_a - x_n)^2 + (y_a - y_n)^2}$$

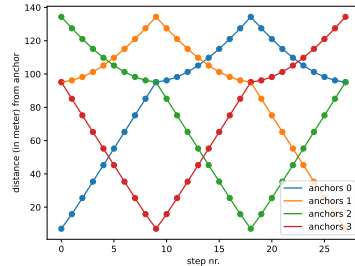


Figure 9: Distances

3 How produce synthetic data

Convert distance to RSSI reading using
log normal shadowing

$$P_r^{[dB]} = P_{r0}^{[dB]} - 10\eta \log \left(\frac{d}{d_0} \right)$$

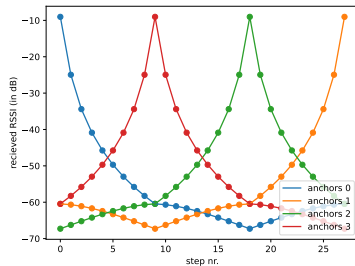


Figure 10: Distances

3 How produce synthetic data

Add noise to RSSI readings

$$P_{rn}^{[dB]} = P_r^{[dB]} + N(3, 0)$$

This is the real world data which we can measure

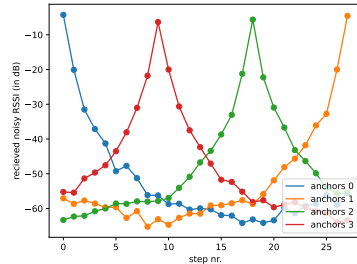


Figure 11: Noisy RSSI

3 How produce synthetic data

Convert RSSI to distances using log normal shadowing

$$d = d_0 10^{\frac{P_{r0}[dB] - P_{rn}[dB]}{10\eta}}$$

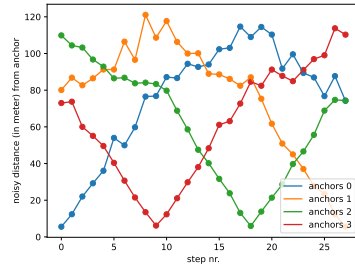


Figure 12: Noisy distances

3 How produce synthetic data

Trilaterate the distances back to locations

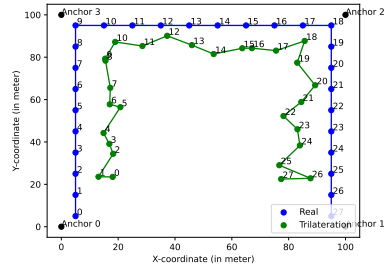


Figure 13: Positions

3 How produce synthetic data

Improve estimations with Kalman Filter

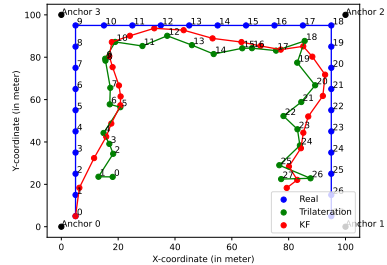


Figure 14: Kalman Filtered values

4

Result

4 Result

Anchor Count	MSQE without KF	MSQE with KF
4	10.01	8.29
5	5.92	4.49
8	4.55	3.26
9	4.2	3.49

4 Conclusion

- It is possible to locate and track objects indoors with RSSI.
- With Kalman Filter result can be slightly improved
- Adding more anchors improves the accuracy on the cost of nodes

4 Questions and Sources

- [1] Fisher, M, (2023) "Missing F-35: US military asks for publics help to find Jet" BBC News. Available at: <https://www.bbc.com/news/world-us-canada-66841194> (Accessed: 26 November 2024).
- [2] Jondhale, S & Maheswar, R & Lloret, J. "Received Signal Strength Based Target Localization and Tracking Using Wireless Sensor Networks" 1st ed. Cham, Switzerland: Springer. 2022. 201 s. ISBN 3-030-74061-7.
- [3] Yang, Junhua & Li, Yong & Cheng, Wei. (2018). "An improved geometric algorithm for indoor localization. International Journal of Distributed Sensor Networks". 14. 155014771876737. 10.1177/1550147718767376.
- [4] Kalman, E. "A new approach to linear filtering and prediction problems.". Journal of basic Engineering 82.1 (1960): 35-45.