ARGUS: Assisting peRsonal GUidance System for people with visual impairment

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Abstract: Visually disabled people have striking needs for trustful navigation systems enabling for efficient mobility services, mainly considering safety and autonomy. In this context, satellite-positioning and navigation technologies are being implemented deriving into innovative personal navigation devices. Existing products and solutions based on GNSS (Global Navigation Satellite Systems) do not meet all of the needs of this collective and fail because they lack accuracy and intergrity; they do not provide a suitable and efficient man machine interface adjusted to this user segment, or rely on costly infrastructure.

ARGUS project focuses onto a satellite based navigation (GNSS/EDAS – EGNOS Data Access System) terminal for people with impaired visually capabilities, guiding them along pre-defined tracks using specifically designed HMI (Human Machine Interface) based on binaural sounds guiding.

Keywords: GNSS/EDAS, AUGMENTED ACOUSTIC REALITY, VISUALLY IMPAIRED PEOPLE, GUIDING

Introduction

Almost 300 million people in the world are visually impaired. About 90% of the world's visually impaired live in developing countries, and about 65 % are aged 50 and older, With an increasing elderly population in many countries, more people will be at risk of age-related visual impairment [1]. The global response to prevention of blindness have had specific results in areas of progress over the last 20 years. Despite the technology state of the art many questions remain open concerning autonomous navigation, acuracy and integrity.

The ARGUS project [2] aims to develop a personal navigation solution based on the

integration of acoustic binaural technologies (i.e. 3D sounds) and GNSS technologies that can guide people along a predefined track.

It introduces the opportunity to develop an innovative guidance support system for visually impaired people based on the provision of a virtual-lead-line perception to the end user that can be perceived and followed. This will provide "track navigation" instead of the classical "waypoint or route navigation" which is used for car navigation or people with all visual capabilities.

This system will be also usable for professional, scientific and sportive activities developed in reduced visibility scenarios that could require accurate guidance on normal or emergency situations, as well as for other people working in reduced visibility environments needing guidance and assistance.

Main objectives of ARGUS project

The challenge that ARGUS project aims to meet is the integration of advanced user interfaces based on generated acoustic and haptic signals, with minimal interference on the perception and operation by users, so that they can move around autonomously based on a three-dimensional mental map of the path to follow and the key features of the surrounding environment. Binaural sounds create the illusion that sounds produced by stereo headphones come from specific directions and distances, based on the interaural differences (arrival time and amplitude between the ears). This allows users perceiving 3D sound positioning which gives them the sense of 3D navigarion. The route can be selected over previously recorded tracks (natural routes: no multilayer cartography available) or selecting origin and destiny (city or urban scenarios, multilayer cartography available). This route is a continuous geolocated points in 2D, therefore this geographical map has to be translated into a binaural sound map.

In addition to this main goal of ARGUS project, some other specific objectives are considered to support visually impaired people in their quotidian mobility :

- To build up a commercial navigation product for visually impaired people which guides them with acoustic binaural signals along a secure, pre-defined track. The positioning component uses satellite based positioning.
- To develop acoustic signals for providing a non-visual track perception and mental map of the path, and supporting the guidance of visually impaired people along a pre-defined track.
- To develop an application for authorised third parties. With the application software, stored pre-defined tracks can be transmitted to the user terminal on demand. Furthermore, the application software uses the positioning information from the user terminal to compute protection levels and re-transmit alerts in case of emergency (e.g. degraded positioning accuracy, etc.).

- Provide updated data through public web services sharing information collected by ARGUS users with other ARGUS users or with general public.

Binaural sounds system

Throughout history, multiple solutions have been designed to help in guiding blind or visually impaired people, based on different technologies. Speech based techniques, as well as more sophisticated devices based on handheld haptic display using verbal and non-verbal communication technologies for visually impaired pedestrians have been developed and compared. However, the ARGUS project will focus on a specific audio-haptic signal, which is binaural audio technology, providing spatial information through three dimensional sound perception [3].

The word binaural means "both or two ears". Human audition is in most of the cases binaural and this term is used to refere anything concerning two ears. To understand what binaural hearing is, it is necessary to understand how sounds are differntely perceived by our ears. The sound waves with their directionality and their amplitude make our ear/brain system locate sounds using our two ears.

This route can be selected over previously recorded tracks (natural routes: no multilayer cartography available) or selecting origin and destiny (city or urban scenarios, multilayer cartography available). This route is based on series of continuous geolocated points in 2D, therefore this geographical map has to be translated into a sound map (binaural map).

Binaural maps have been defined with the funcionality of converting the geographical track points into spatial acoustic cues, so that the right sound is generated in all of the environments where ARGUS will be used.

Two different strategies are considered for the generation of these 3D sounds:

- Predefined Binaural Map: a set of binaural cue sound will be used for getting the binaural cue sounds used. In order to do this each representative point of the track will be associated with a predefined binaural cue sound depending on the final geometrical arrangement and binaural cue sounds distribution.
- Synthesized Binaural Map: each binaural cue sound of the binaural cue sound sequence will be produced by a binaural sound synthesizer, which will process the binaural sound associated with the representative track point based on the cue sound source and the relative position and orientation between the user and the track point.

Both strategies will be compared and users' feedback analysed to select the right way to generate the 3D sounds.

Development of the device

As it has been stated, the technical success of the project hinges on the capability to connect and map tracks or corridors with GNSS real time location and map the guidance into 3D sounds. Therefore, with the aim to test the technical feasibility of this concept in an early

project stage an alpha prototype and a preliminary proof of concept have been conducted to have appropriate feedback for an iterative refinement loop of the prototype at the ARGUS project. It was concluded that different integrated components and are able to guide users along a predefined track in an interurban scenario.

Based on these results, the consortium follows with the implementation of each module and the integration of the first ARGUS prototype.

The ARGUS system will be compound by the next elements:

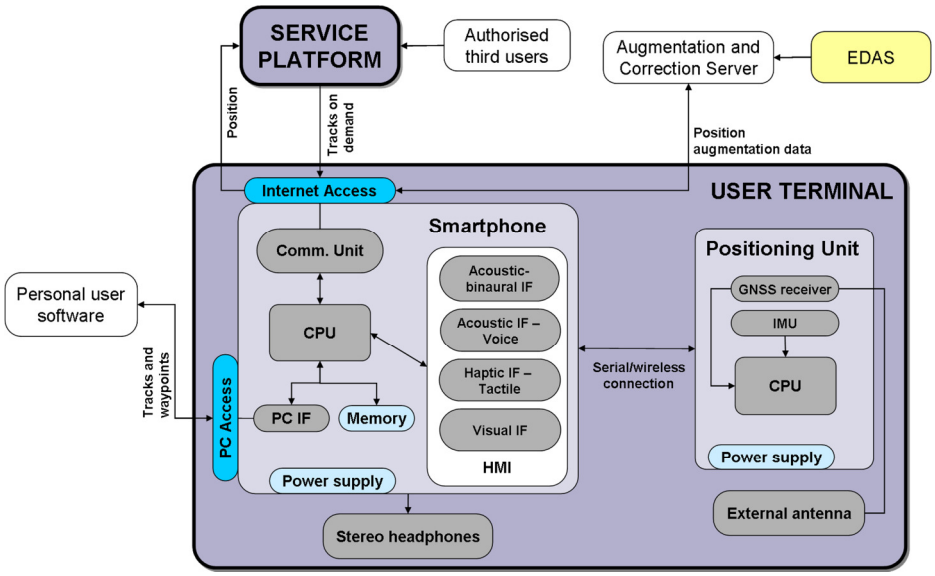

Figure 1 Architecture of ARGUS system

User Terminal

Following a user centered design policy, and in order to check that the initial assumed user requirements were correct, a survey was conducted using a questionnaire which could be answered either in a face-to-face interview or online. A total of 82 replies coming from Spain, UK, Germany, Italy and Austria helped defining the system specifications and developing user terminal. One of the main results of this survey was that users prefer to use their smartphones as guidance device, so this is the core of the ARGUS user terminal. A separate localization and navigation module has been developed since current smartphones do not support the position accuracy and integrity required in ARGUS. This module has to be fixed to the user's body while navigating through the route. With this module, the ARGUS project primarily retrieves benefits from satellite navigation services and technologies to increase the level of positioning accuracy and reliability as well as the level of service availability.

Applications, which provide a binaural insight of the surrounding environment for guidance purposes in different conditions, need important information about the user's position and orientation. The determination of these quantities is ensured by coupling GNSS measurements and measurements provided by an Inertial Measurement Unit (IMU). To reach a high accuracy of the position, the GNSS observations are corrected. Therefore, an augmentation

and correction server was developed to access EGNOS (European Geostationary Overlay Service) information through EDAS (EGNOS Data Access Service).

Finally, the guidance system has the functionality of generating the binaural sounds reproduced in the Smartphone. The first step is to generate the coordinates of the next track points set and these will be the basis for the generation of the binaural sound.

Service Platform

It corresponds to the assistance and service platform based on a client-server architecture which will offer services all along the three travel stages; before (planning), during (visiting destination) and after (remembering and sharing experiences), in order to:

- Prepare their itinerary at home, taking into account specific scoring processes enabling the integration of route safety in the itinerary calculation.
- Manage their itinerary in real-time, with an accurate positioning.
- Share experiences with other users, improve the system and enrich the locations database with personal comments and points of interest (POI), trough the community website (social network).

For routing calculation, GIS (Geoinformation system) information is required. The basic route calculation needs the topology of a network to generate a path, extracted from the different "way" type tags and attributes given by cartographic sources. OpenStreetMap is decided to be the basic geographic data source for the project as it is open data that has been created and is being maintained by its community. It is free to download, it contains a great variety of attributes and it is kept up-to-date in a satisfying way. The city GIS database clearly depends on the availability of specific geodatabase of the municipality one takes into account. Some public administrations are making big efforts in the generation of highly-detailed mapping and offering the information via open data initiatives.

The route calculation is one of the main ARGUS features. In order to generate the route from the origin to the destination, two options are available: pre-recorded tracks that can be used and a routing algorithm that calculates the best path to reach the destination from the origin point.

Pre-recorded tracks can be natural routes which are available in the multilayer cartography, or those previously generated by other users of the ARGUS system and published on the social network thus the community can make use of them. When the routing algorithm is applied, the optimal route is calculated taking into account the restrictions or preferences saved in the personal profile of the user. Not only personal addresses but also particular dangerous or conflicting points as well as specially well-signed points can be stored and considered when calculating the route. In this sense, routes are adapted to special restrictions of people with visual impairments.

Furthermore, routes can be supplied with a surrounding protection zone through the web-based application. The GEOCorridor® function enables additional route supervision by

providing the possibility to define a safety zone around the given route. An alarm is generated if the user leaves the safety zone marked by the GEOCorridor® function.

Preliminary Tests and workshops

A preliminary functional prototype with basic functionalities and using beta developments has been carried out. Thanks to it, preliminary proof of concept has been conducted in Paderborn (Germany) in September 2012 with the aim of test the technical feasibility of ARGUS main concept: the capability to connect tracks with GNSS real time location and match the guidance into 3D sounds. Four expert users with different visual impairments have participated in these tests to technically assess the concept giving out very encouraging outcomes. All of them successfully accomplished assigned navigation tasks and low deviations from control points were achieved (see Figure 2). Only five minutes training on users was required to obtain good performance with the ARGUS system. 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.

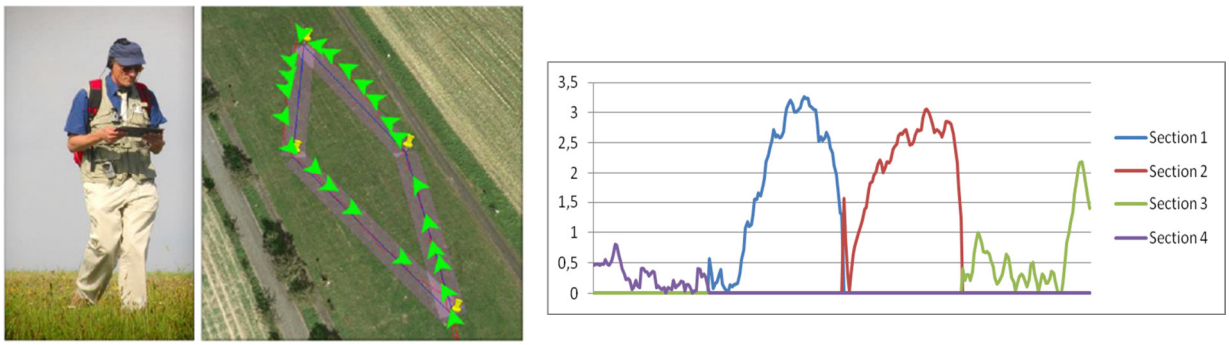

Figure 2: Proof of Concept tests

It is remarkable that seven out of nine tests have an average distance error of below five meters to the ideal track in the four waypoint sections of the proposed route (see Figure 3) However, some of the tracks have significant deviations from the pre-defined track that are related, on one hand, to the technical limitations of the prototype and, on the other hand, to the user's perception and reaction.

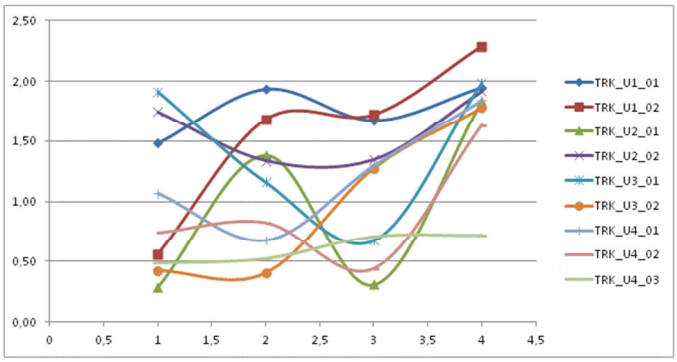

Figure 3: Waypoints pass distance evaluation from the different tests

In order to increase the performance of the system, several improvements are needed, such as the implementation of a track navigation strategy, the tight synchronization of both positioning (GNSS + EDAS) and heading (IMU) measurements, the implementation of a three-frequency positioning receiver and the testing of the integrity of the positioning signals in order to increase the reliability of the system.

On the other hand, some workshops took place; the last one in October 2012 in the facilities of Siemens, to which a group of 28 visual impaired and blind people attended. The tests emphasized that the idea is well accepted and the current state of the implementation is on track, following the right way to fit the user's needs. Most of the participants stated that they would be interested in buying the ARGUS solution.

Conclusions

The ARGUS system provides an acoustic track perception based on the integration of an augmented acoustic reality application developed for a smartphone and an accurate and reliable navigation solution based on the use of GPS signals augmented with EGNOS. The system accurately identifies the position and orientation of the user and, using binaural sounds, provides an innovative acoustic guidance solution for 'track navigation' instead the classical 'waypoint' or 'route navigation'. It effectively provides a virtual guidance rope for blind and partially sighted people or for people working in environments with low visibility.

Preliminary tests with end users were totally encouraging showing that selected headphones allow users to hear ambient sounds without missing the direction from where they are coming and the guidance sound is not interfering by the ambient sounds. It was concluded that the navigation itself was very easy to follow and precise. The GPS signal communicated via the binaural sounds is steady and keeps the users straight on the path to follow. The system significantly reduces the required mobility training of people with visual impairments since they can walk unfamiliar routes alone, even for the first time. The localization signal communicated via the binaural sounds is steady and keeps the users straight on the path to follow. The system significantly reduces the required mobility training of people with visual impairments since they can walk unfamiliar routes alone, even for the first time.

The technical challenges comprise the overall development of a guidance system, which enables the users to follow a pre-defined path autonomously without seeing it by using 3D binaural acoustic signals. One main challenge is the tailor-made development of a suitable Kalman Filter for the application under consideration in order to adapt it most suitable to the dynamic behaviour and thus the so-called dynamic movement model. Thus, extensive work will have to be spent onto this issue. Furthermore, the protection level algorithm has to be tailored carefully taking into account the target environments and ways of the potential users.

Finally, the outcomes of these tests are very encouraging and currently the ARGUS partners are implementing an updated prototype and will perform user tests with a wider sample of users in the course of this year.

Prizes and acknowledgements

The main idea of ARGUS won EGNOS prize at ESNC 2012. The GSA judges highlighted the innovativeness of the idea (the pioneering approach to link GNSS with binaural technology), the importance of EGNOS to the solution, its high performance, relative commercial readiness (a prototype exists and a technology patent is being applied for), its high market potential and clear social benefits.

This project is being conducted by several entities: CEIT Alanova, TeleConsult Austria, The 425 Company, Siemens AG, OK Systems and Vicomtech-IK4 (coordinator).

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