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FEUP

Mobile Environmental Noise Protection System

Group 3A

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Market Survey

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1.0	21/10/12	Team	X	All of them	Completion of document and revision

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List of Figures

List of Acronyms

COTS - Commercial Off-The-Shelf
CSV - Comma-Separated Values
dBFS - Decibels relative to full scale
EEA - European Environment Agency
GPS - Global Positioning System
GSM - Global System for Mobile Communications
HTML - HyperText Markup Language
IEC - International Electrotechnical Commission
JPEG - Joint Photographic Experts Group
LTE - Long Term Evolution Network
NOISE - Noise Observation and Information Service for Europe
QR Code - Quick Response Code
RDF - Resource Description Framework
RSS - Rich Site Summary
SMS - Short Message Service
UMTS - Universal Mobile Telecommunications System
WLAN - Wireless Local Area Network
XML - Extensible Markup Language

Chapter 1

Introduction

Noise pollution is an increasingly acknowledged problem by authorities and governments around the globe. However, creating noise maps with conventional methods is either inaccurate or very expensive. To increase the spatial and temporal data resolution a high number of sensors must be deployed.

This market survey is part of a mobile environmental noise protection system project. It is intended to develop a smartphone-based system to protect citizens from illegal noise emissions.

In this document information is provided about existing similar systems, their functionalities and core technologies available to help the implementation of this product, giving brief descriptions and potential implications for the project of software and hardware found in the market.

Chapter 2

The Product

The product that will be developed is a distributed smartphone based system to protect citizens from illegal noise emissions consisting of integrated software and hardware.

The hardware consists of a set of synchronized "noise monitoring" boxes that include legally approved microphones that measure environmental noise, a smartphone to transmit the collected information and batteries that allow long periods of autonomous work.

The software includes the implementation of a noise protection server and multiple interfaces integrated in a crowdsourcing platform.

The server must collect all the data from the monitoring boxes and implement various noise measurement algorithms according to the locations of the noise monitors and to special noise regulation.

The interfaces should guarantee communication between 3 different types of users: town-halls must be able to report planned incidents; citizens can consult information on certified noisy activities and report noise related problems and the authorities should be alerted in case of possible illegal situations that should be verified.

The final system has to be:

- Easy to Use: automatic, self-organizing, etc.
- Inexpensive: based on 'COTS'
- Holistic: not just a measurement system
- Open and Inclusive: citizens can report problems – crowdsourcing
- Transparent: town halls will need to provide information
- Online: non-compliance will get identified ad-hoc

Market and Clients

Environmental noise means unwanted or harmful outdoor sound created by human activities which includes noise emitted by means of transport, road traffic, rail traffic, air traffic and industrial activity.

Since the environmental noise sources are so varied, noise pollution has become a problem that affects more and more people. High levels of noise can immediately lead to loss of hearing, while elevated and long term noise exposure can induce hearing impairment, hypertension and ischemic heart disease, annoyance, sleep disturbance and decreased school performance.

Not all sounds are considered noise and not all noises should be considered harmful. Although European and national laws define these distinctions, they are not always easy to interpret and to translate into a noise measurement system. The approved equipment to monitor noise is expensive and requires trained users.

This way, the simple and inexpensive environmental noise protection system described in the previous section would be useful to a multiple set of users, since nowadays nobody is immune to this problem.

However, when taking into account the features and functionality of the product to develop, it is obviously possible to distinguish some target audiences that will surely be most interested in this system, public authorities, town-halls and citizens will be able to acquire inexpensive and intuitive equipment to measure environmental noise which will help to determine if a particular situation is non-compliant with the law.

Citizens will be able to report high noise situations to the authorities and consult special information of noise licenses.

Town-halls will be able to manage the noise licenses and make special measurements in critical parts of the cities, which gives them control to reduce the environmental noise pollution. This can be done by consulting noise maps and see the incidents reported by citizens all over the city.

Authorities can be able to consult and control all noise incidents in the city, and consult all licenses issued by the town-halls, in order to enforce the law.

Chapter 3

Technological Tendencies

3.1 Crowdsourcing

The term *crowdsourcing*, first coined in 2006 by *Wired* magazine author Jeff Howe in an article titled "The Rise of Crowdsourcing"[1], describes an online, distributed problem-solving and production model. It consists in outsourcing tasks to a broad, loosely defined external group of people rather than a specific body, such as paid employees, as in ordinary outsourcing.

This idea of soliciting input from many sources is not new but today's technology makes it possible to recruit larger numbers of non-technical people to do increasingly complex and creative tasks.

Crowdsourcing can improve productivity while minimizing labor and costs but, on the other hand, as crowds are not employees, executives can't expect to control them: although they may not ask for cash, participants often seek other types of compensation in form of satisfaction, recognition and freedom[2].

An often cited example of crowdsourcing is Wikipedia (despite objections by its co-founder Jimmy Wales to the term[3]): instead of creating an encyclopedia on their own by hiring writers and editors, they gave a crowd the ability to edit the information on their own.

3.2 Geotagging

Geotagging is the application of geographical identification metadata - usually latitude and longitude coordinates, but it can also include altitude, bearing, distance, etc - to various media such as a geotagged photograph or video, websites, social networks, SMS messages, QR Codes or RSS feeds.

Nowadays, geotagging is extensively used. Everybody has a location-aware smartphone, with built-in GPS receiver and a mapping service, that lets the user transparently contribute to complex problem solving[4].

Images are one of the oldest types of media to use this. The JPEG format allows for geographical information to be embedded within the image and then read by picture viewers, which lets the exact location of where a picture was taken to be saved with the photograph.

A block of text of a piece of HTML code can also be geotagged by using specific standards in communicating the exact location to be attached to the HTML. Twitter and Facebook also support geotagging. By geotagging blog posts and updates on social network, the user can easily alert their friends to his location. He can also track himself through his own “lifefeed”.

3.3 Mobile networks and devices

Since 2005, we’ve been seeing a revolution in computing systems. Mobile devices, and more specifically smartphones, have turned into real computers, allowing their ever growing base of users to take advantage of these devices capabilities in a variety of situations.

Alongside this change, mobile networks are being used much more every year[5]. Mobile traffic has gone from less than 200 petabyte/month globally in the first quarter of 2010 to nearly 700 PB/month in the same period of 2012. Meanwhile, mobile subscriptions (cellphones, smartphones and tablets) have gone from 4000 million in 2008 to almost 7000 million in 2012, which represents an average of one subscription for each living human being.

Despite this huge increase in number in recent years, the growth is still happening. Most forecasts suggest mobile subscriptions will reach about 9000 million by 2017, and they’ll keep growing, but at a slower pace. On the mobile data front, monthly traffic will average 3800 PB from mobile phones and 4200 PB from mobile PCs and tablets, also by 2017, and this growth doesn’t show signs of slowing down, due to the increasing use of multimedia services, like high definition video and music streaming.

Chapter 4

4.1 Integrated Smartphone System

Currently there are available integrated smartphone systems that allow noise measurement and produces noise maps, these kinds of maps facilitates the monitoring of urban noise pollution.

This system allows collecting by crowdsourcing data noise pollution through a smartphone and transfers that data to a building map of the noise location. However, these kinds of systems have a huge limitation to surpass in order to be used by a regulator entity: the type of microphone used on smartphones are not certified and do not comply with the IEC 61672 sound meter standard nor the rules of meteorological control legislation available to measure acoustic sounds. This happens because that type of microphones is developed for the human voice. So, the result and the noise maps created can't be accepted and used by authorities to proceed and act in case of high noise pollution, because these systems don't follow all the legislation presented on the General Regulation of Noise.

An example of this type of system is:

4.1.1 Ear-Phone: An End-to-End Participatory Urban Noise Mapping System

This system is the first application of compressive sensing to environmental noise data collection and allows collect accurate noise pollution at a mobile device that provides accuracy noise map reconstruction using crowdsourcing. The system consists in a mobile phone and a central server, which contains signal-processing software to measure noise pollution, reconstruction software and a query processing software at the central server. Through the signal data the system presents noise maps.

The noise data samples obtained via crowdsourcing is incomplete, so it is used compressive sensing, focused and roadside noise pollution. It was also used compression of the spatial-temporal noise profile to apply reconstruction methods from compressive sensing.

Ear-Phone realized extensive simulations and real world outdoor experiments and the results show that this system and type of systems have reasonable accuracy[6].

4.2 Standalone Professional Systems

There are currently a myriad of professional systems perfectly able to measure environmental noise. These solutions come in multiple sizes and shapes[7]: monitoring fixed terminals, portable noise monitoring kits, mobile noise laboratories or simply portable sound meters.

4.2.1 Noise Monitoring Fixed Terminals[8]

Fixed terminals for noise monitoring are made for permanent or semi-permanent operation, when installed they can be left working unattended. As examples of this sort of terminals we looked at Brüel & Kjær's Type 3639 Family devices. These terminals are robustly-made boxes prepared for outdoor conditions and usually are compliant with noise measuring standards and regulations. They communicate via several interfaces (LAN, WLAN, 3G and CDMA) which enables them for remote operation. These terminals are usually built for continuous data streaming and are equipped with onboard memory for auto-send redundancy so no data is lost during transmission blackouts. Some can even monitor weather, have a camera support, send statistical data, respond to triggers on demand, have GPS or support hard disks[9].

Key Features:

- IEC 61672 Class 1 compliant
- Unattended operation
- Self-monitoring capabilities
- Multiple interfaces for remote operation
- Onboard memory
- Minimizes gaps in data sending
- Charge Injection Calibration
- Reliable security protocols

Limitations:

- Cannot be moved easily
- Installation by trained technicians
- Vulnerable to power outages
- Expensive

4.2.2 Portable noise monitoring kits

Relatively small and portable noise measuring terminals that are designed for temporary measurements. One good example of this sort of equipment is the Brüel & Kjær's 3655 Family[10]. These terminals have a quick set-up time and the units are lightweight for easy transport. They are equipped with a set of batteries and an external power source can be connected if necessary. Data communication is present and synchronization with a remote-PC can be achieved.

Key Features:

- Portable
- Quick assembly
- Standard Compliant
- Independent Power Source
- PC-synchronization

Limitations:

- Installation by trained technicians
- No statistical data
- Batteries only last one day
- No GPS

4.2.3 Mobile noise laboratories

Figure 1 - Example of a mobile noise laboratory

Some companies like S.C.S euroAcoustic offers complete mobile noise laboratory solutions. These laboratories are usually composed of a van with measurement equipment installed and can be dispatched to wherever a measurement is needed.

Key Features:

- Mobile
- Robust
- Completely customized to needs

Limitations:

- Requires at least one technician always present and perhaps a driver
- To the cost of the equipment, the cost of the vehicle is added. Not to mention possible parking costs
- Not really stealthy, easily visible

4.2.4 Portable Sound Meters

Simple professional sound meters are widely available with various specifications and therefore various price ranges which usually start at 300~400 US$[11]. As an example of such devices is the Dutch company Delta Ohm's HD2012UC[12]. A Class 2 compliant integrated sound level meter with data logging capabilities and able to capture and analyze the sound events.

Key Features:

- Data logging
- Capture and analysis of events
- Statistical analysis
- Impulsive and machine noise identification

Limitations:

- Handheld: Can become difficult to comply with the height positioning required by law
- No automatic data is exported
- Battery
- Requires technician present at all times
- Unless a tripod is used the technician's presence could affect results

4.3 Android – Sound Meters

Smartphones have been a prolific way for amateur developers to envision and put in practice their ideas. This is due to the low barriers to market, being relatively easy to develop an application that puts to best use the large gamut of sensors that

smartphones come with. These sensors and hardware modules include accelerometer, gyroscope, compass, GPS, microphone, GSM, UMTS and LTE modems, light and proximity sensors and sometimes even barometers[13].

There are many sound meters present in the Google Play Store, of which two of the best are presented here:

4.3.1 Sound Meter

This sound meter comes calibrated for various Android smartphones by the developer, guaranteeing the most accurate readings as possible. Nevertheless, this sound meter is still bounded by the hardware limitations, as smartphone microphones are developed for the human voice and therefore being limited in frequency and loudness (between 80 and 100 dB, depending on the model)[14].

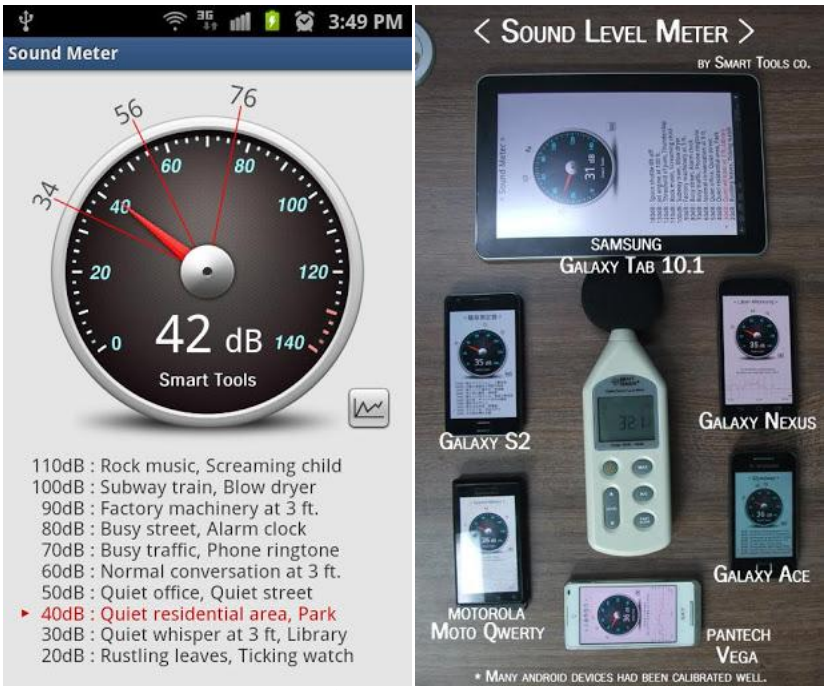

Figure 2 – Sound Meter interface and calibration

4.3.2 Noise Meter

This application was developed by the European Environment Agency, and takes user submitted measurements to build its own crowdsourced database of noise levels. The results can be seen at the website:

http://watch.eyeonearth.org/?SelectedWatch=Noise

but are still very sparse, due to the low installation base of users. Its limitations are about the same as every application that relies exclusively on the smartphone

microphone, as described previously (limited frequency range and bounded loudness scale)[15].

Figure 3 - Noise Meter interface

4.4 Noise Map Applications

4.4.1 Noise Observation and Information Service for Europe – NOISE

The *European Environment Agency (EEA)* made an attempt to expose the scale of exposure of environmental noise. They collected data from the countries in Europe and created a database on noise exposure in Europe, known as the *Noise Observation and Information Service for Europe - NOISE*.

It enables the user to use an interactive web tool (requires the *Adobe Flash* plugin), knowing the main noise sources in Europe with different scales of geographical representation. It also allows the download of data on noise exposure

corresponding to the strategic noise maps delivered by the member countries[16][17].

4.4.2 Laermometer

Laermometer is a community-based mobile noise mapping application that exploits the built-in microphones of mobile phones to create noise maps on-the-go. The software will automatically record sounds and send them to the server at the appropriate time. This means that the users do not have to use the application actively since it can simply run in the background.

It is possible to get an exact position of the device using *GPS* and, using geotagging, it can create sound level points, combining sound levels with *GPS* coordinates.

Laermometer consists of two main parts. The first is a mobile phone application, which is responsible for the sound recording and provides functionality like different visualization of sound points, administrating comments, viewing the noise maps at different points of time via the timeline etc. The second one is the server that is used to store, upload and retrieve sound points. Additionally, it offers a web interface to view and edit the data, make comments and add bookmarks.

4.4.3 NoiseMap

NoiseMap is a participatory sensing application for measuring noise. The measurements are sent to an urban sensing platform named *da_sense* where they are processed.

NoiseMap samples the incoming sound to translate the discrete digital signal to a *dB* full scale (*dbFS*) value and also requests the current location (latitude, longitude, altitude, accuracy). The smartphone (Android only) is able to provide location using cell tower or *WLAN* triangulation or *GPS*. The resulting samples are transmitted to the web service and written to the *da_sense* database.

Da_sense is important to *NoiseMap* for three key aspects:

1. Control over collected data.

   Da_sense provides user management that is working closely with the *NoiseMap* application. All data provided by *NoiseMap* is linked to a user account and can be made private. Private data is only visible to the user after login.

2. Incentive through information.

   All data is visualized using maps and graphs. Users are given direct feedback about all their data.

3. Open data access.

Da_sense allows data access on different levels. The easiest access is done using the web page. Raw data access is provided by a web service to access all public data and the member's own private data set[18][19].

4.5 Crowdsourcing

Over the past decade, the number of crowdsourcing platforms has rapidly increased and their areas of action have become wide and nearly unlimited: from education, to health, to social justice or even urban and transit planning.

The list presented below is in no way exhaustive, but represents a group of crowdsourcing platforms that can serve as starting point for the development of the interfaces of the project of the mobile environmental noise protection system that led to this study.

4.5.1 CitySourced

Figure 4 - CitySourced logo

CitySourced[20] is a real time, location-based, civic engagement platform that provides a mobile app and empowers citizens to identify and report non-emergency civic issues, such as public safety, quality of life, and environmental issues.

The service is part of a movement which aims to connect government and citizens through the use of technology, saving time and money.

A user captures a photo, video, or audio depicting a public problem and submits a report with the media. The location information is pulled directly from the device. Reports may be classified as based on the type of report submitted. The required follow up action is typically based on the report type. Once a report is submitted, feedback is provided to the user based on the action taken by the municipality.

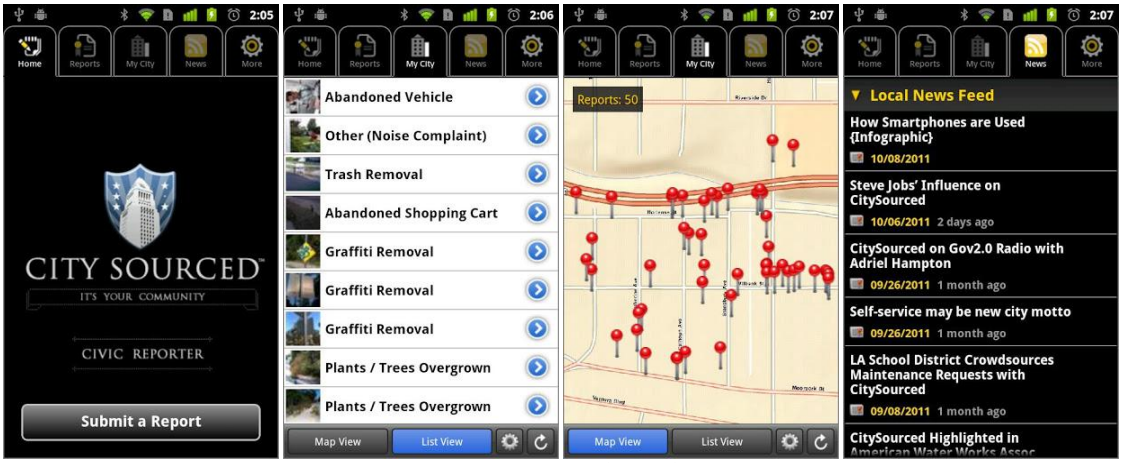

Figure 5 - CitySourced application interface

Key Features

- Leverages the latest technology: the application is compatible with any iOS, Android, Blackberry and Windows 7 device
- Simple: the system is hosted as *Software as a Service* (SaaS) so, after an account is created there is no further requirements for the user
- Real time reports: the application takes advantage of the camera and the GPS in the smartphone to capture a service request, gathering all available data
- Instant notifications: the system immediately and automatically pushes a status update back to the residents' mobile phone

Limitations

- The source code is not available: for municipalities that don't want the cloud, an on-premise solution is offered but in order to create a custom branded application which is built on top of the CitySourced framework, it is necessary to fill a form to contact their staff.

4.5.2 Managing News

Figure 6 - Managing News logo

Managing News[21] is both a product and a platform. Out of the box, it is a powerful news aggregator. As a platform, it can be customized to meet unique

workflow and visualization needs for all kinds of structured data, from CSV to RDF to custom XML formats.

The first step in using Managing News involves adding feeds to bring in content. Then, the information from these feeds will be imported into the site and it can be sorted and discovered via text-based search. Users can then navigate through the news, save their searches and additionally share posts.

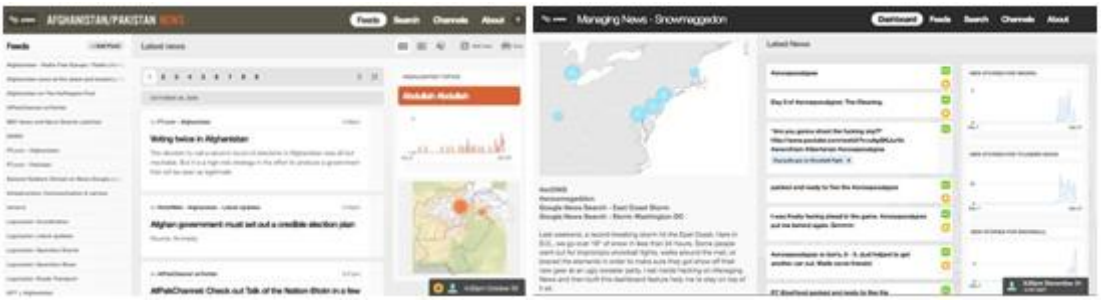

Figure 7 - Managing News web interface

Key Features

- Aggregation of RSS/Atom news;
- Possibility of showing news as list or on a map;
- Republish news by bundling articles into channels: channels provide an additional way to check, display, and redistribute content;
- Configurable location tagging;
- Configurable maps;
- Flexibility: the system can be quickly customized and it is very easy to build extra features on top of it.

Limitations

- This product is very different from the environmental noise protection system in development. It would be necessary a great level of customization.

4.5.3 Ushahidi

Figure 8 – Ushahidi logo

Ushahidi[22] (Swahili word for "testimony") is a web and mobile platform for information collection, visualization and interactive mapping through crowdsourcing.

The website was initially created to map reports of violence in Kenya, sent via SMS, email or the web, after the post-election fallout at the beginning of 2008 but the software developed has since been improved, released freely and used for a number of similar projects around the globe.

Figure 9 - Ushahidi web and app interface

Key features

- Free and open source: the Ushahidi platform is free for download and use. It is released under the GNU Lesser General Public License;
- Interactive mapping: the platform gives rich information mapping tools;
- Dynamic timeline: tracks reports on the map and over time. The data can be filtered by time and it is possible to see when things happened and where, as it's also tied to the map;
- Multiple data streams: allows easy collection of information via text messages, email, twitter, web-forms and over mobile apps (iPhone, Android);
- Fast and simple: Crowdmap, the hosted version of the Ushahidi platform, allows people to crowdsource information in two minutes without having to install it on their own web server.

Limitations

- The SMS service is paid and the reported events have to be mapped based on the information provided in the incoming text messages, which can be time consuming[23].

Chapter 5

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