Cartographic visualization of agricultural sensor

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Abstract

The aim of the presented paper is to present Agrisensor project dealing wiht methods of cartographic visualization and modeling of agricultural data based on wireless sensoric networks monitoring. Cartographic visualization of sensoric data for public purposes is usually referred to as pervasive mapping. The project is technologicaly based on Open Geospatial Consortia (OGC) intiative called Sensor Web Enablement (SWE), which specifies method of connecting arbitrary sensors to the Internet. SWE will provide specification of standardized interface and coding of data for use in a geoinformation service that integrates selected sensors to general, already existing geoinformation infrastructures. Project is primarily focused on three basic cartographic areas of investigation: effective real-time visualization of sensoric data with the use of selected cartographic tools, modelling of monitored spatial phenomena with suitable interpolation procedures and their subsequent cartographic presentation, and visualization of trends of changes of sensoric data and their contingent prediction.

Key words

Cartographic visualization, wireless sensor networks, geoinformation infrastructure, agricultural monitoring.

Introduction

The relationships between human society and the land have been progressively transformed as a result of dramatic changes in the course of the 20th century, particularly by increasing industrialization, the mechanization of agriculture, immediacy in global trade and communication. National, regional and international perspectives on agriculture must examine these and other factors in order to provide the best possible basis for allocating resources, establishing rules, formulating policy, making decisions and finally work with useful control system. More people are becoming aware of the effects to the soil that years of farming and using chemical fertilizers and other chemicals have caused. In that case it's necessary to build up a clear control system for fertilizer chemicals in crop production, crop process in food production and food market. Today there exist many laws, public notices, state standards in crop production and post processing and in many times it is not possible to get all important information about specific crop on one paper. To place this information on web pages make things easier, but crop production is less unite with country side and rural areas and people living in this part mainly have less experience with Information technologies than people in the cities.

Fifth Framework Program start up a research activities and build up a models to spread out systems of progressive farm management (see [5] for details) by using an information technologies in crop production and food market. With advent of wireless communication technology and sensors there is a new possibility for a true integration of agricultural data and interoperable geospatial infrastructure.

Cartographic visualization of senzoric networks in agricultural applications

The effectiveness of decision-making in agriculture domain can be improved by integrating current local environmental and agromonitoring with Geographic Information System (GIS) and sensor web applications. Effectiveness of any information system can be evaluated on the basis of its ability to deliver relevant, accurate, and timely information. Every sensor used for agricultural applications has a location, and a sensor location is almost always important. The spatial extension and near real time availability of sensor information layers in geospatial applications create a great potential. Soil quality, air pressure and crop sensor characteristics in a specific region can be automatically read at frequent intervals and those readings can be aggregated with map layers from diverse sources into spatial data representation/visualization for diverse purposes. Interoperable web services and data encoding models for Spatial Data Infrastructures (SDI) further foster the integration of geo-sensors data with spatio-temporal models. Currently - with the use of intelligent approach to databases and interactive user support - it is possible to find applicable maps on the Internet, but also to create and modify these maps according to specific and individual requirements. Instead of mere utilization of maps created by someone else beforehand, these new geoinformation technologies allow individuals to use cartography interactively, examine and represent spatial information according to specific needs of the particular user. The goal is not only to offer more information to farmers, but offer it in a way which would not task one's mind.

New technologies allow „live connection" to the instinctive inner sphere of our spatial cognition via direct interaction with a new generation of cartographic visualization and thus with potentially infinite resources of the Internet.

Map is a representation of geographic reality with the use of symbols representing selected qualities and characteristics resulting from creative efforts and selection performed by its authors [11]. It is created for further use; spatial relations are of primary importance. Together with new cartographic tools (GIS) based on interactive web maps, it is possible to provide mutual interaction map-user (including map data sources). Cartography in its new form is a unique instinctive multi-dimensional tool, which can be used in research, analyses, and communication of geospatial data [6]. It can utilize available resources on the WWW. Therefore, a map is more than just space for manipulating and creating images; it can be a graphic window with unlimited possibilities. There is necessary to stress, that in this meaning "cartography" is not working and influencing just the "map window", but its part is also the structure of information and interface – together they make formidable tool of wide usability.

This new visual-mental environment uses advantages of our cognitive, instinctive mapping, which can be even more effective if it is performed with the use of geovisual dialogue with cartographic visualization systems.

Sensor networks

A sensor network is a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure, motion or pollutants. A Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces (APIs).

In an Open Geospatial Consortium, Inc. (OGC) initiative called Sensor Web Enablement (SWE), members of the OGC are building a framework of open standards for exploiting Web-connected sensors and sensor systems of all types [8]. SWE presents many opportunities for adding a real-time sensor dimension to the Internet and the Web.

The initial focus of OGC's SWE has been to investigate standardized interfaces for live sensors operating in near-real-time, rather than the conventional static data stores. It addresses information gathering from distributed, heterogeneous, dynamic information sensors and sources of different structure, based on web services. It is the goal to develop common access, planning, and management interfaces and a descriptive markup language (SensorML) for managing sensor information and metadata in common consistent manners, independent of any application. The individual parts were initially designed to fulfil the following needs [9]:

- Describe sensors in a standardized way
- Standardize the access to observed data
- Standardize the process of what is commonly known as sensor planning, but in fact is consisting of the different stages planning, scheduling, tasking, collection, and processing
- Building a framework and encoding for measurements and observations

Some sensors are already on the Web and able to return their location information as well as observations and measurements. The final missing element - a universal standard framework for describing and tasking sensors in XML - has already been built and prototyped by OGC members in specifications like Sensor Observation Services (SOS) or Sensor Planning Services (SNS) [10].

The aforementioned specifications are necessary but not sufficient condition for a fully operable SWE environment. The step further is the development of a real framework of sensors fully compliant with these specifications. SensorNet is a vendor neutral interoperability framework for Web-based discovery, access, control, integration, analysis, and visualization of online sensors, sensor derived data repositories, and sensor related processing capabilities. In other words, SensorNet attempts to create a wide-area system to collect and analyze data from sensors all over the country to monitor and detect threats, and then alert agencies, emergency responders, and others as necessary.

Developing an open standards framework for interoperable sensor networks requires also finding a universal way of connecting two basic interface types – transducer interfaces and application interfaces. This problem is solved by IEEE 1451 standard for transducers interfaces.

Falling producer prices and rising costs of production are increasingly forcing agricultural businesses to optimize production costs. Therefore, the request for the selective use of inputs such as water, fertilizers or chemicals, is now indispensable in modern agriculture. The growing environmental awareness of consumers further accelerates this process. Improved agricultural risk management using the actual knowledge of agricultural indicators becomes more and more important. Every day or hour information made decision more exactly. Plant disease initiation and development is a function of the interaction of several observable factors like soil temperature, air temperature, relative humidity, and other soil and atmospheric variables.

The farmer can for instance define wet temperature low limits (calculated as a function of temperature and relative humidity). Then, when the temperature drops below the predefined thresholds, the software sends an alarm via email or SMS. The farmer can activate frost protection equipment and reduce crop loss to a minimum. The same attitude is applicable in monitoring of growth and development of plants, insects, and many other invertebrate organisms' endangerment.

AgriSensor project framework

The AgriSensor project follws the above mentioned situation and aims to design and develop an integrated framework of dynamic cartographic visualisation and modelling tools for agricultural applications based on wireless sensor networks information. The terms "dynamic visualization" describes mainly the possibility to select required scale, interactive creative communication of users and map authors over the Internet, and also presence of simple modelling tools for spatial as well as temporal analysis. Usability of the proposed solution will be evaluated in a scope of information systems acting in the agricultural domain. The pilot area has been selected as a possible extension of the environmental European INSPIRE initiative.

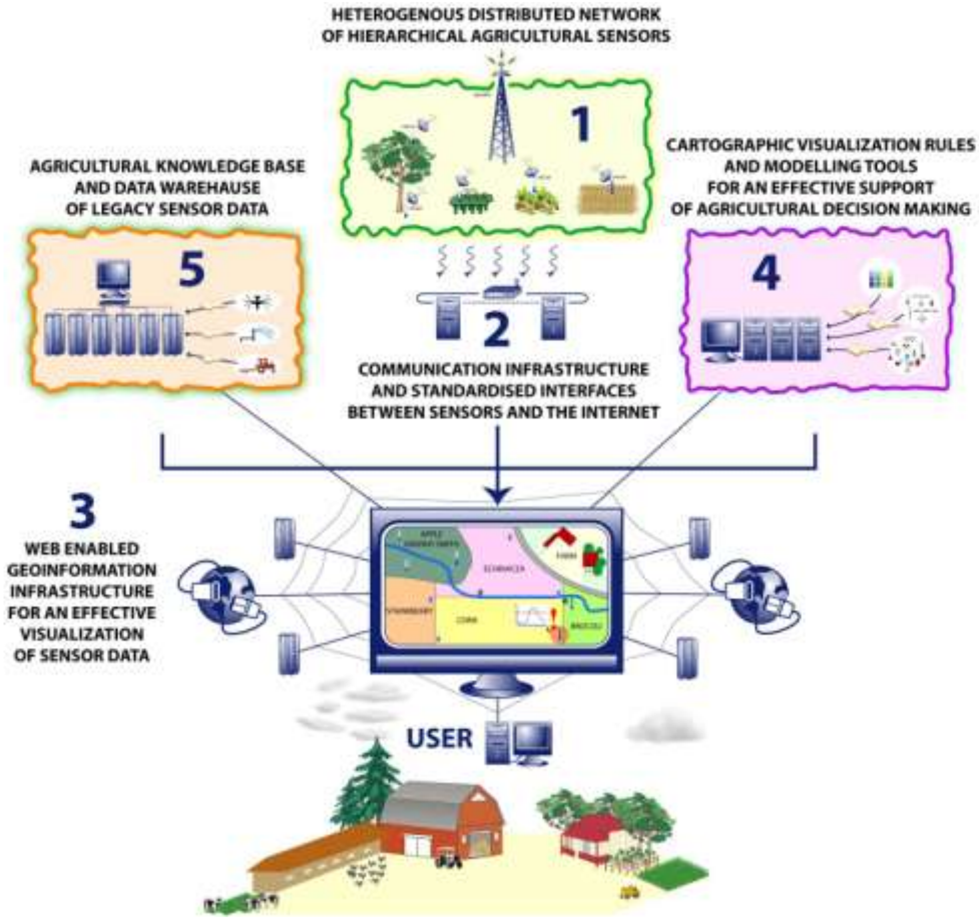


Figure.1:Proposed architecture of AgriSensor project.

The target of the project is a framework developed for agile accessing heterogeneous sensor data and services, which are necessary for effective decision making in the area of agricultural management. The suggested framework is based on following components (see Fig. 1):

(1) Heterogeneous distributed network of hierarchical agricultural sensors
(2) Communication infrastructure and standardised interfaces between sensors and the Internet

(3) Web enabled geoinformation infrastructure for an effective visualization of sensor data
(4) Cartographic visualization rules and modelling tools for an effective support of agricultural decision making, and
(5) Agricultural knowledge base and data warehouse of legacy sensor data.

Methods and workplan

The project is planned for 36 month and shedule has been divided into 4 main areas, each with a separate workplan and tasks:

- Cartographic visualisation and modelling tools for agriculture
- Sensor network development
- Agricultural monitoring and knowledge base
- Infrastructure integration and proof of concept

Cartographic visualisation will be focused primarily on three areas - cartodiagrams, continuous coverage, and change detection. Cartodiagrams (or diagram maps) are specifically aimed on representation of factual values of monitored phenomena via sensors and their evolution in time [1]. The visualization should carry on top of layers of land use (in the sense of crop production) in case there is a need of visual confirmation for taking an action. Cartodiagrams also allows to spot unusual values in data collection. The goal is to use simple, easily readable types of diagrams localized inside the map field and minimize the necessity of study the visual system. For this purpose several types of visualization should be prepared modelled by farmer's demands and habits. Real-time displayed variable factors of attached sensors with alert capability will be visualised as symbol maps.

From sensor data it is supposed to cartographically model continuous (or pseudo continuous) coverages of selected phenomena. Models will be capable to react in a near real time regime and visualisation of uncertainty will be considered. Continuous coverage of phenomena generated from sensor field, in combination with thematic data, is useful especially for delimitation of areas in need of action (as for example irrigation or crop-spraying). Several types of visual solution will be provided. The last of visual tasks – change detection - is in a way combination of point and area form of visualization. The main goal of this type of sign is to alert the farmer about out of range changes in monitored phenomena and, if possible, to estimate spatial range of the change (hence the combination of point and areal form). Type of alert sign should be tied to phenomena representation to easy recognition of affiliation.

Interoperability with other topographic and thematic geodata sources will be sought as well. Important part of visualization techniques will support change tracking with amplification of positive or negative trends or possible dangers.

As a background for the agriculture monitoring, we propose a *sensor network* with fully fledged services that are needed in the different stage of crop production. Four basic types of services have been recognised, which have to be analysed: Sensor services, Networked services, Services integrated sensor services with SDI, and Localisation services.

For the single sensor node, there are proposed four basic components: a sensory transducer(s), a radio transceiver, a power unit and a processing unit, to guarantee its work in sensor network. Certain nodes in the network may possess only the latter three components: these are relay nodes meant to process and pass information from other sensors to the monitors. We assume that heterogeneity of transducers can exist in the sensor network, and that most sensors have limited computational power and storage space [2] [3].

Agricultural monitoring and knowledge base development main objectives is to establish a Crop control model, Soil fertilizer model and Weather control model concluding first step on the field on beginning vegetation season to the last step before crop product is exported to the market. After analysis of currently existing agricultural information and knowledge base systems for phyto-monitoring and prognoses purposes, a new prototype of knowledge base will be proposed and possible monitoring areas for the project purpose identified. Appropriate field data for effective agricultural monitoring and data warehousing will be suggested and granted for cartographic modelling and evaluation. Three monitoring models are expected - crop control model, soil fertilizer model, and weather control model – to be integrated with the project framework.

Pilot implementation will integrate the whole project infrastructure. This work will include the upgrade of the existing sensors and of the prototypes developed by the project, as well as the network integration into an on-line data cartographic visual analysis and infrastructure interoperability to carry out proof-of-concept tests and the final evaluation. Beside the support of the whole partnership, the networks will be deployed, integrated in the on-line analysis infrastructure and finally evaluated. End-user partners will explore and asses the potential of this technology in the framework of agriculture management.

Main conceptual and methodological approaches

Cartographic visualization of sensor data for public uses is often called "pervasive mapping". The core of this cartographic technology is real time or near real time visualization of different phenomena with a short period of updating. Traditional area of pervasive mapping is visualization of topical meteorological data or weather forecast maps. Nowadays this attitude seems to be a vital proposal also for other areas of use like emergency management, transportation information, or fire detection systems. Taking into account only simple visualization of sensor data by standard cartographic visual variables (symbol maps, scalable symbology, and annotation) the initial part of the research is reduced to the perception study and effective software implementation of appropriate visual techniques. While the technological line of sensor-Internet communication is well known and widely used, its implementation with SWE standards in mind is innovative approach and brings new challenges towards sensor geospatial enablement and interoperability. However traditional interpolation methods used for the continuous grid generation with a defined resolution are not appropriate for sensor networks. These methods are often too slow-paced and would take too much time for near real time visualization of sensors. Incremental interpolation methods and other alternative visualization will be tested and validated during the project in order to reach short processing time and minimise delays between data delivery and visualization. It is clear that change detection plays a significant role in sensors visualization. For this reason time series visualization represents the third concept to be solved. Commonly used time series visualization techniques (animation loop) will be studied and new alternatives for change detection and highlight will be proposed.

Concerning the sensor network architecture a network of fixed sensor nodes will be developed that are deployed in a 2 or 3 dimensional space. A set of monitoring nodes, defined as sinks, are responsible for collecting data reports from sensor nodes. It is assumed that knowledge of sensor node locations will be calculated from position of sensors with GPS and from network. The location information needs to be precise. It could be computed even after deployment. The network will have multilevel hierarchy.

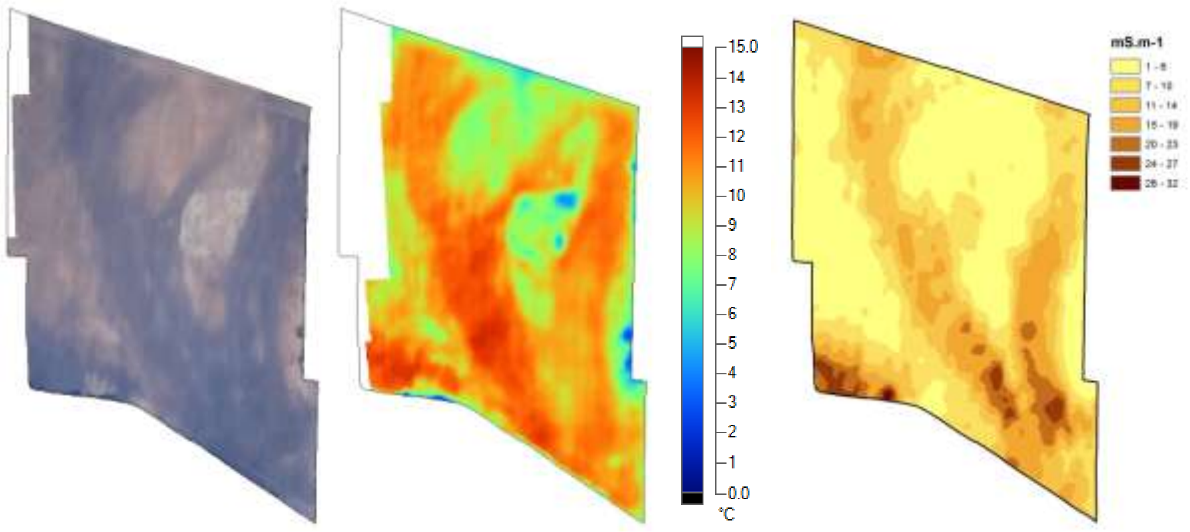
There are three main modules of sensor's network behaviour for the proposed AgriSensors system:

1. Standard reporting - the system can visualize a customized set of measured values and their derivatives, used by a farmer in daily control practice. These values are stored in a separate database for further modelling and time-series visualization.
2. Exception reporting (warning) - the system enables the early detection of unexpected disorders in plants. This function is based on a variety of measured indicators of crops, soil, and weather.
3. Decision-support system - enables the possible tuning of climate and irrigation regimes by trial-end-error approach. Extremely high sensitivity and short response time of the monitoring channels eliminate the risk of crop damage. A farmer can make a little change in a control regime and then he may get a detectable response of plants within 1-2 days. He can also automatically set and change the alert level of variables through the SWE standard interface.

AgriSensor - state of the art

Following the above proposed schedule the analysis of available cartographic web applications has been started and the "Map and Diagram Service" (MDS) has been chosen for further testing. The MDS specifications define extensions to the OGC WMS and SLD standards with cartographic features such as diagrams, patterns and custom symbols expressed in Scalable Vector Graphics [4]. Diagram and other proportional symbol overlays are geo-referenced, and (technically) indistinguishable from regular WMS layers. As a consequence, all WMS client applications are compatible and can be used for viewing thematic layers that can be overlayed on regular cartographic materials. MDS defines several types of diagrams, including pie charts, bar charts, and line charts with others to be developed. Different interpolations and contours (isopleth) representation are another important feature for the effective and intuitive representation of sensor data and interpolated fusion results available as a part of MDS. Moreover a reference implementation of the Map and Diagram Service specifications is already implemented in the "QGIS map server", which is offered under GPL licence [7].

Agricultural monitoring of the spatial and temporal variability of selected agrometeorological characteristics will be made in two fields with larger area in South Moravia region (35 and 52 ha). Soil and canopy sensors for measurement of soil and crop (air) temperature and humidity will be placed in selected plots with a grid density determined according to the analyzed spatial variability in soil conditions and stands in last year’s. The entire plot, its soil conditions and vegetation will be mapped using airborne sensing (multispectral and thermal cameras) and soil electric conductivity, yield and/or other parameters will be measured at selected growth stages through the growing season. These measurements provide a survey about spatial variability in the mentioned characteristics but not about their temporal dynamics due to technology possibilities and cost requirements. If stationary sensors are used, information on temporal dynamics of the examined parameters can be obtained.



a) b) c)

Figure.2: Maps represent soil spatial variability in a 52ha field - a) orthophoto, b) aerial thermography and c) soil electrical conductivity

It can be assumed that mapping, modelling and cartographic visualization the spatial and temporal variability of relevant agrometeorological characteristics can provide more detailed data for decision making in agronomic treatments with regard to concrete conditions of the location.

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