Blind People's Navigation Improvements Using Crowdsourcing

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***Abstract*-The literature review and survey of the Blind and Severely Visually Impaired (BSVI) people showed that BSVI are using the same general-purpose or specialized social networking means for communication, learning, remote working, leisure, navigation as other people. BSVI oriented text (and image) to voice, tactile feedback, and other specialized mobile apps or software and hardware solutions help in this matter. This paper studies how crowdsourcing (participatory social networking) can improve navigation and orientation capabilities outdoors and indoors, using the computer vision-based Electronic Traveling Aid (ETA) approach. This study gives insights into the high potential of crowdsourcing usage to improve BSVI people's ETA performance. In this regard, this paper delivers a short overview, BSVI survey results, and a description of the prototype, which we are developing to meet BSVI expectations. Provided insights can help researchers and developers to exploit social Web and crowdsourcing opportunities for BSVI computer vision-based ETA navigation improvements.**

Keywords-social networking; electronic travelling aids; computer vision; blind and severely visually impaired; navigation indoors.

I. INTRODUCTION

Admittedly, a wide range of general-purpose social networks, web 2.0 media apps, and other smart ICT (information and communication technology) tools are developed to improve people's daily tasks, including navigation and orientation. Although they are not destined to meet specialized requirements of BSVI people, but some adds make them useful. For instance, text (and image) to voice, tactile feedback, and other additional enabling software and hardware solutions are helpful for this matter. However, complexity and abundance of features pose a significant challenge for BSVI persons. According to Raufi et al. [1], the volumes of information together with data from social networks confuse BSVI users. In this way, web 2.0 social networks do not guarantee specialized digital content accessibility for BSVI users [2]. Some more focused approaches are in demand.

In general, BSVI users are actively involved in social networks [3]-[5]. More than 90 % of BSVI persons actively use one or more general-purpose social networking sites, such as Facebook, Twitter, LinkedIn, Instagram, and Snapchat [3][4], and [6]-[8]. However, only a few social networking platforms are specifically oriented for BSVI users. For instance, BSVI surveys reveal that social networking apps are among five most popular mobile apps [11]. The majority of BSVI people - who use social media - choose Facebook social networks [4][9], and [10]. The usage of Twitter was also unusually high, assuming that its simple, text-based interface is more accessible to the screen readers [4].

Next to the general-purpose social networks, BSVI people frequently use apps specifically designed for them to accomplish daily activities. However, N. Griffin-Shirley et al. emphasizes that persons with visual impairments would like to see both improvements in existing apps and new apps [11]. Below, we give an example of some of the most popular navigation apps used for path planning, navigation, and obstacle avoidance [12][13], and [3].

For instance, Walky Talkie helps blind people in navigation, providing real-time haptic feedback [14]. However, the accuracy based on the in-built GPS is low. The vOICe for Android application maps live camera views to soundscapes, providing the visually impaired with augmented reality-based navigation support (see The vOICe for Android - Apps on Google Play). Ariadne GPS works where Google Maps are available (see www.ariadnegps.eu/en). In addition to navigation functions, it also enables users to navigate in large buildings by pre-programming locations. BlindSquare provides information to visually impaired users about their surroundings. From a social networking perspective, BlindSquare is closely linked to FourSquare as it collects information about the user's environment from FourSquare [14].

The above mentioned cases and some other navigation apps are mostly based on the pre-developed navigational information, but do not provide a real-life support, user experience-centric approaches, and participatory Web 2.0 social networking. On the contrary, there are other real-life social apps such as Be my eyes, which enable access to a network of sighted volunteers and company representatives who are ready to provide real-time visual assistance for the orientation, navigation and other tasks at hand [15].

In Section 2, we briefly provide a glimpse of BSVI people's survey results concerning their navigation and social networking needs and expectations. In Section 3, we share some insights concerning navigation and orientation for ETA enhancements using participatory Web 2.0 advantages. Conclusions are provided in Section 4.

II. BSVI PEOPLE'S SURVEY: SOCIAL NETWORKING AND NAVIGATION NEEDS

To define more precisely BSVI persons' social networking needs and expectations concerning navigation help, we conducted a survey and semi-structured interview of blind people of various ages. In total, 78 EU located BSVI persons' responses were analyzed, of which 25 were identified as blind experts (10+ years of experience or active interest in using ETAs for the blind). In the survey, some questions (out of 40 questions in total) concerned ETA navigation functionalities, and others dealt with social networking approaches.

For instance, the question "Are you using the assistance of volunteers over electronic means?" (see Figure 1) revealed that only 12 % of all 78 respondents use such assistance. It indicates that the electronic assistance level is currently deficient, bearing in mind the high potential of social networks, web 2.0 media apps, smartphones, and other ICT (information and communication technology) tools. In other words, it points to the lack of enabling real-time, user-friendly, experience–centric, and participatory Web 2.0 technologies.

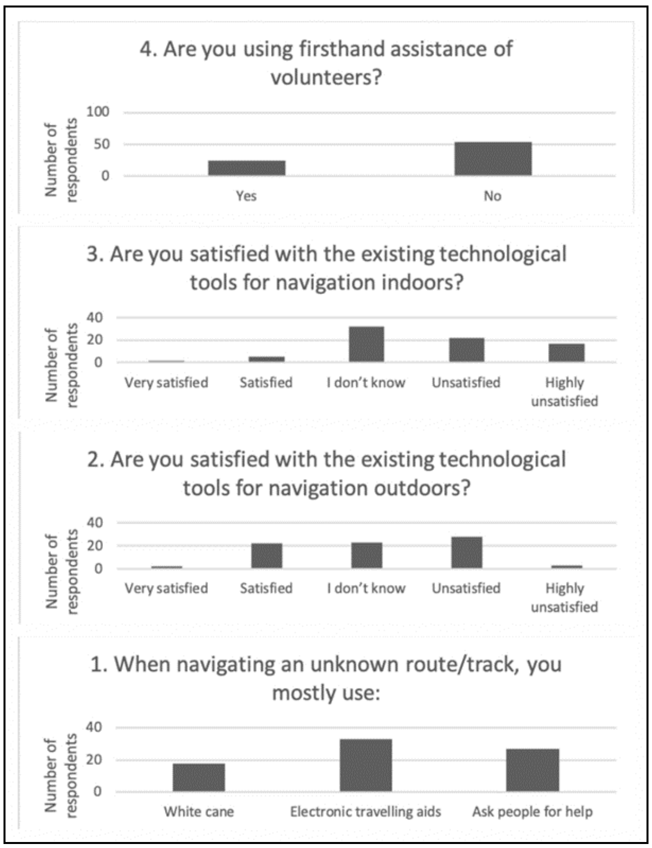

Figure 1. Survey responses from 78 BSVI persons. The order of the questions is piled up from the bottom to the top.

BSVI experts also provided their answers, see Figure 2. They were interviewed concerning the usage of smartphone apps and Web portals. For instance, the questions, such as "What smartphone apps, web portals, and social networks do you know, and which of them do you use to communicate with sighted people?" or "What smartphone apps, web portals and social networks, specifically designed for the blind, do you know?" revealed that most popular apps and social networks used by BSVI people are Facebook, Twitter, LinkedIn, and Snapchat. Besides, BSVI people use Telegram, Youtube, Facetime, Google hangouts, Whatsapp, Skype, Viber, Messenger, Zello, MySpace, Tinder, TeamTalk, Eskimi apps. Only 5 out of 25 BSVI experts mentioned apps or websites specifically designed for the blind: Bee my eyes, Telelight – an accessible telegram client, Voreil, Talking Communities, FourSquare/BlindSquare, Playroom, Applevis.com, Elvis, blindhelp.net, Blindbargens, ACB network, RNIB. It indicates wide variety of smartphone apps and Web portals often used for everyday tasks.

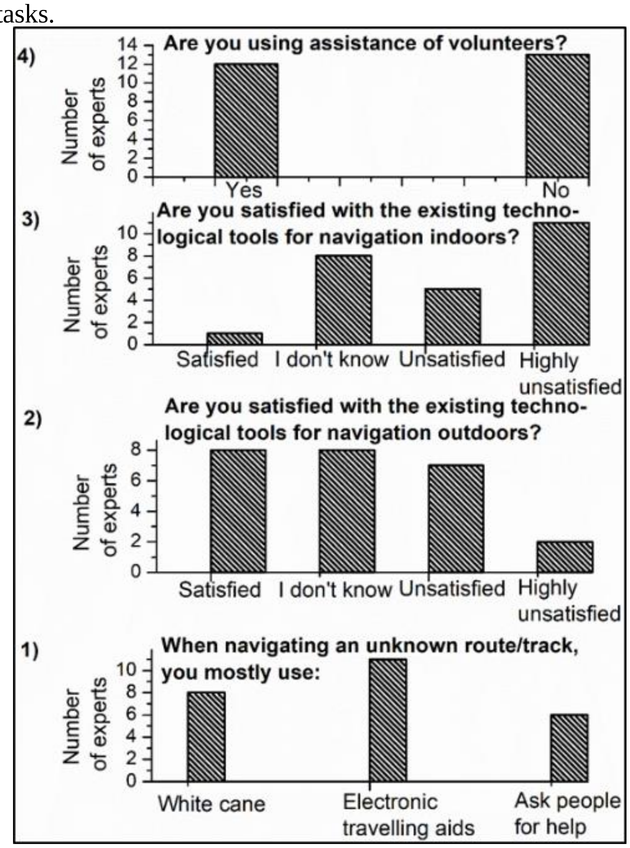

Figure 2. Survey responses from 25 BSVI experts.

Next, we turned our attention to the more specific questions regarding social networking tools used for navigation. For instance, "Are you familiar with social networking tools that support sharing of navigation information (directions) between the blind and/or sighted volunteers?". Surprisingly, most of the BSVI respondents do not know such tools and only a few mentioned What's app, Be my eyes, and Google Groups "Eyes-free group". Thus, social networking tools used for navigation are not very popular. During additional interviews, we figured out a few more details. For instance, social networking tools are (i) in

English mostly; do not operate in other national languages, (ii) casual voluntaries are not accustomed to deal well with the specific BSVI problems, and (iii) applied technology is not specialized enough to tailor real-time and high-quality help.

In another question, “Would you be willing to pay for the functionality of an electronic travel aid listed below? How much?” we identified value-added and monetary estimation of each ETA functionality (however, we present here not the price itself but relative estimates). About 80 % of the first ranked ETA needs included navigation and orientation functionalities, such as recognition of stairs, elevators, doors, navigation directions, assistance to return to a specific location, and so on. Out of the whole price for all twenty chosen ETA functionalities, BSVI were willing to pay 18.3% for outdoor navigation; 12.9% for indoor navigation; 12.5% for recognition of textual and numerical information’ 8.4% for recognition of stairs, lifts/elevators, doors, passages and pavements/sidewalks; 6% for information about products with BAR and QR codes; 5.8% for assistance of remote volunteers to interpret sophisticated surroundings in the mother tongue; 3.1% for ability (through social networking) to record, store and reuse outdoor navigation information; 2.7% for ability (through social networking) to record, store and reuse indoor navigation information; 1.9% for ability to share and exchange outdoor navigation directions through a specially designed social network; 1.8% for ability to share and exchange indoor navigation directions through a specially designed social network, and so on. In sum, around 32% out of the total price, BSVI were willing to pay for ETA functionalities, which can be substantially enhanced using participatory Web 2.0 social networking.

These were just a few exemplary questions. However, based on the entire survey analysis, we find out some perspective niche of research and development in the field of navigational ETA solutions. Based on these insights, we made some inferences regarding a combination of modern enabling technologies, which can be successfully employed. In the next section, we give an exemplary case.

III. Machine Vision-Based Navigation Enhancements Using Participatory Social Networking

In this section, we will share a few participatory Web 2.0 social networking ideas, which could enhance BSVI navigation capabilities for traveling, shopping, and other everyday mobility tasks. For instance, in the case of real-time assistance and guidance' for traveling routes, the primary objective of the specialized mobile app's with wearable services is to assist a visually impaired or blind user in navigating from the chosen point A to point B using reliable directions given from an online community. In this case, a phone with wearable service would be able to (i) stream live video to a crowd server (Social Navigation Networking Services) of sighted users through internet/WiFi, (ii) receive real-time feedback through assistance and guidance instructions. For instance, SoNavNet is designed for connected users of the social network to share navigation information with the intent of providing more personalized navigation methods, routes based on member experience rather than the shortest distance [16]. SoNavNet is based on the experience-based approach - through communication (using online social media) and collaboration (sharing and exchanging experiences), BSVIs can find suitable routes both n outdoors and indoors that can meet their specific needs and preferences. SoNavNet, as an online social navigation network system, facilitate sharing and exchanging experiences on Points Of Interest (POIs), Routes Of Interest (ROIs), and Areas Of Interest (AOIs) [16].

The authors in [17] designed a Tales4Us platform to promote creativity, collaboration, and learning process, for a BVSI and other communities to share their shopping stories through a specialized social network. The application has such major functionalities: (i) the user can play other users’ shopping stories, (ii) users can record new stories and share it with the community.

In the case of “Seeing-eye person” proposed in [18], a crowdsourcing approach enables multimedia data sharing and services for the BSVI navigation. The goal of this work is to provide user-accessible crowd services (uniquely tailored for visually impaired), flexible (with friendly HCI and APIs for the ease of plugging in new apps to motivate online volunteers for their services), and efficient (near real-time response, and a balanced workload between mobile phone, the back end system, and the different types of users).

The authors in [19] dedicate their general-purpose social navigation approach for any users, including BSVI people with impaired mobility. The system allows sharing knowledge between them, reviewing an existent place freely, or uploading new ones to the global database, improving the application content. The ParticipAct infrastructure, implementing calls to different external API services, as geocoding, localization, routing calculation, and POI entities download, enabling a new set of functionalities. However, the system does not include data quality support in the sense of automatic filtering-out of erroneous inputs, as (possibly) fake entities.

In our ETA research, we also use the onboard sensors of a smartphone (iPhone or Android Phone), such as a camera, compass, GPS, and accelerometer, to assist the navigation of a blind user, see Figure 3. The primary function of mobile computing is to stream the video and other sensory information to the crowd server so that volunteers can use the information to provide service. We plan further to tailor these techniques in order to address the unique challenges in crowd-assisted navigation, such as the smoothness and reliability of visual labeling of routes recorded by volunteers, and the contextual information of video frames.

We infer that some of the navigational instructions might also be adapted from the machine vision algorithms that provide direction information [20]. It lays the potential to aggregate all the available instructions into a single one that will be returned to the blind user. We need to consider the expertise, reliability, and reputation (low reputation might indicate noisily, or even malicious volunteer, which we want to filter) in the data aggregation process. Besides, we also need to consider the synchronicity of data coming from different volunteers and the frequency of instructional updates.

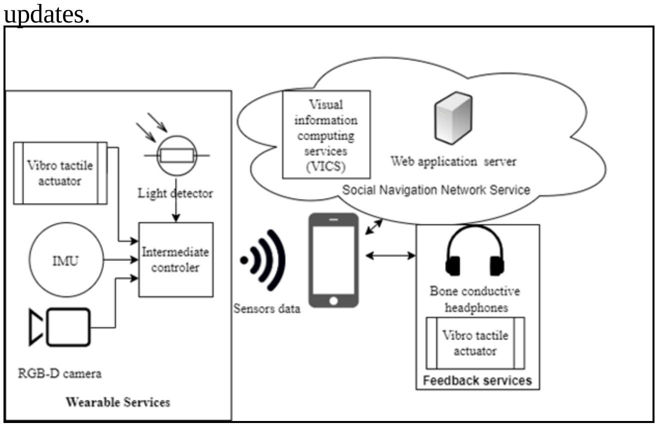

Figure 3. Social navigation network services enabled by mobile device for BSVI

The seamless integration of AI-based vision algorithms in the crowdsourced social networking solutions can provide additional feedback. Vision-based algorithms can be tested for accuracy against live information from human volunteers. Along with the on-line process and data aggregation, an offline analysis will in turn help better tailor context-aware human-computer interfaces and further improve the online analysis tasks.

Based on the survey results and above mentioned considerations, we are reporting an interim result - a prototype of a wearable system configured to help as an offline and online web-crowd assisted decision support system for BSVI people when orientating and navigating in indoor environments (for instance, public institutions, schools, hospitals, airports, stores, and other buildings). Admittedly, there is a lack of feasible indoor navigational solutions that would work well without GPS signal and prearranged infrastructural indoor installations (such as WI-FI routers, beamers, RFID tags). Our survey of blind experts has shown that after outdoor navigation, the second most demanded and not satisfied need concerns ETA solutions for indoor navigation and orientation [12] and [13]. We figured out that BSVI persons need ETA for orientation and navigation in unfamiliar indoor environments to detect and recognize desired indoor destinations such as rooms, WC, staircases, elevators, avoiding obstacles on their way. In Figure 4, we depicted key guidelines for the ETA system's interface with the BSVI person indoors.

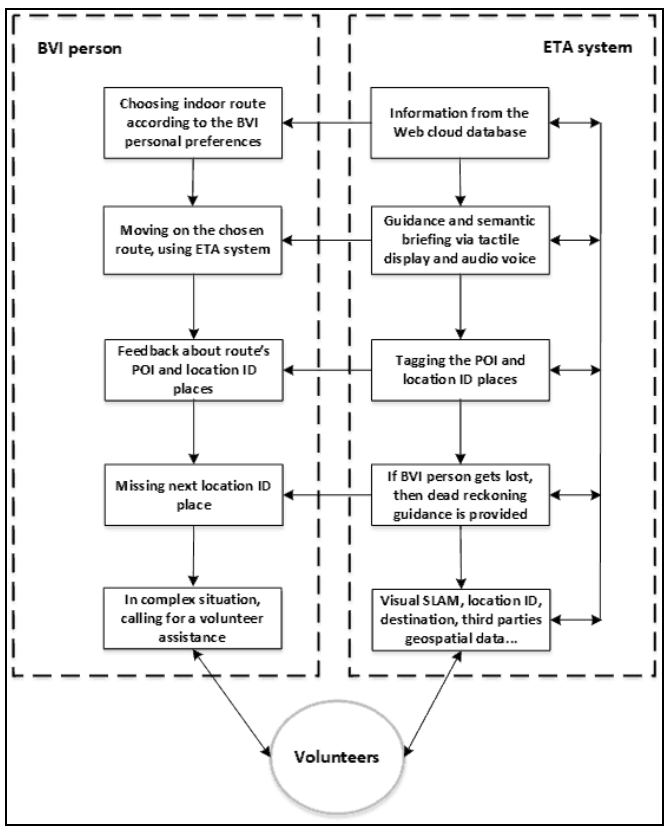

Figure 4. Web crowd (volunteers) assisted method for indoor routing enhancement and optimization, using ETA system functionality

The presented system is a compound technology of innovatively adapted hardware devices like the 3D ToF IR camera, RGB camera, specially designed tactile display with EMG sensors, bone-conducting earphones, controller, and

IMU, GPS, light detector, compass sensors. GSM communication can be implemented as a stand-alone device or smartphone that can work as an intermediate processing device. Passive sensors passively collect environmental data, whereas, active sensor like 3D ToF IR camera emits IR light to estimate distances to the objects. Multi-sensory data is used to (i) find needed objects, (ii) locate obstacles, and (iii) infer users' location in an indoor environment in order to help navigate. The devices and sensors observe the environment in real-time and send data via the controller to the machine learning processing, where features' extraction, object recognition, and data storage occur in the web cloud database server, see Figure 4. The prototype integrates devices and interfaces using modern technologies and methods from machine learning and computational vision domain.

From the point of view of the end-user, this prototype distinguishes among other related wearable indoor navigational ETA novelties in the sense of a) intelligent user interface integrity based on unique tactile display and audio instructions, b) hands-free intuitive control interface using EMG (electromyography), c) comfortable user-orientated headband design, d) machine learning-based real-time guidance, e) web-crowd assistance while mapping indoor navigational routes and solving problematic situations on the way.

For efficient indoor navigational performance, the presented ETA system is used in three consequently interconnected modalities: (i) Web crowd assistance when volunteers go through buildings and gather step-by-step indoor routes' information that is processed in the web cloud server and stored in the online DB; (ii) BSVI usage of web cloud DB indoor routes when they need guided navigational assistance; (iii) in complex indoor situations (such as getting lost, encountering unexpected obstacles and situations), the BSVI ETA system's multisensory data stream can be used in real-time to get voice-guided help from volunteers familiar with the particular route or building.

IV. CONCLUSIONS

This paper studied how crowdsourcing (participatory social networking) can improve navigation and orientation capabilities outdoors and indoors, using the computer vision-based ETA (electronic traveling aid) approach. This study gave insights into the high potential of crowdsourcing usage to improve BSVI people's ETA performance. In this regard, this paper delivered a short overview, BSVI survey results, and a description of the prototype, which we are developing to meet BSVI expectations. Provided insights can help researchers and developers to exploit social Web and crowdsourcing opportunities for BSVI computer vision-based ETA navigation improvements. More specifically, semi-structured survey revealed a clear lack of participatory Web 2.0 social networking usage for the navigation and orientation outdoors and indoors. From one side, it is related with the lack of BSVI people's trust and confidence in the corresponding ETA technological solutions. From another side, it is related with the lack of enabling real-time, user-friendly, user experience–centric, and participatory Web 2.0 social networking technologies.

We found that current research in the area of online social navigation network systems, facilitate sharing and exchanging experiences on POIs, ROIs, and AOIs. We inferred that some of the navigational instructions might also be adapted from the machine vision algorithms that provide direction information [20]. The seamless integration of AI-based vision algorithms in the crowdsourced social networking solutions can provide additional feedback. Vision-based algorithms can be tested for accuracy against live information from human volunteers.

In summary, participatory Web 2.0 social networking systems can enable the integration of smart algorithms together with BSVI and sighted people's best experiences while traveling, navigating, and orientating in outdoor and indoor environments. It helps to build and continuously update real-time metrics of reachable and unreachable POIs to the effect that routes could be averaged, erroneous routes eliminated, and user experience-based optimal solutions found using various optimization approaches (like min-max entropy calculation) [21]-[23]. In this way, crowdsourced navigation social platforms with real-time video streaming and analysis get advantages that none stand-alone navigation systems could ever achieve [9]. It is appealing; even there are still several unresolved tasks like data reliability, integrity, synchronicity, cross-platform compatibility [10] and [24].

The presented ETA system uses crowdsourcing when volunteers go through buildings and gather step-by-step indoor routes' visual and other sensory information that is processed, using machine learning algorithms, in the web cloud server and stored for the BSVI usage in the web cloud DB.

In the presented paper, we provided some framework and concepts of ETA enhancement for indoor guided navigation, using outsourcing of routes mapping. Next, we are step by step developing a wearable ETA device supplemented with the social networking interface, wherein sighted users take an active part in mapping indoor routes and helping BSVI persons in complex situations.

In time, a participatory web 2.0 social networking platform – something like a worldwide "Visiopedia - with big, labeled, crowdsourced, almost real-time updated, and publicly available outdoor and indoor navigational database for BSVI could emerge. It would enable much more efficient and reliable use of AI-based learning algorithms [12] and [13].

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