Performance and Recreating the results of Goldoni's Article

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Contents

1 Introduction

In [1] three methods of RSS ranging are discussed and tested. Their performance with different Shadow Spread for different number of sensors is documented in this report. The details of implementation of the methods are detailed in a previous document "RSS Ranging Method Implementations". An experimentation is done in [1]. Experimentation is done with real hardware in the article therefore similar results are tried to be obtained using simulation instead.

2 Performance of Methods

Performance of methods is measured using the following simulation parameters.

- Region of Interest is: 1000m x 1000m
- Path Loss Exponent (Actual): 3.5
- Transmit Power (Actual): 1 Watt

2.1 Shadow Spread

Sensors and the emitter is placed randomly in the region of interest. 10 different shadow spread values are tested; 0, 2, 4, ..., 10. For each value 1000 placements of sensors and emitter is done and the average error is is calculated.

Shadow spread values are given in dB and are added to the simulated received signal strength values of sensors as given in Equation 1. In this equation m_i is the received signal strength in ideal conditions with no fading at i$^{\text{th}}$ sensor. $m_i = (P_T)(d_i)^{-\alpha}$ is calculated in Watts. ω_i is a normal random variable with mean 0 and with a standard deviation equal to the shadow spread in dB.

$$r_i = 10^{log_{10}(m_i)+\frac{\omega_i}{10}} \tag{1}$$

2.1.1 Performance of 4 Sensors

Simulation output when 4 sensors are used is as shown below. Figure 1 shows the values on a plot.

```
Mean error per shadow spread value;

Trilateration Simulation

Shadow Spread 0 is complete with mean error: 7.6462e-13 meters.
Shadow Spread 2 is complete with mean error: 232.8053 meters.
Shadow Spread 4 is complete with mean error: 531.851 meters.
Shadow Spread 6 is complete with mean error: 951.3077 meters.
Shadow Spread 8 is complete with mean error: 1558.7598 meters.
Shadow Spread 10 is complete with mean error: 2239.4083 meters.

MinMax Simulation

Shadow Spread 0 is complete with mean error: 218.7247 meters.
Shadow Spread 2 is complete with mean error: 239.2147 meters.
Shadow Spread 4 is complete with mean error: 268.9666 meters.
Shadow Spread 6 is complete with mean error: 293.1697 meters.
Shadow Spread 8 is complete with mean error: 314.5921 meters.
Shadow Spread 10 is complete with mean error: 329.209 meters.

Maximum Likelihood Simulation

Shadow Spread 0 is complete with mean error: 8.2804e-13 meters.
Shadow Spread 2 is complete with mean error: 223.8913 meters.
Shadow Spread 4 is complete with mean error: 531.6294 meters.
Shadow Spread 6 is complete with mean error: 1071.1223 meters.
Shadow Spread 8 is complete with mean error: 1719.2706 meters.
Shadow Spread 10 is complete with mean error: 2608.3931 meters.
```

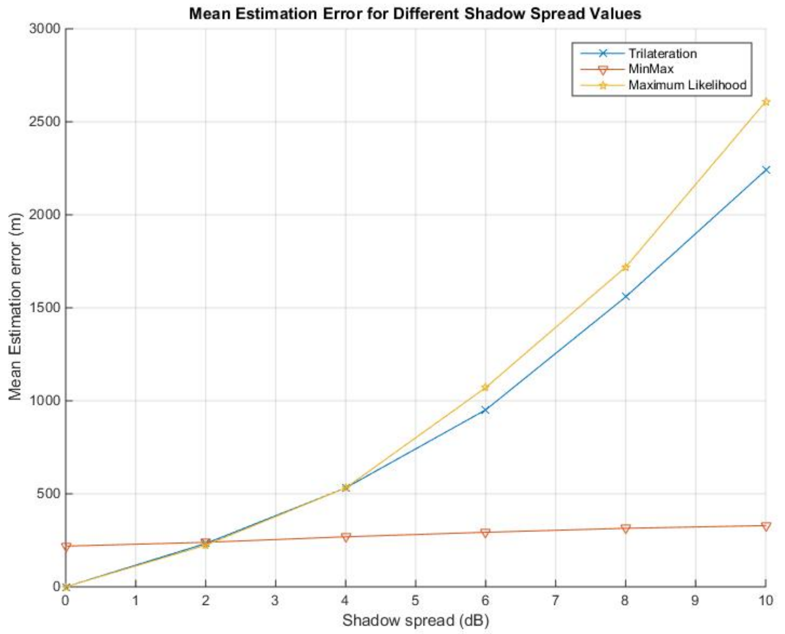

Figure 1: Averaged errors over 1000 placements and localizations using 4 sensors with three different methods for shadow spread values; 0, 2, ... , 10

2.1.2 Performance of 10 Sensors

Simulation output when 10 sensors are used is as shown below. Figure 2 shows the values on a plot.

```
Mean error per shadow spread value;

Trilateration Simulation

Shadow Spread 0 is complete with mean error: 4.8818e-13 meters.
Shadow Spread 2 is complete with mean error: 94.865 meters.
Shadow Spread 4 is complete with mean error: 218.0001 meters.
Shadow Spread 6 is complete with mean error: 388.3499 meters.
Shadow Spread 8 is complete with mean error: 641.5264 meters.
Shadow Spread 10 is complete with mean error: 1119.3206 meters.

MinMax Simulation

Shadow Spread 0 is complete with mean error: 113.5155 meters.
Shadow Spread 2 is complete with mean error: 136.8198 meters.
Shadow Spread 4 is complete with mean error: 180.4698 meters.
Shadow Spread 6 is complete with mean error: 212.9227 meters.
Shadow Spread 8 is complete with mean error: 249.1594 meters.
Shadow Spread 10 is complete with mean error: 258.1911 meters.
```

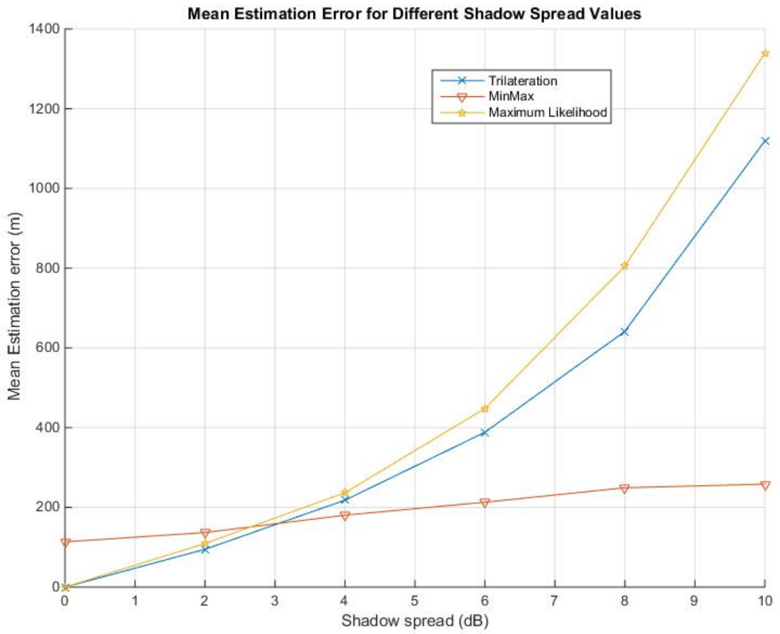

Figure 2: Averaged errors over 1000 placements and localizations using 10 sensors with three different methods for shadow spread values; 0, 2, ... , 10

```
Maximum Likelihood Simulation

Shadow Spread 0 is complete with mean error: 4.7001e-13 meters.
Shadow Spread 2 is complete with mean error: 109.4339 meters.
Shadow Spread 4 is complete with mean error: 236.9043 meters.
Shadow Spread 6 is complete with mean error: 447.8743 meters.
Shadow Spread 8 is complete with mean error: 804.952 meters.
Shadow Spread 10 is complete with mean error: 1338.9988 meters.
```

2.1.3 Performance of 50 Sensors

Simulation output when 50 sensors are used is as shown below. Figure 1 shows the values on a plot.

```
Mean error per shadow spread value;

Trilateration Simulation

Shadow Spread 0 is complete with mean error: 1.1661e-12 meters.
Shadow Spread 2 is complete with mean error: 43.257 meters.
Shadow Spread 4 is complete with mean error: 105.2943 meters.
Shadow Spread 6 is complete with mean error: 216.5751 meters.
Shadow Spread 8 is complete with mean error: 397.3871 meters.
Shadow Spread 10 is complete with mean error: 715.7924 meters.
```

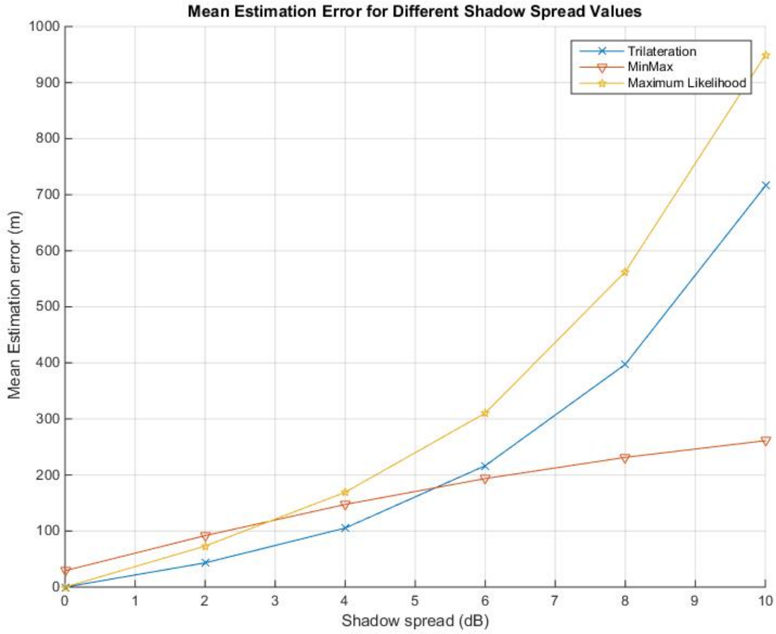

Figure 3: Averaged errors over 1000 placements and localizations using 50 sensors with three different methods for shadow spread values; 0, 2, ... , 10

```
MinMax Simulation

Shadow Spread 0 is complete with mean error: 29.3121 meters.
Shadow Spread 2 is complete with mean error: 91.8177 meters.
Shadow Spread 4 is complete with mean error: 147.4524 meters.
Shadow Spread 6 is complete with mean error: 193.6428 meters.
Shadow Spread 8 is complete with mean error: 231.4681 meters.
Shadow Spread 10 is complete with mean error: 261.1672 meters.

Maximum Likelihood Simulation

Shadow Spread 0 is complete with mean error: 4.2404e-13 meters.
Shadow Spread 2 is complete with mean error: 73.2335 meters.
Shadow Spread 4 is complete with mean error: 169.1796 meters.
Shadow Spread 6 is complete with mean error: 310.3865 meters.
Shadow Spread 8 is complete with mean error: 562.5428 meters.
Shadow Spread 10 is complete with mean error: 949.1802 meters.
```

2.2 Experimentation

In order to have a similar output with experimentation on [1] parameters of the simulation is chosen as follows;

- Region of Interest is: 12m x 19.5m
- Number of sensors: 3
- Shadow Spread: 2 dB
- Path Loss Exponent (Actual): 3.5
- Path Loss Exponent (Assumed): 3.5
- Transmit Power (Actual): 1 Watt
- Transmit Power (Assumed): 1 Watt
- Sensor 1 is located at (2, 17)
- Sensor 2 is located at (10, 9.5)
- Sensor 3 is located at (2, 2)
- Emitter T1 placement (9.5, 17)
- Emitter T2 placement (6, 9.5)
- Emitter T3 placement (9, 9.5)

2.2.1 Min-Max

Output of the simulation is shown in the Figure 4. Mean errors for each emitter placement is as follows;

```
Mean estimated error for T1: 5.1384
Mean estimated error for T2: 2.5934
Mean estimated error for T3: 0.81832
```

The result shows that no matter how much shadow spread is present for T1 placement estimation is always inside the triangle formed by the sensors. In [1] estimations are very uniformly scattered around the actual position. Either implementation of the algorithm is flawed or something else varies during actual experimentation. To show the reasoning of the estimations being inside the triangle a single estimation with the same placement in perfect conditions is shown in Figure 5

2.2.2 Maximum Likelihood

Output of the simulation is shown in the Figure 6. Mean errors for each emitter placement is as follows;

```
Mean estimated error for T1: 4.9856
Mean estimated error for T2: 0.69201
Mean estimated error for T3: 1.3868
```

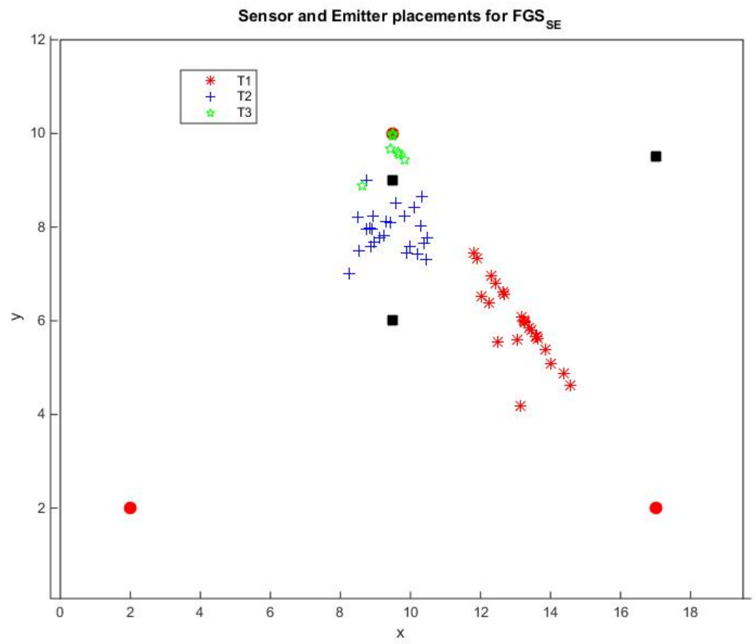

Figure 4: Localization results with the Min-Max algorithm

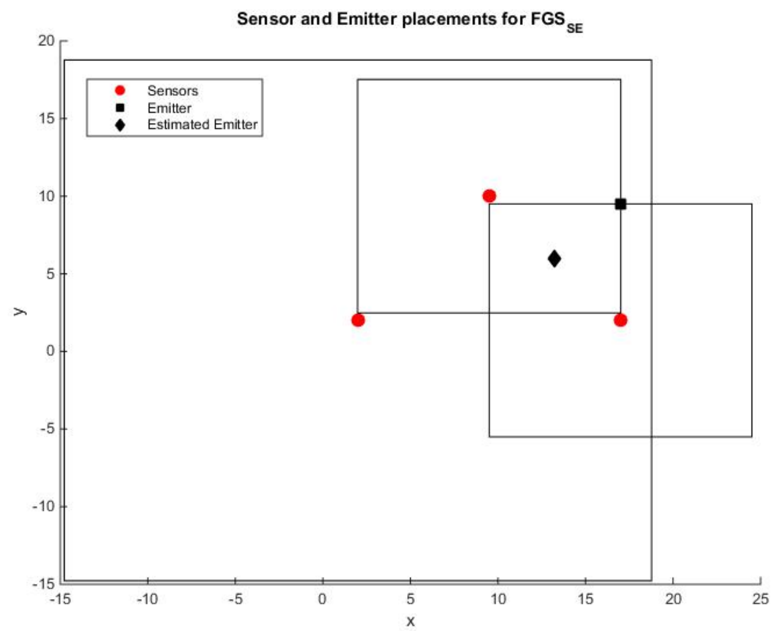

Figure 5: Localization results with the Min-Max algorithm in perfect conditions. Emitter is estimated in the center of the rectangle formed by the intersection of squares around sensors.

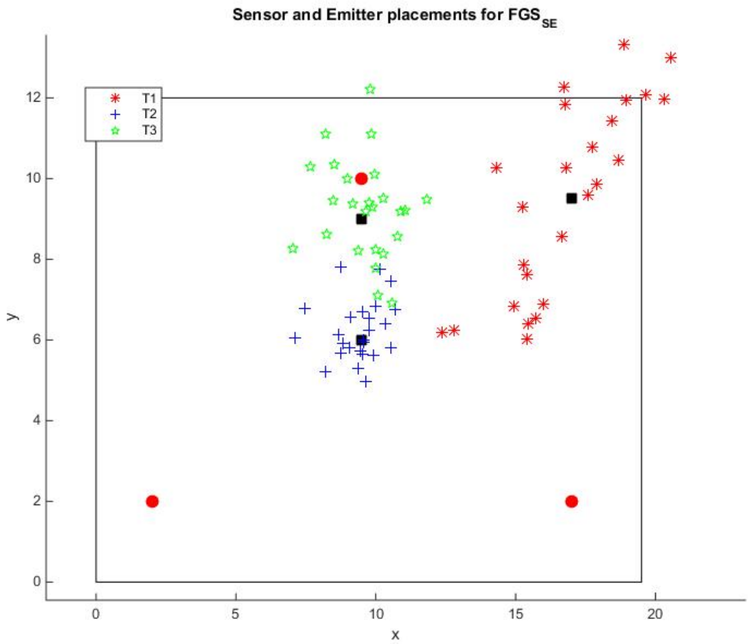

Figure 6: Localization results with the Maximum Likelihood algorithm

2.2.3 Trilateration

Output of the simulation is shown in the Figure 7. Mean errors for each emitter placement is as follows;

```
Mean estimated error for T1: 2.8419
Mean estimated error for T2: 1.1511
Mean estimated error for T3: 0.21619
```

3 Fixes to be made to the implementation

Lateration done in the previous document "RSS Ranging Method Implementations" was done based on a least squares solution of the circle equations based on the estimated distances from known sensor locations. Further investigation of [1] shows that experimentation about trilateration might be done based on the Adapted Multi-Lateration technique explained in [2]. A similar simulation should be done for Trilateration using this type of method.

4 Conclusion

Simulation results for performance of techniques depending on shadow spread values shows that either none of these techniques are robust against multiplicative errors or step size of selected shadow spread values are too large.

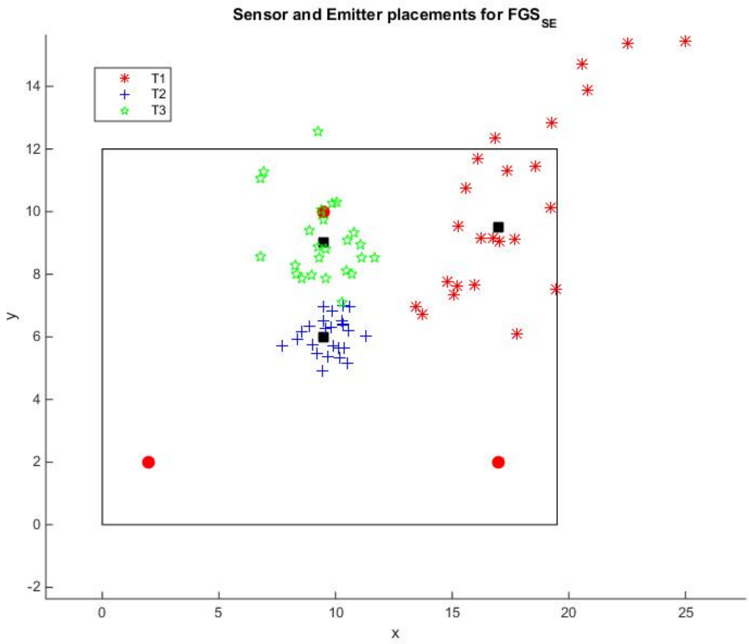

Figure 7: Localization results with the Trilateration algorithm

Actual hardware experimentation has medium parameters that are hard to identify by trial and error using simulations on Matlab. Even though the results wasn't replicated it is obvious there are several differences or missing points in the implementation of methods that should be addressed.

References

[1] E. Goldoni et al. "Experimental analysis of RSSI-based indoor localization with IEEE 802.15.4". In: *Wireless Conference (EW), 2010 European*. Apr. 2010, pp. 71–77. DOI: 10.1109/EW.2010.5483396.

[2] G.S. Kuruoglu, M. Erol, and S. Oktug. "Localization in Wireless Sensor Networks with Range Measurement Errors". In: *Telecommunications, 2009. AICT '09. Fifth Advanced International Conference on*. May 2009, pp. 261–266. DOI: 10.1109/AICT.2009.51.