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A Smartphone Application for an Innovative User Supporting Location Based Shopping Experience

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***Abstract*—Online shopping has become a very competitive way to buy goods. Price and convenience are two strong reasons to buy online. Customers like to choose and evaluate products without time and location constraints. Conventional local stores can hardly keep up with online-prices and lack an objective comparison convenience, but provide another desireable shopping experience – personal communication and touching the products. But what if people visit local stores to choose and finally buy online because of better prices? To prevent this behaviour local stores have to find ways to outweigh the advantages of online shopping. Location based services (LBS) are able to generate that beneficial experience for the store and the customer. With LBS utilizing a customer's smartphone the desireable online-shopping advantages can be brought into the hands of local customers. This paper proposes an LBS smartphone application that customers want to use because they have significant shopping-advantages when doing so. Additionally, the same measures help store-owners to learn about their customers and increase sales. The proposal includes interesting ways of customized advertising, where customer's past shopping data helps to generate individual product sale offers per application usage. Combined with product location information further exciting ways to create a satisfying customer - store relationship will be shown. An obvious product search feature will be extended to location aware routing-applications. Different context adaptive shopping list features will be a key point why customers want to use the application. Actively used shopping lists build a base for a self-checkout functionality speeding up a customer's shopping and stores could reassign freed-up staff to improve the personal customer service even more. User controlled data sharing possibilities will help to manage collective (everyday) shopping demands of somehow connected customers.**

Keywords: LBS Software Suite, Smartphone, Shopping Experience, Inertial Sensor Positioning, Indoor Positioning

I. Introduction

Nowadays location based services (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 (because of signal shielding of [high] buildings and roof covered areas). An accuracy in the range of ±10 meters under optimal conditions (open, clear sky) limits the usage of GPS even outdoors (find house entry door; sidewalk left or right of street?) Therefore *indoor positioning* or in general – a positioning which needs a high spacial resolution (< 3m) has to rely on different technologies and is an open field of research with various approaches taken.

This paper tries to outline how a common smartphone could combine its *positioning* abilities, *computing* power and wireless *data access* to form a helpful LBS device for *indoor* usage. It discusses current technologies and shows essential components of an indoor LBS based on the approach for a *location based shopping smartphone application* currently in development for a Swiss Retailer.

A focus on the indoor application in this paper does not compromise the ability to extend the principles stated to outdoor usages. As nearly every smartphone already incorporates a GPS receiver, such an outdoor-extension could also easily 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 usage application of an indoor LBS app is for areas with a high density of different possible user-actions and/or -interest located within limited space next to each other. Typical areas are *shopping malls, museums* and alike.

LBS apps have to inform their users about things worth noting around the area they are located. Ideally, they help easen already present (location based) needs of users e.g. finding products, rooms 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 users 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 an 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 and 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 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 wanted to buy before they visited the mall or that are a reason for their visit. This category is the main topic for shopping malls and consists of *consumer products*. Additionally to known and wanted products, a user could develop an interest in products just while being in the mall. This behaviour could be triggered or influenced by sensing (seeing, smelling, tasting, hearing) products in a store or advertisement.

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 natural 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 behaviour 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 recipies 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. Technologies for Indoor LBS

A prerequisite for an “all possiblities” LBS is a *location service*. There are basically two 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 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 three dimensional space, the three local axes of the sensor rotate relative to a fixed global coordinate frame e.g. North-East-Down (NED). To determine in which NED direction a measured local acceleration (and finally resulting distance) points, local angular velocities measured by the gyroscopes constantly update a rotation matrix (i.e. the current sensor alignment), which is used to transform these local sensor measurements to global ones. Through this principle procedure an integration into global NED directions is possible and results in global NED 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 can not 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 “known” to be under *zero motion* in reality. Knowing when that state is reached can not 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 continous position drift.

In case the sensor is mounted to the user’s foot - which certainly has zero motion phases while walking - this 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 can 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 data to use it.

A current research project for a Swiss retailer has the goal to create a complete LBS software suite for location based 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 best suited for the LBS system of the retailer will be focused on inertial measurement sensors. From a cost and customer convenience standpoint the retailer wants the system to use the customer’s smartphone 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 will bring 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 can be 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

The Swiss retailer has conducted a customer survey with standardized questions in order to find out about the most desireable 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 an information about *general special offers before entering* the store and a *routing* possibility to find these products. Nearly as desireable 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 an 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."
- "A 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."

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

- "Time constraints or stress during shopping is not so 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 analyzed 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.

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.

1) Floor Plans and Maps Manager

There has to be a way to get floor plans and shop layout drawings into the LBS system. 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).

AIONAV Editor has the possibility to import such images or drawings. For an LBS application these technical drawings certainly have to be simplified. The *AIONAV Editor* allows to outline the important parts of the buildings for the LBS usage quickly. (see Fig. 1)

2) LBS Manager

After drawings have been imported and simplified with *AIONAV Editor* the *AIONAV LBS Manager* uses them to build an LBS for the specific store/mall, which is called *scenario*. (see Fig. 2)

AIONAV LBS Manager implements functionality to *define, categorize and set POI* on the map. A POI is an area with arbitrary form (polygon) and dimensions. Furthermore, a POI can be defined as *active* or *passive.* Active means the LBS smartphone app will bring the POI to the attention of the user 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 user's attention when he approaches them.

Furthermore, *AIONAV LBS Manager* allows the playback of defined scenarios to simulate how a smartphone app user would experience a situation within the defined location and set POI.

C. System Components for an LBS-Consumer

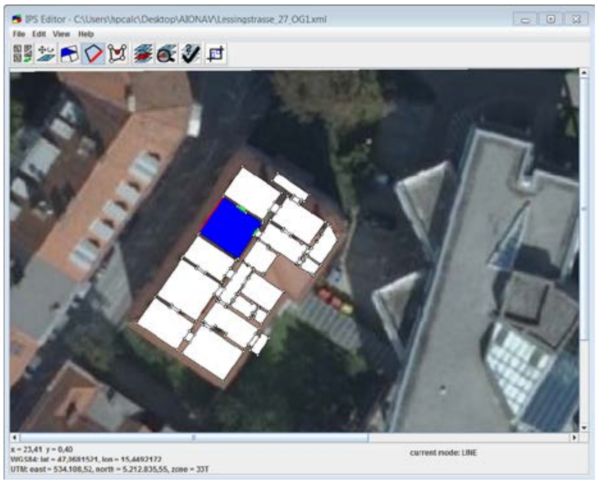

Figure 1. AIONAV Editor allows to import aerial images, technical drawings and simplify them

Figure 2. AIONAV LBS Manager enriches locations with POI and content

After an LBS scenario was created smartphone users can use it with the LBS shopping smartphone app. This part of the project for the Swiss retailer is currently in design stage. A mock up of that app can be seen in Fig. 3.

Key differentiator to discussed, currently available smartphone shopping apps will be the integration of the *user's live position*. This feature alone will significantly increase the useability and enable currently unseen/impossible location based services which are desireable for both – customers and store owners.

V. Conclusion and Future Work

This paper shows how a location based service smartphone application 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 a customer survey conducted by the retailer.

The project will be finished next year and the result will be a novel *LBS shopping application with a smartphone based, inertial positioned, mobile customer part.*

Figure 3. User interface mock-up for a live positioning enabled LBS shopping smartphone app currently under development.

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