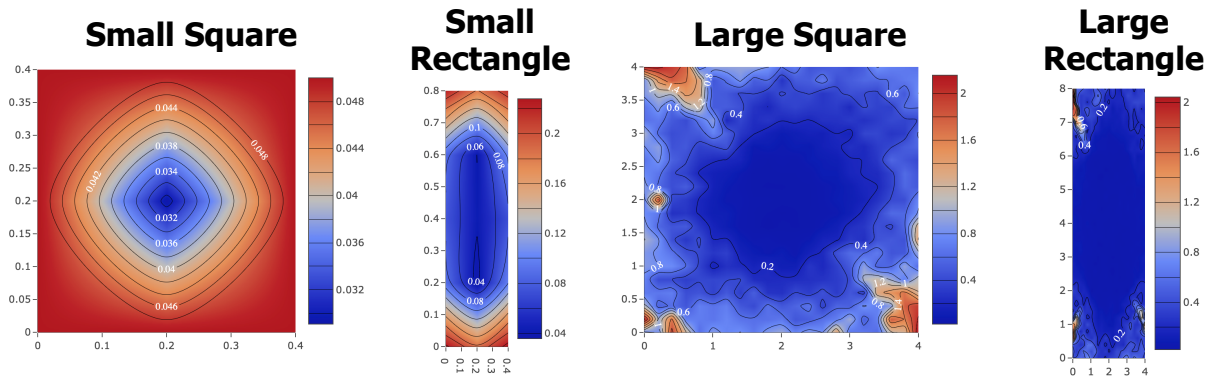
# Time-difference-of-arrival (TDoA) based Simulator for Accuracy of Indoor Localization

## Introduction

Indoor localization, just like GPS, allows people to navigate in indoor spaces. However, GPS signals cannot penetrate into indoor spaces. Hence, we need a different technology to perform indoor localization. The core principle that allows localization is distance measurements from known anchor points using a wireless technique known as time-of-flight. Using multiple distance measurements it is possible to perform multi-lateration that computes the location using geometric constraints—solving intersection of circles. If we want to enable scalable localization, we cannot expect client devices, such as mobile phones, to actively participate in this distance measurement with the anchors. Client devices must instead infer the distance measurement based on signals emitted by the anchors without themselves transmitting any signal. With such constaints, we must rely on time-difference-of-arrival (TDoA) of wireless signals, and not on time-of-flight. Use of TDoA changes the geometric constaints to that of solving for the intersection of hyperbolas. Inherently, the placement of anchors in an indoor space affects how these hyperbolas intersect. Since all distance measurements suffer from measurement errors, computation of the hyperbolic intesections is not exact, which results in different localization accuracy at different areas in an indoor space.

This website simulates the expected localization accuracy in an indoor space given the parameters of the room, locations of the anchors, and a few other parameters which define the errors experienced by the indoor localization technology. Since this is a simulation, it also depends on certain statistical parameters such as seed points, which anchors to consider when there are several anchors, and how intensive the simulation should be, in terms of sampling density and number of trials.




# How to use this website:

The accuracy of indoor localization solutions is tightly governed by the geometric shape made by the anchors in relation to the area where the indoor localization solution is deployed. This is a web tool that will allow you to experiment with various anchor placements in a rectangular room of your choice and demonstrate how the location accuracy of a client is expected to vary in the indoor space purely because of the geometric dilution of precision (DoP). Of course, other parameters such as furniture in the room, absorption by walls, reflections by metallic surface, etc. does impact accuracy, but this website ignore those issues and only concentrates on the DoP. Furthermore, there are multiple ways to perform localization. We will only focus on time-difference of arrival (TDoA) techniques for localization. The solution to localization is an intersection of hyperbolas and since every measurement has errors, the localization accuracy in a space is non-trivial to calculate.

You may give us information about anchor coordinates, room size, distance between sample points, sigma, maximum error shown, choice of initial seed, and your choice of DoP method. Below are **examples and explanations of inputs** (all of your inputs should be in millimeters, and the output contour map is in meters):

| Query Name | Example Input | Meaning |
|---|---|---|
| Anchor Locations | 1500,1500;1500,2500;2500,1500;2500,2500 | The bottom left corner of your room is the origin. This means your initiator is at (1500,1500), and three responders at (1500,2500), (2500,1500), (2500,2500) respectively. |
| Room Size | 4000*4000 | width*height. This is a 4meter*4meter room. |

| Query Name | Example Input | Meaning |
|---|---|---|
| Sample Distance | 200 | distance between each location sample used for accuracy calculation. Sample taken every 0.2meter. Thus, 20*20 = 400 sample points in our case. |
| Sigma | 50 | sigma of Gaussian noises added to TDoA (Mu is set as 0). |
| Maximum error shown | 10000 | maximum error shown in our map. All errors larger than this are rounded down to this maximum value. |
| Initial Seed | custom | This is an initial guess of target location. Our solver starts from this initial seed, and converges to the target location.<br>If custom is chosen, you need to specify your initial seed location in the following Custom Seed parameter. If origin or roomCenter is chosen, then the initial seed will be the bottom left corner of your room or the center of your room respectively, and the input for Custom Seed will be overlooked. |
| Custom Seed | 20,20 | If you choose custom in Initial Seed, specify your initial seed here. Otherwise, just put random location like 0,0. Cannot leave it empty. |

| Query Name | Example Input | Meaning |
|---|---|---|
| DoP | all | “All” means the calculation will run 100 times with different Gaussian noises added to TDoA and return the median error value for each sample point.<br>“Best” means the best anchor combination will be selected based on our DoP value and used for calculation. |
| Count | 50 | 50 counts means each sample point is calculated with random Gaussian noises for 50 times, and the plot shows the median error of those 50 results for each sample. |

Want to get a feel with our website using some input examples? Simply choose one of our 4 inputs and click apply! You do not need to input anything for the example to run.

**Here are the inputs for each example:**

| Example Name | Queries |
|---|---|
| Small Rectangular | anchorLoc = "100,200;300,200;100,600;300,600"<br>roomSize = “400*800"<br>sampleDistance = “200”<br>sigma = "50"<br>maxErrShown = “10000"<br>iniSeed = “roomCenter”<br>customSeed = “20,20"<br>dop = “all”<br>count = “50” |

| Example Name | Queries |
|---|---|
| Small Rectangular | anchorLoc = "100,200;300,200;100,600;300,600"<br>roomSize = “400*800"<br>sampleDistance = “200"<br>maxErrShown = “10000"<br>iniSeed = “roomCenter”<br>customSeed = “20,20"<br>dop = “all" |
| Large Square | anchorLoc ="1500,1500;1500,2500;2500,1500;2500,2500"<br>roomSize ="4000*4000"<br>sampleDistance = “200”<br>sigma = "50"<br>maxErrShown = “10000"<br>iniSeed = “roomCenter”<br>customSeed = “20,20"<br>dop = “all”<br>count = “20” |
| Large Rectangular | anchorLoc ="1000,2000;3000,2000;1000,6000;3000,6000"<br>roomSize ="4000*8000"<br>sampleDistance = “200”<br>sigma = "50"<br>maxErrShown = “10000"<br>iniSeed = “roomCenter”<br>customSeed = “20,20"<br>dop = “best”<br>count = “20” |

# Acknowledgements

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# How to cite?

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