INDOOR NAVIGATION USING APPROXIMATE POSITIONS

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Abstract: Navigation aids have usually concentrated on the great outdoors, whether driving on highways or, more recently, walking through cities. These systems use the Global Positioning System (GPS) for position information. Indoor navigation cannot rely on GPS. In order to provide position information indoors, a technique called device whispering was developed.
The following presents an indoor system currently being developed, which is suited to the imprecise position information provided by device whispering.

1 INTRODUCTION

Computerized aids to navigation are the natural extension to printed maps. Since the advent of GPS, these tools have become interactive, instead of being limited to providing precomputed routes with graphics. The first systems where targeted at supporting vehicle navigation. Early interactive devices used dedicated hardware, but mobile phones are starting to be used as alternative hardware.

This has in turn motivated navigation systems for pedestrians, e.g. Qiro[1] or Nav4All[2]. Qiro actually uses only the current cell as information, and only if it is not ambiguous; users can manually input their current position (see FAQ on Qiro's web page). The use of trilateration, or even multilateration could be a possibility, but are computationally expensive, most likely preventing a satisfactory user experience.

Further, tri- or multilateration based on neighbor cells' signal strengths have difficulty coping with the various propagation effects present in cell based networks. For instance, reflection of radio waves often allows a connection to the base station without a direct line of sight - breaking the assumption lateration techniques are based on. In case of indoor systems, which is considered here, GPS cannot be used for positioning, because the radio waves used by the GPS system do not propagate through roofs (or even dense foliage). However, cell based networks in the form of wireless local area networks (WLAN) can be used for positioning.

Currently, research considering indoor navigation concentrates on improving the position data computed. One possibility, used in (Ohlbach et al., 2006), is fingerprinting, which provides detailed information about local propagation effects. Another technique for indoor positioning named Device Whispering (Krempels and Krebs, 2008; Patzak, 2009), was developed at the Department of Computer Science, Informatik 4, of the RWTH Aachen. This method is based on wireless local area networks, and trades accuracy for speed. After a short description of the technique, a navigation method is presented, which is currently being developed as a real life application based on whispering.

[1] www.qiro.de
[2] www.nav4all.com

2 DEVICE WHISPERING

The main idea of the Device Whispering technique is to reduce the access points considered for position estimation. This is done by controlling the transmitting power WLAN interface: The device is set to minimum power, then queries access points for management information. The closest access point is defined as the one answering to the request with the least amount of transmission power used, which is the minimum information possible.

Access points can be tagged with positions, and if multiple access points are available these tags can

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be used to approximate the current position somewhat more precisely than just giving the closest access point. Various caveats are discussed in (Patzak, 2009), but this work will assume only knowledge of the closest access point. The whispering method is also robust against signal multi-path propagation and power oscillations or automated adaption of access points' transmitting power.

Since the method is based on indoor infrastructure, reception should not be a problem, assuming existing infrastructure. But WLAN for Internet access is more and more provided as a service to guests.

The method's lack of precision makes it necessary to use a novel approach, as current solutions assume precise information. One such approach is presented here, which is based on a sectorization of the map based on the positions of the access points.

3 MAP GENERATION AND REPRESENTATION

The whispering technique defines a mapping from a point in space to the closest element in a set of special points, the access points. This type of mapping, known as Voronoi Diagrams, is an important concept in computational geometry (Aurenhammer and Klein, 2000; Aurenhammer, 1991). Efficient algorithms to compute the voronoi diagram for a set of points exist, see (Aurenhammer and Klein, 2000; Barber and Dobkin, 1996). Thus, a natural, though idealized, sectorization of a floor plan can be generated automatically by calculating the voronoi diagram of the access points, and clipping the resulting sectors to the floor plan.

Based on the assumption that Whispering acts as a filter against propagation effects, such an idealized sectorization should be sufficient. Technically this idealization can be reduced by using a so called approximate Voronoi Diagram, which has fuzzy edges. Instead, the system adds way-points on or close to edges (in the next sector), to lead the user out of ambiguous areas. 4 discusses how way-point instructions are communicated to the user.

The actual map used for navigation operates on a graphs of sectors with edges connecting adjacent sectors. Features of the geometry are positioned inside the containing sectors. These can be Targets (e.g. shops or cafs), Landmarks (e.g. statues or fountains, see 4.1) or connective features like stairs or elevators. Connective features are associated with edges connecting locations not connected by normal sectors.

Thus map representation is supplied to client devices by a local server, which can be contacted using the WLAN infrastructure required for positioning.

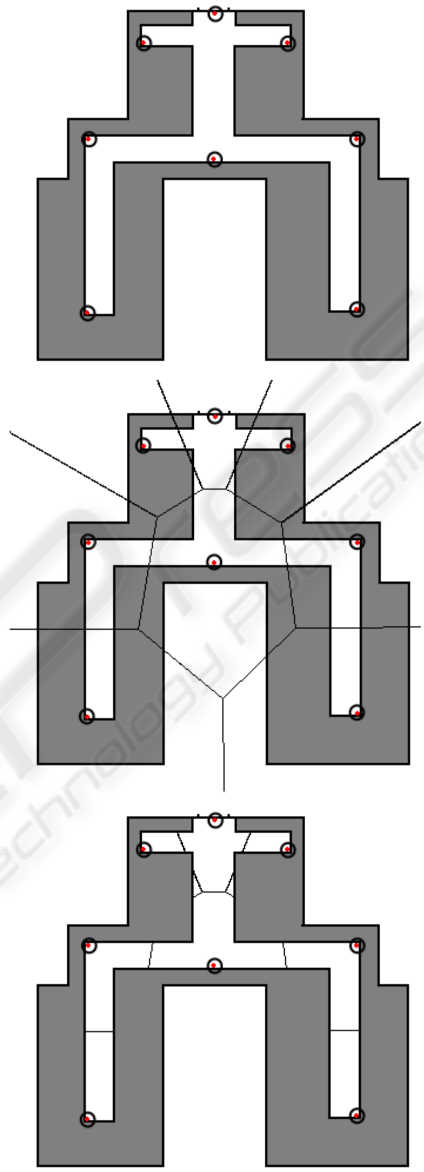

Figure 1: A simple location, access points are the circled red dots. The center image shows the voronoi regions generated from the access points. In the bottom picture, the regions have been clipped to the corridors. Artifact regions generated during clipping can be seen top center below the cross corridor.

4 NAVIGATION COMMANDS FROM APPROXIMATE POSITIONS

The generation of navigation commands must distinguish two types of navigation tasks:

Long Paths have endpoints located in different sectors. Finding such paths in the graph representation is a simple application of the A* algorithm, (Russel and Norvig, 2003; Sánchez-Crespo Dalmau, 2003). This type of path is represented as a series of adjacent sectors. Long paths can be displayed graphically, laid over the map.

Short Paths remain inside a sector. As long paths can be expressed as a series of short ones, generating succinct instructions for the latter is paramount.

For long paths, position information can determine the sector where the mobile device is located. Using this information, it is possible to restrict the navigation instructions to the current location. For short paths, position information is at best an approximation and fine grained instructions like "take the next corridor to the right" are not feasible. Natural language allows the use of coarse grained[3] relative instructions: Instead of alerting the user when no misunderstanding is possible, a navigation instruction should unambiguously describe the target, the corridor in this case.

Natural Language Instructions are attractive for this application (Reiter, 2000; Kray and Blocher, 1999), as their rich descriptive abilities are able to single out targets from a group, if instructions are constructed with care. This can be be done using adjectives which apply to the target (e.g. "the green Column" or "the leftmost door"), or by giving a spatial relationship to a Landmark (see e.g. (Elias et al., 2005; Tversky and Lee, 1999; Lazkano et al., 2005)).

The lack of rigidly detailed instructions may seem inappropriate when navigation instructions are considered from the point of view of a car's driver. For example the instruction "take the next turn left" always refers to a road for cars, but a pedestrian could turn left into a store. As pedestrians are less constrained than cars in their movement, usually traversing areas (Gaisbauer and Frank, 2008), the construction of "short paths" is predominated by avoiding clumps of people, fountains and other landmarks as well as adaption the movement of other pedestrians, forming flows and eddies [4]. These considerations show that fine detailed instructions are not as desirable for pedestrians as they may be for cars: Navigating across a plaza filled with a milling crowd is best left to a humans cognitive abilities.

The remainder of this section elaborates on these topics.

[3]That is, without relying on up-to-date exact positions.

[4]Flocking in AI terms.

4.1 Landmarks

Landmarks can be anything, as long as it is easily seen. Stores and other corporate entities (preferably with a nice iconic logo) are useful. In cities, Statues, fountains, buildings, the cologne cathedral and the tour d'Eiffel, and other elements of the surroundings are used which are less interesting for indoors applications. Staircases, elevators, emergency exits and phone booths (while they exist) are exemplary of architectural features which make for good indoor landmarks. Navigational targets can also serve as landmarks, if they are not targets of the current path. Natural language nicely distinguishes this as e.g. "go to the booth by the stairs" versus "climb the stairs by the booth"

Landmarks can be displayed on the map by drawing icons and logos or even images at the appropriate places. This gives users hints for in-sector navigation where the approximate positions can not be used to generate micro-instructions graphically without becoming confusing. The graphical representations of landmarks need to be provided together with the map information.

Landmarks are regularly used by humans in natural language instructions. Human languages offer a plethora of ways to express absolute directions (straight ahead, turn left, in and out), relative locations (By the stairs, next to the record store) and description (colors, shapes, labels), which can further aid in in-sector route description.

4.2 Natural Language Instructions

Natural Language is an familiar means to convey information. It has the capability to convey navigation information with closer emphasis on significant or detail. For instance, in the above example (booth and stairs), natural language can indicate whether the booth or the stairs, or both, are landmarks, based on the next way-point. It is also able to generate static instructions, which where identified as a necessity describing short paths inside a sector.

Instructions can be fine grained when using spatial and temporal constructs to aid navigation inside a sector. Relative instructions can try to determine what is on the left and what is on the right side, for example when entering a large hall from a corridor. In general, assuming the user walked in a straight line from the last sector to the current one, directions relative to the users orientation (like "left" or "right"). As mentioned in the example at the beginning of this section, context based information can be used to place emphasis on important elements of the Locations (stairs which must be used) and delegating lesser ones to descriptive items, based on the currently scheduled activity. Relative descriptions can be used to associate a target with a mote prominent feature in the close vicinity.

Annotating landmarks or prominent features of the locations (e.g. statues or fountains) with descriptive adjectives makes it possible to convey succinct descriptions of a location or feature.

For a given language, a grammar defines how sentences are formed. While computers are mostly concerned with parsing (Aho et al., 2007), that is understanding a language, the generative aspect of grammars is well known. Based on the current way-point and the next one, as well as the knowledge provided by the extended map, instructions can be generated by expanding productions of the grammar based on the available information. The expansion of productions is controlled by a set of rules, which take the available information into account.

Finally, natural language instructions can be used to convey information related to the users current activity, but not the geometry itself. Platform changes, deadlines like the trains' departure, and gotchas like the fact the train will be split at a later stop (only the back half going to the users destination), can not be conveyed on a map, and thus benefit from a natural language interface.

5 CONCLUSIONS

A system for indoor navigation based on the Whispering technique, which is currently being implemented, was described. While imprecise, it counteracts propagation effects. This motivates the use of voronoi diagrams to represent an idealized sectorization of locations, based on access points provided by local WLAN infrastructure.

User guidance without precise position information relies heavily on natural language instructions. The graphical representation, while simple and familiar, provides only an overview of the path. Natural language instructions are used to provide static path descriptions where dynamic descriptions would require a position with more precision than available using Whispering.

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