Information System for Farms  
using Precision Agriculture Techniques and EDI standards.

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ABSTRACT

There have been many developments in technology, such as Precision Agriculture, as well as an evolution in the relationship between the farm and its environment (administration, advisers, suppliers, etc ...). All this now makes a review of the Information System of the farm necessary.

In order to better understand the new environment of the farm and to better meet the new information demand from end-users, we have tried to define an up-dated general Information System for farming. This general Information System is based on a central module, to which are connected several peripheral thematic modules.

One of these peripheral modules was designed for crop production, taking into account the needs of Precision Farming. Compatibility of this Information System with ISO standards for EDI in agriculture was tested, and a review of the critical points was carried out.

Keyword : Management Information system, Precision agriculture, Electronic Data Interchange

I. Introduction

Precision Agriculture necessitates both the collection of great deal of data coming from various sources (farm equipment, soil sampling, remote sensing) and the exchange of information inside the farm (between Management Computer System and Process Computers) as well as between the farm and its commercial or technical environment (advisers, cooperatives, suppliers).

Hence there is a need to reconsider the Information System of the farm both to integrate the new technical data generated by the development of Precision Agriculture, and to allow data interchanges between different Information Systems.

The management of the farm information system must take into account these new constraints. If Information Technologies increase complexity there also offer some new opportunities.
I. Development of Information Technologies now offers new perspectives

In agriculture, as in the other sectors of activity, the growth of information technologies began about twenty years ago. This growth concerned two well-identified domains:
- farm management,
- process automation and on-board electronic devices.

These two domains, process and management, remained disconnected for a long time in part because the same actors did not participate in both of these two domains and also because the functional link between process and management was not easy to establish.

During the 80’s, several manufacturers tried to establish such a link between on-board computers and crop management software, in order to use data collected in the fields for crops management purpose. (in France, this was done by the Massey-Ferguson company – with the ”Ménotronic” -, and by France-Maïs – with ”Agrocentrale” -, in partnership with software companies such as Isagri and ENITA de Bordeaux).

Unfortunately, these EDI (Electronic Data Interchanges) attempts were not a success for two main reasons:
- EDI was thinking without data modeling, so it was difficult to integrate real-time data registered by the on-board computer in the crop management database (for example job-time did not have the same meaning for driver and for the tractor),
- It was necessary for the user to complete the part of the recordings that could not be automated, which considerably increased the workload in manual data recording entry (what driver, what implement(s), what crop, what field, what product(s), what rate,...). The increase in the workload was such that, often, recordings were incomplete, therefore unusable by software products for crop management.

Starting at that time much research work was undertaken with the objective to define what data could be collected by on-board computers, and what data could be transferred to (or from) the management computer (Zwanepoel, 1990).

A further step came from the change announced in electronic architecture terms for agricultural mobile equipment, with the replacement of analog electronics by digital electronics architecture. This change means new capabilities in data recording and interchanging terms, especially for all data from sensors located on the implements. But such architecture necessitates standardization of electronic data interchanges between tractor and implement, and between process computers and management computer. The data interchanges have to be conceived in the context of a multi brand environment.

Such standardization for mobile equipment is based on CAN bus. In Germany this work resulted in DIN standards (DIN 9684), which have now been published. At the same time, sub-committee SC19 of ISO/TC23 is working on ISO 11783 standard (which is close to DIN 9684 standard, except for the choice of CAN bus version 2.0B), and on the ISO 11787 and 11788 standards for data interchange between stationary process computers and management computers (ADIS = Agricultural Data Interchange Syntax, and ADED = Agricultural Data Element Dictionary). The adoption of CAN bus by many agricultural equipment manufacturers, and the standardization of the linking tractor-implement (standard ISO 11783 or standard DIN 9684) will lead to a
standardization of data that could be collected and exchanged. These changes are going to transform the tractor into a technical data-recording device, and allow for the use of this data for farm management.

II. Growth of Precision Agriculture

At least in Europe, Precision Agriculture is poised to take off. The emergence of this new concept is linked to the tremendous progress in information technologies. It is becoming possible, at a reasonable cost, to measure crop and field variability and, consequently, to optimize crop management. This is due to capabilities that are now offered in measurement, registering and analysis of a very large quantity of information (Stafford, 1996).

These new capabilities, concerning management of in-field variability, will induce a profound evolution in equipment and management software design. Indeed, by nature, Precision Agriculture establishes a very strong link between process and management computers:

• Data collected is linked to the process itself (yield, soil characteristics,...), and is not connected (or less) to equipment control or automation. This data is useful for management and decision-making processes,

• Collected data come from multiple sources (on-board sensors, soil sampling, remote sensing,...), and the work comparing miscellaneous data will be done, mainly, at the management level. Therefore it is required to transfer this information from the equipment to the management computer, in order to analyze it and to establish application maps. After that, it is necessary to transfer data again in the reverse direction, to carry out variable rate applications.

Precision Agriculture also necessitates having reliable means, such as D-GPS devices, to be able to locate both measurements and actions conducted in the field. As a consequence, this necessity allows for bypassing a difficulty that was found using in the 80’s: thanks to a location system, it is now possible to determine automatically in which field the tractor or the equipment is working, or if it is traveling on the road,... With this, a quasi-complete automatic data recording could be designed, so the driver workload, concerning manual data recording, could be reduced to near zero.

Additionally, the new demands from consumers concerning product quality and traceability, will incite farmers to buy equipment allowing them to automatically record what actions they have performed on crops. Tools developed for Precision Agriculture (location devices, mapping software,...) will be precious help in meeting these new demands in a simple manner.

These various tools that farmers are going to need, have to be designed taking into account the necessity of EDI at all levels: between mobile equipment (tractor-implement, between mobile equipment and management computer, between the farm and its technical or commercial partners,...) in a multi brand environment. The definition of a general and unique information system of the farm is more and more difficult to delineate when the boundaries of the area covered are not well defined.

III. Towards a general Information System

To develop multi-function software, which would allow for the integration of both process and management domains and which would meet the expectations of farmers necessitates defining a general Information System.
However this objective may appear overly-ambitious. A simpler method would consist of connecting, by mean of gateways, the various Information Systems developed for specific problems. Some data could be exchanged between these Information Systems without the farmer having to enter them several times.

But with such a method the coherence of data could not be assured. Updating data in a given Information System must be carried out in the other Information Systems in which this data appears.

The definition of a general Information System ensures the coherence of data all the time. The Dutch (Goense and Hofstee, 1994), have already proposed such a method with the CIA (for Computer Integrated Agriculture).

The CIA model is set up as one model for the whole primary agricultural sector. This model was built on a high level of abstraction. For example processes such as feeding or fertilizing are described as one process "executing work". The work is not executed on a field, a crop or an animal group, but on an "account object". This theoretical approach offers a way to save cost and time in software designing.

Our approach is the same as concerns the need of a general Information System, but the way chosen to design it was different. For us, there exists a strong need to ensure the capability of transfer technical data from the farm to the outside, especially to the final consumer. In the future the farmer will have to record in a complete manner all the technical operations carried out in the field. He will have to be able to supply the chain of information for traceability of products and technical operations (the farmer must be able to provide answers to questions like : where, when, what action, what product, what quantity, . .).

In a multi-actor environment the use of data, which is easily understood by everyone, appears to us as mandatory, and as more important than the reduction of costs or time spent in developing software.

**IV. Methodology used**

The work was divided in four steps of varying importance :

- During the first step, we inventoried data elements appearing in main management and technical software used by farmers in France for crop management, and compared the definition of these data elements (Persiault, 1996). This inventory allowed us to identify basic data found in the relevant software, as well as more marginal data. This work was of great help in establishing definitions of entities and data elements which are integrated in the "crop management"
Figure 1: Data model for Crop Management
In a second step, the work focused on the modeling of a General Information System of the farm, using the French method "Merise" (Steffe, 99). We defined the Entity Relationship Diagram (ERD or Data Model), taking care to avoid all redundancy in entities and data elements definitions. To facilitate ease of presentation this ERD was divided into several modules such as "crop management" (figure 1). Nevertheless the Information System thus modeled is truly general and unique. Due to the presentation by modules some entities such as "crop" appear in several modules although they appear only once in the general data model.

The third step was an analysis of the means of data collection in previous model. On-board sensors are used for real-time control not for accounting or farm management, so it could be difficult to obtain all the data we defined in the modeling process. At the end of this step data was classified in four classes:

- Data directly usable (for example: cartography point)
- Data usable after calculation (such as working duration, surface worked,..)
- Data recordable if additionally sensors are mounted on-board (product Id,..)
- Data recordable manually by the driver (repair time versus waiting time),

During this phase, we inventoried data that could be exchanged between a tractor and implements via a standardized bus. This data was simultaneously identified as useful (or not useful) at the management level. Thereafter, we examined new data elements that are now - or soon will be - appearing as Precision Agriculture progresses.

The work done in the fourth step consisted of creating "virtual" record files from on-board computers and to integrated data in analytic accountancy software. Data from on-board computer was used to automatically calculate pesticides and fertilizers quantities per crop. This was done taking into account the need of mixing data from different levels of technology, i.e. different generations of on-board computers (with D-GPS location device or without) or different way of farming (variable rate applications or unvarying applications).

V. Discussion, Conclusion

The design of such a general data model is a time-consuming procedure, and it is difficult to carry it to fruition. The natural inclination, which quickly became apparent, is to split the Information System into sub-information systems (one for each kind of domain).

Another difficulty we encountered was to anticipate data elements that will really be provided by on-board computers (on mobile equipment). That will be of interest in the context of the general Information System. Our work is not exhaustive, but pragmatic: we took into account only those data elements we were sure to find available and worthwhile for management.

The last difficulty is the most important to overcome. We refer to the dissimilarity in technological levels: some equipment will have all devices necessary allowing for the adoption of Precision Agriculture techniques and, simultaneously, will be outfitted of standardized CAN bus. But on the same farm there will be older equipment outfitted with analog electronics and perhaps some farm
equipment with no electronic devices. This problem could increase, when a farmer receives help from his neighbors or when a provider or a cooperative works for him in the field.

Clearly this leads to a great variety in capabilities of collection of information and in the nature of information. Some information will be geographically located thus relevant to a specific area of the field. Still other information will pertain to the entire field and a certain quantity of information will be unknown.

In the general Information System that we have constructed there are entities that may appear as redundant: they have been defined to allow for the cases cited above. In the module "crop management" this can be illustrated by the following example (figure 1):

- If farm equipment allows for Precision Agriculture techniques, the entity "farming task" is connected to the entity "cartography point", which is connected to the entity "treatment", itself connected to the entity "products",
- In the case of conventional crop management, this same entity "farming task" is directly connected to the entity "products" and the relationship concerns only quantities of products applied (at a constant rate) or harvested.

The circularity that seems to appear in the entity diagram relationships is necessary in order to process differently these two possibilities which are linked to different technological levels.

During the third step of this work some difficulties were stood out. Our goal was to bring the need to record data manually to zero in order to avoid increasing the driver workload. This is mandatory because in more and more cases the farmer is not the tractor driver. The driver's implication level in farm management could be low and he could have a lack of motivation to correctly record data.

We try to find a way to transform manually recordable data in automatically recordable data. This concerns:

- **Workforce Id**: this data is needed both for crop management and for workforce management. Identification by way of code entered on a keyboard appears as a wrong solution, insufficient for a high level of good identification (wrong recording could happens when a driver switch takes place without machine stop). The solution could be a personal identification card useful for identification as well as for seat adjustment to the driver and for protection against theft,

- **Product Id**: this data is needed for each application of fertilizer or pesticides, for seeding... In some case, the product could be defined by the nature of the implement (for example: manure). But, for general case, the better way for identifying product would be to use barcode sensor. These devices are less and less expensive and could be linked to the on-board computer. In France doing such product identification with bar code will allow to automatically record product characteristics. Under the aegis of Agro-EDI-Europe a standardization of such bar-codes is taking place. With this, all the product characteristics will be transferable from the product manufacturers to the farm through the cooperative or the provider. This will avoid a manual data recording both at the farm level and at the implement level,
\textbf{Dilution rate}: this data is very important in case of sprayer application. The flow sensor gives data relevant to the mix "water and pesticide". For direct injection sprayers this data could be automatically registered. But, for "classical" sprayer it could be interesting to automatically registered simultaneously the water quantity filled in the tank and the pesticide bar code (such data giving the quantity in the bag). This allows to bypass the manual registering of "dilution rate" in order to simplify the driver task.

Additionally we found that some data not useful for crop management would be interesting to transfer to the farm in order to correct bad location data. Indeed, sometime D-GPS signal correction could be loss, or could be of bad quality. In this case if GPS measurement is not periodic we need to transfer to the farm the following collection of data: "time", "ground speed" and "end of row" (for example, when cutting bar is going up). The objective being to correct location data by calculation of travel distance between two GPS measurements, and calculation of similarity of ending rows.

The current phase of our work encompasses the completion of a \textit{multi-function software} (accounting, crop management...) based on this general Information System. The first version of this software is now operational. This version includes accounting module and EDI between the farm and its environment (accounting office, cooperative). Work is going, last modules of this software including crop management are under development.

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