Exploring the Usage of an Electronic Compass for Human Navigation in Extreme Environments

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ABSTRACT

In this paper we present novel concepts for using the compass to allow navigation of humans in two "extreme" environments. First, we present a prototype that allows indoor navigation without additional infrastructure. In a second scenario we focus on how compass deviation can be used to allow positioning in the vertical domain to design a location-based service (LBS) for climbers. Both scenarios look very contrary, but have in common, that in both environments the disadvantages of the Global Positing System (GPS) does not allow supporting users with location information. GPS cannot be used indoors (in most cases) and the position in z-direction (i.e. height) is very inaccurate, which is crucial for the climbing scenarios. To overcome these disadvantages we propose to use an electronic compass in both scenarios.

1. INTRODUCTION & MOTIVATION

Today's mobile devices easily outperform the desktop computers of even a few years ago. The ongoing miniaturization trend allows us to carry devices with us in situations formerly hostile to technology. While this is certainly true in our daily lives and for indoor environments, it is more and more common to even bring mobile devices to the outdoors, e.g. while hiking or climbing in the mountains. In our daily life's mobile devices assists us in various task. They help to manage or schedule, provide us access to the Internet or allow (in most cases) GPS based navigation. But often in "extreme situations" the assistance of the mobile device is still limited. In this paper we want to highlight two different scenarios that induce navigation problems due to disadvantageous properties of GPS, namely the fact that GPS signals cannot (in normal cases) be received indoors and that the z-positing (i.e. height information) of GPS is very inaccurate compared to the x,y- accuracy (i.e. latitude and longitude). We will explore how the usage of an electronic compass (in combination with other information) can help to overcome these problems in the following two scenarios described above:

- Indoor navigation scenario: GPS signals cannot (normally) be received for determining the position indoors. We introduce an approach, in which we make use of pictures of indoor "You-Are-Here" maps of an indoor environment. For determining the position of the user, we use built-in cell-phone sensors like the accelerometer sensor as well as compass data and compass deviation for a dead reckoning approach. The described approach does not require any further infrastructure.
- Climbing LBS scenario: In the second scenario we present a first concept in which we highlight how climbers can be guided through an alpine climbing route by exploiting compass deviation. This has also a lot of potential for non non-visual interaction.

The paper is structured as follows: In section two, we introduce related work in the area of location-based applications for the indoor as well as the climbing scenario. Section three describes the general concepts of the indoor scenario as well as the climbing scenario. The implementation of our reference system for the indoor navigation is covered in section four. We conclude this paper with a description of future work in section five.

2. RELATED WORK

In the field of indoor localization and navigation a lot of research has been conducted which underlines the fact that location is one of the most important context information needed for ubiquitous computing scenarios. First systems like the BAT- [1] and its predecessor the Active Badge-System [13] were able to determine the position of the user by establishing a large infrastructure of ultra sonic beacons across the building. Bahl et al. implemented with RADAR [2] a location service exploiting the information from an already existing RF data network. The combination of ultra sonic and RF beacons to eliminate the negative

Figure 1: Left: An example of an indoor "You-Are-Here"-map (This photo was taken at the -removed for blind review-). Right: Position visualization on an iPhone on the basis of the You-Are-Here-map using our compass dead reckoning approach.

side effect that each of these techniques has, was proposed by Priyantha et al. with Cricket [9]. Besides these radio and ultra sonic based methods many different approaches utilize a wide variety of sensors. Mulloni et al. used the built-in camera of modern mobile devices to recognize visual markers distributed in the environment [7]. The system called Signpost allows the user to look up the position encoded in the marker. Often accelerometers or gyroscopes have been employed for indoor navigation. For example Woodman et al. [14] achieved a location accuracy of 0.73m in 95% of the time by combining a foot-mounted inertial unit, an accurate model of the building and a particle filter. In most approaches where dead reckoning is used to mark the position, every once in a while correction is needed to reduce the error accumulation. Therefore most of these approaches use data from external sources, for example pre-deployed RFID tags [8].

2.1 Infrastructure less Indoor Navigation

The idea of taking a picture of a YAH-Map ("You-Are-Here"-map) to use for navigation was introduced by Schöning et al. with PhotoMap [11] using GPS for outdoor navigation. In [10], the authors present a Bayesian estimation approach for simultaneous mapping and localization for pedestrians in constrained areas such as buildings. Their approach is based on pedometry with foot mounted inertial sensors. With the collected sensor data, a 2D map of the building can be derived that can be combined with derived maps of other users. The disadvantage of this approach is that the generated map are not appropriate or detailed enough in most cases since they only provide the footprint of the building.

2.2 LBS for Climbers & Hikers

There are some existing location-based applications, like the "Alps Ranger"" [3] and the "Paramount system" [4, 5] that make wilderness experiences safer. These GPS-based LBS run on a PDA, lead hikers through the mountains and can also help rescue teams to locate a stranded hiker. Schöning et al. propose with [12] a conceptual design for a LBS for climbers.

3. CONCEPTS

First we present our concepts for an infrastructure free indoor navigation system followed by the concept for an outdoor navigation system for climbers. Both concepts use the built-in compass of a cell-phone for the determination of the users current position.

Since our indoor application is designed to be as flexible and generic as possible, we relinquish to rely on an additional infrastructure like Wifi- or Bluetooth-cells. For the indoor navigation only the built-in accelerometer (used as a pedometer) of the mobile device is used. Together with the compass of the device, the pedometer enables dead reckoning, where the current position estimation is based upon a previously determined position. To make the picture of the indoor map usable for navigation, a reference-sequence is needed to adopt it to the users physiognomy (i.e. the length of legs and size of foot). Our approach does not estimate a step length, it simply embraces that you keep the same step length most of the time. Our referencing approaches are adoptions of the "Two Point Referencing" of PhotoMap [11]. Instead of assigning WGS84 coordinate offsets to the pixels we use steps done by the user as the unit. We propose the following two methods for referencing which only differ in the number of points one has to mark and walk to. During our first real world tests we discovered that public indoor maps exist that are not true to scale and somehow stretched or compressed in either x- or y-direction. This is different to the set of outdoor maps presented by Schöning et al. in [11]. However the Scale-True-Referencing is just suited for maps that are scale true because the pixel/step calculation is done with just one vector regardless its orientation and for maps that are stretched or compressed in one component a different technique is needed. Therefore we propose the second technique that takes such deformations into account and determines a scale for each, x- and y-direction. In the Scale-True Referencing, after the user has taken the picture of the map he marks the YAH-dot on the map to determine the actual position. After that he walks up to a second position in the building that he can identify and mark in the image as well. The bearing of the second point should be in a straight line with the first point and the user should walk up to it as precisely as possible. While walking the number of steps and the orientation of the compass is recorded. The vector defined by the two marked positions ξ is then used to determine the up orientation of the image by calculating the angle between the ξ and (0,1), and adding it to the average compass angle recorded during the walking phase. Furthermore the scale of the image is identified by dividing the length of ξ (in pixels) by the number of steps counted during the walking phase. Since scale and orientation of the image are known, dead reckoning can be used with the second point as the start. In the Deform-Referencing, just like in the Scale-True Referencing, the user has to mark the YAH-dot on the map and then he can decide whether to calibrate first the x- or y-direction. After having determined which direction should be calibrated first he has to walk in the according direction and then mark a second point that is only shifted in the chosen direction. The same sequence needs to be done for the other direction as well so that a scale for each direction can be determined. During the two walking phases the compass directions are recorded as well and the average angle of both phases is used to determine the up vector which leads to higher accuracy adapted to the two scales.

While in the first scenario we try to overcome the disadvantages of GPS that is not usable indoors with a visual interface, we describe in the next section how we can use the compass and exploit a compass deviation to assist climbers while climbing a route. This scenario also offers good potential for non-visual interaction, which is not in the focus of this scenario.

For climbing, so called "climbing topo maps" are often used (see Figure 2). A "topo" is a guide for a crag or climbing area. It contains details on the grade of each of the climbs. It includes the lengths of the climbs and most importantly it usually specifies which gear has to be used. These maps are often highly abstract and thus difficult to understand. It is not uncommon that climbers get lost during longer climbing routes (so called multi-pitch climbs). Leaving the intended route can lead to dangerous situations, i.e. if the climber enters unknown terrain[1]

For the climbing navigation only the built-in compass of the mobile device is used together with the magnetic bolts in the climbing route. Current bolts are mostly iron and can be easily turned magnetic. To make an iron bolt into a magnet one need to get a bar magnet and stroke the iron one way when one get to the end of iron take the magnet off and jump it back to the start and stroke repeat this several times and the bolt will become magnetic. Of course this process is not ideal, but could help to allow first test.

The bolts are used to deviate the compass. When the bolts are used in combination with the compass of the mobile phone, the compass is deviated towards the magnetic bolts. Instead of pointing to north, the compass points in the direction of the nearest magnetic bolt. In the simplest scenario the user is directed to the next bolt in the climbing route. Having more knowledge about the route, the climber can avoid getting dangerous situations by leaving the intended route as we illustrated in figure 3.

This scenario was inspired by first test we did with our indoor navigation prototype. We experienced compass deviation when passing for example a photocopier. While we already have an implementation for the indoor scenario, the implementation for the climbing scenario is still under development. In the following we describe two reference implementation for our indoor navigation approach.

4. IMPLEMENTATION

As platforms, we chose the Apple iPhone OS (iPhone 3Gs) and the Android OS (HTC Hero and Samsung Galaxy I7500). All three phones have a built-in accelerometer as well as a compass. These are necessary for the dead reckoning approach that is used to mark the users position in both scenarios. The algorithm that we applied to detect the steps utilizing the accelerometer is based on the approach of Mladenov et al. [6]. We ported it to the particular platform and we were able to recreate the accurateness presented in [6]. In

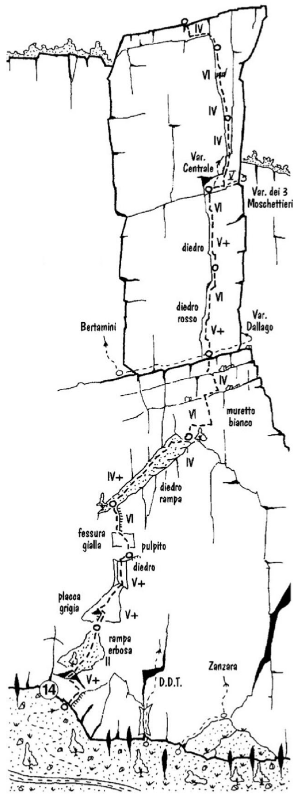

Figure 2: An example of a topo map for climbing. Source: ARCO - ALP cartoguide

our initial real world tests we observed an imprecision of the built-in electronic compass of the Android OS powered phones. Most of the time the inaccuracy of the compass was more than 25 degrees compared to a standard magnetic compass. This error exists on both, the HTC Hero and the Samsung Galaxy. Additionally, the northing of the compass often is shifted to different extends but this shift keeps normally steady during the usage. Since our approach does not rely on a given up-vector of the map but determines this vector itself, the shift of the northing can be neglected. However the compass of the iPhone 3Gs we used was very steady and reliable and significantly less errors were observed. Because of this the Deform-Referencing method was only implemented for the iPhone prototype. As an additional aid for orientation and navigation, the iPhone application allows an optional walking direction oriented rotation of the image of the map. Due to the inaccuracy of the accelerometer-based pedometer and the electronic compass the calculated position drifts with every position update further away from the actual position. Therefore the actual position can also be reseted by the user. Every once in a while when one can identify his own actual position on the map, for example by comparing room numbers in the environment with these shown on the map, the user can point on the position and for the ongoing navigation this position is used.

[1] Although, some might argue that this is part of the climbing experience.

Figure 3: The smart harness - the harness provides information on the climbing partner

5. CONCLUSION & FUTURE WORK

In this paper we have briefly explored two navigation scenarios, which utilizes wearable electronic compasses in extreme environments. One for the case of indoor navigation, where we used an indoor YAH-map to initiate the dead-reckoning process for navigation and a second where magnetized bolts have been used to deviate an electronic compass to guide a climber through a route. Both approaches have in common that they do not rely on an extensive infrastructure, though in both cases landmarks are needed. In the indoor scenario, these landmarks have to be identified by the user on the YAH-map and in the climbing scenario the bolts are used as landmarks. Our first tests have encouraged us to continue in our research, though many questions are still open. We still cannot quantize the localization error and thus have no clear picture yet how useful our approaches will be in practice. We plan to carry out empirical tests in both domains to explore this further. Another important issue regards the role of additional information. In the indoor scenario additional information in usable calibration points in a building could be collected and shared by the users, making it easier to cold-start the system, when entering an unknown building. Something similar accounts for the climbing scenario: it could be interesting to allow climbers to leave a magnetic trace (by either magnetizing the bolts or by placing small magnets throughout the route) and reference these magnetic landmarks in an electronic version of the topo. Subsequent climbers could then directly make use of these traces. Also, in both scenarios it still needs to be investigated which influence the placement of the device on the body has, either on the usability or on the efficiency of the proposed approaches. For first test we use visual interfaces but we plan, with the input of this workshop, to improve the navigation with multi-modal clues. We think that the climbing scenario has lots of potential for multi-modal interfaces.

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