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Open source tools for locomotion and apprehension of space by visually impaired persons: some propositions to build a prototype based on Arduino, speech recognition and OpenStreetMap

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Abstract

In this article, we discuss about the benefit of IoT for people with disabilities, particularly for visually impaired and blind people mobility. We propose a simple prototype using OpenStreetMap data combined to physical environment data measured from sensors connected to a Arduino board through Speech recognition.

Keywords: blind people, usability test, Iot, Arduino, Voice recognition, OpenStreetMap, Open Source.

1 Context

1.1 Internet of Things

The internet of things (IoT) enables and improves the connection between people and things that surround them. Due to its wide applicability, this technology promises significant benefits in the lives of human beings. There is consequently a risk that the IoT technology will prioritize the technical artefacts (things) and will neglect the social aspects of its technical systems and information infrastructures (Crumpp and Brown 2013). Beyond connectivity, IoT has the capability of embedding intelligent behaviour of connected sensors. Thus, the adjective "smart" is often seen in IoT references (Neisse et al. 2014).

Emergence of the Internet of things (IoT) is indeed impacting our lives. We hear more and more about new smart objects on the market. The motivations of professionals working in this field are often economic and IoT covers a wide area of applications: preserving environment, reducing energy consumption, domestic tools, games, durable goods, multipurpose drones, monitoring, etc. The projections for the impact of IoT on the economy is monumental, with some anticipation of \$11 trillion by 2025 (Rose, Eldridge, and Chapin 2015). IoT also promises to be beneficial for people with disabilities. It may improve quality of life and level of independence.

During their locomotion, visually impaired persons need human assistance or other visual compensation tools. On the one hand to avoid obstacles, on another hand to comprehend space (Boularouk, Josselin, and Altman 2016). The evolution of Internet of things and the success of the crowd-sourcing map platform (e.g. OpenStreetMap) may improve the daily life of visually impaired persons by giving them information about surrounding space.

In this paper, we present a simple experience to combine free open-source spatial data (OpenStreetMap) with an open-source electronic platform (Arduino) used in many other applications IoT-oriented like GPS indoor applica-

tions (Vorst et al. 2008; Kolaskar et al. 2016) or domotic applications (Kumar Rath 2013). Visually impaired people can thus communicate using machines through a vocal Human-Machine Interface (HMI) based on the .NET Speech Recognition & Text Synthesis API.

1.2 Blind people in their environment

According to Gibson, the way how a knowledge is acquired is not of major importance: there is no difference in the cognitive functioning of the blind compared to other people. Gibson demonstrated that a human reacts in relation to the close environment (*affordances*) (Virole 2009). Since development of spatial representation depends more on cognitive than on perceptual processes (Hatwell 2003), we propose in this paper to help people to compensate visual perception. This system (fig: 1) can give a dual help: earning map by auditory perception, avoiding obstacles using sensors.

The extension of the concept of *affordance* to language allows us to understand that perception is fundamentally oriented towards the search of meaning. Understanding a word is, first of all, understanding the meaning it refers to. Likewise, a heard sound is meaningful since it corresponds to an adaptation of an object to its environment ("*naturalistic orientation language*" Virole 2009).

The visual perception allow to access, in a direct and fast way, to many spatial properties and features of the environment. However, Vision is a powerful spatial perception. Due to a lack of vision, blind people search information from other stimulus:

- Hearing information helps to identify the nature of objects. However, many objects do not emit sound;
- Proprioceptive information for position of the various body segments in relation to each other and with the surrounding space;
- Tactile information: touch, perception of contact is very limited even if it can be enlarged by exploration

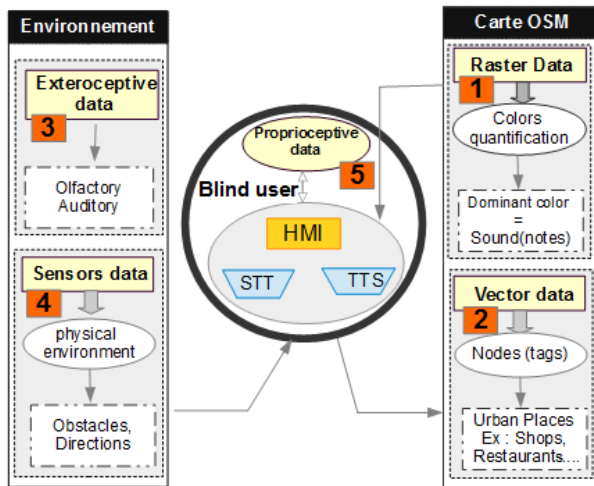
- Olfactory information: smell is the meaning to analyze volatile chemicals (odors) present in the air.

In this paper, we mainly focus on hearing information using auditory transcription and speech recognition.

1.3 Connected systems for blind people locomotion

In order to regulate the interaction between blind users, geographical database and sensors, we use Speech recognition and Synthesis. The HMI (fig: 2) was built for desktop use and we are now working on an embedded application for android (not presented in this paper). Environment is comprehended by the blind people using *exteroceptive* data (auditory) and data from sensors (obstacles and orientation). The system is based on the OSM geographical data base, including raster and vector data.

Figure 1: Global solution for visual compensation



2 Auditory transcription of spatial data

Here we shortly present some aspects of the relation between sounds, voice and spatial data.

2.1 Sonorous raster maps

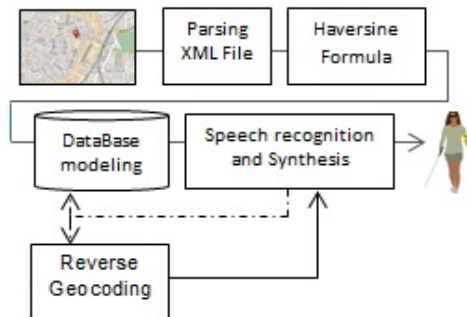
The main goal of raster «sonification» is to convert map colors to sounds close in meaning (Josselin et al. 2016). It is impossible to make a direct correspondence between sounds and colors: there is no overlap between the frequency ranges of the sounds audible by the human ear (20 to 20 KHz) and the light visible by eyes (waves from 400 to 800 THz). A few works dealt with sonorous maps semiotic (Krygier 1994; Jouhaneau 2013), but they concluded that joining images and sound or music still needs major improvements, especially to associate sounds and memory capability.

In fact, auditory stimuli are not interesting as long as a relation between the heard sound and its source cannot be established. It is however possible to convert colors of map legend to sounds from nature (”soundscape”), under condition that both sound and color represent the same thing. For instance, we can represent the blue color of a sea by sounds of sea, green color by sounds of nature, etc.

2.2 Voice reading of OSM vector data

OSM Data is collected at a fine granularity as contributors tend to describe their place of daily life. However, with important flux of data, verification and validation of the data produced is not easy because of means (time, human resources) (Hombiat, Villanova-Oliver, and Gensel 2015).

Figure 2: HMI workflow



Indeed, there are two problems: syntactic heterogeneity and semantic heterogeneity. That is why we propose a spatial ontology (Vangenot 2004) for voice transcription of OpenStreetMap data for visually impaired people. To solve syntactic heterogeneity, we transfer all data, including data collected via sensors, to a database (*in our HMI, we use Mysql*). To solve semantic heterogeneity, we build a taxonomy based on the most visited places and *taginfo* and we exploit statistics to define our queries. We use also Google API translator to assure similarity between human language and English key words.

3 Components of the system

In addition to blind users perception, we propose electronic sensors for obstacle detection.

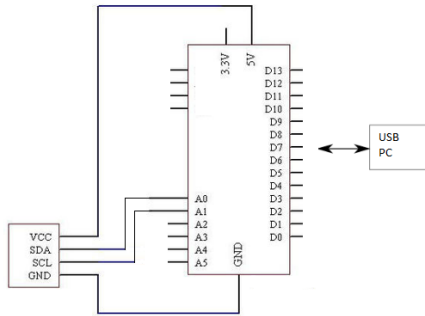
3.1 Arduino board

To process the orientation during the user motion, we use an Arduino electronic board (fig: 3) and a 3-Axis Digital Compass HMC5883L, a sensor to detect cardinal directions. This board is related to the computer or the smartphone.

3.2 A sensor for cardinal directions

A program was developed with C# (.NET) to locate urban places and their details (name, address). It calcu-

Figure 3: Cardinal direction sensor with arduino nano

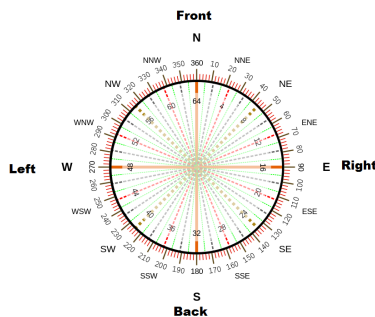


lates the distance between two locations using their latitudes and their longitudes, using the *Haversine* formula (Boularouk, Josselin, and Altman 2016).

This function can tell the blind user where the place he is looking for is located, within the 4, 8 or 16 cardinal directions, which is not really helpful to comprehend space. So this must be change in relative directions.

The 3 axis digital compass sensor (fig:3) helps the user to detect the correct orientation and calculates the correct bearing. With a simple code (cf ??), the cardinal direction will provide a more accurate interpretation of space. Thus, HMI program will situate place in "Left", "Right", "Front", "Back" of the user (cf 4).

Figure 4: Direction using Arduino: compass



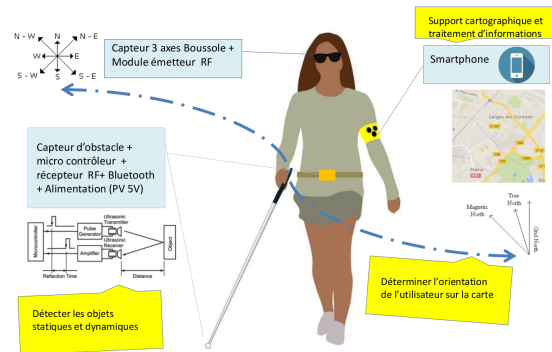
3.3 Obstacle detection

On the one hand, several systems exist to help blind people to move. Those can be based on GPS or beacons. Electronic tools are sometimes used to detect obstacles from different companies (*Cbel*, *Visioprtonic*, *Ultracanne*, etc.). Those can be electronic canes using sounds or vibrations, or connected glasses (augmented reality with *NuEyes*, objects or face recognition with *MyEyes* systems). *OrCAM* also developed a system with a camera (3.000 € each), as *eSight* (13.000 €). Most of those electronic devices are very expensive and only a few blind people can afford them. Research programs were funded and developed mostly, for instance about indoor electronic canes

(*Range-it* in 2015, *I-cane* in 2007) or tactile cognitive maps (*Blindpad* in 2016).

On the other hand, many sensors exist to detect and to avoid obstacles (ultrasounds sensor, laser sensor, infrared sensor, Doppler sensor, etc., cf. 5). They are all cheap but they need some algorithms for more accuracy. Connecting obstacles detection sensors to smart phone for visually impaired persons helps to avoid dangerous zones. In parallel, data from OpenStreetMap can guide the user during his motion, using voice recognition. For instance there exists an on-line OSM application *OSM for the Blind* which allows to identify specific urban street furniture or paths. Much interesting research were developed on improving visually impaired people assistance using different input and output technologies (Kibum and Xiangshi 2014), such as sensory substitution devices (Hamilton-Fletcher et al. 2016, Carcedo et al. 2016), software on smartphones for object recognition (Manduchi and M. Coughlan 2014), haptic systems (Tanaka and Parkinson 2016), wearable systems (Ye et al. 2014) or dedicated interfaces for mapping (Ducasse et al. 2016). An overview of current status and challenges such as sensor-based assistive devices for visually impaired people can be found in Elmannai and Khaled 2017.

Figure 5: Detecting obstacle and direction using ultrasound and 3 axis sensors



3.4 An adapted vocal local gateway

There are many models for communication for IoT Technology. Their choice depends on the application. The device-to-application-layer gateway (ALG) model is frequently used in popular smart devices models (fitness, tracking, personal security...). These devices do not have the native ability to be directly connected to a cloud service, so they frequently rely on smartphone to serve as an intermediary gateway to connect to the cloud (Rose, Eldridge, and Chapin 2015). In general, users directly interact with smartphone. In the case of blind people, we need to replace the screen by another way of interaction. In such a need, voice recognition and text synthesis can play a major role (Boularouk, Josselin, and Altman 2016, cf. Figure 6).

4 Conclusion and perspective about IoT technologies for blind people

The internet of Things became an important topic in economy, industry, research, policy, and has become very popular thanks to the media:

- Cisco IBSG (Rose, Eldridge, and Chapin 2015) predicts there will be 25 billions of devices connected to the Internet by 2015;
- the global IoT market will be \$14.4T by 2022;
- IC Insights predicts a revenue from Industrial Internet IoT spending will increase from \$6.4B in 2012 to \$12.4B in 2015.
- The size of the IoT in manufacturing market is estimated to grow from \$4.11B in 2015 to \$13.49B by 2020, attaining a CAGR¹ of 26.9%²

In this concept, objects are combined using internet connectivity. New applications can be developed by the integration of physical and digital worlds, (Neisse et al. 2014), to remedy to problems that stifle the development of this promising technology. Despite rapid technological developments in many areas (health, business, energy, security), research on the social impact of the IoT is still quite sparse (Crump and Brown 2013). Research community is investigating security and privacy aspects and is constantly developing appropriate solutions for IoT: the cloud for bulk data flow, *6LowPAN* for energy consumption, *6IPv* for internet congestion, etc.

A variety of approaches to intelligent Smart robot interfaces were proposed (Böhme et al. 2003), but most of them concern multi-modal concepts where vision and acoustic have an important role. Since apprehension of space depends on cognitive ability and not on mode of perception, is is possible to use only auditory perception to interact with visually impaired people. A data mining process is needed to extract data from OSM maps. An ontology is also required to construct a rhetoric and constrictive dialog between visually impaired person and the machine (computer, Smart phone). In this article, we proposed a solution to the particular case of the blind persons. We believe that Iot may improve integration of the persons suffering from visual deficiency in society. IoT can ensure security of blinds in their mobility and help them to better apprehend their environment.

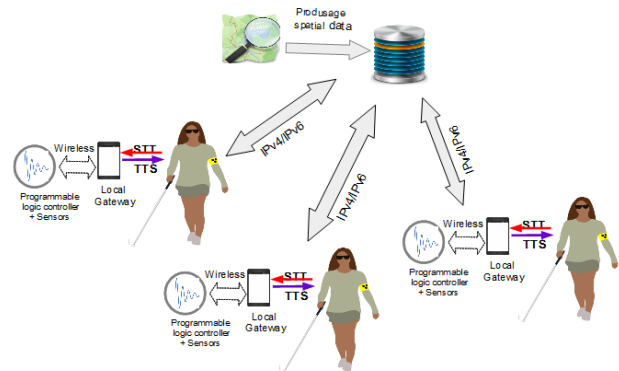
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¹Compound Annual Growth Rate

²<http://www.forbes.com/sites/louisclumbus/2015/12/27/roundup-of-internet-of-things-forecasts-and-market-estimates-2015/#6d00e78a48a0>

Figure 6: Connected objects for the compensation of visual deficiency



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