ICT-AGRI Call 1 Final Project Report

Acronym: GeoWebAgri

Title: Geospatial ICT infrastructure for agricultural machines and FMIS in planning and operation of precision farming

Consortium

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1. Final publishable summary report

The activities of the GeoWebAgri project were targeted towards four objectives relating to the topic of the project: a geospatial ICT infrastructure for agricultural machines and FMIS in planning and operation of precision farming.

The first objective was to specify the ICT infrastructure using current standard technologies of spatial data infrastructure (SDI) from Open Geospatial Consortium (OGC) together with other compatible specifications (e.g. from International Organization for Standardization, World Wide Web Consortium). A survey on the SDI technologies indicated their suitability for the purposes of precision agriculture. A complementing survey of farmers' requirements for this technology pointed out a need for easy-to-use applications (Deliverable 1.2).

The second objective was to design and implement the challenging parts of the ICT infrastructure in order to confirm its viability. The designs and implementations seem to confirm the viability, although practical applications will still require further work. The designs and implementations included an interpreter of agricultural production standards referring to spatial data (Deliverable 2.4), evaluation of an WFS-T service utilising an FMIS (Deliverable 2.2) and own prototype implementations of WFS, WFS-T and WMS services in association to a spatial database.

The third objective was to evaluate the ICT infrastructure through selecting a case study. The case study indicated that it is feasible to fulfill the data access requirements of an ISOBUS-compatible task controller in a precision spaying task with a suitable SDI infrastructure utilizing OGC services (Deliverable 3.1).

The fourth objective was to disseminate and exploit the results of the project. The results of the project were published in about ten scientific publications including one doctoral thesis and presented in a few conference presentations. The results are summarized at the project web site (http://geowebagri.eu).

The project's results prove the benefit of a well defined SDI. There is a huge potential by the integration of spatial data from manifold sources in a standardized way and their intelligent, further processing. The infrastructure offers a wide range of flexible interfaces for many data sources, e.g. sensors. Through the usage of the recommended technologies known bottlenecks of the agrocommunity could be overcome (agriXchange - GeoFertilizer). Exchange processes and the exchanged data by well known standards support location specific applications.

2. Description of activities and final results

The activities of the GeoWebAgri project were organized according to the four objectives of the project. The first three objectives included (1) specification, (2) design and implementation, and (3) evaluation of a geospatial ICT infrastructure for agricultural machines and FMIS in planning and operation of precision farming. In order to achieve these objectives a set of deliverables listed in the table below.

The fourth objective was to disseminate and exploit the results of the project. The publications produced for the dissemination purposes are listed later in the chapter dissemination. Some of the publications were also provided as parts of deliverables. The deliverables with the type of a document are available at the project website alongside some of the publications.

Table 1. List of project deliverables. The deliverables deviating from the project plan are indicated with italic text (additional documents, publications complementing or replacing a deliverable).

Deliverable no.	Short description	Nature
1.1	Documentation of the identified standards related to geospatial data handling as well as their role and applicability for the project tasks	Document
1.2	Evaluation report on user-requirements derived from analysis and workshop	Document
1.3	Modelling of the Integration of FMIS with SDI	Document
2.1	A GeoRIF interpreter for geospatial agricultural production rules.	Software, journal paper [4], *document, conference paper [6]*
2.2	Evaluation report on FMIS (Mark- Online) featuring WFS-T	Software, *conference paper [7]*
2.3	Application framework for conversion of geographical features to control actions on a web server based electronic control unit	Software, *conference paper [7]*
2.4	Implementations of the SDI components	Software, service, *document*
3.1	Automatic operational control of field operations based on interpretation of web feature services	Journal paper [2]
3.2	Evaluation report on precision spraying task	Document
3.3	System integration of external data providers and partners' components, including data from a tractor and sensors	Software, service, data

Objective 1. To specify an ICT infrastructure for handling geospatial data both in agricultural machines and FMIS as a development of current systems.

In arable farming, data exchange between machinery and implements at field level (and partly management systems at farm level) is supported by an extensive and widely adopted ISO standard (ISOBUS/ISO11873). However, data exchange between different systems at farm level is currently insufficient. Some specific examples of point-to-point interfaces are found, but there are no common standards for data exchange at this level of integration. Information exchange between the farm level and other actors (e.g. advisors, government, processors) is also not sufficiently organized (Wolfert et al., 2010). There have been attempts in the past of developing communication standards for farm management systems (agroXML, ISO 11783-10, agriXchange, iGreen). Moreover there are initiatives towards the establishment of infrastructures for spatial information in Europe to support the implementation of environmental policies of the European Community as well as of policies or activities which may have an impact on the environment in Europe (INSPIRE).

This objective is a first attempt to create a novel Agricultural Network (Geo)Information Model that is based on i) a review of SDI components and standards, ii) extracting user-requirements, and iii) specification of an information structure for a selected field operation based on formal data modeling by applying the concepts of the Unified Modeling Language (UML).

The posed general hypothesis was: Can the current standards provide the extensible markup language structure required for the SDI of a specific precision farming operation? An answer was found by evaluating the European INSPIRE project, the ISO 19100 series of international standards of geographic information, and the Open Geospatial Consortium (OGC) implementation standards. In conclusion, the work carried out by the OGC and the ISO TC/211 working group has revealed the conceptual schema language required to generate a novel agricultural network information and associated data model. Ongoing research is conducted by the GeoWebAgri consortium to develop the data model that covers the multiple entities involved in the planning and execution of a precision farming task. The project has decomposed the data entities associated with a spraying task as an example ranging from the strategically to the operational planning level, execution control and evaluation, and a number of underlying processes and sub-processes. The data entities and attributes inherent in the information flows have been identified based on the identified information flows associated with the management functions and controlling of a spraying operation.

Deliverable 1.1 Documentation of the identified standards related to geospatial data handling as well as their role and applicability for the project tasks

The input and output interfaces of the SDI were specified using existing and widely adoptable standards and their applicability was assessed. Necessary modifications or supplements, which are needed to handle Precision Farming data, were identified. The technical components were analyzed in relation to the user requirements of task 1.2.

The identified components for an SDI are so far: geodata stores, meta data services, decision support systems, geodata providers, terminals/controllers, sensors, legislation/rule interpreters, farm management systems, meteorological services. The service infrastructure communicates through interfaces according to standards like OGC Web Processing Service (WPS), OGC Web Map Service (WMS), OGC Web Feature Service (WFS), OGC WFS-T, ISO 19115, OGC Sensor Web Enablement (SWE), ISO 19103 (CSL, UML), ISO 11783-10.

A geographic information dataset in terms of the mentioned standards contains:

- Features, including feature attributes, feature relationships and feature operations.
- Spatial objects that may describe the spatial properties of features, or are complex data structures that associate values of attributes to individual positions within a defined space.
- Descriptions of the position of spatial objects in space and time.
- The semantic structure of the above mentioned dataset for a specific domain as Precision Farming is described through an application schema. Specifically, the application schema identifies the spatial object types and reference systems required to provide a complete description of geographic information in the dataset. The metadata dataset allows users to search for, evaluate, compare and order geographic data. It describes the administration, organization, contents and quality of geographic information in datasets.

Deliverable 1.2 Evaluation report on user-requirements derived from analysis and workshop

As a part of the GeoWebAgri project an internet based questionnaire was conducted among farmers, contractors, agricultural advisors, machine and equipment manufactures and researchers in Germany, Finland and Denmark from June 2012 to September 2012. The link was widely spread by publishing articles about the project in different magazines and distribute it through mailing lists and web pages. A total of 257 respondents completed the questionnaire. 194 of these were farmers. 55% of the respondent farmers were already using desktop farm management systems, and 36% of the respondent farmers also had previous experiences in using precision farming technique. 28% of the respondents with previous experiences in precision farming had 'often' or 'always' experienced difficulties due to 'language problems' between different farm equipment or between their farm equipment and a software program. 59% of the farmers had 'often' or 'always' a reliable mobile internet access in the field, whereas 12% did not know the answer to that question. If the internet access is not improved, then all future systems should be able to work both online and off line. Among the presented precision farming techniques auto steering and automatic boom section control on sprayers both had 50 % or more ratings as 'very important' or 'necessary' techniques. Overall, the ratings of a number of different precision farming techniques were however, surprisingly similar. Finally, no more than 18 % of the farmers were willing to spend more than 3 minutes extra per field task, e.g. for typing in information or waiting for GPS-signal. This demonstrated that highly time efficient and reliable semi-automatic or fully automatic systems with a minimum of manual input will be required, if precision farming should achieve a high penetration in future farming.

Deliverable 1.3 Modelling of the Integration of FMIS with SDI

The basic idea is to model all the activities and decisions, which take place in a targeted production section and combine this modeling with all the relevant data. The specific modeled precision application was a spraying operation. The formal description includes entity definition (entities involved in the planning and execution of the spraying operation), a process model (activities and decision processes) and a data model (data relating to the processes). The defined processes in the process model and the entities and attributes in the data model provide the basis for developing compatible spatial data infrastructure.

The method and the results of the decomposing exercise are found in detail in the resulting internal report [4]. The exercise has revealed the following elements (interfaces) for the GeoWebAgri proposed SDI. The elements are listed as a summary and thus independent of planning levels:

- Geographical data on the environment; i.e. cultivation authorizations, environmental sensitive areas,
- Database of legislative rules for crop growing, i.e. spraying technology, chemical handling, spraying time
- Database of financial reporting of farm data
- Database and access to field experimental results; i.e. advisory services, product registrations
- Database of technologies and products on the market
- Database of crop rotation plans, historical data on spraying operations; from farm recorded data, benchmarking and historical evaluation
- Database of local weather data; i.e. historical data as well as weather forecast.
- The information flow from and to the listed SDI elements was also a result of the exercise presented in the internal report [4]. The exercise of modelling the information flow should also be considered as an attempt to define the spatial dataset relevant for the case of managing a spraying operation.

- The authors of the internal report comprising the results of task 1.1-1.3 have agreed to further revise and submit the paper to an international journal.

Objective 2. To confirm the viability of the challenging parts of the specified ICT infrastructure with proof of concept implementations.

The specified ICT infrastructure was realized in the WP2 of the project. It consists of the SDI with individual equipped web servers, a GeoRIF interpreter and a client for browser based implemented controlling. All components were selected, extended and configured for the precision farming tasks and the information exchange needed for the proof of the theoretical concepts.

From the EU funded project "FutureFarm" a rule interpreter was used, which analyses rules regarding a spatial input. The development focused as well on the spatial data used in agriculture as on the implementation of the GeoRIF-web service into the SDI.

Furthermore a client was developed to post the values of analyzed field samples directly to a central data storage. The client to server communication was realized by the OGC standard WFS-T (Web Feature Service – Transactional). The method realizes a direct, without temporal delay, integration of information of attributes into the spatial data sets. Besides field samples the utilized tools could be used for every other kind of data integration. By the use of standard interfaces, the clients can easily integrated into existing environments (e.g. Mark-Online).

To realize the field operation case studies of the following analysis, a complete framework of an SDI for precision farming was set up. Components are a spatial data base, a web server, different web applications and clients. The access to further external sources is also possible. All components were chosen to reach a maximum performance by highest flexibility. The publishing and integration of spatial data by international standards were needs, as well as the usability of these services by meta data information systems and clients for visualization and browsing through the data.

Deliverable 2.1 A GeoRIF interpreter for geospatial agricultural production rules

GeoRIF interpreter is the inference engine for spatially extended W3C Rules Interchange Format (RIF) for use in the evaluation of RIF-encoded agricultural production standards. The development of the interpreter started during the FutureFarm EU project and was continued in GeoWebAgri.The interpreter is a software library written in the Ruby programming language, which is embedded within a Web-framework to provide a spatial inference service through a RESTful interface. In GeoWebAgri project the utilization of spatial data sources by the GeoRIF interpreter was designed and implemented. The extended design was also evaluated more thoroughly with respect to its performance. The design is based selected data representations and a transformation process that prepares the data for the interpreter. The data representations include GML, GeoRIF and terms of AGROVOC. The spatial data is assumed to be represented as GML. The spatial rules are represented as GeoRIF, which also uses GML for representation of spatial literals. AGROVOC is utilized as a vocabulary for referring to agricultural data. A data transformation is used to change the vocabulary of GML data to AGROVOC.

Deliverable 2.2 Evaluation report on FMIS (Mark-Online) featuring WFS-T

The deliverables 2.2 and 2.3 demonstrates the very first combination of the ISO 19100 and OGC series of standards into a novel practice that geospatial data is created, modified and exchanged via the Internet between the two SDI components; a commercial FMIS and a mobile implement control system (MICS) in this case study.

The ISO 19142 defines two main WFS classes; basic and transaction. The basic WFS can provide three read-only operations; *GetCapabilities, DescribeFeatureType and GetFeature.*

A Transaction WFS (WFS-T) comprise all operations as in basic WFS, with an additional Transaction operation. The following standardized WFS and WFS-T operations were supported by the Danish Knowledge Center for Agriculture (KCA) field database server used in this study (Mark-Online): *GetCapabilities, DescribeFeature, GetFeature, Transaction*, which is four out of a total of eleven defined operations defined by the ISO19142 standard. The Mark-Online also supported SOAP operations for web services for the FMIS web clients. The paper of deliverable 2.3 and 2.4 [10] comprise descriptions and illustrations of the SDI components of the researched and developed service oriented architecture (SOA) within the GeoWebAgri project.

Deliverable 2.3 Application framework for conversion of geographical features to control actions on a web server based electronic control unit

Data was recorded by a novel web client based electronic control unit (ECU) and data was exchanged online with the web server offering WFS from deliverable 2.2. The features in this study refer to field operations management data in terms of e.g. date of operation, dose rate, method, means etc. Data was organized and stored on the server. It was demonstrated that data can easily be requested for further processing and use via the WFS and WFS-T.

The selected exchange format between web client and server was the Geographic Markup Language (GML) specified by the OGC and ISO 19136. The software for the web client ECU was developed in this project. The initial step for the web client ECU software was to request the service meta data, which is a description of the feature types it can service and what operations are supported on each feature type. The service meta data were prepared for demonstration purposes only by KCA and available for web clients by requesting the *GetCapabilities* operation of the WFS via 'HTTP GET'. In the URL a user ID and password is required. The framework for requesting and editing data using ISO 19100 series I detailed in [10] comprise descriptions and illustrations of the SDI components of the researched and developed service oriented architecture (SOA) within the GeoWebAgri project.

Deliverable 2.3 Integration of data from external sources

Deliverable 2.3 is a demonstration of a system that can integrate external data from different SDI components with electronic control units on mobile vehicles and implements. The integration of the essential standardised WFS operations (*GetCapabilities, GetFeatureType, GetFeature and Transaction*) with the presented web client ECU solution for task management worked flawlessly and the transferred amount of data was rather small and the update rate of 0.2 Hz was high [10].

Deliverable 2.4 Implementations of the SDI components

One central component of the SDI optimized for precision farming applications is the central database storing operation data, mainly spatial information, as well as a web server allowing interaction by web services. Regarding the results of WP1 a database and a server were set up at University of Hohenheim. The planing was mainly influenced by the identified needs of an flexible and high performant spatial data infrastructure.

A well proven Apache webserver was chosen and extended by a Tomcat servlet engine. The server environment is extended on the one hand with a powerful geodatabase (PostgreSQL and PostGIS) and on the other hand by web services, like the WebGIS-components "Geoserver" and "MapBender" or the meta data tool Geonetwork Opensource. All components support international standards. The single components acting together as one tool, where every element is assigned to a special function.

Objective 3. To evaluate the impact of the possible application of the specified ICT infrastructure on farming objectives

The objective of this work package was to evaluate the impact of the possible application of the specified ICT infrastructure on farming objectives with a main case study and a group of smaller use cases. The objective was successfully achieved. A complete precision spraying case study was performed together with real time operational case study.

Deliverable 3.1 Automatic operational control of field operations based on interpretation of web feature services

Field operations on arable farming are often very data intensive tasks. There are also an increasing number of regulations to confirm food safety and environmental aspects. Also, the number of tools for the best practice management including precision agriculture is growing. However, there are no standardized, automated methods for the compliance management and the involved standards, regulations or best practices dynamically change over time and are dependent on the specific location. Therefore compliance checks during the work progress (online) or on-demand are difficult to achieve. With current methods, the spatial accuracy of the work can be relatively high while the temporal accuracy can be very poor. In this project, we developed our task controller (TC) prototype with an ISOBUS-compatible process data messages to be able to utilize multiple external services such as WFS (Web Feature Service) during the field operation. The WFS was set up in Germany providing real geo data, while the actual task execution was performed in Finland. We implemented a possibility to use and integrate external data from different sources in the TC on the tractor. The presented methods serve as the basis for the development of multiple tools, improving farming system development, environmental risk reduction of agricultural production and compliance checks. Existing information sources, as delivered by on board sensors, weather and forecast information, disease pressure, spatial environmental risks and real time remote sensing can be combined for new solutions of this kind. The development of technical standards for the seamless data exchange in the agricultural domain is therefore crucial. This work focuses on spatial data exchange between heterogeneous IT systems with an on-field machinery component for precision management approaches.

The highlights of this deliverable were:

- A task controller commanding ISOBUS sprayer and using external spatial data.
- WFS and WMS as a decision support during a task execution.
- Outlined dynamic application task for precision farming.
- Farm machinery standardization and FMIS software components need adjustment.

Deliverable 3.2 Evaluation report on precision spraying task

This document presents a concrete application for a precision spraying case applying the novel Agricultural Network Information Model created in GeoWebAgri project. The presented spraying case included a task planning, spraying work and spraying work evaluation. The objective for the study was to describe the construction and evaluate a case study of the spraying task planning and execution that uses spatial information from many different sources. The central elements were the interoperability of geodata and location aware decision components. The knowledge and components developed and gained in earlier work packages in GeoWebAgri project were utilized for the task preparation.

As a start, a known possible spatial data flow in an operational planning and execution of a precision spraying operation were constructed and a general model for the spraying task planning and execution was presented. Then a case study using the determined SDI (spatial data infrastructure) in the point of interoperability of different geodata and FMIS (farm management information system) was established. The SDI components were: geodata stores (GDB), metadata services, decision support systems (FMIS) (UAV-NIR service), geodata providers (FMIS, WFS), terminals/controllers (TC), sensors (sprayer sensors, FTP), legislation/rule interpreters (GeoRIF), farm management systems (FMIS), metrological services (FTP). This approach required exploitation of multiple prototype components and systems constructed recently by other supporting projects. Hypotheses for each prototype service were determined and these components were evaluated. Also the spraying work was evaluated. Some of the tests were simulations. The major benefits are coming from the increased accuracy and confidence level in the decision making processes and from the traceability aspects. This study served well as revealing the potential ICT-solutions for automating agronomic decisions. Available and usable data makes it possible to construct many new smart decision support systems. However, there is still a high complexity of the definition of different interfaces and the applicability of different services and applications.

Deliverable 3.3. System integration of external data providers and partners' components, including data from a tractor and sensors

This document deals with the system integration of external data. Therefore two additional use cases were developed, presenting the integration of external data providers as well as including sensor data from the machine into the SDI. Both examples show the extensibility of the developed infrastructure.

The first use case describes the importance of meta data for a distributed system. By the example of the German "portalU", a web portal for environment related data, an additional source was integrated into the infrastructure. Users could use a web interface to search for additional information and integrate them directly to the system. By the EU initiative INSPIRE the number of possible data sets for the integration is increasing.The implementation was done by the use of the web service "GeoNetwork Opensource", installed at the GeoWebAgri server. The communication was handled by the CSW (catalogue service for the web), an official standard of the OGC for the standardized exchange of meta data.

A further use case dealt with sensor data handling. Nowadays sensors are an important tool for precision field applications. Sampled data have to be stored for documentation needs and integrated into the infrastructure of machine and FMIS for additional analyses. The OGC offers the powerful tool set of "sensor web enablement" (SWE) for the technical implementation of sensors in an SDI. By a client (52°North SOS Client) in the environment of the server, sensors were registered and observations were inserted. Besides sensor description and sampling data were requested. All communication was done by standards.

3. General description of the cooperation over the duration of the project

The cooperation take place in three project meetings and through bilateral relationships during rest of the time. Aalto University arranged the Kick-off meeting on 21-22 March 2011 in Espoo, Finland, KCA the Mid-Term meeting on 17-18 April 2012 in Aarhus, Denmark, and Rostock University the Final Meeting on 9-10 April 2013 in Rostock, Germany. All partners attended the meetings.

Cooperation relationships existed on one hand between Danish (particularly AU) and German partners, and on the other hand between Finnish and German partners.The theoretical review given in

WP 1 includes a close collaboration of all partners culminating in the mid-term meeting 2012 in Aarhus. By the different scientific backgrounds, every group had a individual view to the topic. File storage and synchronization services were used to enable cooperation over long distances.

In the phase of realization and concrete analyses, tasks were split up to the partners. For example an existing webservice based on a Danish (KCA) rule server (pesticide information database) was used to provide GeoRIF-encoded rules to prove the functionality of the GeoRIF interpreter [D1.3, D2.1]. Another existing webservice from the FMIS at KCA was modified and used as the central geospatial database server for the work carried out in task 2.2 with AU, KCA, UH and RU.

MTT and UH worked together in the precision splaying case study. UH provided the spatial data infrastructure and MTT the case problem and task controller. While the members of UH have experience in the use of sensors and spatial data technologies, the collaboration with the MTT was very productive by the partner's knowledge about machine control. The MTT had already developed a research task controller for the ISOBUS-interface. These experience were used to control a field operation by integrating spatial data, prepared and published by the UH, into the Finnish task controller. The results of the cooperation were published in [2].

Aalto cooperated with RU in development of the GeoRIF interpreter. Again, all other partners benefited from the work of KCA about user requirements. At the mid-term meeting in Denmark, all participants of the project evaluated the initial proposed questions for the internet survey. A number of useful comments and ideas improved the questionnaire. The participants were helpful on the translations and also on distributing the questionnaire in the three countries.

Besides the cooperation between national partner was strengthened. RU and UH intensified their exchange. Both RU and UH are doing research in the domain of geoinformatics in agriculture, although from a different background. Whilst RU has a generic viewpoint on Precision Farming applications from the disciplines of geodesy and geoinformatics, the partner from Hohenheim is situated in the specific domain of phytomedicine. GeoWebAgri allowed a productive cooperation between two parties approaching one topic from two different perspectives. As a first result, both partners presented results at the EFITA-conference [10]. A further publication will follow, dealing with the results of the project and their potential for future technologies.

4. Impact statement

It is justifiable to state that GeoWebAgri project created various impact to the knowledge about technology and utilization of spatial data in precision farming.

The impact of the work about GeoRIF interpreter and geospatial agricultural rules is more academic and application oriented. Some parts of this work could be utilized in applications also in a short time frame. However, as a whole it would require existence of more formalization of agricultural rules and an rules-related ICT infrastructure which is not like to exist in near future.The academic results, particularly the methodology to combine spatial data and rule processing, can be applied also in in other domains than agriculture.

Representatives of the producers of precision farming technologies were interested in the topic and the results of the project. At conferences and presentations they confirmed the importance of an powerful SDI for precision farming applications and encouraged to further work on the topic.

The composition of the project group was very helpful in creating the impacts of the GeoWebAgri project. There were enough interdisciplinary knowledge and synergies among the partners. Some of the partners were more oriented to agriculture (KCA, MTT) whereas some others were oriented to required technologies (Aalto, UH). Some partners had considerable expertise in both (AU, RU). The different expertise were combined though common case studies and comparizons between related technical solutions.

The interdisciplinarity benefits from the cooperation was especially seen between the Danish farm advisory service KCA (with daily contact to farmers and advisors) and the universities conducting more basic technical research, e.g. AU and RU.

5. Exploitation and dissemination measures

The exploitation and dissemination activities were mostly performed according to the project plan. The measures were created.

Project web site

A project website for dissemination purposes. It contains basic information about the project together with public deliverables and scientific publications. The project web site is available at http://geowebagri.eu.

SDI components

The software components for the SDI were installed and configured. All partners were able to access data by services handling the data in required standards like WFS, WMS, GML, ISO 19115 and GeoRIF. An detailed documentation is given in the deliverable 2.4. The applied components were presented to the public at conferences and by publications.

Questionnaire

The results from the questionnaire were published on the internet:

https://www.landbrugsinfo.dk/Planteavl/Praecisionsjordbrug-og-GIS/Sider/Identified-user-requirements-for-precision-farming_pl_13_1369.aspx

Scientific publications

The results of the project were published in several scientific publications during the project. The publications included 3 journal papers, 6 conference papers and one doctoral thesis.

Doctoral thesis

[1] Nikkilä, R. Automated control of compliance with production standards in precision agriculture, Aalto University, Doctoral dissertations 84/2013.

Journal papers

[2] Kaivosoja, J., Jackenkroll, M., Linkolehto, R. Weis, M., Gerhards, R. Automatic Control of Farming Operations Based on Spatial Web Services, Computers and Electronics in Agriculture. (submitted)

[3] Nash, E., Nikkilä, R., Wiebensohn, J., Walter, K., Bill, R. Interchange of geospatial rules – towards georules interchange format (GeoRIF)?. GIS.Science, 24, 82-94, 2011.

[4] Nikkilä, R., Nash, E., Wiebensohn, J., Seilonen, I., Koskinen, K. Spatial inference with an interchangeable rule format, International Journal of Geographical Information Science, Vol. 27, No. 6, 2013, p. 1210-1226.

Conference papers

[5] Jackenkroll, M., Weis, M., Gerhards, R. A spatial data infrastructure concept for precision farming tasks, 33. GIL-Jahrestagung, Potsdam, February 20–21, 2013.

[6] Nikkilä, R., Wiebensohn, J., Seilonen, I., Koskinen, K. Knowledge based methods for spatial data integration in agriculture: Case of automated compliance control, International Conference on Agricultural Engineering (AgEng 2012), Valencia, Spain, July 8-12, 2012.

[7] Nørremark, M., Jørgensen, O., Bligaard, J., Sørensen, C.G. (2013). Data interchange between Web client based task controllers and management information systems using ISO and OGC standards. *In*: Proceedings of the 2013 EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Torino, Italy, June 24-27 2013, 8 pp.

[8] Nørremark, M., Sørensen, C.G. (2013). Geospatial data infrastructure for agricultural machines and FMIS in planning, execution and evaluation of field operations. *In*:Abstracts of the SmartAgriMatics conference, Paris, France, 2 pp.

[9] Rüh, C., Wiebensohn, J. Überführung landwirtschaftlicher Schlagwortlisten in das Simple Knowledge Organization System (SKOS), 33. GIL-Jahrestagung, Potsdam, February 20–21, 2013.

[10] Wiebensohn, J., Jackenkroll, M. Evaluation and Modelling of a Standard Based Spatial Data Infrastructure for Precision Farming, EFITA-WCCA-CIGR Conference, Torino, Italy, June 23-27, 2013.

Non-scientific publications

During the project there were several media presenting the idea of GeoWebAgri:

- magazine ACKERplus (Ulmer-Verlag), 07.2012, page 14
- Facebook page of publisher company "Ulmer Verlag"
- magazine "Agrarnachrichten" of "proplanta" publishing, July 1st 2012
- webpage of the competence center for sensors and geoinformation-systems at the University of Hohenheim
- newsletters of the competence center for sensors and geoinformation systems at the University of Hohenheim (3/2013, 1/2013)
- Introduction to the GeoWebAgri project at http://www.vfl.dk/Projekter/Lettereudvekslingafdatailandbrugsmaskinbranchen.htm
- Dissemination of the user requirements at https://www.landbrugsinfo.dk/Planteavl/Praecisionsjordbrug-og-GIS/Sider/landmaends-erfaringer-krav-praecisionslandbrug_pl_13_1370.aspx

Presentations

The following public presentations were given about the topics of GeoWebAgri during the project:

- ClausG. Sørensen represented the GeoWebAgri project and present specifically the resu lts and outcome of WP1 at the Smart Agrimatics international conference, Forest Hill, Paris-La Villette, France, June 13-14th 2012.
- Nørremark, M. (2013). Data interchange between Web client based task controllers and management information systems using ISO and OGC standards. Oral presentation at the

2013 EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Torino, Italy, June 24-27 2013

- The results of the evaluation of the spatial data infrastructure in precision farming was presented at the annual meeting of the German society for computer Science in agriculture, forestry and the food sector ("Gesellschaft für Informatik in der Land-, Forst- und Ernährungswirtschaft"), Potsdam, Germany, Februar 20-21th 2013.
- Wiebensohn, J., Jackenkroll, M. Evaluation and Modelling of a Standard Based Spatial Data Infrastructure for Precision Farming, EFITA-WCCA-CIGR Conference, Torino, Italy, June 23-27, 2013.

Exploitation

The application of WFS and WFS-T for utilisation directly with machine control will be exploited in the first place by KCA for future generations of their FMIS. Secondly, three Danish machine manufactures that have adapted a commercial server based platform for machine control for sprayers and fertiliser spreaders will be able to exploit the results of the presented studies of the GeoWebAgri project to get more knowledge about the opportunities of spatial data infrastructure given by the OpenGIS standards. The presented demonstration of machine control in WP3.2 was done in the awareness of the products SprayMaster and SpreaderMaster by the company Lykketronic A/S, to enable this electronic manufacturer and inventor of the server based machine control to add value to their products in the future. The company is a pioneer on this novel machine control approach, and has expressed their great interest in a demonstration of the results of WP 3.2 as soon as possible.

There was always a large interest of companies about the results during public presentations. The German company geo-konzept, a service provider dealing with geoinformation in agriculture, contacts the GeoWebAgri group to initiate further research on the project's topic. There are plans for a cooperation.

6. Explanation of the use of resources (final financial report)

There were no deviations participant's use of resources pertinent to the project as a whole.

7. Project deliverables

[D1.1] Deliverable 1.1: Review of SDI components and standards.
Available at: http://geowebagri.eu/system/assets/1/original/Deliverable_1_1.pdf

[D1.2] Deliverable 1.2: Evaluation report on user-requirements derived from analysis and workshop. Available at: https://www.landbrugsinfo.dk/Planteavl/Praecisionsjordbrug-og-GIS/Sider/identified-user-requirements-for-precision-farming_pl_13_1369.aspx

[D1.3] Deliverable 1.3: Modelling of the Integration of FMIS with SDI.
Available at: http://geowebagri.eu/system/assets/2/original/Deliverable_1_3.pdf

[D2.1] Deliverable 2.1: A GeoRIF interpreter for geospatial agricultural production rules.
Available at: http://geowebagri.eu/system/assets/3/original/Deliverable_2_1.pdf

[D2.2] Deliverable 2.2: Evaluation report on FMIS (Mark-Online) featuring WFS-T.
Available at: http://geowebagri.eu/system/assets/9/original/Norremark_2013.pdf

[D2.3] Deliverable 2.3: Application framework for conversion of geographical features to control actions on a web server based electronic control unit.

Available at: http://geowebagri.eu/system/assets/10/original/Norremark__slides_2013.pdf

[D2.4] Deliverable 2.4: Implementations of the SDI components.
Available at: http://geowebagri.eu/system/assets/4/original/deliverable_2_4.pdf

[D3.1] Deliverable 3.1: Automatic operational control of field operations based on interpretation of web feature services.

[D3.2] Deliverable 3.2: Evaluation report on precision spraying task.
Available at: http://geowebagri.eu/system/assets/5/original/Deliverable_3_2.pdf

[D3.3] Deliverable 3.3: System integration of external data providers and partners' components, including data from a tractor and sensors.