GEOSS AND THE SENSOR WEB

GEOSS Sensor Web Workshop Report

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4th GEOSS Sensor Web Workshop Report

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Abstract

On February 11, 2010, the Group on Earth Observation (GEO) Sensor Web community convened at the 4th GEOSS Sensor Web Workshop in Sydney, Australia. This was the fourth workshop of the Sensor Web workshop series following the events of: 2007 in South Africa, 2008 in Switzerland and 2009 in Japan. The workshop took place in conjunction with the APAN 2010 conference , hosted by Australia's Academic and Research network (AARNet). The workshop was jointly organized by the GEO task AR-09-02c, led by the Meraka Institute in South Africa and greatly supported by the GEO Secretariat, Japan's National Agriculture and Food Research Organization (NARO), and Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Sydney Opera House

transformed into a Canvas

by artist Brian Eno

The goal of the workshop was to discuss current activities, new and future concepts, missing bits and pieces, new approaches and the next steps for the GEO task AR-09-02c in the context of Sensor Web. This report provides an annotated in-depth summary of the workshop's discussions and results and provides extensive background information.

Introduction

The Global Earth Observing System of Systems (GEOSS) has the objective to continuously monitor the state of the earth in order to increase knowledge and understanding of our planet and its processes. Being a system of systems, GEOSS has to master the challenge of integrating heterogeneous systems across institutional and political boundaries. Timely delivery of earth observation data is a key aspect in identifying potential natural and human threats, such as tornados, tsunamis, wild fires, or algae blooms.

The Sensor Web: An active Sensing Macro Instrument.

Data from in-situ or remote sensing devices form the basis for analyzing gradual processes, such as increasing drought, water shortages, or rising sea levels. The Sensor Web [3] presents a paradigm in which the Internet is evolving into an active sensing macro instrument. Based on internationally adopted standards, the Sensor Web accomplishes the necessary requirements to ensure interoperability among its various components. Sensor Web software components and services work interactively in arbitrary application domains.

The aim of the Sensor Web Workshop was to discuss sensor service discovery and binding mechanisms, combination of observations and measurements with different time-series encodings, embedding of workflow execution capability into the Sensor Web. We discussed the various approaches, applications, and technologies used within sensor networks and exchanged experiences of sensor networks, sensor data and Sensor Web applications in the context of GEOSS.

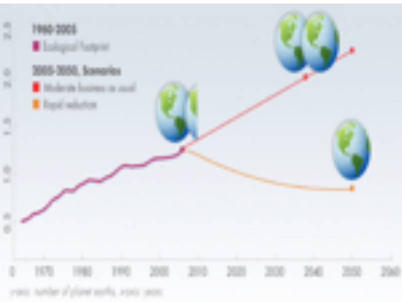
Sensor Webs for an Environment-Friendly Future

The workshop started with an introduction of the current situation in sensor networks standardization and research and their potential to support an environmental sustainable development in energy consumption and usage.The discussion was inspired by the SMART 2020 report[1], which states that "*ICT* [(Information Communication Technology)] *has systematically increased productivity and supported economic growth across both developed and developing countries*", but raises some tough questions about the impact of ICT on global warming and its role in our fight against dangerous climate change.

The report states that the global ICT-enabled CO_2 abatements from PCs, telecom networks and devices and data centers will grow from 0.53 Gt (corresponding to 530,000,000,000 kg) in the year 2002 and 0.83 Gt in the year 2007 to approximately 1.43 Gt in the year 2020. This pure consumption/emission is balanced by a potential save of 7.8 Gt CO_2e (CO_2 emissions) in 2020, which is 15% of the global emissions by that date. The report identifies four areas as having the biggest potential to reduce CO_2 abatements: Smart logistics, smart motors and produc-

[1] http://www.theclimategroup.org

tion processes, smart buildings, and smart power grids. Common to all of those four areas is the fact that sensors and standardization play a major role. Sensors monitor and survey the current situation, control and task actuators to react to given observations, and distribute notifications. Standardization is required to develop protocols and interfaces to enable proper communication and a high level of interoperability between components and systems. As an example, smart buildings control energy consumption autonomously; where sensor readings are used to control lighting and heating, ventilation and air conditioning. The potential savings by smart buildings, summing up to 1.68 Gt of CO_2e, could be higher than the overall ICT-enabled abatements in 2020 (1.43 Gt CO_2e).



Unsustainable Trends (footprintnetwork.org)

Smart2020 (theclimategroup.org)

Smart Opportunities

The discussion during the workshop centered on the great potential of interacting sensor systems. One of the problems is scale; there is a minimum requirement in terms of online and available sensors and system interfaces to open the ground for massive savings (in multiple ways, i.e. costs, energy consumption and corresponding CO_2 abatements, etc.). GEOSS can be seen as a global test bed for preparing guidelines and policies as well as architectural approaches and technical specifications in order to enable future interacting systems. Once again, it became clear that sensor (and actuator) manufacturers need to get involved in the process. The current situation, where sensor metadata and sensor observation standards are developed by software companies and research institutions without much support of the hardware industry is likely to be far less effective compared to an integrated approach. Still, the incentives for the hardware industry, where stove-piped product lines are often essential part of the business model, need to be further investigated and developed. It is likely that this cannot be done without the support of politicians and policy makers, as the SMART2020 report raises the point in terms of global climate change: "*The ICT sector can't act in isolation if it is to seize its opportunity to tackle climate change. It will need the help of governments and other industries. Smart implementation of ICTs will require policy support including standards implementation, secure communication of information within and between sectors and financing for research and pilot projects.*"

W3C Semantic Sensor Networks Group

The W3C Semantic Sensor Networks Group (W3C SSN XG, see http://www.w3.org/2005/Incubator/ssn/wiki/Main_Page) has the mission to “to begin the formal process of producing ontologies that define the capabilities of sensors and sensor networks, and to develop semantic annotations of a key language used by services based sensor networks”. Driven by the basic idea to combine Semantic Web and ontology engineering expertise from W3C with geospatial and Sensor Web standards expertise from OGC, the group performed an in-depth survey of available approaches and technologies. In fact, the motivation to form this group grew when the first GEOSS Sensor Web workshop report, which was published in 2008 and reads “A big issue is the lack of semantically rich discovery mechanisms in SWE services based infrastructures. Search algorithms facilitating semantically enhanced queries from users would be of great benefit for retrieving useful information out of Sensor Web registries and services. At the moment, related concepts, subgroups of sensor types, or other dependencies can hardly be explored. Eventually, the integration of domain ontologies [...], semantic queries and semantic transformations in Sensor Web infrastructures have to be addressed.” [11].

Ontology Art [15]

Ontology Art [16]

Ontology Art [17]

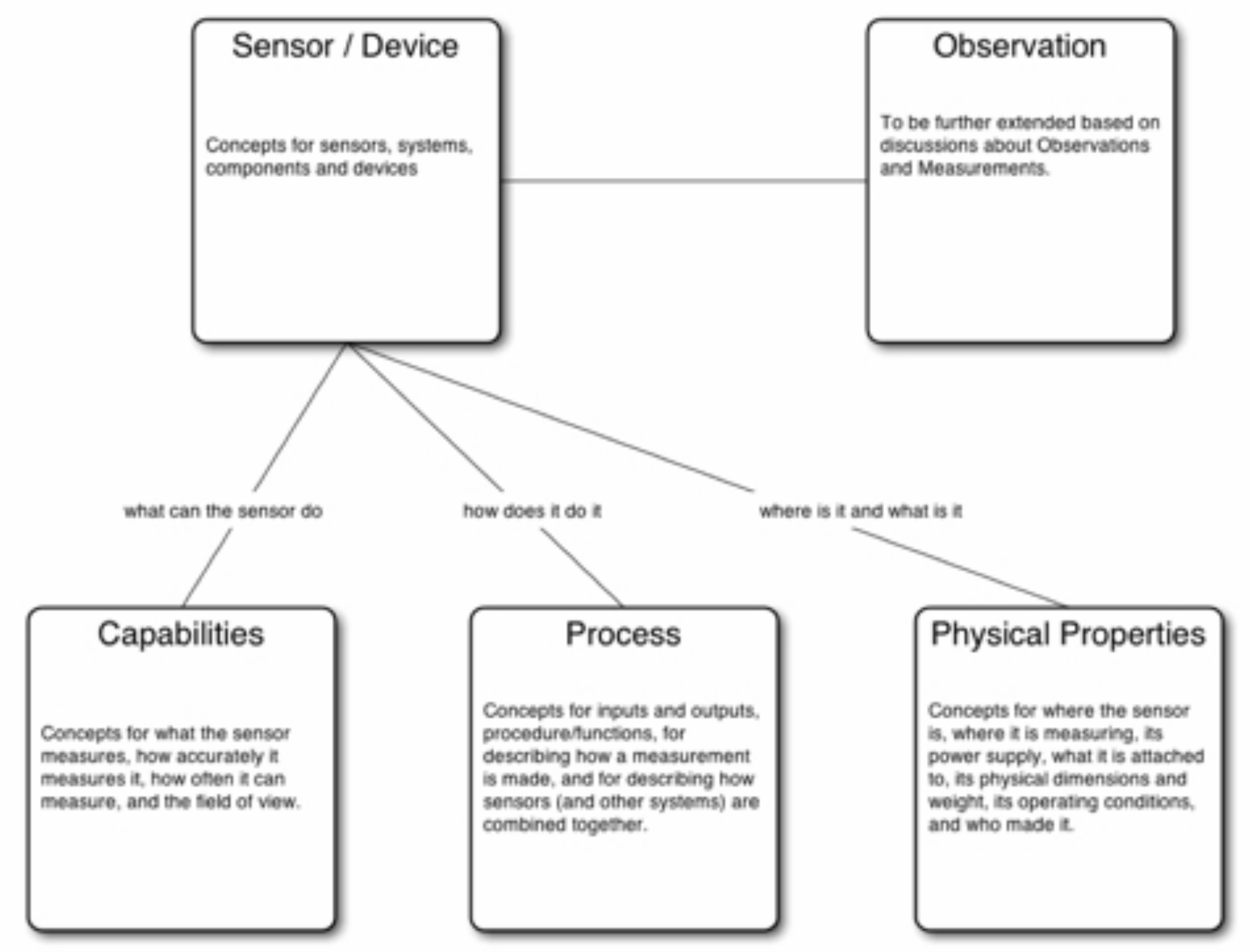
One of the objectives of the Incubator Group is to formally produce ontologies that define the capabilities of sensors and sensor networks. In contrast to existing technologies for modeling information realms that often apply a closed world assumption; the group used OWL for the logically sound formalization of sensor and sensor network capabilities applying open world assumption principles. Prior to the ontology development, a set of use cases was defined to define the scope of work (as well as those aspects that are out of scope). The use cases mainly addressed the aspects of data and device discovery and the capturing of provenance and diagnostic information. During this phase, it became obvious that the range from individual single (miniature) sensors to complex sensor networks is extremely wide and can hardly be captured in a first attempt. Thus, some of the use cases address individual sensors, where others include sensor networks at least partially.

One issue the group has to cope with is the motivation of group members for participation. Most members are participating in international R&D projects such as MMI OntDev/IOOS

[12], SemSorGrid4Env [13], SENSEI [14] and follow their own schedule and priorities, which often results in parallel and duplicated work. It is a general tendency particularly observed in R&D projects co-funded by the European Commission as part of the sixth or seventh framework program that the projects present finalized work that was developed internally rather than joining external standardization efforts at an early stage and align their own developments with the target group.

In parallel to the use case development, the incubator group did a survey of existing material and approaches and had experienced serious difficulties to find a common language because of the lack of textual descriptions in all the reviewed ontologies.

The recent status is illustrated in the following figure. The main elements system, device, process, sensing, and observation are defined.



Ontology Main Elements

A system is a unit of abstraction for pieces of infrastructure. A system has components, which are other systems. The other core elements are defined as follows:

- A **device** is a physical piece of technology - a system in a box.
- A **process** has an output and possibly inputs and, for a composite process, describes the temporal and dataflow dependencies and relationships amongst its parts.
- **Sensing** is a process that results in the estimation (or calculation) of the value of a phenomenon.
- An **observation** is the record of some sensing
- There are some things that can do sensing and thus make observations.
- Some devices can do sensing

A second major work item addresses the development of semantic annotations for services based sensor networks. A semantic annotation is a web annotation which adds information to a web resource that is described in an ontology. According to Wikipedia: [...] [a semantic annotation is] an addition made to information in a book, document, online record, video, or other information. The SAWSDL definition is more adapted to the current XML-fashioned approach in the Sensor Web, as it reads "mechanisms by which concepts from the semantic models [...] can be referenced from within it (and XML Schema sub- components) using annotations."

Here, two types of annotations are differentiated: The first type of annotation as "composition by inclusion of remote resources" using semantic anchors to externally managed data; and the second type of annotation as "model reference to an ontological description" that follows known approaches such as SAWSDL or hREST to "lift" a XML service into a RDF service or using RDFa type of annotations to export a subpart of a data file as RDF. Both approaches need to integrate/harmonize with OGC standards such as SensorML, Observation & Measurement or the GetCapabilities calls of the various OGC SWE service interfaces. OGC currently makes intensive use of the XLink and URN technologies to point to external resources. Unfortunately, the usage of XLink is not consistent within OGC specifications (examples are the usage of *arcrole* and *role* attributes in XLinks). The usage of URNs is somewhat ambiguous as well, as URNs are used to point to an individual, a class or a property with no distinction either way. As a number of OGC users are currently investigating SKOS technologies ("*SKOS is an area of work developing specifications and standards to support the use of knowledge organization systems (KOS) such as thesauri, classification schemes, subject heading lists and taxonomies within the framework of the Semantic Web*" [18]), a smooth migration path from the current mixture of XLink and href technologies in OGC towards a more robust approach based on RDF or SWASDL needs to be defined.

Before concrete recommendations to OGC will be done, the strengths and weaknesses of the aforementioned technologies SAWSDL/hREST and RDFa will be analyzed in further detail, as there is the inherent risk of confusing various communities rather than setting a standard that gets well adopted.

In summary, the incubator group works hard to get a better understanding of the expectations of the various communities of practice and tries to understand the scope of the standards to be built. In order to achieve acceptance by the potential user communities, it is crucial that the semi-formal ontology building process is well defined and comes with sufficient documentation of the ontologies production process. This includes clear explanations on how and why prior work has been used or ignored, including resources which are not ontologies. Regarding the identification of Semantic Markup requirements, the OGC community needs to get involved in the ongoing discussions to allow upgrading of current practices. One somewhat prominent opportunity is represented by the RESTful OGC services. As the development of RESTful services is a young discipline in OGC, there is a good opportunity to extend existing practices with advanced semantic service annotations without arguing against established setups and traditions.

Development of Application Profiles of O&M

The development of application profiles for O&M is making slow but steady progress. We discussed a very advanced approach currently under development in the hydrology domain. As we observe a number of existing standards for hydrological information, the question arose as to why we would develop yet another approach. In fact, none of the existing standards are compatible or particularly re-usable outside their current domain. There is a huge potential for harmonization that would result in better re-use of tools, minimization of load on organizations to develop their own standards, and better interoperability between domains.

Photo by CSIRO [19]

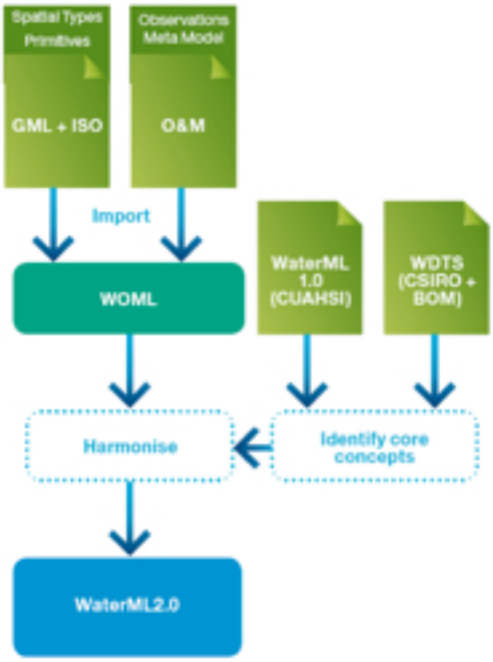
Photo by NASA [20]

Photo by Joel [21]

The hydrology domain exhibits a number of different sampling techniques for typical observed properties such as water level, water temperature, discharge, sediments, water quality, etc. The variety in sampling techniques, including such fundamental differences as in-situ and remote sensing or laboratory analysis, the tradition of the various institutions as well as programmatic and legal criteria led to a variety of result types, formats, encodings, and information models. There are a number of standards trying to bring some interoperability between systems, with the most prominent and widely used being WaterML 1.0 (USA), WDTF (Australia), Xhydro (Germany), the UK Environmental Agencies time series transfer format, the French water information system and others. Though a lot of commonalities exist between these standards, we still see large duplication of effort leading to inconsistencies across them and resulting in difficulties around re-usable tools. In summary, there is a huge potential for a harmonized, reusable information models with well-defined common semantics of concepts. The report on "Harmonising standards for water observation data" was published as a first result as an OGC discussion paper in 2009 [22].

In order to improve future standardization in the hydrology domain, the usage of well established generic base information models shall be used. The next generation of information exchange schemas therefore shall be based on the OGC standard Observation & Measurement (O&M). O&M appears to be the emerging best practice, used by the Integrated Ocean Observing System (IOOS) [23], the Climate Science Markup Language (CSML) [24], the Global Runoff Data Centre's (GRDC)[25] meta data profile and is submitted to ISO (as document ISO19156)[26]. O&M provides generic descriptions of the abstract components that are needed when making any type of observation. Applied here, it describes the relationship between the procedure making the observation (e.g. sensor), the phenomenon being observed (e.g. river level), the real world feature being observed (e.g. a specific river), and the result (e.g. a time series of level measurements).

The methodology to develop the new standard called WaterML version 2.0, foresees an integrated approach that merges existing technologies with generic base models, as illustrated in the figure below.



WaterML 2.0 development methodology

There are many reason to make use of O&M in the development of WaterML2.0. Current experiences have shown that O&M supports observations from multiple domains, which implies that naming is generic, types are non-restrictive, however tool support is difficult. Thus, O&M gives you a generic and robust base, but developing with O&M isn't easy, as tool support is quite restricted at the moment. The development of WaterML2.0 is an open development process. If you interested in joining this community, please send an email to peter.taylor@csir.au. There are currently representatives from Australia, United States, Canada, Germany, France, and UK, but in particular representatives from the Asia-Pacific region are missing.

Provenance & Trusting the Sensor Web

When working in the Sensor Web, it is a given that almost all data sources are owned by someone else, which leads directly to the questions: How can we trust the data? Is it suitable to our needs? Does it meet quality requirements? Who has worked on the data? What generated the data? Has it been processed?

An emerging branch of Sensor Web research deals with provenance issues. Provenance describes the origin or source of data. It should track what happens to data as it flows through systems or the web and assists us to reproduce calculations, inferences, forecasts etc.

Almost everybody, but in particular scientists, analysts, and reporters have an aversion to data that they do not own or control directly; trust needs to be established if higher level information from Sensor Web data shall be produced and reused.

A simple example underpins the importance of provenance. Let's assume that meteorological data is retrieved from sensor A, which is owned by organization A. The current river level information is retrieved from sensor B, which is owned by organization B. The weather forecasts are provided by the local Weather Bureau (i.e. organization C). Now all data sources are incorporated into a rainfall run off model that feeds a river routing model. The model has been calibrated using a range of historical readings as well as a spatially interpolated rainfall grid. This used a particular interpolation algorithm that made certain assumptions. The entire workflow is complicated and based on many assumptions made at various levels of the information flow. Thus, how can trust in the model be generated with such a large number of variables and processing steps?

First approaches currently experiment with provenance information stored in catalogs. The results are still outstanding, but it can easily be anticipated that this field of research will become more and more important as the underlying technologies are established. For now, it is still early stages with a large amount of potential for new research.

Collaboration with Sensor Web R&D projects

A number of R&D projects co-funded by the European Commission have supported this task in the past, with the Sensors Anywhere (SANY)[27] being the most prominent. These projects have mainly focused on research of software architecture and information modeling.

Recently, we saw a shift in the calls published by the European Commission. The calls move away from mainly research oriented projects towards more application oriented projects. The application of Sensor Web techniques and approaches to different domains is now the focus of investigation. This includes profiling of generic models and service interfaces. Two of the best examples are EO2HEAVEN [28] and ESS [29].

The "Earth Observation and Environmental Modelling for the Mitigation of Health Risks " - EO2HEAVEN project will develop a Spatial Information Infrastructure (SII) and associated processing services able to correlate environmental and health time series data. As a result, researchers and epidemiologists in particular will be able to investigate the environmental factors that are causing diseases and on the other hand authorities will be provided with an early warning system. The "Emergency Support System" - ESS project is a project supported by the European Commission / DG Enterprise in frame of the Security Theme 10 of the E.C. Framework Programme seven. The objective of the ESS is to develop a suite of real-time data-centric technologies aiming to provide actionable information to crisis managers during abnormal events. This information will enable improved control and management, resulting in real time synchronization between forces on the ground (police, rescue teams, fire fighters) and out-of-the-theatre command and control centers (C&C).

Another candidate that goes in the same direction is the Generic European Sustainable Information Space for environment - GENESIS project [30]. The GENESIS project addresses three core aims for advancing the OGC Sensor Web Enablement architecture. Firstly, GENESIS has and is contributing to the topic of discovery mechanisms within the SWE framework. Besides and approach for metadata harvesting from SWE services, a mapping between the SensorML metadata model and the ebRIM Catalogue information model has been developed. Secondly, GENESIS has put significant efforts on advancing event based SWE services (based on the OGC Sensor Event Service Discussion Paper). Finally, GENESIS has also investigated the use of OGC SWE components for handling human observations.

Sensor Web Projects

A number of Sensor Web projects have been presented highlighting various aspects of Sensor Web research and applications. The mountain flight route monitoring and the operations of field sensors will be shortly described to get a better understanding of the applicability of Sensor Web concepts and technologies.

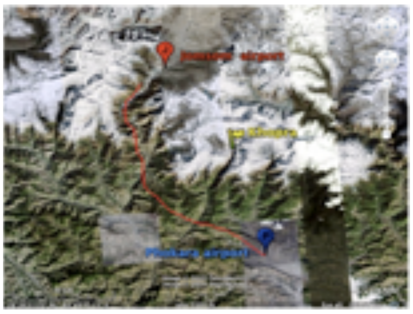
Nepal Air Route Monitoring

Sensor Web Technologies have been very successfully applied to improve mountain flight route monitoring in the Himalaya (Nepal).

Aviation weather is one of the most significant factors for transportation modes because it affects flight operations. The adverse weather conditions affecting aviation include turbulences, low clouds and thunderstorms. It is clear that the most adverse weather conditions are turbulences, wind and precipitation respectively. These conditions can disturb flight operation and fluctuate with topography and elevation. Nepal's weather conditions range from tropical to arctic/high mountainous conditions. The low-land Terai region with its maximum altitude of approximately 305m lies in the tropical southern part of the country. It has a hot and humid climate with maximum temperatures above 45° Celsius (113 degrees Fahrenheit) in summer. Whereas the mid-land regions are pleasant almost all the year round, the northern mountain region with an altitude of around 3,300m and above has an alpine climate with extreme low temperatures and high wind speeds that can affect flight operation considerably. The topography of Nepal with steep mountains and narrow valleys makes flight operations even more vulnerable, as weather conditions may change even on short routes.

Against the adverse weather conditions with low clouds, high wind speed and low temperatures along the flight routes, air traffic is in operation almost all year round. In the past, a number of flights have been canceled or requested to return to origin due to unknown weather conditions along the flight routes.

Monitoring Station, clear day



Flightpath between Jomsom and Phokara

Jomsom Airport, elevation 2700m

Therefore, the objectives of the Nepal Air Route Monitoring project [31] are to:

1. Set up a weather and image sensor node at one site along the flight course (to provide real time weather information of the flight path)
2. Develop a web application to visualize sensor data for the flight controller
3. Evaluate the effectiveness of the system on flight operation

The Air Route between Pokhara and Jomsom airports was selected as the study area. The weather observation station (so called field server) was set up in Myagdi district, Nepal (at 28°28′12.42″North and 83°42′38.75″East at 3,605 meters (11811 feet) altitude). The autonomous station is equipped with a Vaisala WXT 520 weather station, a Panasonic BB-HCM581 PTZ network camera with waterproof housing, and a Northtec Microclient Sr. A Linux Box configured to work as a Sensor Observation Server, a stable power supply (fully solar based and battery backed-up) and Local Area Network (LAN) infrastructure has been deployed for data processing and communication.

Mosaic of images to better understand cloud and visibility situation in the valley

The most important information comes from the camera, which provides high quality information about cloud coverage and visibility in the valley that is used in pre-flight decision making. As all information is continuously available using Sensor Web technologies, flight management has improved significantly with the Nepal Air Route Monitoring project. During the first six months of operation, the system was available 87% of the time. Downtimes have been caused by network issues, lack of power, or human errors in operating the station. Overall, the Sensor Web-based system has fundamentally improved preflight decision making. Instead of guessing and past experience, the decision to start or postpone flights is now based on actual wind speed and direction, precipitation, barometric pressure, relative humidity, temperature and most importantly visibility and cloud coverage and altitude information. For further information on the project, please contact Kiyoshi Honda at honda@ait.ac.th.

FIELD SENSOR IN HYDERABAD

Supported under the "Strategic International Cooperative Program" of the Japan Science and Technology Agency, the "Geo-ICT and Sensor Network based Decision Support Systems in Agriculture and Environment Assessment" project between India and Japan has deployed two generations of field sensors in Hyderabad, India. The Field Server technology is currently developed by the Japanese National Agriculture and Food Research Organization (NARO). The Field Server is a solar powered observation and processing device that is intensively used in Asia for e.g. rice field monitoring. Though not fully standards compliant yet, it makes intensive use of Sensor Web protocols and encodings. Field Servers can be connected to the Internet by a variety of network protocols and technologies, such as WLAN, GSM, or UMTS. The focus in current research is on reducing the costs per device. The goal is to get the costs below US 1000$ including the housing, various sensors, solar powering, processing board, and communication components. To achieve this goal and to reduce maintenance costs, a field server has kit is under development using modular components that can easily fit together and exchanged.

Field Server Kit

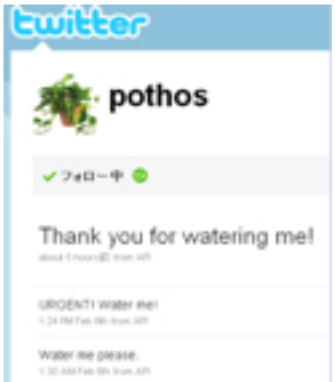
Field Server installation in Hyderabad, India

Field Server installations

Field Servers can be used in various modes. Based on their different communication components, Field Servers can act as observation stations to observe the environment (microclimate, insects, plants, viruses, etc.), Wi-Fi access points routing into the Internet, as data storages, or as relay stations in a Field Server network. The modular construction allows one to configure each Field Server for its own concrete purpose.

Experiences during the first years of operation have shown a stable and valuable set up, that is used more and more used on a global scale. Though the Field Server itself has developed in the last two years into a very rugged device, current technological challenges include connectivity among routers in remote areas, the electric power supply for routers, the stability of the internal PCs and commercial soil moisture sensors. As the devices are deployed mostly on agricultural sites, Field Server technology has to be easy to set up and maintain. Currently, the configuration settings in the rough outdoor environments, the set up of local IP addresses in conjunction with virtual private networks (VPN), as well as robustness against interference on any physical layer needs to be improved. In addition, a reliable ultra-slow-baud-rate communication technology for ultra-low power radios has still to be developed as well as a stable, easy to use and universal Internet protocol technology. Experiences so far have shown that IPv6 is not the solution. Against all odds, Field Servers are likely to be mass produced in the near future.

On the software side, new approaches have been successfully tested to optimize the usability of remote low-power devices. This includes Twitter [32] and Pachube [33] as de facto storage for sensor data and communication. Whereas Twitter is used to send announcements, Pachube is used to store, share & discover realtime sensor and environment data from Field Servers around the world. Plants will then request water - and don't need to wait for a dedicated mind to grab the watering can. For more information on Field Server technology and development, please contact Masayuki Hirafuji at hirafuji@affrc.go.jp.



Twitter feed of a plant

GEO Task AR-09-02c Future Activities

Future activities were discussed towards the end of the workshop. In summary, it was decided to continue the work shop series and to stay in close contact to improve the set up of internet-connected sensor devices and networks. It was decided to further contribute to the OGC Sensor Web Enablement group in order to enhance interoperability across institutions, domains, and juridical boarders as well as to the Semantic Sensor Network Incubator Group in W3C. The general objective is to align the activities of both groups in order to have an even semantically correct Sensor Web.

Next Workshop

The next Sensor Workshop is tentatively scheduled to will probably take place in March/May of 2011. The location has not yet been decided. If you would like to host the workshop, just drop me an email to ingo.simonis@geospatialresearch.de.

Acknowledgments

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