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VLIT NODE Sensor Technology and Prefarm

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Abstract

Precision farming systems are based on a detailed monitoring of information and data that are necessary for successful decision-making in crop production. The system is designed for data collection from several resources. In past years an extensive research and development work has been done in the field of wireless sensor networks (WSN) in the world. When a wireless sensor network (WSN) is used for agricultural purposes, it has to provide first of all a long-reach signal. The present paper describes new long distance RFID based technology implementation - VLIT NODE.

Key words

Wireless Sensor Network, Precision Agriculture, RFID.

Anotace

Systémy precizního zemědělství jsou založené na detailním sledování údajů a informací, které jsou nezbytné pro úspěšné rozhodování v rostlinné výrobě. Systém vyžaduje integraci dat z různých zdrojů. V minulých letech začal ve světě výzkum a vývoj v oblasti bezdrátových senzorových sítí (WSN) Na bezdrátové senzorové sítě (WSN) jsou pro použití v zemědělství kladeny specifické požadavky na dlouhý dosah signálu. Článek popisuje novou technologii založenou na RFID dlouhého dosahu - VLIT NODE.

Klíčová slova

Bezdrátové senzorové sítě, přesné zemědělství, RFID.

Introduction

Current agri-food economy is focused on consumers and their food supply. Consumers should be enabled to make their choices upon such aspects as food safety, quality and sustainability. This means that agri-food production business environment is very dynamic, driven by various and changing needs of consumers and society. Production is becoming more and more demand-driven and though it has to be transparent while meeting quality and environmental standards. Moreover, agricultural markets in Europe are under pressure due to high land and labour costs and intensified global competition. Weather conditions are an important factor too. The importance of meteorology in agriculture has been increasing over last decades due to emerging need to access appropriate information as a consequence of the rapid weather condition changes. Although the quality of weather forecast has been improving constantly on a large scale and agriculture profits from it, in many European regions, currently available meteorological data are not sufficient for crop production as a lot of additional local scale data are to be integrated in the specific agro-meteorological models and to make correct decisions in any farm management system. To meet farmers' ambitions especially in areas with relatively small parcels involving the growth of “expensive” cultivars (e.g. wine production), there is a need for establishing networks of local sensors and meteorological stations. The ongoing significant advancements in sensor technologies and in-situ sensing are expected to support also the development of more systematic capabilities for assimilating all sort of in-situ measurements in agro-meteorological models, at relevant scales, to generate immediately (in real time) useful information for farmer's decision. At the same time, the fusion of meteorological sensors data with the existing agro-production database and implementation of new online agro-meteorological models for farms could open new possibilities for farmers to increase quality of their production, to be more competitive on the market and in this way also to increase the sustainability and profit.

Agro meteorological parameters influence significantly not only the crop growth and development, but also the dynamics of other important biological elements, such as plant diseases and pests. Monitoring agro-meteorological variables on the territory together with the application of simulation models, represents the basis for a correct management of cultivation methods and sanitary treatments. Such monitoring requires the development of a reference detail climatologic study of the area in order to assess the climatic conditions and to identify the most representative sites where the meteorological stations for the measurements of the interested variables have to be placed. Once the strategic sites are monitored by stations, data can be collected for further processes, such as spatial interpolations and application of agro-meteorological simulation models.

Precision farming platform - Prefarm

The technology of precision farming guarantees its market success. Technological difficulties that currently and continually occur in this system argue against its practical use by farmers. In case of failure, a Service Company strives to offer a suitable environment not only for data collection and data processing, but also for high quality of other information related to farm management and crop production. Practical distribution of results to customers helps them ensure a variable application of the results on the field. The most important part of services is a data collection technology and data processing system. Remote sensing, crop scanning and soil sampling for management zones classification facilitate operations and recommendations, including economic calculations, to farmers and other users.

Professional services in this domain use the following tools:

- GPS navigation system with or without Differential GPS

- Geographic information system (GIS) environment

- Internet as a tool for data transport, data presentation

- map server technology, web mapping services (wms / raster)

A complex advisory and service system is based on the results of field trials in different crops and locations. The data for WEB processing are prepared and stored by a service organization and farmers. The following data are stored in the central database:

- soil measuring (EM 38 data, soil type data)

- soil sampling (lab analysis for Phosphor, Potash, Magnesium, Calcium, soil pH….)

- crop scanning (NDVI data created from satellite or airborne pictures)

- yield data from yield monitor created during harvest

- other remote sensing data (N-sensor scanning)

- agronomies, field management data (crop rotation, variety, data of applications, weather conditions…..)

The main point of the system is to collect different data in the easiest possible way on the field and farm, and then to reuse them for data processing via web tools.

Open source solution MapServer. A mobile interface of this Open Source solution was developed and there were also the OGC standards (WMS) implemented in order to use the data in the distributed system. A connection with other open source systems (GRASS etc.) was established. Current solutions are Internet Mobile Systems, including analytical tools. The most successful and currently used application from service system is „GIS server for precision farming application with mobile access“. It is focused on increasing agricultural profitability and reducing bad influence of fertilizers and chemicals on the environment.

Sensors

A **sensor** is a device that measures physical quantity and converts it into a signal which can be read by an observer or by an instrument. There exist many kinds of sensors for surveillance and intrusion detection, such as infrared, other optical, microwave-based, or other types. They, for example, video cameras, can be effectively used to support manned surveillance. There are also video-based systems that sense changes in the image and will trigger an alert. Since every sensor used for this kind of applications can be characterised by its location coordinates (changeable) and a time component, the spatial extension and near-real-time availability of sensor-originated information layers in geospatial applications have a great potential.

Sensors are most commonly used to make quantifiable measurements, as opposed to qualitative detection or presence sensing. There are four criteria of sensor selection:

- measurement object – the measurement object influences the type of sensors to be used. Sensors could measure almost anything, but every phenomenon needs different kinds of sensing.

- measurement environment - different needs for outdoor and indoor sensors, and specific needs for sensors working in extreme conditions

- required measurement accuracy

- whether the system is calibrated/certified or not

These four aspects can influence not only the sensor selection but as well their cost.

Every sensor is described using the following characteristics:

- transfer function - functional relationship between a physical input signal and electrical output signal

- sensitivity - relationship between an input physical signal and output electrical signal

- span or dynamic range - range of input physical signals that may be converted to electrical signals by the sensor

- accuracy or inaccuracy - largest expected error between real and ideal output signals

- hysteresis - width of the expected error in terms of the quantity measured

- nonlinearity - maximum deviation from a linear transfer function over the specified dynamic range

- noise - sensors produce some output noise in addition to the output signal

- resolution - minimum detectable signal fluctuation

- bandwidth - response times to an instantaneous change in physical signal

While speaking about sensors, both parts – a sensor and a transducer, are usually taken into account; a sensor is a device that receives a signal or stimulus and responds with an electrical signal, a transducer on the other hand is a converter of one type of energy into another. From a signal conditioning point of view, it is useful to classify sensors as either active or passive. An active sensor requires an external source of excitation. A passive (or self-generating) one generates its own electrical output signal without requiring external voltages or currents.

Wireless Sensors Networks (WSN)

Future utilization of sensor technologies will be mostly based on Wireless Sensors Network which is an emerging technology made up from tiny, wireless sensors or “motes.” Eventually, these devices will be smart enough to communicate with other sensors yet small enough to fit on the head of a pin. Each mote is a tiny computer with a power supply, one or more sensors, and a communication system. The first one is the network independent module Smart Transducer Interface Module (STIM) that contains the transducers, its signal conditioning circuitry and a standard interface. The second one is a network specific module Network Capable Application Processor (NCAP) that implements the interface to the desired control network and also implements the standard interface of the transducer module. Sensor networks widely attract attention thanks to the numerous potential civilian and military applications they offer. The design of sensor networks faces a number of challenges resulting from very demanding requirements on one side, such as high reliability of the decision taken by the network and robustness to node failure, and very limited resources on the other side, such as energy, bandwidth, and node complexity.

Sensor Network Systems provide a novel paradigm for managing, modelling and supporting complex systems requiring massive data gathering, with pervasive and persistent detection/monitoring capabilities. It is not therefore surprising that in recent years, a growing emphasis has been steered toward the employment of sensor networks in various technological fields: e.g. aerospace, environment monitoring, homeland security, smart buildings. A significant amount of resources has been allocated for national (USA, France, Germany) and international (e.g. European Commission) research programs targeted at developing innovative methodologies and emerging technologies in different application fields of wireless sensor network. Main features of a sensor network include the following:

- each node should have a very low power consumption, the capability of recharging its battery or scavenging energy from the environment, and very limited processing capabilities;

- each node should be allowed to function in stand-by mode (to save as much battery as possible) without severely degrading the connectivity of the whole network and without requiring complicated re-routing strategies;

- the estimation/measurement capabilities of the system as a whole should significantly outperform the capabilities of each sensor and the performance should improve as the number of sensors increases, with no mandatory requirement on the transmission of the data of each single sensor toward a centralised control/processing unit; in other words, the network must be scalable and self-organising, i.e. capable of maintaining its functionality (although modifying the performance) when the number of sensor is increased1;

- a sensor network is ultimately an event-driven system and so it is really necessary to guarantee that the information about events of interest reaches the appropriate control nodes, possibly through the simplest propagation mechanism, not necessarily bounded to the common OSI protocol stack layer;

- congestion around the sink nodes should be avoided by introducing some form of distributed processing;

- the information should flow through the network in the simplest possible way, not necessarily relying on sophisticated modulation or multiplexing techniques.

To sum it up, these are the fundamental requirements of a sensor network:

- very low complexity, elementary sensors, associated with low power consumption and low costs

- high reliability of the decision/estimation/measurement of the network as a whole;

- long network life-time for low maintenance and stand-alone operation;

- high scalability;

Problems of current technologies

In past years in world an extensive research and development work is being done to ensure information technology use in agriculture; long range wireless sensor network creation for specific agricultural use, would ensure a PA technological leap, would solve pressing problems for agriculture and would make PA widely available for farmers, even for a low scale use (cranberry fields, fruit gardens, bee-gardens etc.). However, as far as the existing solutions are concerned, the following problem areas remain:

- the existing WSN solutions are in experimental development phase; their implementation is not possible without the specific WSN technology developers' assistance.

- the existing WSNs have a short working range (ability to guarantee communication between sensors only at a range of several tens of meters); therefore their implementation in large area is very expensive.

- the existing WSN technology application programming is not possible without deep WSN operating system (open source Tiny OS, commercial ZigBee etc.) knowledge, that is possible only in specialized development centres;

- recently known WSN physical node technologies with several hundred meters working range don't support available Operating Systems;

- the existing WSNs are not suited for climatic and geographical factors, as well as production manufacturing problems;

- realistic WSN implementation is unthinkable without specific WSN technology that includes physical nodes, sensors, operating system, application programming environment, competence centre support.

It is then obvious that further development is necessary, especially in the following domains:

- new sensor nodes with communication ranges of 200-800m depending on the environment, weather conditions and sensor location that are suited for use in most European countries;

- development of operating system programming that would collect data from sensor nodes and transport them via wireless network to a base computer, such communication protocol configuration that would comply with respective usage target environment, as well as specific usage application programming development in to the utmost simplified environment (in language C with possibly minimal specific knowledge about operating system and WSN physical realization) that would ensure sensor control and communication between sensor nodes;

- development of network architecture

VLIT technology

Nowadays, there are many technologies for building wireless sensor networks available. They are implemented on different platforms, however, their common drawback is that they are able to guarantee the communication between sensors at a distance of only tens of meters.

The technology is internally known as VLIT. It is characterized by 868 MHz working frequency and by a protocol that supports communication mode Point-To-Point, Point-To-Multipoint and the relay station of long distance over several devices. In combination with the mobile gateway and the software interface that is being developed by the Czech Centre for Science and Society (CCSS), VLIT NODE represents a brand new and unique solution for building mobile sensor networks.

Technical specifications:

- the operating frequency of 868 MHz, divided into several sub bands

- bi-directional communication protocol of anti-collision

- communication distance of 200 - 800 meters depending on the environment, weather and location sensors

- different communication modes: challenge, selective call, communications event management

- support for communication Point-to-point, Point-to-multipoint, multi - hopping

- memory integration

- each tag contains a unique number (physical address)

- the calculation of simple operations

- easy connectivity measuring sensors

-very low power consumption

- lifetime of 6 months - 5 years (depending on battery size and type of communication)

- implementation of wireless sensor networks for collecting and transmission of data

- the ability to connect to the existing mobile solutions that ensure the collection of measurement and its transmission to the Internet environment

- integration into the Web environment, storing data in standardized formats

SWE for measurement integration

The concept of sensor web was introduced by NASA. It enables autonomous collaborative observation collections using a variety of sources. Typically, scientific events of interest trigger observation campaigns in an ad hoc sensor constellation and supply multiple data acquisitions as fast and to such extent as possible in a given time period. This is accomplished through a seamless set of software and communication interactions in a system of linked sensors.

As the critical management is getting more and more up-to-date as far as the GIS tools communication is concerned, the OGC begins to release the Sensor Web Enablement (SWE) that should become a standard in integrating various kinds of sensors into one communication language and well-defined web environment. Open geospatial consortium SWE is intended to be a revolutionary approach for exploiting Web-connected sensors such as flood gauges, air pollution monitors, satellite-borne Earth imaging devices, etc. The goal of SWE is to create web-based sensor networks – the goal that implies making all sensors and repositories of sensor data discoverable, accessible and where applicable, controllable via the Internet. Open geospatial consortium defines a set of specifications and services for this goal. Short description of these services is shown below.

Sensor Observation Service

The SOS is an OGC standard that defines a web service interface for discovery and retrieval of real time or archived data. Data are gathered by many sensors, including mobile, stationary, in-situ or remote sensors. The data can take the form of observations or descriptions of the sensor (calibration information, positions, etc.). Observations return encoded as an O&M Observation and the information about the sensor returns encoded in SensorML or TML.

The operations of the SOS are divided into four profiles:

- core profile – three basic operations, provided by every SOS implementation

- transactional profile – operations to register sensors and insert observations into SOS

- enhanced profile – additional optional operations

- entire profile – implements all operations

The core profile has three mandatory core operations that provide its basic functionality:

- GetCapabilities – returns a service description containing information about the service interface and the available sensor data.

- DescribeSensor – returns a description of one specific sensor, sensor system or data producing procedure. The response returns information such as sensor position, calibration, in- and outputs encoded in SensorML or in TML.

- GetObservation – provides access to sensor observations and measurement-data.

Our recent work was focused on creating an SOS implementation which contains core operations. The communication between consumer and implementation is based on xml documents.

An XML schema describes the structure of an XML document. An XML schema

- defines elements that can appear in a document;

- defines attributes that can appear in a document;

- defines which elements are child elements;

- defines the order of child elements;

- defines the number of child elements;

- defines whether an element is empty or can include text;

- defines data types for elements and attributes;

- defines default and fixed values for elements and attributes.

For reading and parsing an XML document, JAXB utilities that are a core part of JAVA are used. JAXB constitutes a framework for processing XML documents. JAXB accesses the XML document from a Java program by presenting the XML document to the program in Java format. The first step in this process is to bind the schema for the XML document. Binding a schema means generating a set of Java classes that represents the schema. All JAXB implementations provide a tool called binding compiler to bind a schema. We have successfully generated all required classes, so now we can handle all SOS related XML documents. Further steps are concerned with adding a convenient API to deal with specific requirements of SOS in a more comfortable way. This lets us publish the position or the track of the sensor and some of the measurements. To publish the measurements in a better way, we can access the data by SOS service (still in development). We have also implemented web service that generates charts from database query.

The OpenGIS® Web Processing Service (WPS) Interface Standard provides rules for standardizing inputs and outputs for geospatial processing services. The standard describes the way of distributing geospatial operations (referred to as "processes") across networks. WPS server can be configured to offer any sort of GIS functionality to clients across the network. The process can take the form of a simple calculation such as putting raster maps together or making buffer around vector feature, as well as complicated models, such as e.g. the climate change model. The main goal of WPS is that computational high-demanded operations are moved from client stations (general desktop PC) to server.

Three types of request-response pairs are defined. Request can be in Key-Value-Pairs (KVP) encoding, as well as an XML document. Server response is always formatted as an XML document.

- GetCapabilities - Server returns Capabilities document. The first part of the document includes metadata about the server provider and other server features. The second part of the document includes a list of processes available on the server.

- DescribeProcess - Server returns ProcessDescription document. Apart from the process identifier, title and abstract, process inputs and outputs are defined.

- Execute - Client hands over necessary inputs for partial process, the server provides geospatial calculations and returns document with all process outputs.

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Three basic types of input and output data are defined:

- LiteralData - character strings as well as integer or double numbers

- BoundingBoxData - two pairs of coordinates

- ComplexValue and ComplexValueReference - Input and output vector and/or raster data. Vector data (e.g. GML files) can be directly part of request/response execute document (then the input is of type ComplexValue). Client can specify only URL to input data (e.g. address to Web Coveradge Server (WCS)). In this case, the data are those of ComplexValueReference type.

Conclusion

Currently there have been 200 prototypes of sensors nodes developed and their deployment and filed testing started. Intensive filed testing is provided in the Czech Republic and Latvia. Testing in Italy is expected during this season too.

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