
Atmos: A Hybrid Crowdsourcing Approach to Weather Estimation

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Abstract

Motivated by the novel paradigm of participatory sensing in collecting in situ automated data and human input we introduce the Atmos platform. Atmos leverages a crowd-sourcing network of mobile devices for the collection of in situ weather related sensory data, provided by available on-board sensors, along with human input, to generate highly localized information about current and future weather conditions. In this paper, we share our first insights of an 8-month long deployment of Atmos mobile app on Google Play that gathered data from a total of 9 countries across 3 continents. Furthermore, we describe the underlying system infrastructure and showcase how a hybrid people-centric and environment-centric approach to weather estimation could benefit forecasting. Finally, we present our preliminary results originating from questionnaires inquiring into how people perceive the weather, how they use technology to know about the weather and how it affects their habits.

Author Keywords

Sensor networks; smart cities; crowd sensing; mobile sensing;

ACM Classification Keywords

H.5 (Information Interfaces and Presentation)

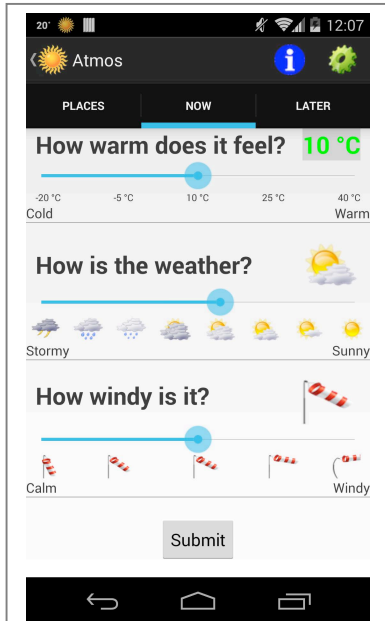


Figure 1: “NOW” screen for collecting empirical reports about current weather conditions. The user can summarize the way she experiences the weather via a 3-bar layout. The first bar is used to indicate current temperature in Celsius, the second bar for providing a visual representation of current weather phenomena (rain, cloudiness etc.) and the third one for describing current weather intensity.

Introduction

Participatory sensing involves the utilization of mobile devices to form interactive, collaborative sensor networks that enable users to garner, analyze and share local knowledge [2]. Under this guise, participatory sensing exhibits a unique level of spatiotemporal coverage in observing phenomena of interest in urban spaces [5]. The key idea behind this new paradigm is the enabling of mobile users to collect and share sensed data about their natural settings in large scale, using their mobile devices. This opportunity emerged as mobile devices are becoming increasingly context aware, equipped with a diversity of embedded sensors, while their connectivity, processing and storage capabilities continue to skyrocket. Apart from the external commonly found sensors, such as cameras and microphones, mobile devices encompass a set of internal sensors such as, GPS, accelerometers, gyroscopes, magnetometers, proximity, biometric (fingerprint), pressure and temperature sensors.

The plethora of sensory hardware combined with traditional (GSM) and more recently added connectivity features (4G, Wi-Fi, Bluetooth, FM receiver, NFC) resulted in mobile application domain to flourish. A showcase of participatory sensing applications distinguishes between two broad categories based on the focus of such systems: People-centric sensing and environment-centric sensing applications [5]. The first category includes applications that focus on collecting user related data. Monitoring one’s personal health and wellbeing (e.g. DietSense [1]), price auditing (e.g. PetrolWatch [3]) or improving social awareness (e.g. CenceMe [7]) are only a few application examples that fall within the people-centric sensing category. In contrast, the second category includes applications that

focus on collecting data related to a user’s surrounding settings. A few examples of environment-centric applications concern mainly the monitoring of surrounding attributes such as air quality (e.g. Common Sense [4]), ambient noise (e.g. NoiseSPY [6]), and traffic conditions (e.g. Nericell [8]).

Research and commercial application examples epitomize the potential of harvesting weather related data by leveraging mobile devices. For example, WeatherSignal application utilized the battery heat sensor, available on every Android mobile device to measure relatively accurately the temperature across eight major cities of the world [9]. The National Oceanic and Atmospheric Administration (NOAA) follows a rather people-centric approach in the frames of PING project [10], collecting real time human input about precipitation. However, a clear-cut distinction is not always possible, as some participatory sensing applications appear on the verge of people-centric and environment-centric categories. As such, we introduce Atmos, a platform that utilizes any available weather-related sensor on a mobile device, while concurrently harvesting people’s estimations about current (Fig. 1) and future (Fig. 2) weather conditions.

Our Approach

Atmos comprises a hybrid environment-centric and people-centric example of participatory sensing application that utilizes a network of mobile devices to collect data about weather. Our approach employs any available sensor found on a mobile device to garner objective weather descriptive measurements, such as environmental pressure, temperature, luminosity and humidity levels. In addition, empirical estimations about the perceived current and future weather

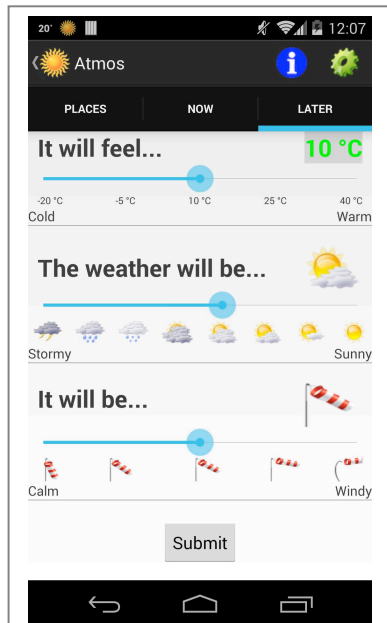


Figure 2: “LATER” screen for collecting empirical predictions about future weather conditions. Leveraging previous experience about weather a user can predict how conditions will be in the next hours. Similarly to “NOW” screen (Fig. 1), the first bar is used to indicate future temperature in Celsius, the second bar for providing a visual representation of future weather phenomena (rain, cloudiness etc.) and the third one for describing future weather intensity.

conditions are collected via a custom user interface. Users report on how they experience current weather conditions via three bars describing temperature feel, weather phenomena and sensed wind intensity (Fig. 1). Similarly, users can provide a short-term prediction about future weather conditions via the corresponding interface (Fig. 2). Collected sensory data along with reports about current and future weather conditions are uploaded, processed and clustered by location when an Internet connection is present. Sensory data is stored on an online database for future elaboration with weather prediction models, whereas empirical data is summarized and instilled back into the device network. Accordingly, users can select places of interest by selecting from those available and access additional weather information about them based on the summary of other users’ reports at a given location (Fig. 3).

Study

The Atmos mobile app has been deployed on Google Play marketplace to attract users from around the globe for a period of eight months. While the app experienced a wide geographic coverage in terms of downloads, spanning across 9 countries and 3 continents, the number of downloads was so far rather limited (69). Despite this limitation, we were able to collect a substantial amount of automated sensory input (>18,000 sensor measurements) and a respectable number of human inputs (>500). In order to unveil potential insights on how to improve our approach, we launched a series of questionnaires via social networking groups and university newsletters that aimed at investigating how people perceive the weather, how they use technology to know about the weather and how weather affects their daily lives and habits. This resulted in a total of 128 responses. In the

following section we present an overview of our results originating from analyses of the aforementioned data.

First Results

Initially, we examined the sensory data collected by the on-board sensors of the mobile devices and the user inputs in order to identify relationships within the two types of data but also with real temperatures. In addition, the questionnaire data had been analyzed in order to record the effect the weather has on users.

Sensor Data and Human Input

A significant positive relationship was revealed between recorded battery temperature and pressure but no significant correlation was found between recorded illumination and pressure. User reported temperature feel and sky clearness revealed a maximum in the morning hours (9:00 - 10:00) and slowly degraded in the course of the day. Similarly, when having a look at reports about future weather conditions, those submitted during morning hours foresee increased sky clearness and temperature feel for the next few hours, an effect that tends to degrade in the course of a day.

Questionnaire Data

An online questionnaire and a set of questions inquired into the extent at which weather affects various aspects of the participants’ everyday live (e.g. mood, transportation, scheduling etc.). The most affected reported aspect, is clothing followed by mood, transportation, scheduling, productivity and finally work. Overall, temperature indicated the highest importance in weather reporting, followed by wind, real feeling and finally humidity. Male population between 26-33 is more confident in predicting the weather for the next hour, as people between 18-25 are more

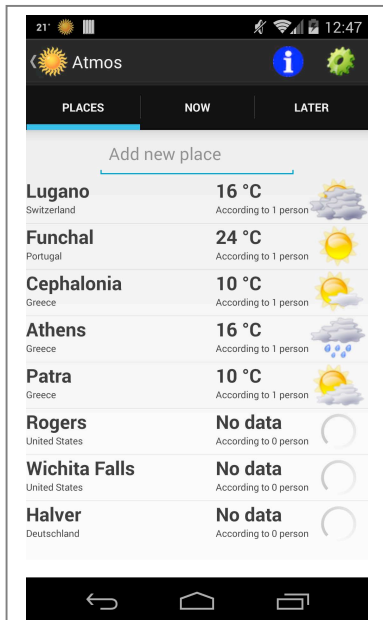


Figure 3: The “PLACES” screen provides an overview of current weather conditions across several locations of interest by summarizing the estimations of other users. Clicking on a specific location grants access to additional information about current and future weather conditions as reported by other users.

confident in predicting the weather in the next five hours from the male population and for the next day from the female population.

Discussion

All in all, the first results indicate the potential of our approach for enhancing weather estimation. Sensor data as collected by on-board sensors can prove of particular value to existing weather models and possibly represent a cost effective way to enhance the accuracy of weather forecasting over large areas, complementing current meteorological ground stations. Some sensor inputs (e.g. pressure) were considered to be less susceptible to overall device usage and user context, whereas others (e.g. illumination) were strongly influenced. As for future work, we will employ context-aware mechanisms for detecting users’ surroundings and activities, excluding sampling that happens for example indoors and we will implement techniques known for increasing user engagement such as, gamification and social networking integration.

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