Towards a Generic Platform for Indoor Positioning using Existing Infrastructure and Symbolic Maps

Kurt Gubi[1], Rainer Wasinger[1], Michael Fry[1], Judy Kay[1], Tsvi Kuflik[2], Bob Kummerfeld[1]

[1] CHAI Group, School of IT, Sydney University, 2006, NSW, Australia
kurt@it.usyd.edu.au, {rainer.wasinger, michael.fry, judy.kay, bob.kummerfeld}@sydney.edu.au
[2] University of Haifa, Haifa, Israel
tsvikak@is.haifa.ac.il

Abstract. One of the important challenges for personalised, context-aware information delivery within buildings is to be able to show the user a map with their own location as well as the locations of points of interest for them. One very desirable property of a personalised, context-aware mobile application is that it can operate at the same time as preserving the user's privacy. To achieve this, we need to do on-device positioning and personalisation. This paper presents the design of a platform, and its implementation for the retrieval of publicly available building data (symbolic maps and associated radio-frequency infrastructure point locations) for the purpose of coarse-grained indoor positioning on mobile devices. In comparison to other indoor positioning systems, this work focuses on the mechanism through which building data is made available to mobile devices, as too the motivation in providing generic coarse-grained indoor positioning based on the use of existing infrastructure and building data.

Keywords: Indoor positioning; symbolic maps; semi-unprepared environments; client-side personalisation

1 Introduction and Motivation

Location-aware services are becoming increasingly common. A key reason for this is the growing number of mobile devices that can now determine their location and have the computational and communication power to deliver sophisticated services. Examples of such devices are smartphones, eReaders, mobile gaming consoles, in-car consoles, and netbooks. Most of these devices now come with a variety of inbuilt technologies as standard: for location sensing, e.g. accelerometer, magnetic field, orientation sensors, GPS; for positioning and communication, e.g. radio-frequency (RF) technologies like 3G, WLAN, and Bluetooth; and also for IO, e.g. inbuilt cameras that can be used for vision sensing, particularly in combination with AR and QR tags. High-profile investments, such as the European Galileo satellite system that is currently being built, are an indication of the value that is placed on location-aware services.

Modern positioning (and navigation) systems now cater for a wide range of scenarios ranging from in-car, to on-foot, and both outside and inside of buildings (e.g. [1]). In comparison to outdoor positioning via GPS, indoor positioning is far less widespread, and there are a number of reasons for this. One reason is the lack of availability of suitable maps. It is important to appreciate that the creation and maintenance of indoor maps is inherently different than is the case for outdoor maps. For example, access to - as well as suitability and privacy of - building blueprints provides a barrier to entry, meaning that coverage of indoor spaces, e.g. on the scale of a whole city, is far less accomplished than is the case for outdoor map locations. This means that we need to explore a different form of mapping approach for indoor positioning, and this must be able to operate with the type of indoor maps that are widely available; notably, we believe it must make use of symbolic maps that are often already available for buildings, despite these often not being particularly accurate in terms of scale and these often being highly selective in the information shown on the map.

Another key challenge of indoor positioning follows from the limitations of the technologies available. While there are several existing and emerging technologies that have been used in indoor positioning prototypes (e.g. based on RF, visual technology, dead-reckoning techniques), each of these has its own merits and pitfalls. None of them, taken independently, have the same planetary-scale applicability, nor the consistent accuracy that GPS provides for outdoor positioning. This means that there is still important research to be done to create systems that can make use of a combination of the available location technologies to achieve effective indoor positioning of a person as they move around a building. Finally, specialty-built indoor positioning solutions often require infrastructural (and software) outlays that are not always feasible.

In this paper, we describe our design for a platform that addresses these problems and describe its implementation for the retrieval of “publicly” available building data in the form of symbolic maps and markup of associated RF infrastructure point locations (though not limited to just RF) like WLAN and Bluetooth.

It can be noted that such a platform and its associated APIs will be an indispensible building block for web-based user-adaptive systems that contain any type of indoor positioning component.

In Section 2, we describe the benefits for both providers and users of such a platform. Section 3 provides an overview of the platform and details of the implemented proof-of-concept client application for Android smartphones. This is followed in Section 4 with a summary of related work in the fields of positioning platforms, and symbolic maps and data modelling. The paper concludes with a description of future work in Section 5.

2 Indoor positioning in Semi-unprepared Building Environments

Buildings are typically constructed based on highly accurate geometric blueprints, which although useful for architects and builders, are rarely accessible and rarely relevant (with regards to the detail they show) to general visitors of the building. Many ‘public’ buildings (i.e. buildings that the general public have access to, either with or without entrance costs attached) do however have maps available to the public (e.g. consider museums, libraries, theatres, hospitals, and so on). These maps are symbolic in nature, meaning that they need not align to any geometric model or linear scale, but instead are specifically designed to highlight aspects deemed to be most relevant to the user.

Similarly, many buildings are nowadays fitted with a range of RF-based communication technologies like Bluetooth and WLAN, and although building administrators may be reluctant to add additional infrastructure specifically for the purpose of indoor positioning, the modelling of already existing infrastructure may be an acceptable compromise. We call such environments “semi-unprepared” in that no additional technologies need be integrated, but the modelling of existing sensor/beacon points is still required.

Consider the following scenario. Tom, a tourist, is keen to visit a well known local museum. Upon arriving at the museum, he loads up the RoughMaps application on his smartphone and is presented with a number of icons on his screen representing nearby public buildings (e.g. museums, libraries, shopping malls). After Tom has selected the particular museum of interest, RoughMaps downloads the relevant mapping data from the web-service via a http request, and presents Tom with a number of symbolic maps, each one typically showing one level in the museum. While Tom considers these maps a useful feature, he is unsure of where he is in the building, so he presses the “Find Me” menu item, and the system positions him on the relevant sub-map. He is also able to take a photo of any of the QR codes scattered around the museum to have his position updated on the map. As he walks around, his position is updated on the map through the use of a dead-reckoning approach that combines readings from the digital compass and accelerometer sensor (i.e. a directional pedometer) contained within his Nexus One smartphone.

This scenario describes how a mobile client-device accesses (through a web service and its associated set of APIs) public indoor map data, to provide an end-user with symbolic indoor maps and indoor positioning information. Such a service would enable different mobile device types (including the myriad of smartphones) to provide personalised context-aware information relating to individual building spaces. Some of the indoor-based context-aware applications that such a service would enable include: personalised tour guides, recommendations for paths to follow and POIs to see (e.g. based on crowd-sourced data), detailed information pop-ups on nearby and relevant POIs, and educational treasure-hunt games for exploring indoor spaces.

3 Server-side Platform and Client-side Demonstrator

This section describes the platform through which building data is made available to mobile clients and the proof-of-concept client application for Android smartphones.

There are two main components described in the above scenario, namely: a web-service that allows for the ‘publishing’ of symbolic map data and associated sensor location points; and an API/client-interface that allows for such map data to be downloaded and interpreted by mobile applications (and foreseeably also web clients in the future). These components are shown in Figure 1A. Figure 1B shows the interface in which building data in the form of floor plans and sensor/beacon-location markup can be published to the server, while Figure’s 1C and 1D show how such map data is selected and downloaded by the user from a client device. It should be noted that certain complexities have been left out of the client-side implementation thus far; in particular, the client-side application only uses QR codes and dead-reckoning to provide indoor positioning information back to the user. This implementation is however clearly extensible to the sensing of additional beacons such as those based on RF technology, and the overarching mechanisms in which other applications and web-services are able to access the symbolic map data are also left unaffected from client-side implementations.

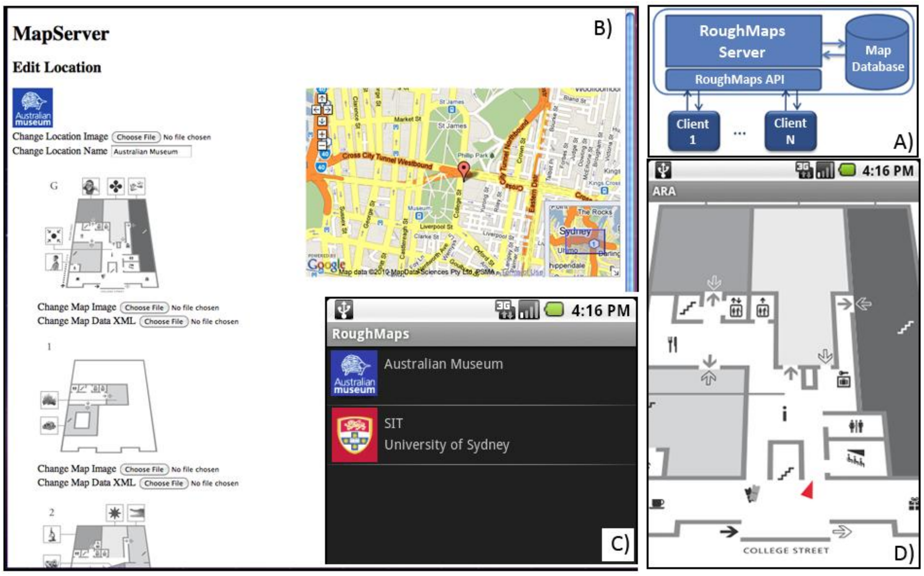

Fig. 1. Client-server architecture (A), the web-interface allowing building administrators to publish building data (B), and map data being selected and downloaded by the end user (C, D).

The generic indoor positioning component described in the scenario above is relevant to a broad range of mobile systems. For example, in [2], a subset of mobile systems are described, namely adaptive mobile guides, and it can be noted that all of the systems described in that work, ranging from museum guides and navigation systems to shopping assistants, use location as part of their application context.

4 Related Work

This work most closely relates to the intersecting fields of indoor positioning platforms, symbolic map use, and data modelling techniques for indoor spaces.

Indoor Positioning Platforms: A number of indoor positioning platforms have been created over the past two decades. The Active Badge system (1992) [3], MIT's Cricket system (2000) [4], BlueStar (2004) [5], and the Personal Navigator (2004) [6] are important examples of such systems.

The Active Badge system represents a class of indoor positioning system in which end-users are required to wear tags that broadcast their location to a centralized service through a network of sensors. The Cricket system, in contrast, represents the class of indoor positioning systems that are based on a decentralized approach, which has the particularly important property of being privacy preserving. In this case, the user carries a specially-designed listening device, which estimates its distance from nearby positioning beacons. The BlueStar and Personal Navigator systems take this basic idea further by allowing the client-side 'location-sniffing' device to be an off-the-shelf commodity phone and/or PDA. Given the importance of location privacy, we have taken a similar location-sniffing approach to BlueStar and Personal Navigator. We move beyond the previous work in that we make use of a range of facilities that are available on the user's smartphone, with various APIs to allow for generic implementation by any number of 3rd-party applications designed for mobile client devices (and foreseeably also mobile web services).

Symbolic Map Use and Data Modelling Techniques for Indoor Spaces: Research into human cognition has identified the use of landmarks for positioning and navigation as immensely useful. In [7], a number of papers are surveyed in which the importance of human conception of space as a collection of familiar landmarks has been shown both behaviourally (e.g. for newcomers to a city) and cognitively. Indeed in [8], it is described how human cognitive maps - by their very nature of needing to find a balance between storing as much useful information as possible against the need to keep the amount of information at a manageable level - emphasise some information at the expense of other data.

Tourist maps, for example, are quite often symbolic in nature, and this is often done to increase the salience of map features that are deemed relevant to the viewer, at the cost of decreasing the salience of the remaining map features/detail. It is this form of graphical symbolic map, which quite often bears little resemblance to the geometric blueprints of the buildings they represent, that we place at the heart of this work and its associated server-side platform and client-side demonstrator.

The Yamamoto map modelling toolkit [9] is one solution that can be used for the modelling of indoor spaces. Yamamoto provides support for the geometric modelling of architectural ground plans through polygon meshes. It is a desktop application written in C# for the .NET framework and has many features that would make it an ideal tool to use, though does not currently offer its functionality in the form of a web service, and would thus require users wishing to upload map data to first download and install the toolkit. Yamamoto also does not focus specifically on the modelling of symbolic maps that may bear little resemblance to their associated geometric building blueprints.

5 Conclusions and Future Work

This paper provides a number of outcomes. Firstly, it describes a platform that allows for single-point of access for downloading publically available indoor mapping data. Secondly, it provides the mechanism in which sensor/beacon location information can be utilised for coarse-grained indoor positioning. Thirdly, it makes use of a developed API and a sample client-side Android implementation of those APIs to demonstrate, as proof-of-concept, how to use the platform.

Future work will focus on continued implementation of the markup notation used to model infrastructure points; surveys into the level of infrastructure that different types of public buildings currently contain; and usability studies into what minimal level of accuracy is required for indoor positioning to be considered useful by end users.

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