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An Urban Sensing System as Backbone of Smart Cities

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1 ABSTRACT

A complex urban ecosystem, with various local climate and air quality influences, emerges within urban structures with interacting anthropogenic and natural factors. These influences have different temporal and spatial characteristics. Human well-being is influenced by a multitude of microclimatic effects, which are elementary for urban planning. These form the basis of intelligent control and design of various processes within urban smart cities. For example, micro climatic modeling helps to get a better understanding of temperature changes in diverse urban areas. Possible consequences of different planning scenarios can be explored in advance. The required data for such scenarios are mainly collected at selected locations by multiple individuals. However, the collection of the complete urban data is expensive and time consuming. The non-standardization of data saving formats and measurement procedures leads to various deviations. In future, all relevant data of a smart city should be available ubiquitously and in real time. The aim of this paper is to present a possibility of data standardization and data saving in a worldwide accessible data base. Furthermore, it should be addressed how the data base has to be structured, where local climate data can be saved, and how the data can be made accessible. The basis for this system consists of the interface between the database and different measurement instruments, whose values are stored directly in this data base. For this reason, the data base is essential for the central data infrastructure of smart cities. In addition, this paper shows how a freely accessible system not only improves the quality of urban life, but also makes it measureable.

2 INTRODUCTION

2.1 Preface

In the course of human history, information and messages have been conveyed in many ways: e. g. oral communication, gestures or pictures, written texts, acoustic or visual signals, and via wire or wireless. The meaning of communication also differs in the way the information reaches the recipient Is the message received directly? Is the message meant for a greater public, or only for one individual? Nowadays, the internet is a popular platform to receive, send, analyse, save and share information [cf. ALLBACH, 2010:3FF]. The human race is moving on from a "Gutenberg galaxy" towards an "Internet galaxy" [cf. CASTELLS, 2005:10]. Therefore, smart cities should accept and adopt the internet and networks with all their information, knowledge and data, and use the positive aspects of those new technologies. "Urban Sensing" is a modern and interesting method to collect data in smart cities.

2.2 What is Urban Sensing?

The so-called "Urban Sensing" is a new method of taking measurements within urban environments. Human beings as well as mobile technical devices can be used as probes [cf. CAMPELL, 2006:1FF]. In connection with the Web 2.0/3.0, urban sensing is a new means of collecting and analysing data. Information that is collected, both actively as well as passively, promises to carry a great potential, and offers new sources of information for planning disciplines and climatology. To discover its full potential, there is a need for new algorithms and programs, that go further than merely processing the input. So, three different settings are possible: Personal scenarios, social scenarios, as well as scenarios concerning society as a whole. Monitoring and analysing one's own vital signs exemplifies a personal scenario. In social scenarios, information is received by a (firmly) defined group of people and is processed via social networks and data services (e.g. Flickr). The scenario concerning society as a whole is open and involves the general public [cf. SRIVASTAVA; ET AL.; 2006:1F]. One of the biggest strengths of this new method of data acquisition is the potential of monitoring large areas over a long period of time [cf. HOF, 2007:1]. Due to financial aspects, this is often impossible with traditional evaluation and measuring methods. The omnipresence of mobile

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devices, which stretches all across geographical and demographical spectra, is important in order to gather precise data.

There are already some projects trying to implement urban sensing. One of them is “Noisetube” (www.noisetube.net), which monitors noise levels. Another one is “Waze” (www.waze.com), which combines crowdsourcing, geotagging, traffic information, and map services in real time. In the meantime, the “Pachube Project” was sold, renamed “Cosm” and eventuallyre-entered the market as “Xively” (www.xively.com) [cf. MACMANUS 2011]. “Xively” already owns many functions necessary for saving urban sensing data, howeverthe development, accessibility, and the strategy of private sector enterprises cannot be predicted. A system that records public data should also be a public and democratic system.

2.2.1 Urban Sensing Data

In any case, it is important to be note that the data collected in such an “Urban Sensing scenario” is extremely diverse, which can pose as a problem. There is a plethora of probesbased all over the city, providing a variety of data and information, all differing in quality and conformity. A suitable method to link and blend this data is needed. blending and linking data is a sensitive topic, as it has to be acknowledged that data is available in a multitude of formats, i.e. is heterogeneous, and will need to be converted into a homogenous state. Especially temporal and local factors are often sources of error when it comes to analyzing and interpreting. This is caused by measurement imprecisions. In order to save the data in any given system, standards to convert in a homogenous format have to be defined. Indicators, including firmly defined names and notations, as well as their units of measurement need to be specified [cf. ALLBACH; HENNINGER, 2013].

2.2.2 Why is an “Urban Sensing System” needed?

One could question if such a system is needed. Indeed, internet technology, web services, data bases, crowdsourcing are no longer ground-breaking topics. However, even these allegedly “old-fashioned” topics are still immensely important and have evolved over time (Web 2.0/ 3.0). Furthermore, it is crucial to observe and adapt them and to shake them up. Adapting these topics needs special attention, since adaption is often not as easy as it seems, and often requires a great amount of personal time and dedication. Additionally, it needs to be noted that mash-ups with synergies can develop between two separate technologies, which do not necessarily form a new invention but perhaps a new application. Ultimaltely, the hereby introduced “Urban Sensing System” offers great potential for urban sensing and the decoding of the relationships between city, human being and climate. Climatoligical and data of an individual’s vital signs, and other meta data is stored in a single system which is accessible bi-directionally.

2.2.3 Communication – XML, TCP & UDP as standards for Urban Sensing Data?

To ensure communication between single computers within a network and between different networks, regulated standards are necessary. These standards as well as the group of “Internet protocols” (TCP/IP protocol group/family) regulate the conduct between them. For addressing online, an Internet protocol (IP) is used, which makes every computer addressable via its own IP address. In the broadest sense, the IP address can be seen as a personal computer’s telephone number. A current “IPv4”- version IP address typically has the following format: 192.168.1.79. Since this manner of reference is not intuitive for humans, the “Domain Name System” (DNS) is used to translate and simplify the code into a much more memorable format, e. g. http://www.uni-kl.de. Computer names, whose IP addresses are translated by DNS, feature a characteristic structure, which is known as “Uniform Resource Locator” (URL). Furthermore, the “Internet protocol”, the “Transmission Control Protocol” is located, which ensures that the sent data arrives at its desired destination. Thus, computers, networks and their data are linked through unique addresses. Documents are described by hypertext and are available within a browser by the “Hypertext Transfer Protocol” (HTTP), which uses “Hypertext Markup Language” (HTML) to display the documents’ graphic structure. In this example, the information content is saved in HTML. It is also necessary to implement XML. The “Extensive Markup Language” allows to store and process information and data. The document markup language XML is a subset to the “Standard Generalized Markup Language” (SGML) and is used to add supplementary information to text documents. This addition, called annotation or mark-up, is not part of the actual text, but describes the relation and the structure of textual elements [cf. MOSEMANN; KOSE, 2009:332FF]. Information added through annotation is called metadata. While XML defines the logical structure of documents, it doesn’t say anything about the way in which they are displayed. However, it is possible to use XML to define mark-up languages, such as XHTML, which is an XML-based version of HTML. Therefore, XML is not only a mark-up language comparable to HTML, but also a meta language to generate mark-up languages [cf. HITZLER; ET AL., 2008:17FF]. “Mark-ups” are information which enlargethe content of documents by marking certain parts and highlighting connections. The manner in which this is done can be compared to the design of a newspaper, in which spaces, different fonts, titles and positions are used to distinguish single articles. Furthermore, on the one hand, XML is a protocol for recording and managing, and on the other hand, it can represent a group of technologies used to format documents and filter data. On its highest tier, XML is a philosophy for the handling of data. Maximum user flexibility and comfort are achieved by limiting it to a structured and straight form of information. Several performance features ensure XML’s success (e. g. the possibility to store and organize information for actual demand). The open standard ensures that the user is not bond to companies or certain software. XML has very rigorous standards regarding the quality of its documents. It demands the strict following of syntax and offers a multitude of methods to test quality. Simple and clear syntax makes it easier to read and analyze XML for both man and machine [cf. RAY, 2002:1FF]. A program called “Parser” is used for checking. It reads XML, validates it, and forwards it for further processing. If the document indicates an error, it is not “well-formed” [cf. RAY, 2002:352]. The distribution and use of XML is supported by the “Open Source” movement with its many adherent programs and by the need for a standardized communication interface [cf. RAY, 2002:1FF].

Just as XML is one of the most popular mark-up languages, UDP (Protocol User Datagram Protocol) is one of the most used protocols for the transmission of data. Typically, it is used for simple question-and-answer protocols (e. g. DNS, DHCP, NTP). One of the characteristics of UDP is that it is a non-connected protocol which does not supervise the correct transmission of data packages. They don’t necessarily arrive in the right order and are directly forwarded to the proper application. Some of its strengths are its speed and system utilization, which is much lower in comparison to TCP [cf. NETWORK SORCERY, 2012].

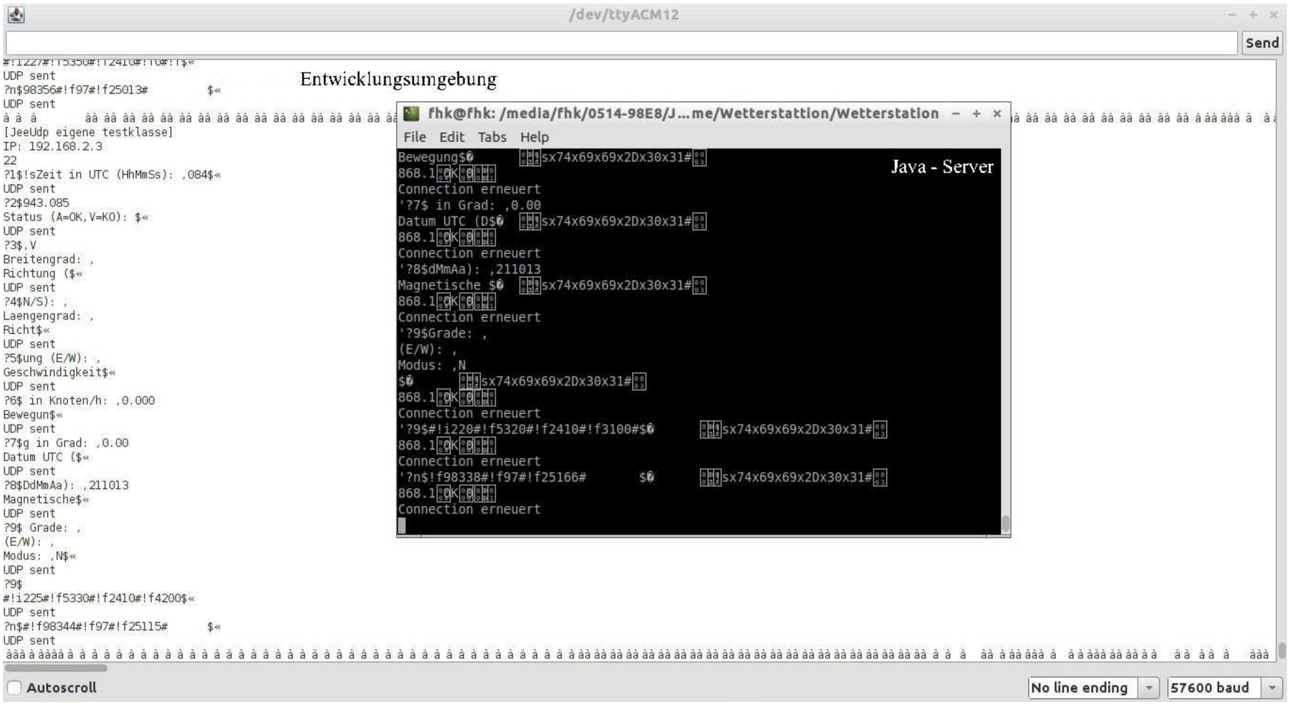

Fig. 1: UDP – runtime – environment of development – sending of climate data.

For this project, UDP protocols were used. They run smoothly and reliably on the low-performance urban sensing devices (Fig. 1). A TCP-connection is not possible with “Urban Sensing System”, as this protocol builds up a firm connection, which would require the sender to wait for the server to respond. However, during this waiting period, all important data would get lost. Skirting the waiting time with interrupts is not as easy, as the regulation (e. g. maximum of seven interrupts) at the multitude of sensing device’s microprocessors also requires these interruptions. In case of a lost package, two procedures have been developed: In a first step, the whole range of packages is dismissed, before, in a second step, the vacancy is filled with a default value (“0”), which makes it possible to calculate the missing value by interpolation.

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Usually, measurements are taken in short intervals (one second), which means that losing data does not have to be a big problem.

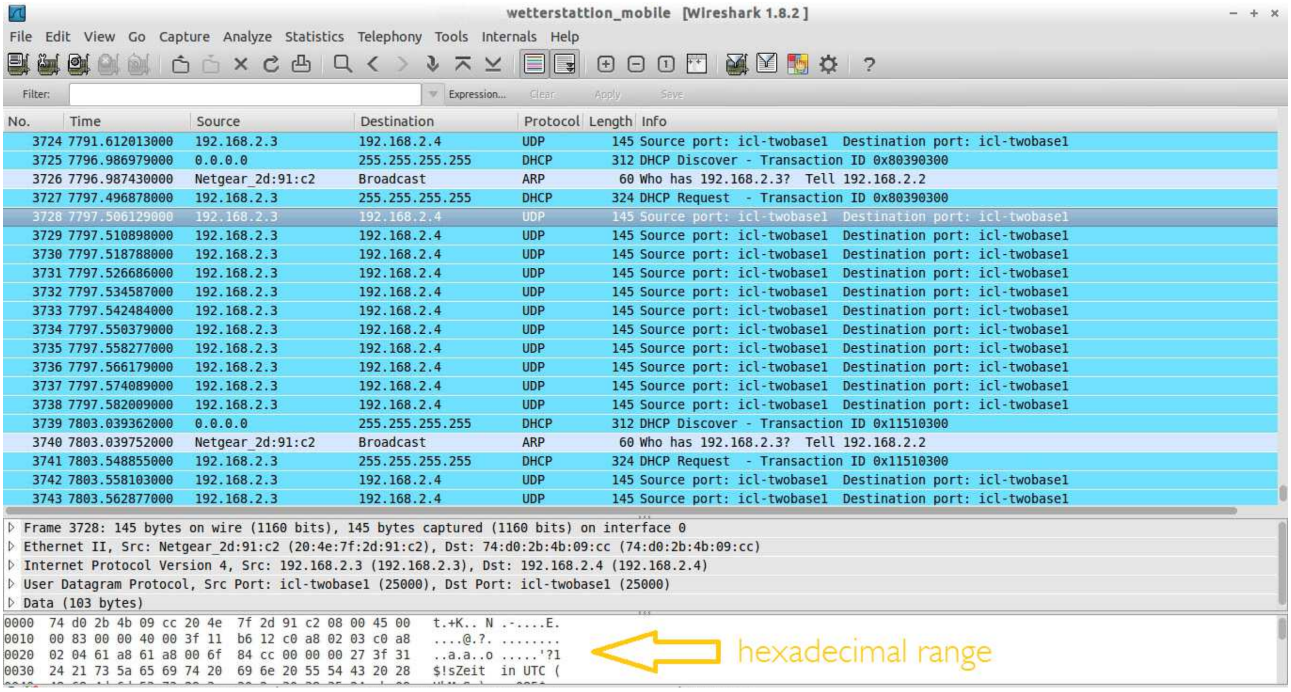

Fig. 2: Wireshark measuring of a network between sensing device and server.

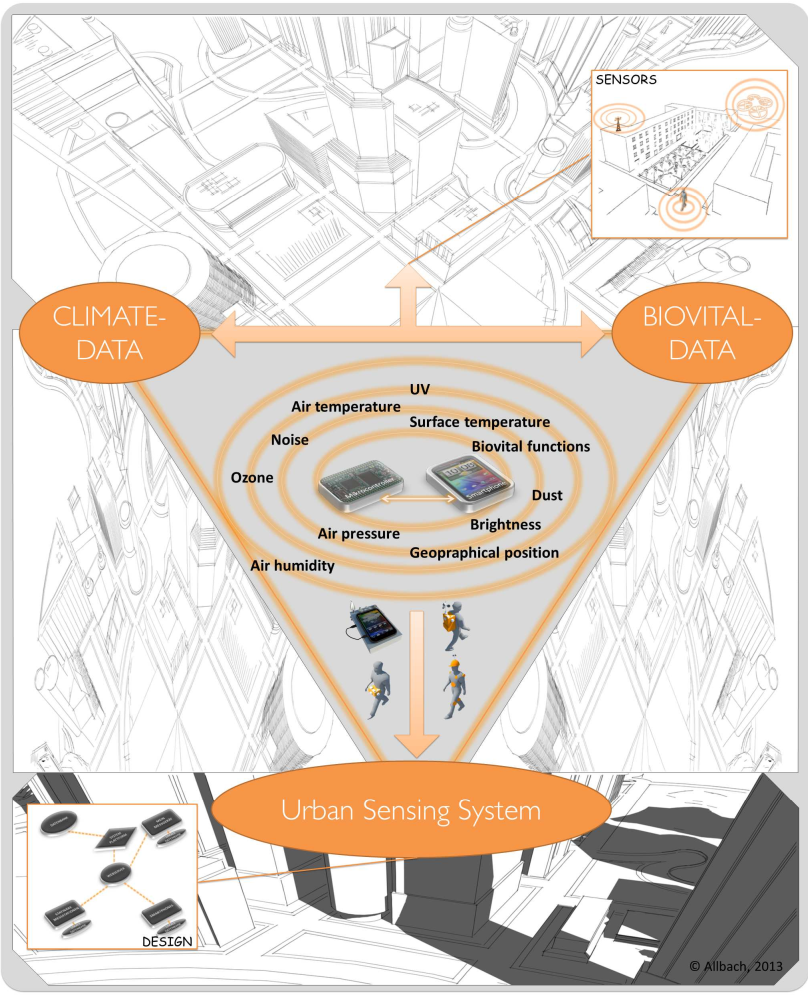

Fig. 3: "Urban Sensing System".

"Wireshark" allows to control data sent over a network connection. Figure 2 displays the connection between "Mobile Sensing Device" (192.168.2.3) and server (192.168.2.4.). The lower window shows the hexadecimal range where a part of the message content is visible. In this case, "?1$!sZeit in UTC (" is the exemplified structure of a message sent via UDP. Number of package ("?!"), beginning of message ("$") and type of variable used ("!s" - "string" in this case), are decoded in this rather cryptic command.

3 "URBAN SENSING SYSTEM"

3.1 Preface – Design

The "Urban Sensing System" is based on the idea of storing geo-referenced data for urban spaces (Fig. 3). This data consists of climate data and data of individuals' vital signs, while a wide array of sensing devices is used as "sensing media" (Smartphones, stationary weather stations, self-constructed mobile weather stations, drones, etc.)

3.2 System requirements

An "Urban Sensing System" needs to fulfil many requirements, such as good availability, connectivity, processing of data volume, stability, performance, storage ability, analyzing ability, openness, expandability, usability and the potential. All of this is necessary to set up user profiles and scenario instances, as well as to create added value for the user by a specific interpretation of the data [cf. ALLBACH; HENNINGER, 2013:1FF].

3.3 Realization

3.3.1 Web-based applications

To fulfill the system's requirements, web-based applications appear suited as a base for later operation scenarios. Web-based applications are typically used in a web-based environment [cf. LANGNER, 2004: 20FF].

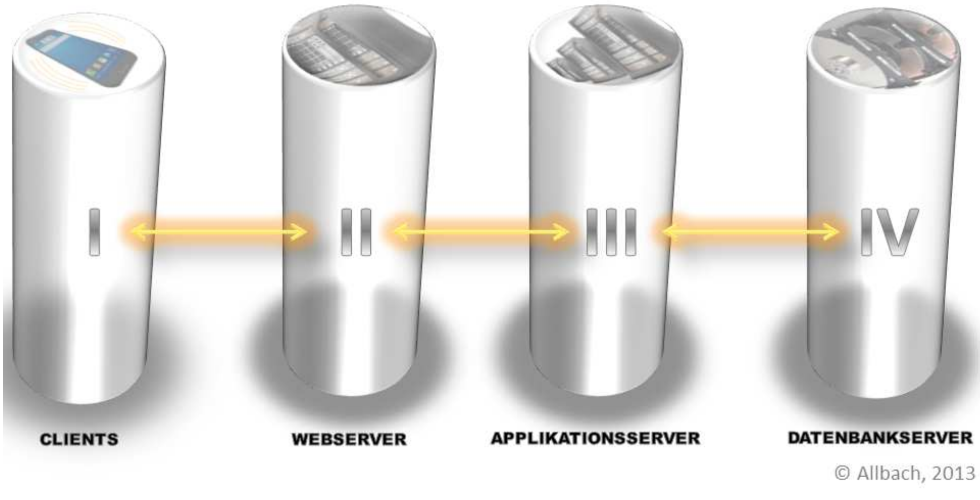

Fig. 4: 4-tier design.

Four columns, each representing an architectural tier, are shown in Figure 4: Tier I represents the client, Tier II a web server, Tier III an application server, and Tier IV represents a data base server. A standard web-application only needs Tiers I, II and IV. However, it must be considered that compatible technologies have to be used on the different tiers. For this reason tiers I-III mainly use XML [e.g., LANGNER, 2004:21]. Diverse technologies can be used for the web servers on Tier II. At this point, it must be decided which technology should be used for the development. Java, NET or PHP are options, and each has its strengths and weaknesses. Every application supposed to accept data from Tier I is called "CGI element" (Common Gateway Interface). Usually, Tier II employs Open Source-project Linux as operation system. Java developtechnologies which have the advantage for the user of being both developer as well as platform independent.

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In a next step, a web server has to be picked. Provided by the Apache Software Foundation, the Apache Webserver is commonly chosen [cf. LANGNER, 2004:27FF]. The latter is a “servlet container” written in Java. The web-based applications are transferred by “Java Servlets” and/or “Java Server Pages” (JSP). This allows a combination of HTML with conventional Java code without special support for the browser, as needed with JavaScript [cf. SAMASCHKE; STARK, 2005:31]. Java servlets are applications running in a server which is connected with the world wide web, and they are complementary to Java Applets running on websites. Servlets are used for designing programs that receive and send information via a webserver. Java Servlets are an alternative to “Common Gateway Interfaces”, the common programming language for gathering information in the www and export data [cf. LEMAY; CADENHEAD, 2002:732FF]. Besides Java, there are also other alternatives to deploy on Tier II. On Tier III, business logic is implemented. If applications from Tier II intend to retrieve logical functionalities on Tier III, they have to use a “Remote Procedure Call” (RPC). An example for the applications server’s function on Tier III is the inquiry at a bank about where a customer owns its account. Tier II is responsible for producing and releasing a document out of this data [cf. LANGNER, 2004:31]. The lowest level, Tier VI, is the one where data is stored. Many different types and developers of data bases are available. Again, there is an open source-solution, MySQL, among many others. Therefore, theoretically, it is possible to design a high-performance, scalable, web-based application that is independent from both platforms and developers. However, it should be considered that a free-of-charge-program requires experience and a higher effort for configuration [e.g., LANGNER, 2004:35FF].

It is not absolutely necessary to use a 4-tier or 4-column design as it is done here. There are alternatives, the most simple one consists of only two tiers. In this case, the client takes on the task of presenting while the server-level stores the data [e.g., BLANKENBACH, 2007:143FF]. The following section will focus on Tier VI, the heart of data storage in general and in the “Urban Sensing System.“

3.3.2 Data bases – Information Systems

Information systems are supposed to represent a faithful model of a fragment of reality (miniature world) on a system. If something happens that changes the circumstances, it has to be represented accurately. Objects and their relations are abstracted and transferred into the miniature world with the aim of matching the modelling and the reality as precisely as possible. State transformations must be interruptible if errors occur. This is guaranteed by transactions that follow the “ACID” (Atomicity, Consistency, Integrity, Durability) paradigm after GRAY, which uses quality assurance for model states [cf. BELL; ET AL, 2013:1FF]. To ensure current, consistent, and persistent data, the application and information systems require a number of measurements. The use of isolated data leads to some disadvantages, which means that changes in constitutions, dependencies, and relationships can only be modelled roughly. Due to the lack of a central control instance to store and update the data, erratic, missing, or contradicting information is hardly detectable. The commitment to an application creates dependencies of data and restricts the usability of data by other applications. This process leads to a high rate of redundancy which makes it impossible to modify all copies of a set in time. Modifications of operational processes require constant adaption of the application system, which can only be met by introducing further redundancies. Thus, the situation gets worse and worse.

The development of data base systems (DBS) complies with a broad spectrum of requirements, which have to be met by suitable implementation and architecture. It focusses on the realization of the following aims: integration of data and its independent and logically centralized administration, independence of data and the application's neutrality by the logical and physical development of the database, application-programming-interfaces for simple and flexible use of data, integrity checking, protected transactions, parallel and efficient processing of big data volumes, maximal availability, fault tolerance, and scalability [cf. HÄRDER; ET AL, 2001:1FF].

Users of the system and many residents of smart cities are provided with a number of different networks for an infrastructure of data and information exchange. Besides HTML-pages and the simple downloading of data, interactive web-based data and services are gaining influence. Web-cartography is only one example for such a service with “Google Maps” and “Google Earth” as the most well-known ones. While the user interacts with the map, certain applications are running in the background. The request for data is received by a web-server and processed by a map server, which uses a data server to gather the information needed to generate a specific map. The main structure of this process can also be transferred to other requests for information; the exchange of data can be described as a statistical or interactive exchange of data via web applications. Another form of information exchange is done by standardized services, e. g. WMS, WFS and OGC. The latter "Open Geospatial Consortium" has developed a multitude of standards for such web services. It allows communication and data exchange between web-mapping applications and other programs and therefore creates interoperability [cf. MITCHELL, 2008:9FF]. Ideally, web services, which convey data through networks use international standards. One of these standards is the internet protocol as described in chapter 2, which can also be used for geo data. "Web service" describes a service, which uses the standardized XML system of communication, independent from the operation system or programming language, and is available via internet. Web services are based on HTTP as transferring protocol, while XML is used as a markup-language [cf. CERAMI, 2002:3FF]. Both are considered as a key technology for many application scenarios. The use of XML ensures a clear structure of data as well as automatic access and processing by client software. Many concurring technologies have been introduced to the market under the general term "web services" with SOAP (Simple Access Protocol) as the main representative [cf. BLANKENBACH, 2007:205FF].

3.3.3 Structure of the "Urban Sensing System"

For the "Urban Sensing System", a MySQL data base has been used (Fig. 5) as it is free of charge, widely spread and technically mature. In order to get better support, MySQL could be replaced by MariaDB (https://mariadb.com) in the future, which is getting more and more support by Open Source supporters.

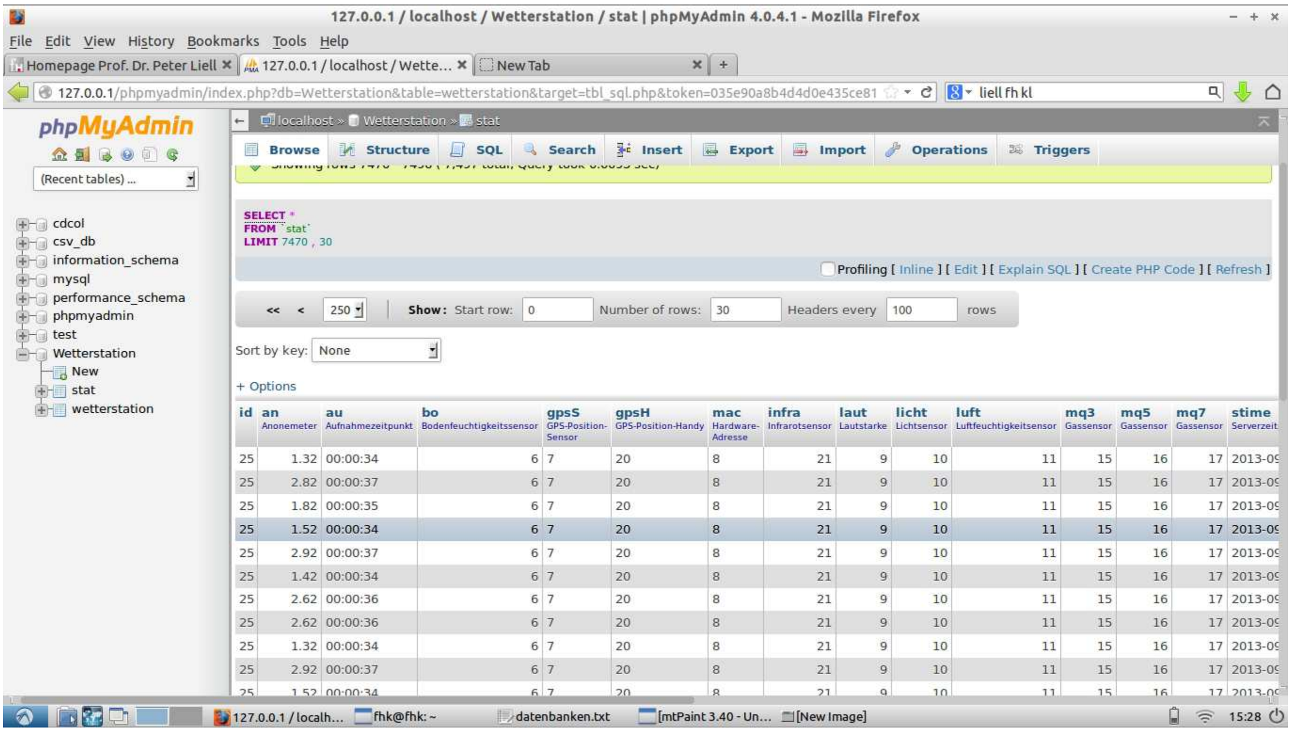

Fig. 5: "phpMyAdmin" – MySQL data base displaying measured climate data (measured by a mobile weather station).

A prototypical web site and various prototypical web-based applications are built on the MySQL data base. Its structure is designed to store all metered data in a chart. A second chart, holding user name, IP, and MAC address of the sensing device, is included in the data base to ensure the correct attribution of the measurement data. Both charts can be linked by SQL commands (e.g., "join").

3.3.4 "Climate data and vital function values in the "Urban Sensing System"

Climate data and values of vital signs are stored in a structure designed for the project, while ID, name, meaning, and type of values (float, int, timestamp) are also defined (Fig. 6). The option "Null" allows a space to stay empty, but it can also be designed to fill the empty space with a value.

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4 VISIONS AND USE-CASES FOR THE "URBAN SENSING SYSTEM"

4.1 Using the "Urban Sensing System"

The "Urban Sensing System" will be tested by an academic hardware club in 2014. Under assistance the pupils will construct a simplified version of the mobile Urban Sensing device (microcontroller-based), which is able to determine air temperature, air humidity, air pressure, light intensity, sound intensity and the geographical position. In terms of vital functions, pulse, skin resistance, skin temperature and skin moisture will also be measured. Further metadata will be saved anonymously. Equipped with these devices, the pupils will go and explore their neighborhood, and the gained data is transmitted to the "Urban Sensing System" and analyzed. This experiment will be interesting as the pupils are all of similar age and are covering the same neighborhood. Additionally, they gain insight into the MINT area (Mathematics, Informatics, Natural Sciences, and Technology) and learn about programming, brazing, and data bases in an active, playful, and age-appropriate way.

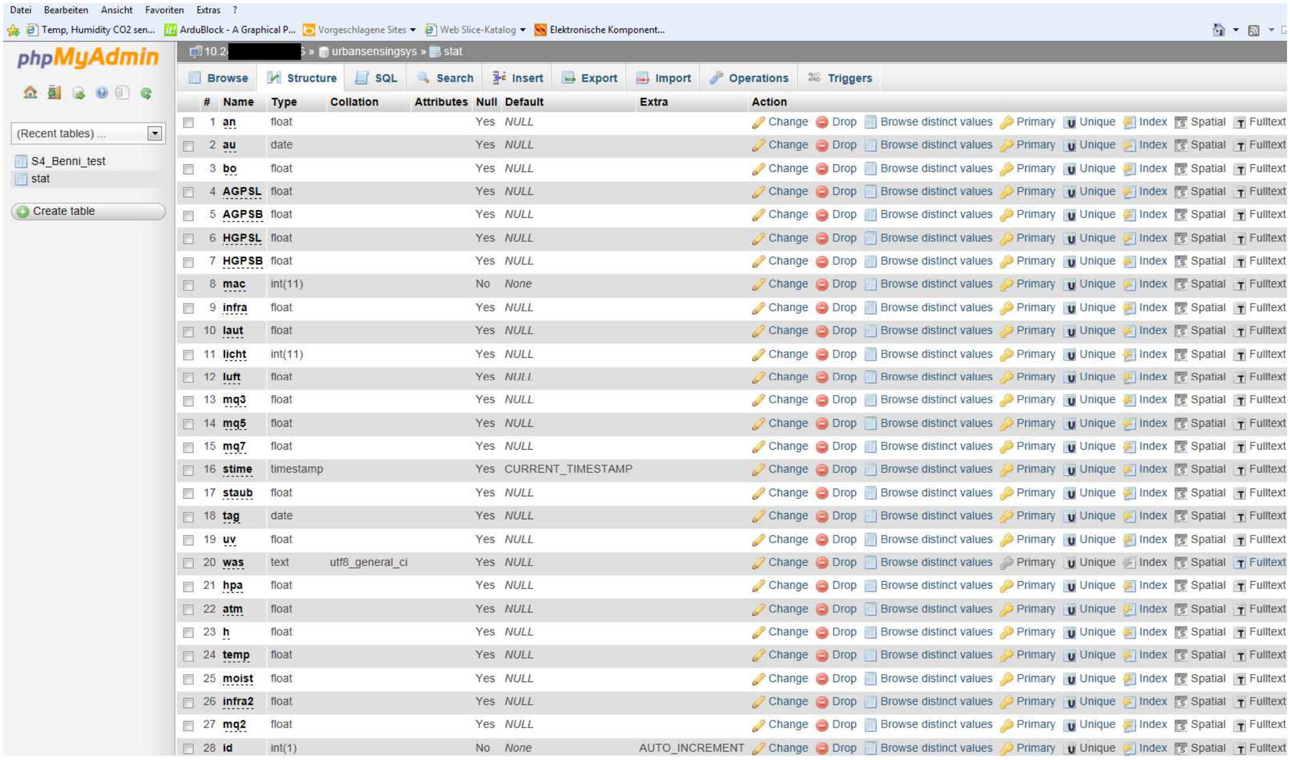

Fig. 6: Structure of the data base: names, types, etc.

The stored data can mainly be used for planning, simulation, cartography, and displaying information. The "Urban Sensing System" allows a decoding of the complex relations found in an urban ecosystem.

Many utopias and dreams can be fulfilled by a program which is able to store climate data and vital function values in a single system simultaneously. The huge spectrum of data and the multitude of sensors make it possible to detect problem and at risk areas in real time. In this manner, they can be skirted, repaired, or isolated, for instance, by warning residents of high air pollution levels. Problems caused by traffic noise could be avoided with intelligent road signs, which redirect traffic or reduce speed limits. Finally, the system could act as a signpost to areas with a high quality of life.

More and more people live in urban areas resulting in increased population density. These local settlements have an influence on the global as well as on the regional climate. The question arises to what extent the settlement climate is creating invisible barriers. Furthermore, it would be interesting to examine if local climates compromise or impede particular groups while others might feel comfortable in the same zone. Are certain structures and facilities really barrier-free or do they only appear to be so? This hypothesis could be tested through an "Urban Sensing System."

5 CONCLUSION

Currently, the “Urban Sensing System” is used exclusively by friends and relatives of the developers, because it is still in an early state of development. It is anticipated to make the system freely accessible in the future, which would require it to run smoothly, be available online, and to be difficult to be manipulated. At present only familiar devices are connected; additional information can be entered by the user on a voluntary basis. The system is bound to require the storage of MAC, Email, and IP addresses, which are not communicated to the user of the system. Therefore, privacy is at least partly guaranteed. In terms of privacy, one needs to cast a critical eye over the fact that climatological data and vital function values are displayed with geographical references. Furthermore, it is extremely time-consuming to activate all users manually. Hence, a function to automatically register and activate users needs to be introduced.

A lot of time must be invested in the system’s web presence, especially for design and usability. Currently, the site is nothing but a mere playground to test different techniques. It is envisaged to launch a “Content Management System”, which could simplify registration and administration. The “Content Management System” is planned to be connected to social media, which, along with a possible reward system, motivates users to enter data and contributions to the data base.

In the future, the “Urban Sensing System” is supposed to run autonomously and autarkically. Interfaces with other systems would allow open and voluntary cooperation, such as other mash-ups. Foundations for it have already been set during the developing process.

Measuring the quality of life is a difficult task. In a philosophical context it is not even thought to be possible. Factors influencing the quality of living are evaluated differently by different people. And also, not all measuring values have a positive influence on the quality of life of urban residents. Noise, dust, light intensity and temperature would have both positive and negative influence on human organisms. The “Urban Sensing System” stores all this data in a single system and makes it possible to develop and test new hypotheses.

The “Urban Sensing System” allows the creation of maps of all kinds, such as maps of climate functions or heatmaps.

The possibility to be part of data acquisition (through the Urban Sensing App [cf. ALLBACH; HENNINGER; GRIEBEL, 2014]) allows active participation instead of simply being a passive consumer. In addition to the collection of climatological, vital, and other data in a bottom-up procedure, future versions of the “Urban Sensing System” will introduce a top-down principle to have users receive warnings or recommendations by the system.

Internet and internet technologies offer a multitude of possibilities and are shaped by society, culture, science, and economics. The society is the basis for planning, and so the internet has to become part of planning processes. If a planner wants to analyze the complex system of a city, he or she needs the knowledge about programming and information systems, although bi-directional communication and exchange of knowledge, information, and news is already being simplified by the internet. Hence, the planner has to engage in these new technologies, and constant advanced training in the sphere of informatics is also necessary. Interdisciplinary projects and partnerships with institutions, faculties and companies become more and more important, because this allows the planner to participate in the development of solutions for today’s and tomorrow’s problems in a creative way. A planner who is confronted with structural and social conditions on a daily basis needs to focus on the conditions of knowledge and information. The smart city can only exist by means of smart networks, tools, planners and systems, and the “Urban Sensing System” could be one of those.

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