A noisemap of the Rolex Learning Center

Nikolaos Maris
Centre de Recherche et d'Appui pour la Formation et ses Technologies (CRAFT), EPFL

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ABSTRACT
The library of EPFL, known as the Rolex Learning Center, provides an opportunity for conducting educational research as it is a huge studying area of 800 seats. The public nature of these spaces requires a minimalistic approach in order to avoid breaking privacy rules or distracting students' study. This report describes a noisemap that shows quiet and noisy areas without interventing a lot with the students' activities.

INTRODUCTION
The Rolex Learning Center, is an example of the interface between formal and informal learning. Inside the building, the territories are not defined explicitly as there are almost no physical boundaries which allows the students to implicitly negotiate the area of their next activity. The curves of the floor create hills and valleys that influence these emergent practices. It is spread over one single fluid space of 20,000 sq meters that includes libraries, social spaces, spaces to study(with 860 seats), restaurants, cafes and open spaces of contemporary architecture.

Figure 1. Students sitting on beanbags

Students use the space in several ways. They tend to study individually in the library, do their teamwork in isolated tables or sometimes even have organized meetings with tutors on the restaurant. Also, they tend to practice informal learning on some curvy parts of the floor by sitting on beanbags as shown on figure 1. In a similar sense, our approach is to support these emergent practices by providing information about the learning activities that take place inside the building. We refer to the design principle of non disturbing technology as modest computing. In contrast, smart computing aims on understanding behavioral patterns in order to predict them and enforce a pedagogical scenario. As a result, smart computing can not be applied in our case as we cannot establish a fully controlled experiment for informal learning at a huge space like the Rolex Learning Center.

The principle of modest computing is applied at the Rolex Learning Center through the notion of livemaps which are maps that make visible, aspect that are usually invisible. We present a noisemap that visualizes the noise intensity in the whole area of the Rolex Learning Center. Its first potential application is to support people on finding a less noisy area. Another one is to report statistics for the committee that decides the policies for noise regulation. Another is to conduct behavioral experiments and use the noise intensity as a dependent variable. Finally, a sound processing step can be used to detect specific activities of the students like collaboration among students. However, all applications have to preserve privacy rules and avoid distracting students' study.

The remainder of this report is organized as follows. After reviewing the literature, we proceed by analyzing the requirements and explaining our design decisions. Then we present the system components along with limitations of the approach from an educational and a technical perspective.

RELATED WORK
The design principle of modest computing is described at Tolmie et al. as unremarkable computing where they also explain its significance.[15]

A platform that can be used as a sensor is mobile devices like smartphones and laptops due to their portability, context sensitivity, connectivity, and ubiquity.[7] For example, mobile phones have been used to characterize people movement[16] by locating their positions and their bluetooth signal (a list of friends within an circle of a few meters). Using mobile devices as a sensor network is known in the literature with several names. Burke et al. call it participatory sensing[1] and then Eisenman et al. call it people-sentric sensing[4], both focus on applications, while Krause et el. call it community sensing and focus on traffic monitoring from a technical point of view[8].

Indoor noisemaps have been neglected compared to measuring the outdoor noise pollution as the latter is driven by governmental regulations. For example, the European Union requires member states to regularly provide accurate mappings of noise levels throughout all agglomerations with more than 250.000 inhabitants and to make this information publicly available through adequate web-interfaces.[2] For establishing an outdoor noisemap, Santini et al. use specialized hardware[13], whereas Schweizer et al. show a real-time noisemap of Frankfurt[1] through collecting data from mobile phones[14]. Rana et al. try to predict the noise levels in all points of the outdoor noisemap.[11] Although, we also collect noise levels from mobile devices, our purpose is to generate an indoor noisemap.

APPROACH

In contrast with indoor noisemaps, outdoor noisemaps have to follow governmental regulations in order to report places with abnormal absolute values. A phone used as an outdoor noise meter has to be calibrated using a commercial sound level meter. Once the difference between the two measurements is detected, the phone can add this difference to all of its future measurements. However, in indoor noisemaps the focus is on the difference of the noise levels between areas, so there is no calibration phase. On the other hand, one technical barrier for the establishment of indoor noisemaps is the low accuracy of the positioning systems that are typically deployed in most mobile devices. As each wireless router has a limited area of coverage, we locate someone by finding the router he is connected to. This custom WiFi positioning system allows us to use not only the phones as sensors but also the laptops which usually do not even have a positioning system.

SYSTEM ARCHITECTURE

Figure 2 shows the noisemap which is available through a web interface that works independent of the sensory system. Students who do not contribute in collecting data can still access the noisemap. When students want to measure and send the noise level of their area, they have to download and run the application from the web interface to their PC or MAC. Alternatively, we provide an application for mobile phones that can be downloaded and installed from the Android Market. For both applications, the user interface is an embedded web browser that shows the web interface. When the application starts, it detects the location of the device. Additionally, while the application is running, the noise intensity is captured every minute and sent to a web server along with the location of the device.

Noise analysis

The sound that comes to the human ear is nothing more than a mechanical wave that is an oscillation (a periodic variation) of air pressure. The energy carried by the sound converts back and forth between dynamic (in the form of air compression) and kinetic energy that makes an inner organ of the human ear move thus triggering the corresponding nerves. Sound pressure p is the difference between average local air pressure and the pressure in the sound wave. The sound pressure in air p_{ref} is used frequently as a reference. Effective sound pressure (usually over an interval of one 8th of a second between samples) is measured as $p_{rms} = \sqrt{\frac{1}{n}\sum_{n} p^2(t)}$. Sound Pressure Level is the ratio of the last two quantities, so it is dimensionless, and it is measured in dB as $L_p = 20log_{10}\left(\frac{p_{rms}}{p_{ref}}\right)$. When our application runs on the students' mobile device, it reads the sound pressure level from the device.

[1] Available at http://www.da-sense.de as of 30/01/12

A-weighting is frequency weighting of the Sound Pressure Level [6] in order to get a more perceptually-correct loudness metric. However, we acknowledge that the knowledge around how the human ear perceives a sound is limited.[5, 3] There are even commercial sound level meters that do not do A-weighting and they are known as Z-weighting (from Zero-weighting). And this is especially true in the case of detecting annoyances while studying. A sound that is disturbing one student may not even be detected by another one. Additionally, a meaningful noise is known to be more annoying than a meaningless noise.[12] As a result, we do not focus on the accuracy of the measurement but on the Sound Level Pressure along with the number of measurements as even the act of measuring noise is an indication that the student needs a silent place. Once a Java application runs on a laptop or an Android application runs on a mobile phone, the mobile device acts as a sound level meter that sends to a web server the noise level over the last two seconds.

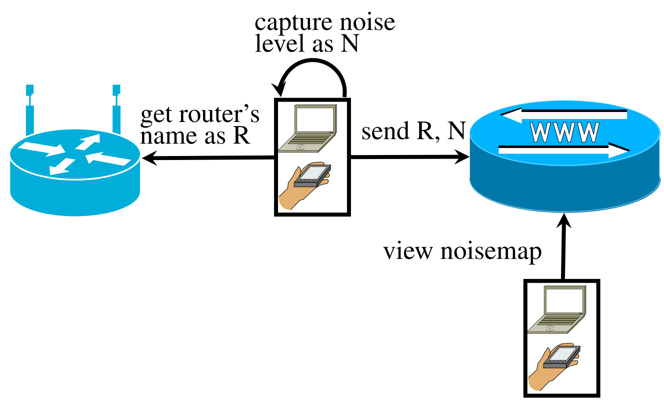

Figure 3. System architecture

Localization

As the Global Positioning System used in most mobile phones is not accurate for indoor positioning[9], a custom Wi-Fi positioning system was made for locating the students at the Rolex Learning center. The system is privacy preserving as it detects the location of the access point that the student's mobile device is connected to and not the location of the student. Due to the density of the Wi-Fi infrastructure of EPFL, the accuracy of the system was good enough for our observations (the noise level within 1-2 meters is assumed to be constant) while the lack of complex calculations makes it energy efficient for usage on mobile phones. Furthermore, the system works in cases where students want to measure and report noise levels not from their mobile phone but from their laptop.

An alternative positioning technique could be trilateration which locates the position based on the position of the three nearest access points. However, the distance to an access point is not proportional to the Wi-Fi signal strength especially in the Rolex Learning Center as there are reflections from the glassy and curvywalls and from the curvy floor and

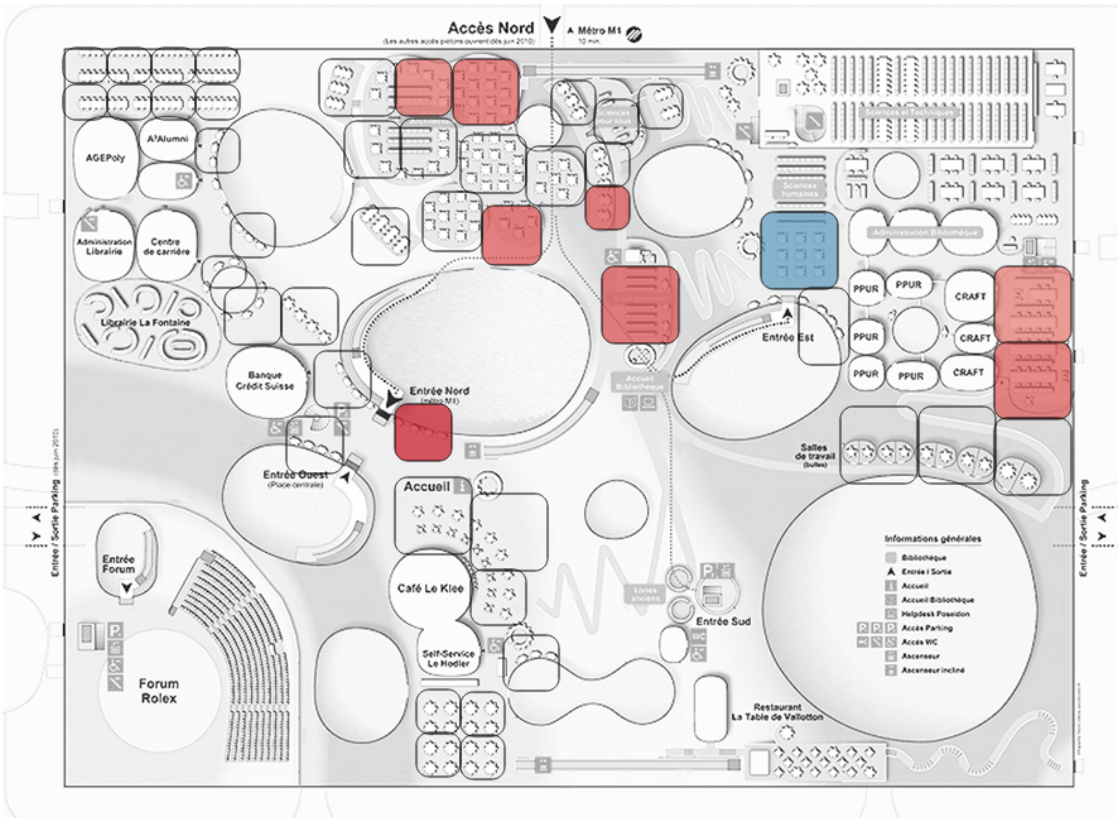

Figure 2. Average noise levels within 1 hour

interference between access points. Additionally, the fingerprint of the signal strength (of different access points on several reference locations) depends on the internet traffic initiated by the connected mobile devices.

Visualization

After the past experience in our laboratory on location-based applications[10], we partition the floor plan into areas of interest rather than into a coordinate system. The areas of interest are studying areas that are big enough to contain study tables but small enough to be acoustically separated due to the height of the curvy floor. Moreover, adding a layer of Scalable Vector Graphics over the floor plan is a general technique that can be used also for future maps of the Rolex Learning Center. Finally, the user interface is minimal as the sensory system of the application runs automatically as long as the application is running.

DISCUSSION

As the microphones are not designed to act as sound level meters and the Wi-Fi receivers as positioning systems, we have to face several challenges. Participatory sensing requires a bootstrapping process where the students start providing the initial data. Additionally, getting information from the hardware (the microphone and the Wi-Fi receiver) requires the installation of an application on the students' mobile device. However, the initial usefullness of the system is expected to overcome the usability issues as students who are annoyed by the noise of their area, are expected to be initial contributors of data. Then, enabling the students to interact with each other in a location-based scenario is expected to keep their motivation to contribute in collecting data.

CONCLUSIONS AND FUTURE WORK

Presenting noisy and less noisy areas of the library of EPFL enables the students to see a big picture of their activity. As EPFL provides wireless internet to almost all areas of the campus, we plan to deploy the system also in other areas of the EPFL campus. Additionally, providing a second map that shows the number of students at each study area (citymap) will help on the interpretation of both maps and also fix some technical problems. For example, a localization issue is that on peak hours a student's mobile device may connect on a further router that has a better signal strength.

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