Findings from a Location Aware Smartphone Application for a novel Retail Shopping Experience

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***Abstract* – This paper discusses findings from a research project for a Swiss retailer. The goal of the project was to show a possible future of retail shopping using LBS augmented by indoor positioning. A developed location aware shopping smartphone application as well as an accompanying administration desktop software framework help customers shop in a store efficiently and maybe lower their demand for additional online shopping. The interdependent components help store-owners to learn about their customers and respond to their preferred (location based) behaviour even more.**

The proposal includes interesting ways of customized advertising, where a customer's past shopping data helps to generate individual product sale offers per application usage. Combined with product location information further ways to create a satisfying customer - store relationship will be shown.

An obvious product search feature was extended with location aware routing-applications. Actively used shopping lists will build a base for a future self-checkout functionality speeding up a customer's shopping and stores could reassign freed-up staff to improve the personal customer service even more.

Biographies

Martin Krammer is a teaching / research assistant and PhD student at the Institute for Building Informatics at Graz University of Technology, Austria. His studies concern several topics in the area of indoor positioning with software applications. Starting from inertial sensor data processing with Kalman filters and sensor fusion techniques to improve position accuracy his works have advanced to the design and implementation of location based mobile information systems for professional and consumer services.

Thomas Bernoulli is a research assistant and PhD student at the Institute for Building Informatics at Graz University of Technology, Austria. His research deals with the design and implementation of large, modular and flexible software frameworks demonstrated by the development of a location based service framework currently in use as a base for several different professional and consumer applications as well as research.

Sergej Muhič is a teaching / research assistant and PhD student at the Institute for Building Informatics at Graz University of Technology, Austria. His research deals with the generation of building information models. He tries to automatically extract information from CAD building plan drawings to get data for a building model used in different applications later in the lifecycle of a building like indoor navigation.

Ulrich Walder is professor and head of the Institute for Building Informatics at Graz University of Technology, Austria. His research targets the development of a novel computer aided disaster management system combining interdisciplinary knowledge of facility management, civil engineering, navigation and software development.

I. Introduction

After the big trend in recent years where customers prefer to shop online for electronics, retail stores now face a situation where many customers are willing to buy even everyday groceries online. The convenience of product search and available price comparison of standard products is a clear driver for such behaviour.

Retail stores have to find beneficial ways to get customers back into the shop. The key feature of retail – comparing goods in hand - has to be emphasized using new technologies to counteract the impersonal online shopping character where it is just unnatural – the everyday grocery. Location based services (LBS) are able to generate a novel retail shopping experience for the customers and store owners. With LBS utilizing a customer's smartphone the desirable online-shopping advantages can be put into the hands of local customers.

Nowadays LBS are already an important part of the electronically augmented life of many people. Even "only" knowing one's own position is very helpful for various leisure and business use cases (e.g. car navigation). Receivers of a Global Navigation Satellite System (GNSS) - like the commonly used Global Positioning System (GPS) - are a cheap way to serve that positioning need outdoors but do not work properly indoors or in urban areas (find house entry door; sidewalk left or right of street?).

This paper discusses current positioning technologies and shows essential components of an LBS system based on the approach for a location aware shopping smartphone application developed for a Swiss retailer. It outlines how a common smartphone could combine its positioning abilities, computing power and wireless data access to form an inexpensive LBS device with a positioning accuracy suitable for indoor usage.

With findings from the LBS system for retail it will be easy to extend the principles stated to other application contexts or outdoor usages. As nearly every smartphone already incorporates a GPS receiver, such an outdoor-extension could also include the usage of GPS positioning where the accuracy is sufficient.

II. Location Based Service Smartphone Applications in General

For indoor usage a smartphone software application (app) is the best choice, because it is the device a user naturally always carries around without having to think about an additional "LBS device"; this fact should increase the user acceptance of that LBS device significantly.

A reasonable application context of an indoor LBS app is for areas with a high density of different possible user-actions and/or –interest as well as information located within limited space next to each other. Typical areas are shopping malls, home improvement stores, museums and alike.

LBS apps have to inform their users about things worth noting around the area they are located. Ideally, they help ease already present (location based) needs of users e.g. finding products, rooms, taking notes etc. Therefore, the base functionality of LBS apps is a visualization of the location context around the user i.e. the map. That clearly helps a user at least in the way a paper map of that location would do.

Additionally to paper maps, an LBS app can improve the orientation purpose by marking the user's position within the map; but doing that automatically and accurately is challenging within cost and convenience constraints of common consumer scenarios described in this paper. The reliability of accuracy is very important since a too (depends on the context) "wrong" indication of the user's position is worse than no position regarding the given orientation purpose.

Further functionalities of LBS apps deal with enriching the location context with useful information. These classic location based services are basically *searching for* and *suggesting* points of interest (POI) for the user and visualizing a *route* to such POI.

It depends on the specific user how or why a POI is "interesting" and there will always be only a certain overlap of interest in a POI when talking to different stakeholders or users; so some kind of customization of information presentation has to be possible.

Stakeholders on one hand are users which consume or experience "products". On the other hand, suppliers or creators try to improve the user experience of their offerings by using LBS. All parties have their own – often divisive – goals which however depend on the other party's cooperation. So every LBS has to create a win-win situation somehow to be provided at first but also to be consumed at last – or in other words – to be successful at all.

POI in general are locations that someone could want to visit. An LBS app provides further information to the user regarding that POI (text, picture, video, hyperlink etc.) and allows actions to be taken on that POI (routing to, communicate with, buy it, note etc.).

III. State of the Art

A. Existing Indoor Location Based Service Smartphone Applications

There exist several LBS apps for indoor facilities. Most of them are focused on finding POI in the context of operation. Most found commercially available LBS apps try to support a customer's shopping experience within shopping malls or stores.

One category of POI in that context always deals with *user needs* like finding restaurants, rest rooms or *convenience* like finding public transport, the parked car and leisure areas. These POI are not the reason one visits a shopping mall for, but for a person they are necessary and assumed or at least appreciated to be offered as sure infrastructure in such facilities.

Another POI category deals with things that users already want before they visit the mall or that are a core reason for their visit. This category is the main topic in shopping and consists of *consumer products*. Additionally to known and wanted products, a user could develop an interest in products just while being in the store. This behaviour could be triggered or influenced by sensing (seeing, smelling, tasting, hearing) products in a store or advertisement. This should be a key point of action within retail stores, where convincing customers of additional products is already easier than within an impersonal online shop.

Available apps always consist of these POI. Based on the creator and the app's purpose, the product POI is structured into sub-categories in a logical way. So, if one wants to find a certain product, he chooses the right *store* (thematically or by user preference), therein the right *product category*, down to *specific product*; this is the real-life shopping behaviour translated to a software app with the advantage over real-life of not having to walk during the (maybe only informative) search process.

Another real-life product finding behaviour would be by asking shop staff. This is ideally suited to be adopted/supported by a software-application because of obvious product database *search* functionalities and the relief of shop staff (mood) from standard questions.

Both ways of finding a product are implemented into these apps, reasonable and helpful to the user. Some apps extend these natural ways to look for products and present them as *necessary goods for a specific context*; especially meal suggestions and recipes lead to corresponding products (plus amount).

In most apps another key feature is “lists of POI”. Such lists could be assembled by the LBS provider and could contain *products currently on sale/discount*, *newly available products*, *best-selling products etc.* For convenience, a user can compose own lists of POI at home for a fast(er) access when needed while shopping; these lists collect needed products to buy (i.e. shopping lists), favorite products and shops.

All these app-actions finally lead to one or more specific POI the user actually wants to walk to. All evaluated apps *show* the user a *route* to POI in the manner of a map/track representation or purely textual. These indoor LBS apps ask for manual user-input of the track start point.

None of the evaluated apps can compute and show the user’s live position, which would be necessary for finding the track starting point without user input and - more important - a live *routing* with current walking direction aids at any time. This lack of live positioning is the main disadvantage of currently available apps, not allowing them to provide all interesting LBS possibilities.

B. Positioning Technologies for Indoor LBS

A prerequisite for an “all possiblities” LBS is a *location service*. There are basically two common options to perform indoor localization: Using *radio signals* or using *inertial measurement sensors*.

1) Localization Using Radio Signals

First attempts to use IEEE 802.11 (WLAN) radio-frequency based network technology for indoor positioning reach back to the first standardized WLAN equipment [1]. More than a decade with a lot of research has passed (e.g. [2], [3], [4]) resulting in today’s ready to use products using WLAN for indoor position (e.g. *awiloc* from Frauenhofer IIS).

The basic idea behind using WLAN for indoor positioning is as follows: The device which location is going to be determined measures the *received signal strength* (RSS) of all available WLAN *access points* (AP). These measurements are then processed to estimate the location of the device. The most basic algorithms have the prerequisite of known locations of the APs and perform a trilateration, taking the RSS measurement as distance estimation to the corresponding AP. But as signals in indoor environments are often reflected, refracted, and diffracted this category of methods does not provide a high accuracy.

A more sophisticated method does not necessarily need the location of the APs as input but has another prerequisite: A so-called *radio-map*. This is basically a collection of locations with associated RSS measurements for a given environment. It has to be recorded before a localization can be done. When localizing a device its measured RSS are basically compared to the given radio-map, resulting in a location estimation.

The more fine-grained the radio-map is, the better the location can be estimated. Generating these radio-maps requires a lot of measuring work. This leads to the trade-off of better localization thanks to fine grained radio-maps and high initial effort. As these radio-maps implicitly take signal reflection, refraction, and diffraction into account they lead to more accurate results than the previously mentioned algorithm category but also cause a new problem: The radio-maps are partly out-dated as soon as anything affecting signal propagation is changed in the mapped area.

2) Inertial Sensors:

Localization and navigation using inertial sensor technology (INS) has been used for decades, first starting in the aeronautics [5]. The key characteristic of INS is: Short-term the positioning method is highly accurate, however suffers from sensor errors which lead to an accumulation of position errors without further stabilization/correction. Back in the days the equipment was big, heavy and very expensive. Over the decades the sensors became more accurate, smaller and cheaper. With the emergence of microelectromechanical systems (MEMS), inertial sensors reached a stage where they became interesting for pedestrian navigation.

Today even lower cost smartphones contain the full range of sensors needed for inertial positioning (three axis *accelerometer* and *gyroscope)* and further sensors which can be useful for positioning (*magnetometer*, *GPS* and occasionally *barometer*).

For inertial positioning, a sequentially measured acceleration [m/s2] is taken, then these values are integrated twice over time [s] to get the distance [m] the sensor covered during the measurement time interval. But as a movement generally happens in 3-dimensional space, the body axes of the sensor rotate relative to a local level coordinate frame e.g. North-East-Down (NED). To determine in which NED direction a measured body acceleration (and finally resulting distance) points, angular velocities measured by the gyroscopes constantly update a rotation matrix (i.e. the current sensor alignment), which is used to transform these sensor measurements to local level. Through this principle procedure double-time-integration along NED directions is possible and results in common positions.

Because of the relative nature of the inertial positioning method, the final location accuracy critically depends on the accuracy of the inertial sensors. It is obvious that with this dead reckoning positioning method a former positioning error always propagates to following positions. The accuracy of the sensor is related to the generation of the sensor (the more recent the better), its size, and its price. As the goal is to use the sensor of the user's smartphone we cannot influence the sensor quality at all, hence a more advanced positioning algorithm should take it into account.

A fundamental and often used measurement error correction of an inertial positioning algorithm is the *zero velocity update* (ZUPT). This is a state where the sensor is supposed to be under *zero motion* in reality. Knowing when that state is reached cannot easily be seen from digital sensor measurements, because sensor biases and resulting time-integration errors always suggest some motion even if no real motion is present. The art is to detect that zero motion state reliably. This is helpful because at such a state the positioning algorithm can be set to appropriate zero values which "resynchronizes" the (erroneous) calculations with the real condition. This technique avoids or minimizes a development and propagation of sensor errors into continuous position drift.

The case where a sensor is mounted at the pedestrian's foot - which certainly has zero motion phases while walking - results in better ZUPT than any other mounting area on the user's body and very high positioning accuracy ([6],[7]). However a system using a smartphone's internal sensor has to work within the given constraint that it is randomly body mounted therefore further algorithms are needed to provide accurate location information.

A sophisticated positioning algorithm always tries to counteract the inertial sensor errors with various approaches. One approach is to use other (absolute) sensors like magnetometers to correct errors of the horizontal direction ("heading") of the globalization matrix generated with gyroscope measurements. Another one is to use barometers to correct inertial positioning height errors. Outdoors a *GPS* sensor can help to keep inertial positioning errors at least in the range of GPS accuracy.

All statements above suggest an inertial positioning algorithm that works with a *combination of different sensors to counteract weaknesses of one sensor with strengths of others.* This helpful technique is called *sensor fusion*. Further improvements of the algorithm could be reached with a possibility to feed realistic, plausible information*/conditions* into the system which could come from heuristically detected states (e.g. the mentioned zero motion states, walk pattern detection for straight lines and past directions).

3) WLAN vs. Inertial Sensor based localization in a shopping application

As depicted in the previous paragraphs both positioning methods have their advantages and disadvantages. WLAN based positioning needs infrastructure installations. The cost of instrumenting the stores with APs and the creation of radio-maps have to be considered for each use case. Further a change regarding received signal characteristics requires an update to the radio-map.

Inertial measurement positioning does not require infrastructure installations. But of course every customer has to be equipped with inertial sensors, which is pricey summed over all customers. Fortunately, the technology is already built into smartphones, so many customers buy or have a usable "inertial measurement device" anyway while the retailer only has to provide positioning software and location context data to use it.

A current research project for a Swiss retailer has the goal to create a complete LBS software suite for location aware retail shopping. As the retailer does not yet have any WLAN infrastructure in its stores it is way too costly to equip all stores with the necessary localization hardware. Not to mention the fact that the layout of the stores is at least partly modified on a regular basis which would impose the company to update the radio-maps to retain the accuracy of the location service.

So the positioning technology for the LBS system of the retailer was chosen to be focused on inertial measurement sensors. From a cost and customer convenience standpoint the retailer wants the system to use the customer's smartphone both as a visualization and positioning device.

IV. The AIONAV LBS System

The LBS system software suite for the Swiss retailer builds on the foundation of the AIONAV system.

The AIONAV system is a multi-platform, modular positioning and visualization software. Up to now it was mainly used to help fulfill the duties of first responders and armed forces. The calculated positions of these deployed forces are visualized locally for their orientation purposes. Additionally the positions can be monitored remotely by wirelessly connected operation leaders. The positioning algorithms can combine/fuse different positioning technologies with emphasis on inertial measurements coming from wireless, foot mounted sensors.

Moving to smartphone hardware and focusing on LBS brings this technology to the consumer market.

Further, based on the above described common knowledge about LBS, and the drawn conclusions of presented concepts within the evaluated, available apps the AIONAV system were extended to the AIONAV LBS system. To find out about the most important requirements and components a user survey has been conducted.

A. Customer Survey

In the beginning of the project the Swiss retailer has conducted a customer survey with standardized questions in order to find out about the most desirable features of a future LBS smartphone app for the stores/malls. The survey asked active customers and likely app users about the three topics *efficiency*, *special offers* and *services*.

Efficiency: Important for most of the asked people in this topic was to *know the location of a product*. Second and still reasonable for some was to be efficiently *routed* to products of their own *shopping list* and finally to the cash register. Least important is an estimation of the shopping duration based on contents of the shopping list.

Special offers: Important for most of the asked people is information about *general special offers before entering* the store and a *routing* possibility to find these products. Nearly as desirable would be a reminder about *(personalized) offers*, when approaching these products inside the store. A minority would find it to be an interesting shopping experience, when they could explore some POI inside the store by following direction instructions and location/product based riddles of the app to win prizes/products if successful.

Services: Important for most of the asked people is information about the *shortest path* and a *routing* possibility to find *rest rooms*, *elevators* and *stairways*. Nice to have for most of the users would be a way to remember the *parking location* of the car and support to find that way back (*routing*). Some would find it convenient to *see their actual position* within the app accompanied by the *location of other shops*.

In the following we list some general *positive remarks* of customers asked about the shopping app matter, which have to be considered when designing an LBS shopping app:

- "Navigation would help to find the location of products after shop layout changes."
- "Private data security or privacy issues do not bother me, if at least no third party gets my data."
- "A navigation system would help me to find Fair Trade products."
- "I often forget where certain products are located."
- "Localization would be good if my child gets lost during shopping."
- "Navigation would help finding products faster."
- "A shortest route to the toilets would be good while shopping with children."
- "I would use it to find out about categories like stationary."

Some general *negative remarks* of customers asked about the shopping app matter are listed below and they have to be considered when designing an LBS shopping app:

- "Time constraints or stress during shopping is not as much of a problem as indicated."
- "Shopping malls in Switzerland are easy enough to not need a mobile navigation."
- "You rely more and more on your mobile phone and finally it will be too much."
- "Such a thing will just cut more jobs."
- "An estimated shopping time will produce even more stress."
- "With navigation I as a customer feel observed and analysed even more."
- "For me, shopping is an experience without time constraints."
- "Using only optimal routing to the products I want, will prevent discovering new products."

Based on the customer survey, three LBS shopping key features were identified:

The customer's mobile app has to…

- … describe the products and show their locations within a store. (Efficiency)
- … show special offers of the local store and guide/route the customer to them. (Special offers)
- … show the shortest route to rest rooms, elevators, stairways and other POI. (Service)

The LBS implementation has to comply with these key features.

An additional online customer surveys regarding map and position presentation with 100 participants at an age of 18 to 65 with smartphone experience showed, that finding a specific POI is easier with a logo presentation (70%) than with a pure text presentation (30%) of the POI. Icons are easier for orientation but could easily make the map look overloaded and all-text is straining to read. There is no difference how easy a POI would be found if logo and text both are unknown.

Further within a map with multiple color-areas delimiting different POI categories, it is easier to find specific products (66%) than with single color maps (34%). Connected color-areas indicate connected products better. Warm pastel color-areas are pleasant, but the color per se is not meaningful in order to know which category of POI it contains.

A further usability test with 10 participants at an age of 22 to 50 with smartphone experience showed, that a "my position" symbol on a map with POI helped all participants to know their position exactly. Without that indication 7 knew exactly where they were and 3 knew it only somehow.

An indication of a customer's viewing direction on the map helps people for orientation purposes who explicitly say that they are bad in reading maps. Good map readers do not need an indication of the viewing direction.

Visual aisles are only necessary if one wants to find a specific product within the store.

B. System Components for an LBS-Provider

The Swiss retailer wants to use the future LBS system within every store/mall. As most of the stores are not commonly layed out and offer locally different products on sale the LBS-managing part of the software has to be operated by many store- and mall-managers individually.

The required desktop applications therefore have to be easy to use, intuitive and user friendly. All system components operate on the same database. The administration desktop-software framework creates the content and a mobile customer part consumes it. Data has to be up-to-date and should be transferred to consumers in a practical way.

There has to be a way to import floor plans and shop layout drawings into the LBS system to build a multi-storey data context. The Swiss retailer's facility management already has technical drawings of all stores/malls. Additionally, it should be possible to import geo-referenced images (e.g. aerial images).

A specific LBS part of the software should allow for an efficient way to generate and manage different kinds of POI within the context of malls and stores. A structuring mechanism allows a categorization of POI.

As manual data input should be minimized an automatic synchronization with available product databases as well as aisle-layout planning tools is considered useful.

The software has to prepare the data context for routing possibilities suitable for shopping. Ideally a data configuration will be layed out like a consumer would see it on the mobile part of the software.

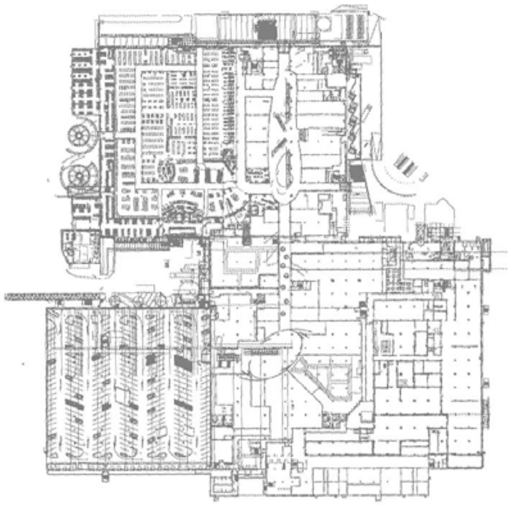

Figure 1 AIONAV Editor imports technical drawings e.g. from facility management

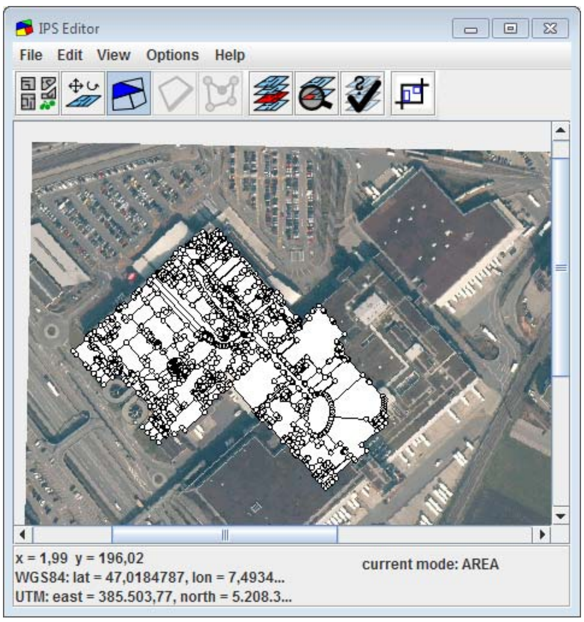

Figure 2 AIONAV Editor creates the AIONAV Building Information Model from images and drawings

1) Floor Plans and Maps Administration Software

To fulfill these requirements the *AIONAV Editor* software has the possibility to import aerial-images or drawings. For an LBS application these technical drawings certainly have to be simplified (see Figure 1). The *AIONAV Editor* allows outlining and geo-referencing the important parts of the buildings for an LBS usage quickly (see Figure 2). Prepared content is saved to a common database.

The resulting building model serves as a base for POI creation and indoor positioning. The building information model helps to improve the positioning accuracy of the mobile system with a building interaction approach. (see Figure 3)

2) LBS Administration Software

After drawings have been imported, simplified and saved to the AIONAV Building Information Model with *AIONAV Editor* the *AIONAV LBS Editor* uses them to build an LBS for the specific store/mall, called Scenario. (see Figure 4)

AIONAV LBS Editor implements functionality to *define, categorize and set POI* on the map. A POI is an area with arbitrary form (polygon) and dimensions. In the future a POI can be defined as *active* or *passive.* Active means the LBS smartphone app will bring the POI to the attention of the customer automatically when he enters the activation area of the POI. Passive POI in general as well as active ones without users close to them are just symbolically layed out within the map, without popping up to the customer's attention when he approaches them. This would be the mechanism for location based advertisements. *AIONAV LBS Editor* should be extended to allow the playback of defined scenarios to simulate how a smartphone app user would experience a situation within the defined location and set POI.

Further the *AIONAV LBS Editor* allows the definition of a 3-dimensional directed graph within the LBS context. This graph is used to allow the mobile customer software to enable the desired routing to POI. (see Figure 5)

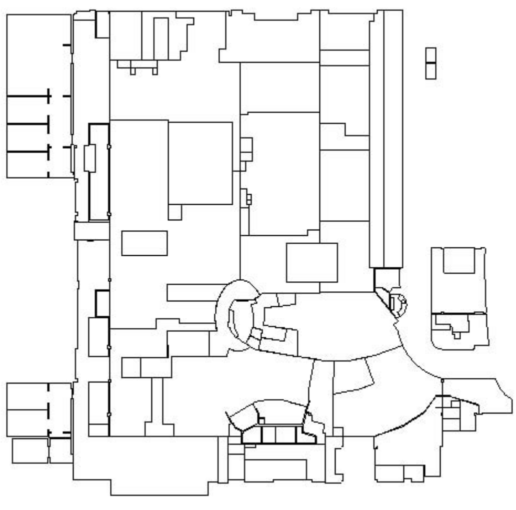

Figure 3 AIONAV Building Information Model

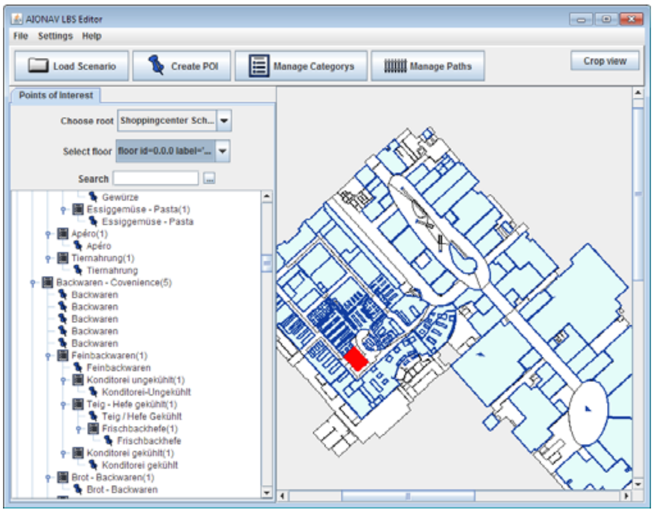

Figure 4 AIONAV LBS Manager enriches locations with POI and content

C. System Components for an LBS-Consumer

After an LBS scenario was created, smartphone users can use it with the LBS shopping smartphone app. POI are presented in a graphical map (see Figure 6), split map/text (see Figure 7), textual scrollable list (see Figure 9), category- and userlist-filtered, because different situations or user preferences demand for choice. In-current-context are colored areas, off-current-context POI are grey but still interactive.

1) Database

The data is shared between the administration part and the mobile part of the software framework by using the same database. A current database could be gathered at the entrance to a shopping center via – what we call - a data-hydrant. This is an abstract concept for data transmission with minimal user configuration/interaction needed. What is suitable depends on the specific application. NFC (RFID), QR-Code, Wi-Fi-Direct, Bluetooth and other technologies

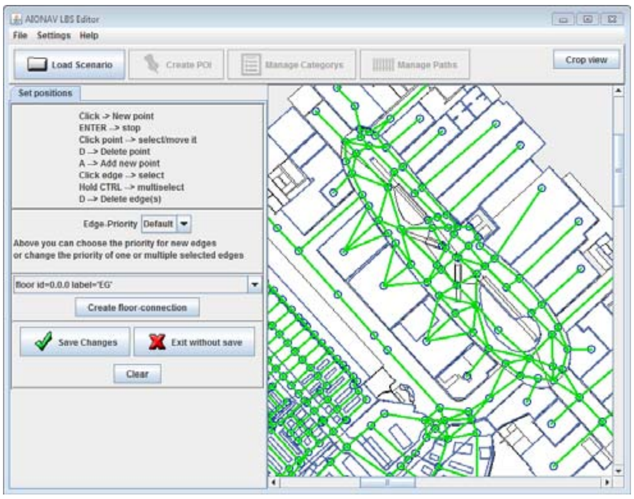

Figure 5 AIONAV LBS Manager defines a 3D directed routing graph

are useful to minimize user distractions to get the data download.

2) Location Service

Key differentiator of the developed app to currently available other smartphone retail shopping apps is the integration of the *customer's live position*. This feature alone significantly increases the usability and enables currently unseen/impossible location based services which are desirable for both – customers and store owners.

Knowing location enables store owners to advertise something only if the customer is nearby – so it is more likely that the customer reacts to a special offer and buys it. From a customer standpoint it is desirable to not get all 40 offers at once, but get them when needed. They have to be location- and user-filtered.

It has to be acknowledged that up to now, using only internal smartphone sensors was not a completely satisfying location determination for some test users, so the app for the Swiss retailer incorporates several positioning choices. One can choose to use different long term quite accurate foot mounted Bluetooth-connected sensors, long term quite inaccurate internal smartphone sensors, constantly quite inaccurate wireless network positions or - the most basic one – the user when setting his position manually.

Nevertheless, using only internal sensors for the calculation of a user's live position would still be the most preferable method and our research to improve accuracy is moving forward. Different sensors in competing smartphones are also one of the bigger problems with a general solution.

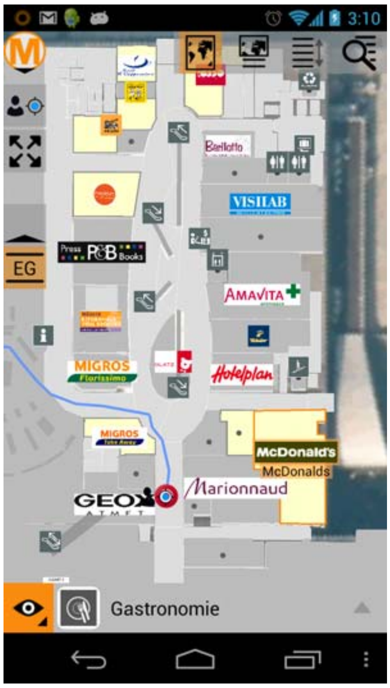

Figure 6 Full map user interface of the customer's location aware LBS shopping smartphone

Figure 7 Split map/text user interface of the customer's location aware LBS shopping smartphone

Figure 8 Optimal route between customer and several POI

3) 3-dimensional Routing

Routing to POI is realized with a directed 3D graph defining possible paths within the context. Edge-weights help to define preferred main paths.

It is possible to route to a single POI or all POI marked on a list in an – up to performance constraints - optimal manner. (see Figure 8 and Figure 9)

4) Multi-Categorized POI and Search

POI are structured by linking them to hierarchical categories – currently of type *Object-Of-Interest* and *Topology*, but can naturally be linked to any future context-useful category.

POI can be searched by keyword, by barcode, by QR-Code, by scrolling through lists or by location navigating through the maps overlaying multi-storey floor plans.

V. Conclusion and Future Work

This paper shows how a location based service smartphone application framework has to be layed out in general. It exposes the software components needed for user acceptance, to serve user-needs and maintenance of underlying data.

The stated approach is explained based on a current development of an LBS shopping system for a Swiss retailer. The developments within that project are stated in this paper and are based on LBS theory, conclusions drawn from currently available smartphone shopping applications and customer surveys conducted by the retailer.

The project was finished only recently and the result is a novel location aware retail shopping application with a smartphone based mobile customer part. The whole software framework was implemented

Figure 9 User generated list of POI

in a very generic way, so different LBS also in different application-contexts can be derived from the current infrastructure quickly.

Acknowledgment

The *AIONAV System* is a positioning system software suite now developed, maintained and commercialized by the Swiss based company *AIONAV Systems AG* (www.aionav.com).

The base of the AIONAV technology has been developed in various research projects at the *Institute* *for Building Informatics of Graz University of Technology*. Graz University of Technology has exclusively licensed these former technological results of the research projects to *AIONAV Systems AG.*

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