Discussing Spatio-temporal Coverage in Urban Sensing Applications

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ABSTRACT

Mobile sensing - the idea to use smartphones as sensor nodes - is picking up steam inside various communities. A major challenge with mobile sensing is the uncontrollable sensor movement. It depends on the people and they might not measure where measurements are needed. Thus, the resulting data can become almost unusable. The main research question we want to ask in this position statement is: *How can we influence and improve the spatio-temporal coverage in urban sensing applications?* We will try to give some first ideas, by sharing the experience we gathered implementing Noisemap and the Incident Reporter application.

Author Keywords

Urban Sensing; Location-awareness; Spatio-temporal Coverage.

INTRODUCTION

Today everybody can be a mobile sensor. Through the accelerated adaptation of smartphones mobile devices are carried all day. They are equipped with an ever increasing amount of new sensors. People take pictures, record sounds, and share location information using their devices. Furthermore, the captured information can easily be shared using the build in wireless connectivity. Hence, more and more people are engaged as *mobile sensors* collecting data everywhere and all the time. This data collection process is known as urban sensing, participatory sensing, human-centered sensing, or opportunistic sensing [1].

Most of the times a urban map is created that provides valuable information to citizens and other urban stakeholders. But the collected data and the applications can be used for different use cases. For example, applications have been implemented for urban infrastructure (e.g., NoiseTube, FixMyStreet, NoiseSpy), disaster management (e.g., Outbreaks Near Me, Ushahidi, RapidSMS), and health monitoring (e.g., DietSense). Over the past years several key challenges of urban sensing [4] have been identified and investigated (e.g., energy consumption of mobile devices during sensing campaigns, the recruitment of participants, and privacy issues). One key challenge has not been investigated enough. In order to enable more complex applications to take advantage of the data we need to discuss the challenge of a controlled spatial-temporal coverage. What does this mean?

The movement of a mobile sensor is controlled by the user. From he perspective of the data collector this movement this might seem random and, more importantly, almost uncontrollable. This poses a set of hard challenges which we are going to discuss in the next section. What we want is either a high spatio-temporal data coverage and a high data quality (e.g., for training machine learning models). Or, for sensing campaigns (e.g., during disaster response and recovery) we want a high peak in data density for a small set of specific locations at a very specific time. In the past, some research has focused on increasing the spatio-temporal coverage [5]. However, in order to increase and modify the spatio-temporal coverage significantly, we have to take the user into account.

The challenges and design considerations we are going to present are based on our previous experience with developing urban sensing applications for different use cases. First, Noisemap [3] for measuring urban noise pollution. Noisemap is a opportunistic sensing application with the goal of covering as much area as possible by people measuring whenever there is a chance to measure. Second, the InfoStrom Incident Reporter [2], which can be used for creating incident reports. The reporter has a campaign model, where information from specific locations is requested as the incident happens. These experiences help facilitate the challenges and we hope they provide some brainstorming ideas.

CHALLENGES IN SPATIO-TEMPORAL COVERAGE

Deriving valuable information from urban sensing applications is highly dependent on the gathered data set. Noise, missing data or statistical bias makes creating highly accurate machine learning models almost impossible. Sometimes it is hard to even infer any result at all. In urban sensing applications most of the data is created in heavily trafficked road sections or at crowded places. In contrast, in much less crowded regions or at uncommon time periods no or few data is gathered. This phenomenon results in the main research question: "How can we influence and improve the spatio-temporal coverage in urban sensing applications?". In the following paragraphs we splits this into a number of smaller questions.

The first questions is: "How can we make people aware of the spatio-temporal coverage?" On one side, opportunistic applications are running as background processes. Here, people are unaware if they are gathering data at a common or uncommon location. On the other side, the campaign model requires direct feedback for the users on where she/he should measure. The feedback needs to be unobtrusive. But, even if users are made aware where they should measure, they might chose not to do so. They need some extrinsic motivation to change their usual measurement behavior.The definition of good coverage also depends on the applications itself. Some

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applications need an equal distribution of measurements in space and time (e.g., Noisemap). Other applications are only interested in specific locations at certain times (e.g., Incident Reporter). All of this has to be considered when trying to guide people to the right location.

The second questions is highly related. It ask: ”How can we provide a feedback channel to the user?”. Participants are key to the sensing campaign. Mobile sensing’s unique promise is to provide a scale not seen in any other sensing approach today. But people must be motivated in order to contribute. They need to receive a value from using the application, either a real value or a perceived value. If user contribute data to a project but there is no direct outcome it is hard to keep them motivated. They will just stop using your application. Currently there is some research looking at the motivation to use an application. But the real question is not about motivating users once but keep them using the application over time. For that the experience shows that users need to receive feedback on their absolute performance, on their relative performance, and how their data is used.

Third, to increase spatio-temporal coverage, another important question is posed by the understanding of the existing data sets. This is used to identify open or low-density measurement spots. Most of the times, measured data is displayed on maps, which are not sufficient in order to detect these spots. This leads to a whole set of questions related to preprocessing and analyzing the data. For other users such as citizens or the city administration, it is more difficult or almost impossible to identify areas of low coverage, depending on visualization. This leads to the question of: ”How to easily identify spots of low coverage in the gathered data sets?”.

Fourth, there are systematic problems with user selection in different areas, which have to be considered. There might be a high user density in residential areas. Much higher as compared to industrial or rural areas. But those users might not be present during their daytime jobs. Noisemap sample noise pollution and there might be a large different in day and night noise levels in industrial areas. In those areas, however, no sensor readings might exist at night. Furthermore, there might be very crowded areas (e.g., shopping or city centers) or rural areas. These aspects can be summarized in the question: ”How to select and motivate appropriate participants to increase spatio-temporal coverage?”.

IDEAS FOR SPATIAL-TEMPORAL COVERAGE

We present design considerations for coping with the challenges presented in the previous section, from our past experience in developing two different sensing application.

First, we can make a technical consideration. For some applications it might be easy to guide people to areas of low coverage (e.g., by displaying a map with traces or other navigation aids). In contrast, some applications might collect data in the background. In this case, easy navigation aids cannot be displayed. Thus, it is necessary to guide people before they join a sensing campaign or to use other types of interaction like voice navigation.

Furthermore, depending on where open or low-density measurement spots are located, appropriate participants have to be found. People are more likely to collect data near their residence. By inferring movement patterns the appropriate participants can be found. This could for example be used to guide people into regions a certain distance (e.g. 500m) from their home or work location. In Noisemap something like this was implemented. The users would see bonus areas scattered in the same region they are most active. These bonus areas would help them gather more points for the ranking. We observed that users like incentive features as long as they are unobtrusive. Other incentive features, such as achievements or a ranking system worked much better, but only provided a general, not specifically spatial, motivation. Both features must be combined for a better spatial incentive system. Users might get feedback on their measurement history, which displays open areas. Combined with a goal to achieve a 100% coverage, traditional incentive mechanisms can be adapted. Other ideas revolve around competitions between participants in spatially restricted areas.

Without the use of incentives, people are intrinsically motivated to gather new data. In this case we can use the principal ideas of viral marketing. Here the action of an individual influences the action or attitudes of other people. In social media this is mainly triggered by word of mouth (WOM). Attracting only a few (but the right) people in the beginning of a sensing campaign, motivates other people to contribute (e.g. during crisis situations). From past experiences we have learned that these kind of mechanisms apply, but only if people see a direct value as a result from their actions. Often people report valuable information, but their is no feedback. In this case a bi-directional channel between the moderator of a campaign and the participant is helpful. Stating that a problem was fixed, because you sent data to the local administrative or displaying the collected data on publicly available platforms, is a good start. Nevertheless, though in these scenarios a high dissemination speed can be reached, there is also a certain lack of control.

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