ICT-AGRI Call 1 Final Project Report

Acronym STRATOS

Title open System for TRAcTOrs' autonomouS Operations

Consortium

Participant Role	Participant Name	Participant Short Name	Country
Coordinator	Università degli studi di Modena e Reggio Emilia	UNIMORE	Italy
Partner	Riga Technical University	UNIRIGA	Latvia
Partner	Università della Svizzera italiana	USI	Switzerland
Partner	Institute for Agricultural and Earthmoving Machines (CNR)	IMAMOTER	Italy
Partner	Israel Institute of Technology	TECHNION	Israel
Partner	Re:Lab	RELAB	Italy

Final publishable summary report

Soil is a complex, living, changing and dynamic component of the agro-ecosystem. It is subject to alteration, and can be either degraded or wisely managed. A thorough understanding of the ecology of the soil ecosystem is a key part of designing and managing agro-ecosystems in which the long-term fertility and productive capacity of the soil is maintained, or even improved. This understanding begins with knowledge of how soil is formed in a given ecological region, and includes integration of all the components that contribute to the structure and function of the entire soil. By measuring some of these components and determining how they respond to management in an agricultural context, a foundation for assessing the health of the soil can be established. Ultimately, indicators of sustainability can be grounded in the assessment of soil conditions and how they change as a result of the choices a farmer makes in managing the agro-ecosystem.

Measurements of soil and terrain parameters, such as pH and soil moisture, soil temperature and bulk density, water holding capacity, etc.; can be obtained by means of the analysis of optical and microwave remote sensing data or by a set of suitable sensors placed on the field. In order to reduce the number of sensors and optimize the agricultural job, the sensors can be placed on board to a tractor which is moving within the area to be monitored. and or carried on the tractor or any other agricultural machine.

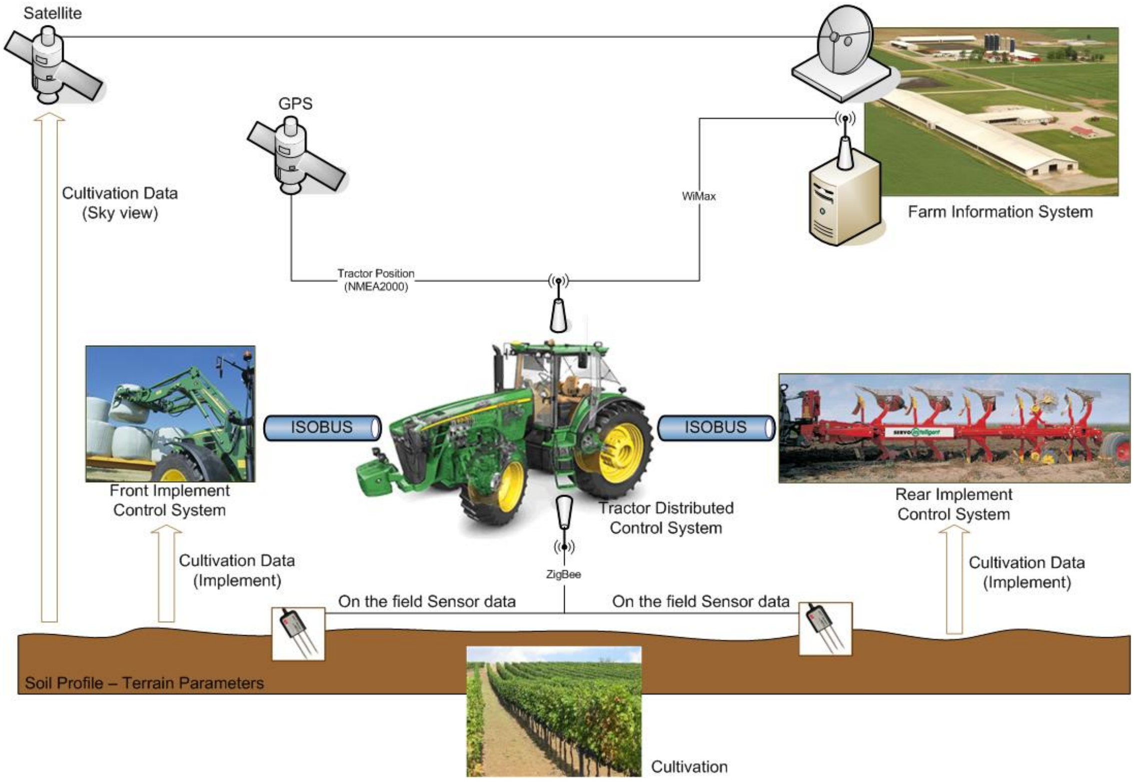

Figure 1. A integrated system for the acquisition of soil and terrain data from various sources.

The main objective of the STRATOS project was to develop an open ICT hardware-software infrastructure, enabling the partial automation of tractors and at the same time enhancing their operational safety and production efficiency, with the positive effects of reduced accident risk and environmental impact.

In more details, STRATOS project target was to develop and demonstrate new functions enabled by the ISOBUS technology (ISO 11783) that supports a substantial improvement of the quality of the farming jobs.

In particular, the project developed a technology based on ISOBUS compliant, wireless self-powered sensor network for the real time measurement of soil and harvester conditions. The sensors was designed and connected to the tractor-implement network and the data acquired were sent to a server through an internet link, using a specially designed fleet management system, able to exchange with a server any type of data, simply modifying the data recognition pattern in the data-base.

In this way, Task Controller (an ICT component defined by ISOBUS specification which supervises actively the farming job performed by the tractor) could optimize the whole tractor and implement operational modes to improve the farming job quality and safety of the overall systems and the Farm Management System (FMIS as defined both in ISOBUS and in the WG5 NWIP for the new ISO standard for Wireless communication in Agriculture) can collect data from the field useful for the field management in the next years.

Moreover, because the second main target of STRATOS project is to increase the operational safety of the tractor, this goal was proven by integrating new significant data sources and implementing new monitoring algorithms and control strategies into the active Task Controller.

The lack of information related to mechanical implements conditions, as an example, can be covered by connecting wireless sensors in the implement, able to link data related to the implement status and geometry, without any complex operation in the same implement, despite its age or old structure.

As a corollary, it can be noted that, even if not directly related with the current work session, wireless sensors can be connected to the tractor in order to collect data from the field, useful to plan the work for the next season or just in for the next week, as a function of the nature of information collected.

Finally it can be stated that ICT can enable a new approach to the tractor-implement management and to the farm management and that the flexibility of the ICT infrastructure has a key role for the efficiency of the integration of the information collected from the machines and from the field. STRATIS project focused this goal and realized an important step in the wireless links integration “in machine”, enabling positive approach to wireless link for ISOBUS operations also in the ISO TC023/SC19/WG1 technical group.

Description of activities and final results

STRATOS project target was to develop and demonstrate new functions enabled by ISOBUS technology (ISO 11783) that support a substantial improvement of the quality of the farming jobs. In particular the idea is to develop a technology based on ISOBUS compliant, wireless self-powered sensor network for the real time measurement of soil and harvester conditions. In this way, Task Controller (an ICT component defined by ISOBUS specification which supervises actively the farming job performed by the tractor) can optimize the whole tractor and implement operational modes to improve the farming job quality and safety of the overall systems.

The STRATOS project exploits the communication standard ISOBUS technology to implement a wireless sensor network for a mobile system for soil and terrain data acquisition through field sensors.

ISOBUS standard

A tractor or an implement taken apart are useless, as only the combination of the two of them performs an effective agricultural job. In the past, all tractors had a proprietary hardware architecture to control implements, and in particular an ad hoc remote control system which must be installed in the tractor cockpit, often installed as an aftermarket kit. Since many implements should be plugged into a single tractor to accomplish various farming jobs, many control and user interface (HMI) devices have to be installed on board often producing a mess of cable and hardware, that prevent ergonomic and safe tractor use.

Since the early 90s' a task force of tractor and implement manufacturers, and standardization authorities is developing the ISO11783 norm (ISOBUS), that aims at introducing a "plug & play" concept into the tractor-implement systems, notably the:

- Virtual Terminal, a standardized control and user interface unit that enables communication of control and supervision signals with any ISOBUS-compliant implement. In such a way, all standard implement can share the same control and user interface unit, simplifying by far the work of the farmer and increasing the usability and, hence, the safety of the tractor.
- Task controller, a software application run by Virtual Terminal for the management of the agricultural job.
- Communication network, based on 2560kbaus CAN communication protocol allowing simultaneous bus access from different nodes.

STRATOS STRUCTURE

The aim of STRATOS project is to demonstrate the application of ICT technology, in particular ISOBUS and wireless communication technologies, to agricultural applications. The structure of the system can be described as follows:

a) The wireless sensors transmit every 30 seconds a data stream containing information in a digital coding through a network (Wireless Sensor Network, WSN).
b) The ISOBUS Task Controller is deployed in a Data Management System (DMS), which gets the continuous data flow from the sensor network, then format this data stream in a defined structure and send these structures to the remote FMIS (Farm Management Information System) into the farm premises.
c) The DMS gets stream of data from the WSN using a serial UART link.
d) The DMS gests the localization data from a GNSS receiver (standard GPS receiver) through an ISOBUS interface.
e) The DMS communicate with the FMIS using a GSM module hosted by the VE-CAN system. The DMS sends the stream of data to the VE-CAN module through the ISOBUS network.
f) The DMS has a human interface which is based on a smartphone connected via blue tooth that permits the user to interact with the STRATOS system to command: (1) start stream (data collection and communication to FMIS), (2) stop Stream, and to display information about (3) communication channel status (working/not working) and (4) average value for each sensor.

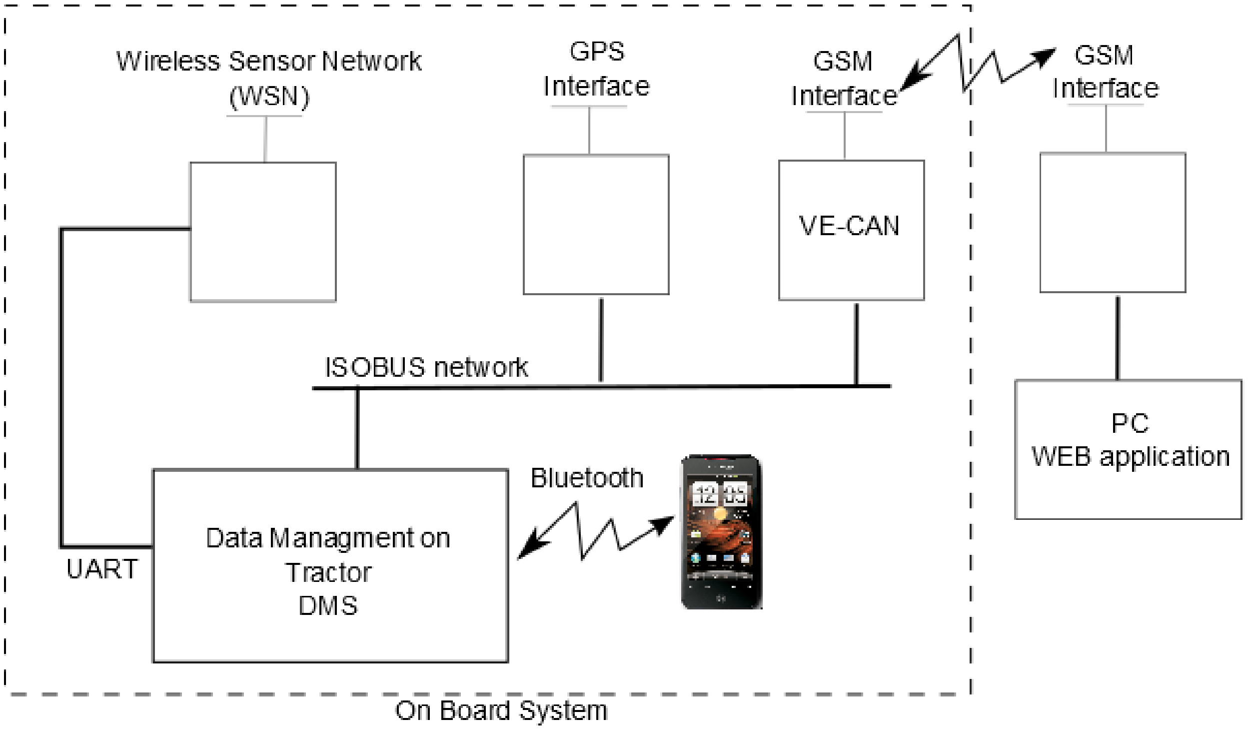

Figure 2. The STRATOS structure.

The system implements the following use cases:

1) The DMS hosted by a ECU on board to the tractor gets the data flows from the wireless sensor network WSN through the UART dongle (access point for the WSN).
2) The DMS gets the position information from the on-board GPS through ISOBUS.
3) The DMS combines the two sources of information and formats the data in a defined structure, suitable for the communication to FMIS using the GSM interface.
4) The GSM interface is hosted by the VE-CAN module. The DMS sends data stream to VE-CAN module through ISOBUS.
5) The PC in the farm premises equipped with a GSM interface receives the data stream from the mobile station through the GSM communication channel.
6) The PC collects and stores the data in a database management system: DBMS.
7) The data are presented to the user by means of a web interface on the PC using also a google map visualization service. A php based internet site, capable to read data from the database and to show the machine position using google maps API and data collected in a web page. The site is http://stratosfleet.imamoter.cnr.it/accesso.php and the access is restricted by username and password (user: stratos; password: stratos).

STRATOS DEVELOPMENT

The development of STRATOS prototype followed the steps:

1. A conceptual model of the system has been developed using the Unified Modeling Language (UML), that is the standard formalism to structure the engineered development of complex systems. A complete conceptual description of the system has been developed using a set of graphical documents following UML syntax. These scheme have been used to share between project partners all the information concerned with the system development, allowing remote collaboration of engineering teams.

2. On the basis of formal specification derived from step 1, the STRATOS infrastructure has been divided in modules, which have been developed separately by partners on the basis of their own competences.

3. The last step was the integration of the subsystems in the complete STRATOS prototype.

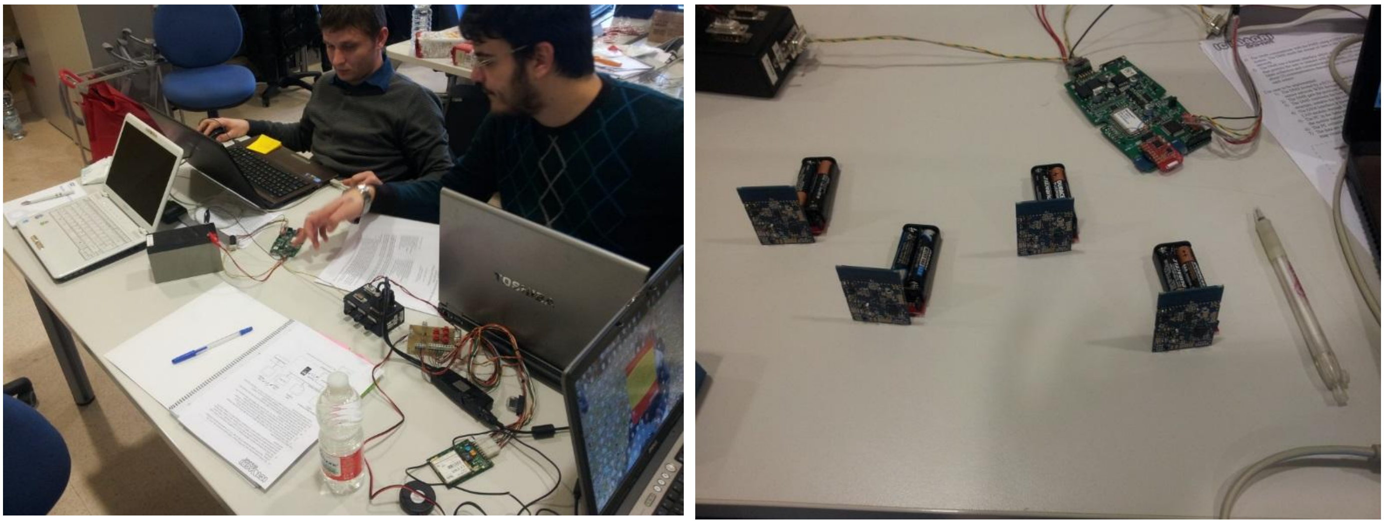

Figure 3. The development of the system in the lab (left) and the prototype of the wireless sensors (right).

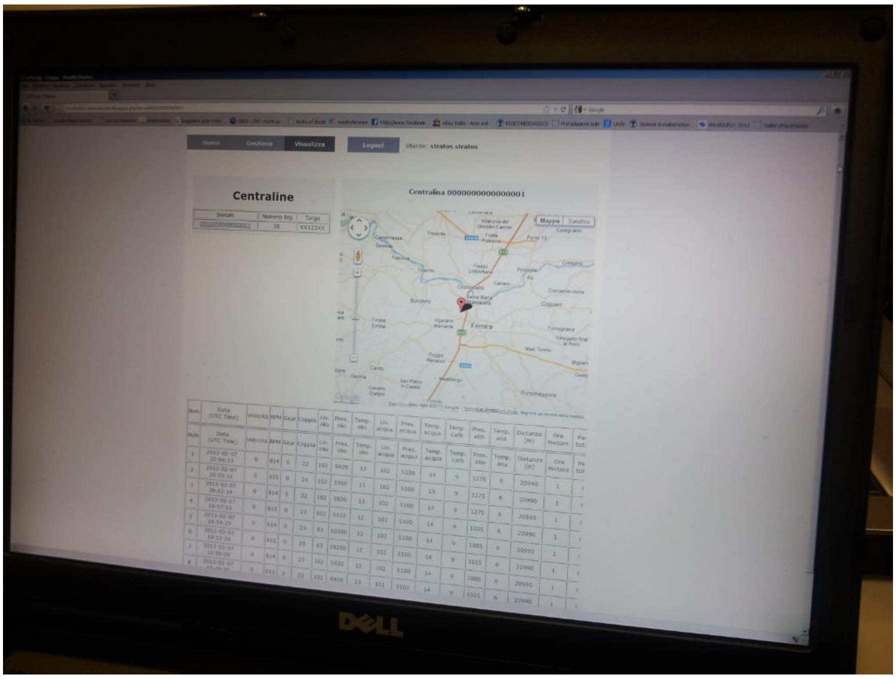

Figure 4. The WEB interface for the localization of a Google service of the data acquired from the field sensors

STRATOS FOR AUTONOMOUS VEHICLES

The existing agricultural practice mostly uses heavy weight and large-power machines that cause damage by compacting of the fields and needed a considerable amount of fuel and manpower. The prospective precision agriculture approach will use relatively small and intelligent autonomous programmed ’driverless’ vehicles and implements that eventually will replace the heavy machines. In addition the potential benefits of automated autonomous agricultural vehicles include increased productivity, application accuracy and job quality, and enhanced operation safety. This trend will be based on the information computer technology (ICT), wireless sensors infrastructure, on field and on-tractor sensors, and computer-controlled task execution, according to the ISOBUS standard.

An autonomous tractors and implements task controller for optimal work time allocation and path planning for the in-field and inter-field (scattered fields) precision agriculture activities have been considered. Two effective heuristic algorithms are designed, described and compared. The path planning has to be proceeded by the task controller of the farm information system. The scheduled information on the routs have to be uploaded by the wireless communication system to the on-tractor task controllers which execute the path tracking and transfer back the deviations from the schedule. In case of need the re-planning operation then have to be performed.

When the delay or the breakdown of the autonomous tractor & implement happens during its inter-field agricultural mission - then the necessary corrective actions must be taken immediately to improve the overall work-time allocation and path planning. These actions are called rescheduling and are the elements of a feedback control scheme. The effective, simple and computationally cheap heuristic algorithms are described here that solve this problem on-line.

The algorithms essentially use results of the previous approximately-optimal scheduling assignments and route descriptions. Wireless interaction between on-tractor task controller (TC) and on-farm information system (FIS) is assumed**.**

General description of the cooperation over the duration of the project

The project STATOS was organized in tasks and activities. Each task has been assigned to a partner who act as a leader, by organizing the input from other partners. The task list is described bu the following table:

Task name	Task description	Partners (leader is marked with bold)
Development of the system model	Development of an UML system model in order to document the system, and support the development and, in particular, the system integration. A particular care into the UML model has been paid to subsystem interfaces and safety requirements. This model is regularly updated to reflect the current state of the project.	**USI**, UNIMORE, TECHNION
Development of components model	In order to provide a more detailed document and better define critical parts of the system previously developed system model should be refined. Based on inputs from partners, a model of each component has been	**USI**, UNIMORE, IMAMOTER, RELAB, TECHNION

	developed. Level of model details is decided based on component's criticality. Critical interaction has been modelled in deeper details as well. These detailed models mostly include state charts, internal structural diagrams and sequence diagrams, and so give a basis for further verification of critical part of the system.	
Development of wireless sensors components.	The sensors that can be inserted in the STRATOS structure are: (1) humidity, (2) temperature (3) pH, (4) barometric pressure and (5) acceleration. It has been developed a full functional sensor of (2) and (5) kind, while for (1), (2) and (3) it will be developed only the wireless interface and a code to simulate the physical variable acquisition and communication to SAP.	**UNIMORE**, UNIRIGA
Development of Sensing access point (SAP)	This task has been devoted to the development of the hardware for the sensing access point with ISOBUS interface. The interface is based on a dongle with serial interface (RS232 /USB) with the Task Controller hosted in the Virtual Terminal and the Implement TECU.	**UNIMORE**, UNIRIGA, RELAB.
Development of LAB prototype of the ISOBUS wired network structure.	This task has been devoted to the developed of the ISOBUS network that will support the system test. The network will be formed at least by: (1) VT and (2) a implement.	**RELAB**, IMAMOTER,UNIMORE
Development of WLAN ISOBUS network structure.	This task is devoted to the development of a WLAN interface to allows wireless communication between implement and tractor. This interface will duplicate the standard wired ISOBUS interface for increase the network reliability.	**IMAMOTER**, UNIRIGA
Development of ISOBUS stack for the SAP.	This task has been devoted to the development of the communication protocol (ISOBUS) that interface the SAP.	**IMAMOTER**, RELAB, UNIMORE
Development of Task Controller	Development of the control algorithm and software to supervise and control all the system. The supervision system will continuously upload to FIS data gathered from Wi-Low sensors, and download from FIS control parameters for implements.	**UNIMORE**, TECHNION
Long range communication	In this task it will be developed the communication layer between the FIS (Farm Information System) and the VT using a GSM technology.	**IMAMOTER**, RE:LAB
Development of FIS (Farm Information System)	In this task it will be developed a data base management system that allows to store the farming data get from the field and communicate back parameters to set up implements.	**IMAMOTER**

The transnational dimension of the project was really important since it made possible to merge different competences and technical background from the participants. In particular, it was really important the inclusion of partners UNIRIGA and TECHNION since it brings into the project really peculiar point of views.

The management of the project enforced the cooperation among the partners with technical meetings and conference calls. The list of the meeting is the following:

09/05/2011 : First meeting in Reggio Emilia (Italy).
07/11/2011 : conference call
22/11/2011 : conference call
24/01/2012 : conference call
20/02/2012 : second meeting in Lugano (Switzerland)
28/08/2012 : conference call.
27-28/11/2012 : Meeting in Haifa, Israel (note: since safety concern about possible terrorist attacks, some partners meet in Italy, and stayed in connection with email and conference call)
04/12/2012: Technical meeting in Reggio Emilia (Italy)
24/01/2013: conference call
08/02/2013: Technical meeting (integration day) in Reggio Emilia (Italy)
11/03/2013: Final meeting in Riga (Latvia).

Impact statement

Interdisciplinarity:

The project helped the startup of a project related to data collecting and remote machine control for forestry machines. The project is a financed project of the Piedmont Region in Italy and is in development with an Italian company Pezzolato S.p.A. that is e leader in chipped wood machines. In this project a new kind of specialized fleet management is designed and developed, in order to collect information on machine status and experiencing remote diagnosis possibility.

Exploitation and dissemination measures

The exploitation of the result of the project can be listed as publication of technical papers and documents, and the realization of a prototype of the system.

Concerning the published papers, mostly wrote in cooperation among the partners, we can list them as follows:

1. An autonomous tractors and implements task controller for optimal work time allocation and path planning. I. Technion R&D Foundation, P.-O. Gutman and I. Ioslovich, Research report, April 2012, working program 838-0568-10, research 2015892.

2. STRATOS: open System for TRAcTOrs' autonomous OperationS. C. Fantuzzi1, P. O. Gutman, I. Kaitovic, L. Larcher, S. Marzani, M. Ruggeri, and V. Zagurskis. Proceedings of CIGR -2012 International conference, paper C1113, July 2012, Spain.

3. I. Kaitovic, R. Rezende, C. Murillo, C. Fantuzzi: Model-driven approach to design ICT infrastructure for precision farming. ETFA 2012, Krakow (PL)

3. Optimal work time allocation and path planning: the heuristic algorithm for autonomous tractor task controller, P.-O. Gutman and I. Ioslovich, Proceedings of the International Conference of Generalized Statesments and Solutions of Control Problems (GSSCP - 2012), Russian Academy of Sciences, Gelendjik, Krasnodar, Russia, (DVD), pp. 29-31.

4. An autonomous tractors and implements task controller for optimal work time allocation and path planning. II. Feedback control and rescheduling. Technion R&D Foundation, P.-O. Gutman and I. Ioslovich, Research report, April 2012, working program 838-0568-10, research 2015892. (In preparation, to be completed until 30.04.2013).

5. Optimalnoe raspredelenie rabochego vremeni i planirovanie marshrutov avtonomnych tractorov na osnove evristicheskich algoritmov (in Russian), P.-O. Gutman and I. Ioslovich, Avtomatika i Telemechanika, 2013, (accepted). This paper will be also translated into English and published by Springer Ltd. in Automation and Remote Control.

6. C. Fantuzzi, P.O. Gutman, I. Kaitovic, L. Larcher, S. Marzani, M. Ruggeri, V. Zagurskis. “open System for TRAcTOrs’ autonomouS Operations” FITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

Concerning the realization of prototypes, two main results were achieved:

1. The realization of the wireless senso networks, which is under evaluation for the development of commercial production by project consortium.

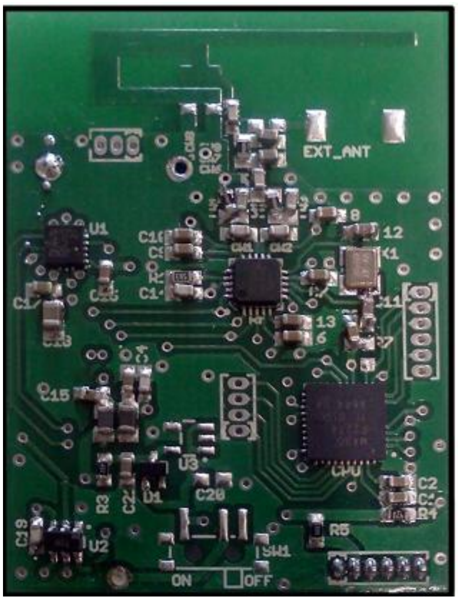

Figure 5: The PCB of the wireless sensor.

2. The realization of the geo-localization of agricultural and soil parameters using a Google apps-

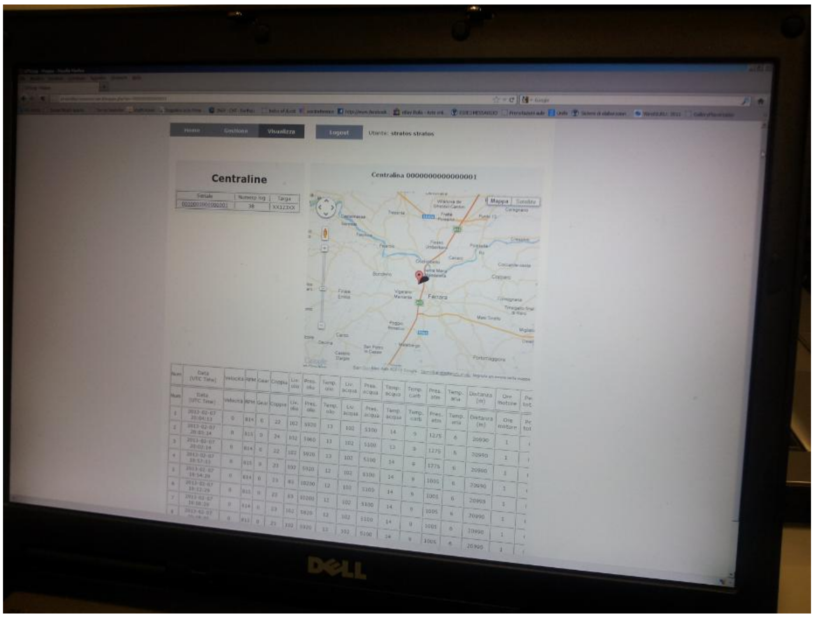

Figure 6. The WEB interface for the localization of a Google service of the data acquired from the field sensors.

Explanation of the use of resources (final financial report)

In the following table is reported the use of the resource of the partners set at the submission of the final proposal, no variations have been reported from partners with respects these figures.

Partner	Funder	Man-months	Salaries	Direct costs[1]	Travel[2]	Other costs[3]	Overhead[4]	Total
1 UNIMOR Italy	National funding	46	165600	5000	10000	0	17560	198160
	Own funding	0	0	0	0	0	0	0
	Total	46	165600	5000	10000	0	17560	198160
2 RIGA Latvia	National funding	24	52080	9910	7000	0	6000	74990
	Own funding	0	0	0	0	0	0	0
	Total	24	52080	9910	7000	0	6000	74990
3 Alari Switzerland	National funding	18	63327	0	8000	0	10699	82026
	Own funding	0	0	0	0	0	0	0
	Total	18	63327	0	8000	0	10699	82026

4 IMAMOT Italy	National funding	4	18000	0	5000	0	2300	25300
	Own funding	4	18000	0	0	0	1800	19800
	Total	8	36000	0	5000	0	4100	45100
5 TECHNI Israel	National funding	14	70333	0	15000	0	17067	102400
	Own funding	0	0	0	0	0	0	0
	Total	14	70333	0	15000	0	17067	102400
6 EIA Belgium	National funding	0	0	0	0	0	0	0
	Own funding	10	50000	0	4000	0	5400	59400
	Total	10	50000	0	4000	0	5400	59400
Total	National funding	106	369340	14910	45000	0	53626	482876
	Own funding	14	68000	0	4000	0	7200	79200
	Total	120	437340	14910	49000	0	60826	562076