SENSEI/O: REALISTIC UBIQUITOUS INDOOR OUTDOOR DETECTION SYSTEM USING SMARTPHONES

By

Mohsen Ali Mohsen Al-awami

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
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in
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Indoor ; Outdoor ; activity ; Rural/Urban ; Cellular ; Wi-Fi ; Light ; Realistic ; Ubiquitous ; Ambiguous ; Clear ; Android ; Environments ; Smartphone ;

Summary:

In this work, we address the problem of realistic and ubiquitous indoor/outdoor detection system (SenseI/O) which is envisioned to be deployed worldwide, with minimum overhead, using mobile devices. Such efficient detection of the surrounding environment (indoor vs. outdoor) definitely serves those upper layer applications to improve their performance, make an effective decision about whether to turn on/off the used sensors and reduce the energy consumption aspects as well. SenseI/O consists of four main modules: (1) Smoothed single cell tower, (2) Activity recognition, (3) Wi-Fi based, and (4) Light intensity to ensure our aimed realistic and ubiquitous principles.

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Abstract

A lot of indoor/outdoor location, tracking, context awareness and activity recognition technologies which have been proposed over the years are based on GPS receiver, Bluetooth, infrared, ultrasound and radio frequency RF (Wi-Fi and GSM) signals. These technologies provide varying levels of accuracy supporting different application needs. Actually, these upper layer applications are applied either in outdoor or indoor environments during identified and controlled areas which should be pre-known. Most of those proposed applications suffer from numerous problems and challenges such as accuracy is related and affected by ambient environment type, energy consumption aspects, continuous sensing and the deployment of special hardware and/or special calibration of the area of interest to provide an accurate performance.

In this thesis, we address the problem of realizing a realistic and ubiquitous indoor/outdoor detection system (SenseI/O) which is envisioned to be deployed on a large scale worldwide, with minimum overhead using heterogeneous devices. Thus, such efficient detection of the surrounding environment (indoor vs. outdoor) definitely serves those upper layer applications to improve their performance, make a clever decision about whether suitable to turn ON/OFF the used sensors which leads to reduce the energy consumption aspects as well. SenseI/O leverages the ubiquity of sensor-rich cell phones, e.g., accelerometer, proximity, light and system time clock as well as multiple radio interfaces; 3G Cellular and Wi-Fi . It tries to use the measurements of those sensors to infer the current user ambient environment. We propose a novel SenseI/O system which consists of four main modules and they are (1) Single smoothed cell tower, (2) Wi-Fi based, (3) Activity recognition and (4) Light intensity to ensure our aimed realistic and ubiquitous principles.

In order to present a realistic system applicable on most of smartphones, we designed *single smoothed 3G cellular module* which relies on single associated

cell readings rather than multiples visible cell towers readings. Moreover, to meet upper layer applications performance requirements, we present a fine-grained *rural, urban and indoor* environment detection instead of binary indoor/outdoor only. An *activity recognition module* is designed, where we employed a hierarchical multi-class classifier to infer current user activity type (e.g., In-vehicle, On-foot and Still) which represents direct approach to infer ambient user environment type even in complex places (e.g., Tunnels and underground stations).

We used *moving average sliding window* technique to smooth absolute single cell towers readings in order to eliminate such previous work challenges (e.g., Handover and corner effect). According to these single smoothed associated 3G cellular readings, we filtered ambient environment into two upper classes (clear and ambiguous) in order to facilitate inferring a fine-grained detection afterwards. In case of *ambiguity* detection, we designed a *Wi-Fi based module* which exploited indoor established Wi-Fi APs to resolve such ambiguity (esp. between Urban/Indoor) and infer accurately ambient environment. In addition, a unique pattern of *light intensity module* through indoor and outdoor areas is exploited to differentiate between such environments efficiently. Each module has an individual algorithm designed according to observed features. Finally, we utilized senseI/O into three main scenarios which rely on combinations of two or more modules to provide realistic and ubiquitous service.

We evaluated SenseI/O in every place of ambient environments such as *Rural outdoor* (open squares, long bridges, highways, wide and open residential areas), *Urban outdoor* (downtown, crowded metropolitan areas and narrow streets bounded by tall buildings), *Indoor* (inside buildings such as houses, malls, companies and universities) and *inside complex places* (e.g., Tunnels and underground stations). Our implementation of SenseI/O was by using different types of android smartphones equipped with different android version levels. Evaluation was in two levels: *level 1*, we evaluated each SenseI/O module individually and estimated the *detection ratio* compared with ground truth reference. *Level 2:* we evaluated three main SenseI/O scenarios through a long paths (2-5 Km) to infer a fine-grained detection and compare them with ground truth and other single modules. All evaluation results for both levels are listed in chapter 5 in detail.

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