Sensor service grid as real-time monitoring infrastructure and its application to soil moisture observation in Thailand

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Abstract: Sensor Service Grid (SSG) makes it possible to collect soil moisture sensor data from farms distributed in various parts of the world. It is useful for agricultural field manager and crop-soil researchers. SSG is the core system in Sensor Asia Initiative for easy setup and management of sensors. It realizes "sensor plug & play" which covers sensor node installation, registration, calibration equation and other sensor metadata, as well as visualization of processed sensor data. In order to evaluate the efficiency of SSG, a spinach field monitoring system has been setup near Chiang Mai, Thailand which collects soil data including moisture, temperature and electrical conductivity, together with meteorological observation data. We have confirmed that the data was accumulated in a SSG server over the Internet, and it was accessible by everyone easily. This system is currently utilized as a practical tool to secure the food safety between agricultural producers in Thailand and consumers in Japan. The real time information can be browsed easily by Japanese consumers using a mobile phone. Moreover, the system is extremely useful to stimulate researches on application of soil sensors.
Key Words : Sensor Service Grid (SSG), Sensor Observation Service (SOS), soil sensors, real-time data collection, sensor metadata

1. Introduction

An initiative called Sensor Asia, started at the Asian Institute of Technology (AIT), Thailand has been promoting high density sensor observation networks. Sensor Service Grid (SSG) is a core system of the initiative to realize sensor plug & play, covering from installation of sensor nodes to visualization and publishing sensor data to applications. SSG services are also capable of storing sensor metadata and configuring sensor nodes on-site or remotely from the server itself. Thus automatic configuration and complete control of the data paths from the beginning to the application end is possible. University Co-operatives in Japan, together with Sojitz Co., Ltd. started to import spinach from Thailand several years ago. The producer in Thailand is SWIFT Co., Ltd., which contracts farmers in Chiang Dao District, Chiang Mai province in Northern Thailand. SWIFT has been applying European Good Agricultural Practices (EuroGAP) for producing safe food as well as for environment conservation and rural development. However, a real time monitoring system is thought to be required because the confidence on food safety especially imported food among consumers in Japan is now in critically low level. We have installed a sensor observation system using SSG at one of the spinach fields to monitor the practices of producers, to provide images and information to Japan real time, and thus to confirm the efficiency of SSG. The system contributes to secure the food safety and to foster the confidence among consumers (Honda et al., 2008, Internet URLs indicated in References).

2. Implementation Overview

The details of the sensors used at Chiang Dao field in Chiang Mai are as follows:

(i) A weather station (Davis Instruments) with rain, wind speed/direction, air temperature, humidity, solar radiation and UV radiation.
(ii) A network camera and fieldserver (Hirafuji et al., 2007).
(iii) CO_2 sensor from SenseAir
(iv) 2 heat flux sensors.
(v) 4 soil moisture sensors (3 Decagon 5TE, and 1 Decagon ECH20-TE sensors which are capable measuring soil moisture, soil temperature and electrical conductivity deployed at depths of 4 cm, 8 cm, 16 cm and 32 cm, connected to Decagon Em50 data logger).

The data from these sensors are being collected in field-side agent box based on Sensor Observation Service (SOS) (Na and Priest, 2007) called SOS Station. The SOS Station is capable of collecting data from different sensor interfaces and storing them in an internal database, and also syncing the data in real-time to SSG servers. The SOS Station is in communication with the SSG server using an Internet connection from near-by primary school, Phatthana

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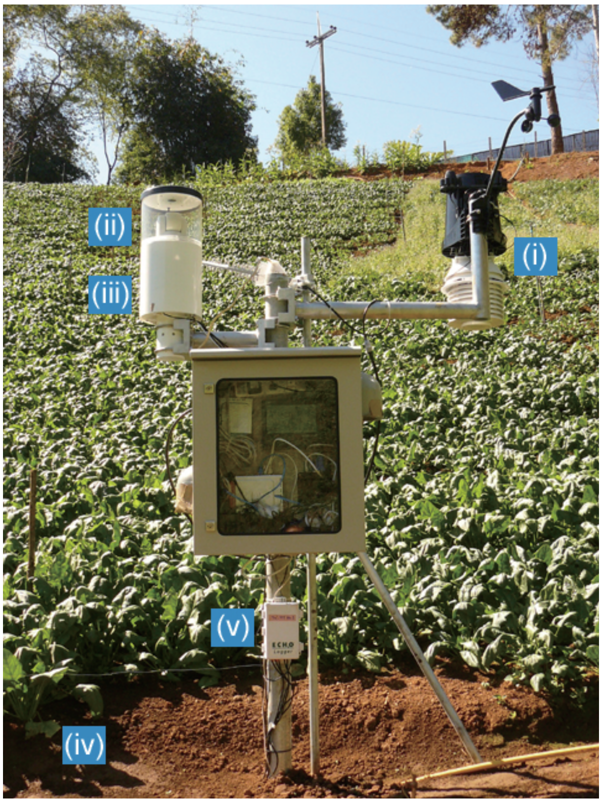


Fig. 1 Sensor setup at Chiang Dao spinach field, Chiang Mai.

Ton Nam Khun Khong School, 400m away. Under the project of "School Net" in Thailand, the school has an IP-STAR satellite internet service provided by Thaicom Plc., even in such remote area. The field site deployment of sensors is shown in Fig. 1.

A WiFi connection covering 400 m has been established from the school to an agricultural research center, Lum Nam Khun Khong Agricultural Research Station, adjacent to the spinach field. The last section of the network to the sensor setup is covered by an 80 m long Ethernet cable, as line-of-sight could not be obtained for the WiFi.

3. Sensor Service Grid (SSG)

SSG is a sensor data middleware which provides users with a platform to receive data from remote field sensor networks. As it follows OpenGIS standards and specifications (OGC, Inc.), other applications can be built based on the SSG. The SSG implementation has been designed to run in two parts – one at the sensor node in the field, i.e. the SOS Station, and the other at the SSG central server. The SOS Station is a combination of sensor systems with a small Linux Box which gives a high capability for storing sensor data and provides data connectivity to outside server using standardized data exchange protocols. The SOS Station is based on Sensor Observation Service (SOS) and the sensor data can be obtained in SensorML Observation and Measurement (O&M) encodings (Honda et al, 2009).

The overall structure and information flow from SOS Station to users via SSG is shown in Fig. 2. The SOS Station collects data from the sensor systems connected to it and stores it in a local database. The data is sent to the SSG server from which users can view it in graphs and maps. The data can also be obtained in standard XML O&M document. At the same time easy configuration and control of SOS Station can either be done locally or from remote locations by connecting through the SSG server. All data and configuration information are synchronized between the SOS Station and the SSG server.

The SOS Station has the capability to collect data from several types of sensor systems, weather stations and data loggers using various interfaces. As shown in Fig. 3, feeder systems have been developed separately for the aforementioned devices. The feeder templates are open, supporting an open system and easy installation; any device manufacturer can utilize these templates. The webserver implemented on the SOS Station gives access to all sensor data as well as device and sensor configuration. A command service linked to the SSG provides remote administration and configuration capabilities. A SOS Station owner with proper authorization can control the system from anywhere. All data is synchronized to SSG server using messaging service. Synchronization is done not only for the sensor data and metadata, but also for sensor and device configuration.

The primary work of the SSG implementation at the central server is the collection of data from all SOS Stations around the world, the management of all such stations, and the dissemination of information collected through the Internet. One of the main features of Sensor Asia is user-friendly data visualization. After the SOS Station is registered at the SSG, and it starts sending data, the position of SOS Station will automatically appear on the Web GIS map, together with its list of sensors as shown in Fig. 4.

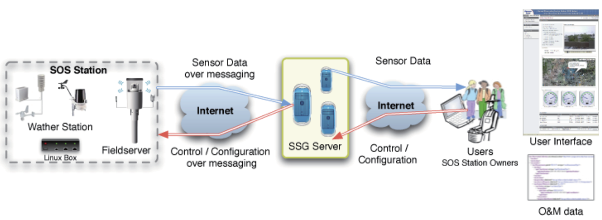


Fig. 2 Information flow from SOS Station to users via SSG.

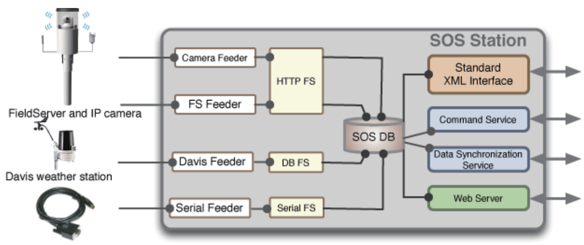


Fig. 3 SOS Station service layer diagram.

Fig. 4　SSG showing the remote field location of SOS Station on Web GIS map.

The data being received from the SOS Station can easily be viewed in real-time in the form of simple dials and graphs. Sensor configuration setup automatically creates this visual interface.

4. Application to Soil Sensor Deployment

Once deployed in the field as in Chiang Dao, the SOS Station can be used to register the soil moisture and other sensors at the SSG central server. Sensor set can be added or changed easily with a user-friendly interface; the calibration equation and other parameters can be set by user or pre-set settings selected appropriately to obtain the correct sensor output.

The data from a Decagon 5TE sensor deployed at Chiang Dao is shown in Fig. 5. The output of this sensor is a complex convoluted value which then needs to be deconvoluted to obtain the three sensor parameters of soil temperature, electrical conductivity and soil moisture. SSG has provisions to pre-set complex calibration equations and other sensor metadata so that the user can just select the proper sensor and required output type from a drop down menu. In case the calibration equation needs to be changed due to a different soil type or because of re-calibration at field, there is also a provision to over-ride the preset equation by user. Fig. 6 shows the soil moisture sensor parameters as well as the calibration equation that has been preset in SSG server. The generation of automatic graphs and dials is enhanced by options of graph type such as round meter or scale, the minimum and maximum values, the digit display format etc..

Once the soil moisture sensors are configured and registered at sensor site, the SOS Station can be controlled and configured remotely from the SSG itself. Accessing to SOS Station (local access) and SSG (global access) is almost transparent to users. They can control sensor configuration and access to sensor data by accessing either SOS Station or SSG. This overcomes the problem of local setting difficulties at the sensor site. SOS Station owners can access their sensor data locally or globally.

Soil sensor data, together with meteorological observation data have been successfully accumulated in a SSG server over the Internet. The data on the server is accessible by everyone. Currently, the data is being displayed in a university's canteen as well as on a home page designed for mobile phones.

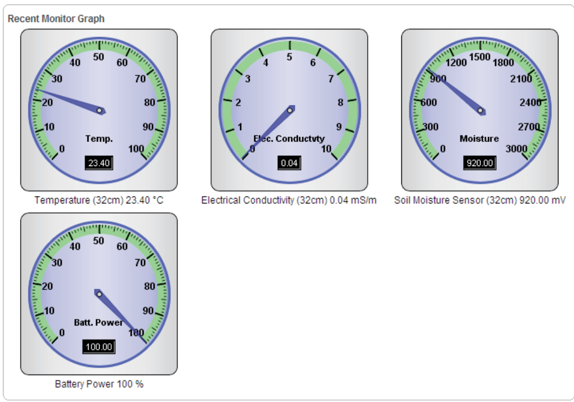
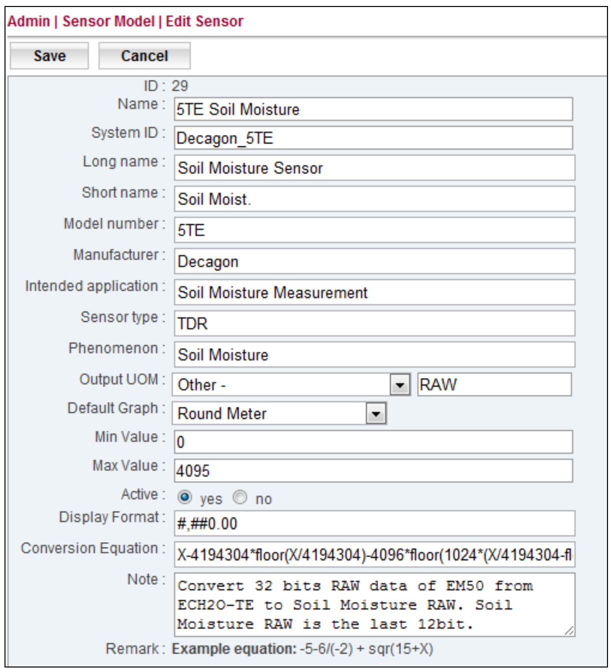


Fig. 5　SSG interface showing de-convoluted data from Decagon 5TE sensors, as well as the battery power of Em50 datalogger (Data acquired midday of 28 October, 2009).


Admin | Sensor Model | Edit Sensor

Save　Cancel

ID :	29
Name :	5TE Soil Moisture
System ID :	Decagon_5TE
Long name :	Soil Moisture Sensor
Short name :	Soil Moist.
Model number :	5TE
Manufacturer :	Decagon
Intended application :	Soil Moisture Measurement
Sensor type :	TDR
Phenomenon :	Soil Moisture
Output UOM :	Other - / RAW
Default Graph :	Round Meter
Min Value :	0
Max Value :	4095
Active :	yes / no
Display Format :	#,##0.00
Conversion Equation :	X-4194304*floor(X/4194304)-4096*floor(1024*(X/4194304-fl
Note :	Convert 32 bits RAW data of EM50 from ECH2O-TE to Soil Moisture RAW. Soil Moisture RAW is the last 12bit.
Remark :	**Example equation:** -5-6/(-2) + sqr(15+X)

Fig. 6　Decagon 5TE sensor parameters and calibration equation preset in SSG server.

5. Conclusions

One of the problems in setting up soil sensors or any other type of sensors in the field and their operation is that the work requires highly skilled engineers. It results in high installation cost and eventually will hinder the deployment of high density sensor networks. SSG has been developed to solve this issue by supporting “sensor plug & play”, registering sensor nodes, archiving, publishing, and visualization. These functions are important to lower the cost of installation and the make soil sensor deployment as a simple off-the-shelf endeavor for everyone. SSG supports SOS as a base technology to standardize sensor information exchange within and outside of the system. SSG and related infrastructure are ideal for soil observations using various sensors and dataloggers as well as for other types of monitoring applications. The test site at Chiang Mai province has proved that SSG is quite useful infrastructure for application in the study of soil sensors.

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URL of the home page for mobile phone users: http://chiangdao.sensor-asia.net.

URL of the home page of Sensor Asia : http://www.sensor-asia.net.

要　　旨

世界の農場に設置された土壌センサーのデータを GIS 上でリアルタイムに一覧できると，農地管理者や作物 · 土壌系の研究者にとって，大変便利である．開発したセンサーサービスグリッド（SSG）はこれを実現するセンサーアジア構想の中核のシステムである．SSG ではセンサーの登録，補正式やその他のセンサーメタデータの管理，可視化などに関するセンサープラグ＆プレイが実現されており，容易に土壌センサーデータをリアルタイムに収集し，管理することができる．この SSG の有効性を検証するために，タイ王国チェンマイのホウレンソウ草畑に圃場モニタリング装置を設置し，現地の気象条件と一緒に畑土壌の水分 · 温度 · 電気伝導度をリアルタイムで測定できるようにした．実証実験の結果，開発した SSG により，測定データがインターネット経由でデータサーバに蓄積され，誰もが簡単にデータ閲覧できることが確認された．現在，このシステムは，タイの農作物生産者と日本の消費者で食の安全を確保する１つのツールとして実際に利用されており，携帯電話で現地の情報を確認できる．SSG は土壌センサーの応用開発研究を促進させる上できわめて有用である．

キーワード：センサーサービスグリッド（SSG）, センサーオブザベーションサービス（SOS）, 土壌センサー, リアルタイムデータ収集, センサーメタデータ