Report

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HENGSTBERGER SYMPOSIUM 2011

Towards Digital Earth - 3D Spatial Data Infrastructures

Heidelberg, 7-8 September 2011

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GIScience

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by

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1. Executive summary

Three-dimensional (3D) mapping and characterization of the Earth using sensor technology is increasingly gaining importance. Detailed 3D topographic information is essential in a great variety of research fields aiming at mapping, modeling, exploiting and increasing the understanding of phenomena located on the Earth surface, such as for modeling natural hazards and environmental change monitoring. New **remote sensors** allow highly detailed 3D topographic mapping with sub-meter accuracy such as the LiDAR technology. In contrast to these high quality but costly sensor data, the last years have witnessed a compelling advent of collaborative Web 2.0 projects (e.g. wikis and social networks) collecting freely available user-generated geographic content such as the OpenStreetMap (OSM). Each contributor in these communities represents a "**human sensor**" in a world-wide network adding new geographic observations.

The **Hengstberger Symposium "Towards Digital Earth - 3D Spatial Data Infrastructures"** aimed at identifying possibilities and limitations of combining the best of both worlds by fusing 3D remote and (2D) human sensor data. Furthermore, new research impulses for the next steps towards the **3D Digital Earth (3D-DE)** "by and for people" were discussed.

The two-day symposium, 7-8 September 2011, was held in Heidelberg (Germany) at the Internationales Wissenschaftsforum Heidelberg (IWH) - a workshop center of the University of Heidelberg located in the old town. The workshop hosted 32 participants from 8 countries. The social program included a guided night tour through the old town of Heidelberg and a symposium dinner in the old town of Heidelberg where further exchange of ideas and discussion took place in a relaxed setting.

The overall conclusions of the workshop were manifold due to the rationale of the symposium of bringing together **Digital Earth (DE)**, crowdsourced geoinformation and remote sensing. The broad range of fruitful discussions identified that by definition the third and more dimensions (4D..nD) are an essential property of DE. Volumetric information (e.g. subsurface) and the interior of artificial spaces (e.g. rooms in buildings) will be an important part of DE as we already spend most of our time indoors. Furthermore, visualization in 3D - by augmented reality - is crucial in order to understand and represent model results of phenomena having a strong 3D component such as exposure to noise or the impact of natural hazards. Totally new integrative model concepts of handling multidimensional geographic data (e.g. object-centric view) are required rather than extending the existing 2D GIS world by 3D solutions.

A clash of paradigms can be witnessed how **volunteered geographic information (VGI)** collected by human sensors and authorative data (e.g. organized in SDIs) can be conflated. Current initiatives such as INSPIRE - the European SDI - focus on 2D and ignore non-authorative datasets. Will VGI supplement and enrich or even replace authorative data to a certain degree in the next generation DE? This indicates that the relation between (authorative) SDIs and DE is still not entirely clear. SDIs focus on the organization of geographic data driven by policy for serving the public administration, in contrast to the GeoWeb, which is driven by individuals, groups and companies aiming at serving the society and mass market, respectively.

Regarding **crowdsourcing of 3D geoinformation** it was observed that the available technology has not yet been fully exploited for 3D geoinformation generation. The crowd has not been extensively involved in 3D geoinformation generation. Active and direct 3D data acquisition is rare (e.g. making 3D models of objects). Indirect, passive 3D VGI by utilization of crowdsourced data (e.g. tagged OSM data or Flickr photos) for 3D data generation is promising as pioneer projects such as OSM-3D or Rome in a Day clearly indicate. However, easy-to-use, "cool" tools and sensors (e.g. smarthpone app) with respect to crowdsourcing 3D data are still missing. For DE up-to-date geographic data is required. This also applies for 3D data: a single LiDAR campaign can provide a base model but current sensor technology and costs do not allow gathering the full dynamics of the landscape in real-time. Thus, easy and fast update mechanisms for 3D objects are needed, which integrate all available data streams (crowdsourced GI, satellite data, etc.) to ensure data quality with respect to geometric, semantic and temporal properties.

To date, emphasis is put on visualization of the "Digital Earth" such as the majority proprietary solutions (e.g. Google Earth). The need for free and open access to analysis tools, such as geoprocessing services, provided along with geographic data is particularly important from a scientific point of view. The "**democratization of analysis**" requires access to the underlying geographic data, which is, for example, not a prerequisite for the usage of visualization tools. Having tools to search, retrieve and run "your own" suitable analysis offers great chances but also new risks and adds tremendous complexity w.r.t. communication of science to the citizens but also other scientific disciplines. Is it possible to maintain scientific rigor and to communicate processing and modeling results with proper (scientific) explanation in the (unknown) context the tools are used? Furthermore, interoperability issues (e.g. metadata of processes) of analysis services are still to be solved. However, providing both geoprocessing tools and data is of high importance to educate people and should be subject of intensified research.

This symposium focused on 3D geoinformation which excludes large parts of the world as the availability of detailed 3D datasets is still limited and mainly concentrated on certain, “rich” countries. For example, 3D city models and nation-wide LiDAR datasets are rare due to the high costs of data acquisition. Digital Earth is a media to represent the entire and only Earth we have. In this respect DE is a large chance to account for the imbalance in economic wealth, power and political situations by providing open access to Earth information on the GeoWeb, including commercial and political apps, citizen science and collaborative knowledge production as well as social networks. Ethical, social, economic and political impacts of DE, also on individuals, have to be assessed and legal frameworks are subject to be evaluated and adapted. For this purpose **multidisciplinary science** with greater integration of social and health sciences, and humanities with strong participation of citizens is needed.

Public relations and dissemination of the Hengstberger symposium was done on the symposium website - 3dde.uni-hd.de - where the programme booklet, presentations, materials and this report are available online. Furthermore, a press release on the university main website as well as a short article in the leading regional newspaper (Rhein-Neckar-Zeitung) was published.

2. Scientific content of the event

The initial outline of the Hengstberger Symposium was to provide an overview of the three main domains i) Human Sensors, ii) Remote Sensors and iii) 3D Spatial Data Infrastructures (3D-SDIs) on **Day 1** and to converge the three topics on **Day 2** in order to discuss the potential and limitations of this combination for a 3D Digital Earth (3D-DE) (Fig. 1).

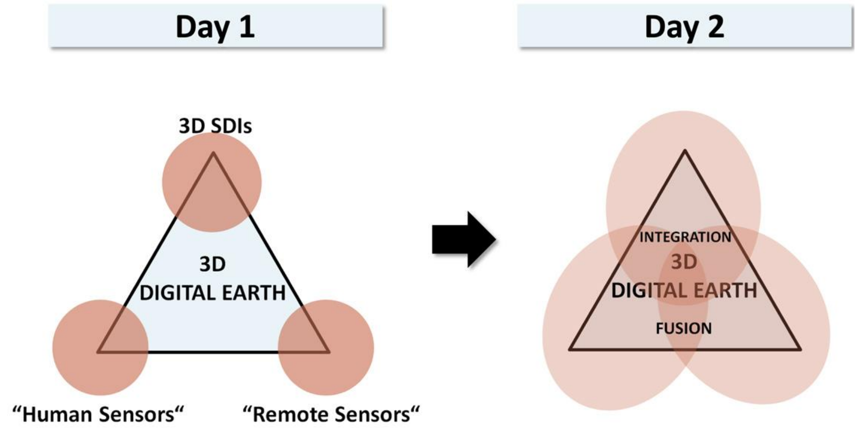


Fig. 1: General outline of the scientific programme for the two symposium days.

The symposium was divided into **five sessions** with direct scientific input by means of keynote and several short presentations. At the end of each presentation session a discussion block was scheduled in order to discuss and summarize the presentations of each session in detail. Furthermore, a final **plenary discussion** session was dedicated to intensive discussion as well as structuring and summarizing the overall content. Details on the schedule are described below. The following summary of the scientific content was compiled based on protocols provided by student assistants and PhD students and shall be acknowledged at this point: Hannah Deierling, Julian Hagenauer, Andreas Jochem, Johannes Lauer and Oliver Roick.

Wednesday, 7 September 2011

The symposium was opened with a short welcome address by Peter Comba, director of the IWH. Thereafter, the convener, **Bernhard Höfle**, gave the introductory mission statement presentation. This presentation gave a foundation of the symposium rationale and formulated impulse research questions. Additionally an overview was given of the intersecting scientific topics (Fig. 1) to be joined at this symposium. In order to give a clear structure and aim of the workshop several impulse questions were addressed such as:

- Which application(s) of DE will benefit most from "hybrid 3D geoinformation"?
- What methods and strategies are appropriate for fusion and analysis?
- Which type of Volunteered Geographic Information (VGI) and (3D) remote sensing data can be fused?
- How can different data quality, temporal and spatial resolution, semantics, etc., be handled in the sensor data fusion?

The introductory presentation ended with an overview of the symposium schedule including scientific and social program.

►**Session 1** ("Digital Earth: Human and 3D Remote Sensors"), chaired by **Yola Georgiadou**, provided overview presentations on key topics of the symposium: Digital Earth (M. Goodchild), human sensors providing crowdsourced geoinformation (A. Zipf) as well as remote sensing sensors (G. Mandlburger).

The keynote of **Michael Goodchild** introduced the current state and future of the Digital Earth. He stated that the DE can be an effective tool for communication between science and citizens and we should be aware that we all are invested in the future of our planet as it is only one we will ever have. To date, mainly commercial data and software (e.g. Google Earth) provide virtual globes but the DE should be free in order to avoid black boxes and to fulfill scientific rigor. Volunteered geographic information (VGI) where the citizen is producer and consumer at the same time ("prosumer") is increasingly playing an important role in DE research. How can quality aspects of VGI be assessed and improved - such as via a social (e.g. hierarchy of users) or a geographic solution (e.g. "the more data the more accurate" and Tobler's law)? Concluding, it was emphasized that a new generation of DE is needed and should be defined, promoted and developed by concerted effort. This new generation has to provide two central elements: i) communication between science and citizen and ii) should achieve scientific rigor. The question remains whether these two objectives are compatible?

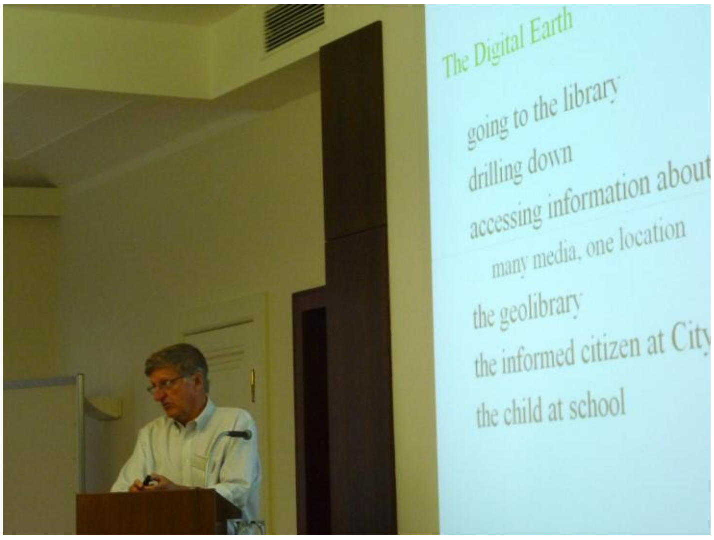


Photo: Opening keynote presentation by Michael Goodchild on "*Digital Earth: Inventory and Prospect*".

Next, **Alexander Zipf** gave a presentation on crowdsourcing Digital Earth, on how we can proceed from data fusion to knowledge generation. We witness an "explosion of data" such as from technical sensors as well as human sensors (i.e. VGI). However, today only few data sources are (jointly) used and with narrow focus on data management and visualization, mainly implemented in proprietary software and services. Based on the current situation he stated three main consequences for research (Fig. 2), for which integrating (3D) services going beyond pure visualization (e.g. analysis), control of data quality and use of different sensor sources are needed. For this purpose not only mashups of data but also of service for analysis should evolve. Thus, DE should have analytical capabilities and tools where e.g. OSMatrix was mentioned as an analytical tool for VGI data. In this respect he raised the question whether it is possible and useful to democratize also the analytics?

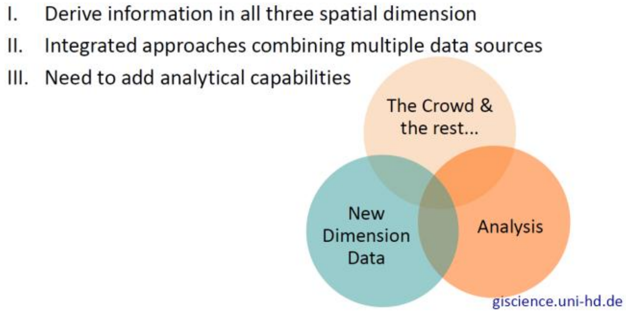
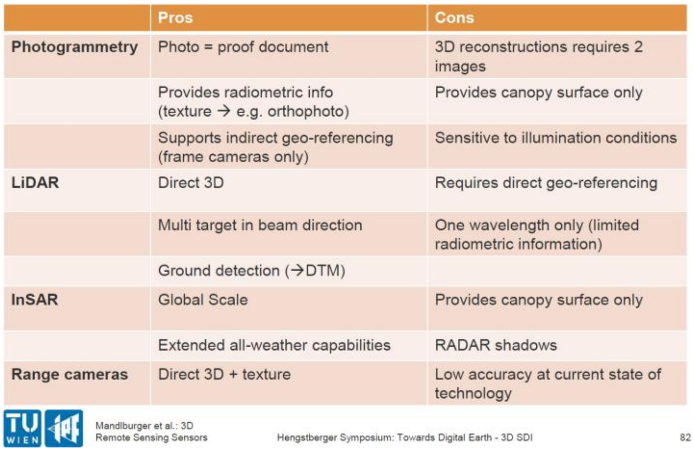


Fig. 2: Explosion of data and consequences for research (source: A. Zipf).

The last presentation of the keynote session by **Gottfried Mandlburger** was dedicated to "3D remote sensors". The presentation aimed at giving an overview of existing and near future sensor systems, which can provide 3D data for mapping the Earth (Fig. 3). After insight into the derivation of 3D information from 2D images by means of photogrammetry, spaceborne optical sensors, radar and laser scanning systems mounted on different platforms were presented. He showed the ongoing technological progress in sensor technology exemplified by the "full-waveform" laser scanning technology, which exhibits major advantages for the characterization of the Earth surface compared to the older sensor generations. The last part of the presentation discussed the possibilities of using "remote sensors [by human sensors]" to generate 3D crowdsourced data. In particular the "classic photogrammetry" has a huge potential to provide methods for 3D generation as most portable devices are already equipped with suitable cameras together with GPS devices (cf. "Building Rome in a Day").



	Pros	Cons
Photogrammetry	Photo = proof document	3D reconstructions requires 2 images
	Provides radiometric info (texture → e.g. orthophoto)	Provides canopy surface only
	Supports indirect geo-referencing (frame cameras only)	Sensitive to illumination conditions
LiDAR	Direct 3D	Requires direct geo-referencing
	Multi target in beam direction	One wavelength only (limited radiometric information)
	Ground detection (→DTM)	
InSAR	Global Scale	Provides canopy surface only
	Extended all-weather capabilities	RADAR shadows
Range cameras	Direct 3D + texture	Low accuracy at current state of technology

Fig. 3: Summary of the pros and cons of 3D remote sensors (source: G. Mandlburger).

►In the following, partly diverse, **discussion** it became evident that the options of DE are not explored yet. As the major part of life (e.g. >80% in the US) takes place indoors, 3D has to be considered increasingly in the next generation of DE. The "presentation/portrayal of data" is just the first level of DE. On a higher level methods are provided by scientists (e.g. spatial statistics) for the citizens. Analysis functionality requires access to the original data and thus the question arises who really wants to share data with everyone? One idea was that scientists/engineers provide the framework and citizens can contribute data into this system. A further point of discussion with contradictory opinions was whether all information should be made available for everyone, such as dynamically generated geoinformation using the tools provided in DE due to the inherent risk of misuse and misinterpretation of complex analysis results provided and geolocated with high accuracy (e.g. result of natural hazard modeling). Who decides what should be provided to the citizens or not directly related scientific fields? What are the ethics of crowdsourcing and what are the constraints for information retrieval? DE should be an open and free space across the globe, which exhibits opportunities and dangers at the same time such as privacy and security considerations versus transparency and openness.

Photo: Intensive discussion chaired by Yola Georgiadou.

►**Session 2** ("Volunteered/crowdsourced Geographic information"), chaired by **Michael Goodchild**, provided a look on the evolution and spatial volatility of OpenStreetMap (OSM) (P. Mooney), how metadata can be captured by non-GI specialists (C. Ellul) and the conflation of authorative and crowdsourced data (M. Jackson).

Peter Mooney presented a look at OSM and its evolution over time. A key motivation for the investigation of VGI data (here OSM) is the potentially higher up-to-dateness of OSM compared to the relatively long update cycles of authorative datasets. The historical analysis reveals the edit and contribution history of heavily edited features as well as user interaction. The presented analysis investigated not only changes in the feature geometry but also how tag ontology changes, e.g. which tags are changed, how do tags change and how often? What are the parameters quantifying quality of OSM features, such a stable and long history, consistent tagging and "collaborative" (i.e. many contributors and user interaction) development. Regarding volatility the question arised if volatility is a pro or a con of a feature and if editing does converge? For example, some places are volatile by definition. In the presentation and discussion it is concluded that science should increase communicating research findings to the OSM community and made results available. Specific items of future work are listed in Fig. 4.

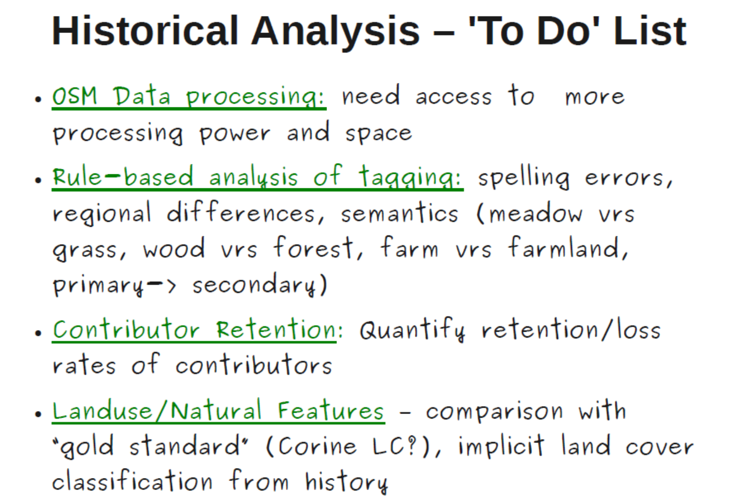


Fig. 4: What are the next steps and To-Dos in the historical analysis of OSM (source: P. Mooney).

In her presentation **Claire Ellul** discussed how users can be motivated to contribute metadata based on the experiences made in the FP7 project SECOA. The main aim for metadata creation is to allow users to correctly, scientifically use and integrate datasets from multiple data sources. Thus, metadata is crucial for discovery, evaluation and use of data provided via Digital Earth. Problems of capturing metadata are e.g. that the public is not familiar with metadata, standards are too complex, the end-user (and thus "user" of metadata) is unknown and there are challenges when working in a multinational and multilingual context (Fig. 5). Possible solutions include e.g. education of users, provide examples, automate parts of metadata capturing, cut down standards and mandate metadata creation. In the SECOA project several investigations and tests were made, such as giving rewards for metadata capturing, involve users in software design and give the opportunity to ask the contributors to clarify problems. It was e.g. shown that deadlines lead to an increased number of new contributions as the deadline approaches. A major challenge was

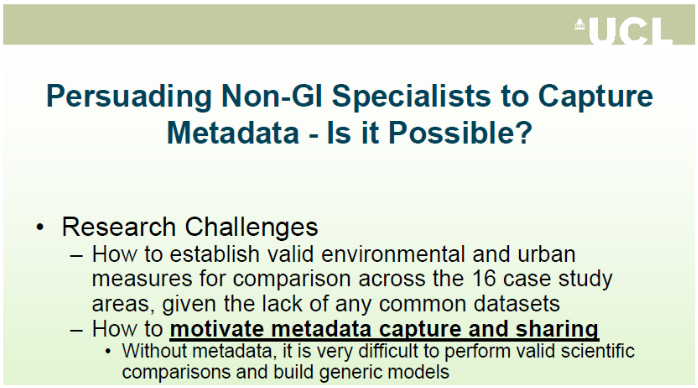


Fig. 5: Main research questions w.r.t. metadata (source: C. Ellul).

discussed after the presentation and remains an open research question: To which extent can metadata capturing be automated and thus improved? It cannot be fully automated as some information cannot be gathered without user input but automating as much as possible is expected to increase homogeneity (w.r.t. a standard), completeness and correctness of metadata. As there is no “single view” on the Earth it is a challenge to achieve a common (universal) agreement on metadata. Furthermore, a clear definition and separation of data versus metadata is not clear as it depends on the point of view (of the resp. community) and application and “who” decides and draws the border between data and metadata?

Mike Jackson gave a review of the current situation of the conflation of authorative government data and new data sources such as crowdsourced geoinformation (Fig. 6). Due to the fast technological progress (e.g. positioning systems and mobile communication) and evolving new data sources (e.g. remote sensing, VGI and social networks), large long-term SDI projects such as INSPIRE, the European SDI, are confronted with new, not yet included technologies and data sources in the course of the life span of the project. The questions are whether these new technologies meet the SDI principles and goals, and how they should be considered in the (authorative) SDI framework? Potential synergies of crowdsourced GI and authorative data are listed in Fig. 6. The question arised if these new data and technologies supplement current SDI frameworks or if they disruptively, incompatibly replace current approaches? Current research is trying to increase the understanding of issues of conflation and linking the data (e.g. using authorative data as template, developing a dynamic model for validation and interaction, and how people respond data mash-ups in terms of credibility and trust). Furthermore, the use of crowdsourcing for extending SDIs into 3D building interiors is of interest, but still the position determination indoors is not yet solved. A first software tool for the integration of Ordnance Survey and OSM data works well, considering also ontology based attribute matching techniques.

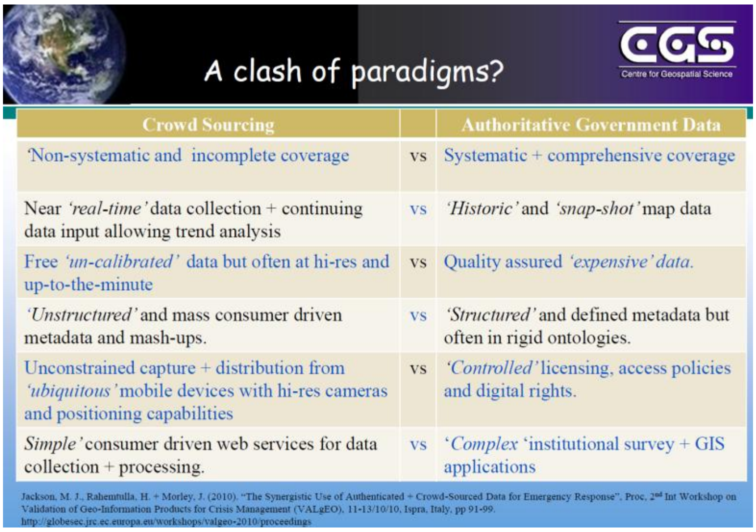


Fig. 6: Comparison of VGI and authorative data (source: M. Jackson; JACKSON et al. 2010).

In the **discussion** of the session the need for 3D and 4D data – not considered yet - in SDIs was brought up. One opinion was to first focus on 3D integration (e.g. indoor environments) because 4D is considerably more complex. In the discussion it was agreed that the idea of authorative data as only data source should be given up. The topic of the talk – conflation of data – reveals the need for further research on the VGI side, as new problems arise from VGI, e.g. different perspectives of space, etc., which directly influence possible fusion strategies and methods (e.g. top-down versus bottom-up approach or integration possible at all).

►**<u>Session 3</u>** ("Case Studies – Crowdsourced Geographic Information"), chaired by **Mike Jackson**, aimed at exemplifying the potential of VGI for DE based on specific case studies utilizing human sensor data. First, the development of a bicycle routing system based on free data (M. Ehlers) was presented, followed by a study on developing methods for learning from GI on the web (C. Sengstock) and a case study on human sensors, empowerment and accountability in Africa (Y. Georgiadou).

In his presentation **Manfred Ehlers** gave insights into *Fahrradies*, a bicycle routing system working directly on OSM data. A server architecture including web server, map server and spatial database management system (PostGIS) was built. The systems uses the road properties tagged in OSM (e.g. type of road and restrictions) and the freely available SRTM data for slope information extraction in order to account for 3D (here terrain elevation) (Fig. 7). In the second part of the presentation current and future global elevation datasets were presented, which could improve routing including elevation for larger areas with higher resolution. The next step from SRTM (90 m or 30 m) is the ASTER GDEM (30 m resolution) that is produced by stereo matching and thus represents the surface elevation e.g. of vegetation. Future global elevation datasets will be available from the TanDEM-X radar satellite (~1 m resolution) and most probably also from spaceborne scanning LiDAR. To date, just LiDAR profiling (the GLAS instrument of the ICESat) with low spatial coverage and large footprints is available.

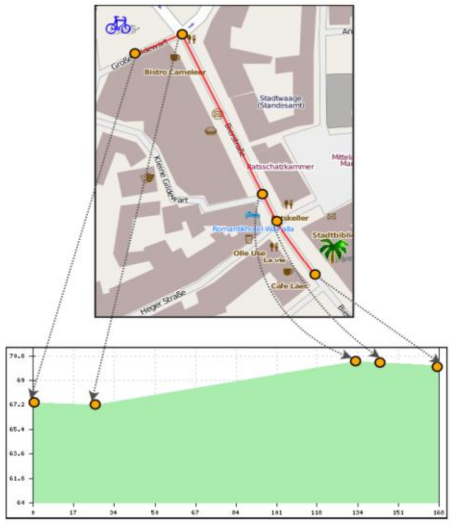
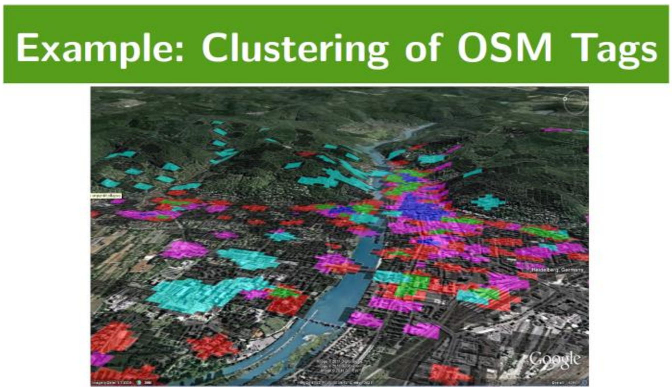


Fig. 7: Accounting for terrain elevation in the bicycle routing system *Fahrradies* based on OSM data (source: M. Ehlers).

Christian Sengstock described a machine learning approach for learning from VGI from the Web such as geo-tagged media, Flickr, Twitter or Wikipedia articles, and OSM. In particular the high dimensionality and the noisy, sparse and highly clustered feature space make it challenging to automatically perform segmentation and to extract meaningful geographic regions (Fig. 8). It is assumed that regions are represented by features in the crowdsourced data which are in spatial proximity. For this purpose a *Geographic Feature Space Kernel* was developed, which can cope with noisy, unstructured spatial data. In the current approach, areas with no data result in unclassified pixels. It was concluded that prior features selection and feature extraction (e.g. create new dimensions by Singular Value Decomposition, SVD) of the input data could improve the workflow e.g. by reducing the feature space dimension. Including data quality (e.g. uncertainty)



restaurant cafe parking fast_food	o	+	+	+	o	+
bench tree viewpoint spring	o	o	-	-	+	o
pharmacy hotel clothes bakery	o	-	-	+	o	+

Input: OSM poi identifiers (p=6329) with 3 selected latent geographic features (SVD). Kmeans clustering (k=6) at n=8767 location observations using regular grid. Base function: Gaussian kernel (sigma=50 meters).

Fig. 8: Clustering of OSM POIs using 3 latent geographic features (SVD) in Kmeans clustering (source: C. Sengstock).

and to evaluate different data sources will be investigated in the future. Further topics on the future research agenda include i) indexing of documents based on latent geographic topics, ii) link and compare geographic datasets and iii) predict valuable locations for users (e.g. showing contextual ads).

The talk of **Yola Georgiadou** was dedicated to the important aspects of voluntary sensors which go beyond the collection of geometric primitives. Digital Earth includes all *apps* for commerce, social interaction, collaborative knowledge production, citizen science and political action on the GeoWeb. The question arises to what extent citizen apps can become "*killer apps*", meaning that the user adopts the app and abandons the old way of doing something; or that organizations harnessing the app displace the ones using old apps. In developing countries Internet access is limited but mobile phones are very current. The "human sensors" can e.g. report on water, health, education issues via text messages on standard mobile phones. In this respect the unbalanced ownership of phones was mentioned (mainly man have access to phones). This public disclosure and reports on the web may pressure local authorities to take action. A pilot study – "human sensor web" – in Zanzibar is presented (Fig. 9), in which a human sensor (via mobile phone) reports and publicizes water and health problems in traditional mass media and Google Maps, public water points and clinics, and stakeholders and users. Such *political apps*, a tool to link the citizen and the government, just become killer apps if the implementation results in political action. The presented case study clearly showed that this complex system of human sensors, empowerment and accountability in Africa is not a technological issue: Social sciences are needed to understand the dynamics. Furthermore, traditional steps between citizens and public action (e.g. NGOs, media and donors) should not be ignored and accounted for.

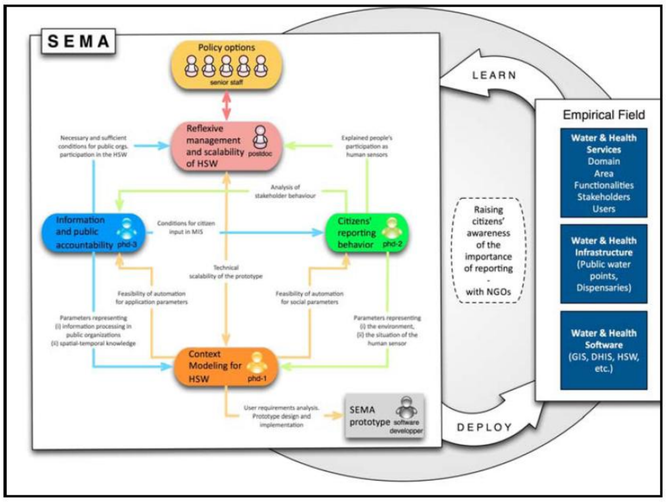


Fig. 9: Human sensor web studied in the SEMA project located in East Africa (source: Y. Georgiadou; cf. GEORGIADOU et al. 2011).

The **discussion** of this session mainly concentrated on the huge potential of harvesting geographic information from the web. It was discussed whether the 3rd dimension is really required for most applications: Do we need it and for what do we need it? Still, 3D VGI does not play a significant role compared to 2D crowdsourced data and the question is how 3D VGI can be acquired by human sensors (e.g. image matching of geocoded photos; manual with Google Sketchup for interior space) and how it can be analyzed and utilized by scientists using machine learning algorithms. A second aspect is the fusion with remote sensing data. Remote sensing can provide elevation

Photo: Exchange of ideas during the coffee breaks in front of the poster boards: J. Kolar (left) and B. Höfle.

(models) but semantics are best assigned by human sensors. To date, most 3D data (e.g. LiDAR datasets) are commercial. How can the citizens be motivated to acquire 3D data? Which tools (e.g. software for image matching of smartphone data) for the generation of 3D data are already available or have to be developed? The "new generation" – compared to the "map reading generations" - has grown up with 3D (from cinema, via computer games to Google Earth) and expects 3D virtual reality in applications. Thus, as a consequence the 3rd dimension will gain in importance in the next version of Digital Earth for the next generation of users and contributors.

Thursday, 8 September 2011

►**Session 4** ("(3D) Spatial Data Infrastructure (SDI)"), chaired by **Bernhard Höfle**, showed how 3D SDIs can contribute to energy-efficiency (V. Coors), how interoperability in SDIs can be improved for 3D city models (L. Bodum) and how 3D models can be derived from crowdsourced geodata (M. Goetz).

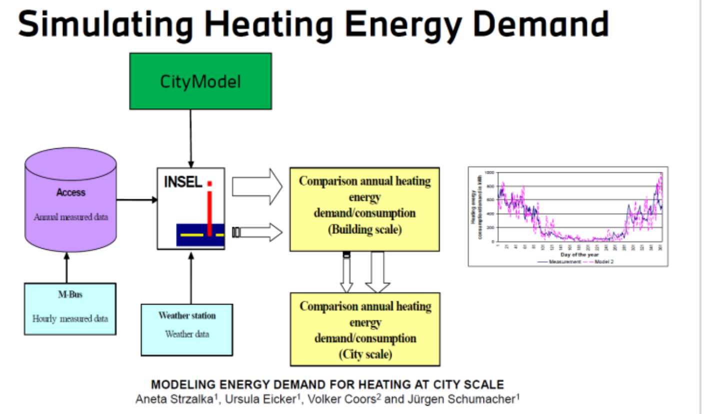


Fig. 10: Modeling the energy demand in a 3D-SDI (source: V. Coors).

In order to assess a clear benefit of the 3D-DE for society, **Volker Coors** presented an application of 3D SDIs for modeling and increasing energy-efficiency. There is a large potential for reduction of energy consumption as e.g. more than 75% of the buildings in Germany were constructed before the first Heat Insulation Ordinance in 1977. For optimized energy management mash-ups are set up including e.g. energy balance simulation and 3D GIS component (Fig. 10). Key issues in the presented study are to i) enhance data quality. In general data quality depends on the application of the data. In the BMBF project CityDoctor the quality aspect will be investigated in more detail. ii) Simulation tools will be integrated into the 3D-SDI via standardized web services. iii) Crowdsourcing for 3D building models shall be enabled. An example for a potential tool for 3D building model generation by human sensors, is the software "Photofly", which computes 3D models based on photos via server-side cloud computing. We should aim at multi-purpose 3D models, not just for visualization as commonly used. CityGML Level-of-Detail (LoD) 3-4 models are required for energy simulation of single buildings but LoD 2 is suitable to simulate the average heat energy demand for larger urban areas. A city and buildings within a city, respectively, is a "cultural thing". W.r.t. DE this means that different countries consist of different kinds of buildings made of different kinds of materials (also depending on the climatic conditions within the specific country). This leads to fact that the simulation of energy consumption of cities has to be adjusted to the building and climatic conditions of the corresponding country in order to make the presented simulation transferable. Another point of discussion was the fact whether data on heat energy consumption per building should be made available for everyone due to privacy issues?

Lars Bodum introduced how "*Managed Objects*" (MO) can solve some interoperability issues for 3D city models. The future challenge is not to handle 3D city models but to handle semantics within these 3D models. The focus should be on interoperability within the model including dynamics, analysis, scale and communication. The major aim should be to learn from the models to become smarter. The GRIFIN technology based on the MO concept is an implementation strategy that can account for some of the mentioned challenges (e.g. geocentric coordinates, timestamp part of object and executable code is coming along with the objects). The case study on the "EnergyCity Frederikshavn" aiming at sustainable energy production and consumption was selected to prove the MO concept for 3D models (Fig. 11). For this purpose the 3D city model was imported into the system based on the semantic GRIFIN technology. Different geovisualizations for certain aspects of energy (e.g. production, transmission and consumption) were selected and presented as web-based solution. It was concluded that we should not primarily focus on realistic and aesthetic 3D models (e.g. with texture) but we should look at it from a point of view that considers the real challenges of the society today. Communicating complex models and modeling results to the users remains a future challenge. 3D city models should make us smarter with regard to solve problems of the society. Improved city models will lead to improved simulation results. However, in simulations many things are unpredictable and even highly complex 3D city models are not capable to solve unpredictability.

Fig. 11: Case study "*EnergyCity*" using the GRIFIN technology (source: L. Bodum).

The last presentation of the 3D-SDI session by **Marcus Goetz** concentrated on the possibility to crowdsource 3D (building) models exemplified by OSM-3D (Fig. 12). The presented research used crowdsourced geodata of more than 42 million buildings stored in the OSM database for 3D city modeling. Roof forms were derived by investigating the semantics tagged to each building polygon. First, a semantic transformation from OSM to CityGML was done. Second, valid LoD-2 CityGML models were generated from 2D OSM data and the relevant OSM key-value-pairs (→ 3D). To date, not enough information is tagged to produce higher level of detail models from OSM. Ideally tagged buildings are rarely available, such as just 1.5% of buildings in OSM have a tagged "height value". Future research will focus on OSM for indoor environments and how building roofs can be automatically generated from tagged information. The discussion directly after presentation raised the idea to combine OSM and remote sensing data such as LiDAR data in order to improve 3D city models. However, this procedure can only be performed in regions covered by both LiDAR and VGI data. In such regions more realistic building models could be derived and cross-checks of data quality and up-to-dateness would become possible.

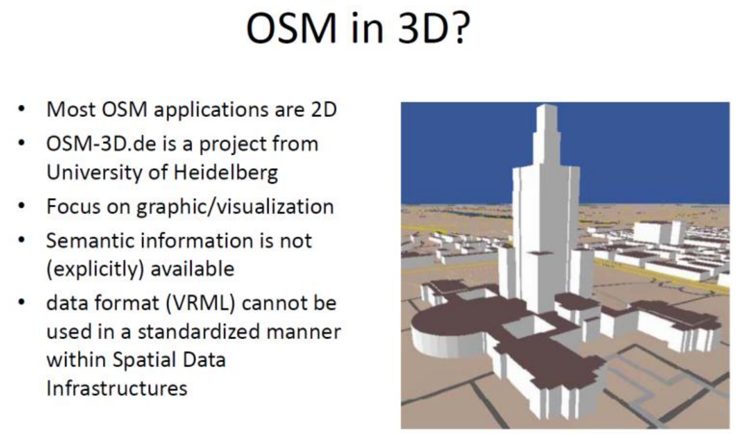


Fig. 12: The OSM-3D project (source: M. Goetz).

The **discussion** dealt with the questions whether LiDAR point clouds should become part of DE? In most parts of the world LiDAR point clouds are not freely available. This kind of data is licensed and not "open data". However, despite this limitation LiDAR point clouds should be

addressed by 3D-SDI and licensing issues should be discussed. This kind of data is necessary for both scientists and the users. As soon as the data is available to the user they will benefit from the added value of this 3D data for a variety of applications. In this context new methods should be developed allowing interaction and the generation of workflows within SDI based on 2D geodata and 3D point cloud data, respectively. Analyzing functionality within SDIs might push the integration of LiDAR point clouds in DE one step forward.
The second topic discussed if 3D-VGI is the future? To date, most 3D projects have a local (and not world-wide) focus and global coverage of 3D VGI seems to be impossible at the moment, as even the amount of active mappers in 2D OSM is minor. Gaining active mappers contributing to a "3D VGI Digital Earth Project" is a challenging task and requires suitable simple technologies dealing with highly accurate 3D information and making 3D mapping for the average person possible and attractive. But in times of "fast technological developments" some future scenarios should be set up. This might contribute to a 3D VGI based Digital Earth.

►**Session 5** ("Sensor Data Integration and Fusion"), chaired by **Gottfried Mandlburger**, aimed at showing studies dealing with sensor data and software integration and fusion. First, the OpenEarth Framework was introduced (C. Baru), followed by the presentation of the GRIFIN technology (J. Kolar) and a study on the chances of combining crowdsourced data for mapping of natural environments (M. Rutzinger).

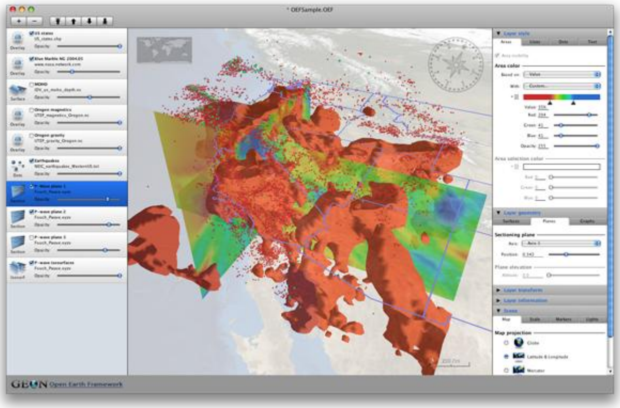


Fig. 13: OpenEarth Framework Viewer (source: http://oef.geongrid.org).

Chaitan Baru introduced the *OpenEarth Framework (OEF)* – an interactive system that can return a 3D structural model including physical parameters (e.g. density, seismic velocity, geochemistry, and geologic ages) using a cell size of 10 km for any location (lat./lon./depth) on Earth (Fig. 13). The system combines into an integrated model a lot of different data such as derived 3D volumetric model, 2D/2.5D surface data (e.g. remote sensing data, street maps, etc.) and point observations (e.g. bore hole and well data). The challenges of data integration include the issue of different "data types" (e.g. topography and seismic tomography), which are associated with different groups of experts from different disciplines. Thus, the OEF deals with a not stable situation of community of experts versus community of users. A further challenge is the integration of multiple coordinate spaces and dimensionality such as 2D and 3D representations and the time dimension, and how models can be derived from observed data. A strong structural heterogeneity has to be considered by the system such as data formats (e.g. shapefiles), data models (geometry and semantics), interfaces and data delivery (e.g. local files, OGC web services or new services for new data types). This technological approach includes a 3D visual framework based on NASA World Wind (implemented in Java and Java OpenGL), which supports netCDF and is cross-platform compatible. Future challenges for research are metadata standards, the definition (of semantics) of terms (e.g. z-value) as well as the development and specification of a Web Volume Service (WVS), which is extending existing OGC services such as WFS, WMS and WCS. As the speaker could not attend the workshop, the presentation was played from a recording C. Baru performed the day before.

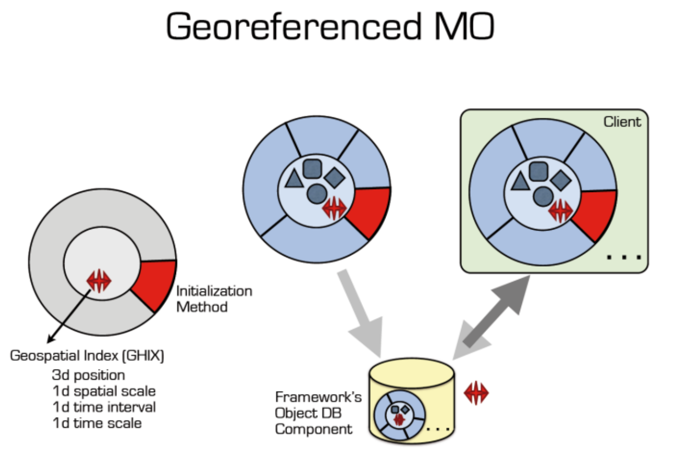


Fig. 14: The concept of Managed Objects (source: J. Kolar).

Jan Kolar introduced the concept of *georeferenced Managed Objects* (MO) and its potential for sensor data. A case study using MO has already been presented by L. Bodum in the previous session. In the Grifinor project it is aimed at developing a flexible data representation for geoinformation, which can handle highly heterogeneous data. The proposed MOs refer to an object-oriented and cross-platform binary representation including both executable behaviors (methods) and attributes of an object (Fig. 14). This means a 3D city model can have not just the geometry and attributes but also operations (methods), which could for example be used for simulation purposes or many other scenarios in urban data management. The georeferenced MO rely on a single geospatial index supporting 3D and time. The MO solution needs a Runtime (e.g. .NET, Java RE), i.e. Virtual Machine. The technology provides a uniform approach from data handling to system programming and is particularly beneficial for large heterogeneous systems. After the presentation the following issues were discussed: The dependence on the runtime environment (e.g. JDK) can be problematic and beneficial at the same time (e.g. for a strong heterogeneity of data representations). The capability of using the MO concept as technological solution for 3D VGI projects needs to be assessed in the future. Furthermore, the transition of the Grifinor project to a community-based open source project may be a chance for faster development and dissemination of the concept.

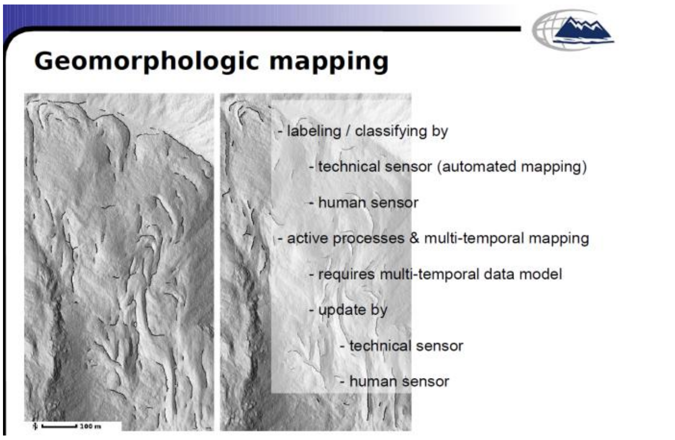


Fig. 15: Integrating technical and human sensors for improving geomorphological mapping (source: M. Rutzinger).

In the talk of **Martin Rutzinger** the questions i) how can topographic LiDAR provide 3D base mapping source for VGI, ii) how VGI can improve automated classification results of remote sensing data and iii) who are the communities interested in natural environments (e.g. high mountain areas in the Alps). Compared to 3D data from image matching, 3D data from LiDAR has not yet been used or integrated for crowdsourcing GI. Different current research topics in LiDAR remote sensing were investigated in terms of how crowdsourcing could improve the methods and vice versa what benefit LiDAR could be generated for different communities (e.g. mountaineers, tourists, and scientists). For example, LiDAR could provide base maps (e.g. shadings) for geomorphological mapping (Fig. 15) and human sensors could provide the semantics for automatically derived geomorphological features (e.g. breaklines). A second example was the mapping of crevasses of glaciers, which are very dynamic and of high interest for mountaineers to have up-to-date maps. Mountaineers could e.g. tag whether crevasses - prior detected in the LiDAR data – are snow covered or not. Concluding there is an overlap of interest as well as spatial overlap of communities performing

LiDAR data acquisition (e.g. glaciologists) and human sensors (e.g. mountaineers). Bringing data and knowledge of the different communities together could improve data quality.

►**Session 6 – Final Discussion** moderated by **Manfred Ehlers** was structured by elementary questions how 3D and crowdsourced geoinformation can be integrated into the Digital Earth, what role SDIs play in DE and if 3D VGI has a future?

- **What is the relationship between 3D SDI and DE?**
  Are they identical, is SDI a part of DE and necessary for DE and is DE just a concept?

Photo: Final discussion of the Hengstberger Symposium moderated by Manfred Ehlers.

Digital Earth is also media to present scientific results to citizen aiming at a global scale. It is discussed that DE must be more than just a presentation medium. First, the next generation must increasingly integrate data acquired by citizens (i.e. crowdsourced geoinformation). Second, additionally to the current focus on geoinformation and how to present it in a DE, the agenda should be extended by "tools" providing analysis functionality to DE. Thus, DE should include *Data & Tools* together allowing deeper insight into the processes, reproduction of results and production of new results, which have not been obvious and considered so far. Integrating, e.g. scientific tools, into DE will increase complexity of usage (for non-experts). To date, presenting finalized results enables the control of the communication of scientific information, such as by "moderated information" but limits the free access and usage of tools, such as to "build" new data and set up mash-ups for analysis. In this respect, metadata (also metadata for tools/analysis) becomes more important. It is concluded that the term "3D SDI" should not be used synonymously to DE. The term "Digital Earth" should be preferred as general concept including also (3D) SDIs.

- **What is a 3D Digital Earth?**
  Does it include DEMs, city/building models, LiDAR point clouds, interior space, 3D VGI and "true 3D"?

In this respect, "3D" has to be defined first. Is it the "three-dimensional representation of the planet", a 3D virtual globe, stated by Al Gore or does it go even farther and into more detail? Does 3D means 2.5D elevation models, representation of cliffs, even subsurface structures/volumes or interior space with complex geometries and semantics? Is 3D just a question of scale, meaning that 3D is only required in a very detailed and local scale (e.g. for distinct objects such as a building)? The OpenEarth Framework shows that subsurface 3D geoinformation can be provided worldwide and that the technological solutions already exist.

"People think and move in 3D" and we spend most of our time indoors. This shows that even from a non-scientific point-of-view the third dimension (in any definition) is a crucial factor in everybody's life and, thus, should be integral part of the DE. It is expected that the next generation will be more familiar or even expect 3D as they have grown up with 3D computer games and 3D movies compared to the pre-Web generation of (2D) paper map readers.

- **Where do you see the most potential but also limitations of joining human sensors and remote sensor data w.r.t. 3D DE?**

VGI for 2D is accepted but active and "long-term" mappers are just a small group of people. What should motivate people to map in 3D? What level of detail is really needed from a geometric and semantic point-of-view? Still, we have technological issues hampering the acquisition of 3D VGI such as the problem of positioning indoors, lack of affordable and easy-to-use sensors to acquire 3D data directly (cf. range cameras). We have different levels of crowdsourcing 3D data, from tagging e.g. the number of building levels in OSM, via taking pictures (without the direct intention to generate 3D data) and deriving a 3D model (cf. "Rome in a Day") to direct measurement and modeling of 3D objects. This can be called "active" and "passive" contribution of the crowd to gather 3D geoinformation. A main discussion issue was the question how the crowd can be motivated to acquire 3D models, even models that scientists can use (i.e. having a known data quality). Intrinsic motivation is required, how can we increase participation? It should be "fun to make the world a better place" by crowdsourcing 3D data in order to solve some of the compelling social problems (e.g. disaster management, emergency response and pollution). The direct implication should be "visible" such as the acquired data is used in "great" applications and, thus, the acquired data is "useful". In this respect "experts" from social sciences should be invited for discussion in the future. Crowdsourced data can stimulate new applications and vice versa applications can be drivers for data collection. This cycle has to be entered and exemplified by impressive case studies and projects. Another motivation could be "micropayments" (cf. Mechanical Turk) or combinations of industry driven projects and community need.

One conclusion was that things need to be kept simple in terms of tools and interfaces the crowd can use to acquire and "use" 3D geodata. The crowd should not be confronted with standardization of formats, services and data model concepts. It should be easy, self-explanatory and "fun" to use web tools providing the generation and usage of 3D VGI. Pilot projects showed that the "3D computer games generation" (even school kids) is capable of handling existing 3D tools and can learn very quickly. Thus, it is possible to handle 3D but is a question of "education" and technological involvement, which is a very heterogeneous global phenomenon and cannot be identified as "solved".

- **How continue from here to achieve a Digital Earth in "3D"?**

It is important to involve the citizens in the development of the 3D-DE: They can formulate the needs and can be data producers at the same time. A grassroots approach would be a chance to achieve increased awareness and understanding of Digital Earth in general and the need for 3D in particular. School kids and students could be inspired and could be partners in the development, which would be an involvement of the next generation for designing the next generation DE. More case studies and beneficial applications based on 3D data are required in order to show the benefit and added value for society. Which social problems can be solved by free 3D geoinformation and why is it useful for everyone? Open platforms and easy-to-use tools to create and analyze 3D information have to be developed by scientists. Furthermore, more scientific disciplines (e.g. social sciences) are required in future discussions and workshops.

To conclude, the 3D-DE workshop in one sentence: “It is a long way to go” but general consensus could be achieved that a three-dimensional representation going beyond the presentation as 3D globe is essential and beneficial.

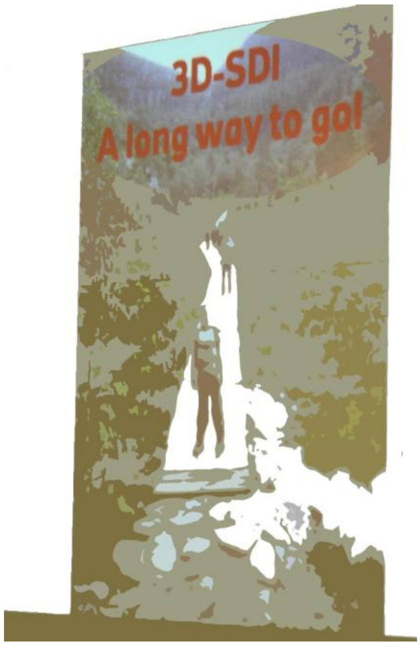


Photo: 3D-DE – “It is a long way to go”.

Related Publications

ANNONI, A., et al. (2011): A European perspective on Digital Earth. *International Journal of Digital Earth*, Vol. 4 (4), 271-284.

CRAGLIA, M., et al. (2012): Digital Earth 2020: towards the vision for the next decade, *International Journal of Digital Earth*, Vol. 5 (1), 4-21.

CRAGLIA, M., et al. (2008): Next-generation Digital Earth. A position paper from the Vespucci initiative for the advancement of geographic information science. *International Journal of Spatial Data Infrastructure Research*, Vol. 3, 146-167.

GEORGIADOU, Y., et al. (2011): Sensors, empowerment, and accountability: a Digital Earth view from East Africa. *International Journal of Digital Earth*, Vol. 4 (4), 285-304.

GOODCHILD, M.F. (2008): The use cases of digital earth. *International Journal of Digital Earth*, Vol. 1 (1), 31-42.

GORE, A. (1999): The Digital Earth: understanding our planet in the 21st century. *Photogrammetric Engineering and Remote Sensing*, Vol. 65 (5), 528.

JACKSON, M. J., RAHEMTULLA, H., MORLEY, J. (2010): The Synergistic Use of Authenticated + Crowd-Sourced Data for Emergency Response. *Proc, 2nd Int Workshop on Validation of Geo-Information Products for Crisis Management (VALgEO)*, pp. 91-99.

3. Finale Programme

Wednesday, 7 September 2011

09:00-09:15	**Welcome Address**
	Peter Comba (Director IWH, University of Heidelberg, DE)
09:15-09:30	**Mission Statement**
	Bernhard Höfle (University of Heidelberg, DE)
09:30-12:00	**Session: Digital Earth: Human and 3D Remote Sensors**
	Chair: Yola Georgiadou (University Twente, NL)
09:30-10:00	**Digital Earth: Inventory and Prospect**
	Michael Goodchild (UC Santa Barbara, US)
10:00-10:30	*Coffee / tea break*
10:30:11:00	**Crowdsourcing Digital Earth - From Data Fusion to Knowledge Generation?**
	Alexander Zipf (University of Heidelberg, DE)
11:00-11:30	**3D Remote Sensing Sensors - Mapping the Earth in 3D**
	Gottfried Mandlburger (Vienna University of Technology, AT)
11:30-12:00	**Discussion**
12:00-13:30	*Lunch*
13:30-15:00	**Session: Volunteered/Crowdsourced Geographic Information**
	Chair: Michael Goodchild (UC Santa Barbara, US)
13:30-13:50	**The Evolution and Spatial Volatility of VGI in OpenStreetMap**
	Peter Mooney (National University of Ireland Maynooth, IE)
13:50-14:10	**Persuading Non-GI Specialists to Capture Metadata - Is it Possible?**
	Claire Ellul (University College London, UK)
14:10-14:30	**The conflation of authoritative and crowd-sourced data for future development of spatial data infrastructures**
	Mike Jackson (University of Nottingham, UK)
14:30-15:00	**Discussion**
15:00-15:30	*Coffee / tea break*
15:30-17:00	**Session: Case Studies - Crowdsourced Geographic Information**
	Chair: Mike Jackson (University of Nottingham, UK)
15:30-15:50	**Fahrradies: A Bicycle Routing System Based on Open Source Software and Free 2D and 3D Geodata**
	Manfred Ehlers, Kai Behnke (University of Osnabrück, DE)
15:50-16:10	**Learning from Geographic Information on the Web**
	Christian Sengstock, Michael Gertz (University of Heidelberg, DE)
16:10-16:30	**Human Sensors, Empowerment, and Accountability in Africa**
	Yola Georgiadou (University Twente, NL)
16:30-17:00	**Discussion**
17:00	**Concluding Remarks**
	Convenors
19:00	*Dinner: Restaurant Oskar (Haspelgasse 5, Heidelberg / www.oskar-hd.de)*

Thursday, 8 September 2011

09:00-10:30	**Session: (3D) Spatial Data Infrastructure (SDI)**
	Chair: Bernhard Höfle (University of Heidelberg, DE)
09:00-09:20	**3D-SDI contribution to energy-efficient cities**
	Volker Coors (Hochschule für Technik Stuttgart, DE)
09:20-09:40	**Managed Objects Can Solve Some of the Interoperability Issues for 3D City Models**
	Lars Bodum (Aalborg University, DK)
09:40-10:00	**Deriving Standardized 3D City Models from Crowdsourced Geodata**
	Marcus Goetz (University of Heidelberg, DE)
10:00-10:30	**Discussion**
10:30-11:00	*Coffee / Tea Break*
11:00-12:30	**Session: Sensor Data Integration and Fusion**
	Chair: Gottfried Mandlburger (Vienna University of Technology, AT)
11:00-11:20	**The OpenEarth Framework and 3D data integration**
	Chaitan Baru (UC San Diego, US) [*recorded video presentation*]
11:20-11:40	**Introduction to georeferenced managed objects and their potential for sensor data**
	Jan Kolar (Grifinor Project, DK)
11:40-12:00	**3D spatial data extraction for crowd sourcing and volunteered geographic information mapping of natural environments**
	Martin Rutzinger (University of Innsbruck, AT)
12:00-12:30	**Discussion**
12:30-13:45	*Lunch*
13:45-14:45	**Plenary Discussion: Beyond the Current 3D Digital Earth: Possibilities and Limitations**
	Chair: Manfred Ehlers (University of Osnabrück, DE)
14:45	**Concluding Remarks**
	Convenor
15:00	*End of Workshop with Coffee / Tea*
20:00	*Guided Night Tour Old Town of Heidelberg*

4. Final list of participants

In total 32 researchers actively participated in the symposium. International participation originated from 8 different countries: AT (2), DK (2), IE (1), IT (1), NL (1), UK (2) and the US (2). Chaitan Baru (US) could not join the workshop in person but provided a recorded presentation and important questions for discussion. More than 43% of the participants were young scientists (mainly PhD students), which is a very important part in supporting young researchers and providing them access to international scientific networks, and thus is a very positive signal for further activities.

Convener (1)

- **Bernhard Höfle**, University of Heidelberg, Institute of Geography (DE)

Participants (31)

- **Chaitan Baru**, UC San Diego, San Diego Supercomputer Center (US)
- **Lars Bodum**, Aalborg University, Department of Development and Planning (DK)
- **Volker Coors**, Hochschule für Technik Stuttgart (DE)
- **Manfred Ehlers**,Universtität Osnabrück, Institut für Geoinformatik und Fernerkundung, (DE)
- **Claire Ellul**, University College London, Civil, Environmental & Geomatic Engineering (UK)
- **Yola Georgiadou**, University Twente, ITC (NL)
- **Michael Gertz**, University of Heidelberg, Institute of Computer Science (DE)
- **Michael Goodchild**, UC Santa Barbara, Department of Geography (US)
- **Marcus Goetz**, University of Heidelberg, Institute of Geography (DE)
- **Julian Hagenauer**, University of Heidelberg, Institute of Geography (DE)
- **Marco Helbich**, University of Heidelberg, Institute of Geography (DE)
- **Florian Hillen**,Universtität Osnabrück, Institut für Geoinformatik und Fernerkundung (DE)
- **Mike Jackson**, Centre for Geospatial Science, The University of Nottingham (UK)
- **Heike Jänicke**, University of Heidelberg, Interdisciplinary Center for Scientific Computing (DE)
- **Thomas Jarmer**,Universtität Osnabrück, Institut für Geoinformatik und Fernerkundung (DE)
- **Jan Kolar**, Grifinor Project (DK)
- **Susanne Krömker**, University of Heidelberg, Interdisciplinary Center for Scientific Computing (DE)
- **Sandra Lanig**, University of Heidelberg, Institute of Geography (DE)
- **Johannes Lauer**, University of Heidelberg, Institute of Geography (DE)
- **Lukas Loos**, University of Heidelberg, Institute of Geography (DE)
- **Sara Lucca**, Politecnico Di Milano Diiar, Polo Regionale Como, Faculty of Engineering (IT)
- **Gottfried Mandlburger**, Vienna University of Technology, Inst. of Photogr. and Remote Sens. (AT)
- **Hubert Mara**, University of Heidelberg, Interdisciplinary Center for Scientific Computing (DE)
- **Hossein Shafeezadeh Moghaddam**, University of Heidelberg, Institute of Geography (DE)
- **Peter Mooney**, National University of Ireland Maynooth (IE)
- **Pascal Neis**, University of Heidelberg, Institute of Geography (DE)
- **Oliver Roick**, University of Heidelberg, Institute of Geography (DE)
- **Martin Rutzinger**, University of Innsbruck, Institute of Geography (AT)
- **Matthias Uden**, University of Heidelberg, Institute of Geography (DE)
- **Christian Sengstock**, University of Heidelberg, Institute of Computer Science (DE)
- **Alexander Zipf**, University of Heidelberg, Institute of Geography (DE)

Local organization team (3)

- **Hannah Deierling**, University of Heidelberg, Institute of Geography (DE)
- **Bettina Knorr**, University of Heidelberg, Institute of Geography (DE)
- **Kristina König**, University of Heidelberg, Institute of Geography (DE)

5. Press and Media

Dissemination of the Hengstberger Symposium was performed via press and via the symposium **website** http://3dde.uni-hd.de where all important information on the symposium is provided (e.g. programme and abstract booklet, reports, links and digital media: for participants only). The following **press releases** were made in the course of the Hengstberger Prize 2010 and the Hengstberger Symposium "*Towards Digital Earth: 3D Spatial Data Infrastructures*":

- **22.10.2010: Pressemitteilung Ruprecht-Karls-Universität Heidelberg**:
  22. Oktober 2010 – Nr. 237/2010: „Hengstberger-Preis für herausragende Heidelberger Nachwuchswissenschaftler"

- **26.10.2010: News HARZER GEObranchen.de - Geobusiness & Geowissenschaft:** „Hengstberger-Preis 2010 für Heidelberger Geoinformatik"

GEObranchen.de
Geobusiness & Geowissenschaft

- **26.08.2011:Pressemitteilung Ruprecht-Karls-Universität Heidelberg**:
  26. August 2011 – Nr. 275/2011: „Die digitale Erfassung der Welt"

- **07.09.2011: Rhein-Neckar-Zeitung (RNZ):**
  Nr. 207/2011 (p. 6): „Die digitale Erfassung der Welt"

Die digitale Erfassung der Welt

Teilnehmer eines internationalen Symposiums befassen sich mit dreidimensionalen Geodaten

RNZ. Die digitale Erfassung und geographische Analyse der Welt durch dreidimensionale Geodateninfrastrukturen ist Thema eines Hengstberger-Symposiums, das heute und morgen an der Universität Heidelberg stattfindet. Rund 30 Experten aus Deutschland, dem europäischen Ausland und den USA diskutieren dabei über die wissenschaftlichen Grundlagen neuer Geoinformationstechnologien. Die englischsprachige Veranstaltung „Towards Digital Earth – 3D Spatial Data Infrastructures" wird von Wissenschaftlern der Abteilung Geoinformatik am Geographischen Institut der Ruperto Carola durchgeführt und findet am Internationalen Wissenschaftsforum Heidelberg (IWH) statt.

Ein Großteil der vorhandenen digitalen Daten kann über einen Raumbezug geografisch verortet werden, zum Beispiel über Koordinaten oder Adressen. Diese sogenannten Geodaten werden mit Geographischen Informationssystemen (GIS) verwaltet, analysiert und visualisiert. „Die daraus gewonnenen Informationen unterstützen eine Vielzahl von wissenschaftlichen Fragestellungen, ebenso wie politische und gesellschaftliche Entscheidungen", erläutert der Organisator der Veranstaltung, Juniorprofessor Dr. Bernhard Höfle. „Zugleich sind Geoinformationstechnologien aus dem Alltag kaum mehr wegzudenken. Ein Beispiel dafür sind Smartphones, die bereits eine Vielzahl von ortsbezogenen Geo-Anwendungen und Diensten unterstützen."

Zusammenführung und Auswertung der Daten

Die Teilnehmer des interdisziplinären Symposiums beschäftigen sich insbesondere mit Sensordaten, die einerseits durch hochgenaue Erdbeobachtungssensoren wie zum Beispiel Laserscanning und andererseits durch eine kollaborative Datenerfassung im Internet, etwa mit „OpenStreetMap", gewonnen werden. Dabei geht es um die Zusammenführung und übergreifende Auswertung dieser unterschiedlichen Datenbestände. „Ziel der hochrangig besetzten Tagung ist es, wesentliche Forschungsfragen in der Entwicklung einer Infrastruktur für dreidimensionale Geodaten zu identifizieren und formulieren", betont Professor Höfle.

Bernhard Höfle gehört zu den Hengstberger-Preisträgern 2010. Der Klaus-Georg und Sigrid Hengstberger-Preis wird jährlich an drei Nachwuchswissenschaftler oder Wissenschaftlerteams der Universität Heidelberg vergeben. Mit der Preissumme von jeweils 12 500 Euro erhalten junge Forscher die Möglichkeit, ein interdisziplinäres wissenschaftliches Symposion im IWH durchzuführen.

ⓘ **Info:** Weitere Informationen können im Internet unter der Webadresse http://3dde.uni-hd.de sowie unter www.iwh.uni-hd.de/hengstberger abgerufen werden.

Press release in the Rhein-Neckar-Zeitung (RNZ) Nr. 207/2011 (p. 6), 7 September 2011.

6. Abstracts

Session: Digital Earth: Human and 3D Remote Sensors

Title	Digital Earth: Inventory and Prospect
Author(s)	Michael Goodchild
Session	Digital Earth: Human and 3D Remote Sensors
Affiliation	Department of Geography, University of California, Santa Barbara
Abstract	
With Google Earth and various other virtual globes providing a first generation of Digital Earth implementations, based on the vision outlined by Gore in 1998, it is appropriate to consider what the next generation might be like. On the one hand, one might conduct a traditional waterfall analysis by identifying use cases and then functionality and architecture. On the other one might echo the early developers at Keyhole and speculate on how the next generation might push the technical envelope. The presentation outlines discussions that have taken place in Florence in 2008 under the auspices of the Vespucci Initiative, and in Beijing in 2011 under the auspices of the Chinese Academy of Sciences, aimed at revisioning Digital Earth for the next decade, and provides a personal interpretation and perspective. The presentation explores the relationships between Digital Earth and other cutting-edge topics in geographic information science, including cyberGIS and volunteered geographic information.	

Title	Crowdsourcing Digital Earth - From data fusion to knowledge generation?
Author(s)	Alexander Zipf
Session	Digital Earth: Human and 3D Remote Sensors
Affiliation	University of Heidelberg, Institute of Geography, Chair of GIScience
Abstract	
Recently we have seen an explosion of data being generated both by technical as well as human sensors. Together they give an increasingly comprehensive digital representation of our planet covering both physical and social aspects. While we see attempts to harvest and integrate those data with respect to its geographic context, most of the approaches do cover only a single or very few data sources, they keep the concept of flat maps and they focus on data management, fusion and visualisation (rather than analysis). I conclude that more research is needed on: a) integrated approaches combining multiple data sources for generating data for the Digital Earth covering different crowdsourcing approaches and technical sensors. b) We need to think about ways to derive information in all three spatial dimensions both for natural objects as well as man-made structures. Further we need to handle also moving and dynamic objects, i.e. their "behaviour" and even social interactions. c) Finally we do not only need to generate, fusion, manage and visualize this data in its „Earth“ context, but also think about ways how to empower the crowd with analytical capabilities, i.e. tools that generate new information (or even knowledge) from the data being available. Current approaches focus on providing analysis tools for domain experts, but there is the question if – and how - we can democratize not only geographic data generation and visualization, but even some aspects of spatial analysis.	

Title	3D Remote Sensing Sensors - Mapping the Earth in 3D
Author(s)	Gottfried Mandlburger
Session	Digital Earth: Human and 3D Remote Sensors
Affiliation	Vienna University of Technology, Institute of Photogrammetry and Remote Sensing

Abstract

Capturing and reconstructing the Earth's surface and artificial objects is of prime importance for many applications in our everyday world; from transport infrastructure to telecommunication, from disaster management to ecological issues, from agricultural measures to city planning and many more. The magic triangle is: Sensors – Algorithms – Applications. In other words, the raw sensor data is transformed using a set of algorithms to a final model, be it a 1D cross section, a 2D map, a 3D virtual reality computer model. Capturing 3D data was long restricted to a handful of mapping experts. Today however, with the tremendous progress in sensor (GPS, UMTS, digital consumer cameras) as well as computer (mobile devices) and internet technology (Google, Virtual globe), this field is also open to a wider community of non-experts (i.e., collaborative crowdsourcing). This contribution, therefore, reviews well established and uprising 3D remote sensing sensors. Instruments enabling high geometric and radiometric quality will be equally discussed along with low price consumer devices. The principles of both, passive sensors (photometric frame cameras, line scanners, hyperspectral scanners) and active systems like RADAR, LiDAR and range cameras are introduced and their pros and cons are confronted. As 3D data capturing is, nowadays, often carried out in a multi-sensor environment, fusion of data from different sources becomes more and more important. This applies to specific sensor systems like full waveform Airborne Laser Scanning (ALS), where precise point clouds are obtained by combining data from Global Navigation Satellite System (sensor position), inertial measurement units (sensor alignment), the laser scanner (range and beam deflection) and a waveform processing unit as well as for the integration of models with different levels of detail. Embedding local Google SketchUp 3D photo models into precise, countrywide 2.5D ALS DTMs may serve as an example of the latter. One of the challenges of tomorrows geo-data infrastructure is to combine the high accuracy level of modern 3D sensors with the potentially high up-to-dateness of crowd source data.

Session: Volunteered/Crowdsourced Geographic Information

Title	The Evolution and Spatial Volatility of VGI in OpenStreetMap
Author(s)	Peter Mooney
Session	Volunteered/Crowdsourced Geographic Information
Affiliation	National University of Ireland Maynooth

Abstract

Volunteered Geographic Information (VGI), and in particular OpenStreetMap (OSM), is being used for many real-world applications such as: building 3-D city models, automobile/cycle/pedestrian navigation applications, gazeteer development, etc). One of the most exciting characteristics of VGI, while potentially being the most controversial, is the dynamic nature of contributions to projects such as OSM coupled with the GIS/spatial data handling abilities of OSM contributors. In this paper I shall discuss ongoing research and development towards understanding the dynamic and evolutionary nature of the spatial data “inside” OSM. Case study examples and analysis are presented. Accessing the edit history of features in OSM is a complicated process, compounded by the ever increasing volume of the spatial data within OSM. Subsequently, little research is being conducted on the historical evolution of the spatial data in OSM up to the current version of the globally accessible OSM database. Unlike National Mapping Agency data products the “current version” of OSM may not be the “best available” or “highest quality” for certain applications. The results of my work indicate that researchers, commercial companies, etc developing applications or services using OSM must be cognizant of the potential problems caused by the volatile nature of the underlying spatial data and its attributes/metadata. I explore the effects of this volatility in terms of VGI integration into iniativies such as Spatial Data Infrastructures (SDI) and Digital Earth.

Title	Persuading Non-GI Specialists to Capture Metadata - Is it Possible?
Author(s)	Claire Ellul
Session	Volunteered/Crowdsourced Geographic Information
Affiliation	University College London (UCL), Civil, Environmental & Geomatic Engineering

Abstract

Metadata, and how it is captured, maintained and used, is fundamental to any Spatial Data Infrastructure. This is possibly even more the case in a 3D context, where the types of errors in the 3D geometry may vary widely depending on the source and capture method for the data itself. Issues relating to data quality, described by metadata in the context of terms such as completeness, currency, positional accuracy and coverage, apply in 3D as much as they do in 2D. The presentation will give an overview of the use of metadata in a multi-national Coastal Environmental Science research project, presenting the differing views about the importance of various metadata elements expressed by the producers and the users of this metadata. Issues relating to metadata capture and motivating team members to undertake this task will also be examined, in the context of a multi-disciplinary team whose expertise ranges from environmental science to population migration, and whose familiarity with GIS and metadata is limited.

Title	The conflation of authoritative and crowd-sourced data for future development of spatial data infrastructures
Author(s)	Mike Jackson
Session	Volunteered/Crowdsourced Geographic Information
Affiliation	Centre for Geospatial Science, The University of Nottingham

Abstract

Spatial data infrastructures (SDI) have moved from the concept stage to being accepted policy and an increasingly essential component of the environmental and economic planning programmes of most countries. They have been defined and built from a top-down perspective, harmonising and making interoperable the spatial data holdings, particularly map-based data, of government ministries and related governmental bodies. At the time of their inception this was compatible with the reality that most of the relevant data were collected and mapped by such agencies. Over the last decade, however, we have experienced a situation where the ability to accurately locate an objects position, boundary or trajectory no longer requires expensive survey equipment operated by highly trained professionals. Such a capability is now within the scope of the general public most notably through the technology which is part of the almost ubiquitous mobile phone. This has led to an explosion in people positioning themselves, the places that they visit, the photographs that they take and the digital trails that they create as part of their day-to-day work and social activity. The value of this data in aggregated form, for social and commercial application, has been recognised but it has as yet produced more of a parallel path towards spatial data acquisition and utilisation than an integrated contribution to "governmental" SDI. This presentation will discuss this situation, compare the nature of the two sources of data and present some research results aiming to achieve conflation of the two to achieve the best of both worlds.

Session: Case Studies - Crowdsourced Geographic Information

Title	Fahrradies: A Bicycle Routing System Based on Open Source Software and Free 2D and 3D Geodata
Author(s)	Manfred Ehlers, Kai Behncke
Session	Case Studies - Crowdsourced Geographic Information
Affiliation	Institute for Geoinformatics and Remote Sensing, University of Osnabrück

Abstract

Nowadays the world market is overloaded with routing applications. Those routing services are mostly designed for the usage with motorized vehicles, for this purpose they are well-engineered. However, the requirements of cyclists often differ from those of motorists. Cyclists are typically not interested in finding the shortest way to their destination; they prefer choosing paths where they can enjoy nature without interfering with motorized traffic. In view of the fact that digital geographic material for bicycles is rare, the project Farradies.net was developed to offer new possibilities by using solely open source software (e.g. OpenLayers, MapServer) and free geodata (e.g. OpenStreetMap and SRTM global digital elevation data). This project provides a routing service which is particularly designed for cyclists and for the region around the city of Osnabrück. Based on free geodata from OpenStreetMap.org, Fahrradies.net uses pgRouting, which enables users to plan their tracking routes more individually. For using pgRouting in the Web, a special algorithm was developed (written in PL/pgSQL). Furthermore, users can choose from several routing profiles. The offroad-profil, for example, is optimized for mountain bikers and will prefer ways through rough terrain, like paths or tracks with cobblestone pavement and appropriate slopes that are derived from SRTM elevation data. In addition, Fahrradies.net offers information about many points of interest along the calculated routes. Interactively designed tracks can be downloaded for mobile devices. Another important innovation is that the routing service offers functions referring to the Web 2.0 definition. For example, it is possible for users to rank routes, based on various evaluation criteria. These ratings can also be taken into account when planning individual biking excursions. The main idea behind that is that people can actively interact with the system, in contrast to only use a given service. Bicyclists, for example, can either avoid certain steep slopes when crossing mountainous landscapes. Mountain bikers, on the other hand, can select tracks with maximum altitude differences for their workout. Fahrradies is designed to give cyclists the tools to plan their routes as individually as possible.

Title	Learning from Geographic Information on the Web
Author(s)	Christian Sengstock, Michael Gertz
Session	Case Studies - Crowdsourced Geographic Information
Affiliation	Institute of Computer Science, Heidelberg University

Abstract

The rapidly increasing amount of Volunteered Geographic Information (VGI) on the Web provides a rich resource for describing and exploring locations and regions in geographic space. Popular sources managing large numbers of geographic features (VGI-features) include geo-tagged media, like Flickr, Twitter, or Wikipedia articles, and dedicated open geographic information sources like OpenStreetMap. Learning tasks based on the representation of locations and regions using VGI include, among others, the prediction of events at a given location based on event observations in other regions, or the segmentation of geographic space into meaningful regions to automatically generate maps or extract vector representations. But how can VGI be used to build a generalized, meaningful, and structured representation of arbitrary locations and regions in geographic space that can be input to learning tasks? We assume that locations and regions can be represented by VGI-features that are close in spatial proximity, inspired by the process how people get a sense of their environment based on surrounding real-world phenomena. A major challenge in developing and using such a representation is that existing data sources manage a high dimensional, noisy, sparse, and highly clustered feature space, which is difficult to handle by learning tasks. To overcome some of these problems, feature selection and extraction methods tailored to the characteristics of VGI are needed. In this talk, a general approach to represent arbitrary locations by VGI-features and a model to define a structured VGI-feature space are introduced. Feature selection and extraction algorithms and example learning tasks are proposed that demonstrate the benefits and the generality of the approach. Finally, we outline future research topics related to VGI-feature spaces.

Title	Human Sensors, Empowerment, and Accountability in Africa
Author(s)	Yola Georgiadou
Session	Case Studies - Crowdsourced Geographic Information
Affiliation	Chair Geo-information for Governance, Faculty of Geo-information Science and Earth Observation (ITC), University Twente
Abstract	

Reports of citizens as voluntary sensors can go beyond the geometric primitives of point, line, or polygon. Empowered citizens can report failures in the delivery of local government services—e.g., water, health, education—via text messages on standard mobile phones. The public disclosure of these reports on the web and other mass media may pressure local authorities to take remedial action. The voice of ordinary citizens can be amplified, and citizens' capacity to directly influence public service delivery and hold local government accountable can be improved. With mobile phone coverage and ownership expanding rapidly in Africa more and more initiatives are developed for citizens to make innovative use of mobile telephony and SMS-based services in Africa. In this paper, we outline the challenges pertaining to citizen sensing for domestic accountability, based on a pilot 'human sensor web' in Zanzibar, with UN Habitat and Google funding between 2009 and 2010. A human sensor web is an assembly of geographic web services, citizens with mobile phones ('human sensors') reporting & publicizing water and health problems in traditional mass media and Google Maps, public water points & clinics, and stakeholders & users. The lessons we learned during the pilot form the backbone of a research agenda to advance an African contribution to Digital Earth.

Session: (3D) Spatial Data Infrastructure (SDI)

Title	3D-SDI contribution to energy-efficient cities
Author(s)	Volker Coors
Session	(3D) Spatial Data Infrastructure (SDI)
Affiliation	Hochschule für Technik Stuttgart
Abstract	

Climate change, the limitations of fossil fuels and sustainable energy production are some of the biggest challenges of the 21st Century. Heating and cooling of buildings is one of the largest sources of energy consumption in the European Union. In Germany, we have about 18 million residential buildings, 75% of these have been build 30 years ago. How can 3D spatial data infrastructure (SDI) contribute to the energy-efficiency of our cities? Unfortunately, a SDI has no direct impact on energy consumption. However, a 3D city model available and usable by professional energy managers as well as private building owners will have a significant impact to reduce the energy consumption of a city and in addition to raise the local energy production such as PV. A 3D SDI enables energy managers to get an overview of the expected future energy demand due to improved simulation methods. In addition, the performance of a building can be improved by optimized building control due to online access of current energy consumption and predicted / simulation. To achieve this, we need to (i) be able to share multipurpose 3D city models, which requires a mapping between domain specific ontologies, (ii) enable energy simulation tools to deal with 3D city models to improve simulation results at city level (Strzalka et al. 2011), (iii) enhance the quality of existing city models, (iv) support crowd sourcing to capture detailed models of building including interior. For instance, the availability of simple web-based modeling tools (such as Google SketchUp) will enable every owner of a building to prepare a suitable model for energy simulation. Currently, semantic modeling is lacking, and (v) ensure privacy issues.

Title	Managed Objects Can Solve Some of the Interoperability Issues for 3D City Models
Author(s)	Lars Bodum
Session	(3D) Spatial Data Infrastructure (SDI)
Affiliation	Aalborg University, Department of Development and Planning

Abstract

The road towards interoperability within the domain of 3D city modelling is long and despite the strong technological progress there are still many decisions to make and a lot of specific implementations to do before the situation could be described as satisfying. 3D city models must adapt to a spatial data infrastructure and they also have to advance from simple geometric models to more complex information models. A big step in the right direction has been taken with the introduction of CityGML. The OGC specification allows exchange of 3D city models and furthermore there are numerous possibilities to define semantic properties together with the geometry. But introducing CityGML as the preferred information model and data exchange format for the future will not solve all problems. A further enrichment of the information model is suggested by the use of Managed Objects (MO) in a conceptual model on the application level. MO refers to a pure object-oriented and platform-independent binary representation that carries both the executable behaviours and attribute data regarding an object. The MO's allow having not only properties (attributes) for the objects in the 3D city model but also operations (methods). This will make the 3D city model much more interesting for simulation purposes or other applications that are demanding functionality and intelligence.

Title	Deriving Standardized 3D City Models from Crowdsourced Geodata
Author(s)	Marcus Goetz
Session	(3D) Spatial Data Infrastructure (SDI)
Affiliation	University of Heidelberg, Institute of Geography, Chair of GIScience

Abstract

Professional tasks such as urban planning more often require precise 3D models for computation and visualization. Moreover, applications for the broad public such as Google Earth do also allow a three-dimensional visualization of a virtual globe. Thereby, professional applications and enterprises mainly utilize proprietary data obtained by public authorities or commercial providers. In contrast, research institutes or small companies always seek alternative (and cheap) data sources, which are capable for their requirements. One type of such alternative data sources has evolved in the last couple of years, namely Volunteered Geographic Information or Crowdsourced Geodata. Thereby, both terms describe the collaborative collection of different types of spatial and geographic data. That is, both layman and professionals collect such data and share it in a Web 2.0 community platform with other users at no charge. One very popular example for this trend is OpenStreetMap (OSM) – a project aiming at providing a massive data source of spatial information. It began as an online map, but soon evolved to a source of various types of information. That is, OSM not only contains information about streets, but currently also details about roughly 36 million buildings. Projects such as OSM-3D (www.osm-3d.de) already demonstrated, how OSM data can be utilized for visualizing urban areas, but it mainly focuses on visualization and not on semantics. If it is possible to create standardized 3D city models containing both geometric and semantic information, OSM and other crowdsourced geodata could be considered as a real alternative data source for diverse applications. This paper discusses how 3D models could be created from OSM and furthermore it investigates how the current data situation looks like (referring to buildings).

Session: Sensor Data Integration and Fusion

Title	The OpenEarth Framework and 3D data integration
Author(s)	Chaitan Baru
Session	Sensor Data Integration and Fusion
Affiliation	San Diego Supercomputer Center, UC San Diego
Abstract	

In an age where scientists and the general public have access to free software such as Google Earth that permit whole-Earth data visualization, the scientific community still struggles to fuse and visualize heterogeneous, multidimensional data products. At a time when raw data archives and derived products are growing rapidly, the pathways to integrate and visualize these data are limited. New approaches must be developed to maximize the utility of a broad range of community data products, and to enable intuitive data integration and visualization for research and education and outreach. One such effort is the OpenEarth Framework (OEF), initially developed as part of the Geosciences Network project (GEON, www.geongrid.org). Beyond supporting the myriad file formats, data types, and metadata associated with such data, a system like OEF also needs to explore the ability to scale to large data, for example, via data partitioning algorithms to tackle the underlying challenges of managing large individual and integrated data sets that exceed computer memory capacities. OEF provides a visual analytics environment. The goal of such environments is to provide users an interactive experience, as much as possible. We will discuss experiences with different data types including, for example, tomography, 3D orthophotography, high-resolution topography, and terrestrial laser scans.

Integration of 3D data has broad applications not only in the solid earth sciences but across a broad range of domains from surface and ground water hydrology, to petroleum reservoir characterization, urban modeling, emergency response, and the atmospheric sciences.

Title	Introduction to georeferenced managed objects and their potential for sensor data
Author(s)	Jan Kolar
Session	Sensor Data Integration and Fusion
Affiliation	Grifinor Project
Abstract	

This contribution is about experimental research on georeferenced managed objects that can provide possibly highly specialized data representations. These representations can be tailored for a very concrete type of data, information and actions related to the real world. Delivering data in a traditional way is also possible, but the main strength of the concept is that the specialization in data representation does not hamper technical interoperability. This is useful especially for large and highly heterogenous information systems, such as SDI for cities, countries or entire world. This talk will introduce how managed objects can allow for this flexibility in terms of data representation. How to empower data and information creators in devising new representation of any feature related to our planet, publishing the result, and how clients can instantly start using the content without changing the client's software.These properties of georeferenced managed objects have a great potential for being associated with broad variety of sensor data ranging from satellite data systematically covering entire globe to specialized in-situ data. Even individuals collecting data manually can use managed objects directly using simple user interfaces, because the design supports GUI, 3d visualization and time at many levels of resolution. Outlined concepts will be supported by an experimental implementation called GRIFIN. Several ideas will be given for merging various georeferenced data, being it from connected sensor devices, data from databases, Web services, or raw data, and turning it into a specific, accessible information.

Title	3D spatial data extraction for crowd sourcing and volunteered geographic information mapping of natural environments
Author(s)	Martin Rutzinger
Session	Sensor Data Integration and Fusion
Affiliation	Institute of Geography, University of Innsbruck, Austria

Abstract

The availability of spatial data has strongly increased in the last decade due to freely accessible remote sensing data, integration of sensors in user devices (e.g. Global Positioning Systems in mobile phones), and the development of online globes, mapping, and spatial data management platforms (e.g. Open Street Map). Spatial data description, collection and modification by users i.e. volunteers is increasing. This phenomenon has led to a "wikification" of geographical information, which is known as Crowd Sourcing and Volunteered Geographic Information (VGI). So far major user activities focus on urban area and infrastructure mapping such as adding streets and buildings and tagging locations such as restaurants and meeting points. However, there is increasing interest in using VGI describing natural phenomena and surfaces such as geomorphologic structures, water bodies, mapping of vegetation, and sighting sites of specific species of fauna. Current examples exist where VGI is used for biodiversity mapping, updating of land use and land cover maps, mapping of water extent, etc. We propose a concept integrating data derivatives, which were automatically extracted from existing 3D topographic LiDAR data, which was for example collected within research projects. The idea is to upload and collect 3D vector data such as extracted crevasses of glaciers, current glacier extent, geologic faults, erosion scraps, etc. Crowd sourced and volunteered mapped spatial data plays already significant role in many applications. VGI for mapping the natural environment will help to distribute new data sets among diverse scientific, public, and private user communities, which highly benefit by this kind of interaction, information and knowledge sharing.

Posters

Title	Improving the fitness for use of OpenStreetMap for planning tasks
Author(s)	Julian Hagenauer, Marco Helbich
Session	Poster
Affiliation	University of Heidelberg, Institute of Geography, Chair of GIScience

Abstract

One important task in spatial planning is to delimit urban regions. For this purpose actual and detailed data are needed. Volunteered geographic information (VGI) like OpenStreetMap (OSM) fulfills both aspects. Nevertheless, a limitation of crowd-sourced spatial data are their spatial data quality, in particular their completeness, which affects their fitness for use. The presentation proposes a methodological framework to delimit urban regions in Europe that are currently not mapped or only partially mapped in OSM. By predicting such areas, completeness of OSM can be enhanced considerably, and thus its fitness for use can be improved. For this purpose machine learning methods, i.e. artificial neural networks and genetic algorithms are applied. The resulting model estimates urban regions, under the premise of existing OSM data, comparably well. The model shows spatial heterogeneity of its performance across different European regions. These results indicate that the potential for improving the fitness for use is related to location. Finally, potential research areas are identified whereas VGI can enhance traditional data sources.

Title	Fusion of VGI and highly accurate laser scanning data for 3D city modeling
Author(s)	Andreas Jochem, Bernhard Höfle, Marcus Goetz
Session	Poster
Affiliation	University of Heidelberg, Institute of Geography, Chair of GIScience
Abstract	
In recent years Airborne Laser Scanning (ALS) has evolved as a standard technology for highly accurate three dimensional topographic mapping. These high quality and expensive sensor data is increasingly gaining importance in many research fields such as 3D city modeling. Besides remote sensing data collaborative Web 2.0 projects such as Open Street Map (OSM) aim at collecting and providing freely available user generated geographic data of e.g. streets and buildings. These data is less accurate but in general more up to date, meaning that there is a spatio-temporal shift between ALS data and Volunteered Geographic Information (VGI). However, both datasets have already been used for 3D city modeling. By fusing datasets from both worlds existing 3D city models can be improved and new methods can be developed updating both remote sensing and user generated geographic data. Furthermore, quality assessment of VGI in areas matching with ALS data is possible.	

Title	Combined 3D Acquisition of Inscriptions and Terrain of the Worms Medieval Jewish Cemetery ‚Heiliger Sand’
Author(s)	Susanne Krömker, Hubert Mara
Session	Poster
Affiliation	Interdisciplinary Center for Scientific Computing (IWR), University of Heidelberg
Abstract	
Inscriptions on medieval tombstones made from sandstone become extremely weathered leading to characters hardly visible and partly lost. Digitally capturing the geometric information is to preserve the today’s state and to analyze it with tailored algorithms. Simple light models can be used to simulate a neutral material without shadowing, and virtual light sources can be moved by the user making him independent from the once fixed setting up of a photographer. Additionally, curvature based analysis using Multi-Scale Integral Invariants (MSII) allows for enhancement of script and elimination of noise due to weathered surfaces. We will show exemplary results of the 30 most endangered tombstone acquired with a close-range 3D-scanner. An outlook is given concerning the embedding of high resolution scans in midrange area scans of the terrain, a big challenge for level-of-detail methods across several orders of magnitude.	

Title	DSMs validation and merging methods and procedures
Author(s)	Sara Lucca, Maria Antonia Brovelli
Session	Poster
Affiliation	Politecnico Di Milano Diiar, Polo Regionale Como, Faculty of Engineering
Abstract	
The work consists in two parts: in the former original DSM (Digital Surface Model) validation approaches are presented. The validation consists of different steps: an inner outlier detection computed by means of a command developed within GRASS (an open source and free GIS software); an external 3-dimensional bias detection computed by means of a MATLAB ad hoc developed software; the analysis of the DSM quality dependent on the slope and on the aspect (using a two way analysis of variance ANOVA) and on the terrain coverage using GRASS. The latter part of the work, still in progress, has as target the creation of a multi-resolution digital model rigorously obtained from the different DSM sources available. For such an aim, the statistical analysis and comparisons of the models to be merged is a pre-condition to define the optimal procedure. The DSMs taken into account as examples refer to a morphological complex area in the North of Italy (the region around the Como lake). They were obtained from different techniques: the SRTM (step of 90 m) from SAR, the ASTER (step of 30 m) from aerial photogrammetry and the Regione Lombardia DSM (step of 2m) from photogrammetry. The data used to validate these DSMs are GPS ground spread points taken with RTK surveying modality and the LiDAR filtered point cloud from which the DSM (step of 2m) was computed using GRASS GIS. Finally the terrain coverage considered is that obtained from the Regione Lombardia DUSAF land use database at scale 1:10000.	