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Urban Sensing App – A Mobile Tool for Urban Sensing and Climate Monitoring in Smart Cities

Benjamin Allbach, Sascha Henninger, Oliver Griebel

(Dipl.-Ing. Benjamin Allbach, Fachhochschule Kaiserslautern, University of Applied Sciences, Dept. of Engineering and Dept. of Building and Design, Morlauterer Straße 31, 67657 Kaiserslautern, benjamin.allbach@fh-kl.de)
(Univ.-Prof. Dr. rer. nat. Sascha Henninger, University of Kaiserslautern, Dept. of Physical Geography, Pfaffenbergstr. 95, 67663 Kaiserslautern, sascha.henninger@ru.uni-kl.de)
(Oliver Griebel, Fachhochschule Kaiserslautern, University of Applied Sciences, Dept. of Engineering, Morlauterer Straße 31, 67657 Kaiserslautern, Allbach.Hiwi07@fh-kl.de)

1 ABSTRACT

Mobility is a central aspect of today´s life. Humans have becomedigital nomads, just as information and knowledge is increasingly ubiquitously available. In addition to the smart networks (grid-based and wireless), which create a new urban topography, a new multifunctional tool becomes prominent: the smartphone. It has developed into an all-rounder and has established its significance for urban life. The homo sapiens has developed into the permanently wired homo junctus (or homo sapiens junctus). He takes in and designs his surroundings by using this new tool. It is the key to bi-directional exchange of information, money, authentications, support and communication with other people.

The aim of this paper is to present a newly developed application, which will extend the smartphone functions in order to collect climate data automatically and autonomously in an urban sensing scenario. The smartphone sensors are read out and the results are converted into climate data. Thus, combined with crowd sourcing, a new type of climate monitoring is created. Additionally, it is demonstrated how the results of such measurements can be saved, interpreted, and of course used. Furthermore, some specific examples of mobile monitoring using smartphones, coupled with crowd sourcing, are presented, which illustrate how this type of climate measurement can increase the quality of life of the urban population.

2 INTRODUCTION

2.1 Smartphone market analysis – Smartphone market conditions

At the moment, there are almost innumerable different smartphones available. Every year, new models are introduced. In 2013, 1,804,334 smartphones were sold around the world. The predominant systems are Android, iOS, Windows, and Rim. It is predicted that even more smartphones and tablet PCs will be sold in the future. In 2013, 877.9 million devices running the Android system, were sold. This equates to approximately 38 % of all PCs, cellphones, ultraphones, and tablets which were sold in that year. Until 2015, the market share of Android could increase to 50 % [GARTNER, 2014]. Android 4.4.2 (KitKat) is the latest version of this system, and by January 2014 it was used on 1.5 % of all Android smartphones. Currently approximately 60 % of Android owners are using versions 4.1.x – 4.3 (Jelly Bean) [STATISTA, 2014]. Within every smartphone sensors are integrated. Such a sensor consists of two elements: a sensing device and an evaluation unit. Thus, it is possible to conduct quantitative and qualitative analyses of chemical, physical, climatological, biological conditions, as well as of medical conditions. Sensors in our enviroments are ubiquitous and can have various forms [cf. HERING; ET AL, 2012:1FF]. For instance, absolute position transducer, acceleration sensor, and lighting sensor are part of most smartphones. GPS is another sensor which allows to enhance every information with the specific location of the smartphone. The spreading of smartphones in our society changes the spatial and temporal availability of knowledge. Additionally, new ways to acquire knowledge are created. The possibility of individuals to participate in creating and spreading knowledge is increased by the internet. Thus, the knowledge of the masses is in opposition to the knowledge of experts. The free online encyclopaedia Wikipedia is one of the most prominent examples [cf. SCHWALBE; MEYER, 2010:34FF].

For meteorology as well as urban climatology the collection of data by urban sensing is of interest and has various advantages for climate monitoring [cf. ALLBACH; HENNINGER, 2013:1FF]. The Committee on Urban Meteorology states that the usage of “personal digital assistants” (e.g. smartphones and their sensors) might lead to improved databases for urban climatology [cf. SNOW; ET AL, 2012]. Mobile measurements are well suited to analyse the climate in an urban area. There are various methods of measurement which are conducted, for instance, by car, by bicycle, or on foot [cf. HENNINGER, 2011]. Smartphones have become a new tool for such mobile measurements (Fig. 1). A detailed analysis of the currently available smartphone

'Samsung Galaxy S4', which uses the Android system, would be the best choice because of its integrated sensors.

2.2 Best sensing smartphone

The Samsung Galaxy S4 has a multitude of sensors: a GPS sensor to track one's position, a temperature sensor to measure air temperature, and a humidity sensor to measure the air humidity. Additionally, the barometer can determine atmospheric pressure and the altitude. The integrated RGB sensor measures light intensity and colour temperature and can automatically adapt the brightness of the display to the local lighting conditions. The gyro-sensor coordinates the 'intelligent turning' and orientation of the smartphone. The Galaxy S4 uses 'smart stay' in order to assess if the display needs to be rotated or if the user is lying down. An electromagnetic sensor (the Hall-Geber; S view cover) enables the Galaxy S4 to know if its protective cover is open or closed. Thus, depending on the status of the protective cover, the display can be switched on or off automatically. The accelerometer can measure how far and how fast the smartphone has moved. The digital compass measures the magnetic fields and is also used by navigation apps. All these mentioned sensors allow its user to measure the ambient atmosphere at a specific location.

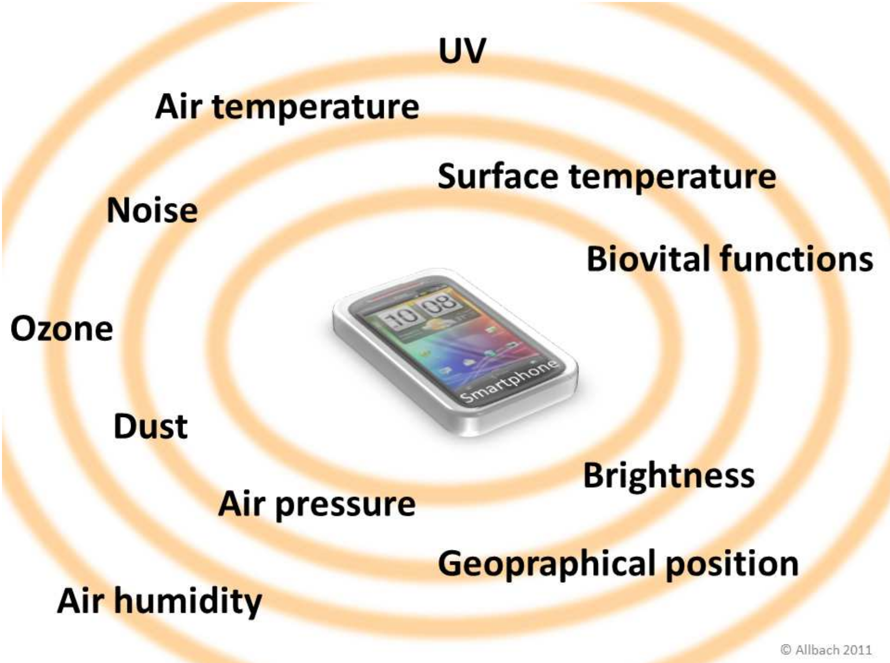

Fig. 1: Smartphone as a "Sensing Device".

Entwickler	Maciej Komur	Sensirion AG	ThePaze	Boneco Switzerland	pabl3st	Delamaire Nicolas	Moletag	YD Visual
Market-Link (Download)	n/store/apps/details?id=pl.komur.android.g	e/apps/details?id=com.sens	n/store/apps/details?id=com.the	n/store/apps/details?id=at.s	https://play.google.com/store/apps	https://play.google.com/store/a	https://play.google.com/store/apps/de	https://play.google.com/st
Sensoren Anzahl	4	2	4	2	6	4	9	4, zusätzlich 5 Batteriesens
Geoposition	nein	nein	nein	ja	nein	nein	nein	nein
Umgebungstemperatur	ja in °C und °F	ja in °C und °F	ja in °C und °F	ja in °C und °F	ja in °C	ja in °C	ja in °C und °F und °K	ja in °C
Luftdruck Umgebung	ja in hPa, PSI und Hg	nein	ja in hPa	nein	ja in Hg	ja in hPa	ja in hPa, PSI und Hg	ja in mbar
Lichtintensität	ja in lx	nein	nein	nein	ja in lx	nein	ja in lx	ja in lx
Höhe (ü.n.N.)	nein	nein	ja in m	nein	nein	nein	ja in m und ft	nein
Relative Feuchtigkeit	ja in %	ja in %	ja in %	ja in %	ja in %	ja in %	ja in %	ja in %
Darstellung	grafisch, numerisch	grafisch, numerisch	numerisch	grafisch, numerisch	numerisch	numerisch	numerisch	numerisch
Benutzeradaptivität	Einheiten	inheiten, grafische Darstellur	Themes, Einheiten	Einheiten	Themes	Schriftgröße	Einheiten, Widgetrate	nein
Datenübermittlung und Speicherung	nein	ung lokal, Verlaufskurvendars	nein	kal, Verlaufskurvendarstellun	nein	nein	nein	nein
Exportfunktion	nein	nein	nein	nein	nein	nein	nein	nein
Betriebssystem	Andoid	Android	Android	Android	Android	Android	Android	Android
Preis	kostenlos	kostenlos	kostenlos	kostenlos	kostenlos	kostenlos	kostenlos	0,73€ (11.02.2104)
Aktueller Stand	02.06.13	13.01.14	31.05.2013	27.09.13	02.02.14	17.10.2013	30.01.2014	07.02.2013
Größe	134k	182k	365k	4,7M	851k	450k	381k	15M
Installationen (Android Market)	100.000 – 500.000	10.000 – 50.000	10.000 – 50.000	1.000 - 5.000	10.000 - 50.000	10.000 - 50.000	1.000 - 5.000	500 - 1.000
Aktuelle Version	1.0	1.2.2	1.3.2	1.2.1	3.1	1.6	1.2	2.0
Erforderliche Android-Version (min.)	4.2	4.0	4.2	2.2	2.2	3.0	4.0	3.0
Sonstiges	nur mit Samsung Galaxy S4	nur mit Samsung Galaxy S4 und Samsung Galaxy Note3, Widget Rate anpassbar, Messungen können im Hintergrund laufen	nur mit Samsung Galaxy S4	Messungen nur mit Samsung Galaxy S4, mit anderen Geräten nur standortabhängige Schätzangaben, Feature von Gerätehersteller zur Regulierung der Luftfeuchtigkeit und -reinigung	Messung von Nähe und Beschleunigung, läuft nur mit Samsung Galaxy S4, Einheiten nicht anpassbar	nur mit Samsung Galaxy S4 und Samsung Galaxy Note3, Widget, zusätzliche Anzeige der Akkutemperatur	nur mit Samsung Galaxy S4 und Samsung Galaxy Note3, zusätzlich Rotations-, Magnetfeld-, Beschleunigungs-, und Nähesensor	Läuft auf allen Smartphones, auch wenn die entsprechenden Sensoren fehlen, am besten mit Galaxy S4 und Note 3

Table 1: Extract and functions of Sensing Apps.

2.3 Analysing "Sensing Apps" for the Samsung Galaxy S4

Before the development of the "Urban Sensing App", various apps for urban sensing scenarios (e.g. 'Baumkataster [cf. ALLBACH; HENNINGER, 2013] or concepts like the „Baumbestimmungs-App" [cf. GRUB, 2013]) had already been programmed. After the integrated sensors of the Galaxy S4 were announced, it became obvious that this smartphone could be suited for local climate monitoring. Samsung had already provided the Galaxy S4 with a health and environment app, and later on several other applications followed. It is therefore necessary to analyse and evaluate the functions of these available apps

(Table 1). The publication „Crowdsourcing urban air temperatures from smartphone battery temperatures“ has to be acknowledged, because its focus is on the air temperature, and because it has a huge data base [cf. OVEREEM; ET AL, 2013]. However, the “Urban Sensing App” will be able to record more than one climatological parameter.

3 “URBAN SENSING APP”

3.1 Functions and Characteristics of the “Urban Sensing App”

- Measurement of climate data and other relevant information (meta-data)
- Recording the geoposition
- Recording the data
- Possibility to export the data
- Measurement of the present data (action point & of data for a specific time period
- Possibility to present the data in a list
- Gateway for additional sensors (under construction)

The “Urban Sensing App” is able to measure climatological and environmental data by using the smartphone’s sensors. Futhermore, the app records the date, time, position, and identity (anonymized). All data is saved on the smartphone and, additionally, the app offers the possibility to export the datato use them, for instance, in an “Urban Sensing System” [cf. ALLBACH; HENNINGER; DEITCHE, 2014]. There are two ways of collecting the data: 1. actively by pressing a button to start a measurement of the current situation, or 2. passively by pressing an extra button to start measuring over a specific period of time („∞“).

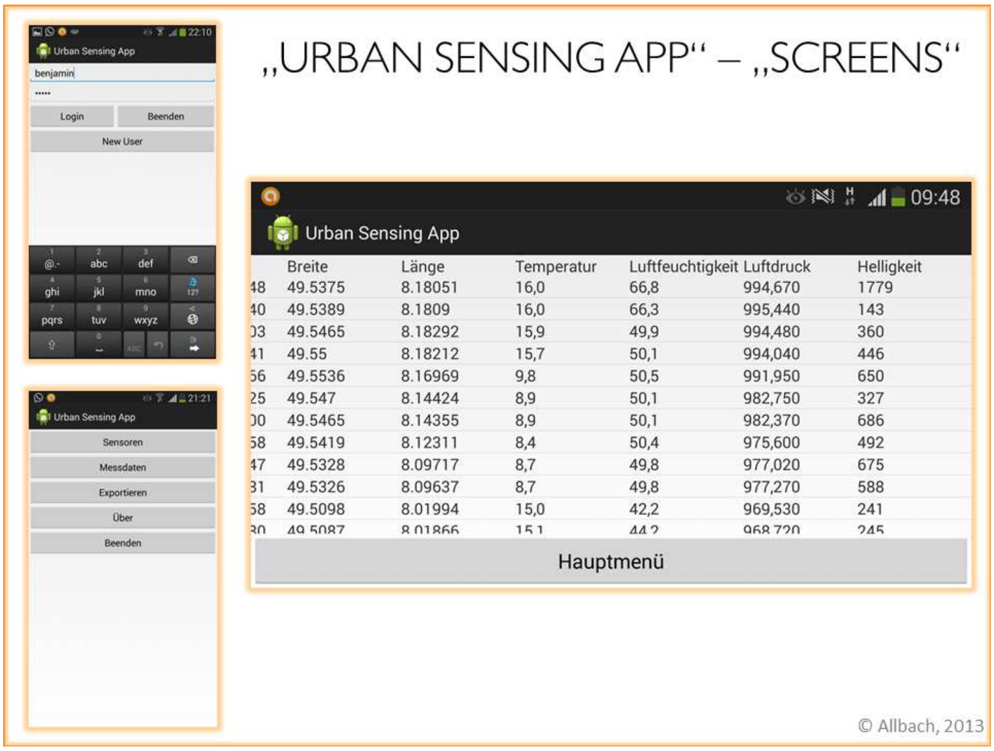

Fig. 2: “Urban Sensing App” – “Screens”.

The current version of the “Urban Sensing App” allows to display the collected data in a listing (Fig. 2). At some future date it is planned to extend this function with additional graphs and options for comparison. A function to read out and save data collected by other sensors, which are not part of the smartphone, via USB, WLAN, or Bluetooth has currently not yet been developed.

3.2 Tools for the Development and Programming of an App

In this chapter, a brief introduction to programming an application is given. While a markup language describes the “how”, a programming language stands for “what” should be done. Every Android App is

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based on Sun`s, or rather now Oracle`s programming language Java. Eclipse is mostly used as the development environment for Java. Originally, it was exclusively used for Java development and (version 4.3, its name is “Kepler”) it provides a lot of plug-ins and extensions [cf. Eclipse, 2014]. This is the reason why eclipse is also used for other development tasks. Due to Android Development Tool (ADT-Plugin) it is possible to integrate the APIs (Application Programming Interface) and tools of Google`s Android SDK (Software Development Kit) with an emulator, a project assistant with a special view and a GUI-Editor. This is necessary for the development of Java-based Android Apps in eclipse [cf. LAU, 2011].

The Java platform consists of the Java APIs, which contains the virtual machine (VM) and compiled libraries that can be integrated into programs. The VM executes and interprets the machine-readable code. Thus, it is possible, that each system with the Java VM, can execute the code independently of the system on which the code was originally developed. A compiler is used to transform the source code into a byte code. If the program was compiled successfully, the code interpreter translates it into a platform dependent code that can be understood and executed by the system [cf. PAWLA, 2000]. Java is a powerful and common object-oriented programming language that pursues the following objectives: simplicity, object orientation, platform independence, robustness, security, interpretability, performance, distribution, adaptability and multi-threading. Despite the similarities with C++, Java is a slim language. It provides help to the programmer, e.g. by automatic memory-management, space allocation and the garbage collection.

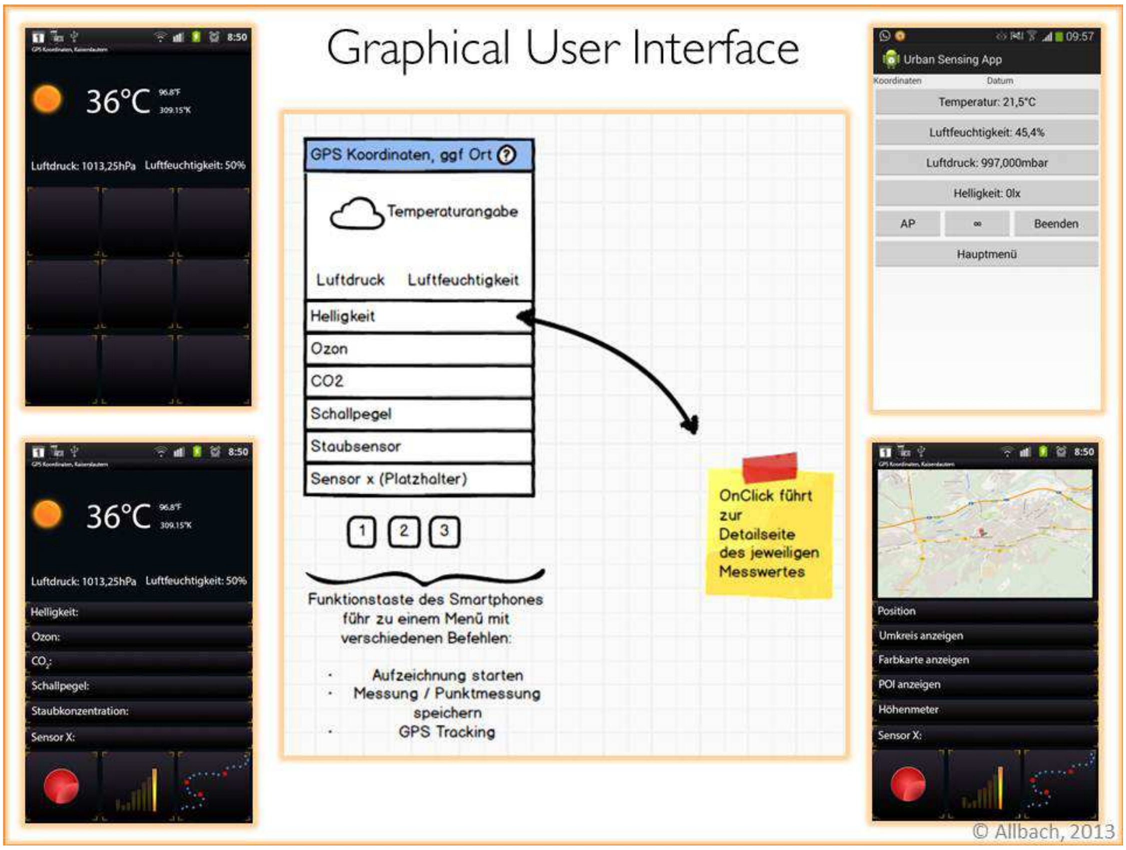

Fig. 3: Graphical User Interface.

Java applets are programs that are initiated within a HTML page. These external programs, which are executed on the user`s machine, could potentially cause many security risks. To avoid damage, the Java applets are executed on a virtual machine, the so called “sandbox”. All programming commands are translated and executed at runtime. Java, as a dynamic language, is able to adapt flexibly to its environment. Database access via SQL is made possible by the Java Database Connectivity API (JDBC). With the aid of JDBC classes and interfaces, it is possible to implement a database entirely in Java and to send SQL requests to any relational database. The closer a programming language is to the machine code, the faster it can be processed. Java is efficient due to using a compiler and the multi-threading, even though is an interpreted language. For optimum performance, the virtual machine uses just-in-time compilers.

Beside the development of graphical user interfaces, Java is applied on servers and mobile devices. JSP (Java Server Pages) is able to produce content dynamically, which is why Java is used for web-server programming. J2ME (Java Platform 2 Micro Edition) completes the Java-family. J2ME is mainly used on mobile devices with only limited resources. Java is particularly suited for client/server applications, because it implements APIs for distributed applications as well as its database connection with JDBC [cf. TEIA, 2002].

3.3 Development & Evolution of the "Urban Sensing App"

During the "Urban Sensing App" project, the application was not only programmed in code; Structures, hierarchies, graphical elements of the display, and the GUI (Graphical User Interface) were also created (Fig 3). This development has not yet been completed and is constantly under construction as well as, improvement.

Diverse layouts have been created, improved, slashed, and recreated. In order to create sketches of the user interface, the program Balsamiq Mockup (Fig. 3 middle) is used, because it can present the graphical user interface and a simplified scope of operation [cf. BALSAMIQ STUDIOS, 2013]. Balsamiq Mockup is coded in Adobe Flex and can easily and intuitively be used to create wireframes and sketches. The integrated molds appear as if drawn by hand and help the user to create a digital version. However, wireframes are often misinterpreted by users as suggestions for a design [ANNEN; SCHMITZ, 2010].

3.4 Data Storage

The recorded sensor data is stored straight onto the smartphone. The most popular storage solutions are TinyDB, TinyWebDB, and the SQLite software library. So, the focus of the following consideration is really on the requirements of mobile applications. Foremost, TinyDB and TinyWebDB of the Google-based App-Inventor are introduced, because they offer several simplifications to the user. The surface provides some components, which reduces the communication between user and database to simplify storage- and call-functions. It depends on the purpose of the application whether TinyDB or TinyWebDB is chosen. If it is sufficient to store the date on the device, Tiny DB is appropriate. Since most apps require data-sharing, TinyWebDB is usually chosen. In comparison to TinyDB, the selection of data from TinyWebDB is more complex, because two steps are necessary: 1. TinyWebDB sends a data-request via the World Wide Web to a web-database. 2. the database processes the request and sends it back to the device. An event-handler on the device passes the arguments to another function. Such an event-handler is called "callback-procedure" [cf. WOLBER; ET AL., 2011: 305FF].

One database that is frequently used in combination with mobile devices operating systems is SQLite. This is a compact, open source program library, programmed in C, which provides an embedded database server. The special feature of the program library is, that it can be directly integrated without the need for an extra server. SQLite is a transaction-consistent database. It comprises different tables, indices, triggers, and views. Because of its platform-independent format, it is possible to copy the database between 32- and 64-bit systems. The particular suitability for resource-limited devices, like cellphones, results in the need of a minimal stack-space with a size of 4kB, and a minimal heap-pace size of 100kB [cf. MELTON; ET AL., 1993]. The following goals were in focus at the development of SQLite: simple administration, simple execution, simple embedding in larger programs, simple maintenance and simple adaption. Typical uses of SQLite as application-data-format for embedded applications are e.g. internal and temporal databases or websites. For large websites, client/server applications, and very large datasets, this library is not suitable Overall, SQLite supports the SQL92 standard [cf. SQLITE, 2014]. For the "Urban Sensing App", a SQLite database is sufficient and is therefore used. Additionally, it is possible to store the data in comma-separated-value files (CSV) that facilitates storing and processing the data in other systems. The application offers the option to send locally stored data to a web database. In this case, the information is stored in an "Urban Sensing System" [cf. ALLBACH; HENNINGER; DEITCHE, 2014].

4 TEST OF THE "URBAN SENSING APP"

4.1 Validity of data – Samsung Galaxy S4 vs. common measurement devices

To ensure the validity and accuracy of the data, various tests were run multiple times (Fig.4). For this purpose one version of the Samsung Galaxy S4 was compared to different mobile measurement devices.

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Fig. 4: Samsung Galaxy S4 vs. common measurement devices.

Initial tests confirm similar results in comparing the "Urban Sensing App" with mobile measuring devices regularly used for climatological measurements within urban areas. Of course, it has to be noted that even these devices do not always deliver exact values and should therefore not be regarded as absolute. After elaborate, specifically conducted tests, the difference in air temperature is at ΔTmax = 1,5° C; the difference in air humidity was no more than 3 %. The results of the light intensity (brightness) were almost incommensurable, but considering the different methods of measurement, they are still within the same range. However, differences in brightness were noticed while measuring during movement; the position of the smartphone has great influence on the outcome. Small changes in position can result in great changes in e.g. brightness. Further development is also necessary for measuring noise. The precision of GPS is consistent with other measurement devices; it typically varies depending on where it was used. Depending on the singular measuring device used, the reaction time of these is quicker in comparison to the Galaxy S4. However, this could be modified by adapting the frequency of measurement intervals in the "Urban Sensing App."

4.2 Comparing Samsung Galaxy S4 to Samsung Galaxy S4

Fig. 5: Samsung Galaxy S4 vs. Samsung Galaxy S4.

Tests comparing seemingly identical Samsung Galaxy S4 models offered differing results, even though the same version of the sensing app was used. The test results indicated that there is only a minimal discrepancy between different Samsung S4 smartphones (Fig. 5). However, some tests did show striking deviations (e.g. ~2°C, ~3% humidity, ~10 millibar air pressure) as well as a different measuring speed.

Fig. 6: Samsung Galaxy S4 vs. Samsung Galaxy S: different system versions may cause difference.

It was also found that the sensors' differences in accuracy not only occur between different models but also between different system versions. In addition to the various sensor models, the age of the sensors and how long the smartphone has already been used for, influences the measurement results (Fig. 5 & Fig. 6). Hence, it is necessary to gather this meta-information along with the measurement results.

4.3 Comparison of the location of the smartphone: unobstructed vs. in a pocket/ bag

A huge discrepancy between the measurement results depending on the position of the smartphone can be expected. Depending on whether it is held in the hand, carried in a pocket or bag, close to the body, or positioned at a fixed location, different readings will be received. Tests indicated that air temperature, brightness, and humidity differ if the smartphone is located close to the body. The measurement of brightness, obviously, makes no sense if the smartphone is in a pocket or bag and not exposed to light. Additionally, noise levels of the surroundings would be adulterated by the pocket or bag. Likewise, the body temperature could influence the measurement results just like sweat would influence the humidity measurement. Whether these results would be even more falsified by different seasons could not be tested, but it can be assumed. The GPS sensor is not affected by whether the smartphone is carried close to the body or if it is unobstructed. In the future, special algorithms have to be developed in order to correct these disruptive factors.

5 USE CASES

It is necessary to have a data basis for energetic, economic, urban and ecologic simulations. This basis can be created by the "Urban Sensing App" and smartphones. The data of the App can be used as a basis for the presentation as a map, e.g. heatmaps and climate-function maps. A heatmap, or hot-spot-map, is a map based on the accumulation of a certain phenomenon at a specific location. Thus, the "heat" in the heatmap does not necessarily show the temperature of the environment. Phenomena could be criminality, traffic accidents, air quality, pollutants, and humidity [cf. DEMPSEY, 2012]. These offer information and can be interpreted by planners and scientists as well as by non-professional users. Thus, the "Urban Sensing App" in connection with a freely available "Urban Sensing System" could become a helpful tool for mapping. A connection of the App with devices used in sports (e.g. cyclometer and heart rate monitor) in order to record their data would be interesting. The analysis of the data in relation to the altitude and climate situation could lead to improved training schedules. Additionally, individuals could be warned about environmental hazards. The App is able to record and analyse the indoor climatic conditions. Based on that, the average humidity, noise, or temperature of an indoor situation could be analysed. Climate and weather monitoring are complex and complicated circumstances, just like the urban area. Further investigations are necessary in order to gain a better understanding of the interrelation between city, climate, human being, and individual health. Using the "Urban Sensing App", makes possible to collect and analyse data, relevant for planning and climatology, in a new way.

6 PERSPECTIVES – FUTURE – UPCOMING VERSIONS

In a future version, additional new functions will be integrated in the App. In the future, it will be possible to draw conclusions from meta-data for the general as well as climate monitoring. For instance, through acceleration sensor, GPS, light intensity sensor, and position sensor it is possible to tell how the smartphone is transported and, thereby, how accurate the measurements are. Additionally, information about calorie consumption, speed, means of transportation, and typical routines in movement and recreational behaviour of the user can be collected. The “Urban Sensing App” should be used on as many Android smartphones as possible. Even if sensors like the humidity sensor are lacking on some smartphones, all other sensors can still be used and the collected data be saved. The possibility to connect the App with another “Urban Sensing Device,” which is based on a microcontroller, allows one to conduct specialized measurements, for instance of the air quality or climate accessibility. Even heart rate monitors could be connected to the App. The well-being of the user could be evaluated by various mathematical calculations. A simple and adequate method would be PMV (Predicted Mean Vote). It compares the absorbed and the emitted heat of the human body. The calculated PMV value depicts the average thermal sensation of the majority of humans. A positive PMV value shows an overload of heat, while a negative one offers the opposite. In order to calculate the PMV value, air and radiation temperature, humidity, and average wind speed are included. Additionally, physical activity and clothes are of importance. In order to gain significant and comparable results by smartphones, it is necessary to create formulas for bug-fixing and optimized interpretation of the data. For instance, by including the date and season, external conditions, average body temperature, and location of the smartphone on the body, a factor could be calculated to correct the measured air temperature and humidity.

7 CONCLUSION

The developed application shows the potential of our daily available gadgets, like smartphones and tablet PCs. Even if measurements are currently not as accurate as other mobile measurement instruments, the spread of smartphones and tablet PCs in today's society allows a multitude of measurements over a longer period of time. Since not all measurements can be conducted using the traditional methods (e.g. counting), smartphones offer the possibility to conduct these measurements cost-efficiently and simultaneously by various individuals. Furthermore, the smartphone is mobile, light, and can be used in terrains that are difficult to access. Furthermore, the hardware is cost-efficient, and through the depicted method and technology it is already possible to collect and analyse datarelevant for planning.

Currently, it is being attempted to analyse a connection between climate, city, and people. By using the "Urban Sensing App" and the "Urban Sensing System," it is possible to collect new and specialized data and scenarios about our society. This new technology can lead to new ideas and results. Consequently, urban sensing scenarios have a huge potential irrespective of privacy protection concerns. This technology can influence the planning of and the living conditions in a city, if data is anonymized Since data can be send as well as received, it is possible to analyse it in an "Urban Sensing System." Users can then be informed, warned, or guided. Thus, the smartphone becomes an important tool for the urban being and, additionally, becomes a measurement device for Smart Cities. However, this technology is still not fully developed and its reliability, system stability, and usability needs improvement.

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