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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)
- Trilaturation
- 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 themself 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

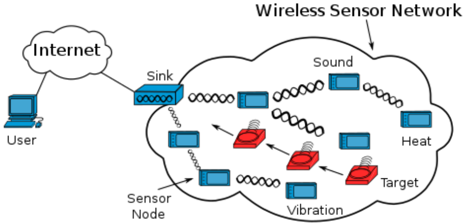


**Figure 2:** Simple WSN

# 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]

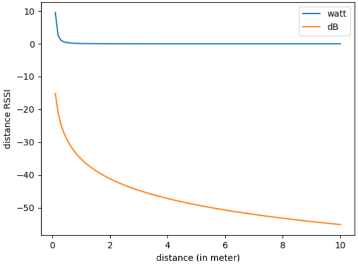


**Figure 3:** RSSI vs Dist

# 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
- $\lambda$ 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
- $\eta$ is path loss exponent

# 2 Trilaturation

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

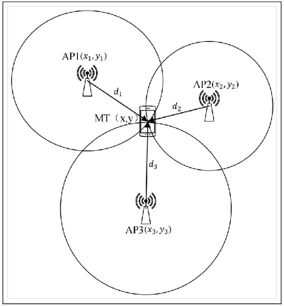


**Figure 4:** Illustration of trilateration [3]

# 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
- $N$ it the count of all points

# 2 Result for trilateration – 4 anchors

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

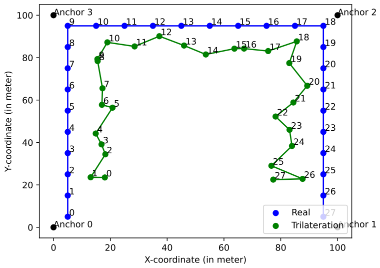


**Figure 5:** Trilateration with four nodes

# 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

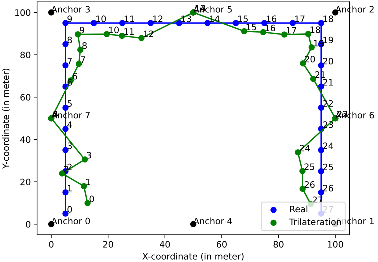


**Figure 6:** Trilateration with eight nodes

# 2 Kalman Filter (KF) [4]

- R. Kalman published a revolutionary paper in 1960
- Recursive solution to a discrete-time linear optimization problem
- Recursive $\rightarrow$ 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

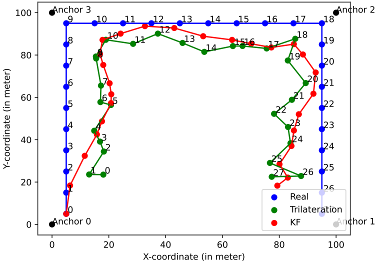


**Figure 7:** Improvements with Kalman Filter

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.

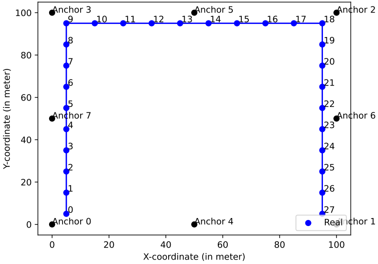


**Figure 8:** Simple path

# 3 How produce synthetic data

Calculate distances between each step and anchor

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

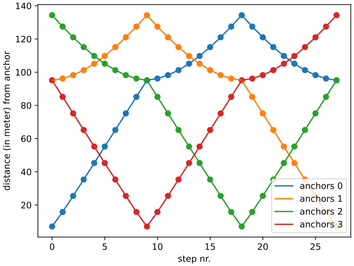


**Figure 9:** Distances

# 3 How produce synthetic data

Convert distance to RSSI reading using log normal shadowing

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

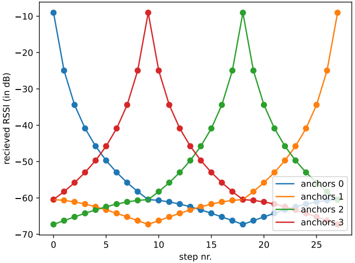


**Figure 10:** Distances

# 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

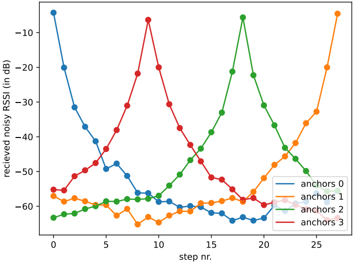


**Figure 11:** Noisy RSSI

# 3 How produce synthetic data

Convert RSSI to distances using log normal shadowing

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

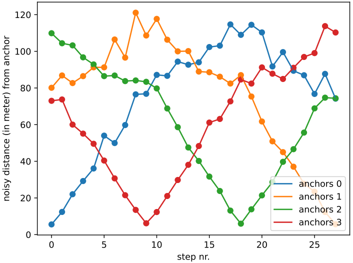


**Figure 12:** Noisy distances

# 3 How produce synthetic data

Trilaterate the distances back to locations

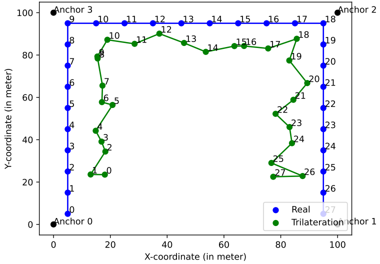


Figure 13: Positions

# 3 How produce synthetic data

Improve estimations with Kalman Filter

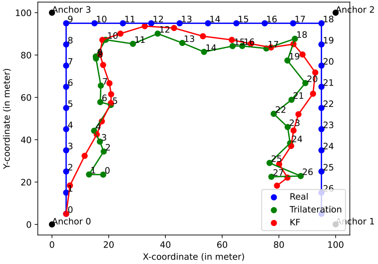


**Figure 14:** Kalman Filtered values

# 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.