Indoor/Outdoor -sensor

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2015

Abstract

Indoor/Outdoor-sensor is implemented using five lightweight mobile phone sensors; proximity-, location-, light-, signal($\times 2$)- and battery-temperature-sensor. These sensors data are then handled properly to give user probabilities whether phone is outside or inside a building.

1 Introduction

Nowadays phones give us plenty of sensors to be used for different purposes. Especially health- and social-sciences are interested what kind of data engineers and programmers could offer. This coursework main goal was to make indoor/outdoor -sensor using at least three mobile phone sensors as this "indoor/outdoor-sensor" is using five as three of them is doing the job, proximity- and location-sensors are only supporting the light-sensor.

2 Background

Aware is Denzil Ferreira's cellular framework for social sciences. It gives easy access to all sensors of the mobile phone and also to other features. The coursework was made by using Aware as a base and developing indoor/outdoor plugin on that. Older plugins were good examples how the job is done and therefore similar approaches are used in this plugin. As this is only a coursework, some settings and the appearance of data provider are almost straight copies from previously made Aware-plugins. [3, 4, 5]

First I tried to follow the article [1] approach, but accelerometer didn't work very well and got my phone freeze so I had to drop it and magnetometer was useless without accelerometer so I had to drop it too. However those two sensors consume battery more than many other sensors so I think my current approach is even better from that point of view.

3 Methods

3.1 Telephony-sensor

Telephony-sensor gives a lot of data about telephony signal including network provider, network type etc. Only relevant information in indoor/outdoor context was the signal strength. Signal strength is given in decibels in range where -50 db is very good signal and below -100 is pretty bad. In telephony-sensor description is given the "asu" range which says 0 is -113 db or worse and 31 is -51 or better signal strength. Asu range can be used as linear relation to probability if we make assumption that indoors signal is usually worse because of walls. The formula for conversion is given as

$$P_s = \frac{(signalstrength + 113)}{62},$$

where *signalstrength* includes also neighbour tower signal strength. *Signalstrength* is weighted average of these two where weights are $\frac{2}{3}$ for main tower and $\frac{1}{3}$ for neighbour tower.

3.2 Light-, location and proximity-sensors

First of all, proximity-sensor is used to detect if light-sensor is covered or not, for example if phone is in pocket or in similar environment.[1] In such environment light-sensor is obviously unreliable. Location-sensor is used only to give coordinates of ones current location. These coordinates are then used to calculate sunrise and sunset times.[2] Because light-sensor "thinks" outdoors have much more powerful light lux, light-sensor is only used between sunrise and sunset. So light-sensor gives current lux which can be converted to indoor/outdoor probability using following formula

$$P_l = \frac{1}{(\frac{500}{lux} + 1)},$$

where 500 is empirical threshold for change from indoor to outdoor.

3.3 Battery-sensor

Battery-sensor's main purpose is to keep track of battery's health, condition and current voltage. However it also gives value of battery' temperature. Of course it is not straightforward to convert this to temperature outside the phone but there is clearly a dependency. This dependency can be used to detect transition from out to in or vice versa. Accurate real temperature dependency is not important here, but also that could be extracted.

This approach uses temperature average of last three days(just to get some average). Then difference between current and average temperatures are taken which is used in Gaussian distribution to give probability. The Gaussian is formulated as

$$P_b = e^{-\frac{(average-current)^2}{2*2^2}},$$

where distribution width is determinated empirically as 2.

3.4 Total probability

Total probability is weighted average of these as

$$P_{out} = \frac{(P_s w_s)^2 + (P_l w_l)^2 + (P_b w_b)^2}{w_s + w_l + w_b},$$

Time	S_1	S_2	T_b	**Prox**	**Lux**	P_{out}	P_{in}	
12.08	-81	-82	14	Far	340	72.1	27.9	Correct
12.12	-51	-67	14	Far	319	88.2	11.8	Correct
12.22	-85	-121	17	Far	2	44.7	55.3	Correct
14.19	-79	-86	22	Far	66	7.6	92.4	Correct
14.26	-65	-72	22	Far	3146	99.8	0.2	Correct
14.31	-63	-88	19	Near	2	95.5	4.5	Correct
14.39	-83	-70	16	Far	3516	100	0	Correct
15.00	-73	-74	15	Far	5	88.2	11.8	Incorrect
19.53	-83	-86	27	Far	2	24.1	75.9	Correct
19.55	-59	-73	27	Far	2	48.5	51.5	Incorrect
19.55	-59	-73	26	Far	2	69.9	30.1	Correct
20.08	-87	-86	18	Far	2	99.2	0.8	Correct
20.29	-83	-83	21	Far	2	38.9	61.1	Correct

Table 1: Some random measurements. First three are from different day than the rest.

where powers of two are just making results look nicer and plugin work better, they are not based on any theory. Weights depend on situation and they are: $w_{signal} = 1$ or 0 if no signal, $w_{light} = 2$ or 3 if lux is over 1000 and $w_{battery} = 2$.

4 Results

Battery temperature changes relatively slowly so also total in/out-probability may change slowly, which means few minutes. With battery-sensor is assumed that outside is colder than indoors. This is not true in summer or in warm countries especially when A/C is used.

Telephony-sensor usually gives at least acceptable results but sometimes signal is good even indoors and bad outside buildings for example in Lapland.

So these sensors can't be 100% sure about one's environment but they are very lightweight and don't consume battery much. And as we can see from the Table 1, incorrect results are in transitions as most of the table is taken in one day.

Those formulas for probability calculations are not based on anything and maybe could have been made better, but they are giving good results.

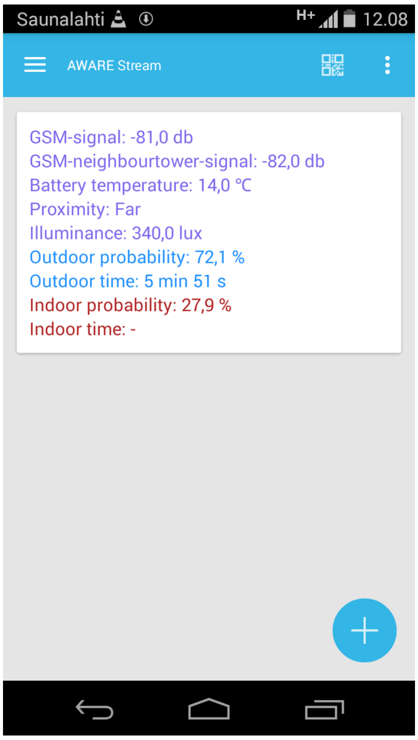

Figure 1: Screenshot of the plugin during sun eclipse. Like data shows, phone is outside.

5 Discussion

In testing period the plugin was pretty accurate. To improve thinks, battery- and telephony sensors could have been made react faster. They may be slow because of the structure of my plugin and not because of hardware, but didn't dare to change the code just before the return date. Of course it is physical fact that the battery temperature changes slowly, but telephony sensor has this strange behaviour to give data rarely and in packets.

So these sensors and their usage is very lightweight and this kind of plugin could have many applications. For example some kind of alarm for people with dementia, who sometimes go outside when it is freezing cold. Alarm could inform nurses or relatives that grandma is outside again in night with no reason. Also some fitness people may want to gather data of their outside time with no reason.

References

[1] IODetector: A Generic Service for Indoor Outdoor Detection, Pengfei Zhou, Yuanqing Zheng, Zhenjiang Li, Mo Li, and Guobin Shen, Nanyang Technological University, Singapore, SenSys12, November 6-9, 2012, Toronto

[2] http://williams.best.vwh.net/sunrise_sunset_algorithm.htm

[3] http://www.awareframework.com/

[4] https://github.com/denzilferreira/

[5] https://github.com/heppu