Location-based services

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Location-based services: definitions

- Location-based services (LBS) provide mobile device users with information/functionality related to their geographical location
- LBS are a subset of context-aware mobile computer services
  - Context-aware services provide information/functionality based on multiple forms of context, not just location e.g. time of day, weather, user profile information

LBS for pedestrians and also users within vehicles.
LBS can be provided to mobile devices carried or worn by pedestrians or to devices embedded within vehicles (e.g. cars, boats, trains, planes). The focus of this lecture is mainly on location-based services developed for pedestrians, although LBS designed for devices within vehicles will be mentioned occasionally.

LBS sometimes a subset of context aware services, sometimes terms used interchangeably.
Some academic papers & media sources refer to LBS as a subset of context-aware applications.
Others use the terms interchangeably i.e. when they say LBS, they mean context-aware services that use other forms of context as well as location.

Not just mobile devices
While LBS generally involve access to services through mobile devices based on location, they are sometimes wider systems involving users who access location-based information of others via fixed desktop displays. For example, one of the main users of fleet tracking systems is the person sitting at a desktop in a fixed location monitoring the location of other people.
**GIS stands for ‘Geographic Information System’:**

Often used in the literature to refer to geographic information on mobile devices targeted to specific user groups e.g. environmental scientists operating carrying out field research.

But can also be used to refer to simple navigation applications for mobile devices which do not receive additional information from the internet e.g. Tomtom Citymaps for PDA.
1) The first part of the lecture focuses on navigation assistance. Discuss some different types of digital mobile navigation assistance.
Note: lecture focuses on applications developed for pedestrians (either as research prototypes & commercial apps) plus some other forms that are possible in theory.
Why focus on navigation assistance?
Navigation assistance is an LBS in its own right (provided that it at least displays GPS).
But also, navigation assistance integral part of most LBS e.g. to find a business or tourist attraction, the user needs to be able to navigate to it. This part of the lecture will include discussion of some usability problems associated with digital navigation assistants.

2) The second part of the lecture focuses on additional information/functionality that can be provided by LBS.
Aim: i) to draw attention to the various forms of information & functionality that can be provided ii) discuss some existing services, either commercial apps or systems developed within research projects iii) discuss some interaction issues e.g. privacy.
To reiterate, most navigation assistants can be considered LBS, though not all. If a map application, for example, does not provide any services or information linked with the user’s current location (even just a GPS icon), it can be considered a mobile GIS but not a LBS.

*Navigation apps now standard*

Now bundled as on many mobile phones, particular high-end ones. Eventually, navigation assistants on mobile phones likely to be as common as music players. While paper maps may have some advantages (e.g. cheap, hard to break, wide visual display area), digital navigation assistants are likely to be widely used because they will be part of most people’s mobile phones and so therefore ready-to-hand with the relevant map in most situations.
Possible user goals

- To navigate to unfamiliar locations or to familiar locations via unfamiliar routes
  - Maximise speed, minimize frustration (e.g. getting lost),
  - Ensure safety, provide scenery, avoid certain locations or areas etc
- To stay orientated whilst exploring an unfamiliar environment
  - Ensure safety, stay in scenic areas etc, avoid certain areas etc
- Browse area remotely for information or to plan routes
- Acquire a cognitive map

These are some possible user goals in relation to application that provide navigation/orientation assistance.

Navigation to unfamiliar locations via unfamiliar routes is probably the most common goal. But, sometimes, people also use navigation aids to stay orientated whilst navigating. For most LBS, the application should support this user goal as well as goal-directed navigation.

Sub goals:

Note, usually when people navigate to particular destinations, they want to do so as quickly as possible with minimum frustration. Frustration likely to be cause by getting lost, but also by disorientation, or a difficult-to-use interface. Other possible goals include a desire to navigate via safe routes and/or via scenic routes.

Navigation aids also used to plan routes remotely or access information about an area.
And they can be used to develop cognitive maps i.e. mental representations of the environment. (Some forms of navigation assistant may be better at supporting these than others).
Types of navigational assistance

- Two main formats
  - Spatial information (maps or photos) where the user is free to set the view using pan & zoom controls
  - Information organized around a pre-specified route (sometimes called ‘turn-by-turn’ route guidance)

Two main types of navigational assistance via mobile devices:
Those that provide spatial information (maps & photos) where the presentation is not organised around a pre-specified route
Those formats where the presentation is organized around a pre-specified route, known as ‘turn-by-turn’ (TBT) formats in the literature on in vehicle navigation.

(Note that this is a slightly fuzzy distinction since…route information can be provided within the first format through route highlighting – i.e. displaying a line on the map – though, not here, that the presentation of information is not organized around a route. Plus, most TBT formats also often provide spatial information e.g. maps, photos also possible).

Most commercial apps provide both
Most commercial navigation products for mobile devices provide users with the option to use either format e.g. a 2D top-down map they are free to browse or they can plan a route and see sequential route information as they move along the route. Though note that, given the small display areas, these formats cannot usually be presented at the same time.
Maps on mobile devices can be 2D or 3D. 2D most common.
2D maps can be presented from top-down or oblique perspectives. Top-down
most common perspective.

*Information/Functionality often provided with apps that display 2D maps:*
- Usually, the user is free to alter the map view using pan and zoom controls
  (the zoom control alters the scale while the pan control changes the area of
  map visible on screen).
- It is also common for applications to provide positioning information via an
  embedded or external GPS unit. GPS information is usually presented to the
  user as icon which overlays the map and tracks the user’s position as he/she
  moves through the environment. Often, the icon embodies heading
  information, which can be inferred from compass data or dead reckoning.
- Some applications allow users to specify a route and see the route overlaid
  onto the map.
Top-down 2D maps (non route based)

Can also include...
- Semantic zoom i.e. information varies with scale setting e.g. street labelling, road definition, roads, landmarks
- Street highlighting
- History trails i.e. with GPS, can leave a breadcrumb trail indicating earlier path

Semantic zoom
The purpose of semantic zoom is to avoid clutter at low scales (i.e. when zoomed out). (Many atlas-style paper maps do the same thing but with just 2 or 3 scales i.e. they show an overview map at the front where just the main roads are marked and then more detailed views through the main body or the atlas).

Street highlighting
Because all the roads are not always marked when zoomed out, street highlighting is a useful feature for bringing up street labels for unmarked roads. Also, helps by showing the full extent of a particular road/street. Works well with stylus-based operation on a touchscreen. Would not work so well with touchscreen interfaces designed to be operated mainly via fingers, nor with traditional mobile phones where it is difficult to point at particular areas of the screen.
**Visualizing off-screen locations: Halo**

- Off-screen locations are indicated by semi-circles at the edge of the screen.
- Shape indicates the direction & distance to off-screen location.

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*Halo*

A useful interaction idea for indicating the position of off-screen locations relative to the map visible on screen.

With Halo, off-screen locations are indicated by semi-circles at the edge of the screen where the shape of the semi-circle indicates the direction to & distance away from the off-screen location.

An alternative is to use arrows but arrows only indicate direction.

Likely to be a very useful feature for LBS where the user is given a number of options e.g. the user wants to see ‘pharmacies’ within 500 metres walk or nearby tourist attractions. Allows the user to stay maintain an awareness of this locations despite the small screen area provided by most mobile phones or other mobile devices. Could also be very useful for social networking applications by allowing users to stay orientated to friend/contacts in the local environment.
Positioning data

Positioning data – e.g. provided by the Geographical Information System (GPS) or via other positioning systems - is fundamental to most forms of digital navigation assistance and LBS. (though note possible to have a LBS that determines location solely through self-positioning i.e. the user indicates their position on a map).

GPS

GPS is probably the most useful type of positioning information in outdoor locations since it is available almost everywhere.

Plus it does not rely, as some positioning systems do, on infrastructure embedded in the environment e.g. positioning via radio beacons and cell tower triangulation.

Plus, compared with cell tower triangulation, it provides much more precise data.

(Note that various research projects are working on the problem of how to provide positioning indoors without embedded infrastructure e.g. ultrasound, machine vision etc).

GPS, accuracy & Galileo
The Global Positioning system (GPS) was developed by the US Department of Defence.

With messages received from a minimum of four visible satellites, a GPS receiver is able to determine the satellite positions and time sent, and thereby the approximate current location of the GPS receiver.

GPS was made available for civilian use by Ronald Regan in 1983 after a Korean passenger jet was shot down by a Russian fighter plane.

To maintain military advantage, an error component was added to the signal for civilian use.

The need for more accurate data led to the EU-funded Galileo project, which is supposed to be operational by 2013.

With Galileo, the accuracy of location data for civilian use should greatly improve.

Current availability of GPS on mobile phones

InStat estimates that last year [2007], 153 million cell phones were sold with integrated GPS, and that number will surge to 590 million a year by 2011.


Note: the original iPhone used cell tower triangulation; the ‘iPhone 3G’ has an embedded GPS unit.
GPS icons on maps

- GPS information is usually presented as an icon overlaid on a map
- Map matching – keeps icon on known paths
- Icon often embodies heading information (e.g. arrow) inferred from compass data or dead reckoning
- Icon should also indicate when signal lost

Icon should also indicate when signal lost.
E.g. With the Tomtom Citymaps application shown in the picture, the icon changed from an arrow to a clear circle.
One study found that, even when provided with GPS icons, people still use traditional methods to track their position as they move through the environment e.g. matching landmarks (in urban areas, mainly street names). Also, people can become confused by pinpoint icons e.g. they think they are further back or further forward than they are. Or, the map matching algorithm can fail to place the icon on the correct road. It’s best to use a transparent icon to indicate the degree of accuracy.
Usability problem: focus + context

- Users need detailed views & overviews
- Need for frequent scale changes, particularly with small screens and/or long routes
  - Effort
  - getting “lost on the map”
- Design should support simple switching between views

If users aren’t following turn-by-turn instructions, they need both focus information (i.e. map detail) + context information (i.e. map overviews). They require overviews to plan routes and detailed views to find and track their position as they move through the environment.

(Note that the presentation of focus + context views of large documents is a classic problem in HCI).

Design should support simple switching between views e.g. user sets an overview homepage which he/she can easily return to by pressing a button or plus there are just a few pre-set scales that the user has to alternative between.
Zone zoom

- Good solution to the 'focus + context' issue for traditional mobile phones i.e. with 12 key hard keyboards
- If the user is able to set an overview at one scale, he/she can easily access detailed views & easily switch back to the overview
Usability problem: map rotation

- Many rotate paper maps to ‘track-up alignment’
- Users can rotate the device in their hands but concern/risk of dropping
- Alternatives…
  - The map can digitally rotate via compass data
  - User can digitally rotate the map by pressing buttons
- Automatic map rotation works well for TBT formats but not for non-route map formats
  - With non-route map formats, main problem is failure to recognize the map after it has rotated
  - Rotating device best for non-route map formats

Track-up alignment (also known as ‘egocentric alignment’).
It is a well-established finding that, on average, people find maps easier to use when aligned so that ‘up’ on the map is aligned with their forward direction in the environment. Robust for abstract map stimuli, you-are-here maps, aircraft navigation systems.

Note…

It can be time consuming to rotate the map using buttons (digital rotation via buttons not as easy as physically rotating the device).

Plus, it requires concentration due to relative lack of tactile/visual feedback during rotation (compared with physically rotating the device3).

A problem with both forms of digital rotation, manual & automatic, key landmarks disappear off-screen.

One study has found…

Automatic rotation works well for TBT formats
Physical rotation (i.e. rotating the device in your hands) works best for formats where the presentation is not organized around a route.

Ideally, devices should be made more robust & robust looking to reduce fear of dropping and risk of breakages.
3D maps have been explored as research prototypes.
They are not, as yet, available as commercial products due the amount
processing power and memory needed to render 3D maps & the limited
processing power/memory available on most mobile devices.

Possible advantage:
Landmark identification is easier from ground-level view as the perspective &
detail matches more closely what the user sees.
Note the same advantage applies to photos presented at ground level.
Like maps…
Photos can be freely browsed (e.g. via pan & zoom controls).
They can be presented in different orientations e.g. top-down, oblique, street level.
Similar kinds of information can be overlaid e.g. GPS, route highlighting, history trails etc

Databases of aerial photos now available for most urban areas (e.g. Google or Microsoft maps).
Google ‘streetview’ in the process of obtaining street level photos for many large urban areas.

Aerial maps VS top down 2D maps:
There is some research suggests which suggests that maps are preferable to aerial maps whilst navigating. Maps provide the core information that users need to navigate (e.g. streets shapes, street names, key landmarks). Photos provide extra detail but certain detail taken from an aerial perspective can be difficult to interpret & match to real environmental information as viewed from the user’s ground level perspective. Plus, too much detail takes longer to interpret and understand.

Generally, commercial applications that provide photos (e.g. Google maps for mobile) do so via the map view e.g. users can switch between a 2D top down map and an aerial photograph of the same area. Or, with recent versions of Google maps for mobile, users can access street-level photographs of some urban areas.
Research study:
Found that street level photos were easier to use for many people, particularly old people.
So some people may find Google streetview easier to use when navigating compared with 2D top down maps.

As with 3D maps, users may find it easier to match landmark information (real and represented) plus interpret route instructions.
Though, currently & for some time to come, Google Streetview only likely to be available for large cities.
Plus, even where people do prefer to navigate using street level photos, they may still want to access 2D maps for area overviews.

Another application of photos:
Photos can be tagged to maps e.g. some evidence that this can provide some navigational assistance.
Turn-by-turn route instructions

- Sequential presentation of single turns
- Each turn triggered by position data
- Turn information can be graphical, verbal or even tactile

**Turn-by-turn format**

Individual turns are presented sequentially & in context i.e. according to the user’s current location.

Usually, each turn is triggered by positioning information (e.g. GPS) so delivered as needed.

(Note, in theory, each turn could be triggered by the user. However, this would likely be unreliable as the user would make mistakes and lose his/her place in the sequence. Plus, positioning information can let the system and user know when mistakes have been made and re-compute the route to direct the user back on track).

Turn information can be graphical (e.g. an arrow or line), verbal (e.g. audio instructions) or tactile (e.g. the right side of the device vibrates).

Usually, the user’s current location & next turn is depicted.
**Background spatial information**

Turn instructions is usually accompanied by background spatial information i.e. maps or photos.

As with the non-route based formats, maps and photos can be presented in different orientation: top-down, street level or tethered.

TBT formats should have a mechanism for re-routing when users make mistakes or at least re-routing user back onto the original route.

**Note that with route information, start and destination must be specified**

With all route guidance (whether just a simple route highlight or whether organized as TBT instructions), a starting point & destination must be specified.

Generally, the user must define a destination. In a fleet LBS, this can be someone else e.g. control room in a taxi LBS system.

The starting location can either be entered by the user or else inferred by positioning information (e.g. GPS).
**Pedestrian navigation: formats**

<table>
<thead>
<tr>
<th>Turn-by-turn:</th>
<th>Map-based applications:</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Some evidence that A to B navigation faster and entails lower mental workload</td>
<td>- Evidence more difficult for some people to use</td>
</tr>
<tr>
<td>- Relies on accurate positioning information (not good for areas where there are urban canyons)</td>
<td>+ Doesn’t rely on accurate positioning information (better for areas where urban canyons)</td>
</tr>
<tr>
<td>- User needs to know specific destination</td>
<td>+ Doesn’t require known destination (good where destination undecided e.g. exploration)</td>
</tr>
<tr>
<td>- Not good for orientation &amp; possibly worse for cognitive map formation</td>
<td>+ Provides wider view so better for orientation &amp; cognitive map formation</td>
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</tbody>
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TBT formats:
Research comparing 2D maps with street-level photo-based guidance found greater speeds & fewer errors with photo-based guidance.
But...
- Relies on timely presentation of turns via accurate positioning information so requires a GPS chip plus maybe not good for areas where large ‘urban canyons’ e.g. user will turn a corner and not see the new turn for some time.
- User needs to know his/her specific destination…so not good when the user is just exploring or when he/she may want to wander off the path, or visit multiple locations but not necessarily in a fixed order.
- Not good for orientation/cognitive map formation, particular when zoomed in to a single turn. There is some evidence that digital maps are better for cognitive map formation.

Obvious solution is for apps to provide both types of format e.g. TBT route guidance and map that the user can freely browse. (Note, of the 2 largest mass market apps available at present – Nokia maps 2.0 and Google maps for mobile – Nokia maps 2.0 does provide both formats, although you have to pay extra each time you want to use TBT guidance, while Google maps does not provide TBT, probably because many mobile devices do not yet have integrated GPS).
From this point on, the lecture will move on from navigation assistance to talk about the type of additional information & functionality that can be provided by LBS.
Push services triggered by an event, usually the movement of a user into a certain location/area, but there also other possible triggers (e.g. various aspects of context such as timing or weather etc).

Examples:
An advertising message in a specific area of a shopping mall.

Push services are more difficult to design well (i.e. so that they are accepted/wanted by the user). Relies on system sensing user needs/preferences at any given time. Likelihood of the system getting this wrong.
LBS example: information services

- Allow users to find the nearest services e.g. shops, taxi ranks, tourist information
- Navigation support often an important feature of these services
- Often provided together with other functionality e.g. summon a taxi, book a hotel

Community-generated location-based data:

Note that information & media can be generated by ordinary users, not just by the service providers.

Ultimately, such user-generated information may prove to be a valuable resource.

Too much information?

One challenge for LBS that provide this kind of user-generated information or other large information databases will be to provide ways to filter it & to tailor it to user preferences or goals at any particular time.

One method – allow the user to choose filters e.g. filter by time, type of information, upload period, or by person uploading information (e.g. they could restrict to friends/contacts or people of a certain age group).

Another method – the systems attempts to guess at preferences based on user profile & usage patterns. This is essentially the problem addressed by various forms of recommendation systems e.g. Amazon.
Alerts
Too many alerts can lead to users ignoring them and/or can cause annoyance. Annoyance depends on how many alerts users receive and also on how they are delivered e.g. whether they are distracting. Distraction likely to be greater with audio alerts. Some visual alerts are more distracting than others e.g. alerts that users have to respond to (e.g. a pop-up box) are more distracting than other kinds e.g. an unobtrusive icon at the bottom of the screen. Note: sometimes users want to be distracted by alerts e.g. mobile phone calls.
LBS example: social networking

- Citysense
  - Tracks anonymous GPS positioning data from large numbers of mobile devices to:
    - Build up a record of night-time hotspots.
    - Show where is busy right now.

Screenshot from Citysense

Citysense:
For now, just based in San Francisco.
Tracks anonymous positioning data (e.g. GPS) from large numbers of mobile phones to build up a record of night-time hotspots.
Also analyses data in real-time to show where is busy right now.
Presents this information on a map.
Also filters data by tracking where you go and making inferences about the kinds of places you like & matching these with other people. In theory, this shows you where people with similar tastes are right now.
Sanoodi:
Idea that you record routes and other data (e.g. messages, photos) as you hike, explore new places, travel etc.
Others can follow your progress live.
Or they can follow your route & other routes at a later stage.
Sanoodi also allow users to create groups for people with similar interests e.g. ramblers groups etc.
Location-based games

- Games where the gameplay progresses via the user’s location

Example...
- GPS mission:
  - Treasure-hunt style game where players walk around to collect gold, answer riddles, find new places, and share pictures.

‘Geocaching’ is another popular treasure-hunt style location-based game
Location-based games

Example:
Uncle Roy is All around
• Mixed street players in interaction with online players
• Online players viewed a virtual model of the game with street players represented
• Street players received messages from the game & from online players – goal to find ‘Uncle Roy’s office’

Uncle Roy is All around was a game that trialled in 2003. Location data from the game (produced via self-positioning) was relayed to the game server and then represented within the virtual world visible to the online players. Online players could move around the game and locate street players and send messages to them.
LBS example: emergency services

- Reveal location of user’s device to emergency services e.g. following vehicle breakdown, injury, criminal attack etc.

These services reveal location of user’s device to emergency services in response to the user pressing a button or to sensor data.
The LBS service is an advance on simple communication over the telephone because users are often unsure of their position or there are problems with communication.

Examples:
With one application in development, the user can press a button on the car dashboard when they break down to alert roadside assistance to their exact position.
Or, emergency services could be summoned automatically in response to impact sensors that detect a crash has occurred.
Or, an elderly person with dementia could press an dedicated button on their mobile phone to summon assistance when lost or fallen over.
LBS example: management services

- Tracking vehicles, products or people e.g. ambulances, sales people etc.

Allow management to…

Dispatch nearest vehicle or person e.g. taxi or ambulance services.
Send messages to drivers or personnel e.g. on foot to inform them about next delivery location.
Provide accurate information to customers concerning the progress of deliveries.
To track lost products.
Automatically monitor wear & tear on vehicles.
Monitor workforce e.g. to ensure personnel are not spending too much time on breaks, to verify expense claims etc.
So, we’ve talked mostly about location. But LBS can also incorporate other kinds of context (although, according to some definitions, this makes them ‘context aware services’ rather than strictly just LBS, but we won’t split hairs).
The figure shows a number of categories of context e.g. time of day, user profile information (e.g. age, interests, goals), physical surroundings (e.g. whether in an urban area or not, whether raining), social/cultural situation.

Note: context provided by user input as well as sensor data
Often, when people talk of LBS or context-aware applications, they are thinking in terms of sensors on the user’s mobile device automatically picking up elements of the user’s context. But context can also be provided via user input e.g. would be difficult to infer purpose of use from sensor data alone.
LBS & privacy concerns

- LBS gather & store location & other data from users e.g. preferences, messages, photos
  - => Privacy concerns
  - Some steps to reduce privacy concerns...
- Ensure secure data transfer
- Where possible, anonymize & pseudonymize
- Inform users about what information is collected and made public
- Allow user to control what is stored & what is made public & to whom

As much as possible…

Anonymize:
Example: Citysense mostly makes use of anonymous data.

Inform…
Inform users about what information (including their input but also information tracked through interactions with the system) is collected by the system & stored & for how long. Too often, users are not aware what exactly is being monitored & stored by computer systems.
Inform users about what information is made available to others.

Control…
Allow users to control which information is made available to others.
For example, social networking applications could allow users to set different levels of privacy, attach settings specifying the types of information available at each level, and assign individuals to each level.
Example: Citysense allows users to delete any personal data.
When designing a LBS, it is important to consider the type of mobile device the service is being designed for.
E.g. handheld, wearable or vehicle-based device? If handheld, are you designing for a traditional mobile phone, touchscreen mobile phone, ultra-mobile PC or laptop, or for a mixture of these?

Example – screen size:
Screen size affects the amount of map you can show. Users of devices with very small screens may have to switch between overviews and detailed views more often i.e. greater need for simple ways to switch between views.

Example – touchscreen:
With a touchscreen, users can pan the map by dragging their finger or a stylus across the screen. Different type of panning interaction required if the device does not have a touchscreen. Also, pointing difficult without a touchscreen so features like street highlighting or scroll bars difficult to realize.

Example – finger based interaction:
With finger-based interaction, the buttons need to be bigger. Fine pointing difficult.

Processing power, memory & battery can also be important.
Further reading

LBS overview
- Steiniger, S., Neun M., & Edwardes, A. Foundations of Location Based Services
- Some location-based services developed in research projects
  - Workshop on mobile spatial interaction at CHI 2007
    http://msi.ftw.at/program.html
  - Navigation assistance (focusing on specific topics)

Some existing commercial applications:
- http://www.bsppt.com/
- http://brightkite.com/
- http://www.whirl.com/
- http://www.doppler.com
- http://www.sanodii.com/
- http://gpsmission.com/