Measure and map noise pollution with your mobile phone

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Abstract

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Links

Original « Instructables » submission :	http://www.instructables.com/id/Measure_and_map_noise_pollution_with_your_mobile_p
DIY for CHI workshop website:	http://people.ischool.berkeley.edu/~daniela/diy
Full workshop proceedings (Print):	http://www.lulu.com/content/6612273
Full workshop proceedings (PDF):	http://www.lulu.com/items/volume_64/6612000/6612273/1/print/0329_diychi.pdf
CHI 2009 conference website:	http://www.chi2009.org
NoiseTube project website:	http://www.noisetube.net

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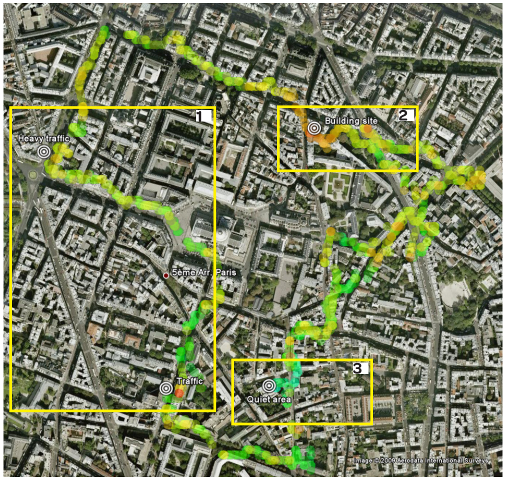
In this "Instructable" you will learn how you can use your GPS-equipped mobile phone as a mobile station to measure your personal exposure to noise and participate to the collective noise mapping of your neighbourhood or city. The maps can be visualised using Google Earth.

Noise pollution is a serious problem in many cities. Although authorities in some big cities have launched campaigns to monitor the problem, the maps they create are not always easily accessible and are usually not detailed enough to grasp the variations (in time and space) in the noise people are exposed to. However, using our new technologies you can help to improve the monitoring of such environmental issues by contributing to the noise mapping of your neighbourhood or city and thus participate to a kind of "Wikimapia" of noise pollution.

NoiseTube[1] is a research project of the Sony Computer Science Laboratory[2] in Paris. The project is focused on developing a new participative approach for monitoring noise pollution involving the general public. Our goal is to extend the current usage of mobile phones by turning them into noise sensors enabling each citizen to measure his own exposure in his everyday environment and participate in the collective noise mapping of his city or neighborhood. More generally this research project investigates how the concept of participatory sensing can be applied to environmental issues and especially to

1. http://noisetube.net/
2. http://www.csl.sony.fr/



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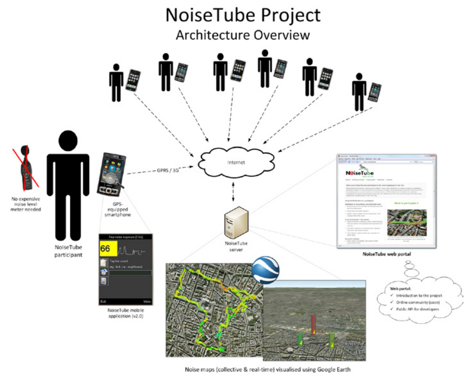


1) An example of a noise map created with NoiseTube. The map shows the noise level data - collected with the NoiseTube mobile application - as an overlay on top of a satellite picture of the centre of Paris in Google Earth. The colours correspond to a scale of loudness (green = most quiet areas, red = noisiest areas).

2) A building site Red circles represent loud sound measurements (> 80 dB(A))
3) A quiet area Green circles represent low loudness measurements (around 40 dB(A))
4) Overview of the NoiseTube architecture.

monitor noise pollution. Participatory sensing advocates the use of widely deployed mobile devices (e.g. smart phones, PDAs) to form distributed sensor networks that enable public and professional users to gather, analyze and share local knowledge.

By installing a free application on your GPS-equipped mobile phone, you will be able to measure the level of noise in dB(A) (with a precision of few decibels compared to professional devices), comment on how you perceive the noise (tagging, subjective level of annoyance) and send all information (timestamp + geo-localized measurements + human input) automatically to the NoiseTube server through your phone's Internet connection. Afterwards the (collective) results can be visualisated on maps, as shown by the example in the 1st figure.

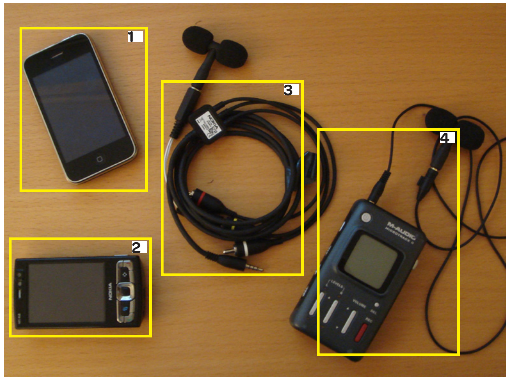
Motivations to participate in the NoiseTube experience

1. Measure your personal sound exposure and be more aware of your environment

How much decibel am I exposed to during my day? Such information is currently hard to obtain for citizens. Thanks to our application you will be able to measure your exposure in dB(A) in real-time without the need of an expensive sound level meter. We think that personalized environmental information may have a bigger impact on public awareness and behaviour than the global environmental statistics currently provided by governmental agencies.

2. Participate to the monitoring/mapping of noise pollution of your city

With your mobile phone you (and your group) can gather geo-localized measurements, annotate them and send them automatically to map local noise pollution, providing helpful information for local



1) An iPhone application will be released soon.
2) A Symbian/S60 compatible mobile phone with GPS and internet connection. We recommand the Nokia N95 8GB (pictured) or a similar model.
3) Optionally you can also use an external microphone.
4) A portable digital audio recorder. To be used with v1.0 of the NoiseTube software. We recommend the M-Audio MicroTrack II (pictured).

communities or public institutions to support decision making on local issues without waiting for officials (environmental agencies, government funding for expensive measuring campaigns) to turn their attention to your neighbourhood.

3. Help scientists to better understand noise from your experience

Unlike current noise pollution data coming from static sensors installed on fixed, specific locations, your 'people-centric' data could have great value to scientists to better understand the noise pollution issue through the people's exposure.

NoiseTube architecture

The NoiseTube platform consists of an application which the participants must install on their mobile phone to turn it into a noise sensor device. This mobile application collects local information from different sensors and sends it to the NoiseTube server, where the data from all participants is centralised and processed. The 2nd figure show an overview of this architecture.

An overview of the NoiseTube architecture variation ("v1.0") which uses a portable digital sound recorder and a desktop application to process audio recordings.

Because the mobile application is the most important element for our participants we will now discuss it in detail in step 1.

1. Equipment and software

The mobile application

Features

- Measuring and visualizing your the noise level you are exposed to in real time
- Tagging to comment on the measurements (e.g. the source of the noise, rating the perceived annoyance, ...). This information is used to add a semantic layer to the noise maps that are created.
- Automatically sending the (geo-localized and timestamped) data to your account on our server to update your personal "exposure profile" and the collective noise map.

Requirements

- A phone with a build-in GPS-chipset or an external GPS-receiver that can be connected to the phone through Bluetooth.
- A phone supporting the Java J2ME platform (CLDC/ MIDP profile with the extensions: JSR-179 (Location API) and JSR-135 (Mobile Media API)).
- A data plan subscription for Internet access (through GPRS/EDGE/3G).

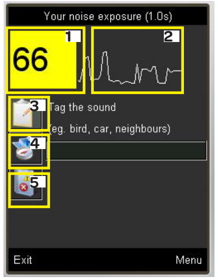
Notes:

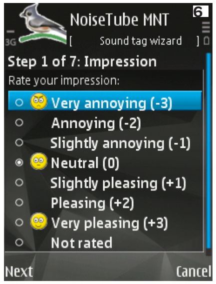
- For the moment, the application has only been thoroughly tested on the Nokia N95 8GB and the Nokia 6220C. Other brands/models may or may not work. In a few weeks we plan to release a version for the Apple iPhone[1]. You can subscribe through NoiseTube.net to stay informed about this and other future releases.
- To achieve credible decibel measurements it is recommended that only supported (calibrated) telephone models are used.

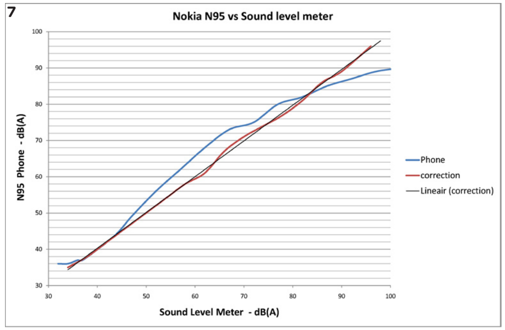
Alternative approaches

Phone + external microphone

Instead of using the built-in microphone, you can plug an external microphone. On figure 1 you see a custom-made external microphone for the Nokia N95[2]. If you are using an external microphone, we advice you to place the microphone not too close to your face to avoid only measuring your own voice; attaching the microphone close to your wrist is a good option.







1) the Leq in decibel dB(A)
2)The history of the measures
3) The Tagging component: to tag a measure with your notes
4) The localisation component: to switch between automatic/manual mode. (and so manually enter a location e.g. an adress)
5) for experts: to see the logs of the applications
6) An example of what a subjective input component could look like. This was partially supported in v1.0 of the NoiseTube platform and will be improved and merged back into v2.0 in the near future.
7) Result of the calibration: - Blue function = original response (for given loudness measured by a sound level meter (e.g. 60 db(A), the corresponding result with our application (e.g. 67 dB(A)), - Red function = response with a very small deviation, after applying a corrector.

Digital sound recorder + mobile application + desktop application

In the first version of Noisetube, the loudness measurement was not done in real time by the mobile application. Instead, a digital sound recorder (e.g.: M-Audio MicroTrack x series[3]) was used to record the ambient sound. The mobile application (v1.0) aimed to localise the user (through GPS) and to facilitate commenting (tagging, rating, ...). A desktop application was then used to extract the loudness measures from the recorded sound, combine that data with the location track and user comments and send this information to the server. Figure 2 shows an overview of the architecture of Noise-Tube v1.0.

2. Using the NoiseTube mobile application

Getting started

Once you have created an account on the NoiseTube website[4], found the necessary equipment and installed our software, you can start using the NoiseTube application.

1) You will first have to authenticate yourself with your account details. Once you successfully logged in once, the next time you start it the application will bypass this step.

2) You can now start measuring and contributing to the NoiseTube project.

The user interface

The screenshot in the first figure shows the user interface. Below we discuss the different parts, each of which corresponds to a principal feature of the application.

1) Measuring the loudness of ambient noise.
The measurement will start automatically. You can see the current loudness value - measure in dB(A) - at the upper-left. To add meaning to this value it is associated with a colour representing the potential health risk of the current exposure level:

1. http://www.apple.com/iphone
2. http://shelbinator.com/2008/05/04/n95-external-microphone
3. http://www.m-audio.com/products/en_us/MicroTrackII.html
4. http://noisetube.net/
5. http://en.wikipedia.org/wiki/Sound_level_meter
6. http://en.wikipedia.org/wiki/A-weighted
7. http://en.wikipedia.org/wiki/Pink_noise

* < 60 dB(A): Green (no risk)
* >= 60 and < 70: Yellow (annoying)
* >=70 and <80: Orange (be careful)
* > 80: Red (risky).

A history curve is also drawn to see the evolution of the measured loudness. To better understand what is actually measured refer to the 'About loudness measuring' section below.

2) Commenting
Tagging adds a layer of meaning to the physical measurements to inform the community and to visualize the nature of the noise on maps afterwards. Like tagging movies on YouTube or webpages on Delicious, you can tag the noise measurements by adding any free words separated by a comma (e.g. the source of the noise or the context, a rating, etc..).

Noise is a complex phenomenon due to the highly subjective way humans perceive it. To study these subjective factors we will add more subjective components to the mobile application to use it as a "(social) annoyance meter" (the 2nd figure shows a preview of what this could look like) and build subjective maps of noise pollution.

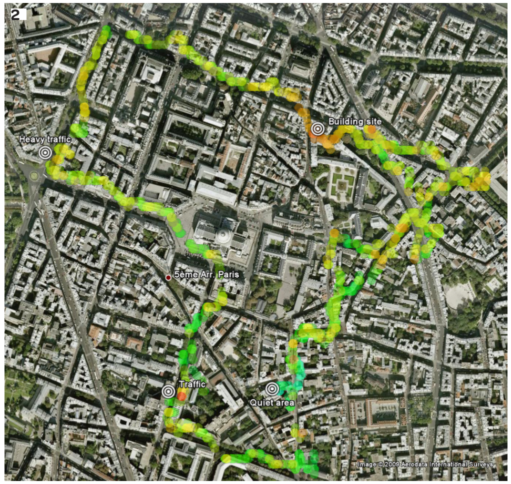
3) Geo-localizing measurements
The user can switch to between an automatic (using GPS) or a manual localisation mode by clicking to the localisation icon (see figure 1).

Upon starting the application will activate the automatic mode and try to localize the user using GPS. If it does not succeed (e.g. because of an indoor situation) it will switch to the manual mode, where the user has to enter his location (e.g. an address, the subway station line). It is also possible to select your current location from a list of predefined locations. These locations can be personal "favourites" (e.g.: home or office) or public places (e.g.: streets, subway stations).

More information
About loudness measuring. The loudness meter displays the equivalent continuous sound level (Leq)[5] measured in dB(A)[6] of the sound recorded at a given interval of time. At each cycle the application records the environmental sound (at 22500 Hz, 16bits) during an interval of time, then processes the signal to extract the Leq value. Two intervals are possible: 1) Slow response (1 second, the default mode), this allows you to measure the slow sound variation, useful for constant or background noise; 2) Fast response/short Leq (125ms), for time-varying sounds (e.g. short events). The fast response mode is currently still experimental so for now we advise to use the slow response mode.

About sound calibration and information credibility
To calibrate our application to get credible information on a Nokia N95 8GB, we used a sound level meter. We generated a pink noise as source of noise and compared the decibels measured by a sound level meter and those measured by our application on the N95 phone at different levels of loudness (every 5 dB, from 35 dB to 100dB). Figure 3 shows a graph of this the values we registered. We obtained a curve with a precision around +/- 10 dB(A). After using the inverse of this function as a corrector we then obtained good results (precision of +/- 3 db). We plan to do the same calibration with the future iPhone version.

Once you have understood how to use the NoiseTube application, we invite you to test it on the street in your neighbourhood!



1) Visualisation on Google Earth of the real-time monitoring of the noise exposure of anonymized participants (Paris).
2) A NoiseTube noise map of streets in Paris (5th arr.)

3. Visualizing the results

Two visualizations are currently accessible.

Real-time Monitoring of people's exposure
Real-time monitoring is proposed to visualize the collective noise exposure of participants using Google Earth. You can see it by going to http://noisetube.net/public/realtime.kml. A user is represented by a cylinder whose height and color are proportionate with the loudness (Leq measured in dB(A)) of the user's sound exposure.

Map of noise pollution in your city
You can also see the current map of your personal exposure by going to your account and selecting "My map" (or directly via: http://noisetube.net/users/{username}/map.kml). To see the collective sound exposure map go to the public map. Each circle signifies a loudness measure (the colour being proportionate with the loudness level). On top of this physical layer there is a semantic layer describing the meaning of the measures (i.e. the sources of the noise).

4. Future research and conclusion

True to the "beta" spirit of Web 2.0 we decided to open our platform to everyone, despite the early stage of development. In the near future updated versions of our tools will offer improved and new features. Our research and development will continue along several tracks:

Calibration

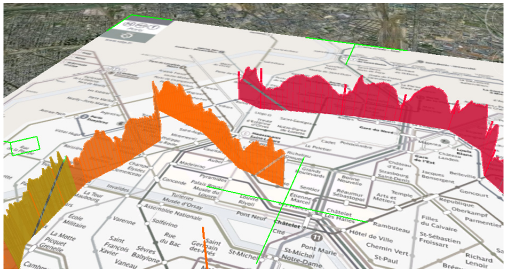
Without proper calibration, sensor devices produce data that may not be representative or can even be misleading. So how can we calibrate hundreds of different mobile phone types or other sound recorders without using an expensive sound level meter each time? We propose to investigate such research questions by different tracks, where calibrated phones or acoustical stable locations can be used as reference points to automatically (re)calibrate a phone (e.g. calibration between 2 phones, connected through Bluetooth, where one is the reference and the other is the phone to calibrate).

Indoor localization

The GPS system does not support indoor localization. Because most people spend a lot of their daily lives indoors this is an important shortcoming which we have partially solved through manual localization (see step 2). However, there are technologies which can act as alternatives for GPS in indoor scenarios. One of the more promising (and widely studied) approaches is GSM-based positioning. Such technologies could be especially helpful to investigate noise in subway (such as Paris' Metro network), which are known to be very noisy environments. We have already done some experimentation with temporal markers and a reconstruction of locations by interpolation (see figure). However, by employing GSM-based positioning (identifying antennas in different stations, to automatically detect the location of the user), we expect we will be able to produce more accurately localized measurements in this special environment in the future.

Social aspect: Community building

Projecting noise pollution data onto maps is the common feature. But recording sound exposure from the people's activity allows also us to gather a kind of data which is more people-centric and not only place-centric data which is collected by traditional static sound level



Sound level measurements along subway lines in Paris. The map was created by using temporal markers which where afterwards manually matched with subway stations.

meters put in streets. From this observation we will look into more social-related features. For instance, creating personal noise profiles containing your noise exposure in temporal and geographic dimensions and a list of your own tagged sources of noise, providing a way to compare people and find similar profiles in order to support collective action.

Conclusion

In this "Instructable" we have presented a new way to monitor and map noise pollution thanks to the participation of the people. The NoiseTube platform enables you to contribute to a distributed noise measurement campaign using your mobile phone. This platform is still under heavy development and the near future will bring further improvements. However, we would like to invite you to join the NoiseTube community and try out our software.

If you have any questions, suggestions or other comments, please do not hesitate to contact us or react through the comments on this Instructable. Furthermore we would like to stress that we are open to collaborate with both public or research organizations.

Further reading

To find out more and stay informed about the NoiseTube project please visit our website at www.noisetube.net. If you would like to read up on the scientific background of this work please refer to these papers:

* Nicolas Maisonneuve, Matthias Stevens, Maria Niessen, Peter Hanappe and Luc Steels. NoiseTube: Measuring and mapping noise pollution with mobile phones. Submitted to 4th International Symposium on Information Technologies in Environmental Engineering(ITEE 2009), Thessaloniki, Greece. May 28-29, 2009. Under review. PDF
* Nicolas Maisonneuve, Matthias Stevens, Maria Niessen, Peter Hanappe and Luc Steels. Citizen Noise Pollution Monitoring. Submitted to 10th Annual International Conference on Digital Government Research(dg.o2009), Puebla, Mexico, May 17-20, 2009. Under review. PDF

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