Motion-based Single-Anchor Localization in a Two-Robot System

TU Delft Delft University of Technology

Suleyman Ali
Supervised by: Ranga Rao Venkatesha Prasad, Ashutosh Simha, Suryansh Sharma

1 Introduction

- Precise localization is a challenging subtask of multi-robot navigation [1]
- Popular methods use multi-anchor setups (Fig. 1)
  - High setup cost [2]
- Single-anchor methods have been explored
  - Use (special) antenna arrays, which leads to complexity, increased power use and higher costs [3]
- **How can we develop a single-anchor localization method that does not require antenna arrays or special antennas?**

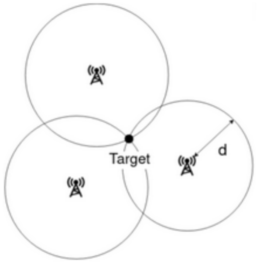

Fig. 1: Multi-anchor localization setup

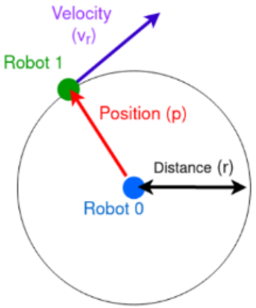

Fig. 2: Model of problem setup

2 Problem Statement

- Given are two robots $\{R_0, R_1\}$
- R_0 acts as (mobile) anchor and R_1 as target
- Measurements:
  - Distance r between robots
  - Velocity v_r of R_1 relative to R_0
- Goal: find position p

3 Motion-based Single-Anchor Localization Algorithm

- θ is the angle between v_r and p:

$$\theta(t) = \arccos \frac{\dot{r}(t)}{||v_r(t)||}$$

- With θ, we can get two possibilities for position p *(Fig. 3):*

$$p(t) = \begin{bmatrix} r(t)\cos(\alpha(t) \pm \theta(t)) \\ r(t)\sin(\alpha(t) \pm \theta(t)) \end{bmatrix}$$

where α is the angle of v_r

- We can choose one of the two possible positions when there is a change in velocity direction (Fig. 4)

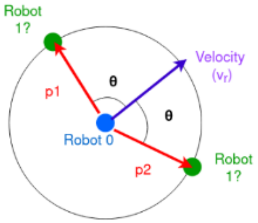

Fig. 3: Two position estimates using θ and v_r

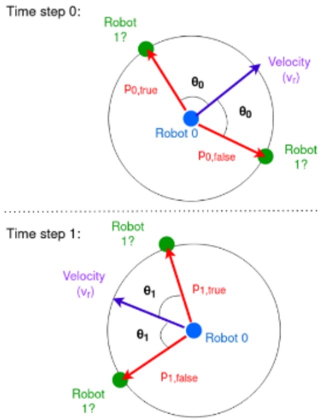

Fig. 4: When a change of velocity direction happens, we can pick one of the two position estimates

4 Noise and Filtering

- In reality, there will be noise in the measurements
- Kalman Filter
  - state estimator of the movement of the target robot
- Savitzky-Golay filter
  - To obtain filtered r and ṙ

5 Performance Evaluation

- Static anchor
- Target robot moving at 1 m/s, measurements every 0.5 seconds (T = 0.5)
  - starts at (-9, -5), runs in a straight line, turns onto circular track and does 5 laps (Figure 5)

Experiment 1 - Impact of filtering techniques

- Zero-mean Gaussian noise added to the measurements (σ_r = 1.0, σ_v=0.1)

- Figures 5 to 8 show the influence of noise and filtering techniques on the algorithm performance

- Kalman and Savitzky-Golay filters are important for accurate results
- Filtering ṙ dramatically improves accuracy of measured paths

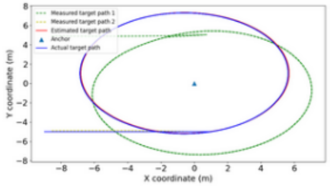

Fig. 5: Noiseless run of the simulation.

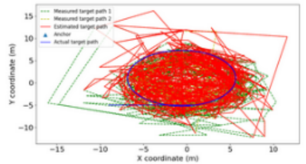

Fig. 6: Simulation with Gaussian noise added to measurements ($\sigma_r = 1.0$, $\sigma_v = .1$).

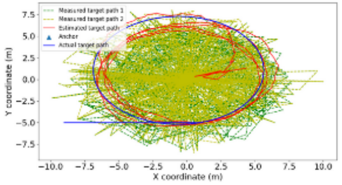

Fig. 7: Simulation with Gaussian noise added to measurements, using Kalman filter ($\sigma_r = 1.0$, $\sigma_v = .1$).

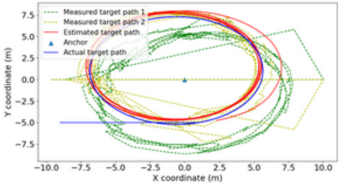

Fig. 8: Simulation with Gaussian noise added to the measurements, combining Kalman filter and Savitzky-Golay filter to filter the distance measurements ($\sigma_r = 1.0$, $\sigma_v = 0.1$).

Experiment 2 - RSSI-based distance measurements

- Simulation using RSSI to measure distance
- Lognormal shadowing path loss model
- RMSE of position estimate is 1.38 meters, which is comparable to other RSSI-based localization methods [4] [5]

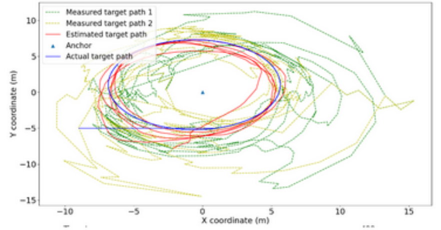

Fig. 9: Simulation using RSSI for distance measurements, according to the lognormal shadowing path loss model described in section V-A

6 Conclusions and Future work

- Developed a motion-based single-anchor algorithm that uses change in distance and velocity of target, without requiring antenna arrays
- Kalman filter and Savitzky-Golay filter were used to improve accuracy despite noisy measurements
- Precise ṙ is essential for accurate estimates from the proposed algorithm
- The proposed algorithm could be promising for RSSI-based localization

In the future:

- Try out different robot paths
- Improve filtering of r and ṙ
- Expand to more robots

References

[1] Han Wu, Shizhen Qu, Dongdong Xu, and Chunlin Chen. Precise localization and formation control of swarm robots via wireless sensor networks. Mathematical Problems in Engineering, 2014:1–12, 2014.
[2] Dimitrios Lymberopoulos and Jie Liu. The microsoft indoor localization competition: Experiences and lessons learned. IEEE Signal Processing Magazine, 34(5):125–140, 2017.
[3] S A Zekavat. Handbook of position location - theory, practice, and advances, second edition. IEEE Series on Digital & Mobile Communication. Wiley-Blackwell, Hoboken, NJ, 2 edition, April 2019.
[4] Veerachai Malyavej and Prakasit Udomthanatheera. Rssi/imu sensor fusion-based localization using unscented kalman filter. In The 20th Asia-Pacific Conference on Communication (APCC2014), pages 227–232, 2014.
[5] Md. Osman Gani, Casey OBrien, Sheikh I. Ahamed, and Roger O. Smith. Rssi based indoor localization for smartphone using fixed and mobile wireless node. In 2013 IEEE 37th Annual Computer Software and Applications Conference, pages 110–117, 2013.