OLS – Opportunistic Localization System for Smart Phones Devices

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ABSTRACT
In this paper, we describe the opportunistic localization, which enables localization services that works seamlessly in heterogeneous environments including indoors as oppose to GPS based outdoor-only systems.

Categories and Subject Descriptors
C.5.3 [**Computer System Implementation**]: Microcomputers – *Portable devices (e.g., laptops, personal digital assistants), Personal computers*

General Terms
Algorithms, Design, Reliability, Experimentation

Keywords
opportunistic localization, smart phone, localization, tracking, data fusion, particle filter

1. INTRODUCTION
People are eager to locate their peers on a campus or in buildings and stay connected with them. OLS makes that simple. OLS's core technology is an opportunistic location system based on smart phone devices. Its main advantage is that it seamlessly works throughout heterogeneous environment including indoors as opposed to GPS based systems being available only outdoors under unobstructed sky.

OLS is a phone-centric localisation system which grasps at any location related information readily available in the mobile phone. In contrast to most of the competing indoor localisation systems, OLS does not require a fixed dedicated infrastructure to be installed in the environment making OLS a truly ubiquitous localisation service. The latest version of OLS strives to reduce the system ownership cost by adopting a patent covered self-calibration mechanism minimising the system installation and maintenance cost.

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The proposed demonstration will allow OLS to be tried out from the end user perspective, and will particularly give insight of the OLS core technology that is the adaptive fusion of information.

2. OLS's ARCHITECTURE
OLS's architecture migrated from the original client-server to the current service-oriented architecture to cope with increasing demands on reusability across various environments and platforms and to scale up to service a large number of various clients. The server side runs the main OLS services such as the location, management, registration and communication service, data fusion engine, database, and visualisation provider (Fig.1).

OLS can also interface third-party external services such as Google Earth. The key feature when designing OLS is its ease-of-use. Therefore, when interfaced with Google Earth, an OLS customer can build an indoor building environment with Google Sketch-Up drawing tool or just reuse existing *kmz* models from the Google Earth warehouse and publish them on Google Earth. OLS then imports the Sketch-Up building model and parses it to the data fusion engine to perform the map filtering upon the fused location information [1,2].

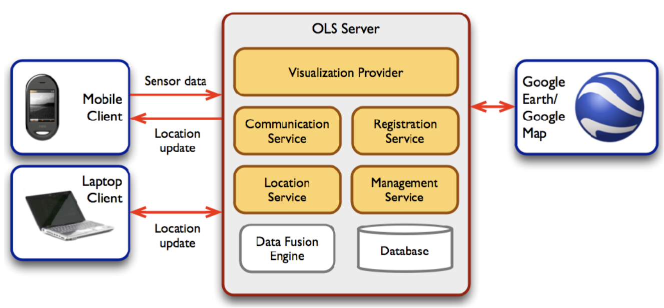

Figure 1. OLS Architecture

2.1 System Components
The OLS Server is responsible for hosting the application and providing all the services. *The Visualization Provider* offers 2D and 3D visualisation. *The Communication Service* is responsible for providing and maintaining communication interface between clients and the OLS Server. *The Registration Service* registers localized objects and OLS clients, the users of the Location

Service. *The Location Service* provides location updates for localised objects and instantiates and manages the instances of the main processing components of OLS Server. *The Data Fusion Engine* provides the data fusion service.. *The Management Service* manages and maintains the OLS Server and facilitates its administration. *The Database* stores environment description such as maps and 3D model of buildings. It also stores information necessary for the data fusion algorithm etc. *The Mobile Client* is a smart phone device, which is localised by the OLS server upon the streamed sensory data from its GPS, GSM/UMTS, accelerometers, Wi-Fi and Bluetooth. The Mobile client can also subscribe for location updates in order to further process and visualise its location etc. *The Laptop Client* is a third-party client typically with higher processing and 3D visualization capabilities. The laptop clients run third-parties location based applications, which further process the location data provided by OLS.

3. LOCATION RELATED INFORMATION AND ITS SEAMLESS FUSION

The location related information used for the estimation of mobile device location is existing signals in the environment, which can be sensed by a smart phone. The readily available information depending on the phone capability is typically a subset or all of the followings: the GSM/UMTS signal strength, Wi-Fi signal strength, GPS, reading from embedded accelerometers and Bluetooth proximity information.

The reliability and availability of input information depends strongly on the actual character of the mobile client's physical environment. When the client is outdoors under the open sky, GPS is a favourable choice typically combined with pedometry data derived from the 3D acceleration measurement. When the client is in dense urban and indoor environment the GSM/UMTS and Wi-Fi signal strength combined with pedometry data usually perform best. If indoor floor plan layouts are available the map filtering algorithm can further contribute to the location estimation reliability. However, the information about the actual type of environment is not available and proper importance weighting of all input information in the fusion engine is paramount.

The fusion engine runs the nonlinear recursive Bayesian Filter to seamlessly combine all incoming location information. Discrete Bayesian Filter is implemented using Sequential Monte Carlo Method known as the Particle Filter [1-2,4]. A particle Filter is based on a set of random samples with weights to represent the probability density of the mobile client's location.

Within the Particle Filter, the location related information is represented by likelihood observation functions, which differ for each localisation method and technology considered. Implemented localisation methods and technologies are following:

- Wi-Fi is a well established technology nowadays and OLS benefits from the omnipresence of Wi-Fi networks and advanced RSSI based fusion methods developed and published in above papers [2-4]. Depending on the availability of signal strength fingerprints and the level of details in environment description, the following localisation methods are used: the fingerprinting (and its variants described in [4]), multi-lateration or simple proximity.
- The measured GSM/UMTS signals strengths from the serving and all neighbouring cells are treated similarly to Wi-Fi signal strength. Cell-ID localisation is used in different case studies and applications already. The implementation of Cell-ID localisation adds straightforward coarse-grained indoor and outdoor location information to OLS. However, the main benefit of GSM is in urban (near-) indoor environments where the pattern of the GSM field strength can provide a localisation with the higher accuracy than GPS. Therefore, OLS uses GSM fingerprinting to cover areas with poor GPS and Wi-Fi coverage.
- GPS performs well in an outdoor open sky environment where previous technologies, Wi-Fi and GSM/UMTS, often cannot offer sufficient location accuracy due to low signal strength variation by uncluttered environment. OLS uses A-GPS, which can be initiated by it last estimated position computed from i.e. Wi-Fi or GSM, to speed up the start up process (Time-to-First-Fix) of the GPS receiver by a transition to an outdoor environment [3].
- The last sensory information complementing the previous technologies are pedometry data estimated from acceleration measurement. Pedometry data contributes to the seamless transition between outdoor and indoor localisation. Pedometry data consists of number of detected steps and their length.
- The availability of Bluetooth signal can also be used to detect the proximity of other Bluetooth enabled devices. If such a relation is detected, OLS can incorporate this knowledge in its location estimation process.

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