PASSIVE INDOOR LOCALIZATION

OUHAN YOU

June 20, 2016

Contents

1	Brie	ef Introduction of IPS	1
2	Mo	deling Process	2
3	Pro	blem Raising	3
4	Solutions		
	4.1	Maximum Coverage Problem	3
	4.2	Correlation of Our Problem	4
	4.3	Our innovation	4
5	Experiment Content		
	5.1	Procedure	5
	5.2	Layout	5
	5.3	Data Processing	6
	5.4	Result	6
6	Cor	nclusion	7

1 Brief Introduction of IPS

The majority of research in the context of wireless-based localization systems has focused on devicebased active localization, in which a device is attached to tracked entities. Recently, device-free passive localization (DfP) has been proposed where the tracked entity is neither required to carry devices nor participate actively in the localization process.

An indoor positioning system (IPS) is a system to locate objects or people inside a building using radio waves, magnetic fields, acoustic signals, or other sensory information collected by mobile devices.

An example of the different components of a device-free passive localization system in a typical office environment. APs represent signal transmitters. Standard laptops and wireless-enabled desktops represent monitoring points. Any device can be used as an application server.



2 Modeling Process

In order to compute the ideal Radio Signal Strength(RSS), we firstly build a model to abstract this system to mathematical field. According to one paper named "Radio Tomographic Imaging", we use the following model.

$$y_i(t) = P_i - L_i - S_i(t) - F_i(t) - \nu_i(t).$$

where

- P_i : Transmitted power in decibels.
- $P_i(t)$: Shadowing loss in decibels due to objects that attenuate the signal.
- $F_i(t)$: Fading loss in decibels that occurs from constructive and destructive interference of narrowband signals in multipath environments.
- L_i : Static losses in decibels due to distance, antenna patterns, device inconsistencies, etc.
- $v_i(t)$: Measurement noise.

$$S_i(t) = \sum_{j=1}^N w_{ij} x_j(t),$$

$$w_{ij} = \frac{1}{\sqrt{d}} \begin{cases} 1, & \text{if } d_{ij}(1) + d_{ij}(2) < d + \lambda, \\ 0, & \text{otherwise,} \end{cases}$$

To be more clear, we draw the following figure. The physical meaning of each variable should be selfevident.



3 Problem Raising

Since we have built our model, now we can start with theoretical work. If we can compute all the RSS when people is at different positions, we can know whether a place is easy to be locate or not. Combine all this information, we can use this model to compute which layout of Access Points (APs) and Monitor Points (MPs).

In a word, our problem is to find the optimal layout. That is we should determine using which layout we can achieve the most localization accuracy. Just as the following figure shows.



4 Solutions

4.1 Maximum Coverage Problem

Generalized maximum coverage In the generalized maximum coverage version every set S_i has a cost $c(S_i)$, element e_j has a different weight and cost depending on which set covers it. Namely, if e_j is covered by set S_i the weight of e_j is $w_i(e_j)$ and its cost is $c_i(e_j)$. A budget B is given for the total cost of the solution.

maximize $\sum_{e \in E, S_i} w_i(e_j) \cdot y_{ij}$. (maximizing the weighted sum of covered elements in the sets in which they are covered). subject to $\sum c_i(e_j) \cdot y_{ij} + \sum c(S_i) \cdot x_i \leq B$; (the cost of the selected sets cannot exceed B).

Generalized maximum coverage algorithm The algorithm uses the concept of residual cost/weight. The residual cost/weight is measured against a tentative solution and it is the difference of the cost/weight from the cost/weight gained by a tentative solution.

The algorithm has several stages. First, find a solution using greedy algorithm. In each iteration of the greedy algorithm the tentative solution is added the set which contains the maximum residual weight of elements divided by the residual cost of these elements along with the residual cost of the set. Second, compare the solution gained by the first step to the best solution which uses a small number of sets. Third, return the best out of all examined solutions. This algorithm achieves an approximation ratio of $1 - \frac{1}{e} - o(1)$

4.2 Correlation of Our Problem

- As input you are given several sets and a number K
- The sets may have some elements in common.
- You must select at most K of these sets such that the union of the selected sets has maximal size.

where sets correspond to The voxels an ellipse contains.

K corresponds to The number of T-R pair

4.3 Our innovation

The paper "The Generalized Maximum Coverage Problem" uses Greedy Strategy and finally achieve the following result:

$$ApproximateRatio = \frac{e-1}{e} - \delta$$

 δ is an arbitrary positive number.

Our team improve the greedy strategy to be suitable for our problem. Eventually, we increase the Approximate ratio to

$$OurApproximateRatio = 1 - \frac{1}{e-1}$$

Notice: our analysis only suits our problem

5 Experiment Content

5.1 Procedure

There are five steps of our experiments:

- Layout Design
- Select Experimental site
- Carry out the experiment
- Data Processing
- Data Analysis

5.2 Layout

Our design of layout shows as:



5.3 Data Processing

We use half of the data to be the training sets, the other to be the test sets. Then we use different algorithms to compute the supposed position and use a simple program to get the accuracy of different algorithms.

```
1
      import os, sys
 2
      name = sys.argv[1]
 3
      from openpyxl import Workbook, load workbook
 4
      wb = load workbook(filename = name)
 5
      sheets = wb.get sheet names()
 6
      sheet0 = sheets[0]
 7
      ws = wb.get sheet by name(sheet0)
 8
      rows = ws.rows
 9
      columns = ws.columns
10
      SUM = len(rows)
11
      correct = 0
12
    for i in range(len(rows)):
13
          a = rows[i][0].value
14
          b = rows[i][1].value
15
          if (a==b):
    Þ
16
              correct += 1
17
18
      print correct
      print SUM
19
```

5.4 Result

Above all the procedure, we get the result showed in the figure.



6 Conclusion

Radio tomographic imaging is a new and exciting method for imaging the attenuation of physical objects with wireless networks operating at RF wavelengths. Based on this model, we raised an interesting problem, i.e. to find the optimal layout. After a long time analysis, we find the solution. In others words, the whole problem is actually an example of the Maximum Coverage Problem. Then we did a lot of theoretical work and apply the greedy strategy to our problem, and achieve the better approximate ratio. At last, we did our own passive indoor localization. Experimental results show that accuracy differs by choosing different algorithms. The good news is knn Random Forest algorithm has the highest accuracy which is close to 1.