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Proposal of an ontological approach to design and analyse farm information systems to support Precision Agriculture techniques

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Abstract. After a comparative evaluation around the concepts of Industry 4.0, Precision Agriculture and Smart Farming, the paper discusses the necessity of identifying solutions able to apply the methods of the so-called Knowledge Management 4.0 in the agri-environmental enterprises. To this aim, an ontology based on a conceptual map derived from the data-to-information transformation is here proposed to support the design of a new generation of Farm Information Systems (FIS) able to fit the production needs of agri-environmental enterprises. The data-to-information cycle is split into four phases: A) Data collection, B) Data processing, C) Data analysis and evaluation, and D) Use of information. Phases A and D comprise tools of “light digitization” typically referring to OLTP components (On Line Transactional Processes). On their turn, phases B and C are typically formed by “heavy digitization” components (On Line Analytical Processes), generally more complicated to be managed by the farmers directly. The conceptual map defined by the ontology is firstly useful to plan the composition of the FIS according to a modular approach, possibly following a strategy that starts to consider the introduction of OLTP components, for then evolving gradually towards more articulated solutions that include also OLAP component and related functions. In this way, decision makers can manage practical planning instrument able to show clearly the level of complexity a FIS can reach, thus evaluating its sustainability with respect to the financial, cultural and professional resources available at the farm. Finally, after having underlined the opportunities offered by Cloud Computing and widespread connectivity, that provide an easier adoption of OLAP tools, some application cases are presented and discussed.

1. General background

1.1. Industry vs. Agriculture

The recent proposals of the so-called *Industry 4.0* (**Ind-4.0**) have introduced new paradigms in the management of production processes through ICT [1, 7]. Many solutions can also be applied in the agricultural sector, within which the application of *Precision Agriculture* (PA) techniques has been considered for over twenty years [2, 3, 4].

An exhaustive definition provided by the US NRC (1997, [8]) states that PA is a “management strategy that uses information & communication technologies (ICT) to collect data from multiple sources in view of their later use in decisions concerning production activities”. Originally, this definition was firstly intended to refer to field processes, being mainly focused on the highly automated site-specific



approaches, aiming at overcome the management limits imposed by the relevant spatial variability in field properties (from which also the names of “*prescription-*” or “*target-farming*”). Later, it was extended to many other types of farming systems, such as livestock, viticulture and orchards. Despite the relevance of the original definition, for a long time the PA has been mainly intended as a means to allow the transfer of advanced automated applications into the agricultural sector. This created great confusion on the market among potential users, often disappointed by completely unsatisfied expectations. Only recently also the name “*Smart Agriculture*” has started to be used by many producers in the sector, probably more to reflect a fashion rather than to affirm a new technological principle.

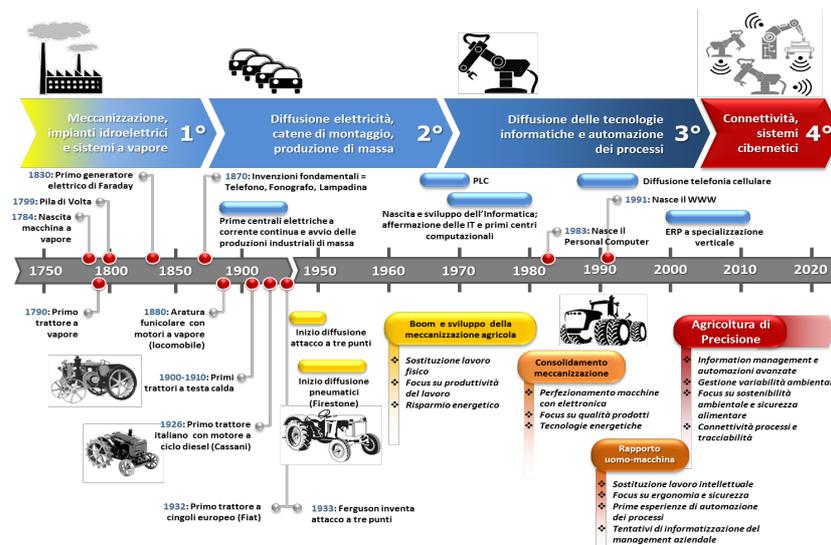


Figure 1. Comparative scheme of the evolutionary stages of industry and agriculture

Surely this term has its usefulness because it tends more to shift the attention on the need to realize *forms of quality management* rather than pursuing mere purposes of advanced automation. In relation to this, the quality of management can be firstly intended as the ability to make decisions based on targeted information, previously collected through a global monitoring of production processes, thus reconnecting to the original NRC’s definition. Sometimes even the name “Agriculture 4.0” is provided, just to underline an assonance of concepts with Ind.4.0. However, as shown in Fig.1, this is rather improper because the 4th industrial revolution implicitly mentioned in the concept of Ind.4.0 follows the 3rd industrial revolution approximately occurred at the end of last century (1970-2000). Basically, this is the period of the industrial digitization with the introduction of **ERPs** (*Enterprise Resource Planning*) and related information systems. This has not occurred in agriculture and the technological gap to be tackled must also take into account the shortcomings in the use of ICT. Here, therefore, every innovation must consider different approaches, starting from the proposal of new farm information systems (FIS) able to manage the problems of agro-environmental enterprises whose production means are delocalized in the territory and subject to specific needs as indicated in Fig.2 (moving processes in uncontrolled open spaces, climatic aleatory, lower professional skills, multitasking workers, scarce financial resources) [5, 6].

In summary, with regard to the five different aspects considered in Fig.2, we note that: 1) industry and agriculture have diametrically opposed tendencies; all aspects that are generally favourable to the industry represent serious weaknesses for agriculture; 2) there are actually different types of agriculture; the most negative effects relate to arable farms and crop cultivations, while animal husbandry shows less suffering due to production methods typical of industrial processes (obviously except for forage production processes); this also explains why the first experiences of digitization of agriculture were related to the management of milking processes; 3) the sector of farm contractors shows further strengths, both for the high specialization in technologies, often equipped with advanced automated solutions, and for a better skill of employees, basically more suited to pay more attention to the quality

of management (although also here, obviously, the weak point of the management of the processes on large portions of the territory remains still relevant).

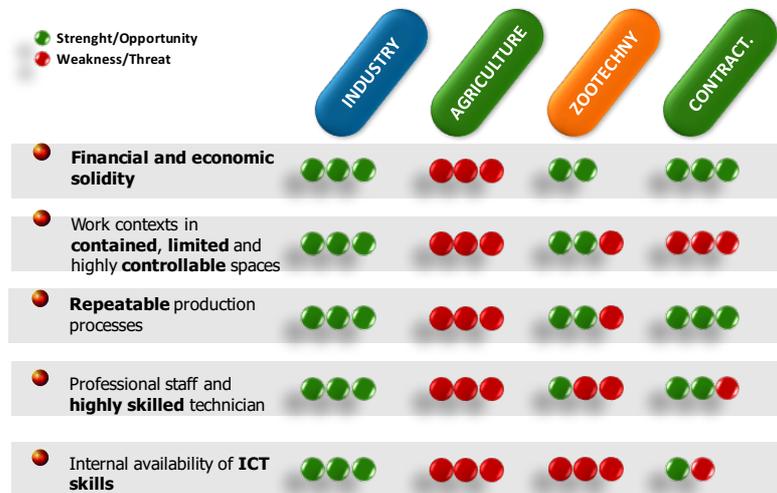


Figure 2. Aspects influencing ICT use in different production contexts

1.2. Industry 4.0 & Precision Agriculture

Ind-4.0 and PA share many objectives, such as: 1) process digitization, necessary for confirming and reinforcing the use of *Information System* for managing production processes, planning resources and supporting advanced strategic decisions at the enterprise (ERP evolution); 2) searching for *robotics* and *advance automated processes* (for both monitoring the production lines and improving process productivity); 3) *hyper-connectivity* between production agents (both human and machines), searching for advanced cybernetic approaches (for the moment, with a large focus on industry, only); 4) Treatment of huge amount of data (*Big Data*), and 5) *Machine Learning*, with quick data interpretation to make information easier to use in decision-making processes.

Internet of Things (IoT) and *Internet of Services (IoS)* are tools and methods that can largely contribute in supporting good results for the above objectives. As mentioned, these objectives are much more feasible for the industry than for agriculture, since the latter has yet to recover a significant technological gap on the ICT front. In fact, here the digitalisation of the sector has been lacking, as basically has been limited to the diffusion of electronic technologies (basic automation) on board the machines (especially tractors).

Nowadays, however, even the introduction of automated solutions always requires the use of digital applications designed to become increasingly complex. In this regard, we can speak of "*light digitization*", when ICT requires simple firmware embedded in the application devices, designed to convert in real time the signals measured by sensors or identification systems into elementary actions through appropriate actuators. Instead, we can speak of "*heavy digitization*" when the measured data are recorded on special supports to be used in later times, after appropriate processing, transformation and evaluation. From this point of view, we can state that while in the Ind.3.0 phase the industrial sector (in parallel with the commercial sector) has contributed to consolidate technological solutions, with related professional profiles, suitable for managing forms of heavy digitization, in the agricultural sector even today many users interested to PA tend to focus more on solutions of light digitization, showing considerable inertia in moving towards mixed forms.

1.3. Knowledge Management 4.0 (KM4.0)

Smart Agriculture, similar to Ind.4.0, has the objective of implementing the quality production systems by applying forms of information management in which *light + heavy digitization components are*

integrated. This is possible through the introduction of Information Systems (IS) that provide tools to support the transformation of raw data into information. The latter in turn are then transformed into decisions through the so-called Knowledge Management (KM) phases described in Fig.3. Raw data represent a message of the real world that is worth registering when a priori is expected to be of some importance in the decisions to be taken with respect to the farm domain of interest. Data becomes information when actually enter the decision-making process. The decision maker then manipulates the information transforming them through his cognitive processes first into "Knowledge" (apply context) and then into "Wisdom" (apply insight), to finally arrive to the actual decision (apply purpose).



Figure 3. Transformation of raw data into information and then into decisions according to the view of Knowledge Management

Therefore: 1) the IS, with all its components, supports the transformation "*raw data into information*"; 2) the Decision-maker then personally performs the transformation "*information into decision*" throughout his own mental processes.

In short, ISs enable decision makers to:

- Collect data related to processes, materials and products;
- Process and archive the collected data, through models and databases coherent with the future decisions to be taken;
- Analyse and use processed data, being supported in the transformation of information into knowledge and wisdom, according to their decision-making processes;
- Access information at any time they need.

Thus, the IS becomes the main KM instrument, since it also promotes the sharing of knowledge among all the members of the productive system, each with his/her own *hierarchical role* (decision-making level). From this standpoint, KM is a practice independent of current technological levels as it tends to pursue a sort of "philosophy" of collaboration and sharing in the workplace.

Thus, the concept of knowledge based mainly on the skills of individuals is overcome (while is still strongly common in traditional agricultural contexts), to affirm instead the need to produce new knowledge only through the sharing and processing of information. Obviously, the ICTs have largely contributed to affirm this conceptual model, so much so that the vision of Ind.4.0 parallels the concept of **KM4.0**. The essential aspects of the latter include:

- Ensuring an approach highly oriented to **IoT** knowledge processes;
- Managing and treating Big Data acquired directly from **things** (= *elements of processes and products*) and **customers** (*people acting in the system*);
- Sharing information** between people or things without any limitation;
- Storing all data and information directly in **clouds (IoS)**;
- Ensuring that all contents are always available **online**, also to implement any **real-time** automation process;
- Providing information sharing (**C2C, C2M**) via wireless solutions (**Hyper-connectivity**);
- Fostering of **predictive analysis** in the main maintenance and control tasks.

Even Smart Agriculture must be able to guarantee a gradual process of methodological and technological evolution along the direction of these approaches.

2. Scope

An ontology is here proposed to design Farm Information Systems (**FIS**) specifically conceived for agro-environmental enterprises. The latter, as we have seen, present profound differences with respect to industrial companies, above all in terms of size, profitability, staff and work organization, need to manage mobile processes distributed throughout the territory with all the related implications (necessity

of positioning, adaptation to weather conditions, site-specific variability of lands, need to process and monitor biological and environmental elements).

In industrial companies, classic ERP systems are generally divided into 5 vertical sectors (1. human resources, 2. warehouse, 3. production, 4. logistics, 5. accountability), which are integrated within an IS of varying complexity. Regardless of the type of enterprise, all sectors are usually of equal importance in the IS structure, and the system tends to maintain a certain degree of management autonomy in each sector. Things change significantly in the Ind.4.0 modalities, with an increase in the relative importance of the production and logistics sectors when compared to the other three.

In the case of KM4.0 applied to agro-environmental enterprises, the FIS can generally be limited to only three vertical sectors, namely:

1. **Warehouse**, to keep track of all the materials in input and output for the company, including energy items, thereby also responding to traceability tasks;
2. **Processes**, with the functions of: a) monitoring, which here assumes - also for environmental constraints - fundamental and often cogent importance, b) synthesis and analysis, with the support of a series of packages for specific decision support to be evaluated from case to case; c) control, with functions of direct intervention on the individual processes through sensors or actuators (automation);
3. **Administration**, including staff, customers, suppliers and accounting.

The need of an ontology for FIS designing is here felt, as we have to deal with: i) an application domain that cannot be clearly split into independent sectors, ii) a core "process domain" that must share many common resources among many production goals, iii) the need of limiting to internal re-organization of the farm as a consequence of the introduction of new managing tools, both for cultural and financial constraints.

The ontology aims to provide a conceptual map capable of describing components and functionalities of the FISes themselves, defining either the strategies for their modular development, or the level of management and structural complexity to be achieved. The "map" starts from the conceptual difference existing between "data" and "information" and takes into account the whole pathway with which data are transformed into information.

3. Approach and methodology

3.1. OLTP and OLAP components

The life cycle data-to-information is described in Fig.4.

The cycle includes 4 phases: **A. Data collection**, **B. Processing**, **C. Analysis and evaluation**, **D. Use**. In each phase the data take different states: raw data (A), data processed (B), data evaluated or formatted (C), information (D).

The scheme also distinguishes between 2 FIS areas featured by different levels of digitalization:

- The **operational areas**, referring to specific elements of production processes, dealing with individual events with great details and usually following highly standardized procedures; they include components that have in charge single, specific transaction, and are even named **OLTP** components (*On Line Transactional Processes*); they include the phases A and D of the data-to-information cycle;
- The **informational areas**, with opposite characteristics, as include components dealing with aggregated facts through overall views, analyses and global controls typically carried out through flexible procedures in which the experience and the subjective standpoint of the various decision-makers often weigh heavily; here the key-point is a global analysis approach and they are even named **OLAP** components (*On Line Analytical Processes*); they include the phases B and C of the data-to-information cycle.

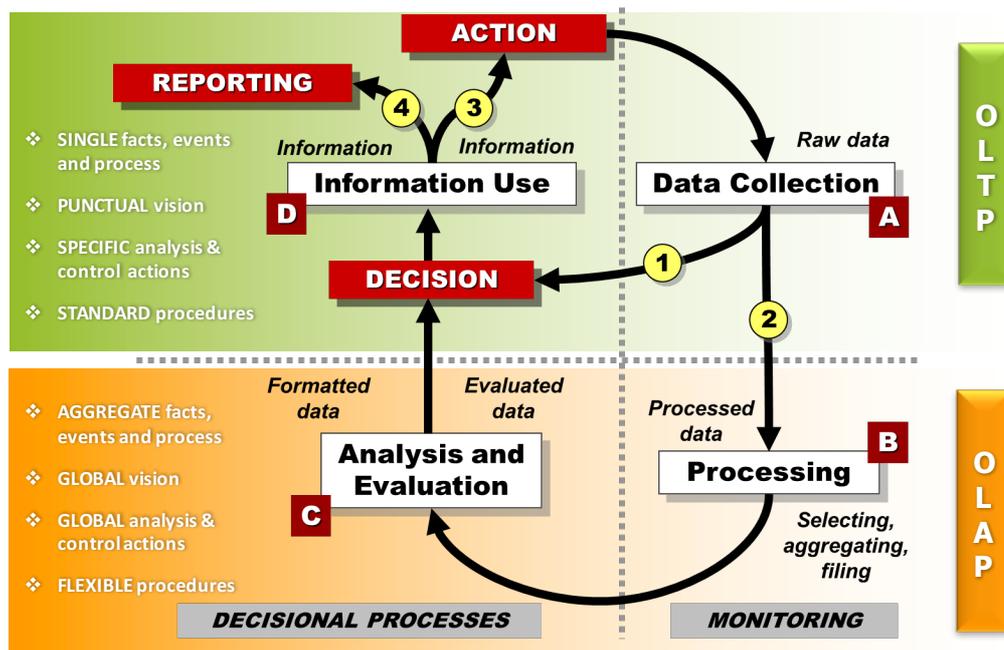


Figure 4. Schematic representation of the data-information life cycle. The scheme highlights the information flows and the conceptual methods of integration between operational components (OLTP, *On Line Transactional Processes*) and informational components (OLAP, *On Line Analytical Processes*)

The above features make OLAP components significantly more complex to use than OLTP components. That's way OLTP and OLAP components can be assimilated to the afore mentioned concepts of light and heavy digitization solutions, respectively.

3.2. FIS phases

Phase A consists in the acquisition of data of potential interest to the decision maker. The acquired data can then undertake two alternative routes:

1. be *used immediately*, even through real-time processing, to make instant decisions (automated processes);
2. provide for *deferred use over time*, thus passing to **phase B**, with the archiving and possible integration/synthesis with other data from different periods; it is the path of common management applications, with the typical directional control functions.

The cycle closes with the **phase C** related to analysis and **phase D** related to the use of the information. The decisions to be taken concern problems of:

3. *control of on-farm processes*, operational or managerial; the decision is followed by an action to intervene on the processes themselves;
4. *certification towards third parties* (verify of production protocols or product quality standards); the decision then becomes a documentation activity (traceability).

In each phase, the FIS must provide a variety of hardware and software components, to support (or completely replace) the work of decision-makers, within the phase. To this aim we can distinguish between aiding tools and automating devices. For this reason, the scheme also becomes useful for defining a "*conceptual map*" with which to identify the different components of the FIS to: i) facilitate the design of the FIS; ii) provide adequate forms of integration between components; iii) define its degree of complexity to evaluate a priori the difficulties of its transfer in the production context.



Figure 5. Approach derived from previous Fig.4 to define a conceptual map with which to classify the components of an information system. For internal data collection, two situations are taken into account to distinguish between crop monitoring (A_{IN1}) and operational monitoring (A_{IN2})

Such a map can be derived from Fig.4 according to the approaches presented in Fig.5, where we observe:

- four circular sectors corresponding to the four afore mentioned functional FIS phases;
- two concentric sectors (**IN**, **OUT**) related to the degree of integration of potential FIS components with the enterprise's core business, as well as with the FIS data warehouse.

By overlaying circular and concentric sectors, we obtain the final conceptual map of the FIS, in which each X -th phase is divided into two distinct X-IN and X-OUT fields. "IN" sectors indicate aspects intimately connected to the execution and management of farm internal processes, with the implication that here every FIS component must be necessarily "customized" on the characteristics of the farm structures and behaviour, usually with direct connections to the central FIS DBMS. "OUT" sectors, on their turn, indicate components linked to situations that are more conditioned by the different external environment types with which the farm interacts (meteorological, physical, commercial, regulatory, etc.). Their components are limited to forms of conceptual integration, with limited or completely absent connections to the central DBMS.

3.3. FIS sectors

The FIS sectors that can be thus identified on the conceptual map are defined as follow:

- **A_{IN1} : Production monitoring**, including any component aiming to achieve data on conditions and *properties of elements that are the objects of the production process*; in case of cultivations, it is referred as "*crop monitoring*", and for example includes all sensors used to detect NDVI or yield mapping data;
- **A_{IN2} : Operational monitoring**, including any component aiming to achieve data on the *ways by which a process is carried out*; frequently, it requires the application of identification system for the automatic detections of all the agents that take part to a process (power units, implements, workplaces etc.);
- **A_{OUT} : Environmental monitoring**, it usually aims at the observation of the physic-chemical variables that characterize the *environment in which the productive activity takes place*; in case of crop cultivation, it frequently concerns the use of sensors for the measurement of pedological and meteorological parameters;
- **B_{IN} : Basic processing**, it regards the use of essential ICT components for the *basic digitalisation* of management processes; therefore, in addition to the fundamental hardware (PCs, PDAs, any servers, network connections, etc.) and the operating system, it firstly includes the components

of the farm data warehouse, together with all the tools for modifying and querying the DBMS; secondly, there are the classic software packages for office automation (word processing, spreadsheets, graphics programs, e-mail, etc.);

- **B_{OUT}: Advanced processing**, it provides the use of software packages of medium and high complexity, normally dedicated to the *management of digital maps* interfaced with DBMS (GIS), possibly also supported by advanced management procedures of vector graphics (CAD), geo-referencing, image analysis and statistical processing and / or geostatistics. Their use is typically intended for expert users (knowledge workers), who in large enterprise should have to permanently assist the farm direction. Since this is usually not possible, most of the features of this phase are often outsourced;
- **C_{IN}: Customized assessments**, they concern the use of *Decision or Management Support Systems* (DSS and MSS) directly integrated in the FIS structure for an efficient and direct data exchange with the farm DBMS; these are often highly complex applications based on stochastic simulation methods that require knowledge of historical and climate local data. As such, they operate on mainly structured or semi-structured information. Their use is occasional or relatively frequent and require the assistance of highly qualified personnel (knowledge workers or external technical assistance); for example, they could concern programs for: the definition of fertilization plans, the creation of prescription maps in chemical spreading operations, the simulation of the productive behavior of alternative cultivation plans; the creation of diagnostic maps etc .;
- **C_{OUT}: General utility assessments**, they concern *applications for general analyses*, often limited to a "conceptual" integration in the FIS, rarely used and mainly intended to operate on unstructured data, totally independent from the FIS DBMS, often with the need for access to external databases (open access applications available in the net); they usually relate to models based on deterministic calculations and optimization methods, such as packages for: exercise cost estimation, investment analysis, energy balances, LCA analysis (Life Cycle Assessment), multicriteria analysis etc.
- **D_{IN}: In-Farm use of information**: it usually concerns the implementation domain of production activities, and provides for the use of all those components of various kinds (frequently actuator devices, but also displays for improving the H2M communication) that allow the use of the information in farm processes featured by different levels of automated execution.
- **D_{OUT}: Out-Farm use of information**: it includes the set of tools able to make the farm suitable to produce the necessary documentation to perform, according to various purposes, *process and/or product certification tasks* (both on compulsory or voluntary basis); application examples can range from the simple printing of invoices or transport documents, till the formulation of complete EPD reports (Environmental Product Declaration); related components are usually represented by specific software packages suitable for this purpose; however, it still remains subordinated to the preventive implementation of both Monitoring (phase A) and Basic Processing (B_{IN}) phases.

3.4. Using the FIS conceptual map

The conceptual map of the FIS can firstly highlight the logic role of each hardware and/or software component within the FIS, according to the function it performs in the data-to-information life cycle. This also provides a prompt appraisal of the level of complexity at hand, according to the number and the distribution of the components: *higher the number of the components and the number of "activated areas", higher the FIS complexity*. As the application of OLAP components is generally more complex than OLTP ones, a step-by-step and modular introduction from OLTP to OLAP components should be always expected, in order to achieve a progressive perception of the usefulness from the FIS use, also becoming gradually more familiar in the conduction of information management finalized to a quality production system. As the application of OLAP components is generally more complex than OLTP ones, a step-by-step and modular introduction from OLTP to OLAP components should be always expected (Fig.6), in order to achieve a progressive perception of the usefulness from the FIS use, also

becoming gradually more familiar in the conduction of information management finalized to a quality production system.



Figure 6. Qualitative example of a FIS evolution on a farm, starting from the introduction of OLTP and progressively moving towards OLAP solutions. Hardware (red) and Software components (blue) are here indicated.

The modularity should also ensure a strong control on investments, avoiding component redundancies or unnecessary repeated expenses. However, searching for modularity is still an hard task requiring the identification of standard approaches and methods that must pass necessarily through the agreement among the main player and producers of the sector.

4. Application examples

The proposed logical map offers a key to interpreting the levels of complexity and integration between FIS components in the design phase. It is not possible to define an "information system" as such if some OLAP components are not foreseen, starting from the presence of a DBMS, even in an essential format.

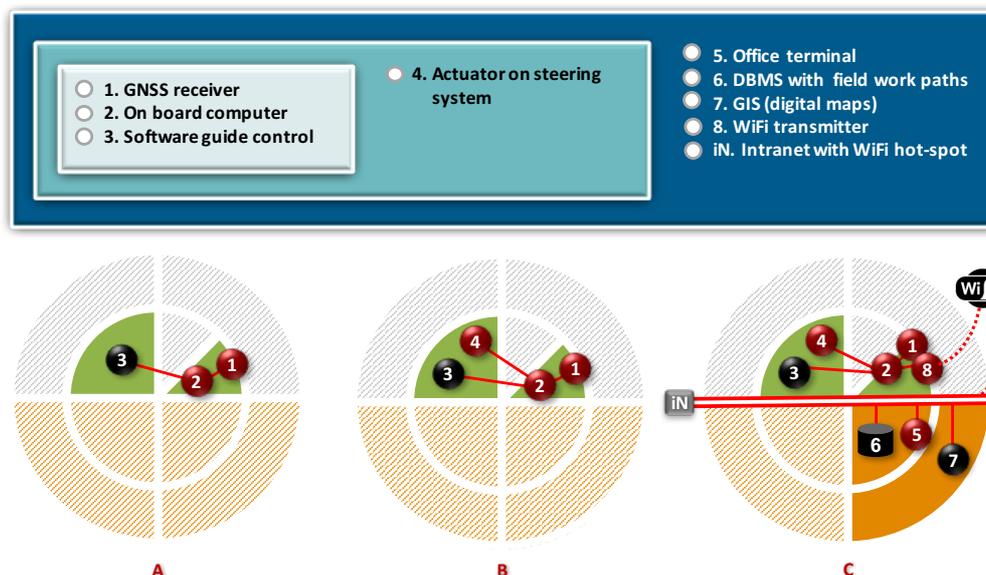


Figure 7. Example of classification of A FIS components according to the approach of Fig.6. A) Swath guidance (the driver is only assisted in the direction adjustments that must be manually provided); B) Automatic guidance (adjustments are automated by an actuator on the steer); C) As B, with in addition registration and consultation of the tracks.

A first example is given in Fig.7, where two solutions for assisted and automatic guidance are illustrated. In the first two cases (Figs.7A and 7B), we have stand-alone applications, without any connectivity with other users. However, the scheme highlights how even in this case it is advisable to proceed with possibly modular solutions: the automatic guidance is a sort of upgrade of the assisted one (even named

swath guidance), with the addition of an actuator device on the steering system, controlled directly by the same software already in use for the assisted driving.

Despite their simplicity, these applications have proved useful on several occasions as they have given rise to unprecedented interest in farmers in the use of IT, inducing in some of them the desire to also record the traces of the field operations for some later consultations. Although simple (but not trivial), this request introduces the use of OLAP systems (Fig.7C) because it requires the presence of a data storage system (B_{IN}) with related querying methods, possibly on GIS components (B_{OUT}). A further improvement implemented in Fig.7C is also linked to the introduction of a farm intranet line, to facilitate data transfer through a WiFi solution.

A further typical PA application example concerns the distribution of materials (pests or fertilizers) with automated dosages according to site-specific logics. Two approaches can be followed, depending on whether the dose control is performed by:

- a) an *on-board sensor* (typically optical) that, based on predefined rules, allows to independently set the dosages in real time (**OLTP-oriented solution**, Fig.8);
- b) a *pre-defined prescription map*, which combines the planned doses with the current position of the spreader (supplied by a GNSS device) to select the dose to be sent to a VRT system (**OLAP-oriented solution**, Fig.9A).

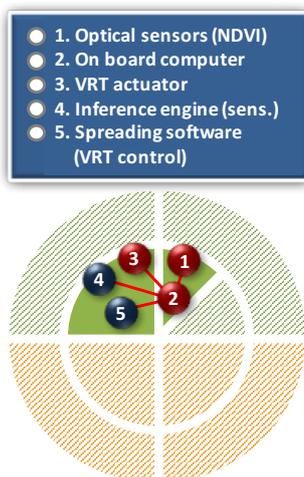


Figure 8. OLTP-oriented spreading solutions, driven in real time by tractor on board optical sensors.

Only this last solution needs to be supported by a FIS, as it requires the integration of synthetic analytical skills prior to the execution of the works. It could then evolve modularly towards even more integrated and complex solutions to include all the functional areas of the SIA, as indicated in Fig.9B. In particular, here we can observe: i) DSS for generating prescription maps; ii) environmental monitoring tools; iii) procedures enabling traceability reports. In addition, the increased complexity leads to the use of wireless data transmissions (GPRS) and the introduction of a Server with related Intranet.

In general, it is useful to keep in mind that:

- the higher the number of components in the OLAP phases, the more the management of the FIS will be complex, at least at an early stage;
- some OLTP components have no practical meaning unless properly integrated into specific OLAP components; for example, traceability functions require the presence of data storage systems that can be consulted on demand;
- the integration of systems within a FIS (i.e. solutions

already composed of several tools) usually leads to positive synergistic effects in strengthening the analytical capabilities of decision makers. This is the case, for example, of the combination of automated electronic scouting solutions (crop monitoring) and operational monitoring in orchard farming systems or wineries: the integrated combination of knowledge of current activities and phytosanitary conditions significantly increases the information content finalized to diagnostic and management purposes.

5. Cloud computing and service centres

The applicative examples so far discussed, regardless of their level of complexity, are nevertheless confined within the framework of a "classical" digitization, not yet fully satisfying the requirements of the KM4.0 approaches. In fact, while ensuring a good degree of automation of spreading processes (Fig.9B), as well as automated monitoring activities supported by forms of wireless data transfer, hyper-connectivity levels are there still confined within the farm. In addition, the farm must be also provided with an internal server, with all the management complications of the case.

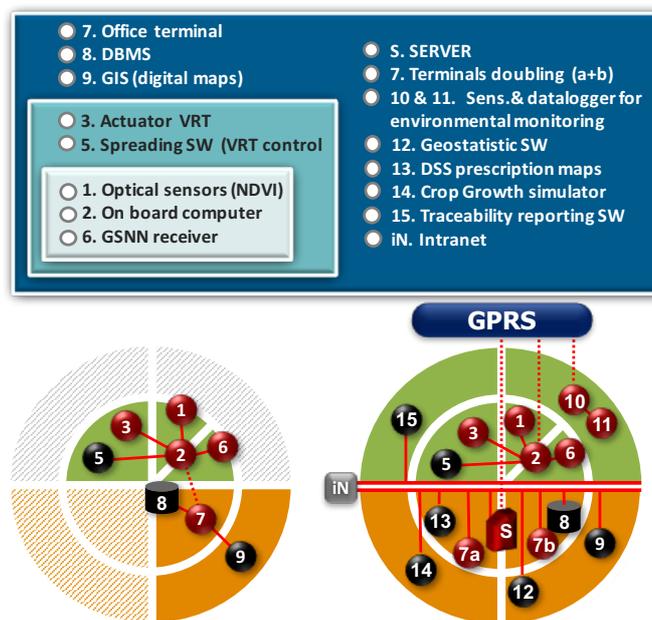


Figure 9. A) OLAP-oriented spreading solutions, driven in real time by a prescription map, manually predefined by the user (no MSS component in phase C); B) as A), but with extended functions related to data transmission (via GPRS and through an intranet line, with an internal server), environmental and operational monitoring, evaluations and traceability tools.

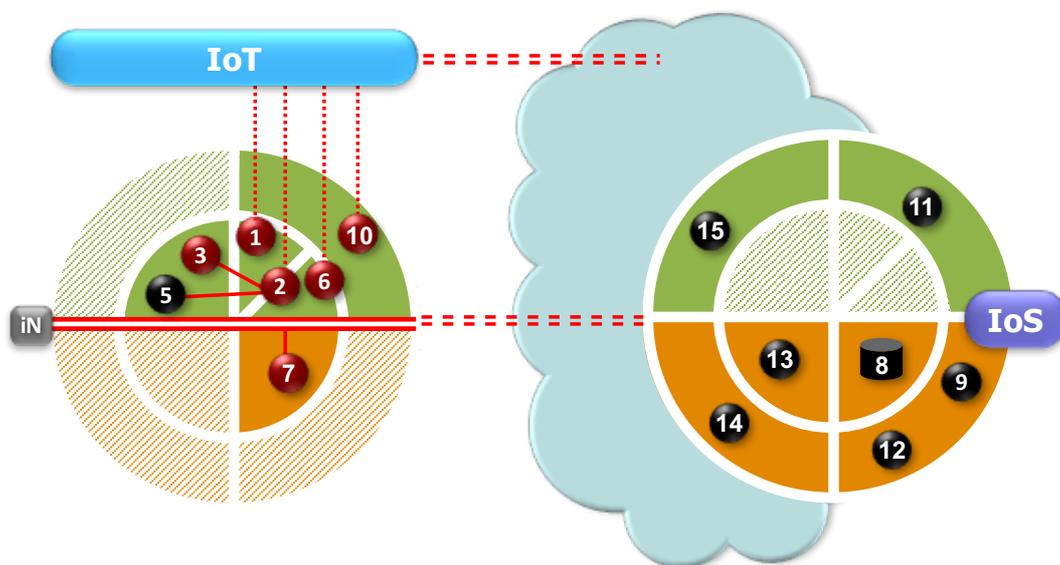


Figure 10. Evolution towards KM4.0 approaches of the previous solution discussed in Fig.9B. All the data and the main OLAP functions stay on the “Cloud” managed by a Service Centre.

A possible evolution towards a KM4.0 logic is described in Fig.10, in which we can note a sort of “FIS decoupling” where: a) a IoS platform enables to transfer all the OLAP complexities into the cloud (including the server maintenance); b) the most relevant OLTP components remain in charge to the farm, excepts the packages related to environmental monitoring and traceability; c) IoT solutions largely

simplifies the hardware management of monitoring tasks; d) the main OLAP component that must remain in charge to the farm is a terminal for net connections with the IoS.

The new frontiers of Cloud Computing and widespread connectivity today open new possibilities for positive future developments of FIS KM4.0-based. Many commercial services are already available on the net, offering a large part of these FIS functions, making easier the availability of OLAP technological resources to remote users.

In general, there are three type of actors that have independent roles on the "cloud": 1) the *cloud provider*, which makes available under payment the required resources (virtual servers, archives, any possible applications); 2) the *administrator*, which configures the services offered by the cloud provider according to the final user's requests (he can also manage access rights and add any customized proprietary applications); 3) the *user* (final customer) who applies the services appropriately configured by the administrator.

It is desirable that as soon as possible new Service Centers specialized in Smart Agriculture (SASC) can be established and organized, in order to take in charge the roles of administrator, thus freeing the FIS responsible of single farms (users) - through totally online services - from the most burdensome responsibilities in the data management (physical maintenance of ITC equipment, with any intermediate data processing, including relative consistency checks) [4].

The support of the SASCs, moreover, could also favor the creation of diffused FIS, with a hierarchical over-company structure, in which single farms depend on a single main reference enterprise, enabled to perform control functions on single associate members. A typical example concerns the situation shown in Fig.11, in which N viticulture farms confer the grapes to a single winery. The latter has its own W-FIS which also performs monitoring tasks, aiming at controlling the quality of the supplied grapes through as much information as possible. These are obtainable from the F-FIS of the single conferring farms, available to share part of their DBMS with the winery. All roles are managed by the SASC, together with the data access policies compatible with the levels of confidentiality established between the parties. Here, too, all the main OLAP functions are left to the SASC, while all the peripheral farms remain focused on the management of the requested OLTP components.



Figure 11. Conceptual example of a IoS platform providing FIS services to a winery together with all the farms conferring grapes to it (traceability of suppliers to improve grape selection for high quality wine production).

6. Final remarks

An ontology based on a conceptual map derived from the data-to-information transformation has been here proposed to support the design of a new generation of Farm Information Systems (FIS) able to fit the production needs of agri-environmental enterprises. Such a conceptual map is firstly useful to plan the composition of the FIS according to a modular approach, possibly following a strategy that starts to consider the introduction of OLTP components, for then evolving gradually towards more articulated solutions that include also OLAP component and functions. In this way, decision makers can manage practical planning instrument able to show clearly the level of complexity a FIS can reach, thus evaluating its sustainability with respect to the financial, cultural and professional resources available at the farm.

The FIS designing activity must be always organized following an infological approach (ie, oriented to the need of information), rather than a datalogical one (ie, oriented to the data that must be collected). Such a distinction is not trivial, and a mistake on this can occur very frequently (also in the better-trained industrial sector). Indeed, thinking of data is always simpler than thinking of problems to solve, on their turn linked to decisions that must be taken. The logical map provided by the ontology could be useful also to this aim.

Components selection, modular growths strategy and general FIS structure should be always decided trying to satisfy the requirements of a KM4.0 approach. To this aim the availability of a Service Center specialized in Smart Agriculture (SASC) is always a great help for the possibility of decoupling as much as possible OLTP and OLAP components at the farm, leaving the OLAP management directly to the SASC.

Moreover, these SASC could also provide on-site services, with supports for company auditing and training in the initial phase, as well as providing assistance in monitoring activities in the form of: i) rental of recording devices, in the case of operational monitoring (the ownership of the hardware components would thus remain in charge to the SASC, maintenance included); ii) execution of on-demand crop monitoring surveys with own means (with ground/remote sensing activities through terrestrial or aerial vectors, such as UAV); iii) processing and/or interpretation of user data.

The success of this approach will depend on: 1) SASC service reliability, with related completeness and timeliness; 2) SACS competence in identifying highly interdisciplinary forms of aggregation of their internal staff; 3) the ability to propose service tariffs compatible with the expected benefits in the use of FIS, not always easily to assess in purely monetary terms.

For sure, the needs of Smart Agriculture require to start a deep cultural revolution among its workers and responsible. While waiting for “digital natives”, such a revolution must even start from revising the education programs in Agricultural Curricula to meet the digital perspective of future generations. In fact, while the management of the ITC devices to be used can stay in charge to engineer and computer experts, the management of knowledge and wisdom must remain in charge to agricultural experts, that however must be able to move with enough autonomy through the new technological frontiers of the sector.

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