CS724 Assignment 1 Report for Question 2

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As given in the question, I have taken variables to store the position of user (named "user") and 5 satellites named s1, s2, s3, s4 and s5. User is fixed at (100,100,100). I have also made a variable to store the speed of light named "c". Location of satellites are:

- Satellite 1 is at (25,50,75)
- Satellite 2 is at (130,160,190)
- Satellite 3 is at (200,275,250)
- Satellite 4 is at (75,150,300)
- Satellite 5 is at (45,90,180)

2a) I have defined a function which takes the position of user and satellite and speed of light to return the signal travelling time and then called the function to get the signal time between each satellite and user. The output received from a sample execution is given below:

```
Time taken from satellite 1 is 311.80478223116177 ns
Time taken from satellite 2 is 374.1657386773942 ns
Time taken from satellite 3 is 837.4896350934075 ns
Time taken from satellite 4 is 692.218655243173 ns
Time taken from satellite 5 is 325.32035493238556 ns
```

2b) I calculated the distance between user and each satellite by multiplying the time with speed of light and stored them in variables d1, d2, d3, d4 and d5. For the reverse operation, I made the matrices A and B as a system of linear equation AX=B and applied the formula $X = (A^TA)^{-1}A^TB$ to get the location of user. The output received from a sample execution is given below:

```
Actual location of user is (100,100,100)
Estimated location of user without any error is ([100.],[100.],[100.])
```

2c) I used random.randint(-10,10) function to generate random integers from the range of [-10, +10] and added with each signal time and repeated the experiment of finding the location of the user. The output received from a sample execution is given below:

```
Time taken from satellite 1 with random errors is 318.80478223116177 ns. Difference with actual time is 7.0 ns.
Time taken from satellite 2 with random errors is 366.1657386773942 ns. Difference with actual time is -8.0 ns.
Time taken from satellite 3 with random errors is 834.4896350934075 ns. Difference with actual time is -3.0 ns.
Time taken from satellite 4 with random errors is 691.218655243173 ns. Difference with actual time is -1.0 ns.
Time taken from satellite 5 with random errors is 316.32035493238556 ns. Difference with actual time is -9.0 ns.

Actual location of user was (100,100,100)
New estimated location of user after introducing error is (111.56234352140447,90.99595598224525,101.37005472348845)
Localization error is 14.718615638910546 metres
```

2d) Since the distance between user and each satellite is different, it is expected that errors introduced in their respective times will also be different. For plotting purpose, I decided to generate errors around a single value which I am calling a mean point. Errors will be then generated from the range of [mean-5, mean+5] and then I keep moving the mean point ahead to generate higher amount of timing errors. I have made a function (named avg_err) that runs 20 times and returns the average localized error.

I have assumed that random timing errors generated will still have the average as the mean point, so a point on my graph is of the form (mean point, average localized error). List of localized errors(y-axis) and timing error mean point(x-axis) from a sample execution is given below:

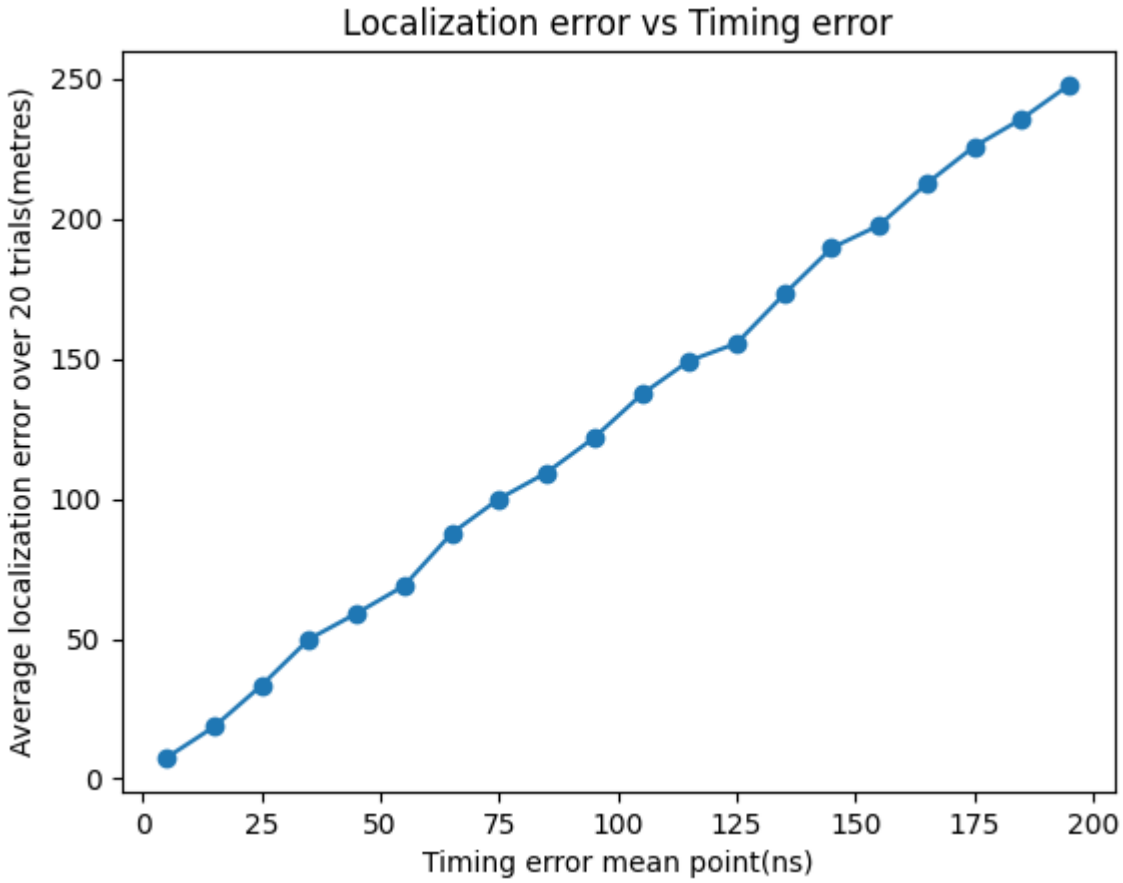
List of localization errors(y):

[np.float64(7.538466751852892), np.float64(18.580169250979147),
np.float64(33.3485418069324), np.float64(49.874398145563546),
np.float64(59.0566306655234), np.float64(68.88112970666282),
np.float64(87.58877510398945), np.float64(99.95458402944477),
np.float64(109.29811757720124), np.float64(121.73444002556428),
np.float64(137.20152636526313), np.float64(149.19779170008837),
np.float64(155.4430551728687), np.float64(172.95974592169864),
np.float64(189.50161895433288), np.float64(197.58568137463067),
np.float64(212.4688929822583), np.float64(225.67821175603325),
np.float64(235.56544663431018), np.float64(247.66703968207244)]

Error mean points(x):

[5, 15, 25, 35, 45, 55, 65, 75, 85, 95, 105, 115, 125, 135, 145, 155, 165, 175, 185, 195]

The corresponding plot generated is provided below:



From the plot we can infer that as amount of timing error increases, the average localization error increases.