Algorithm and Beacon Deployment for Sensor Localization

Localization, Beacon, Projection method

1. Background

Recent reports showed the reliability of the structures during earthquakes must be checked again using rational design methods. For this purpose, E-defense has been built, which has the world largest shaking table to enhance the reliability of structures to against large earthquakes.

EDgrid stands for E-Defense grid and is inspired by the NEES project. It is the cyber infrastructure to support full-scale experiments to be conducted at the E-Defense. The EDgrid has 960 sensors, 27 cameras and 2 High-Definition (HD) cameras. With so many sensors and other devices available, automation including self-installation, self-organization and self-management of the sensor grid becomes necessary.

Embedded sensor network systems are always coupled to the physical world. To acquire the sensor’s position information is important and necessary. With more and more sensors are deployed in the buildings, manual sensor localization is not practical any longer. An automatic sensor localization system for structural health monitoring is expected to be developed. In this paper, the localization algorism is discussed and the effect of the beacon deployment is also studied.

2. Localization algorithm

Generally speaking, the localization algorisms can be classified into two categories. That is rang-based algorism and range free algorism. Rang-based algorism is used in our research because of its good localization accuracy. For range based algorism, triangulation is used to locate a node. Usually, three beacons can be used to determine a node in a two dimensional plane, while four beacons not in same plane can be used to determined a node in a three dimensional space.

In practice, however, it will be more convenient if we can deploy the beacons on a same plane, say, deploy the beacons on the ceilings. If the beacons in the same plane but not in on line, obviously it tends to be a two dimensional problem. This means, for the view of localization, these 4 beacons are correlated. Only 3 of them are independent. In this case, they can only give the node position information of 2 DOFs, say, $x$ and $y$, while the third DOF information can not be determined. Locating with 3 beacons will generate two possible positions which are symmetry to the beacon plane. However, we can get the right answer by adding some other information such as beacons are on the ceiling or on the floor.

Projection method is used with which only three beacons are required to locate a node in a three dimensional space. Figure 2 shows that if the crossing part of two crossing spherical surface is projected to any plane which is parallel to the beacon plane, it should be a line. Two of such lines that are not parallel to each other can definitely determine a point which is just the projected point of the original node. Then the $z$ value can be obtained according to the sphere equations.

3. Simulations

3.1 Direct localization using four beacons

We randomly selected a node (position at $(1,2,1)$) and tested the result in different conditions when the beacons are deployed at one side of the node (four beacons are at $B1(0,0,3)$, $B2(4,0,3)$, $B3(4,5,3)$, $B4(0,5,2)$) and are deployed around the node (four beacons are at $B1(0,0,0)$, $B2(4,0,3)$, $B3(4,5,0)$, $B4(0,5,3)$). The Figures 3 shows the localization error when beacons are at one side of the node. The Figures 4 shows the localization error when beacons are deployed around the node. In these figures, for every
time, 50 iterations are used to calculate each position result. From those figures we can see that when the beacons are deployed at one side of node, the node’s position result error of z direction is much bigger than that of x and y direction. Fortunately, with the beacons deployed around the node, the z error drops dramatically. It can be concluded that expending the beacons in one direction to be around the node can improve the error of that direction.

We also examined the situation in case of many samples used. We get the mean error and the standard deviation by averaging 20000 samples, then we find that the mean error is converge to 0 while the standard deviation converge to the values shown in Table 1 which shows that the standard deviations of the localization errors are inverse proportional to the beacon span of the relative direction.

### Table-1 Standard deviation and beacon span

<table>
<thead>
<tr>
<th></th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation (m)</td>
<td>0.094</td>
<td>0.075</td>
<td>0.125</td>
</tr>
<tr>
<td>Beacon span (m)</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Multiple result (m)</td>
<td>0.376</td>
<td>0.375</td>
<td>0.375</td>
</tr>
</tbody>
</table>

#### 3.2 Localization using projection method

This time we set the beacons at B1(0,0,3), B2(4,0,3), B3(4,5,3) and B4(0,5,3).

**Fig-5 Localization with B1, B2, B3**

Figure 5 shows that using projection method with 3 beacons, the x, y and z error, including mean and standard deviation, are nearly the same. This shows z error is no longer much bigger than x and y error. Figure 6 shows with 4 beacons using projection method, the errors of both mean and standard deviation are decreased.

**4 Conclusions**

Simulation shows that deploying the beacons around the node will improve its localization accuracy; expanding the beacon span can decrease the localization error. However, expending the beacon span will often degrade the ranging accuracy, thus compromise should be considered. Projection method allows the beacons to be deployed at one plane and the accuracy is good.

**Reference:**


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