ARGUS Autonomous Navigation System for People with Visual Impairments

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Abstract. This work addresses the challenge of designing an effective, reliable and affordable autonomous navigation system for blind and visually impaired people which also covers journey planning and post journey activities (such as recommendations and experiences sharing) . The main contribution focuses on the integration of accurate real-time user positioning data with binaural 3D audio based guiding techniques on mobile devices and a web services delivering platform. The aim is to produce an autonomous navigation system that can be used to guide targeted users along pre-defined tracks and that can be used also before and after the journey to carry out several related tasks such as journey planning, training and sharing of experiences. A preliminary prototype of this concept has been built and tested with 4 end users in both rural and urban environments, obtaining encouraging results.

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

1 Introduction

The population of blind and visually impaired 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 1 in 3 senior citizens over 65 experiencing it. [1].

Being able to navigate autonomously is one of the most relevant needs for blind people. Research on autonomous navigation systems which use spatialised audio (also

adfa, p. 1, 2011.

known as binaural audio) information [2] for guiding blind people has been carried out since 1985 [3]. Recently, it has been discovered that spatialised audio instructions are faster to interpret, more accurate and more reliable than 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. The European Geostationary Navigation Overlay Service (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].

Besides, significant industrial activity has been carried out in order to provide useful navigation support systems for blind people. It’s worth noticing that eAdept [6,7] has succeeded in validating a complete navigation support platform in the city of Stockholm. Furthermore, commercial products like Kapten by Kapsys [8] or Trecker Breeze by Humaware [9] have successfully reached the market. Nevertheless, they don’t provide yet binaural audio guidance support in order to safely and thoroughly meet the navigation needs of the blind users. To overcome current systems’ limitations research is still ongoing [10, 11].

2 The ARGUS autonomous navigation concept

ARGUS FP7 project [12] proposes an innovative system for the safe and autonomous navigation of blind and partially sighted people based on binaural audio guidance, which also covers pre-journey activities for journey planning and post-journey activities including sharing experiences and recommendations.

Fig. 1. ARGUS autonomous navigation support system concept.

The ARGUS autonomous navigation concept is explained next. Firstly, an ARGUS Website is provided to perform the journey planning activities. The ARGUS Web User Interface is hosted in the ARGUS Service Platform. Secondly, by means of the ARGUS App running in an Android Smartphone with Internet connection, the planned routes can be downloaded from the Web Service Platform. Then, once on the route, the external High-Performance Positioning Unit (HPPU) corrects the GPS signals with EDAS data for obtaining accurate user positions and, using an Inertial Navigation System (INS), the user's heading is also calculated. Additionally, dead reckoning is implemented in the HPPU in order to support the user in areas with limited satellite coverage. The HPPU continuously transfers the updated user position and heading in real time to the Smartphone. Then, the Smartphone uses a navigation algorithm that compares the actual current user position and heading with the route to follow, and computes the binaural acoustic cues that will be transmitted in order to guide the user through the planned route. Bone conduction open headsets will be used in order to allow the user to hear surrounding sounds. Finally, the ARGUS Website is available after the journey for sharing recommendations, points of interests or performed tracks with friends or relatives through current mainstream social networks.

3 Methodology

3.1 Prototype

A user centric approach has been followed during the whole design and technical development process of the ARGUS prototype in which the end users and accessibility experts have been intensively involved. Table 1 shows the main technical features.

Table 1. Technical specifications of the integrated ARGUS prototype.

#	Module	Technical specifications
1	High-Performance Positioning Unit	i) 1 frequency (GPS L1 [1575.42MHz]) corrected with EDAS data, ii) Inertial Navigation System: accelerations, angular rates & magnetometer, iii) Extended Kalman Filter for fusion of GNSS and INS measurements (tightly coupled), iv) Wi-Fi communication with smartphone, & v) total positioning accuracy in optimum conditions of 2 to 3 meters, at 4 Hz.
2	Smartphone Application (for Android)	i) Cross-platform architecture design, ii) dedicated guidance algorithm for navigating within the safety corridor (GEOCorridor®) [13], iii) binaural cue generation for audio guiding, & iv) accessible user interface.
3	Service Platform	i) Web service architecture, ii) Route Calculation module, & iii) Multilayer Information Management System.
4	User Website	i) Access / Create Itinerary / Download itinerary / Upload itinerary functionalities, ii) registration using social networks & iii) WCAG 2.0 Level AA conformance
5	Headphones.	Open bone-conducting wireless headphones have been integrated to meet users' needs on comfort and safety (AfterShokz®).

Fig. 2. Pictures of the portable components of the ARGUS prototype: Smartphone running ARGUS App, wireless open headphones and High-Performance Positioning Unit.

3.2 User Tests

Small scale tests with 4 end users have been carried out in order to assess the performance of the ARGUS autonomous navigation prototype and gather initial users' opinions. Table 2 summarizes the main specifications of these tests.

Table 2. Description of the main specifications of the user tests.

#	Specification	Description
1	Testing sites	User tests took place in October 2013, in Soest (Germany). Two routes were defined: i) urban route in the city centre, & ii) suburban route in a public park.
2	User recruitment	4 end users were recruited. Age, technical skills, gender and visual impairment were balanced : i) 2 users < 30 years old, ii) 2 users were technically skilled, iii) 1 woman, & iv) 2 blind people & 2 partially sighted
3	User training	The training covered 4 main stages: i) ARGUS web user interface, ii) gesture training for Android devices, iii) ARGUS App handling, & iv) ARGUS binaural guidance
4	User Tests	Users were requested to perform a set of tasks related to: i) journey planning, ii) binaural navigation, & iii) experience sharing after the journey.
5	User feedback retrieval	All users were interviewed on a one-by-one basis after each task. 2 dedicated questionnaires (Likert 1-5 scale based) were developed, i) one for the pre and post journey activities evaluation, and ii) one for the evaluation of the binaural guided navigation.
6	Privacy	Users signed an informed consent document & the user tests were video recorded.

In addition, a demonstrative video[1] has been produced for dissemination activities.

[1] http://youtu.be/IskZZ58Ih50

Fig. 3. Photographs taken during the user tests.

4 Main results

4.1 Analysis of users' tracks

First of all, the accuracy of the routes provided by the ARGUS Service Platform was assessed. Both urban and suburban routes were first automatically computed and downloaded from the ARGUS Service Platform, and then compared to the real track performed by a sighted expert person. The results obtained show a deviation less than 1 meter for both scenarios.

Next, users performed 6 tracks, 4 in the urban scenario and the other 2 in the suburban scenario. Corresponding data has been collected: i) GNSS reception: the numbers of satellites in view, Dilution of Precision (DOP) and Horizontal Dilution of Precision (HDOP) values, ii) User track: distances from resulting tracks to the ideal path and distances to the safety corridor (GEOCorridor®) have been computed, and iii) Heading instructions & user reaction: real heading instructions transmitted to the users during the journey and the real track performed by them have been compared.

Graphical and numerical analysis have been carried out on the previous data. Results obtained show that all users achieved to follow the routes. Next table shows the distances to the ideal path.

Table 3. Numerical analysis of distances to ideal track on urban and suburban routes.

User	Scenario	Maximum(m)	Average(m)	Stdev(m)
U1	Urban	9,37	6,32	2,51
U2	Urban	13,66	6,86	3,33
U3	Urban	11,76	6,4	2,94
U4	Urban	4,69	1,54	1,37
U1	Suburban	6,68	0,9	1,53
U2	Suburban	6,19	2,6	1,51

The analysis shows that average distances to the ideal path for suburban tracks take really low values (<3m), due to the good coverage of these areas. However, this data is less encouraging for the urban scenarios where user positioning is worse. Besides, results show that in most of the cases spatial sound perception was clearly perceived and followed by the users.

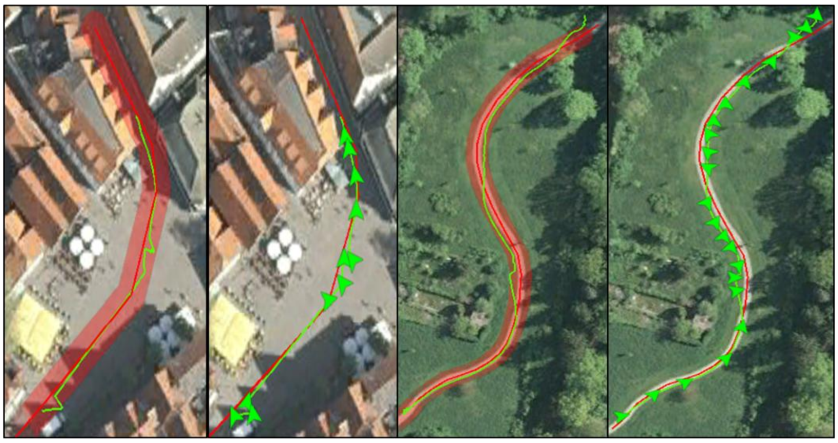

Fig. 4. User track and heading instructions analysis of urban and suburban scenarios.

4.2 Analysis of users' feedback

Pre and post-journey activities evaluation

Users were requested to perform a set of pre and post-journey activities by means of the ARGUS Website. The results obtained by means of the questionnaire confirmed that the specific requirements of all test users in terms of accessibility were met. Besides, all users were able to accomplish all proposed tasks successfully. Next picture shows the answers that were collected.

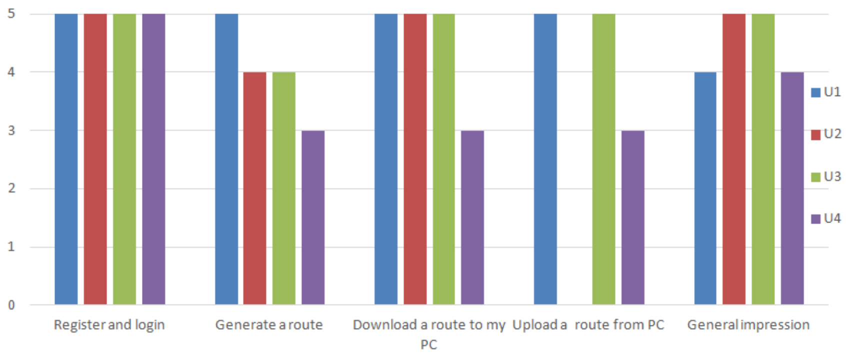

Fig. 5. Results to the questionnaire regarding pre and post journey activities.

Binaural guided navigation evaluation

Users were asked to navigate an urban and suburban route using the ARGUS system (Figure 2). All users were able to use it properly. All assistive technologies requested by the users such as the screen reader Talkback, Zoom and speech control capabilities of the used Android OS were fully supported. Additional equipment like external keyboards, headphones and Braille-devices were also used. Results to the questionnaire are shown in the next picture.

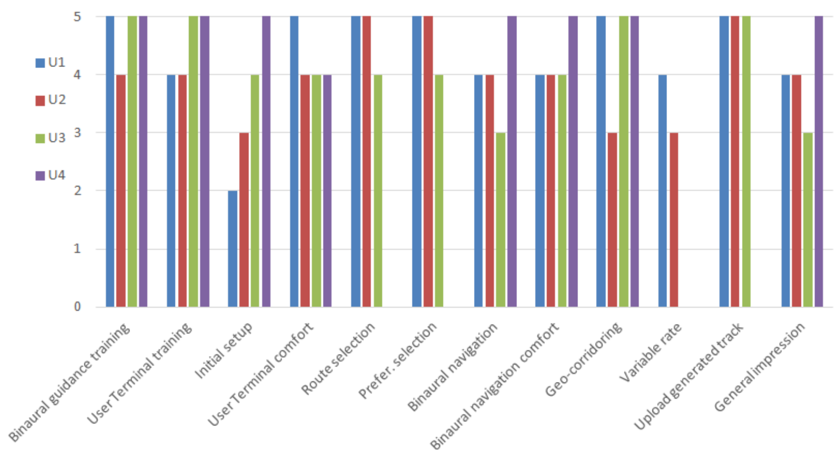

Fig. 6. Results to the questionnaire regarding binaural guided navigation.

With regards to the outdoor navigation performance, users reported at the personal interviews conducted after each test that the current version of the ARGUS system worked already excellent for partially sighted users on both urban and suburban scenarios. Additionally, blind users reported that the system worked excellent for them in the suburban scenario, but that was not still reliable enough for them in the urban scenario, because blind users require higher accuracy of the system for safe navigation in the urban scenario. Besides, users reported that the training session on binaural guiding principles previous to the tests was relevant for them.

5 Conclusion

The ARGUS autonomous navigation system has been successfully implemented and a preliminary validation has been conducted with a small sample of 4 end users. The ARGUS consortium has demonstrated that the binaural guiding functionality has been met both for urban and suburban scenarios. Additionally, pre and post journey activities have been successfully evaluated in the tests as well.

The results of the user tests show that all users were satisfied with the ARGUS system guiding capability, simplicity and facility of use, although blind user requested more accuracy in the urban scenario to fully meet their safety needs. Additionally, users stated that a short training session on binaural guiding principles previous to the guiding process is needed in order to use the system correctly.

The data analysis of the tracks performed after the tests confirmed that the system is suitable for partially sighted people in both urban and suburban scenarios, but it does not provide yet accuracy enough in order to meet the needs of blind people in urban environments.

In this sense, the positioning accuracy of the system in urban areas will be improved for example by adding GLONASS to increase the number of satellites in view. Adaptive navigation algorithms may be also needed to meet the differences between urban and suburban scenarios.

Finally, the outcomes of these tests have been very encouraging. Currently the prototype is being updated and the full validation of the system at a larger scale will be carried out during 2014.

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