

REVIEW ARTICLE

Applications of location-based services: a selected review

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This article reviews a selected set of location-based services (LBS) that have been published in the research literature, focussing on mobile guides, transport support, gaming, assistive technology and health. The research needs and opportunities in each area are evaluated and the connections between each category of LBS are discussed. The review illustrates the enormous diversity of forms in which LBS are appearing and the wide range of application sectors that are represented. However, very few of these applications are implemented pervasively on a commercial basis as this is still challenging technically and economically.

Keywords: mobile guides; location-based gaming; intelligent transport systems

1. Introduction

In this second Editorial Lead Paper for the Journal of Location Based Services (JLBS) we aim to review a selection of published applications studies in the field and assess the way they implement the theoretical developments discussed in the first Editorial Lead Paper (Raper *et al.* 2007). The distribution of the papers found in a thorough but selective literature review is also assessed as an indication of the real domain of utility for LBS and to indicate where further theoretical work is needed. This work is intended to be inclusive of all disciplines in which location can be a driver for information selection, processing and delivery, so that the Journal can facilitate the exchange of experiences between application sectors developing LBS.

2. Literature review

Inevitably in such a fractured and multi-disciplinary field, many applications will have escaped our attention or will lie in the gap between implementation and appearance in the literature. This review is being completed in the second half of 2007 and represents the state of knowledge as close to this date as possible. However, note that this review only

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covers the published literature, and no material from white papers or online presentations is included as it is impossible to know the origin or validity of some (much?) of this material. It is a medium term aspiration of this Journal to establish an online repository/link library of this 'grey literature', so that it may be accessed and read on a 'caveat emptor' basis, and curated for the long term when patent disputes may make such documentation particularly important.

The rest of this article reviews the key areas where LBS technology has been influential, looking at established areas such as mobile guides and intelligent transport systems as well as emerging areas such as location-based gaming, assistive technology and location-based health applications.

3. Mobile guides

The largest group of LBS applications is in a field known as 'mobile guides'. A mobile guide can be defined as a portable, location-sensitive and information-rich digital guide to the user's surroundings. This definition covers a wide range of designs and usage situations, which can be classified and evaluated in a variety of different ways. Most mobile guides are offering new services to users, but a part of all mobile guides is the potential replacement of paper guides and map books. This has opened a debate about what functions are best provided on paper or digitally, with the update rate and need for spatial precision being the best discriminators. Most paper guidebooks are published no more than annually and do not have built-in positioning, which creates a natural opportunity for digital mobile guides to fill.

A survey of mobile guides by Baus *et al.* (2005) characterised them by:

- Geopositioning (whether GPS, wifi or other)
- Architecture (client-server or distributed applications)
- Situational factors (focussed on what the user is doing and how this changes)
- Adaptation (e.g. handling varying positional quality)
- Interface (multi-modal or text/pointing systems)
- Network access (whether connected or using local caching)
- Maps used (map interfaces on a small screen should be schematised if possible)

Baus *et al.* (2005) argued that the greatest future potential lay in collaborative usage of mobile guides where users are able to view the tracks and recommendations of colleagues, i.e. mobile social networking.

Kruger *et al.* (2007) reviewed 'adaptive mobile guides' with a navigation focus, which they considered to be classic examples of context-sensitive applications. They divided mobile guides into the following categories:

- Resource adapted– optimised in advance for regular patterns of usage
- Resource adaptive– rely on a single strategy for resource usage
- Resource adapting– has ability to adapt to resource situations using multiple strategies

They argued that these categories of adaptation are particularly important for location determination (where the outdoor/indoor transition requires a switch between methods), and for situational responsiveness. They further explore modelling of users, context and

situations as drivers for adaptation through the use of the conceptual model UBISWORLD, the user markup language UserML and the ontology model Gumo.

Kruger *et al.* (2007) developed a further classification of indoor and outdoor mobile guides (including shopping guides not considered here) along the following axes:

- Adaptivity (using the Kruger *et al.* 2007 template)
- Geopositioning (GPS or wifi outdoors, infrared indoors)
- Knowledge representation (relational model or ontology model)
- Number of users (mostly one)
- User model (based on stereotypes, user preferences or UBISWORLD)
- Social context (multi-user approach)
- Presentation metaphor (map, virtual model, book, kiosk)
- Platform (PDA, phone, kiosk)

However, this classification is strongly influenced by the user modelling approach, and it does not evaluate whether the information is pushed or pulled by the user, the spatio-temporal expression of the location-based content, or the use case for the system.

Based on a wide survey of the many systems now being built, and building on these previous classifications, it is argued here that the canonical axes of comparison for mobile guides should be defined from a broader perspective. It is argued therefore that the following factors should be used to characterise mobile guides:

- Positioning quality (focussing on the accuracy and pervasiveness of the technology)
- Architecture (client-server or distributed applications)
- Presentation metaphor (map, web page, book, kiosk, AR, VR)
- Content relevance (geographic and semantic relevance of the content for the user)
- Delivery (focussing on whether the user actively selects or passively receives)
- Use case (whether navigation, mobile search, tour etc.)
- Adaptivity (using the Kruger *et al.* 2007 template)

Though a classification with seven axes is complex, and some of these axes are part-correlated (e.g. presentation metaphor and use case), by classifying the existing mobile guides, patterns of design choices and evolution through time can clearly be seen. Searching the current JLBS bibliography of ~500 research publications yields 34 mobile guides that have progressed beyond temporary laboratory existence, been tested with real users and published in the literature. This is an approximation of the total number of mobile guides as some have been developed and not published, some lack distinguishing characteristics, e.g. a screen, and others such as commercial personal navigation devices have proprietary and unpublished architectures and limited informational features and so cannot be evaluated easily.

The list of mobile guides has been clustered using two different strategies to explore the commonalities, firstly by architecture/positioning, secondly by use case, and the resulting groupings are discussed below and shown in Tables 1 and 2. As the scoring of the mobile guides is based on published (and interpreted) information, the groups are inherently conjectural, however, the exercise serves to erect some hypotheses that may be tested by further analysis. The citations to each of the systems mentioned are in the tables.

Table 1. Mobile guides classified by architecture and presentation.

Short Name	Application	Positioning	Architecture	Presentation	Content relevance	Delivery	Use case	Adaptivity	Publication
Cyberguide	Tourism	GPS/IR	Client/server	Map/book	Around Me	Pull	Mobile Search	Adapted	Abowd <i>et al.</i> (1997)
Guide	Tourism	WiFi/self	Client/server	Book/map	Around Me	Push	Mobile Search	Adapting	Davies <i>et al.</i> (1999)
Cooltown	Tourism	IR	Client/server	Book/map	Around Me	Push/pull	Mobile Search	Adapting	Kindberg <i>et al.</i> (2000)
DeepMap	Tourism	WiFi	Client/server	Map/book	Around Me	Push	Tour	Adapting	Malaka and Zipf (2000)
Hypergeo	Tourism	GPS	Client/server	Map/book	Around Me/ahead	Pull	Mobile Search	Adapting	Mountain & Raper (2000)
Lol@	Tourism	GPS/self	Client/server	Map/book	Around Me	Push/pull	Tour	Adapted	Pospischil <i>et al.</i> (2002)
CRUMPET	Tourism	GPS	Client/server	Map/book	Around Me	Pull	Tour	Adapted	Schmidt-Belz <i>et al.</i> (2003)
WebPark	Tourism	GPS	Client/server	Map/book	Around Me/ahead	Pull	Mobile Search	Adapting	Edwardes <i>et al.</i> (2003)
Tourist Guide	Tourism	GPS/DGPS	Client/server	Map/book	Around Me	Push/pull	Mobile Search	Adapted	Simcock <i>et al.</i> (2003)
Ambiesense	Tourism	Tags	Client/server	Map/book	Around Me	Push/pull	Mobile Search	Adaptive	Göker <i>et al.</i> (2004)
TGH	Tourism	GPS	Client/server	Map/book/speech	Around Me	Pull	Mobile Search	Adapting	Yue <i>et al.</i> (2005)
Tellmaris	Transport	GPS/self	Client/server	Map/VR	Around Me	Pull	Navigation	Adapted	Schilling <i>et al.</i> (2005)
MobileSeoulSearch	Tourism	GPS	Client/server	Map/book	Around Me	Pull	Mobile Search	Adaptive	Kwon <i>et al.</i> (2005)
GIMODIG	Recreation	GPS	Client/server	Map	Route	Pull	Navigation	Adapting	Sarjakoski <i>et al.</i> (2005)
MUMS	Transport	GPS	Client/server	Map	Route	Pull	Navigation	Adapted	Topi (2006)
Wiggleslick	Tourism	GPS	Client/server	Map/book	Around Me	Pull	Mobile Search	Adaptive	Jimison <i>et al.</i> (2007)
Camineo	Tourism	GPS/compass	Client/server	Map/book/AR/VR	Around Me/ahead	Pull/push	Mobile Search/tour	Adapting	M'tain & MacFarlane (2007)
Navitime	Transport	GPS/compass	Client/server	Map/book/VR	Route	Pull	Navigation	Adapting	Arikawa <i>et al.</i> (2007a)
Gullivers Genie	Tourism	GPS	Client/server	Map/book	Around Me	Push/agent	Mobile Search	Adaptive	O'Grady <i>et al.</i> (2005)
MARS	Tourism	GPS	Client/server	Video imagery	AR	Push	Mobile Search	Adapted	Feiner <i>et al.</i> (1997)
Museum Wearable	Museum	IR	Client/server	Video imagery	AR	Push	Tour	Adapting	Sparacino (2002)
PEACH	Museum	IR/WiFi	Client/server	Video imagery	Authored	Push	Tour	Adapting	Rocchi <i>et al.</i> (2004)
Entertainment Guide	Tourism	GPS	Client/server	Video imagery	Around Me	Push/pull	Mobile Search	Adapting	Koutsouris <i>et al.</i> (2007)
REAL	Transport	GPS/IR/compass	Broadcast	Map/speech	Around Me/AR	Push/pull	Navigation	Adapting	Baus <i>et al.</i> (2002)
Sotto Voce	Museum	WiFi	Broadcast	Book/speech	Around Me	Push	Tour	Adapted	Aoki <i>et al.</i> (2002)
BPN	Transport	GPS/IR	Broadcast	Map/speech/VR	Route	Push	Navigation	Adapting	Krüger (2004)
Syren	Museum	GPS/compass	Broadcast	Soundscape	Authored	Push	Tour	Adapted	Woo <i>et al.</i> (2004)
LISTEN	Museum	WiFi	Broadcast	Soundscape	Around Me	Push	Tour	Adaptive	Eisenhauer <i>et al.</i> (2005)
PhoneGuide	Tourism	Tags	Event trigger	Video imagery	AR	Pull	Mobile Search	Adapted	Möhring <i>et al.</i> (2004)
Marble Museum	Museum	IR/tags/gesture	Event trigger	Map/book/speech	Around Me	Push/pull	Tour	Adaptive	Santoro <i>et al.</i> (2007)
Mimotour	Tourism	GPS	Event trigger	Map/book/speech	Authored	Push	Tour	Adaptive	Hecht <i>et al.</i> (2007)
WikiEye	Tourism	Self/gesture	Event trigger	Map/book	Authored	Push	Mobile Search	Adaptive	Hecht <i>et al.</i> (2007)
MOBE	Tourism	WiFi/Tags	Applets	Map/book	Around Me	Push	Mobile Search	Adapting	Coppola <i>et al.</i> (2004)
Taeneb City Guide	Tourism	WiFi/self	Sync	Map/book	Around Me	Pull	Mobile Search	Adapted	Dunlop <i>et al.</i> (2004)

Table 2. Mobile guides classified by use case and delivery.

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WikiEye	Tourism	Self/gesture	Event trigger	Map/book	Authored	Push	Mobile Search	Adaptive	Hecht <i>et al.</i> (2007)
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