reviewed paper

A New Urban Sensing and Monitoring Approach: Tagging the City with the RADAR SENSING App

Peter Zeile, Martin Memmel, Jan-Philipp Exner

(Dr.-Ing. Peter Zeile, University of Kaiserslautern, Department of CAD & Planning Methods in Urban Planning and Architecture (CPE), Pfaffenbergstraße 95, 67663 Kaiserslautern, Germany, zeile@rhrk.uni-kl.de)
(Dipl.-Math. Martin Memmel, German Research Centre for Artificial Intelligence (DFKI GmbH), FB Knowledge Management, Trippstadter Straße 122, 67663 Kaiserslautern, memmel@dfki.de)
(Dipl.-Ing. M.Sc. Jan-Philipp Exner, University of Kaiserslautern, Department of CAD & Planning Methods in Urban Planning and Architecture (CPE), Pfaffenbergstraße 95, 67663 Kaiserslautern, Germany, exner@rhrk.uni-kl.de)

1 ABSTRACT

Focal point of this conference is to examine urban patterns and city structures regarding the changing needs of people in their everyday life. In order to do so, involved stakeholders such as planners and decision makers need to have precise information about citizens' needs and feelings concerning actual difficulties or tasks. Thus, approaches are needed to identify such topics, and to evaluate urban processes. One potential for this can be seen in new developments like Ubiquitous Computing and pervasive sensing with mobile devices which can act as small and connected sensors in the spatial environment. Due to the increasing prevalence of such mobile devices, more and more geospatial data is being produced, and some of it allows for inferring information about people's behaviour in specific areas. The main problems in these tasks are on one side that the processing of such data is a difficult task, due to the heterogeneity of interfaces and used data formats, but also because of the absence of a target-oriented question and the overlook of the potential for spatial and urban planning. We consider mobile crowdsourcing approaches to gather data in combination with the potentials of ubiquitous computing via new generation smartphones with the RADAR SENSING app as a promising approach. This app is a target-oriented software application that allows non-experts and citizens of a city to easily provide location based data just by using their mobile device and to attach urban spaces with specific planning relevant information. The presented test study was conducted in Kaiserslautern and aimed at validating methods to process and analyse localised tags in an urban area with the RADAR infrastructure. Hence, this study is an elaboration of the potential of new sensing and monitoring methods for urban areas.

2 INTRODUCTION

As mentioned in the conference title, the changes in cities and urban areas are inevitable phenomena with a high relevance for urban planning. It is thus important to create a sense of understanding for monitoring the various spatial patterns of a city, and there is a need to develop tools and methods for this purpose. From a planning perspective, the RADAR SENSING app and the associated RADAR infrastructure can be seen as a real-time monitoring tool. With these technologies, it is possible to install a monitoring system for the observation of a phenomenon in a chronological sequence. With the help of sensor technology, it is possible to install so called deductive monitoring systems. Main characteristic of these monitoring systems is that a public or private authority in a top-down process with a specific task initiates them. The opposite of deductive monitoring is "inductive monitoring", where no fixed top-down oriented infrastructure is given. The main idea behind inductive monitoring is that expressions and statements regarding a special topic are collected, but without being initiated by in a traditional, organisationally driven top-down process. So people aren't instructed to observe preselected phenomena that shall be examined. Examples are .g., postings and other traces that people leave when interacting with digital media and respective devices can be important information sources for planners. Some promising approaches for such bottom-up driven, mobile apps are "next hamburg mobile"[1] and "leerstandsmelder"[2] in the city of Hamburg. These apps were designed for only one specific task in one specific area, and they are top down initiated. However, for our solution, it was important to have a tool which is able to detect new urban spatial patterns. So a mobile application was developed that allows citizens to easily contribute information about the quality of arbitrary places in a city. Therefore, a number of predefined "urban categories" was provided. Each of these predefined categories can be rated as "positive" or "negative" for the selected location. Additionally, users can add own categories. The information is stored in a generic geodata infrastructure with various means for data analysis and visualisation. Hence, it can be used by planners for an analysis of spatial-temporal interactions and be embedded in the planning process. First results of these approaches were gathered within a sound

[1] See "next hamburg mobile" for iPhone (Source: http://www.nexthamburg.de/mobile.php)
[2] See "Leerstandsmelder online" (Source: http://www.leerstandsmelder.de/)

propagation project (compare Paper "Sensing the City", Bergner et al. 2012) where a group of test persons tried to identify noise hotspots, and also provided related "city parameters" using the newly developed smartphone app in the city of Kaiserslautern.

The paper is into three major parts. Whereas the state of research presented in Section 3 will give insights about developments like ubiquitous computing, monitoring, and humans as sensors, the Section 4 will explain the RADAR infrastructure and the RADAR Sensing app. The study set-up described in Section 5 will provide information about the field study including results and further research approaches. We conclude with a a summary and an outlook on future work.

3 STATE OF RESEARCH

3.1 Ubiquitous computing and pervasive sensing

New technologies like smartphones and sensors as well as the prevalence of wireless access to the Internet and will induce lots of changes for urban planners. With the rapid development of mobile communication devices, the postulated vision of ubiquitous computing as already predicted by Mark Weiser in 1991 seems to come true. This means that all devices are mutually connected and able to share data in order to create an additional value for its users. Smartphones in this context have to be considered as pioneers of a new era of computers that allow the user to share data and to participate, simply by using their Internet connection (Zeile, 2010). These small, connected, flexible sensors build the basis for pervasive sensing approaches of urban areas (Martino et al., 2010). Mobile communication devices are small, smart, and flexible, and the functionalities they offer will be constantly enhanced in the future. GPS-tagged pictures or sound files are just some simple examples. In contrast to ordinary sensor networks, where all measurement devices are constituted in a top-down-approach, lots of new potentials will emerge around crowdsourcing approaches as predicted by O'Reilly (2005). If those bottom-up-approaches are producing geospatial content, they are described with the term "Volunteered Geographical Information" (VGI) (Goodchild, 2007). Hence, it will be possible for citizens to interact with their electronic devices as a sensing unit together with their urban environment.

Smartphones equipped with various kinds of sensors could be considered as perfect sensors for spatial planning issues. These sensors can be subdivided in sensors for self-location (for example a GPS-Tracker) or position detecting, (Streich, 2011). Other available technologies are data collecting methods with the assistance of visual sensors (like digital cameras), audio sensors or with the help of newly developed and additional sensors, the measurement of the degree of pollution. A general classification in sensor types can be stated as follows: sensors for state variables and material properties, sensors for geometrical and mechanical parameters, electromagnetic and optical sensors and other possibilities for image processing (Schanz, 2007) or especially for psychophysiological monitoring purposes in spatial planning like it is done by the skin conductance and the skin temperature (Bergner et al., 2012). The sensors produce mostly quantifiable data and could be used in different planning related issues. Hence, the crucial point is to organise these complex and heterogeneous data sets together with new technologies and to develop new planning methods for their administration, organisation, and management. In order to show the potential of combined data flows, the SENSEable City Lab at the MIT in Boston followed a promising approach with the "Copenhagen Wheel" project. In In this project, bikes were used as mobile sensors in which environmental conditions like carbon monoxide or nitrogen concentration, temperature, noise, and humidity were directly measured by built-in sensors during the biker's city tours. With the help of these data, a thematic map of different ecological values (Outram et al., 2010) can be produced. Foci in these cases were particularly citywide sensory data, data management and the integrated real time visualisation, which embeds the bikers as dynamic and connected urban sensors. This example shows the huge potential of involving humans in a sensing process for urban planning purposes.

Generally, sensing units in sensing systems for urban planning issues with mobile devices can be divided into two main subcategories:

1. Mobile devices as (location based) communication units

One approach is the use of smartphones primarily as communication devices in order provide and share information. Predominant function is the use of various kinds of channels in order to provide an explicit statement for a specific location. The localised statements are called location-based tags. Besides the GPS-sensor of the smartphone and the timestamp, the use of other sensor technologies is not necessary. The RADAR system could be considered as such an approach to collect and provide people's explicit statements regarding specific locations in the urban area. Features to share and provide data are often provided via common social media apps like Facebook or Twitter. Other good examples of apps, which are collecting people's explicit comments on the environment, are the previously mentioned app "NextHamburgMobile" or "trendsmap"[3], which maps the twitter-activity of users. With "NextHamburgMobile", it is possible to set up localised addendums in the urban area related to urban planning topics. Due to the use of interfaces, the gained data could also be used by third-party-developers for own specific research questions. E.g., Fabian Neuhaus from UC London created Twitter density maps, which allow detecting locations with a high concentration of Twitter posts (Neuhaus, 2012). As an example, the map of San Francisco shows that geolocated Twitter messages are also reflecting the urban area of the Bay Area in California.

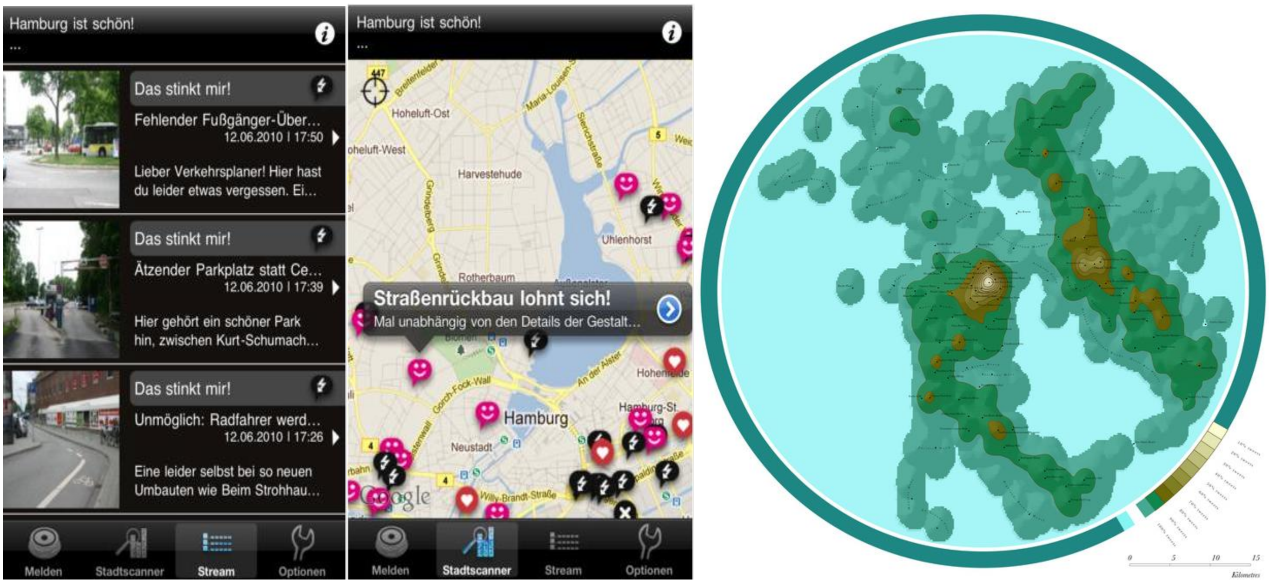

Fig. 1: iPhone App "NextHamburg Mobile" & Twitter heatmap San Francisco

2. Mobile devices as sensor units

As stated before, smartphones are multisensory devices and could be used as mobile urban sensors. The variety of embedded sensors like GPS or noise level recorder, and the possibility to dock on additional sensors open a wide range of opportunities for creating additional geospatial data.

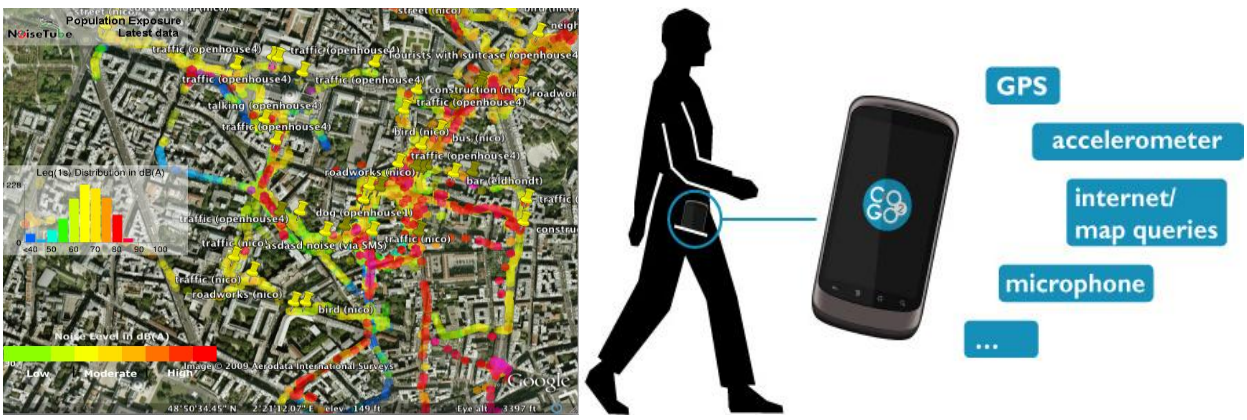

Fig. 2: App "Noisetube" & App "CO2GO"

Another value of this concept lies in the ability to aggregate those different data streams to gain new insights. E.g., the app "Noisetube"[4] is able to create a noise load level map just with a smartphone. The app "CO2GO"[5] from the SENSEable City Lab at MIT uses a combination of the GPS tracks and the

[3] See Trendsmaps online (Source: http://trendsmap.com/)
[4] See App "Noisetube" (Source: http://noisetube.net/)
[5] See App "CO2GO" (Source: http://senseable.mit.edu/co2go/)

ISBN: 978-3-9503110-2-0 (CD-ROM); ISBN: 978-3-9503110-3-7 (Print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI

smartphone's acceleration sensor to calculate a carbon footprint. The already mentioned project "Copenhagen Wheel" pursues a similar approach. In this project, local bikes are equipped with a wide range of sensing devices. With a smartphone app, all the integrated sensors could be observed and maintained to see the actual concentration of pollution or the prevailing weather conditions. All equipped sensor bikes also send these data to a server which is calculating the conditions in the whole city.

3. Sensing systems

With these devices and applications, it is necessary to develop holistic methods to create systems, which will function as a city wide sensing network. The development towards Smart Cities is an approach where such networks are top-down-oriented and planned by an authority, organisation or enterprise. If a deeper collaboration with citizens is intended, it should easily be possible for people to embed their device and data into the system and as well to share and access already existing data. Besides the technological hurdles, there also has to be an intuitive, easily understandable and attractive system for users to encourage them to participate and contribute with own data. This is crucial in order to create an additional value for users and a city. The RADAR[6] infrastructure is such an approach, because it allows integrating geocontents from a variety of different sources, and it also provides means to organise, aggregate and visualise this data via a web based user interface as well as a smartphone app. In addition to that, RADAR enables the user to also go deeper into analysing the data, which, e.g., is possible by using heatmap visualisations for tags. Another comprehensive approach is SMART-Singapore which is a project that could be classified as a Smart City initiative. The setup of this project is an opportunistic monitoring approach including various deployed sensors in the city with an inductive approach. Various data streams are provided on a platform which makes it possible for citizens and developers, to create their own apps to use this data in order to create data with an additional value for city and community (Ratti, 2011).

3.2 Monitoring

Monitoring comes from the Latin word "monitor", which means some kind of surveillance or observation. Hence, essential point is the observation of a phenomenon over a longer period, with the result of using the gained forecasts for a reactive or constructive control. This also embraces data collection, analysis and interpretation in a systematic way in order to have data as a basis for decisions and further observations. Thus, a monitoring system consists of two elements: One part is the approach to gather and process data, the other is the infrastructure needed collect and manage the considered data. Monitoring systems are the basis for forecasts, which makes them important especially in the working field of spatial planning (Streich, 2011).

Web 2.0 and associated technological opportunities already had an influence on monitoring approaches, and they will continue to do so in the future. Monitoring approaches were historically initiated in top-down approaches by mostly public authorities and organisations. With the development of pervasive sensing, the fertile ground for bottom-up approaches was set. Hence, with the empowerment of non-experts to create, analyse, visualise and publish geospatial information, there will be a new mode for monitoring issues in spatial planning. Due to the mentioned elaborations, monitoring has to be distinguished between deductive monitoring (top-down) and inductive monitoring (bottom-up) approaches. Deductive monitoring is an approach, which is mainly top-down oriented and composed of data generated by time series analysis: People collect data sets, with or without the awareness that they wear a sensor device and collect data. Or data were collected unconsciously, e.g., by cell phone carriers or hardware developers with the help of the cell phones internet connection and ability to access and store data. The use of the data gained by sensor networks like climatologic measurements is such an approach. The gained data could be used for various purposes and it has a large potential, not only for spatial planning. Opportunistic sensing could also be part of a deductive monitoring system. Regardless of the way these monitoring technologies deal with personal data and data security, the continuous recording of this kind of data has a large potential, not only for spatial planning.

Mobile devices give users the possibility to create this data in an explicit way related to a specific situation. So it is an active use of a smart device as "communication unit" and as "sensor unit". If this bottom-up approach is making use of mobile devices to collect and share data, it is considered as participatory sensing.

[6] See RADAR Project (Source http://radar-project.de)

However, if such systems are aiming to involve citizens into participatory monitoring projects, there has to be some kind of incentive mechanism to encourage them to participate in the project.

3.3 Humans as sensors

As previously mentioned, the consideration of new sensor technologies for urban planning purposes will be more important in the future. In 2010, "The Economist" stated that "Everything will become a sensor, and humans may be the best of all" (The Economist 2010). It thus has to be elaborated how a person senses its environment, and how these impressions and emotions could be measured in an objective way. This ensures that citizens, who should be the focal point of any planning consideration, could act as active sensors for the urban environment. The synchronised multi-sensor „human" thus should be considered as the most important sensor for urban planning issues (Exner et al., 2011). Due to the technological development in mobile device technologies, the combination of smartphones and human interaction will provide huge potential in planners' everyday work because the generated data could be used for monitoring purposes in urban planning. Hence, crowdsourcing and inductive monitoring integrates an entirely new mode of participation in processes of urban discussion for geospatial data gathering (Exner et al. 2011). The study project „Sensing the City" at TU Kaiserslautern shows the potential of this approach, because it combines the mentioned sensor technologies with both implicitly and explicitly generated crowdsourcing data of the test persons. Whereas the implicit emotions of the test persons were recorded via psychophysiological monitoring with a SMART-Band for measuring skin arousal and stress, the test persons were equipped with mobile phones and a tagging app that allowed them to tag their surrounding area making use of several predefined criteria. Exploiting the above mentioned potentials given by smartphones and monitoring approaches, and using the new RADAR technology that will now be introduced, it is possible to gain new insights for defining the quality of an urban place in order to show the potentials of psychophysiological monitoring and prospects for their use in urban planning like it has been done in the project "Sensing the city" (Bergner et al., 2012).

4 THE RADAR INFRASTRUCTURE AND THE RADAR SENSING APP

RADAR[7] (Resource Annotation and Delivery for Mobile Augmented Reality Services) was a one-year project initiated in 2010 at the Knowledge Management department of the German Research Center for Artificial Intelligence in Kaiserslautern. The aim was to realize an open and flexible infrastructure that allows users to contribute and manage arbitrary types of geocontents. On the one hand, the RADAR infrastructure is able to process very simple representations of geocontents; on the other hand, it is also be possible to use more complex and multidimensional objects.

The RADAR infrastructure consists of two main components:

- The RADAR Web Interface is an intuitive, web based GUI for comfortable contribution, sharing, and management of arbitrary geocontents. It is based on DFKI's ALOE[8] infrastructure and offers a plenitude of social media features.
- The RADAR Web Service realises a rich Web Service API and thus allows integrating RADAR contents and functionalities in different contexts and applications, such as the RADAR SENSING App.

For different scenarios, specific RADAR instances can be set up, thus allowing the realisation of controlled and closed as well as open and collaborative scenarios. Figure 1 provides a coarse overview of the RADAR main components. For a detailed description of the system architecture as well as system features please refer to (Memmel 2012).

To address the needs of inductive monitoring approaches, a specific instance of the RADAR infrastructure (RADAR-SENSING) was set up. In addition to the usual RADAR functionalities, means to analyse user contributions by means of heatmaps are offered on this instance. The RADAR SENSING app was developed for Android-based devices and connects to the RADAR-SENSING backend where all information such as user data, user contributions, etc is stored in a respective database. As exchange format, JSON was chosen because it allows for efficient processing of information while still providing means to exchange arbitrary data types.

[7] See http://radar-project.de
[8] See http://aloe-project.de

To take part in experiments on this platform, users first have to register using the RADAR-SENSING Web frontend. After installing the RADAR SENSING app, they have to provide the respective credentials and can then provide positive and negative votes for a set of predefined categories. Optionally, a free category can also be entered. After submitting these votes, the app tries to estimate the user's position by means of several sensors (preferably GPS) and shows this position on a map. The users then have the possibility to change this position in case the sensors were not able to retrieve the precise location.

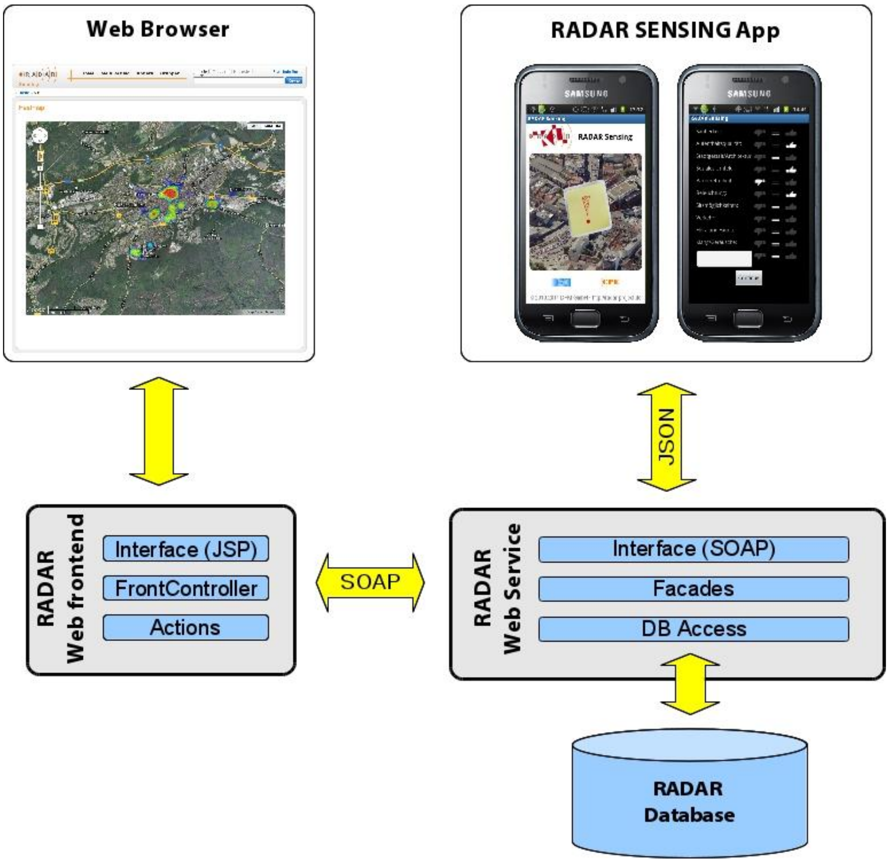

Fig. 3: Simplified architecture of the RADAR infrastructure

Furthermore, it is possible to get first impressions about the tagged attributes by means of a tag cloud accessible through the RADAR Web Interface. However, the most helpful tool for spatial planning is the interactive heatmap of the tagged points. Here, users can select which attributes to take into account for the generation of the heatmap, and whether only positive, negative or both votes are used. The heatmap is then displayed on an interactive map where users can drag and zoom. Furthermore, it is possible to provide further parameters to filter the used data (e.g., time restrictions), and the heatmap can optionally be refreshed automatically in case new relevant data for the heatmap shall be displayed on-the-fly.

5 STUDY SET-UP

Accompanying to the project „Sensing the City – How to identify Recreational Benefits of Urban Green Areas with the Help of Sensor Technology", the "tagging the city" –project (attribute tagging) should consolidate the findings of the above mentioned study (compare Bergner et al., 2012): In this study, the topic was to identify urban retreat areas against the background of the EU environmental noise directive with the help of psychophysiological measurements. Parameters like the subjective perception were measured by using SMART-Bands. The SMART-Bands record through Skin Conductance Level and Skin Temperature, which allow doing a statement about people's arousal in the city. , The study was in addition supported by traditional, 5 level ICBEN-questionnaire (International commission on biological effects of noise), which described the perception of noise pollution.

In support of this set-up, it was possible to record volunteers' impressions in the city with the help of RADAR SENSING App. The collected data support the plausibility check of planning and it can be seen as a combination of implicit human emotions (stress measured vie SMART-Bands) and explicit emotions (Tags and questionnaires). During the measurement period, the test persons were able to tag points with noise, or points where is silent in the city. Additionally it is possible to give ratings about other urban properties, like cleanliness, attractiveness of urban areas, urban design, accessibility, lighting, seating, traffic and flora/fauna. These tagged points can deliver hints for planners, where it is a pressure to act.

5.1 Findings

Within the test period of two weeks, the test persons collected almost 1900 tagged places, spread over 20 micro places at the city of Kaiserslautern. A distinction was made by the following categories, because these values are highly relevant for urban planners.

	Sojourn quality (+)	Sojourn quality (-)	Accessibility (+)	Accessibility (-)	Lighting (+)	Lighting (-)	Flora & Fauna (+)	Flora & Fauna (-)	Sound / Noise (+)	Sound / Noise (-)	Cleanliness (+)	Cleanliness (-)	Seating (+)	Seating (-)	Social Environment (+)	Social Environment (-)	Urban Design (+)	Urban Design (-)	Traffic (+)	Traffic (-)
Tags	149	63	187	35	98	28	120	85	128	79	176	35	158	77	100	55	120	47	86	129

Fig. 4: Totalised values of the "tagging the city" project

The upcoming figure shows this for the attribute "noise" (Fig. 5).

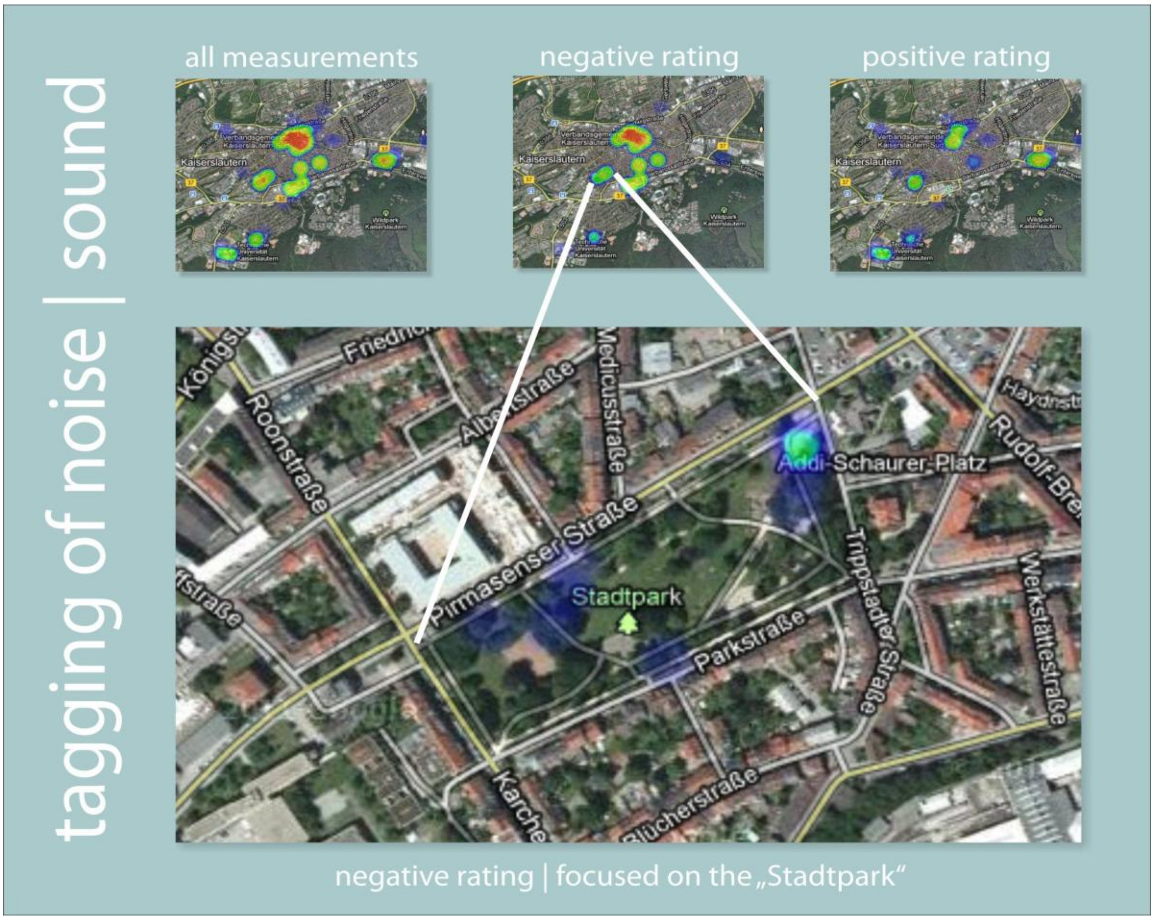

Fig. 5: Real-time heatmaps of the collected tag "noise" (own figure, based on Google Maps)

A full validation of the results for the location "Stadtpark" within the "Sensing the City"- project (compare Bergner et al., 2012), is not possible in the moment in fact of to less tagged points in the test area. But it can be observed, that the negative comments about the noise level were mostly done on the street sides of the park and not in the calmer centre.

Besides for the tagged attributes, it is now possible to produce specific heatmaps, even for the newly developed attributes. The system will also display this data in real-time. Another important value for urban planners is the accessibility of public open areas, especially for those ones with retreat function. If accessibility has to be considered (in German: Barrierefreiheit), it is possible just by choosing the parameter accessibility. After closing the first study period, it was remarkable, that a place called “Stadtplatane” was identified by the heatmap visualisation which has an insufficient accessibility level compared to other places. This small inner-city recreational area with its six park benches is just accessible via stairs which would be a big hurdle for wheelchair users. With the help of the respective heatmap, this important point could be identified.

Fig. 6: Bad accessibility at location “Stadtplatane” (own figure, based on Google Maps)

5.2 Problems and Questions

One problem of the present study is the homogeneity of the group. It is necessary to have a heterogeneous volunteer group that represents the cross-section of the public. Furthermore, tagging and also questionnaires are explicit expression. Hence, it could be interesting to combine those data with implicitly gained data, for example via emotional mapping with SMART-Bands in order to make a cross-validation. Methods and approaches to merge these two types of data have to be developed and get maturity in order to have resilient data for the planning process. Another important point will be the detection of “wrong” data. This could be on the one hand a bad GPS-signal but also manipulative entries of users. Methods for additional validation have to be developed in order to get the guarantee that the gained data is reliable in terms of technology and content-relation. Questions about how to delete “wrong” data and when to delete older data which isn’t needed anymore (e.g. because of a repaired trashcan which was tagged as broken). Furthermore, especially when it comes to the point of visualizing data with heatmaps, it has to considered, that the chosen way complies with the set standards and the has to be an awareness of the manipulative elements of maps with for example simple elements like positive or negative colour schemes.

6 CONCLUSION

From a technical perspective, there are several potentials which could be exploited for improved and enhanced analysis means in the future. E.g., it will be interesting to compare the different tagging timestamps to analyse how grievances and complaints appear in the urban space. With this approach, static phenomena at the specific location (e.g., accessibility for wheelchair users) and more dynamic phenomena (e.g., a broken trashcan) could be distinguished. Further options in displaying the datasets will help planners to derive demands for multi-layer analysis to gain better planning insights. E.g., there could be an overlay of the negative content of “noise“and “sojourn quality” which might lead to better results. In addition, it would be interesting to integrate information from other social media applications (e.g., Twitter or Facebook) and process this information for further analysis. And, at least, there will be the question about how to deal with this data and to interact with population and government. The question of the resilience of this kind of data will emerge and it has to fit demands of the various planning processes, like the integration in formal or informal processes. Hence urban planners have to be aware not only of potentials, but also of challenges and difficulties when using these new methods for the planning purpose. Without a basic understanding of the complex interactions, they won’t be able to use these new tools in the most promising way.

7 ACKNOWLEDGMENTS

The authors are grateful to the support of the University of Kaiserslautern, which enabled these research studies by support this department and the faculty of spatial and environmental planning with financing the “Laboratory for Monitoring and Spatial Sensing”. Furthermore, thank goes to the German Research Centre for Artificial Intelligence (DFKI) for extensive knowledge transfer and for cooperating in informal projects.

The authors would like to express their gratitude to German Research Foundation (DFG – Deutsche Forschungsgemeinschaft) for supporting the project "Development of methods for spatial planning with GeoWeb and Mobile Computing (Städtebauliche Methodenentwicklung mit GeoWeb und Mobile Computing)". In addition, this study contains some data of seminar works of students in the summer 2011. The RADAR project was funded by the Stiftung Rheinland-Pfalz für Innovation.

8 REFERENCES

BATTY, M., SUCHID, A. CROOKS, A., HUDSON-SMITH, A., JACKSON, M., MILTON, R, MORLEY, J.: Data mash-ups and the future of mapping. Tech Watch. Bristol, United Kingdom. 2010.

BERGNER, B., EXNER, JP, ZEILE, P., RUMBERG, M.: Sensing the City – How to identify Recreational Benefits of Urban Green Areas with the Help of Sensor Technology, RealCORP 2012. Waiting for acceptance.

CAMPBEL A.T., EISENMAN S.B., LANE N.D., MILUZZO E., PETERSON R.A.: People-centric urban sensing [Internet]. In: Proceedings of the 2nd annual international workshop on Wireless internet. Boston, Massachusetts: ACM; 2006 p. 18. [Online] http://portal.acm.org/citation.cfm?id=1234179&dl=GUIDE&coll=GUIDE&CFID=96064310&CFTOKEN=76972106

EXNER, J.-P., ZEILE, P., STREICH, B.: Urban Monitoring laboratory spatial planning: New benefits and potentials for urban planning through the use of urban sensing, geo- and mobile web. Proceedings of the 12th International Conference on Computers in Urban Planning and Urban Management (CUPUM2011), Lake Louise. 2011.

GOODCHILD, Michael F.: Citizens as Sensors: the World of Volunteered Geography. Geo- Journal, 69 (4), S. 211-221.New York/Heidelberg.

NEUHAUS, F.: New City Landscape - Mapping urban Twitter usage. Proceedings of the 12th International Conference on Computers in Urban Planning and Urban Management (CUPUM2011), Lake Louise. 2011.

MARTINO, M., BRITTER, R., ZACHARIAS C., BIDERMANN, A.: Senseable City: Digital Urban and Modelling. Boston/MA, 2010.

MEMMEL, M.: RADAR White Paper, Technical Report, [Online] http://radar-project, 2012. c

NEUHAUS, F.: Twittermap of San Francisco [Online] Available at: http://urbantick.blogspot.com/2011/04/ncl-san-francisco-update.html [Accessed 2 February 2012].

NEXTHAMBURGMOBILE: NextHamburgMobile App [Online] Available at: http://itunes.apple.com/de/app/nexthamburg-mobile/ [Accessed 2 February 2012].

O'REILLY, T.: WHAT IS THE WEB 2.0? Design Patterns and Business Models for the Next Generation of Software, O'Reilly 2005. [Online] Available at: http://www.oreilly.de/artikel/web20.html) [Accessed 2 March 2011].

OUTRAM, C., Ratti, C., Biderman, A.: The Copenhagen Wheel: An innovative electric bicycle system that harnesses the power of real-time information and crowdsourcing. EVER Monaco International Exhibition & Conference on Ecologic Vehicles & Renewable Energies. Monaco, 2010.

RATTI, C., KLOCKEL, C.: CO2GO App [Online] Available at: http://senseable.mit.edu/co2go/ [Accessed 2 February 2012].

RATTI, C., TOWNSEND, A.: The Social Nexus. Scientific American, P. 42-48. New York, 2011.

STEVENS, M., D'HONDT E.: Noisetube App [Online] Available at: http://noisetube.net/ [Accessed 2 February 2012].

STREICH, B.: Stadtplanung in der Wissensgesellschaft – 2.Auflage. VS Verlag, Wiesbaden. 2011.

WEISER, M.: The computer for the 21th century. Scientific American, P. 94-104. Palo Alto.1991.

ZEILE, P.: Echtzeitplanung - Die Fortentwicklung der Simulations- und Visualisierungsmethoden für die städtebauliche Gestaltungsplanung. Dissertation an der TU Kaiserslautern. Kaiserslautern, 2010.