Wireless Localization of Laboratory Devices

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PROJECT GOAL

- Evaluate wireless localization methods (e.g., RSSI, ToF, UWB) **without external receivers**.
- Assess feasibility for < **50 cm accuracy** under real lab conditions.
- Develop and test a software prototype to demonstrate the selected approach.

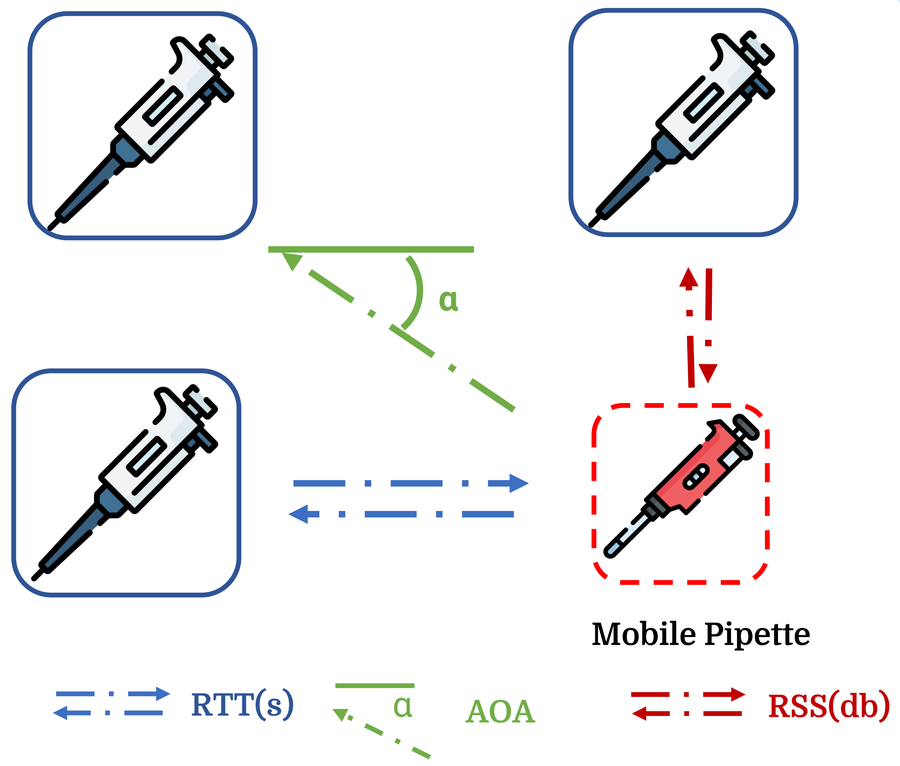
METHODOLOGY

- **A literature review** on Ultra-Wideband (UWB), Received Signal Strength (RSS), Angle of Arrival (AoA), Bluetooth Low Energy (BLE), Wi-Fi, and Round-trip time (RTT) technologies.
- **Select a use-case scenario** and define the final setup to meet ≤ 50 cm accuracy.
- **Implement a simulation environment** to test the selected localization approach.
- **Evaluate performance, analyze results**

APPROACH

- **Setup:** Use three fixed pipettes (anchors) and one mobile pipette (target).
- **Data Collection:**
  - *Phase 1:* Gather RTT and AoA measurements from known positions to create a reference database and train the positioning model.
  - *Phase 2:* Use real-time RTT and AoA in simulation workspace to estimate the mobile pipette's position via the trained model.
- **Validation:** Compare estimated and actual positions to quantify accuracy.

LOCALIZATION TOPOLOGY



*RTT: Round Trip Time RSS: Received Signal Strength AOA: Angle of Arrival

SIMULATION RESULTS

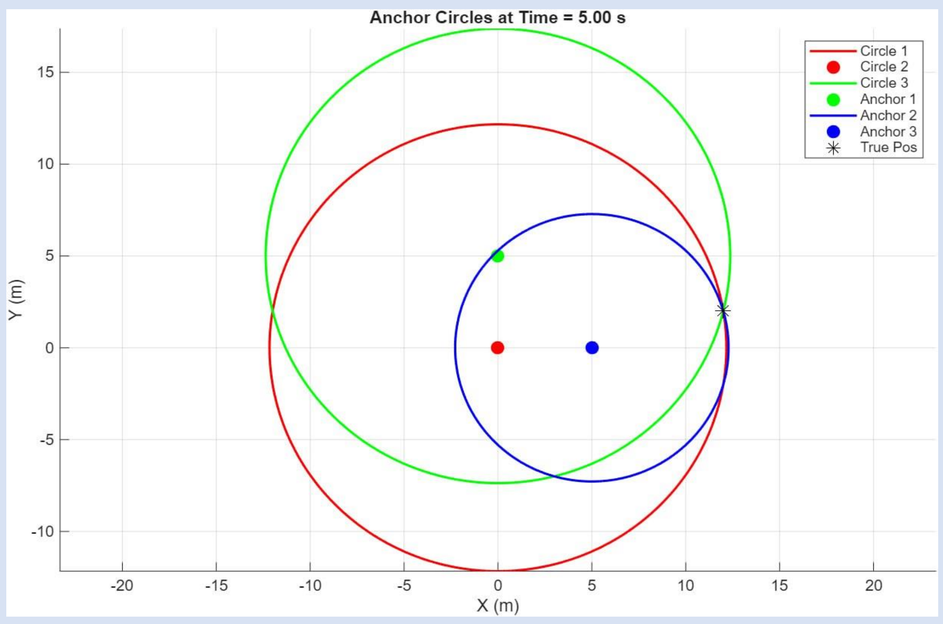


Fig 1: Trilateration of True Position from Anchor Circles at Time t = 5s

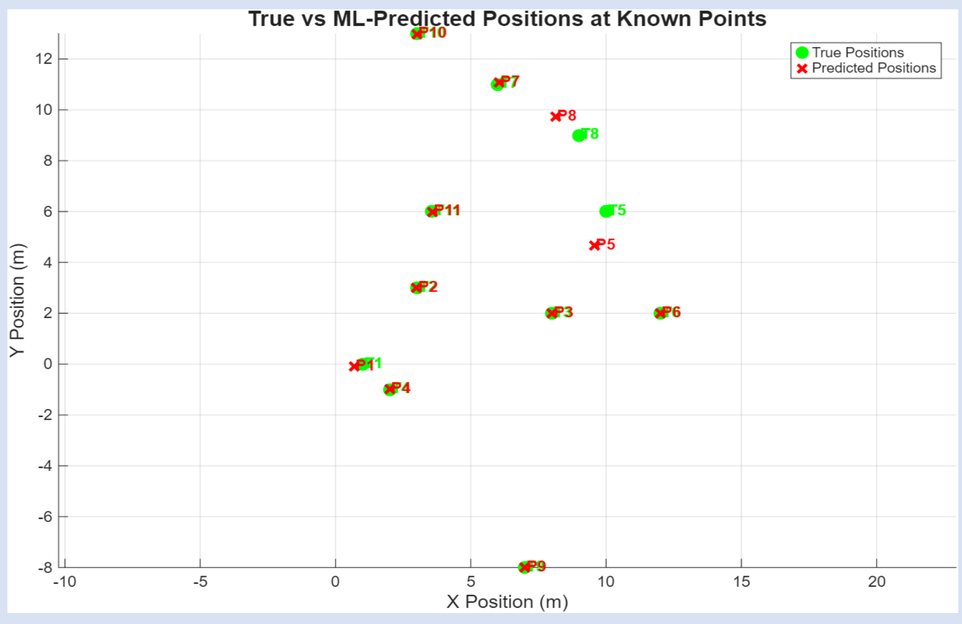


Fig 2: Comparison of true positions with ML-predicted positions at known points, showing localization accuracy.

ACCURACY RESULTS

Min Error: ± 3.30 cm **Max Error**: ± 113.88 cm **Mean Error**: ± 38.27 cm **Std**: ± 30.75 cm

CONCLUSION

- **UWB was excluded** due to hardware limitations.
- **RSS showed poor accuracy** and was not suitable for precise localization.
- **RTT and AoA performed best** based on simulation results and accuracy comparison.
- **Machine learning improves accuracy** to 88.12% and enables scalable localization in larger lab environments

FUTURE WORK

- Build a real-world dataset using actual lab devices in live environments.
- **Compute localization parameters** under real lab conditions, including noise and signal collisions.
- Develop a user-friendly app for labs and customers to simplify setup and usage.
- Refine accuracy metrics by testing in dynamic, real-world scenarios.