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Automatic Filling of Field Activities Register, from Challenge into Reality

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Operational monitoring includes all those tasks performed to observe, survey and report all the information necessary to get an overview of the operational processes carried out during a specific field activity. The focus of this research is to develop a complete system able to collect and interpret all the operative parameters, for each different agricultural operations, in order to obtain information suitable to carry out management and strategical decisions. In short, the aim of the research is to develop a new concept of intelligent system supporting Precision Farming applications, capable to translate ex post actual operative parameters into information, so as to automatically perform an objectivity compilation of the field activities register.
Through this system the farmer is able to have, on demand, updated information to be used for certification and traceability processes, as well as to satisfy any other management task, including the estimation of the actual operative costs at the farm. The solution here proposed is based on the identification of working processes through a tractor-oriented approach, where the power unit is equipped with a GNSS-data logger and an identification system acting as a detector able to recognize the coupled implements (on their turn equipped with a RF-transmitter sending identifying codes) and the related operations. Both devices are provided with an accelerometer to allow them to switch on only when they record a vibration. The raw data are collected with a frequency of 0.2 Hz fixing and compressed in data packets formed by geographical coordinates, day and hour of detection, and coupling information.
Data-packets are then sent to a server, thanks to a GPRS-modem integrated into the GNSS-data logger, where they are finally stored into a relational database. Here, an Operational Inference Engine software (OIE) manages all these data through a set of automatic procedures to get final intelligible information on the monitored operations. The OIE results can be then uploaded by a Web-GIS client, that allows the farmer to get an easy and intuitive access to the information directly from his own private web domain.
A series of field surveys were organized in order to perform the validation of the proposed procedure, through a manual time study and assessment of the followed working sessions. The main operative information obtained automatically by this new system (i.e. speeds, hour of start and finish, working session (WS) duration, operation recognition) were compared with those manually registered. Comparisons between automatically estimated and manually registered parameters revealed high level of correlations (R^2 > 0.6), especially in terms of time comparison and identification of the working session, thus it highlights the capability and reliability of the proposed system to monitor agricultural operations in an automatic way. This solution will facilitate and enable new generations of farm information systems to be specifically developed for applications on agri-environmental enterprises.

1. Introduction

Operational monitoring refers to all those tasks carried out to monitor survey and report all those information necessary to get an overview of the working processes carried out during a specific activity. The operational monitoring are done to carry out a continuous traceability of the input insert in the system. In these sectors, the assessment of these aspects is a strategical point to be monitored in order to optimize all the resources. Agriculture is considered among these working sectors too.

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All the operative information are very important for the farmers, in order to have under control logistic and management of their own activity. For this reason, since several decades, the Farm Management Information System (FMIS) was developed and used. The FMIS is considered as an electronic tool suitable to generate operative information acceptable to be used by the farmer, in order to carry out decisional tasks through well-established procedures for collecting, processing and elaborating data (Fountas et al., 2015a).
To have an efficient and reliable FMIS, all the operational parameters collected during the working activities must be uploaded on the FMIS at the end of every working day. Nowadays, the traditional FMIS is still in use, mainly in small farm enterprises. This system is based on the manual data entry of all the operational parameters in order to obtain paper reports (Nikkilä et al., 2010). Therefore, in theory, during the working session the operator should take note of every input and output, and then insert these values into the FMIS. The farmers consider these tasks as high time-consuming and they do not always accomplished it for reasons of time.
In order to lighten the compilation task for the farmer, and to facilitate and automate the insertion of the operative data into a FMIS, a new device of precision agriculture was developed.
The focus of this research is to develop a complete system, including hardware and software, to support the Precision Farming applications. The provided system will be able to automatically collect and interpret all the operative parameters, obtained with the different agricultural operations done achieving management and logistic information. This automatic system will permit not only to improve the efficiency of human labor but also to reduce it, by speeding up the processes of operational parameters acquisition, improving the production and motivating skilled labor (Lopes and Neto 2010). In the end, this new concept of intelligent system is capable to translate ex post or actual operative parameters into information, in order to automatically perform an objectivity compilation of the field activity register. Thus, the farmer will have automatically updated information to be used for certification and traceability processes, as well as to satisfy any other management task, including the estimation of the actual operative costs (and impacts) at the farm.

2. Materials and methods

2.1 The automatic system description

The aim of this research is to develop a system capable to perform an automatic operational monitoring of field activities in order to carry out an automatic compilation of the field activity register. Final focus is to develop a management tool where the farmer have to deal only with the agricultural planned operations.
To achieve the research goal, an innovative hardware and software solution were developed. The proposed solution is compose by a FDL (Field-Data Logger) and by an active RFID transmitter for data detection, with a dedicated client Web-GIS platform for on-demand data consulting and reporting. The FDL and RFID are installed on the tractor and on the implement, respectively (Figure 1).

Figure 1: The left figure shows the FDL installed on the tractor. Thanks to its simply design configuration, the power supply is taken from the cigar lighter, while the right figure shows active RFID fixed at the frame of a mulching machine.

The active RFID is a small component which transmit an univocal identifying code to a receiver operating on 433 MHz (UHF). In the present study, this code is used to recognize the connected implement, by identifying the coupling between power unit and implement. In addition to the code emitter, the RFID is composed also by an accelerometer, which is used to turn on the device when the accelerometer records vibrations higher than a threshold (which should correspond to the implement movement). When the RFID is on, it starts the transmission of its univocal code that will be intercepted by a receiver. Besides these components, in the RFID is also present an internal long life battery for the power supplying. The FDL is an embedded unit with its own ID code. It is composed by an accelerometer module, a GNSS unit (GPS+GLONASS), a GPRS unit and a

RFID receiver antenna. Beside these, there is also a multiprocessor which drives all these components and carries out a first data processing. All those modules are contained in an IP67 plastic box. Since the FDL is directly linked to the tractor's battery, it is constantly under electric power. It turns on when the accelerometer records a vibration – generally due to the engine – over a set threshold for a set duration. When the FDL is on, a warming up period for the GNSS acquisition and for the connection to the phone network is required. The time spent for the warming depends by the GNSS and telephone signal coverage and, according to their specifications, it is maximum 30 seconds. The code transmitted by the RFID is intercepted by the receiver installed on the FDL and storage.

Data recording starts when the GNSS unit receives the satellite signals, with a fixing sampling frequency of 0.2 Hz. At the same time, when the recording procedure starts, the multiprocessor processes the coordinates and coupling info in order to obtain, every 5 seconds for each fixing, a data string with:

- X,Y and Z coordinates;
- Time of each detection;
- Advancement speeds;
- Tracking angle;
- Tractor-implement coupling;

In case of poor phone coverage, these strings are temporarily stored in the buffer memory of the FDL until its improvement, while every 5 strings the multiprocessor creates a data package to be sent to a server.

In the server, a relational database management system (RDBMS) is developed in order to storage and elaborate the data. Here, all the stored data are organized in tables in order to be analysed by the so-called *Operational Inference Engine* (OIE). The OIE is a set of mathematical and statistical procedures able to elaborate and translate raw data into useful information. Therefore, thanks to specifically developed algorithms, which are driven by the OIE, it is possible to carry out an operative monitoring of the field activities (Mazzetto et al., 2012; Gallo et al., 2013). In chronological order, the OIE analysis carries out:

- The identification of the Working Sections (WS, is considered as a sequence of activities comprised between two switching on/off subsequent events);
- The elimination of possible fixings classified as outliers (all the records far from the collected dataset centroid a distance (*d*) higher of $d>d_{avg.}\pm 2\delta$);
- The classification of the different working phases in effective work, stops, auxiliary operations and manoeuvres, transports and displacements, according to the monitored field operation, applying an algorithm based on speed, the direction and the working pattern;
- The clustering of all contiguous fixings classified as effective work into a common area;
- The splitting of this clustered area among the crop units that intersect with it;
- The computation of the working coverage rate on each crop unit, as well as a summary of all the consumed inputs and the worktimes occurred during the current WS.

Since the OIE manages also algorithms based on spatial analysis, the mapping of the entire farm was necessary. Hence, the external farm boundary, the parcels boundary, the functional areas and the buildings, were manually surveyed during the mapping operations. The only not surveyed elements inside the external farm boundary are the internal roads. All the computations done by the OIE are then summarized and displayed on a Web-GIS platform for an easy and quick consultation. Thus, the final user (the farmer) can accesses through his domain and his own credentials to his personal page, in order to monitor and to check all the supervised operational parameters.

Thanks to this system, it is possible to carry out an automatic operational monitoring, which is able to collect, elaborate and interpret operational parameters by itself (Figure 2).

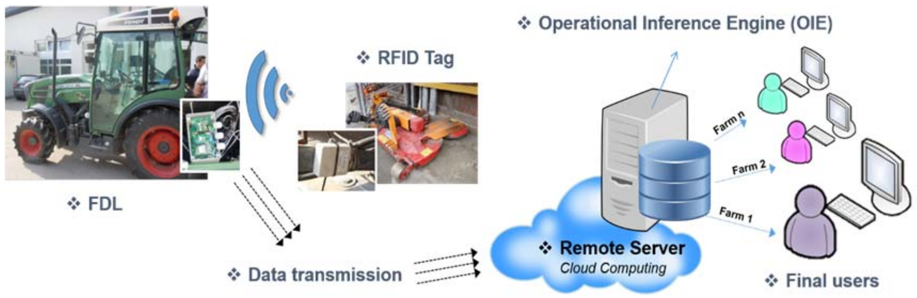

Figure 2. In the figure the conceptual model followed is reported. The operational parameters were collected and transmitted to a remote sever (left part of the picture), here a specific operational inference engine interprets the raw data and translates them into intelligible information in order to be consulted by the farmer.

2.2 The validation of the system

The validation of the system was done comparing the results obtained by the automatic OIE's elaborations with those collected by a manual elemental time study. In the last autumn, several days of surveys were planned in order to carry out a complete elemental time study of harvesting operations in apple orchards. A surveyor manually carried out the time study with a chronometer. The tractor monitored was a Deutz F320 coupled with a forklift mounted on the three-points hitch. The operator had the task to bring empty fruit bins to the harvesting machines, placed inside the inter-row of the same or different parcels, to pick up full bins and to bring them to the trailer. Generally, these operations were performed running in the orchard inter-rows or on the border of the field (used as temporary storage for the bins or parking for the trailer). Displacements among the fields were done running on internal roads. At the contrary of those operations which have a well-defined operational pattern (such as the spraying), the harvesting operations are characterized by undefined movements. Therefore, to accomplish the elemental time study, the operation were divided and classified in three main activities: i) operation inside the field, ii) stops and iii) displacements. The duration of the manually assessed working phases were then compared with those computed by the OIE.

3. Results and discussions

In literature some papers which describe the ontology, the data flows and the functioning of the FMIS were found (Fountas et al., 2015a, Fountas et al., 2015b, Sørensen et al., 2011), nevertheless no quantitative results to be compared with the present research were reported. During the study, considering the definition of the working session, 23 of these were monitored and evaluated. From the manual and the automatic time study were calculated the duration of each WS as well as the time spent during the effective work in field, the stops and the displacements (Table 1).

Table 1. Summary of the operational monitoring results obtained by the different survey methods. The results are reported in hundredth of minutes. Data are divided in work in field (WF), stops (ST) and displacements (DP).

	Manual time study (min)				Automatic time study (min)			
WS	Duration	WF	ST	DP	Duration	WF	ST	DP
1	25.58	23.38	0.00	2.20	23.50	15.50	4.00	4.08
2	199.27	92.02	84.22	23.03	199.68	111.22	71.25	17.30
3	132.23	44.42	60.23	27.58	132.17	70.05	51.28	10.92
4	20.33	11.63	4.50	4.20	21.25	10.50	5.92	4.92
5	130.72	65.73	46.68	18.30	130.17	69.88	47.70	12.58
6	119.08	38.13	63.27	17.68	119.00	71.20	37.72	10.17
7	28.75	22.28	6.47	0.00	35.00	14.95	14.00	4.80
8	40.02	38.08	1.93	0.00	36.08	19.17	10.25	6.75
9	23.17	11.45	6.07	5.65	23.92	14.42	8.25	1.33
10	85.72	48.97	33.78	2.97	85.62	42.83	32.53	10.33
11	29.88	23.97	5.92	0.00	30.60	15.27	8.33	7.08
12	29.33	21.42	4.43	3.48	29.55	18.13	7.50	4.00
13	79.98	46.67	24.55	8.77	80.75	47.97	22.87	10.00
14	15.73	13.00	2.73	0.00	15.30	9.63	3.92	1.83
15	26.28	24.05	0.40	1.83	26.20	18.45	3.75	4.08
16	44.18	29.53	8.98	5.67	44.58	32.58	6.33	5.75
17	54.95	34.22	7.93	12.80	54.73	32.07	14.17	8.58
18	28.22	16.32	3.00	8.90	27.70	15.37	6.17	6.25
19	112.55	65.88	25.72	20.95	112.50	55.17	40.07	17.35
20	126.57	65.00	41.87	19.70	126.83	66.58	44.25	16.08
21	88.53	55.63	22.20	10.70	88.45	49.25	27.58	11.70
22	62.60	34.58	18.00	10.02	62.25	40.72	16.20	5.42
23	13.53	5.35	8.18	0.00	13.37	6.60	6.27	0.58

The results were compared in order to establish the reliability and the accuracy of the procedure proposed to accomplish the automatic operational monitoring. On average, very small differences were marked from the comparison between the two methods. Indeed, considering the duration of each WS, the WF and ST the differences were lower than 2%, in absolute terms. A difference equal to 11% was recorded for the displacements. In terms of minutes, these differences are equal to 0.09, 0.69, 0.40 and 0.98 for WS, WF, ST, and DS, respectively (Figure 3).

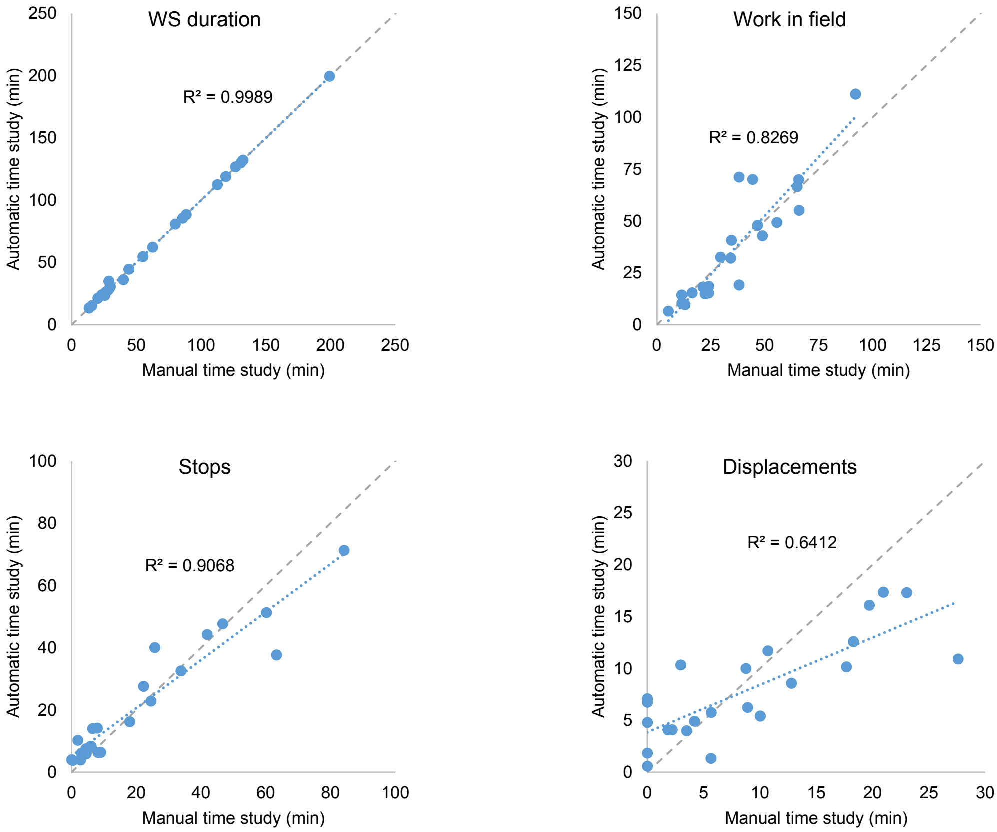

Figure 3. Comparison between the manual and the automatic time study. Very good correlation values were obtained for the duration of the working sessions, the work in field and the stops. Instead, lower correlation values was detected for the displacement phase.

The higher differences in the displacement phases can be due to a no proper identification of the phase beginning and ending calculated by the automatic survey. Indeed, the OIE assesses more fixings than the actual as displacements instead of work in field with the consequence of a not proper assessment. This happens because part of the field operation works carried out on the parcel border are considered displacement by the OIE, as they *jump* outside the parcel because of a GNSS drift, as consequence of multipath or cycle slip phenomena. In this case, these points are considered as displacements by OIE's elaboration. To resolve these assessment issues, a buffer zone should be applied around the orchard's boundary in order to enlarge the parcel surface ensuring the correct assessment also for those operations that have parts of the working phases on the parcel margin.
Nevertheless, no statistical differences were recorded between the two methods (*t>0.05)*.

4. Conclusions

Aim of the present study was to developed a system able to carry out the automatic operational monitoring for the automatic filling of field activities register. A system based on the use of a field-data logger and RFID transmitter, as well as a dedicated OIE for data collection and interpretation, was proposed. Despite the

harvesting operations do not have a characteristic working pattern when repetitive working phases are done, situation more easy to be described, the experience has obtained very interesting and important outcomes achieving very satisfactory results in term of capability and accuracy. In general, differences lower than 2% were recorded, while only for the displacement working phases the difference was 11%. Since this difference in terms of time is lower than 1 minute, it can be considered acceptable.
In conclusion, the positive results here obtained highlighted that the application of the proposed approach can be considered as a good and interesting tool for the automatic operational monitoring of agricultural activities. To sum up, the proposed system can be seen as an innovative operational procedure of Precision Agriculture. Indeed, this can be a useful tool to obtain operative information for the automatic compilation of the field activity registers, suitable to be used also for certification and traceability processes. This tool can be also employed for the operative costs and input consumption estimation, applying specific estimative parameters. Further study will be planned in order to assess other field activities as well as to improve the recognition of displacements working phases.

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