Capstone Thesis

RSSI based local positioning system

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Plan

- Introduction to Location Positioning Systems
- Positioning Techniques: A Comparative Overview
- Objectives of the Capstone Project
- RSSI-Based Local Positioning System Overview
- LPS specifications

Global Positioning Systems

Local Positioning Systems

Global Positioning Systems

Utilize satellites to provide worldwide coverage and relatively accurate location information

Local Positioning Systems

Use short-range signaling nodes to obtain the location of systems

Global Positioning Systems

Advantages

- provides worldwide coverage
- most integrated and used system
- accuracy of ~ 5 meters

Disadvantages

- minimally efficient in closed, underground, subsurface areas
- spoofing or jamming rise security risks for critical applications

Local Positioning Systems

Advantages

- enable systems to alternate their precision
- outperforms when GPS is denied, or precision is limited

Disadvantages

- operate in limited geographical areas

Common techniques for positioning

Time of Arrival (TOA)

Based on time taken by a signal to travel between two points

- Is more accurate
- Requires precise time synchronization
- Requires line of sight (LOS)

Received Signal Strength Indicator (RSSI)

Relies on measuring the strength of the received signal

- More reliable in non-line of sight (NLOS)
- Simpler
- More nodes needed

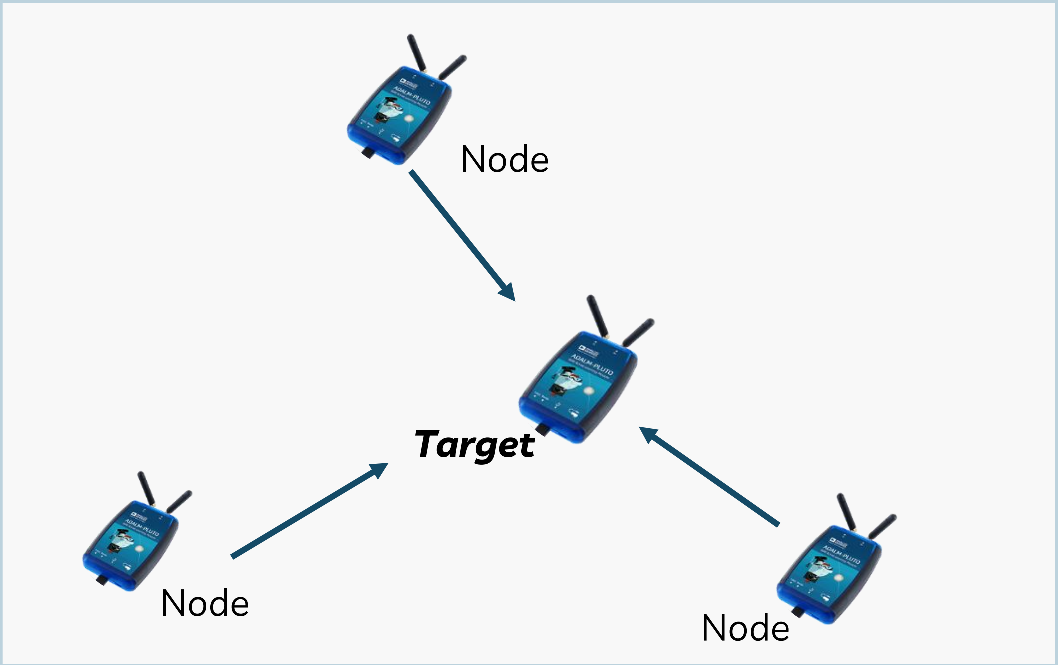
The goal

Implement a positioning system that will operate when GPS is denied, both in LOS and NLOS environments.

Implement a new system designed to meet the challenges of GPS-denied environments across varied scenarios ensuring reliability

RSSI based LPS system

- Implementation based on Software Defined Radio (SDR)
- Used RSSI technique
- Built on Adalm-Pluto SDR module
- Operates both in LOS and NLOS



Adalm-Pluto module

- Developed by Analog Devices
- A compact and cost-effective Software-Defined Radio
- Accessible platform for experimenting with wireless communication protocols and signal processing techniques
- Integrated FPGA

System Scope

- A basis for various platforms including automated vehicles
- Focused on improving distance measurement precision
- Provides the key operational modes to obtain positioning information
- External housing and mounting specifications adjusted when integrating

RSSI based LPS system

- Implementation based on Software Defined Radio (SDR)
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Factors affecting RSSI

Modulation Techniques

- Needed a simple technique
- Minimal amplitude changes
- Message to be transmitted in noisy environment
- Tested: FSK and QPSK

Operational Frequency

- propagation losses and the free space path loss
- relative to GPS operational range
- License Free: 433 MHz

Antenna characteristic

- Omnidirectional
- Transmitter and receiver are parallel

Distance measurement

$$RSSI_i = RSSI_0 - 10 \cdot n \cdot \log_{10} \frac{d_i}{d_0} + X$$

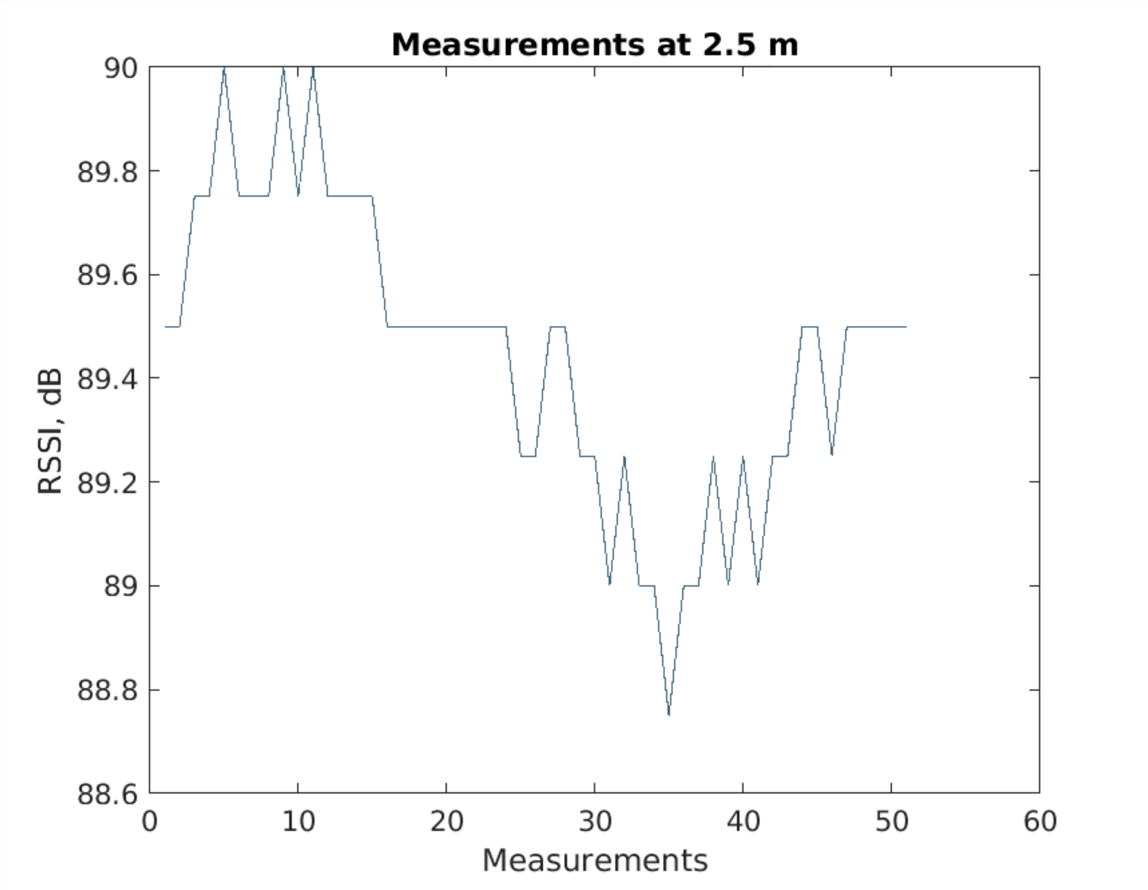
$RSSI_0$ – RSSI at reference distance d_0

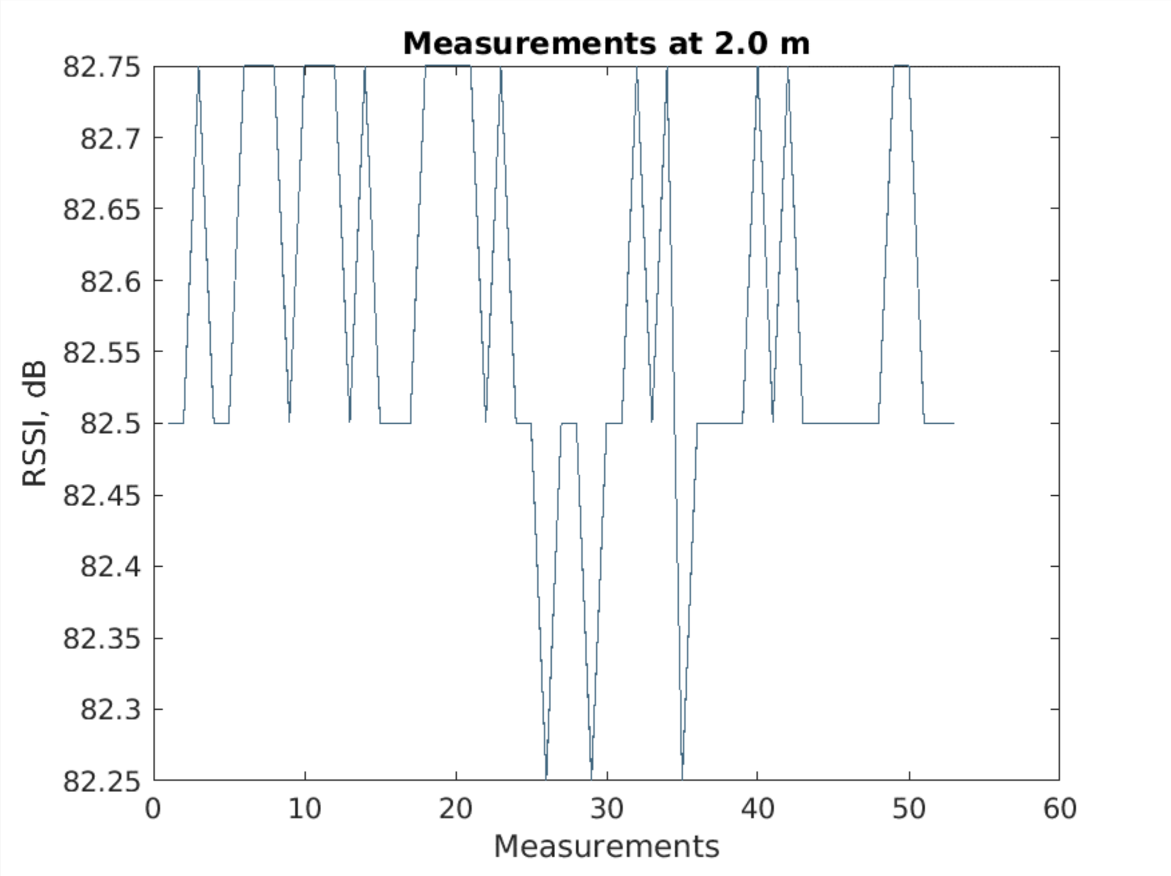
d_i – distance between the target and node i

n – path loss exponent

X – random variable for additional factors (i.e. noise)

Experimental RSSI

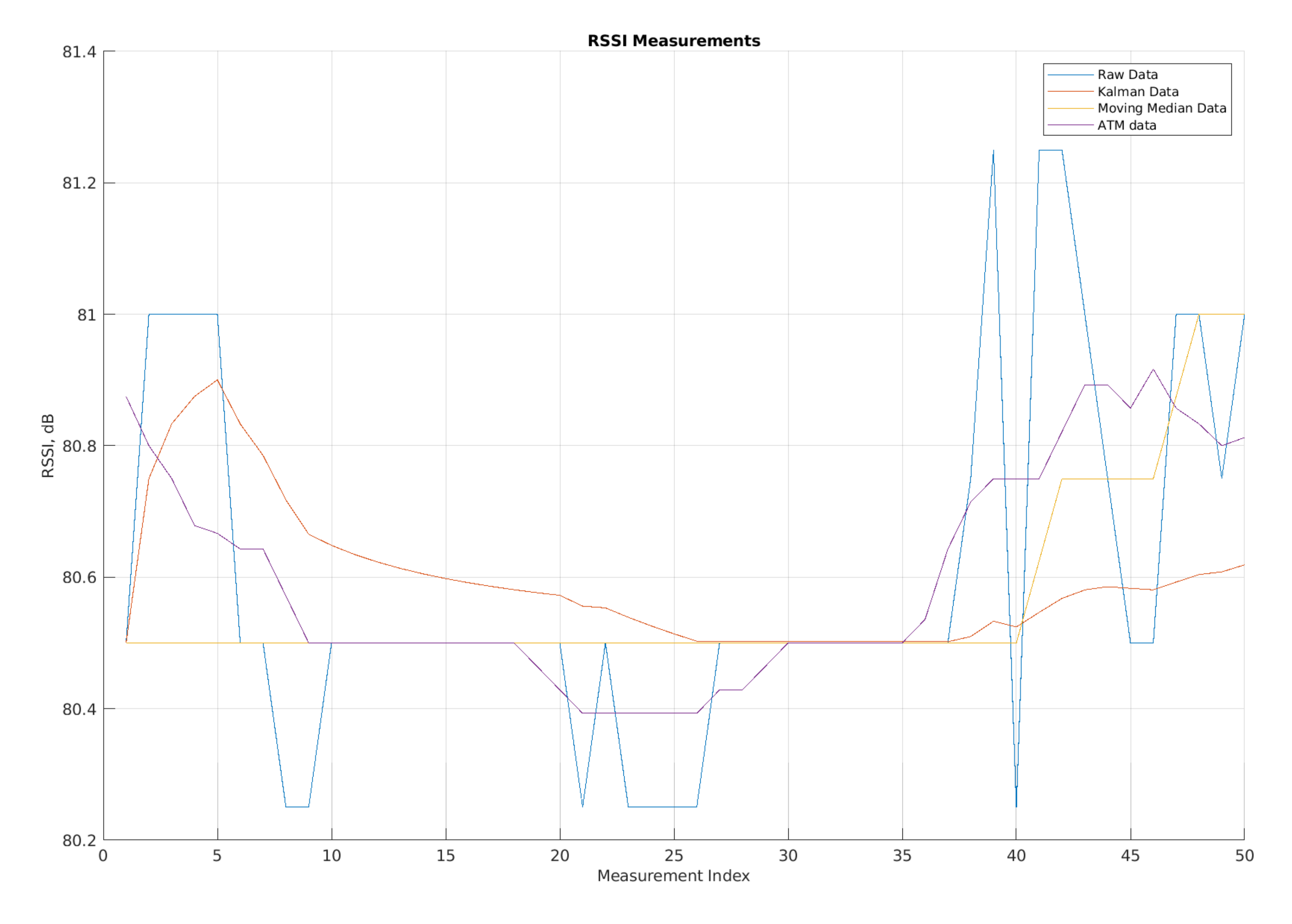




RSSI filtering

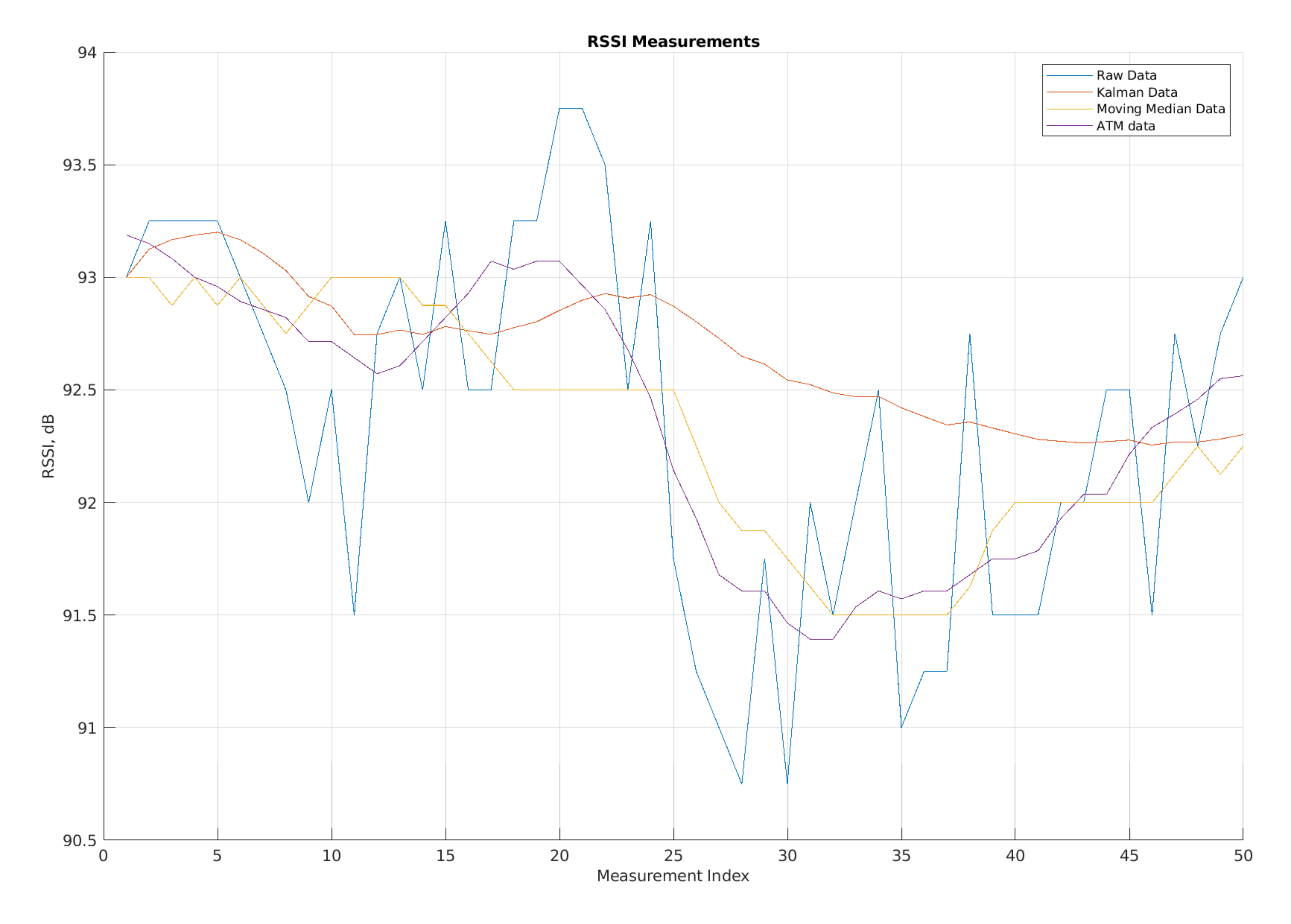
- Reducing noises and variability
- Improving the accuracy
- Smoothing out irregular changes
- Filters considered
  - *Moving median, **Kalman**, Gaussian, Alpha-trimmed mean*

Applied filters

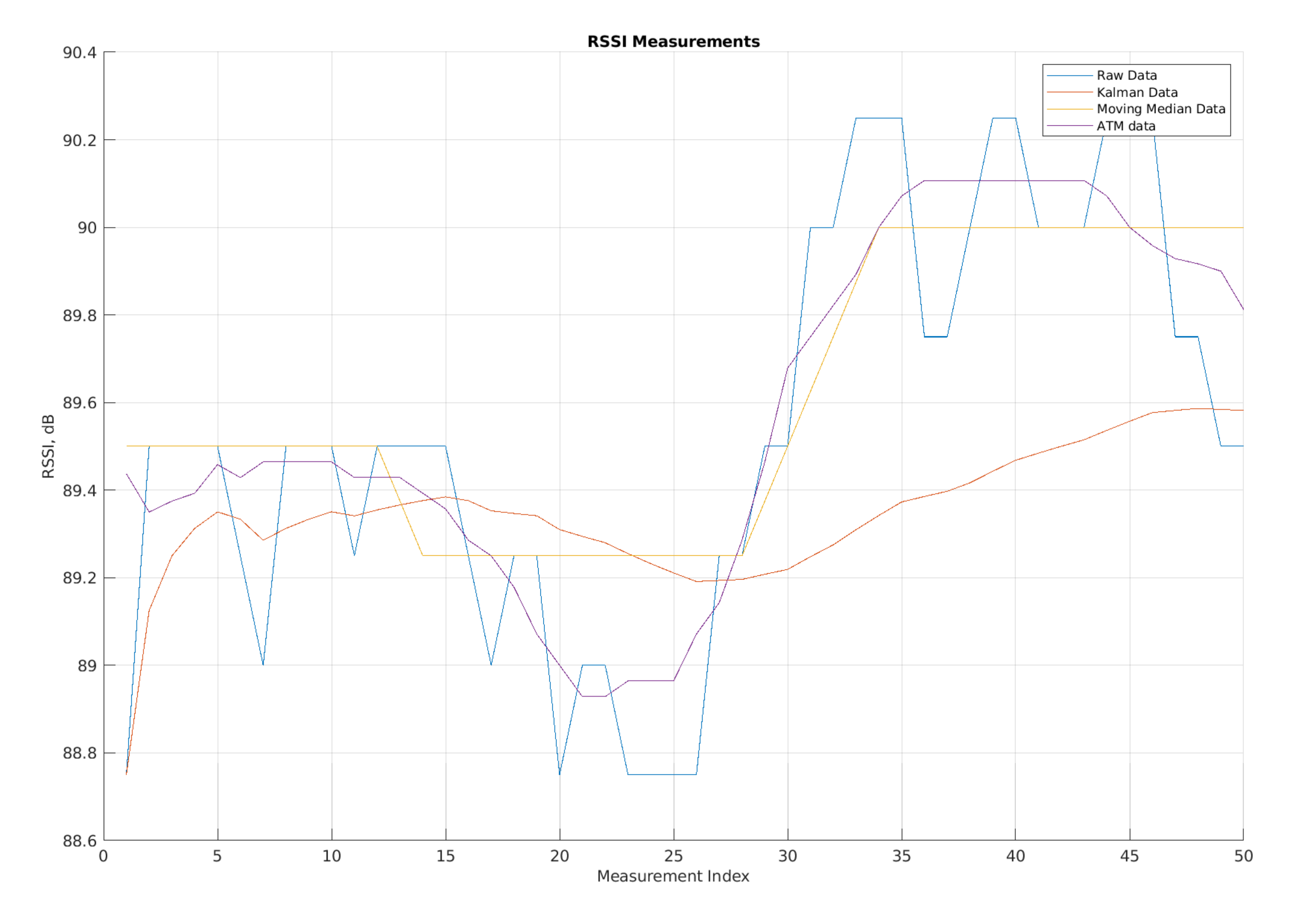


**Note:* RSSI values are negative, on the plot are positive for simpler visualization

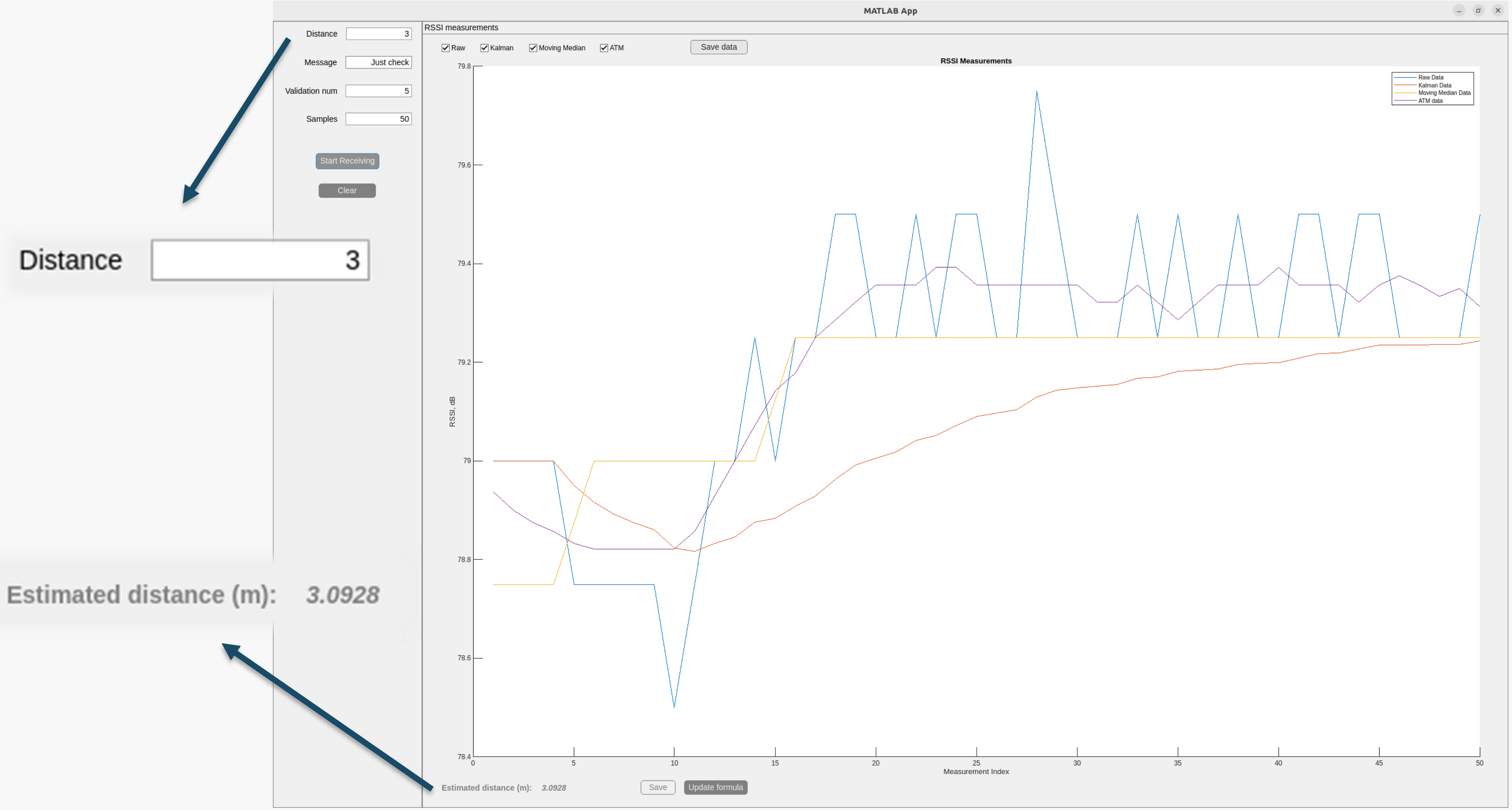
Applied filters



Applied filters



Experimental RSSI vs distance



Experimental results

Actual Distance (m)	Measured Distance (m)	Absolute Error (m)	Relative Error (%)
2.0	1.895	0.105	5.25
2.0	1.9671	0.0329	1.645
2.5	2.26	0.24	9.6
3.0	3.093	0.093	3.1
3.0	2.82	0.18	6.0
4.0	4.039	**0.039**	**0.975**
5.0	4.89	0.11	2.2
7.0	7.099	0.099	1.414
8.0	8.89	**0.89**	**11.125**
10.0	10.45	0.45	4.5

Trilateration ideally

The primary objective ~ accurate distance measurement between nodes, using the RSSI technique within the SDR framework

Target-node distances → trilateration → position information

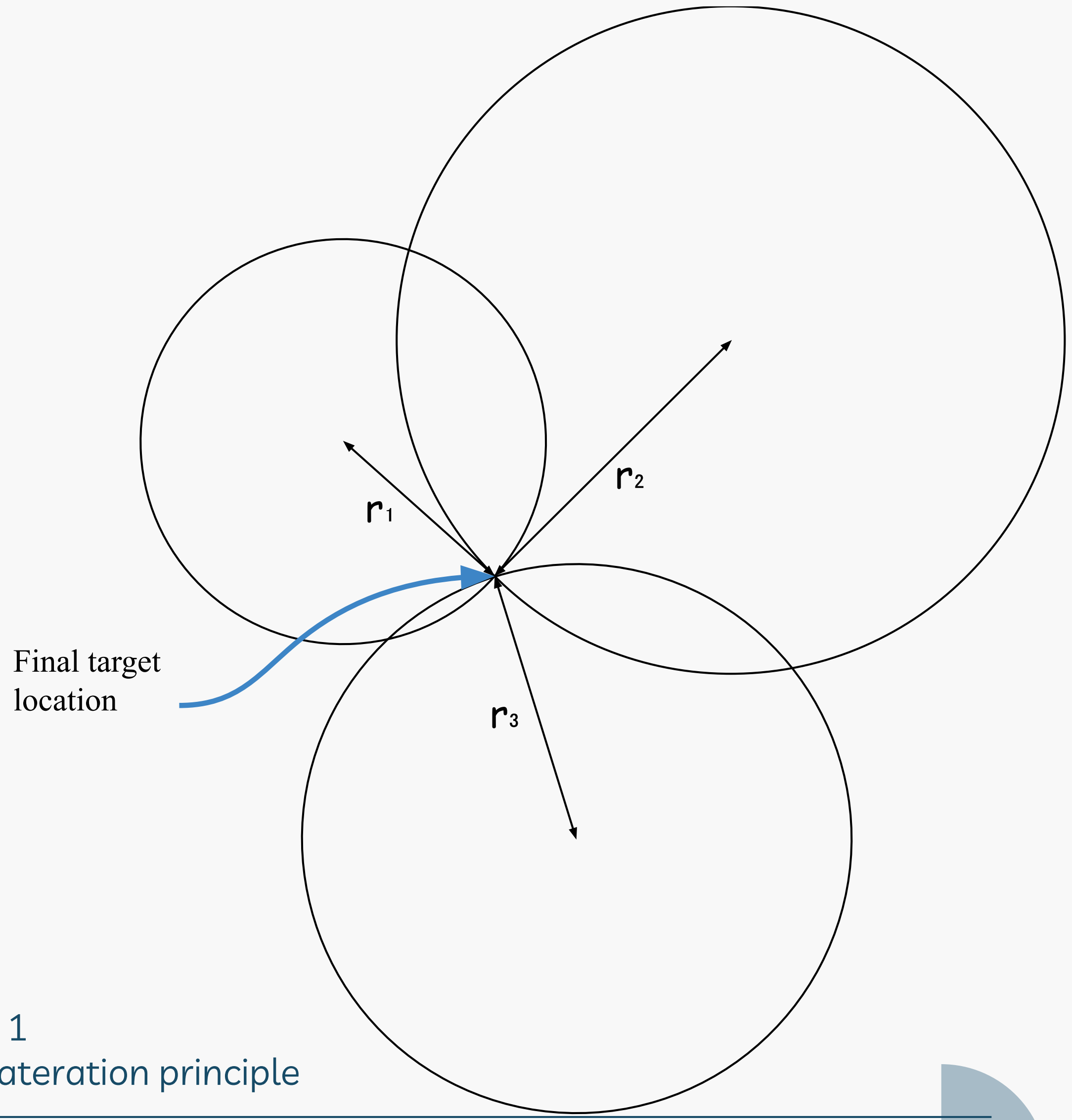
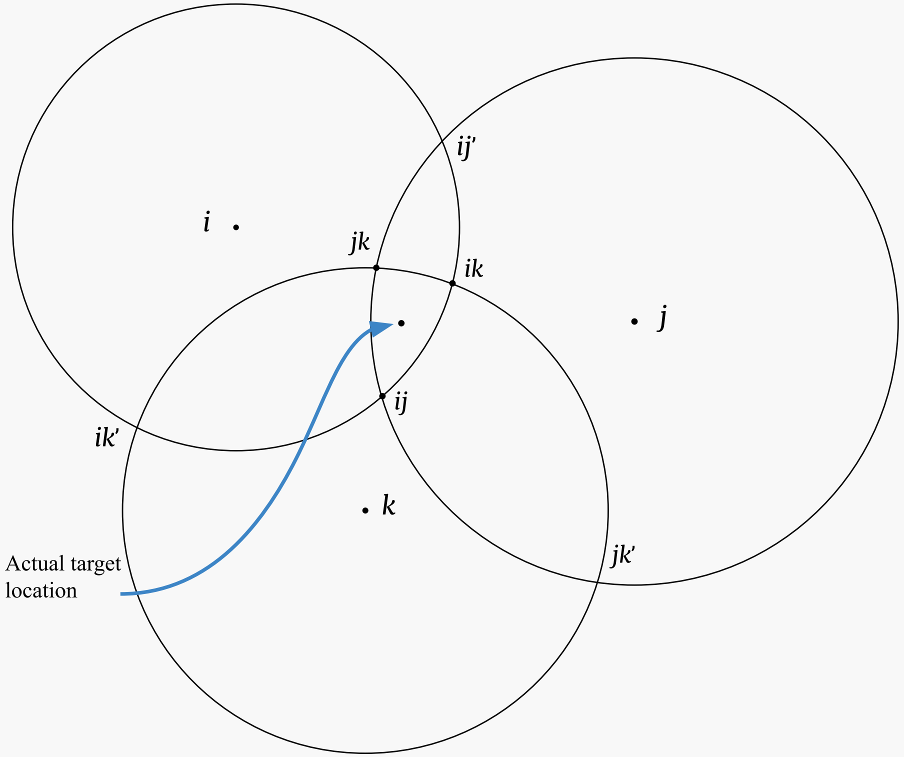
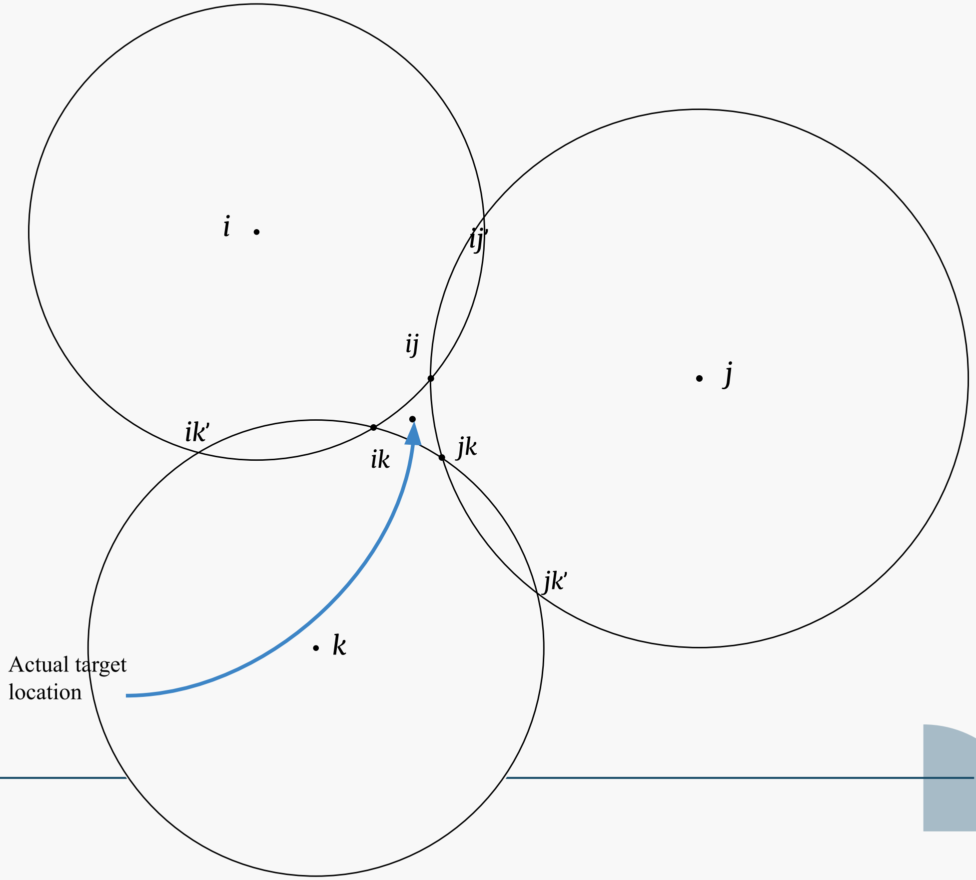


Fig. 1
Trilateration principle

Trilateration in use

Even small errors in distance measurements $\rightarrow$ Not perfectly intersecting circles

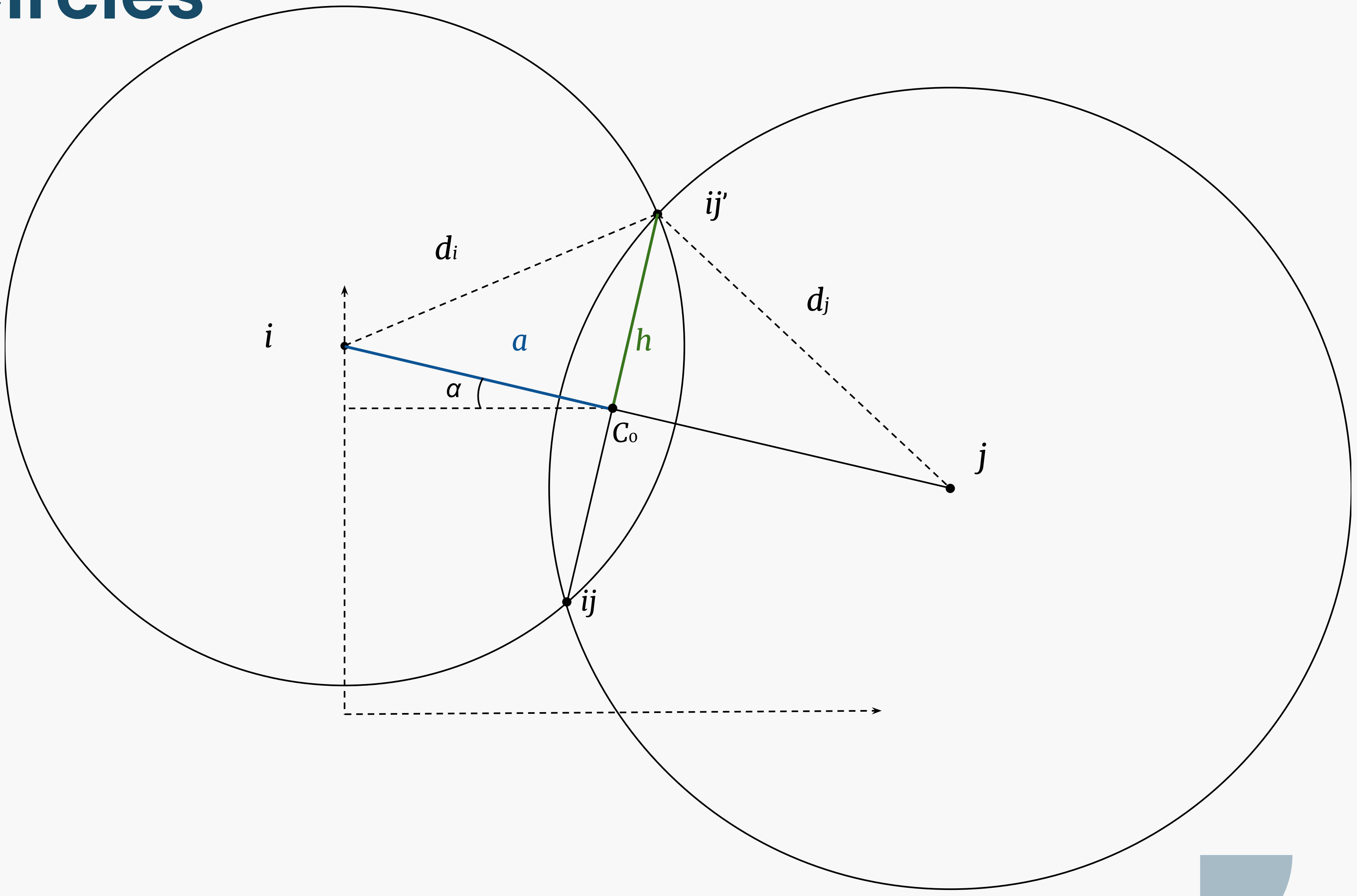




Intersection of Circles

$$x_{ij}, x'_{ij} = C_0 \pm h\left(\frac{y_j - y_i}{a}\right)$$

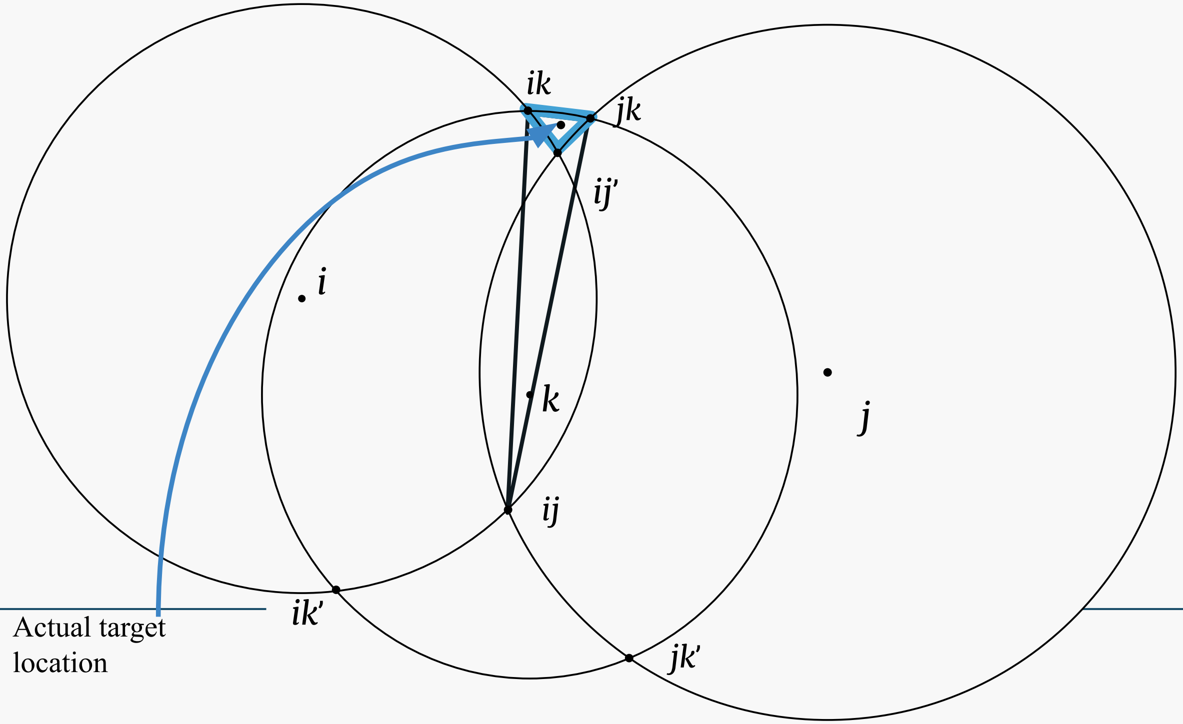
$$y_{ij}, y'_{ij} = C_0 \pm h\left(\frac{x_j - x_i}{d}\right)$$



Best intersection point

Traditional method: $\left(x_{ij} - x_k\right)^2 + \left(y_{ij} - y_k\right)^2 < \left(x'_{ij} - x_k\right)^2 + \left(y'_{ij} - y_k\right)^2$

Used method: $\left(\mathrm{d}_k - \sqrt{\left(x_{ij} - x_k\right)^2 + \left(y_{ij} - y_k\right)^2}\right)^2 < \left(\mathrm{d}_k - \sqrt{\left(x'_{ij} - x_k\right)^2 + \left(y'_{ij} - y_k\right)^2}\right)^2$



Node-Target signal transmission

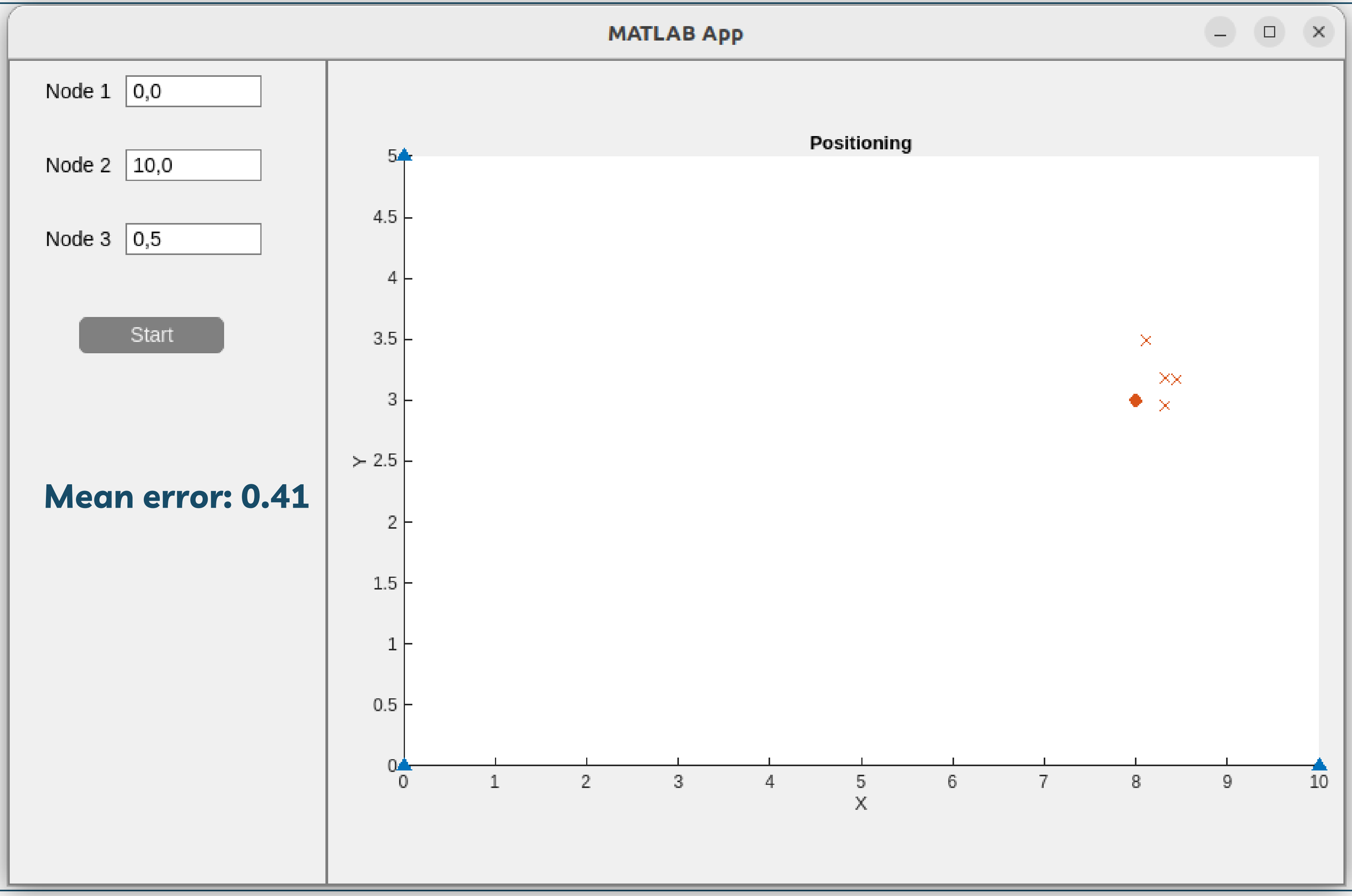
Time-Division Multiple Access

- Each node transmits data in its designated time slot
- Less likely signal collision
- Improved system organization

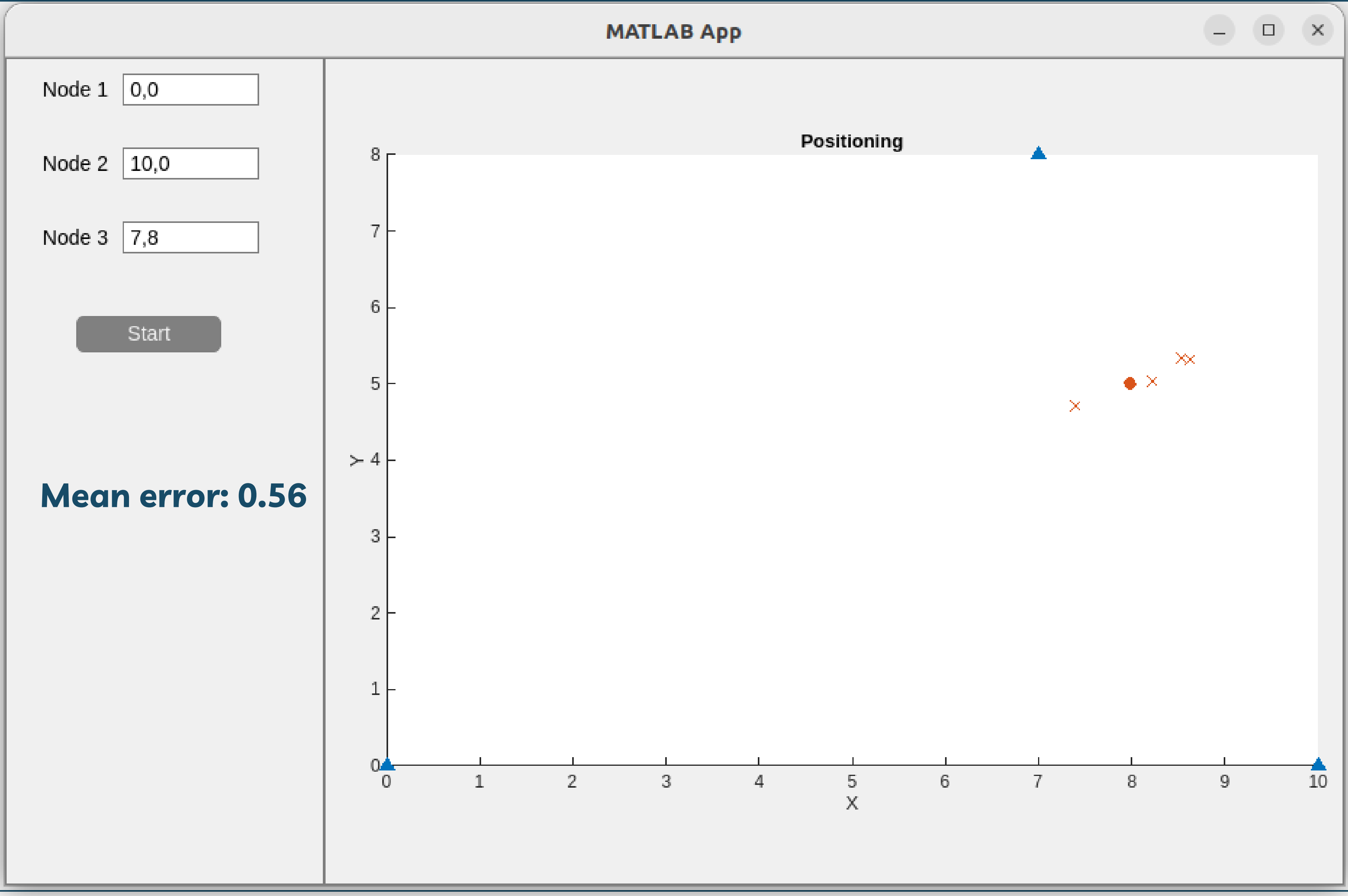
Unique ID

- Unique message
- Identifying each node
- Ensure Compatibility

Target location estimations: Optimal Conditions



Target location estimations: NLOS



Future work

- Nodes operating as a standalone device
- Faster computations: shift from Matlab
- Precise synchronization between nodes
- Optimizing filters for dynamic environments
- Data encryption

Conclusion

- Most optimal in static environments
- Operates in lower frequencies than GPS, in case GPS is jammed
- Effective Local Positioning high precision of RSSI-based systems
- LPS is superior in GPS denied
- Focus on accurate distance measurement and advanced filtering algorithms
- System flexibility: SDR technology for adaptable configurations
- Prototype Development to shows feasibility

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Thank you