# *Business Intelligence in the Vineyard*


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## *Abstract*

The evolution that is nowadays taking place in the information and communication fields, namely in mobile computing and remote monitoring, constitutes a very interesting challenge to the agricultural sector. This reality places agronomic knowledge in centre stage as these technologies are dramatically improving data collection and storage capacities, challenging the farmers and the agricultural field experts to develop processes that efficiently transform data into information and knowledge and are able to support the everyday decision making at farm level. In this work we will present a demonstration project under way in a vineyard in Portugal where we are exploring the potential of the most recent technological innovations available in the market to build the i-Farm, the information and knowledge society intelligent farm.
i-Farm (intelligent farm) applies at farm level the potential offered by using in an integrated way mobile solutions, sensor networks, wireless communication and digital imagery materialized in a information system that supports farmer real time decision making in the field and in the office.
The i-Farm project creates a unique knowledge repository containing information from multiple sources (crop, environment, soil, operations, market, etc.) enabling accurate and timely decisions.
For the project development a Business Intelligence approach is used. In the context of this paper this broad term is used to refer to the process of aggregating, processing and building rich and relevant information which is made available dynamically in real time to managers in an interactive way to support decisions and planning activities.


**Keywords**: business intelligence, vineyard, precision viticulture, wireless sensors

## *Introduction*

The evolution in the information and communication fields, namely in the mobile computing and remote monitoring context, made available in the market devices with growing processing capacities and smaller sizes which are able to offer sensing functionalities, wireless communication, integrated energy source and action capacities is posing a very interesting challenge to the agricultural sector (Wang et al., 2006, Hart and Martinez, 2006).
This reality places agronomic knowledge under the lights since these technologies are amplifying our data collection and storage capacities (Pokorny, 2006), challenging the farmers and the agricultural field experts to develop processes that can convert data into information and knowledge in order to support the everyday decision making at farm level. In this context

the use of different types of sensors to evaluate crops physiologic conditions is becoming a common practice in agriculture (Gurovich and Saggé, 2005).

In our work we will explore the potential of the most recent technological innovations available in the market to build i-Farm, the information and knowledge society intelligent farm. The i-Farm project, which is now underway, is being financed by Agência de Inovação DEMTEC Program, and will be applied to a vineyard, since viticulture is considered a strategic activity in the framework of the Portuguese Rural Development Strategic Plan (GPP, 2007), aiming to contribute to an increasing competitiveness of the agricultural sector.

Viticulture in general and precision viticulture in particular are receiving increasing attention from the academic and business communities since it is a capital intensive activity where the investments in modern information and communication technologies can be justified with a solid cost/benefit analysis. Today we can find in scientific literature and in service providers companies examples of the most recent wireless remote sensing solutions applied in the vineyard (Camilli et al., 2007, Morais et al., 2007, Neto et al., 2007).

***Information and Communication Technologies in Agriculture***

The practice of agriculture, in an ever changing environment and growing competition coupled with increasing concerns in terms of economic, social and environmental issues has greatly benefited from a fast evolution of the technologies available for its practice. One of the driving forces of this reality is undoubtedly the knowledge and information revolution we live in society in general and in the agricultural sector in particular.

A leading vector of this evolution, also felt in the agricultural sector, is the constant arrival to the market of new solutions incorporating advanced information and communication technologies promoting the collection and availability in real time of a wide range of data sources at farm level with geo-referenced attributes. Amongst the examples considered nowadays trivial we can refer information covering weather and soil data, productivity levels, production factors use, etc. Furthermore now are arriving to the market the so called phyto-sensors promoting the automatic collection of information about crops growth, physiological and health parameters (Phytec, 2008). At the same time and with a high application potential in the rural environment we have been observing a great evolution in the wireless data communication systems, from Blue-Tooth to Wi-Fi and finally to WiMax and mesh networks offerings solutions which can cover great areas with acceptable costs (Intell, 2008, FarmNetworks, 2006, WiMax Forum, 2008).

This evolution can be framed in the so called Precision Farming. This agriculture production model adopts such diverse information and communication technologies as: Geographical Information Systems (GIS); Global Positioning Systems (GPS); Remote Sensing; Variable Rate Technologies (VRT); numerous sensors; telecommunications; decision support systems; etc.

Precision Farming appears generally with two main objectives: increase farmer's income; and reduce the environmental impact resulting from agricultural activity. The first of these objectives can be achieved by two distinct but complementary approaches: production costs reduction and crops productivity gains (sometimes also quality ones). The fulfilment of the second objective relates to a tighter control in production factors usage (mainly chemical inputs due to the negative environmental externalities usually associated with them) which should be made in the exact measure of the plants needs (Coelho et al., 2004).

After a first stage where precision farming was adopted in cash crops and precision animal production in dairy farms we believe that we are now watching a major shift where this

production model will be adopted by the generality of agricultural activities and input use decision will be made at a much more detailed scale offering greater input usage efficiency. At the same time we see today appearing in the market numerous technologies which support this production model and are making increasing pressure in the sector actors, including not only farmers but also the professional that provide technical support.
In this context we believe that in a not distant future all agricultural activity will be done in a precision framework since all the decisions made and the actions taken will take place in an intensive information context. Thus, all the sector actors must develop the abilities that can increase their competitiveness, most notably the ability to increase value based on the recent information and communication technologies developments.
The main question we face today is to know if the capacity and the agronomic knowledge to develop the tools to use the huge amounts of data susceptible of being collected in real time and transform it into information is available. In this new scenario the critical success factor will be to have the capacity to explore data repositories of different origins, nature and formats and to supply only those which in the right moment and in the proper format become information and in the interaction with de decision maker are transformed into knowledge and support him in his decision making processes.
In this work we will present our vision of this future that we believe is not very far away materialized in i-Farm (intelligent farm) concept that we propose and that is being put into place in an vineyard in the Alentejo region of Portugal (Herdade da Pimenta in São Miguel de Machede, Évora). The choice of the vineyard is justified by the fact that this activity has been pointed out lately in several technical and economical viability prospective analysis as one cluster to be exploited by the Portuguese agriculture in the global market context.

## *i-Farm*

i-Farm applies at farm level the potential offered by the integrated use of mobile solutions, sensor networks, wireless communications and digital imagery materialized in a geo-referenced information system. It supports both in the field and in the office real time farmers decision making taking advantage of a unique knowledge repository combining crop, environmental, economical, etc. variables.
i-Farm consists of an information and decision support system for viticulture working at farm level and combining innovative software and hardware to collect and analyze data from multiple sources dynamically integrated in real time and taking advantage of last generation sensors, digital imagery capture, wireless communications combined with personal digital assistants, unmanned aerial vehicles and Web services.

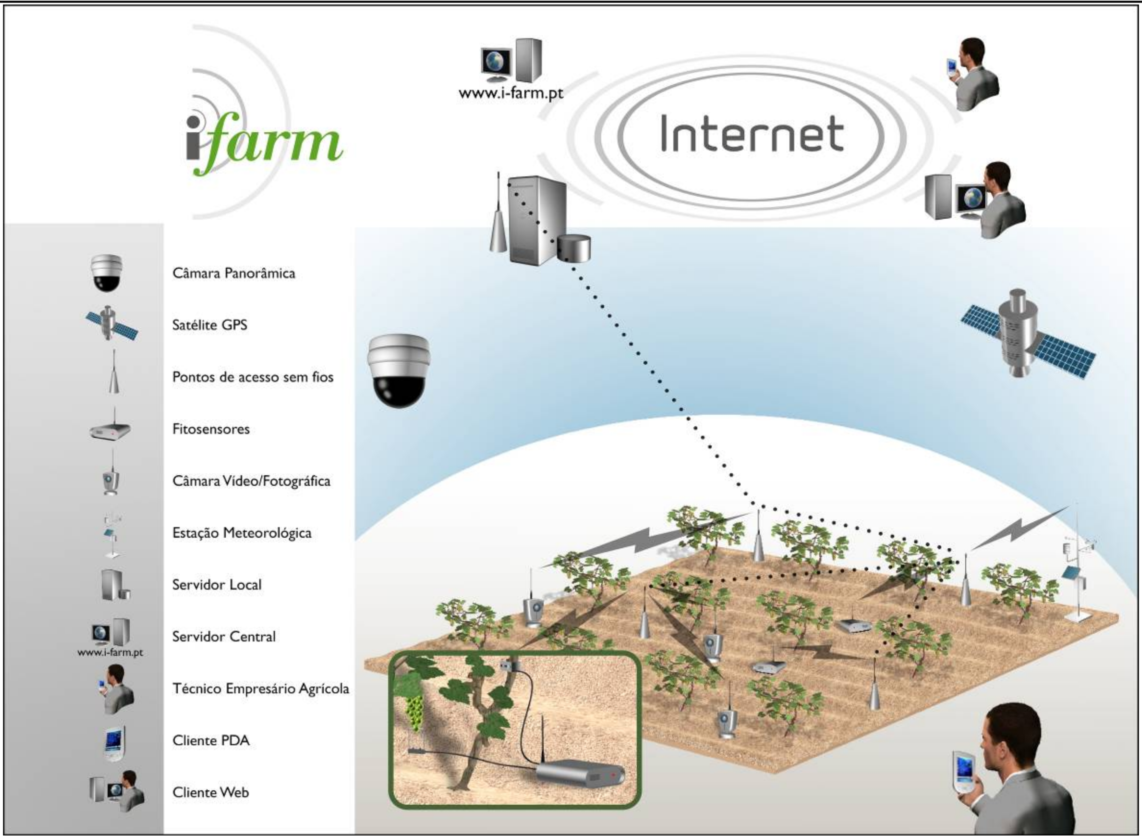


Fig. 1 i-Farm arquitechture.

i-Farm (Fig. 1) will be made available through an information system integrating, in a modular approach, multiple functionalities accessible through one single Web access point, such as:

- Wireless remote sensors offering the possibility of collecting different types of data, namely:
    - Context/environmental information (soil and weather) – air temperature, soil surface temperature, air relative humidity, solar radiation, wind speed, rain, soil moisture, etc.
    - Crop information (phyto-sensors) – sap flow, fruit growth, leaf temperature, wet leaf, trunk microvariation dendrometer, photosynthesis monitor, etc.
- Wireless photographic/video cameras to collect digital imagery and support virtual field visits;
- Personal digital assistants integrating communications capacities/Internet access to collect field data and support instant access from the field to the information system knowledge repository;
- Farm wireless coverage to support real time monitored data collection and transmission and Internet/Intranet access from the field.

### *Business Intelligence*

In the presented above context we believe the fulfillment of i-Farm concept is more suitable in Business Intelligence (BI) approach. BI is a broad term including tools, architectures, data bases, data warehouses, performance management, methodologies, etc. all integrated in a single computer application aiming at make available to the organization managers and technical personal a fast and simple way of accessing dynamically all business data in real time and also to offer the possibility of performing manipulation and analysis operations over it (Turban, 2007).

Through the analysis of historic and present data as well as with metrics and performance indicators built upon them decision makers obtain a knowledge that supports better and less risky decision making. Amongst the traditional functionalities offered by BI solutions we can refer: reporting and querying, complex analysis, data mining, forecasting, etc.

Business Intelligence solutions in an organizational environment has five main components: the different data sources either from operational information systems or even from outside the company; a data warehouse (DW) where the data from the data sources is loaded in ETL processes; a business analytics component which is a collection of tools to manipulate and analyze the data warehouse records and could include data mining functionalities and business performance management (BPM) for performance monitoring and analysis; and a user interface such as a digital dashboard.

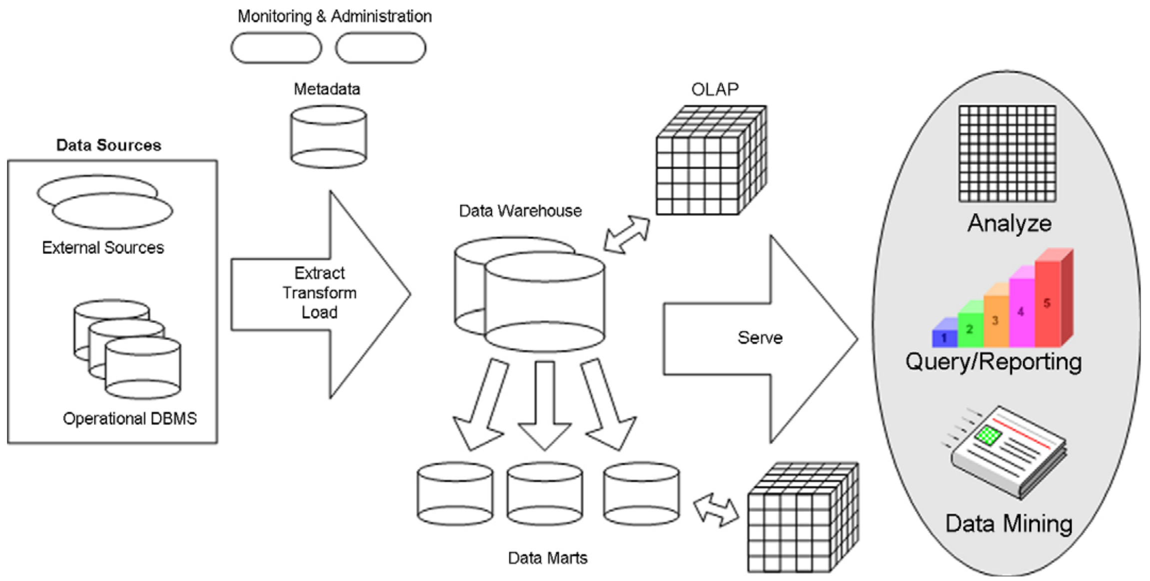


Fig. 2 High level BI architecture [11].

A BI solution high level architecture can be observed in Figure 2, which is detailed as follows (Nilakanta et al. 2007):

**Data sources** – the different data repositories scattered in the organization mainly in the operational database management systems and also the external sources the organization uses to support the environment scan activities.

**Data warehouse** – data from several sources flow to a DW which is a special data base or a data repository that was prepared to support decision making applications ranging from simple reporting and querying operations to complex optimization. A DW is a subject-oriented, integrated, time variant and non-volatile collection of data used in strategic decision making. DW are built mainly with metadata and ETL (Extraction, Transformation and Loading) methodologies. There can also exist data marts which are repositories of a specific subject or department;

**Business analytics –** consists in the possibility offered to the users to create at their request and in an interactive way queries and reports, perform data analysis known initially as Online Analytic Processing (OLAP) and can include a data mining component for more complex modeling and prediction tasks;
**User interface –** we include in this area the digital dashboards and information transmission tools that offers the users an integrated and comprehensive vision of the firm performance metrics, the Key Performance Indicators (KPI), trends and exceptions, combining information from multiple business sources. Digital dashboards offer business performance intuitive graphical visualization similar to a car dashboard. The secret of dashboard design consists in capturing the metrics and the performance indicators that, when compared with the actual business performance and combined as graphics, translate business health condition.

***Business Intelligence in i-Farm***

In the specific case of i-Farm, considered as an integrated decision support system at viticulture farm level in a demonstration unit installed in Herdade da Pimenta (São Miguel de Machede, Évora), three wireless monitoring islands were installed, each one at a different vineyard variety plot as illustrated in the image below.


Fig. 3 i-Farm “Islands” localization.

In a BI approach i-Farm system is materialized in Herdade da Pimenta in a model represented in figure 4 and detailed below.

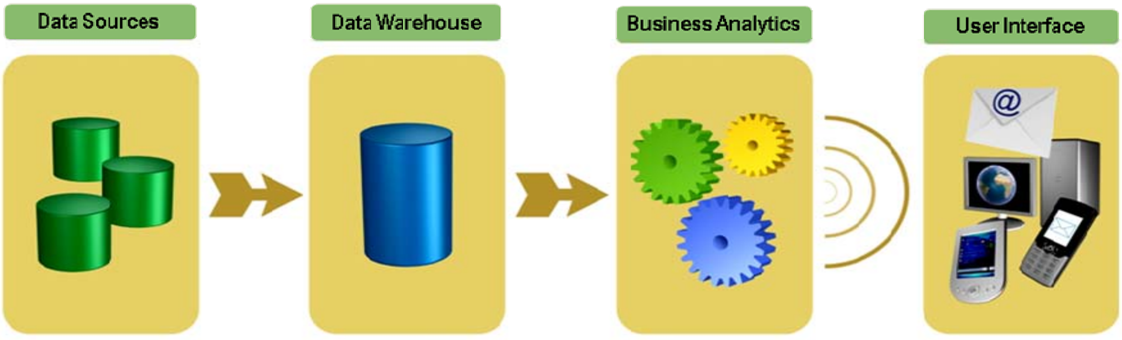


Fig. 4 High level i-Farm BI architecture.

**Data sources** – automatic and continuously data collection with various distinct origins which can be grouped in the following:

- Context information – from the environmental/soil sensors installed in each island;
- Crop information – trough the phyto-sensors wireless network;
- Operational information – from the farm operational information systems and from expert/farmers field visits trough the use PDAs with Internet/Intranet connection;
- Visual information - from photographic/video cameras.

Fig. 5 Images of the equipment installed in i-Farm.

**Data warehouse** – all the collected data will be integrated in one single knowledge repository offering the possibility of storing alphanumerical and spatial information and also images and videos. This repository will implement a set of internal validation procedures executed in an automatic and continuously way aiming at assuring the integrity and liability of the collected information.

**Business Analytics** – in this stage of the process we will make available a bundle of analytical processes including querying and reporting operations and OnLine Analytical Processing (OLAP) capabilities. IN the near future we intend to explore the potential offered by data mining techniques for knowledge discovery and forecasting.

**User Interface** – the system critical success factor will be the "client" interface that both field technicians and farmers will have to use to take advantage of the possibilities offered by the system and access the underlying knowledge repository. Thus it will be made available the possibility of querying and manipulating in real time all the information that is being collected in a certain moment, to visualize the repository existing information in multiple formats (graphics, tables, GIS, photos, videos, etc.) and also receive evolution trends forecast when suitable.

This layer will support two different approaches to information delivery. In one hand in a push logic mobile telephony short messages service and e-mail will be used to send alerts to the user when any event considered not normal is detected. On the other hand and in a pull logic the access to the information system can be done in a web friendly user interface for two different platforms desktop/laptop computers and personal digital assistants (PDAs).

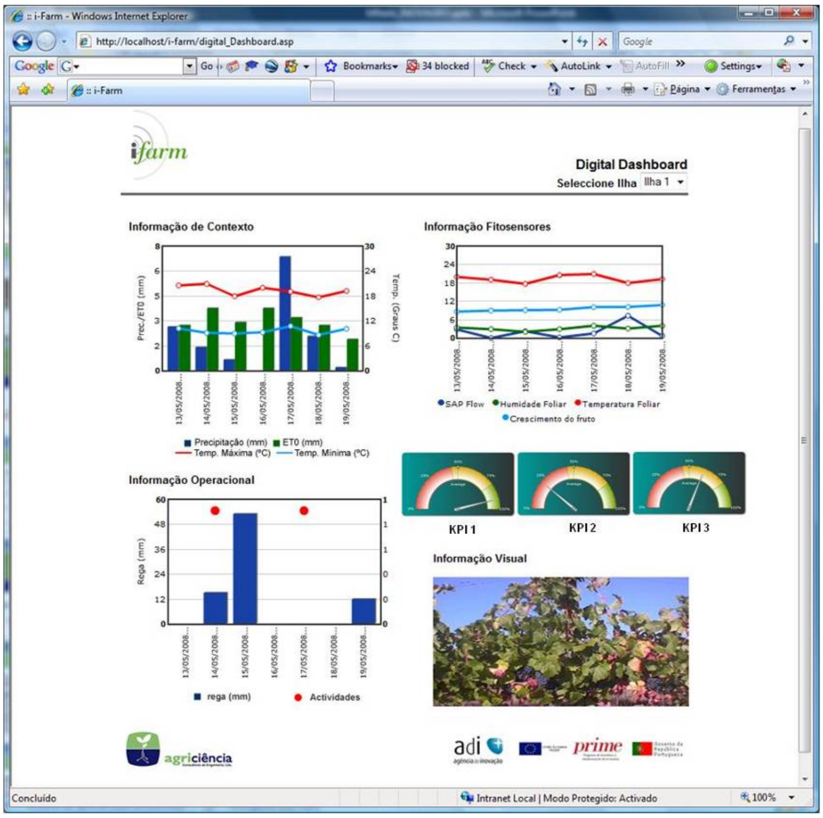


Fig. 6 i-Farm digital dashboard mash-up.

The main goal of this web interface is to make available a set of key performance indicators (KPIs) displayed in a digital dashboard where in a glance we can get a global and unified picture of the company performance. Besides given this instantaneous graphical and easy to capture vision of the organization's health the selected KPIs are presented with context information, namely information about what is considered to be a good, average and bad reading for the metric under analysis. Finally they should also support drill-down operations in

order to present more detailed about the composition of a given KPI or to allow time granularity manipulation.
In the case of PDAs use in the field and if a wireless local/Internet connection is available it will support the information system access directly from the vineyard.

***Future Developments***

At present we are putting the technological infrastructure into place and starting the permanent automatic monitoring activities covering environmental, soil and crop variables aiming at beginning the process of loading the data warehouse supporting the information system.
The digital dashboard user interface is being tested being visible in figure 6 the present version for desktop web browsers. The mobile web browser digital dashboard will be a simplified version of the desktop GUI to answers the specific needs of this kind of platform.
Clearly, the ability to extract knowledge from the large amounts of data that the system will produce is central to its success. The ability to find empirical regularities has the potential to create new and improved practices, especially in terms of the optimization and a tighter control in the usage of production factors. Particularly, the possibility of establishing an automatic and real time system for managing input usage, seems particularly appealing. Also, the development of predictive models for crop size estimation and harvest scheduling can constitute important tools to establish i-Farm as a valuable tool.
The i-Farm system allows a close monitoring of the relation between inputs usage and their impact in production. This link constitutes an opportunity for generating knowledge based on assumption free methods which search for robust patterns in data. The i-Farm system poses some additional challenges due to the relevancy of the geographic variables. It is essential that the geographic location is used not just as another variable but as a leading factor in the analysis. Farming conditions vary a lot even in relatively small areas, thus it is important to accommodate these particularities in the modeling or prediction tasks.
There is evidence that the knowledge and practices of farmers is far from homogeneous. Different farmers will do things differently, and it is of the utmost importance to adopt a more scientific approach to vineyard management, allowing the establishment of best practices. It will be interesting to contrast the farmer's practices with the finding of a knowledge discovery system based on the i-Farm data.
In this context special attention will be paid to the potential offered by data mining techniques after the business analytics module starts working aiming at creating new knowledge bases on the built data warehouse.
Data mining is a knowledge discovery process oriented base on patterns and hypothesis automatically extracted from the data, unlike statistical inference where hypothesis are formulated and validated by the data. In this sense data mining is data oriented meanwhile statistics is Man oriented (Teixeira and Santos, 2006).
The modular logic i-Farm adopts allows us to assure the future possibility of aggregating different decision support systems made available by third parties in a distributed logic such as irrigation scheduling, pests and diseases forecasting, nutrient needs, harvest forecast, etc.
Also important is the attention that will be given to assure that the system will be able to "speak" with the remaining sectorial information systems existing in the farm such as production, stocks, sales, accounting, human resources, etc.
Finally being supported by Internet technologies it must guarantee the possibility of collecting, storing and making available information from external sources such as market, legal and administrative information in a service oriented approach (SOA).

Also, as a result from the collected data processing and analysis, the system can make available in the future remote control functionalities over some specific crop management techniques such as irrigation or site specific weed control.

### *Conclusion*

The knowledge acquired until now trough the execution of i-Farm demonstration project using advanced agricultural information and communication technologies applied to a vineyard allows us to conclude that using a Business Intelligence approach in an agricultural capital intensive activity can be very successful.
Furthermore, we think that is possible to be optimistic about its potential of generalized adoption and usage not only with this crop, but also with other strategic crops such as olive growing, horticulture, etc.
In this moment the biggest challenge we face is to develop the processes in the business analytics module in such a way that they create added value over the data warehouse content and that we can make it available in a friendly and interactive user interface to the final users.
Furthermore we are currently working together with a technological center with specific expertise in irrigation scheduling management in order to integrate in the system their knowledge on the subject in a web services approach.

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