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New Methods of Climate Monitoring

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1 ABSTRACT

The atmosphere is a crucial ecological factor which could strongly influence the human being, the community, and nature by local weather conditions. One part of this ecosystem is the city in which anthropogenic factors (traffic, industry, housing complexes) and natural factors (water, soil, air) interact in a tight space. The interconnection of the various factors creates a highly complex urban ecosystem. One of the most important reasons for the intensive research in the field of urban ecosystem is the realization that physical and meteorological processes are at work within the climate of these agglomerations and the local climate, which influences the human being. However, humans are also unconsciously influencing this climate. Urban design and other artificial changes in the terrain also create anthropogenic climate modifications. This can have positive as well as negative consequences. Since the climatology is ever more developing from a descriptive science toa global, interdisciplinary system science which has an increasing social position, because of energetic processes of transformation that can be displayed more and more accurately. Especially, the anthropogenic influenced climate and its ecological systems and processes are in the focus of numerous disciplines. Some of these disciplines are geography, urban design, architecture, environmental design, medicine, and agriculture. This paper wants to show how micro scale climate measuring could be performed in habitats nowadays in a new way. The most important climatological measurement units will be introduced. Furthermore, it will be described how currently manual measurements are performed by the use of individual devices. Subsequently, it will be explained why these classical measurement units are not adequate to describe an urban ecosystem. The question should be answered, which indicators must be gathered, in order to optimize the analysis of the influence of the urban climate on the human well-being and how adequate data and information infrastructure could look like? It will be discussed which additional data and methods of climate monitoring are necessary to describe the urban ecosystem more accurately. Finally, new concepts will be introduced how the urban ecosystem can be explored by a new innovative combination of psychological, physical, and climate data. In the process, bio-vital functions, crowd sourcing as well as emotional data will be gathered additionally to climatological data.

2 INTRODUCTION

The atmosphere extents up to a height of 1000 km. Especially, in its lower sections it is an factor for the environment. The climate and the weather are important for the nature and the society. The climate describes the condition of the atmosphere at a certain location over a long period of time.The weather, on the opposite, describes the perceivable short term conditions of the atmosphere at a certain location [cf. KUTTLER, 2006:1]. Meteorology has its roots in the Greek language and means the science of the celestrial phenomenons, and is therefore a part of geoscience. It deals with the physical and chemical phenomenons and processes of the atmosphere as well as reactions with solar radiation and the surface of the earth. In a time-space relation, its interest includes everything between microturbolences and climatology, for instance the local weather. The research field of climatology is, because of its interdisciplinarity, than the one of the meteorology [cf. Brockhaus, 2009:218FF]. Meteorology can be seperated into the dynamic or theoretical meteorology, synoptic metrology, and the experimental metrology (physics of the atmosphere) [cf. Brockhaus, 2009:218FF]. One basis of the observation of the weather is a constant recording of it. By using current data and taking the condition of the atmosphere into account, a weather forecast can be created. Amogst others, the measureable data consists of the air temperature, air pressure, and precipitation. Furthermore, parameters like wind direction, cloudiness, layer of snow, hours of sunshine, special weather phenomenons (e.g. hail, thunderstorms, fog), the behavior of animals, and the phases of the vegetation is being analyzed [cf. Brockhaus, 2009:40FF]. Climatology is the science of the climate, the change of climate and its consequences. Climatology is a part of meteorology as well as of geography. It has connections to biology, chemistry, physics, glaciology and geology. Climatology can contentwise be subdivided into climatological aquisation of information, climate diagnostics, climate modelling, and the research of climate effects. Because of the complex and manifold processes of the climate system, a special, physical climatology arises, which primarily uses physical climate modelling. It is regarded as impossible to understand climatological processes completely in the foreseebale future. Additionally, applied climatology is important for the engery industry (usage of wind, water, and solar energy), agriculture (bioclimatology), the public health sector (humanbiometeorology), and water economy (hydrometeorology) [cf. Brockhaus, 2009:183].

As a result, it can be concluded that climate effects are cumulative and have consequences on human beings. These consequences occur spatially very in different ways. Resarch to increase our understanding of the connection between the global climate change and health is strongly needed [cf. Kappas, 2009:223].

Nowadays, the applied urban climatology has gained importance beyond the controversy of the global climate change. Most scenarios for developments of the climate in the next decades point towards an increasing global temperature. Extrem weather conditions will increase, especially in urban areas will be an intensification because of local climatological and air quality factors. The applied urban climatology deals with climate and air quality modifications. There is not only observating and analysing the climate and air quality, but also the analysis of the consequences for the biotic and abiotic factors of the urban ecosystem. The applied urban climatology can be considered as a link between climatology and urban design. Knowledge, gained out of urban climatological analysis, is transcribed by analytical climate maps and planning reference maps respectively. By now, humanbiometeorology is a constant part of urban climate. Human biometeorology analyzes, amongst others, the effect of the urban climate on the well-being of humans [cf. HENNINGER, 2011:89F].

Various micro, meso, and macro factors are shaping the urban climate. For instance, latitude, landscape, height above sea level, the distance to major oceans or sees, the size of the city, the population, the type of rural and urban land use, the topographical, rural and urban structures, the rate of sealed areas, source of emission and the perceivable and latent rejected heat of technical processes [cf. KUTTLER, 2006:372F].

3 MEASUREMENT PROCESSES

3.1 General Measurement Processes

Different measurement processes are suited differently well for various situations. Therefore, it is regarded as reasonable to formulate definitions and declarations of the measured area. Afterwards, the measurement precision, the scale, and the measurement duration have to be determined. Depending on the stage of development and the standartization of the measurement methodology, these preconditions can vary. It has to be differenciated between stationary measurement, remote sensing methods, additional methods and mobile measurement.

3.2 Stationary Measurements

The stationary measurement is often executed in measurement networks. Established networks in Germany are the synoptic-climatologic measurement and observation network, and the extraofficial climate and precipitation measurement network of the German Weather Service (DWD). However, these measurement networks were not meant for the data aquiring in an urban climatological context. These networks are for the weather forecast. The major problem is that the spatial density of the individual measurement stations is too wide for an analysis of the urban climate. Nevertheless, measurement stations near an urban area can be used as reference. Stationary measurement processes are well suited for observations over a long period of time [cf. OTTE, 1999:289FF]. Professional measurements are conducted in a Stevenson screen, what means that a box is attached at the top of a two meter high frame. The relevant measuring instruments are inside the box. The box protects the sensible instruments from damage as well as outside influences which could distort the measurements. Blinds secure an undisturbed air circulation. Another type of measurement stations are the various small and semi professional private stations. The basis for a private measurement station is a thermometer, a hygrometer, and a barometer. Additionally, one can add a rain gauge and an anemometer. All these instruments can be found seperatly or as a single measurement instrument. Private stations can be distortet because of inaccurate measurement technique and frequently wrong locations.

3.3 Remote Sensing Methods

Remote sensing methods like, for instance, RADAR, LIDAR, and SODAR are mostly ground based methods, but an exploration via airplane and satellite is also possible. Thereby, the atmosphere is explored by radio, light and sonic waves. The development of drones ("anmanned air vehicle" (UAV) or "unmanned air system" (UAS)) has increased in the past few years. Nowadays, drones are mainly used by the military. However, a civil or private usage is possible. Drones would offer new possibilities for the climate observation and landscape monitoring. Due to low costs for aquisation and maintance, a multitude of data can be gathered with these unmanned helpers. Unlike ballons and airplanes, drones would allow to monitor the climate and the weather in street canyons and close above buildings. This could be done at a fixed position as well as over a distinct transect. A more precise horizontal observation of the urban boundary layer would be possible. Also a theoretical determination of the urban canopy layer and urban turbulent layer respectively is possible. Another idea could be to follow individual persons in the city from a "birds eye view". The person could be observed with an infared camera to gain new insights into the reaction between the human organism and the urban structure (if it is not against the law).

3.4 Additional Methods

Phenological obervations are part of the additional methods. The vegetation offers information related to the climatological advantages and disadvantages. However, often various different factors are playing a role, for instance soil quality [cf. OTTE, 1999:299]. One example of additional methods would be the project "Klimabiene" (www.klimabiene.de). By spreading out researchers over a wide area, questions about correlations between weather, the development of the vegetation, and flock events could be answered.

3.5 Mobile Measurement

Another possibility detecting the inhomogeneous urban structure is using mobile measurements. The advantage of this type of methodology is the high density of measurements, which could be mapped spatially. Although, especially in the applied urban climatology, the methodology of mobile measurements to detect data of air temperature and air humidity has been practiced for a long time, mobile air quality measurements do not have quite a long tradition. Already in the 1920´s, mobile air temperature measurements were made by Schmidt and Peppler. The first ones were semi-mobile, but in the course of the time the technological development allowed to measure continuously from the beginning to the end of the transect [cf. Henninger, 2011]. At the department of Physical Geography at the University of Kaiserslautern, such measurements are carried out by the students regularly. The climate data are gathered by individual portable measuring instruments and e.g. the results are written down manually. Exemplarily, the measurement devices record air temperature, air humidity, surface temperature, lighting conditions, and the wind speed. Later on, the gathered data can be copied into a Geographic Information System (GIS) and can be analyzed. The GIS makes it possible to show the relation between the different types of soil-coverage and air temperature. For example, the air above the natural surface is colder than the one above the asphalt (Fig. 1).

Fig. 1: Mobile measurement – Map of the air temperature – Group project – GSP&Stadtklimatologie 2009

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However, it is easier if the data could automatically be determined and recorded. Hence, another method of climate monitoring is an electronic and mobile field book.

It is desireable to include smartphones as mobile measurement devices. Beside localization via GPS, smartphones have various sensors which can be used to collect environmental data. Furthermore, smartphones allow data transfer (e.g. UMTS, LTE) and the possibility to store, amongst others, digital documents, pictures, and audio recordings in a database.These functions enable smartphones to be used as electronical field books.

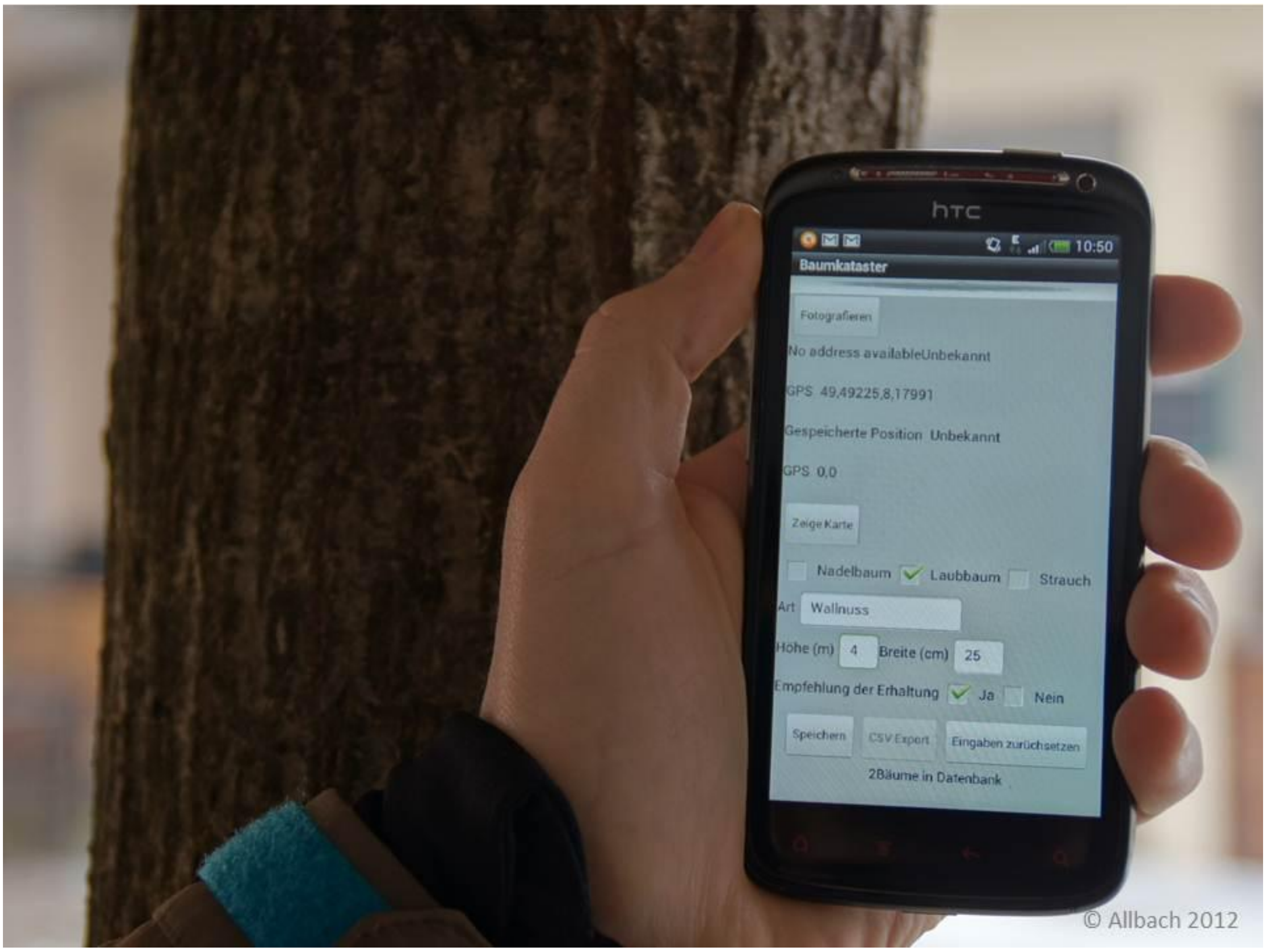

Fig. 2: App: „Baumkataster“ – Recording position & data of a tree

The self-developed (ALLBACH, GERMANN) mobile tree app (“Baumkataster”) is an example for an electronic field book (Fig.2). It is possible to store the location of a tree as well as to determine it according to its classification. Some meta data, such as the height and the circumference of the tree, can also be stored. Afterwards, the data can easily be edited on the computer.

Another way of mobile measurement of the climate is done by car. A monitoring car can continually gather stationary, as well as mobile meteorological and air quality data. In Essen it was possible to show the connection between an average CO_2 emission and various types of land use [cf. HENNINGER, 2005, 2011]. Tracer and drift smoke experiments are also mobile measurement techniques. They are especially suited for the phenomenological and visual proof of air movement near the ground. They can be used to measure nightly cold air flow under autochthonous weather conditions. Tracer experiments use easily managable chemical tracers such as sulfurhexafluoride (SF_6). This gas can be measured short after it was emitted in the investigation area. By this, it is possible to gain knowledge about the penetration depth and the volumetric flow rate [cf. KUTTLER, 1996] [cf. OTTE, 1999:289].

3.6 Urban Sensing

A new type of measurement could be the so-called ‘urban sensing.’ The individual human being or his or her carried equipment can be used as a measurement instrument for ‘urban sensing.’ A combination of stationary and mobile sensors is possible [cf. Campell 2006]. Urban sensing in combination with the 'Web 2.0/ Web 3.0' is a new possibility to gather and analyze data. These data, which can be gathered actively as well as passively, have a yet unpredictable value for urban design and climatology. It might be necessary to develop new algorithms and programs, which are able to do more than simply process physical input, in order to make this new data source complete accessable. The possible usage could be separated into three fields: personal scenarios, social scenarios, and public scenarios. A personal scenario could be the monitoring and analysis of one's own vital functions. In a social scenario data of a fixed group of people could be gathered and handled by social networks like Flickr. In a public scenario there would not be any limit and the whole population could take part in it [cf. Srivastava; et al., 2006:1F]. One advantage of this kind of data collection is the possibility of monitoring huge areas over a long period of time [cf. Hof, 2007:1]. Out of financial reasons, this is mostly not possible with the classic methods like couting and measuring. Also the already existing ubiquiority of mobile devices is important for the accuracy of the data [cf. Goldman; et al., 2009:4FF]. There are already projects which try to use urban sensing. Noisetube (http://noisetube.net) is a system for the monitoring of noise. Waze (www.waze.com) is a mixture of crowdsourcing, geotagging, traffic information system, and real time map. Users are able to inform each other about traffic jams, accidents, and other problems. They can even use it for mapping a city on their own. Because data could be collected in real time and it is also possible to send the data directly to the system, this program is interesting for planners. Another aspect which might be interesting for planners is the possibility to monitor areas like nature protection areas or new development sites. A combination with an augemented reality technique might even increase the popularity of urban sensing [cf. Allbach, 2010]. A simple use of urban sensing was the project tracking people of CPE at the TU Kaiserslautern. During this project the movement, activities, way of locomotion, and various other metadata of students was manually gathered and analyzed around-the-clock over a longer period of time. Additionally to the aspects of covered distance and way of transportation, it is also possible to analyze the availability of parking spots at certain locations, the demand for public transportation and the availability of electronic vehicle networks. Furthermore, it is possible to gather climatological data directly and indirectly. The metadata can also be used to draw even more conclusions. The average movement speed, the rate of emission of each person or in a specific area can be calculated. It is possible to compare the influence of the development of the temperature in a certain time frame. Which ways of transportation are selected during a specific season or temperature? How long does a certain group of people expose themselve to the weather? These are questions which could be answered through urban sensing.

Fig. 3: Tracking People 2.0: – Presentation oft the routes and frequency taken by car – [Allbach, Fabisch 2009]

This, of course, very simple system could be automated and expanded with state of the art technology. Updated and expanded information content could lead to the development of new theories which could base upon new statistical facts and new combinations of data.

The data could be used to identify the monitored area and select the required measurement techniques as described in the introduction about measuring methods. In figure 3 the transects of the students taken by car can be seen, sorted by frequency. At the red marked main routes it might be possible to measure extreme magnitudes of e.g. emissions. These data can also be helpful to select and postion suitable measurement instruments. Connections between the way of usage and climatological and medical metrologcal data could be discovered. Additionally, it is possible to create special subgroups through the metadata, e.g. male, female, student, pupil, senior citizen, allergic subject, etc..

Another type of urban sensing is called tagging. Thereby, information is connected to a geographical position, e.g. uploading pictures to google maps. In the field of urban design, tagging is used in the two dimensional space in the study “A New Urban Sensing and Monitoring Approach: Tagging the City with the RADAR SENSING App” (Zeile, Memmel, Exner 2012), the “Sensing the City” project (Bergner, Exner, Zeile, Rumberg 2012), and “Mobile Digitalisierung von Baulücken – Baulückenerfassung mit GIS, iPad und Geoweb” (Biwer, Broschart, Höffken). Especially the plattforms ALOE and RADAR, which were developed by Martin Memmel at the German Research Center for Artificial Intelligence (DFKI), offer various possibilities how urban sensing scenarios could be realized.

Fig. 4: Tagging with augmented reality – Emotinal Maps & Partizipation – Allbach 2010

New technologies like augemented reality (AR) can be used for urban sensing. The diploma thesis “Augmented City Kaiserslautern” (ALLBACH 2010) explains how virtual tags, as an information carrier, can be blended into the real world. For planners, the active tagging of objects in the real world offers an comprehensive database. How a project is accepted by the puplic can be analyzed. Nuisances like noice, dirt, problems with a typ of ground covering, or insuffcent accessability could be identified in a new way and through the uploading of pictures and voice recordings be further documented [cf. ALLBACH 2010, 2011].

The project „Emomap“ of CPE of the TU Kaiserslautern tries to discover in how far it is possible to gather and analyze georeferent emotions with the prototype of a ‘smartband’ (developed by Dr. Papastefanou at the GESIS – Leibniz-Institute for the Social Sciences) and a GPS logger. Another similar and interesting project was called “Biomapping”. It is a puplic project which is analysing the perception of puplic areas.

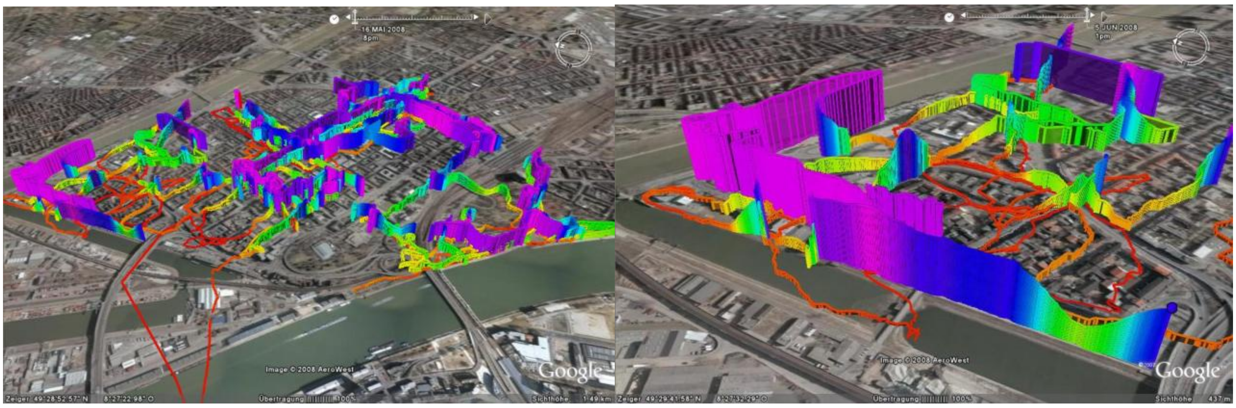

Fig. 5: Emomap: Analysis of the results of all groups – Allbach et al. 2008

Figure 5 shows the different routes which were used in the urban area of Mannheim. The "emotions" are depicted by the height of the graphs. It is striking that in some areas of the city higher amplitudes can be seen. Already during the experimentit could be realized that the emotional mapping of a city is hardy possible out of various reasons. It was not possible to explain definitly what caused the emotions or the psychophysiological processes. However, they supposed that climatolocigal or bioclimatological aspects could have been the reason for the reactions, for instance a shadily park as seen in figure 6. A certain statistically conection between temperature, stress and emotions could be proven. It has to be noted that the prototypical test procedure as well as the insturments are error-prone.

Fig.5: Emomap: Possible interconnection of climate & "emotions" – Allbach et al. 2008

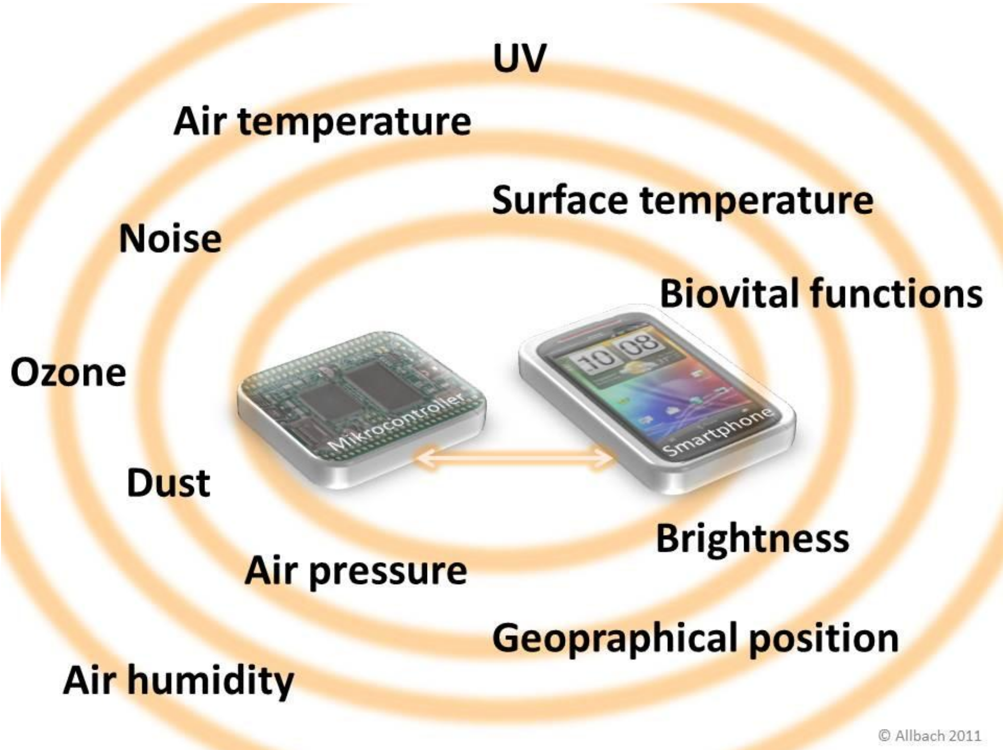

Fig. 7: Embedded Urban Sensing – Example for the measured data

4 DEVELOPMENT OF A WEB BASED SYSTEM TO STORE CLIMATE DATA

A multitude of biovital functions could be recorded by the sensors. For instance, heart rate, airflow, temperature, level of blood oxygen and skin resistance will be recorded, but much more is possible. The climate indicators depicted in figure 6 shall be linked with the biovital functions. Unfortunately, it is not possible to measure all biovital functions at present. It would be revealing to measure blood counts of various probands. This has already been tested by companies such as Medisana, Withings, and Sanofi-Aventis, but it is not possible to combine all existing single sensing instruments into an all-in-one gadget. Also, most instruments do not offer the possibility to access the data since most producers favour closed systems. However, it is detectable that the publication of various crowdsourcing applications, which monitor the biovital functions, in the context of social media plattforms, are appealing to the users. For instance, the sharing of covered distance, energy consumption, time needed, and covered difference in altitude with friends in Facebook. This might pressure the producers of E-Health-plattforms to create an open system.

The various sensors gather a multitude of different data. They have a highly differentiated quality and conformity. A method must be found to connect and blend them which one another, since this is an important aspect. It has to be considered that data is available in various different formats and that it has to be brought into a compliant format later on. Especially time and geoprathical position are critical values and can lead to severe misinterpretations, if they are imprecisely measured. If the data is to be saved in a system, standards have to be defined in order to make the data compareable. Measurement units, names, spelling, and units have to be defined, too.

Since as much as possible data should be gathered, it seems to be reasonable to keep the maximum amount of attributes of the data unlimited. At the same time, the collected data has to offer a certain amount of information content. This content has to be at least date, value, unit, and the precise geopraphical position of the measurement.

The processing of the data will be done by a centralized system. A GIS seems to be the most suitable way to gather, analyze, and publish the “Complex-Urban-Sensing-Daten.” Questing, whether it makes sense to intermingle the data, and if they are in some way connected, is also an important aspect of the work. The project requires not only knowledge of the subject, but also creativity. Especially this creative process can at the moment hardly be done by machines or an artificial intelligence (AI). At this point it must be alluded to Pachube, which continuously developed further in the past years. Meanwhile, the Pachube project has be sold and renamed to Cosm. Many of the described functions can partly be achieved by Cosm. However, the dewvelopment, availability, and the interests of a company can not be predicted [cf. MACMANUS 2011].

This short description illustraits it and a complex system is needed in order to gather the complete data. Out of this reason we want to define a minimum of the essential requirements.

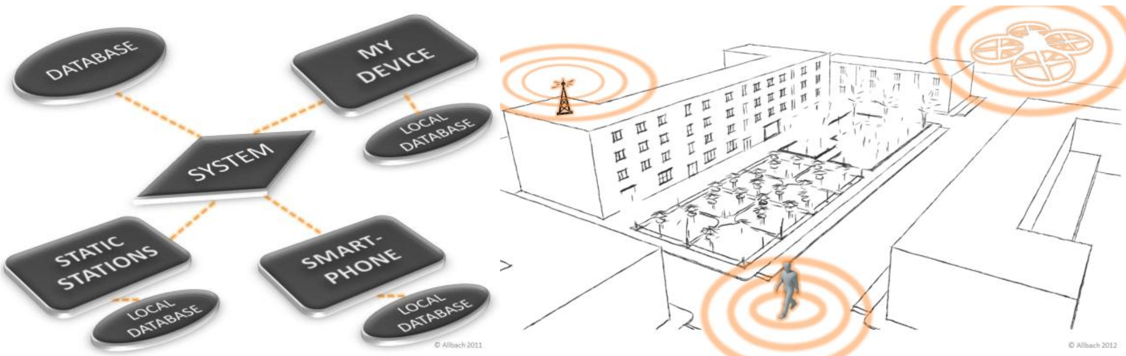

Fig. 8: Structure of the System (KUSS – CUSS) – various measurements in the city

Requirements

- Availability
- Connectivity
- Handling of heterogenic data
- Stability and performance
- Storage capacity

- Capability to analyze
- Open source and expandability
- User profiles and scenario instances
- Usability
- Additional values for the user

There are various requirements for an all-encompasing sensing plattform. Ideally, it should be accessable world wide. However, this will not be possible in the early stages because of language differences and lacking accessability of data connections.The system has to have a high connectivity, which means the ability to connect as many as possible sensor devices of various sorts as well as to spread the gathered data to other plattforms. Furthermore, it must be able to export and import the gathered data. This allows the processing of specialized local data as offered by GOSOL and ENVI-met and the uploading of additional information about the urban and natural structure, for instance urban ground composition. Another linkage could be a connection to a social media network.

The system has to be able to store various heterogenic data. But this is problematic. An example could be the temperature at a certain place, but also the information about the height of a tree. The potential data and its information content are wide spread. The "Semantic Web" technique might be helpful to achieve this goal. Another requiement is the stability and perforemance of the system. The system has to be able to handle the amount of quickly succeeding measured data, which can consist of large mounds of data, e.g. pictures, and which can be used by various users simultaneously in real time. The system has to be failsafe and independent of any company which might shut it down or sell it. It has to offer enough storage capacity, secure the data, and guarantee that data are unmodified. Furthermore, it has to be possible to import data directly and manually. The system should have at least a rudimentary ability to analyze the data. Expandability and being open source are important features of the platform. In order to impliment new functions and develop it further, it would be helpful if the system was built up in a modular way. User profils and scenario instances will help to order and filter the data in the system. It could be possible to create spezialized user groups like allergic subjects or pupils which are effected more by certain factors. Usability is important since users prefer a simple and easy system. Furthermore, it should not be ignored that older people and people without technical knowledge must be able to use the system. For the administrators it could be helpful if the system was easily manageable and developable. The plattform should offer something to the user. It would be possible to include an alarm function for special weather conditions, dangerous measurement results, and advices for the user.

5 CONCLUSION – AND FUTURE WORK

Climate and weather are complicated and complex. Likewise is the heterogenuous structure of an urban area. Research is required in order to gain a better understanding of the connections between an urban area, climate, human beings and their health. Out of the single topics and fields a new system science will arise. The presented methods and techniques will allow it to observe and analyze climatological data and data which are relevant for urban desgin. A multitude of individual measurements try to establish a connection between the climate, the city and human beings. The use of crowdsourcing and urban sensing will allow to gather novel and specific data. Even scenarios which include the complete population could be realizeable. New techniques like smartphones, mobile internet, embedded systems, and AR offer a new potential for the monitoring. The gathered data can be digitalized and further processed, for instance in a GIS and new kinds of maps could be created. Climate data are often defined by thresholds and guidelines which are based on long term basic and empirical research. A direct and complex research within the urban ecosystem would be remarkable. The presented standard climate measurement methods are mostly directed at special fields of climate research. Manual measurements are often required. Missing or inconsitant measurement results are mathematically calculated. The presented possibilities of crowdsourcing, urban sensing, and Web 2.0 plattforms should be used in climate research. A new form of climate monitoring is coming into existance, one which not only supplies the planner with pure measurements result, but also with human biovital functions and other metadata of the urban population. This should be done by a centralized system ("Complex-Urban-Sensing-System" CUSS) (Fig. 8). The recording of immidiate bodily reactions could lead to new insights into the complex urban ecosystem which might change the planning process and offer a new way of monitoring. These new observations should be done by daily carried gadgets and stationary measurement stations as well as a new developed sensing instruments. Out of this reason, the authors want to point to their other paper “Mobile Embedded Climate Sensing 2.0” in which, amongst others, this instrument will be introduced in detail.

A basis for the system could be geographic information system, which in connection with a database can be used for analytical purposes. Also the WEB 2.0 / Web 3.0 can be used for the realization of an urban sensing system. It is our intention to develop a system which is qualified for the storage of climate data. Our expanded measurements of the climate will start with the first autochthonous weather situation of 2013. At present we are also analysing climate accessibility (www.klimabarrierefreiheit.de) and we hope to present our results in 2014.

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