Autonomous Navigation based on Binaural Guidance for People with Visual Impairment

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Abstract. This work addresses the challenge of designing an effective, reliable and affordable navigation system for blind and visually impaired people (BVIP). Our contribution focuses essentially on the integration of accurate real-time user positioning data with binaural 3D audio based guiding techniques on mobile devices. The purpose is to produce a binaural navigation system that can be used to guide BVIP along pre-defined tracks. A preliminary prototype of this concept has been built and tested with 4 expert users obtaining encouraging results.

Keywords. Blind navigation, binaural audio, Global Navigation Satellite System (GNSS), Inertial Navigation System (INS), assistive technology.

Introduction

The population of blind and visually impaired (BVIP) in Europe is estimated over 30 million. On average, 1 in 30 Europeans experience sight loss. Furthermore, sight loss is closely related to old age in Europe, where age-related eye conditions are its most common cause, resulting in that 1 in 3 senior citizens over 65 experience it. [1].

Being able to navigate autonomously is one of the most relevant needs for BVIP. Research on autonomous navigation systems which uses spatialized audio (also known as binaural audio) information [2] for guiding BVIP has been carried out since 1985 [3]. Recently, evidence has been established that, when guiding BVIP through different routes, spatialised audio instructions are faster to interpret, more accurate and more reliable when compared to instructions given in natural language . Also spatialised audio perception is less affected by increased cognitive load on users than language information [4].

In parallel, relevant progress is being carried out regarding satellite positioning technology and currently the European Geostationary Navigation Overlay Service

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(EGNOS), which is essentially Europe's precursor to the GALILEO system, is currently providing a terrestrial commercial data service named EDAS (EGNOS Data Access Service). It offers GPS data correction for providing increased positioning accuracy and integrity [5].

Finally, significant industrial activity has been carried out in order to provide useful navigation support systems for BVIP. It's worth noticing that eAdept [6,7] has succeeded in validating a complete navigation support platform in the city of Stockholm. Besides, commercial products like the Kapten Mobility by Kapsys [8], BrailleNote GPS by Sendero Group [9], and Trekker by VisuAide [10] have successfully reached the market. Nevertheless, these initiatives are still based on instructions given in natural language, which reduces their potential from our understanding.

1. The ARGUS guiding concept

Taking into account previous findings, ARGUS FP7 project [11] aims to implement and validate the binaural guiding concept, which integrates both binaural sounds and precise user positioning technologies on mobile devices, resulting in a binaural navigation system that can be used to safely guide BVIP along pre-defined tracks.

Figure 1 illustrates from a broad perspective the ARGUS guiding concept. The GPS signals are corrected with EDAS data through an external positioning unit for obtaining accurate user position. Additionally, an Inertial Navigation System (INS) is used by the positioning unit in order to obtain user's heading. Later, the positioning unit transfers user position and heading in real time to the Smartphone using a wireless communication protocol. Then, the smartphone uses a navigation algorithm that compares the actual user position and heading to the defined track, and finally the binaural guiding system emits binaural audio cues to the user through dedicated open headsets.

Figure 1. ARGUS binaural guiding concept.

2. Prototype

A preliminary prototype has been developed to test the ARGUS binaural guiding concept. Table 1 summarizes the main technical features of the prototype.

Table 1. Technical specifications of the implemented prototype to test the ARGUS guiding concept.

#	Technical specifications	Details
1	Real-time positioning using GPS and EDAS	Accuracy of 2 to 3 meters, at 1 Hz.
2	Mobile device's magnetometer is used for obtaining heading information.	Output frequency of 1 Hz. Loosely coupled data fusion between heading and positioning measurements.
3	A point navigation strategy has been implemented in the navigation module which provides the bearing to next waypoint.	Waypoints reached within a given radius will be marked as visited.
4	Acoustic module which provides guiding binaural sounds has been implemented.	Different 3D sounds are available to accommodate to users' preferences.
6	Android application which integrates the developed binaural guiding concept.	Core of the application developed in C++ to maximize cross-platform portability.
7	Open headphones have been integrated.	A wide offer of headphones is available to meet users' preferences on comfort and safety.

3. User tests

Small scale user tests have been carried out in order to assess the performance of the preliminary prototype and gather initial users' opinions about the system. In order to minimize the positioning errors, the tests have been conducted in an open environment scenario. Table 2 summarizes the main specifications of these tests.

Table 2. Specifications of the user tests carried out to assess the prototype.

#	Protocol	Comments
1	User tests took place in September 2012, in Paderborn (Germany).	The testing site was a public meadow at the south of the Airfield Paderborn-Haxterberg.
2	Two blind and two partially sighted people were recruited.	All of them were volunteer experts on navigation and assistive technologies.
3	The users were guided by the ARGUS preliminary prototype on a route composed of 4 waypoints.	Distance among waypoints was 40 metres on average. There was no time restriction. Users were asked to perform the same route twice.
4	The task was considered as successful whenever the user reached all 4 waypoints.	Waypoints had to be reached within the radius of 2 meters around them.
5	3 users received 5 min training on binaural guiding before the tests.	The fourth user did the training after the first navigational task.
6	User positions and headings were logged for off-line processing.	Users wore two different GPS devices and a third device was fixed to floor for further off-line positioning data comparison and error analysis.
7	All users were interviewed after each navigation task.	A short questionnaire was used also during the open interview.
8	User tests were video recorded.	Users signed an informed consent document.

Figure 2. Photographs of the user tests.

4. Results

4.1. Analysis of users' feedback

The main test parameters that were examined, including acceptance, ease of use, reliability, accuracy, non-disturbance of the general hearing as well as the wearing comfort led to very satisfying results. All involved users outlined that the test with the prototype was a very good indicator for getting a first impression on how the binaural guiding principle works in real life scenarios. Besides, users pointed out several requirements that the prototype should meet before mainstreaming the technology. Among the suggested improvements were: the need of training before using the system in real navigational tasks, providing more personalization options in order to better adapt to personal preferences and enhancing safety by increasing frequency of binaural sound cues when user deviates from the main track.

In addition, a demonstrative video[2] has been produced for dissemination activities.

4.2. Analysis of users' tracks

Although diverse tracks with different shapes have been obtained, in general it has been observed that all users completed the routes, reaching all marked track points. It is worth noticing that 7 out of 9 tests have an average distance error below 5 meters to the ideal track in the four waypoint sections of the proposed route. However, some of the tracks have significant deviations from the predefined track that were conditioned on one hand, by the technical limitations of the prototype, and on the other hand by the user's perception and reaction.

In order to increase the performance of the system several improvements are needed, like the implementation of a track navigation strategy, the tight

[2] http://youtu.be/6qyrZbbeB4g

synchronization of both positioning (GPS+EDAS) and heading (IMU) measurements, the implementation of 3 frequency positioning receiver to enhance positioning accuracy and the integrity testing of positioning signals for a better reliability of the system.

5. Conclusion and planned activities

The ARGUS binaural guidance concept for the autonomous navigation of blind and partially sighted people has been successfully implemented and validated with a small sample of expert users.

Users reported very satisfying feedback regarding acceptance, ease of use, reliability, non-disturbance of ambient hearing as well as comfort. Additional features to enhance training provision, personalization and safety were also requested.

A subsequent analysis of the tracks performed during the tests showed that a more accurate and robust solution has to be provided in order to maximise system's performance.

Finally, the outcomes of these tests are very encouraging, and currently the ARGUS partners are implementing an updated prototype and are designing new user tests with a wider sample of users planned for the first quarter of 2014.

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