GEOSENSOR NETWORKS - USAGE IN AGRICULTURE

A. RISTIĆ, M. GOVEDARICA, M. VRTUNSKI, D. PETROVAČKI

University of Novi Sad, Faculty of Technical Sciences, Geospatial Technologies and Systems Centre
Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, e-mail: aristic@uns.ac.rs

Abstract: *this paper presents various types of applications of geosensor networks in agriculture. Since the sensor technology has developed rapidly in recent years it led to emergence of systems which provide autonomous monitoring of environment – the geosensor networks. These networks have various areas of application, one of them being the agriculture. Usage of geosensor network in agriculture results in more efficient usage of recourses, less production costs, higher yields and higher degree of environment conservation.*

Keywords: *sensor network, geosensor network, sensor node*

INTRODUCTION

GEOSENSOR NETWORK STRUCTURE AND TASKS

The basic task of geosensor network is to yield a conclusion about a phenomenon, which would be much harder or even impossible to produce using usual measurement procedures (STEFANIDIS AND NITTEL, 2004). It is done by monitoring using sets of spatially distributed sensors which work in a network mode.

Sensor network (SN) is distributed system (DS) consisting of sensors of various types connected with communication network. Data from sensors outputs can be shared and they are lead to a DS input to be estimated. The task of DS is to separate the most probable information about phenomenon being monitored, based on available sensor data.

Operational characteristics of SN are: high reliability, relatively high accuracy, flexibility, low price and relatively easy distribution of nodes into AOI (Area Of Interest).

SN is formed of individual multifunctional sensor nodes. Nodes are connected in a wireless network called Wireless Sensor Network (WSN). WSN consists of battery-powered modules which represent nodes.

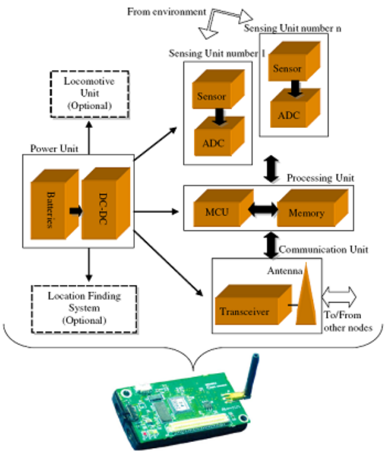

Fig. 1. Sensor node segments

Basic segments of sensor node are: sensor/sensors, transmitter/receiver (Tx/Rx), one or more processors with memory and power supply. Sensor is a data source. Transmitter/receiver sends nodes own data or receives and forwards data from neighboring nodes. Processors with memory control other segments and implement network and routing protocols.

Optional segments are energy generating module (e.g. solar panel), node positioning module and mobilizer (in case of moving nodes).

Considering these terms, geosensor networks (GSN) are implementations of wire/wireless sensor networks designed for monitoring of natural phenomena in terms of fast and efficient acquisition, processing and modeling of geospatial data (EL-KADER AND EL-BASIONI, 2013).

Aspects of monitoring using GSN are:

- Measurements of parameters which characterize the phenomenon
- Identification/estimation of phenomenon characteristics
- Monitoring of identified characteristics of phenomenon spatially and in time.

Since geosensor networks are battery powered, due to limited energy source most of the data processing is done within the network itself, between neighboring nodes which are spatially distributed in a vicinity of the event being monitored, avoiding any calculations and unnecessary communication between the nodes (FERNANDES ET AL., 2013).

Design and implementation of GSN, in terms of geoinformatics, includes following tasks:

- Mass implementation
- Standardization - formal basics
- Multipurpose interfaces
- GSN visualization
- Sensor Web
    - Achieving interoperability, accessibility and repeatability of real-time sensors, using web pages
    - Real-time data integration according to different spatial and time defined frames, with overlapping with archive data
- Real-time data integration from all sensor platforms
- Levels of data access
- Data protection

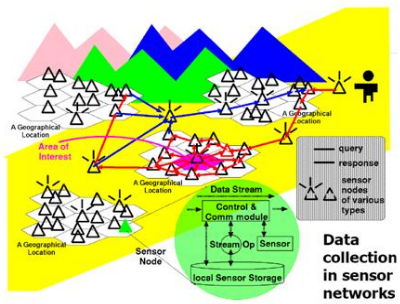

Fig. 2. Architecture and concept of GSN

Basic tasks of database management system for measurement data acquisition and processing:

- High abstraction level of data and monitoring process
- Data centric data download
- Interaction with GSN as with an entity, using spatial queries.

Types of queries in Database management system (Fig. 3):

- Combined time/spatial queries for monitoring processes
- Event detection queries and feature extraction queries
    - Edge detection and continuous phenomenon monitoring
    - Object detection and discrete phenomenon monitoring
- Intelligent query processing in a network – energy efficient processing, with autonomous failure recovery, application robustness is increased.

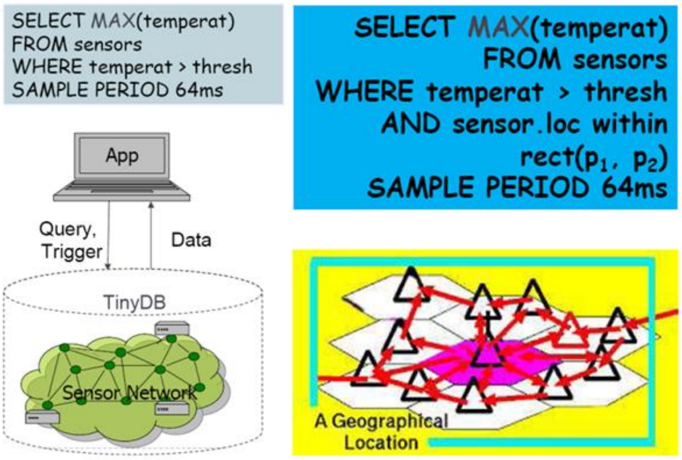

Fig. 3. Queries in GSM

Information from measurements is described in two ways:

- Object: identifier, geometry (point, line, polygon – vectors)
- Fields (regions): for all coordinate pairs (x,y): $F(x,y) \rightarrow v$ (raster)

Processing of both vector and raster data is relevant in GSN: monitoring of car movement/monitoring of air quality in the city center. Step forward is object extraction from the field (vector from raster):

- Example: position of toxic cloud above the chemical plant
- Contour lines and maps
- Real-time monitoring of edge changes in space and time

GSN – AREAS OF APPLICATION IN AGRICULTURE

Considering the variety of ways of usage of GSN, there are a number of possible applications of GSN in agriculture (LI ET AL., 2013). They can be classified into groups:

1 – acquisition of data about the weather, crops and soil characteristics (SRBINOVSKA ET AL., 2015).

2 – monitoring of crop and soil characteristics on spatially distributed parcels

3 – monitoring of various crops on a single parcel

4 – determining the amount of fertilizer/nutrients/irrigation for parcels with inhomogeneous soil (NIKOLIDAKIS ET AL, 2015)

5 – determining different demands for same crops in different weather conditions and for different soil types

6 – analysis by measurements for prevention solutions rather than post-festum.

Characteristics of intelligent GSN sensor nodes provide simultaneous execution of more than one mentioned application (REHMAN ET AL., 2014). Intelligent sensor modules (ISM) also provide certain degree of data processing (e.g. data aggregation). ISMs can be classified as follows:

- ISM for the analysis of soil characteristics (Fig. 4a). Measurements: temperature, volumetric moisture content, dielectric constant, distribution of water through the soil, underground water level, soil conductivity, salinity (ALLRED ET AL., 2008).
- ISM for the analysis of characteristics of the leaf or plant body (Fig. 4b): measuring of chlorophyll content, moisture, hydrogen, CO2 ratio, and leaf/body temperature.
- ISM for weather analysis: air temperature, humidity, pressure, wind speed and direction, etc.

Fig. 4. a) Soil pH and volumetric moisture ratio sensor; b) Sensor for chlorophyll and moisture content in a plant body and/or leaf

REALISATION OF GSN APPLICATIONS IN AGRICULTURE

1. Watering systems – water consumption is 30-60%, time-defined start of watering, control of volumetric moisture content in the soil, sensors can powered using solar panels, data acquisition for statistical analysis, measuring of spatial coordinates of mobile watering systems using GNSS technology (Fig. 5) (DONG ET AL, 2013).

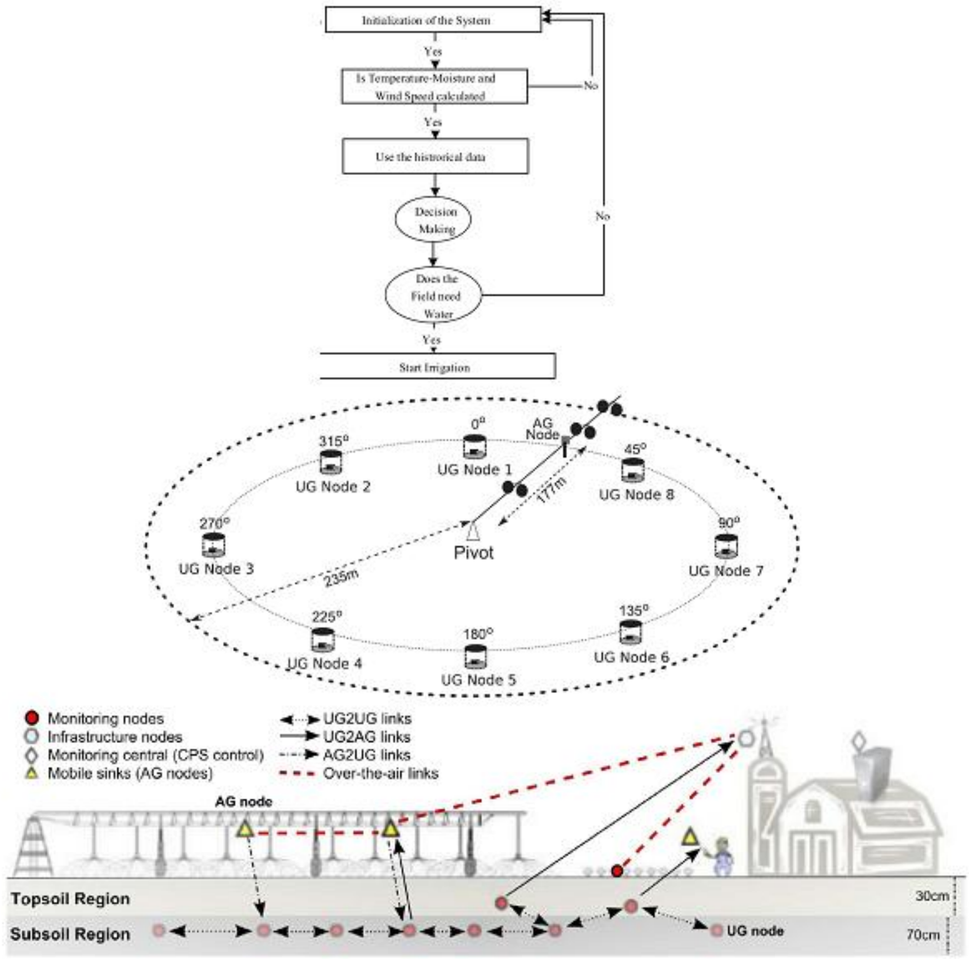

Fig. 5. GSM architecture for watering monitoring

2. Fertilizing systems – the most representative example is automated system with adjustable dosage (amount) and zone of dispersion (area) of fertilizer (Fig. 6). Measurements are conducted in real-time: volumetric moisture content, conductivity, temperature, pH, air temperature and humidity, CO_2 concentration, insolation etc. Trajectory of a tool and tractor is defined using GNSS technology, and monitored within GIS application. Up to 30% is the reduction of fertilizer usage while the results of fertilizing are significantly better.

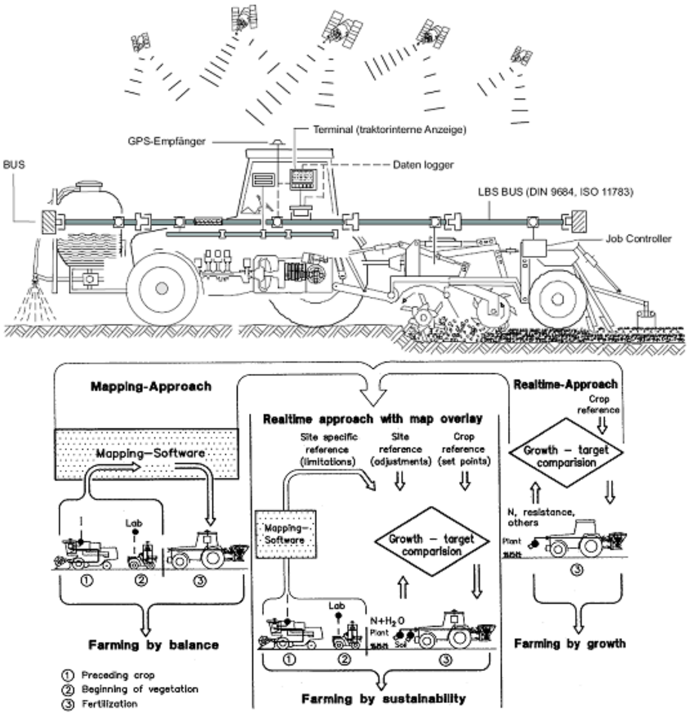

Fig. 6. Fertilizing with real-time measurements

3. Control and treatment of pests – measurements of temperature and humidity to determine the optimal conditions for development of fungal disease defining the zones of increased chemical treatment, measuring the biomass density(Fig. 7).

Fig. 7. Treating of crops using UAV

4. Control of herd movements on pasture – using flock algorithm for detection of exclusion of individual from the herd and reaction only if exclusion occurs, applications for directing of herd towards less used areas of pasture (Fig. 8).

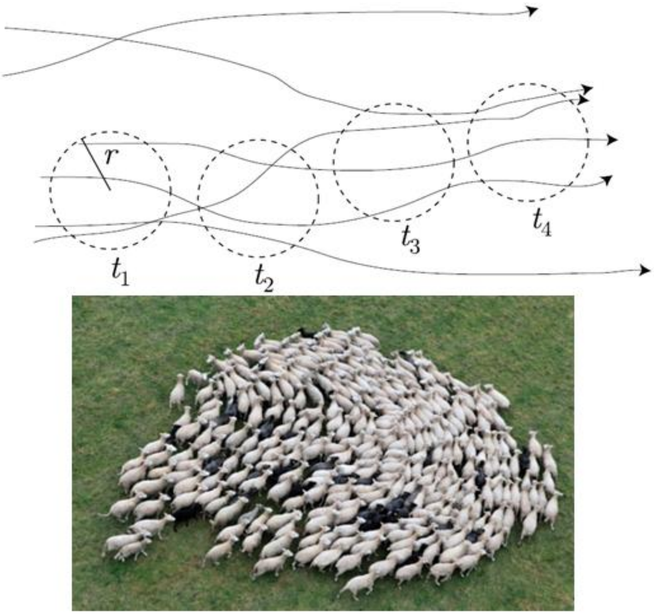

Fig. 8. Monitoring of individual movements within a group

5. Usage of GSN in horticulture – measuring of air temperature and humidity, ambiance light, volumetric moisture content in the soil, recommendations for prevention, watering and fertilizing (Fig 9) (LOPEZ RIQUELME ET AL, 2009).

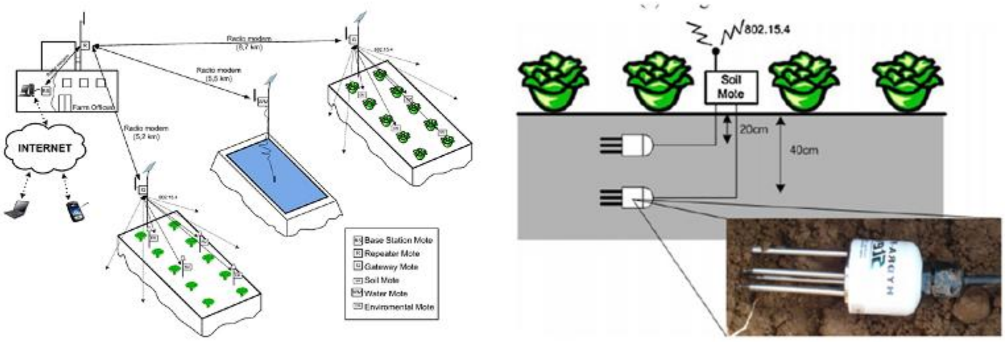

Fig. 9. GSN for monitoring of horticulture crops

6. Usage of GSN for environment parameter control in greenhouses, vineyards and orchards – measured variables are the same as in previous applications.

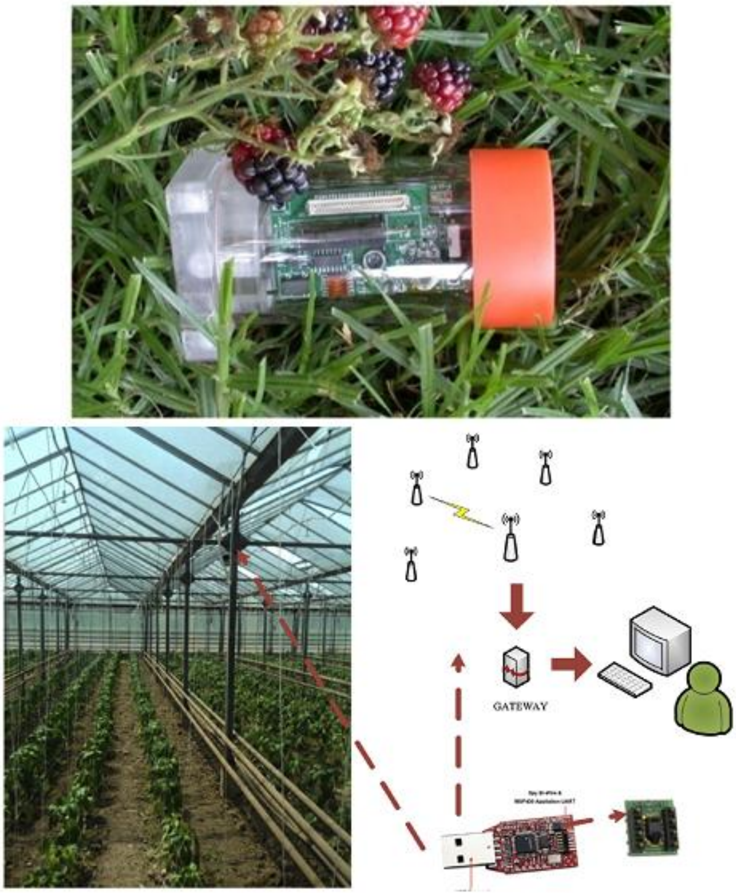

Fig. 10. Realization of parameter monitoring in orchards and greenhouses

DESIGNING A FRAME FOR COMPLETE SOLUTIONS – A STEP TOWARDS THE STANDARDS

Designing a frame means defining the standardized concepts of survey, modeling and control of complex systems in the area of agriculture. It contains three layers:

- Sensor network layer
- Grid computing layer
- Context-aware application layer

Several research groups are working independently and developing such systems using standard technologies under the Precision Agriculture terminology. The Food and Agriculture Organization of the United Nations (http://www.fao.org) is performing one of standardization efforts by working towards the development of multilingual Agriculture Vocabulary (AGROVOC) to support the development of context modeling through ontology. In this regard they have also presented the concept of Agricultural Ontology Service/Concept Server (AOS/CS) to standardize agricultural vocabulary and providing rich and semantically sound terminology.

CONCLUSION

Agriculture is a context rich domain in which the potential of using GSN is very high. A review of several solutions and efforts has been presented in this paper towards agriculture domain. The major concerns that we feel are:

- Solutions are too complex to implement and requires major technical support
- Intense Cost is involved
- Lack of generalized solution to different services and problems
- Majority of the research works present solution in parts like only context modeling, data acquisition, data processing and storage techniques or network related problem solutions. The complex or sometimes unavailable interlinks among part solutions reduces the impact of several researches.

Adaptation of GSN based solutions on large scale requires the following:

- Development of low cost and rugged sensor/actuator nodes
- Generalized solutions to different problems
- Complete frameworks to develop systems from acquisition to the modeling and the decision support.
- Solutions in part should be supported with comprehensive details of other compatible procedures that could make the intended resolution complete.

BIBLIOGRAPHY

1.ALLRED, J., DANIELS, J., REZA-ESHANI, M. (2008). Handbook of Agricultural Geophysics. Taylor & Francis, Boca Raton, FL, USA.

2.DONG, X., VURAN, M.C., IRMAK, S. (2013) Autonomous precision agriculture through integration of wireless underground sensor networks with center pivot irrigation systems. Ad Hoc Networks, 11, 1975-1987.

3.EL-KADER, S.M.A., EL-BASIONI, B.M.M. (2013) Precision farming solution in Egypt using the wireless sensor network technology. Egyptian Informatics Journal, 14, 221-233.

4.FERNANDES, M.A., MATOS, S.G., PERES, E., CUNHA, C.R., LOPEZ, J.A., FERREIRA, P.J.S.G., REIS, M.J.C.S., MORAIS, R. (2013) A framework for wireless sensor networks management for precision viticulture and agriculture based od IEEE 1451 standard. Computers and Electronics in Agriculture, 95, 19-30.

5.LI, S., PENG, S., CHEN, W., LU, X. (2013) INCOME: Practical land monitoring in precision agriculture with sensor networks. Computer Communications, 36, 459-467.
6.LOPEZ RIQUELME, J.A., SOTO, F., SUARDIAZ, J., SANCHEZ, P., IBORRA, A., VERA, J.A. (2009) Wireless sensor networks for precision horticulture in Southern Spain. Computers and Electronics in Agriculture, 68, 25-35.
7.NIKOLIDAKIS, S.A., KANDRIS, D., VERGADOS, D.D., DOULIGERIS, C. (2015) Energy efficient automated control of irrigation in agriculture by using wireless sensor networks. Computers and Electronics in Agriculture, 113, 154-163.
8.REHMAN, A., ABBASI, A.Z., ISLAM, N., SHAIKH, Z.A. (2014). A review of wireless sensors and networks' applications in agriculture. Computer Standards & Interfaces, 36, 263-270.
9.SRBINOVSKA, M., GAVROVSKI, C., DIMCEV, V., KRKOLEVA, A., BOROZAN, V. (2015) Environmental parameters monitoring in precision agriculture using wireless sensor networks. Journal of Cleaner Production, 88, 297-307.
10.STEFANIDIS, A., NITTEL, S. (EDITORS) (2004) Geosensor networks, CRC Press, USA