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Sensing and Information Technologies for the Environment (SITE); Hardware and Software Innovations in Mobile Sensing Technologies

ABSTRACT

This research focuses on the development and integration of low-cost Mobile Urban Sensing Technologies (MUST) and immersive environmental data exploration mechanisms with the ambition to inform citizens about their environments and aid scientists in uncovering the relations between the surface attributes and the urban environment. We propose to use 3D immersive environmental visualization techniques to enable a user-centered interactive analysis and rationalization of the available urban environmental data in relation to further urban attributes. With this ambition, we have developed three mobile apps that explore three strategies of Augmented Reality (AR) 3D visualizations of urban environmental data. While some data could be acquired from urban Geographic Information System (GIS) and existing sensor networks, we also developed an urban sensing kit specifically designed for deployment on mobile platforms such as buses or cars.

KEYWORDS

Urban Microclimate, Urban Sensing, Mobile Sensing, Augmented Reality, Environmental Visualization.

INTRODUCTION

Big data is changing urban science. Digitalization of information and ubiquitous sensing in cities are enabling the collection of data at unprecedentedly high temporal and spatial resolutions. This is most true in regard to urban environmental data. Sensor networks, remote sensing, thermal imaging, and crowd-sourced environmental monitoring are rapidly growing the availability of urban environmental data.

While high spatio-temporal resolution urban microclimate data are continuously becoming easier to collect, these data are not always analyzed in relation to further urban properties. We are generally only aware about city scale mean pollutant concentration values, and fail to understand the variable environmental quality conditions present in the urban fabric. One of the reasons for the persistence of this challenge is that while the study of urban sensing tools and strategies has been a consistent focus of research within the environmental and earth science communities, little attention has been placed on the development of data compilation and visualization techniques and methods for interactive exploration of environmental data for urban analysis, both from the scientist's and the interested citizen's perspectives. The result is that urban environmental data fail to reach wide audiences. The hypothesis of this research is that immersive and interactive urban environmental visualizations will enable the engagement of a broad team of stakeholders including scientists, citizens, policy makers and urban planners to reshape the discussion and analysis of contemporary urban environments, and the planning of future cities. This can be achieved through user-centered interactive analysis and rationalization of urban data which 3D immersive visualization techniques enable, thus removing some of the barriers that current tabular data or 2D plots engender. Specifically, we outline the development of novel 3D immersive Augmented Reality (AR) visualizations of urban air quality data. Such visualization strategies, which are currently lacking, aim for the

analysis of environmental data in relation to further urban parameters to enable the participation of a wide audience of users. The scientist would use them to understand how urban attributes modulate environmental quality, while citizens would use them to better understand their city and how to navigate while minimizing their exposure to adverse air quality or heat. However, since current sensor networks in cities mostly consist of fixed stations that cannot provide the spatial information needed to support such visualization of the entire city, we also develop a low-cost sensing kit designed specifically for mobile deployment over cars or buses, for example.

2. URBAN SENSING AND VISUALIZATION METHODS

When the access to environmental data of a site under study is limited, the use of mobile weather stations can be an effective low-cost technology to capture high spatial resolution urban air quality data. Mobile weather station studies can enable a fast response and site specific data acquisition methodology to understand parameters such as pollution sources or temperature gradients (Mahoney et al. 2010, Zwack et al. 2011, Kolb et al. 2004, Li et al. 2012). However the deployment of mobile sensing technologies specially so in urban environments still lags behind fixed sensors due to various challenges. The reliance on power sources, deployment constraints, security concerns, and the difficulty to access the kits for maintenance and calibration purposes, are amongst some of the main reasons why urban sensing technologies are not more widespread. Aiming to address these challenges, a robust and low-cost sensing kit has been developed to enable the acquisition of a high spatial resolution urban microclimate data (see Fig.1). This mobile sensing tool is essential to support the visualization techniques described next, which require high spatial resolution data (for further details on the MUST sensing kit see must.princeton.edu).

Immersive 3D visualization techniques have not yet been explored for urban environmental data representations. However urban data visualization strategies have recently been experiencing a rapid transformation with the arrival of Augmented Reality (AR) (also referred to as Mixed Reality (MR)) technologies. Urban augmented reality applications are changing the way we navigate the city. Apps such as ARCity or Yelp aid citizens to navigate the city based on the information of traffic, road conditions or amenities. Apps such as England's Historic Cities add historic layers to the city also enable citizens to navigate the city while traveling in time. However while various weather apps are available both in iOS and Android, augmented reality technologies have not yet been explored for the visualization of urban environmental data. In this context, this research explores AR technologies for environmental visualization aiming to encourage the engagement of wide communities including scientist and citizens in the discussion and management of urban environments. With this ambition three 3D immersive AR environmental visualization apps are being developed. These apps utilize the acquired mobile sensing data from the MUST sensing kits and visualize it following 3 strategies. The Navigating Urban Environments (NUE) app targeted for wide audiences, uses a mobile phone to explore a 3D urban navigation strategy were environmental data is spatially represented in relation to the physical structures of the city to enable a first person and on site exploration of the environmental data in relation to the visible urban

properties. The Virtual Urban Environments (VUE) app introduces a 3D immersive off site map visualization strategy to explore the environmental data over a city map marker deployable in interiors and exteriors; it typically uses a tablet and is aimed at very engaged citizens or city managers and policy makers. Finally the Holographic Urban Environments (HUE) app uses augmented reality smart glasses to enable further degrees of interactivity with the environmental data through spatial user hand textures or voice activation; it is designed for scientists and urban planners who want to interact with various scenarios to gage their impact on urban environmental quality.

Figure 1. MUST Sensing Kit

2.1 NUE

Despite the increasing availability of 2D and 3D urban navigation apps, urban navigation has not yet been explored to enable on site environmental visualization. Environmental navigation in cities could however transform the way citizens travel across cities. The Navigating Urban Environments (NUE) app is an augmented reality mobile app that aims to aid citizens navigate the city informed by environmental data. The app operates in two modes, i) the first-person view, and ii) the map view. In the first-person view, locational services of the user's mobile device are accessed, and the geo-tagged environmental data are overlaid on the camera view as graphic filters (see Fig.2). The map view is developed using Google Map API services over which environmental gradients are overlaid. The app queries data from the online server where the MUST sensing kit data are stored, as well as from other online web services such as OpenWeatherMap and AQICN. Through these combined sources, data on temperature, humidity and air quality are compiled. Furthermore, through GeoNames geocoding, the location for the different urban intersections is stored. This setup enables that when a geocoded user points the smartphone towards a nearby intersection, the app draws a marker over the intersection to show the street names as well as the relevant environmental data for that given intersection. Thus the app allows the user to decide on the most favorable path towards their destination, as well as to associate certain temperatures or AQI values with the urban fabric.

Figure 2. NUE app.

2.2 VUE

Not only the average citizen, but also city managers and policy makers can benefit from AR visualizations to understand their urban domain. Virtual Urban Environments (VUE) is a marker based augmented reality mobile app that aims to enable off-site environmental data visualization and analysis. To test the app, environmental data on the city of Seoul have been collected. The app recognizes a marker composed by the map of the city of Seoul and scales the environmental data over it. Historical air quality data from 1986 to 2016 can be viewed through interacting with a slider and dropdown menu. Data for PM1O, PM2.5, O3, SO_2, NO_2, and CO were available. Furthermore, the app enables real time data to be visualized over the city map. The air quality data is queried from the same sources as NUE. The setup aims to encourage the user to make correlations between the historical and real-time air quality data, while viewing the complexity of urban and geographic layers. This would help urban planners or policy makers to understand what modulates urban environmental quality.
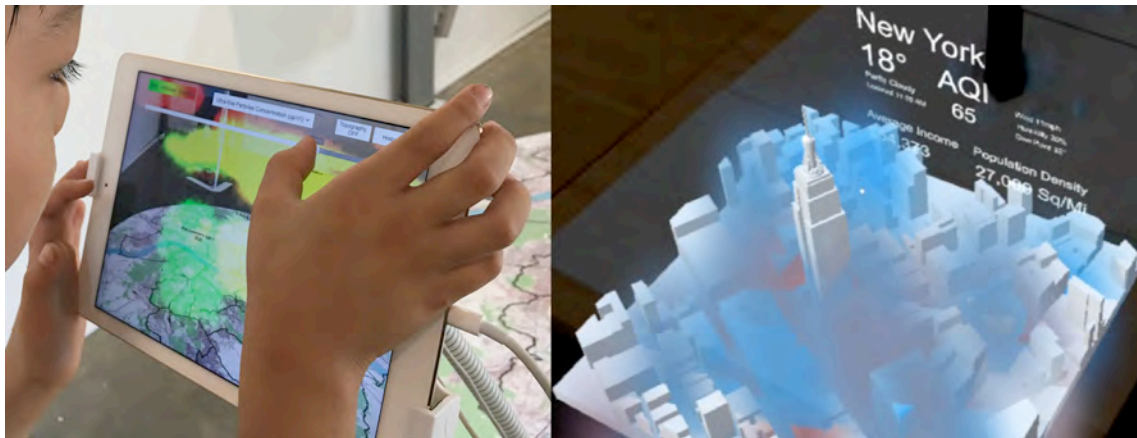

Figure 3. Left figure, VUE app. Right Figure, HUE app.

2.3 HUE

Holographic Urban Environments (HUE) is an augmented reality mobile app that utilizes a smartglass handset to enable immersive environmental data visualization and analysis. The app uses an environmental visualization platform based on the game engine Unity and the Microsoft Hololens smartglass handset. The app queries data in real time from real-time data

is queried from online weather station databases and visualized as a particle simulation. The environmental data are mapped onto 3D physical model that the Hololens kit uses as a marker. This app is being developed aiming for a further degree of interactivity with the environmental data through spatial user hand textures or voice activation. It would allow for example, once couple to modeling tools, city planners or scientists to see what is the effect of altering the cityscape on environmental quality.

RESULTS

The MUST sensing kits and the developed AR environmental visualization applications where tested at the 2017 Seoul Architecture and Urbanism Biennale. Four MUST sensing kits were installed in the Seoul intercity bus network, collecting data from August 30th until October 4th 2017. Data on temperature, humidity, CO_2 and PM2.5 were acquired at time intervals of 30 s. Given that the sensing kits were powered by a solar panel, the battery was only charged when the weather conditions were good, thus from the time the kits were installed, only 26 days of data were acquired. The data was initially compared against a nearby Seoul city weather station and it was found in agreement with the weather station observations. In Figure 4b the averaged CO_2 and temperature data for the 31st of August are shown. With the ambition to relate the acquired environmental data with the urban spatial differences present in this area of the city, a district scale analysis has been developed. The buses travelled through 9 different districts in the city of Seoul. The Kolmogorov-Smirnov test with a 5% significance level was tested for every pair of these 9 districts (in Fig.4a the pdf distributions for temperature and for all 9 districts are shown); it showed that data from neighboring district are likely to be related (drawn from the same distribution), as expected.
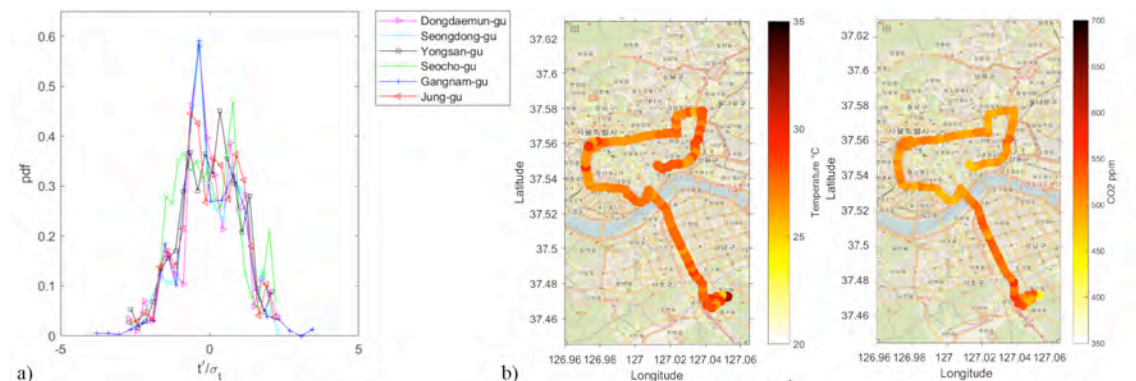

Figure 4 a) PDF of the acquired temperature for the different districts in Seoul. b) Spatial map for temperature and CO_2 collected on the 31st of August.

Two of the developed augmented reality applications were displayed in the Seoul architecture and urbanism biennale in an exhibition with the title Seoul On-Air. For the VUE app, a 2.5m diameter map of the city of Seoul was installed on the exhibition floor around which 5 iPads displayed the app enabling visitors to experience real time and historical air quality data of the city of Seoul. The NUE app was also displayed in the exhibition space. Given that this app is to be used for outdoor urban environmental navigation purposes, it was only included as a video recording for the visitors to become familiar with the functionalities of the application.

Both apps accessed the real time data collected from the MUST sensing kits and local weather stations.

CONCLUSIONS

Aiming for the acquisition of low-cost and high spatial resolution urban environmental data, a mobile urban sensing technology has been developed. The prepared sensing kits were mounted over the Seoul intercity network, and environmental data was acquired for 26 days. The data collected from the sensing kits was utilized to communicate the real time high spatiotemporal resolution air quality data to the Seoul Citizens through 2 augmented reality applications. These apps were launched at the 2017 Seoul architecture and urbanism biennale to motivate an inclusive discussion between the different stakeholders that can affect how our cities are and will be designed in the future, including scientists, urban planners, architects, policy makers and citizens. The apps were made available in an exhibition space where city planning authorities and the citizens of Seoul interacted with the applications and provided very positive feedback about their experience. A third application has also been presented which utilizes immersive smartglasses for immersive environmental visualizations. A field experimental campaign for the city of New York is currently under development where the MUST sensing kits in combination with the three AR applications will be tested. We are also currently working on an updated version of the AR apps, aiming to introduce features that make them more immersive and interactive.

REFERENCES

ARCity app: https://itunes.apple.com/us/app/arcity-ar-navigation/id1282527727?mt=8
England's Historic Cities app store link: https://itunes.apple.com/us/app/englands-historic-cities/id1215745809?mt=8
Fitness AR app: https://itunes.apple.com/us/app/fitness-ar/id1274233318?mt=8
Monument Valley app: https://itunes.apple.com/us/app/monument-valley/id728293409?mt=8
Morpholio Trace app: https://itunes.apple.com/us/app/morpholio-trace-sketch-cad/id547274918?mt=8
Pokemon Go app: https://itunes.apple.com/us/app/pok%C3%A9mon-go/id1094591345?mt=8
Yelp app: https://itunes.apple.com/us/app/yelp-discover-local-favorites/id284910350?mt=8

J. J. Li, B. Faltings, O. Saukh, D. Hasenfratz, J. Beutel, "Sensing the air we breathe: The opensense zurich dataset", *Proceedings of the Twenty-Sixth AAAI Conference on Artificial Intelligence ser. AAAI'12*, AAAI Press, pp. 323-325, 2012.

Kolb, C.E., S.C. Herndon, B.J. McManus, J.H. Shorter, M.S. Zahniser, D.D. Nelson, J.T. Jayne, M.R. Canagaratna, and D.R. Worsnop. 2004. "Mobile Laboratory with Rapid Response Instruments for Real-Time Measurements of Urban and Regional Trace Gas and Particulate Distributions and Emission Source Characteristics."

Mahoney, B., S. Drobot, P. Pisano, B. MacKeever, and J. O'Sullivan. 2010. "Vehicles as Mobile Weather Observation Systems." Metereological Society 91:1179-1182.

Zwack, L.M., C.J. Paciorek, J.D. Spengler, and J.I. Levy. 2011. "Characterizing Local Traffic Contributions to Particulate Air Pollution in Street Canyons Using Mobile Monitoring Techniques." Atmospheric Environment 45 (15):2507-2514.