Federal Pervasive Sensor Networks
Serving Geographic Information Services

Manfred Mittlboeck and Bernd Resch
Research Studio iSPACE, Research Studios Austria Forschungsgesellschaft mbH.
Salzburg, Austria
manfred.mittlboeck@researchstudio.at, bernd.resch@researchstudio.at

Abstract

Meanwhile sensors are a vital part of our everyday's lives. But due to the lack of standardizing their measurement output, its information can often not be fully leveraged. With the convergence of GIS and embedded technologies the context driven usage of spatial information anytime and anywhere is one of the major challenges in broad pervasive utilization of Geographic Information Systems (GIS). The purpose of this paper is to propose a solution for integrating federally organized mobile sensor networks into GI-software. The main contribution includes a prototype embedded device system architecture for federal organized sensor networks, software components (embedded web-services) serving standardized near real-time sensor information as well as connector components for GI-software to interface and analyze this information based on open standards. The mobile prototype infrastructure, which has been practically proven in several smaller research projects, will be fully implemented on a large scale case study in Bavaria including tests utilizing the GALILEO positioning signal and a project together with MIT.

Introduction

A major future challenge is the fusion, i.e. full integration, of real-time sensor measurement information, legacy GIS resources (data and services) and earth observation information in a 'live' geo-aware environment. This requires an appropriate supply of input information streams from both space and terrestrial observation systems. It will be necessary to identify effective ways for providing this data for fusion in a reliable way and with a guarantee of long-term continuity. The aim is also to support the future development of an appropriate European capacity in this context (Commission of the European Communities, 2008), coupled with a long-term perspective of sustainability as well as the integration feasibility into global system infrastructures like GEOSS (Global Earth Observation System of Systems – www.earthobservations.org).

Federated Standards-based Sensor Networks Using Embedded Technology

Together with these standardization initiatives, enhancements in communication technologies will enable a broad integration of real-time federally organized mobile sensor networks as part of a Europe-wide integrated information system. The goal is to provide people with measurement information facing environmental challenges like floods, forest fires, air quality, health effects, preserving ecosystems or biodiversity. Embedded computers serve specialized tasks exposing use case specific sensor data via Open Geospatial Consortium (OGC) conformant Sensor Observation (SOS) and Sensor Alerting Services (SAS).

In comparison to general purpose computers, embedded systems with their specific nature of functionality and their real-time behaviour – either hard real-time or soft real-time – are unique in comparison to existing personal computing platforms, where ubiquitous software has been developed from washing machines to network routers (Pothukuchi, 2005). The main characteristics of embedded systems is therefore their specific design to custom tasks, the integrated nature of the devices and the software infrastructure – adopted to the limited capabilities of the computer hardware resources.

Pervasive Computing and GIS

As Wright (Wright, 2002) already stated in 2002 the emergence of the internet changed the way in which we produce and view maps. Nearly every internet user is using location-enabled services with Google Earth and Microsoft Virtual Earth in a ‘pervasive’ way. We are changing from using static hardcopies to dynamic and interactive mapping technologies. To positively impact society on a large scale, the usage of geospatial technology is opened to a much broader community. Therefore there is the need to use most accurate, complete and recent information layers as well as putting effort into increasing usability of web-mapping and geographic analysis and processing techniques.

Besides all these technological capabilities with pervasive computing we also have to consider social impacts on using ubiquitous spatial information. Friend Finder applications and geo-tagged community portals like Geo-Twitter are very popular on the internet. On the other hand people are concerned about privacy issues especially when dealing with personalized spatially aware information.

Implementing Standardized Embedded Sensor Services

The OGC Sensor Web Enablement (OGC SWE) initiative is an assembly of standards providing for a broad and easy discovery, accessibility and controllability of different sensor types in a standardized way over the internet. As a new approach for supporting ubiquitous location-aware embedded computers the Research Studio iSPACE designed a system concept to serve the OGC SWE needs interfacing sensor data through federated mobile embedded web services.

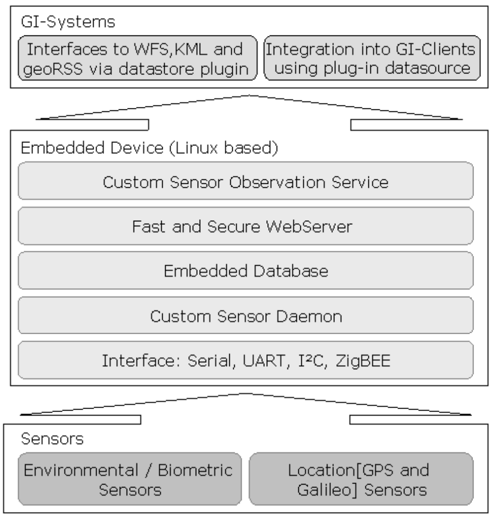
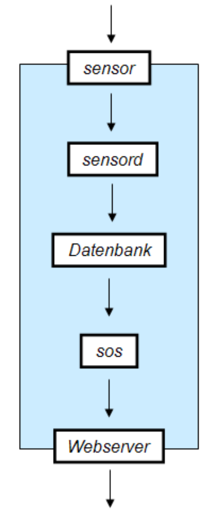


Figure 1: Components: (a) Sensor, (b) Embedded Device and (c) GIS-Client System for Serving and Consuming OGC SOS Standardized Measurement Information.

A prototype framework based on this conceptual architecture has been developed to provide standardized real-time measurement information using our own developed small footprint (C programming language) OGC SOS 1.0 and OGC SAS 1.0 compliant web services on an ARM7-based GPS enabled tiny computer. It consists of the following elements:

Table 1: Prototype Framework Used for the iSPACE OGC SOS and SAS 1.0 Services.

• Environmental sensors measuring humidity, temperature, pressure, CO, NOx, SOx, as well as biometric sensors measuring pulse, blood pressure and oxygen saturation • Fixed, and mobile positioning using GPS and DGPS over IP {NTRIP} • Standardized sensor-daemon services listening on serial, UART, I²C and ZigBEE interfaces for gathering measurement information • Embedded database SQLite for organizing and exposing measurement information from environmental sensors • Custom small footprint OGC SOS 1.0 compliant web service providing measurement information via the standardized Sensor Observation Service interface. • Custom small footprint OGC SAS 1.0 compliant web service • Embedded secure web server (HTTP/HTTPS) • Embedded Jabber Server (XMPP) • Mobile Web Access through UMTS/HSDPA with static IP-adress	

Our prototype implementation is based on the free open source embedded operating system ‘OpenEmbedded’, a very small footprint Linux OS for tiny computers. To reduce power consumption, memory and computing costs the usage of C and C++ programming languages proved most effective. Equipped with a web and XMPP server in our case these computers deliver standardized sensor measurements via various kinds of wireless services (WLAN and GPRS/UMTS/HSDPA) to ensure maximum connectivity and mobility.

Using a partnership with the Austrian railways infrastructure unit (OEBB) we integrated NTRIP (Network Transport of RTCM via internet) differential RTCM GPS correction information to perform near real-time using the DGPSD library. This method increases GPS-inaccuracy from 10-15 meters to 1-2 meters. Together with live access to a mobile embedded device via UMTS/HSDPA (static IP address provided by Austrian mobile communications network provider ‘Drei’) an interpolated temperature map from Salzburg has been created using three different mobile sensors mounted on cars to get as many sample points as possible throughout the city. The usage of mobile sensors in comparison to a vast amount of stationary sensors helps reducing the costs tremendously, especially when using expensive sensor measurement equipment.


Figure 2: Embedded Device (l.) and UMTS Modem (r.).

To ensure compatibility with a wide range of established GIS software products, a generic datastore plug-in for open source GeoServer has been developed to enable on-the-fly transformation of OGC SOS into more common and established standardized interfaces such as OGC Web Feature Service (WFS), OGC Web Map Service (WMS) using Styled Layer Descriptors and Google’s KML. The geoRSS Interface can be used to feed various applications in as specified time interval to automatically update clients. This converter guarantees easy integration into a broad set of COTS and open source GI software products. Furthermore, this datastore plug-in serves as a data fusion engine by homogenizing a variety of different sensor measurements. In other words, various sensor data sources are harmonised by fusion processes like CRS reprojection, measurement unit conversion or time zone normalization. Apart from making data from several sensor networks available over a single interface, this mechanism offers the convenience of performing a number of data pre-processing operations in an automated way. Generally speaking, the forceful usage of open standards for resources and protocols guarantees the ease of interchanging and processing near real-time sensor observations with generic GI - systems.

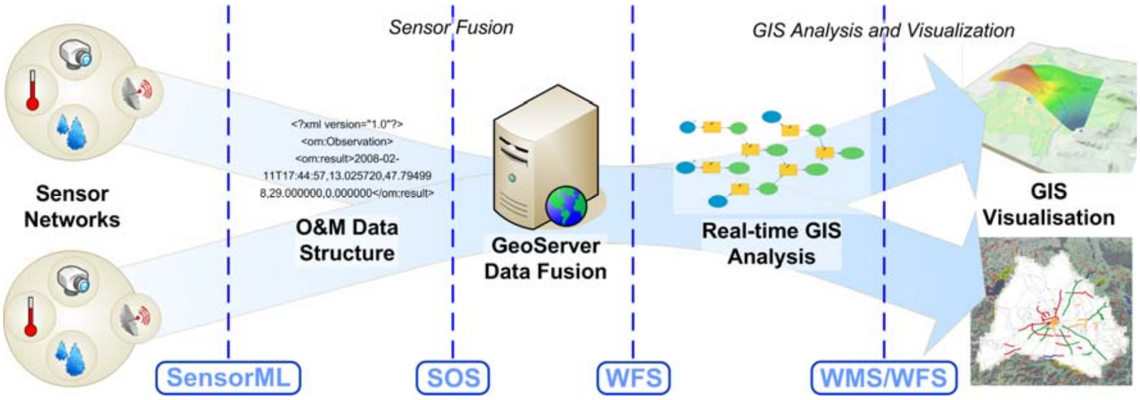


Figure 3: Workflow for Real-time Data Integration and Analysis.

For ESRI’s ArcGIS products, a plug-in has been developed to incorporate this information as ‘live’ standard geographic feature class for further spatio-temporal modelling and analysis. Users can treat these real-time measurements like any other shape file, feature class or other spatial dataset. This tight integration empowers ArcGIS clients to perform ‘live’ analysis like Inverse Distance Weighting (IDW), Kriging and Co-Kriging interpolations on real-time measurements. Because of the establishment of an easy to use spatio-temporal data-model these sensor data can also be leveraged by ESRI’s spatio-temporal Tracking Analyst.
The system utilizes the Extensible Messaging and Presence Protocol (XMPP) to perform near real-time instant messaging for standardized alerting (OGC SAS 1.0). These alerts are incorporated into ArcGIS Clients using Dynamic Display Technology to update moving features on a map on-the-fly without reloading the whole data frame.

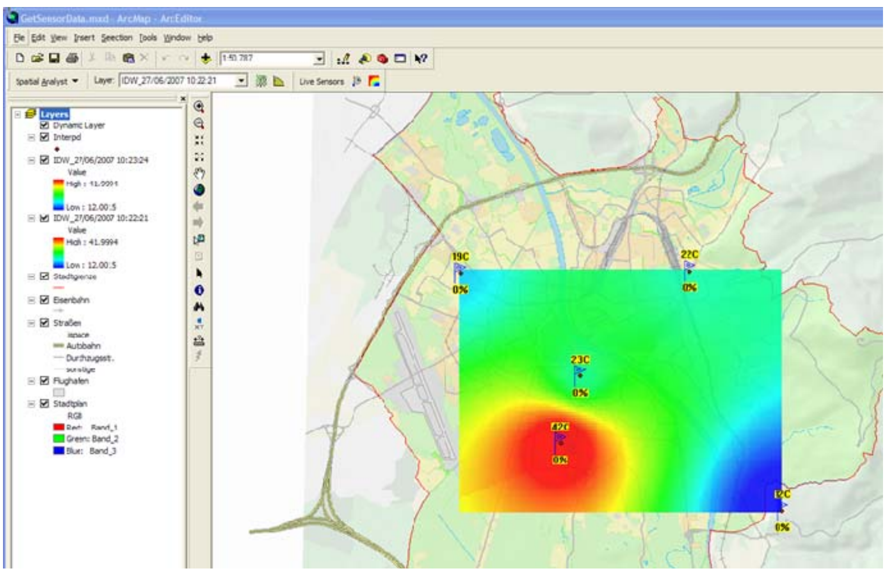


Figure 4: ArcGIS Environment Showing Interpolation Map and ‘live’ Measurements.

Additionally, an interactive web mapping and diagram visualization client based on Microsoft's Silverlight 2.0 technology has been developed with students (Lippautz, 2008) together with Salzburg University of Applied Sciences, study programme Information Technology and Systems Management, to view the real-time measurements in 2D and 3D MS Virtual Earth.

Conclusion

Sensors are increasingly integrated into our everyday's lives. Establishing a federal standardized communication framework opens up new possibilities and application domains by implicating the organization of information – using spatio-temporal parameters. The integration of near real-time sensor measurements in GI-analysis as additional information layer considerably increases GI-analysis quality and boosts GI service-oriented processing architectures.

Due to the fast growing number of sensors we chose to prototype pervasive computing technology to integrate as many sensors as possible into a global federal standardized measuring network feeding GI-software and services. This federated infrastructure concept serves the need for ready access to data for near real-time server-based GI-analysis, web mapping and mobile GIS.

The next step of the implementation will comprise the integration of event processing capabilities. Complex Event Processing (CEP) and Event Stream Processing (ESP) capabilities enhanced with geographic organization capabilities will be added to the system, using emerging open standards from the OGC SWE family. This will not only allow better organization for push-based alerting, but also for preventive error detection and data pre-processing (spatial and temporal averaging, filtering, pattern recognition etc.). Furthermore, this enhancement leads the way to a whole new GI processing infrastructure paradigm by connecting event-based sensor fusion mechanisms with automated server-based GIS analysis methods.

First large-scale implementations of the described infrastructure will be deployed in testbeds in Bavaria, Germany in 2009 serving first-rescue units, and in the city of Cambridge, MA together with MIT and the city government, where the main goal is to provide an extensible and reliable system to perform long-term environmental health impact studies in the urban context supported by the city management.

References

Commission of the European Communities (2008). *Towards a Shared Environmental Information System (SEIS)*. Online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0046:FIN:EN:PDF, Brussels. (August 27, 2008)

Chen, F., Yang, C., Yu, W. and Cheng, Q. (2004). *Research on Embedded GIS Based on Wireless Networks*. IN: Proceedings of the 2004 IEEE International Geoscience and Remote Sensing Symposium, IGARSS '04, Beijing, 20-24 September 2004.

Lewis, F. (2004). *Wireless Sensor Networks*. In Cook D.J. and S. K. Das (eds.) Smart Environments: Technologies, Protocols, and Applications, John Wiley, New York, 432 pages, ISBN: 978-0-471-54448-7.

Lippautz, M., Kohlmann, M., Sternig, C., Piralli, I., Rauchenschwandtner, R., Haber, P. and Kranzer, S. (in press). *geoHealth Monitoring – Real-Time Monitoring for Action Forces During*

Disaster Operations. 5th International Symposium on LBS and Telecartography. November 26-28, 2008, Salzburg, Austria.

Mittlboeck, M. and Resch, B. (2008). *Standardisierte Integration von Real-time Sensormessungen für Zeitnahe GIS-Analyse*. IN: Strobl, J., Blaschke, T., Griesebner, G. (eds.) Angewandte Geoinformatik 2008, Wichmann Verlag, Heidelberg, 112-117.

Pothukuchi, S. (2005). *Embedded GIS*. Online: http://www.mapindia.org/ 2005/papers/pdf/121.pdf, Hyderabad. (August 31, 2008)

Resch, B., Mittlboeck, M., Girardin, F. and Britter, R. (in press). *Real-time Geo-awareness - Sensor Data Integration for Environmental Monitoring in the City*. IN: Proceedings of the IEEE-IARIA International Conference on Advanced Geographic Information Systems & Web Services – GEOWS2009, 1-7 February 2009, Cancun, Mexico, pages pending.

Resch, B., Calabrese, F., Ratti, C. and Biderman, A. (2008). *An Approach Towards a Real-time Data Exchange Platform System Architecture*. Sixth Annual IEEE International Conference on Pervasive Computing and Communications, Hong Kong, 17-21 March 2008. Hong Kong.

Wright, D. (2002). *Pervasive Computing*. UCGIS. Online: http://www.ucgis.org/ priorities/research/2002researchPDF/shortterm/q_pervasive_computing.pdf, Oregon. (September 9, 2008)