Computational Precision Livestock – Position Paper

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1. Introduction

The beef cattle industry in Brazil is developed in all units of the Federation and includes approximately 225 million hectares distributed in 2.20 million properties, according to Instituto Brasileiro de Geografia e Estatística (IBGE). These properties shelter a total of 170 million animals, according to Conselho Nacional de Pecuária de Corte (CNPC) and the Fórum Nacional Permanente para a Pecuária de Corte. According to these same sources, this is one of the supply chains that employs most, accounting for 7.2 million direct jobs (IBGE, 2003). The beef agribusiness has been growing every year in Brazil, while at the same time this industry has been structured competitively. In the last decade, average growth was about 30 %, while export growth was higher than 200 %.

In 2003 Brazil surpassed Australia in export rate of meat, and becomes today the largest exporter of beef in the world. According to estimates of Fórum Nacional Permanente para a Pecuária de Corte, the total production of beef in 2002 was more than 7 million tons, of which approximately 900 thousand tons were exported, with a revenue of 1.1 billion dollars. The GDP generated by the segment represents U.S. $ 1.5 billion, although only a small portion of total production is competitive in the international market.

In recent years, food safety is an important issue in the world. In the specific case of beef, with the diagnosis of bovine spongiform encephalopathy (BSE1) in March 1996 and the subsequent hypothesis of a link between this cattle disease and the disease of Creutzfeld-Jacob (CJD2) as a new variant of similar disorder in humans, traceability has become the focus of attention of both consumers and the beef industry in the world (Wiemers 2000). Since then, to regain consumer confidence, participants in the livestock and meat supply chain are working to raise food safety standards.

The Brazilian beef cattle industry started timidly in the decade of 1990. With the increase in production efficiency, its demand has intensified considerably, especially as a result of pressures imposed by globalization of the economy. The markets of several countries, exposed to this global competitivity observed in the last years, have as consequence the necessity of efficient and effective production. Often such characteristics have become synonymous of survival or stay in business (Embrapa Gado de Corte, 2002).

The European Union, through Resolution CE No. 820/97, requires that all meat production process be inserted into an identification and registration program to keep track of all relevant information of the animal, from birth until the consumption of the final product. This resolution affects both producers and industries of Europe, and their suppliers (Projeto IDEA, 2000). This requirement imposes the development of systems that allow the individual identification of animals with total security and enables the retrieval of information in real time (Projeto IDEA, 2000).

The meat production process, from farm to the slaughterhouse, directly influences another supply chain of fundamental importance: the leather supply chain. Brazil has assumed an increasingly relevant role in this chain, with a significant increase of participation in the world market in recent years. In April 2011 only, exports of leather hit the value of U.S. $ 190.2 million and 34.8 thousand tons, an increase of 121 % in cumulative value in relation to the same period in 2009.

It becomes evident that we need to appropriate knowledge from other areas. In different problems of planning, production, security, logistics and decision making processes, we often face the need to optimize existing resources in search of greater profits and/or lower costs.

This industry needs an auxiliary way of indisputable effectiveness in the processes of Traceability, Food Safety, Certification and Evaluation Compliance and Production Process. This is especially important in Brazil, where large distances and regional dissimilarities complicate this work. Furthermore, a system with these characteristics should play an invaluable role in developing technology in all areas of agribusiness in Brazil.

2. Computing in Precision Livestock

The new information and communication technologies and the increasing accessibility of interactive multimedia widely extended the possibilities of management and optimization of production processes, in addition to promoting the dissemination of good production practices and effective control of the meat industry. These technologies can help the meat producer in decision making regarding purchase/sale of animals, forecast revenue and manage risk in the production of meat.

Thus, the search for the improvement and excellence of a herd monitoring and management system depends on the judicious knowledge of the flock and, indeed, the correct identification of animals. To monitor effectively the herds, and ensure good meat production practices, several measures have been taken. For such measures to become effective, resources of the area of information and communication technology (ICT) are used. The use of ICTs in agribusiness enables increased competitiveness and assists in meeting the requirements imposed by society and the market. The area that studies the use of ICTs in cattle is called Precision Livestock (PL).

Precision Livestock (PL) can be defined as a practice of management of bovine herds in which information and communication technology is used to ensure good meat production practices. Based on specific data of herd, geo-referenced grazing areas, automation at all stages of the meat industry, precision livestock aims at optimizing the production costs in obtaining a quality meat. In addition, Precision Livestock studies the environmental and social impacts in the production of meat and increased productivity.

The use of information and communication technology takes place at various levels and areas. The set of problems, and their complexity, in precision livestock presents new challenges and opportunities for the area of Computer Science. This brings us to the area of Computational Precision Livestock.

Computational Precision Livestock is a multi-disciplinary area that is based on hardware devices and use of software as key tools for increasing the competitiveness of the meat industry.

The main objective of this area is the study of computational solutions to the problems of precision livestock. The problems include the management of the herd with the use of electronic devices, the simulation of pasture growth, forecasting commodity prices, early diagnosis of animal diseases, study of genetic lineages of animals, automatic classification of carcasses, bovine meat and leather, simulation of alternative management practices, logistics, etc.

Computational Precision Livestock involves different knowledge domains of knowledge in Computer Science. If we consider that Web Science deals with how the Web can make things better (Wright 2011), then we can say Computational Precision Livestock plays a similar role. Moreover, to obtain animal data, rural properties, slaughterhouses, distribution networks, commodity markets, etc., we use various hardware devices ranging from simple radio frequency chips, non-tripulated planes, sensors and satellites. All these information require knowledge of the Information Management area to be stored and managed. The set of acquired information, together with those available on the Web, requires computational tools to extract knowledge and formulate hypotheses which can be done with the help of Data Mining. The decision making "at the right time" is crucial in the meat industry. With Computer Modeling one can make a prediction of profit, environmental and social impacts in decision making inherent in the different production stages.

The problems addressed in Computational Precision Livestock involve the obtention and classification of data, optimization and simulation. To solve these problems we use several areas of Computer Science:

1. Database
2. Artificial Intelligence
3. Bioinformatics
4. Visual Computing
5. Data Mining
6. Ubiquitous Computing
7. Human-Computer Interface
8. Cloud Computing
9. Robotics
10. Combinatorial Optimization
11. Numerical Analysis
12. Computational Statistics

We will make a brief description of each of these areas (ACM08). Then we describe some problems of precision livestock and how the various areas of Computer Science contribute in modeling and providing solutions to these problems.

Most problems involve a large set of information. The use of Cloud Computing is essential in solving problems of precision livestock. The network-oriented computing involves the study of communication in computer networks, standards and Web technology, mobile and wireless computing, security and communication protocols.

In the design of solutions, Human-Computer Interface is essential to ensure the effective use, since the users range from the staff responsible for managing the farm to operators of the Commodity Markets, veterinarians, zootechnicians, and the production unit owners. The design and implementation of good interfaces for these systems is a guarantee to its effective usage.

Visual Computing involves Visualization, Virtual Reality and Computer Vision. Computer Vision can assist in solving problems related to the classification of carcasses, meat and leather. With the decreasing cost of devices for capturing images, the use of surveillance systems and computer vision software for identification, tracking and automatic classification of certain types of behavior in herds, including open field, also becomes an interesting research and development target. Virtual Reality is a tool that enables remote management of gates, feed control, etc. Visualization associated with simulation helps in the study of problems associated with the growth of pasture, environmental impact studies, interpretation of satellite images, etc.

Ubiquitous Computing is used in solutions based on electronic chips, sensors and satellites. It enables the monitoring of the herd in real time and can monitor weight, temperature and location of animals in real time.

Robotics uses non-tripulated planes or drones, electro-mechanical devices and sensors in the design of solutions to several stages of animal management, especially in the creation of confined cattle. Moreover, the whole area of Intelligent Systems plays a key role in the solution of problems related to meat industry automation.

As in all areas, Information Management plays a critical role in Precision Livestock. All information obtained by the devices must be stored, analyzed and mined. In problem solving, knowledge of Database Management Systems, Data Mining and Hypermedia Systems is essential.

Many problems in precision livestock involve location and resource allocation and simulation of production models. In the modeling and solution of these problems we need Combinatorial Optimization, Simulation, Heuristics and Numerical Methods.

Finally, to ensure that the software developed meet specifications and requirements of users and customers we need to design solutions using Software Engineering.

3. A Case Study - Bovine Traceability

In this section we present a case study on Computational Precision Livestock. We describe a solution of bovine traceability using electronic systems to identify animals. The proposed solution exploits the additional features of the electronic tags and, in addition to identification, the proposed solution enables remote weighing and temperature measurement of cattle in the field.

In this case study, we present the integration of various technologies in the area of agribusiness, precision livestock, communication and computing in the development of a platform that supports bovine traceability and the complete management of agricultural production unit.

The use of classic identifiers such as tattoos on the inner surface of the ear, the branding marks by hot iron and use of numbered earrings, constitutes the most widely used to identify cattle. However, the diversity of races and managements, and the constant errors in manual transcription of data have motivated the search of more efficient methods of identifying animals, since the revision of the numbers marked with a hot iron on the skin or tattoo ear of the animals are often invisible in dark skin of animals or excessive body hair, becoming overly cumbersome and inefficient. In the case of earrings, the occurred loss that varies according to race and type of environment lies between 3 and 15% annually, which results in errors in the traceability process, in addition to economic losses for farmers (Ferreira and Meirelles, 2001). Moreover, marking the hot iron on many occasions when poorly located, damages the leather of the animal, a product of great economic value. The use of earrings, when misplaced, can result in infections and myiasis, in addition to the traumatic process.

Leather is a product of great relevance to the national economy, especially as raw material for industry, particularly footwear. As raw material for export, its economic importance is even larger than meat. Recent years have seen a growth in foreign exchange obtained with this product, which passed from 600 million in 1996 to 2.7 billion, according to the expectations for 2002 (Cardoso and Lee, 2002).

Several factors contribute to reduced quality of meat and Brazilian leather and most of them still occurs on the property due to improper handling. Ectoparasites, the tick, the larva and the horn fly, account for 40 % of lesions in bovine leather, while marking and use of stingers account for 20 % of the lesions (Grisi et al., 2002).

The electronic system not only eliminates the flaws and difficulties, it also enables the handling of animals, previously performed in the corrals, to be accomplished in the field, as is the case of weighing and measuring of temperature. Thus, one can expect increase in the yield of livestock due to frequency in data collection, which is now daily, and also the speed in making decisions that can increase the yield of livestock, as well as enabling a differentiated analysis of the results of research experiments, because the speed of decision making can affect the results.

One way to trace cattle is through telemetry. Electronic implants activated remotely emit an electromagnetic signal with the numbering of the animal. This signal is received by a computing system that checks quickly and unquestionably the presence of the animal in that herd (radio frequency identification) (Geers et al., 1997).

The meaning of telemetry has changed in recent years. The original goal was the remote measuring of organic and biological parameters such as electrocardiograms, electroencephalograms, pH, body temperature, blood pressure, muscle contraction forces, physical activity, blood flow and other physiological parameters (Hansen et al., 1983).

With the use of (bio)telemetry we can access and/or control measures, without interference and noiselessly, of an animal or human body. Therefore, biotelemetry includes the concept of biomedical instrumentation, which allows the transmission of physiological information of a generally inaccessible location to a remote monitoring site, always through micro-instrumentation techniques (Hansen et al., 1983).

Electronic systems that can be fully implanted in animals have evolved in the last 30 years from a simple transmitter to a smart ultrasonic sensor with interface systems (Goedseels et al., 1990).

The use of radio frequency identification chips (RFID tags) to trace animals enables a real-time monitoring of the herd and provides the information necessary for an Integrated System of Precision Livestock. These chips can be coupled with temperature measurement tools, sensors and other instruments. This enables a series of information that, together with other datas bases and a suitable web framework, can assistant producer in decision making.

RFID chips or "electronic labels" are activated by remote transceivers using a pulse-echo principle around 132 KHz. These methods are mainly used for identification, and transmission occurs only in response to a previous stimulus (Blackburn, 2001). The basic system consists of a transmitter/receiver and one or more transponders. In pilot projects carried out at Embrapa Gado de Corte since 1996 (Pires, 2000), some conclusions described below have been reached.

In the case of identification methodology with subcutaneous or intra ruminal implants:

1. The transponder used should be covered with biocompatible substance, and does not leave residue in meat. Furthermore, it should be sufficiently resistant to prevent breakage from impact or pressure from daily handling;
2. It should be powerful enough to be "read" at a distance of 1.5 meters and with the animal at an accelerated speed (40 km/h);
3. It should be easy to implant and put in a place of the animal's body so it does not "migrate" to enable reliable reading and can be easily recovered at slaughter (bottom bag umbilical fold and stomach);
4. The transponders must be "read only" or "programmable only once" thereby not permitting the change of numbers;
5. Both the readers and transponders, stationary or portable, should be ISO compliant, i.e., the transponders can be read by any reader regardless of brand or model.

The technical concept of electronic identification of animals as well as the code structure used were determined according to International ISO 11784 and ISO 11785.

With the use of RFID chips it has been possible to design a solution to monitor the daily weight gain of the animals. The computational solution to this problem involved the analysis of animal behavior, adequacy of the weighing scale to allow the weighing of cattle in movement, the development of a middleware to integrate the readings of the identifiers with the weight recorded by the scale. All these information are transmitted directly to a farm management system and integrated with the Portal e-SAPI bovis (Portal da Carne).

Associated with this solution, and motivated by the remote measurement in horses, an RFID chip with the capacity to record the temperature was designed and built. In this case, the problem of location in the bovine was more complicated because it was necessary to establish a correlation between the temperature obtained by the chip and the actual temperature of the animal. The use of this type of chip enables the remote temperature measurement of the cattle, in addition to obtaining the weight gain. This measurement is critical in the detection of diseases, including foot-and-mouth disease (FMD).

4. Problems to be dealt with

One of the main challenges of Computational Precision Livestock is the design and development a framework that is able to assist producers in making decisions in various areas. The most important is to enable the producer who, based on the weight gain of the flock, cost production, meat market conditions, risks of disease, and other factors, can decide what is the best time to sell/increase his flock. Furthermore, based on the use of resources (pasture, water, handling, etc.), weather forecast, cost recovery from grazing, the producer can decide when to move the herd to another property. From the standpoint of the consumer (or health authorities), it is important to enable full traceability of the product, i.e. at the purchase of a package of meat at the supermarket, it is possible to have a complete history of origin of the product. These information are critical in situations of health emergency (BSE - mad cow disease, foot-and-mouth disease, etc.).

In the case of pastures, the use of optimization techniques is essential because beef cattle in Brazil is characterized mainly by farming system based on pasture. Among the factors that cause reduction in production and productivity of the herd, we can cite seasonal fluctuations in pasture, both quantitative and qualitative, depending on climatic variations, inadequate handling, high incidence of parasites, other diseases and mineral deficiencies. These losses result not only from mortality but also the low production efficiency of animals (Bianchin, 1987).

The solution of the combinatorial optimization problem, when coupled with real problems, becomes much more complex due to the large number of constraints that must be considered as well as its characteristic that is often dynamic. Thus, solving optimization problems in practice becomes a task of extreme computational complexity.

Additionally, the producer needs an identification system that ensures a rigid assets control, and that allows the traceability required by international trade, and that allows the herd management, health management, reproductive and nutritional status of cattle and that allows programs of genetic improvement of the herd.

In slaughterhouses, the problems involve the classification of carcasses, meat and leather and storage logistics and distribution of its products.

To study these problems, Computational Precision Livestock has many technological challenges:

- design of new RFID chips
- use these chips
- design and location of antennas
- design of electronic and computational instruments suitable for Computational Precision Livestock
- communication and power in remote locations

In addition, in the study of problems of precision livestock, it is necessary to have new knowledge in various areas of Computer Science to address the following issues:

- Data Mining in Genetic Cattle Databases

- Integration of wireless devices
- Computer Vision
- Intelligent Systems
- Problems of Location and Transport of animals.
- Problems of balancing animal feed.
- Problems of optimal allocation of animals in pasture.
- On-Line Monitoring of cattle on growth (weight, vaccinations, etc.)
- Problems of optimal decision making (determine when a particular animal should go to the slaughter, selection of animals for breeding, etc.).
- Other problems in logistics, manufacturing, transportation and planning.

In the case of optimization problems listed above, most do not have a polynomial solution (NP-complete problems and NP-hard), thereby limiting the exclusive use of exact methods.

There are basically two classes for the solution of optimization problems: exact methods and approximate or heuristic methods. The exact methods have the advantage of obtaining optimal solution but they can usually only be used to solve small problems. This in practice severely limits their use in real problems.

Approximate or heuristic methods, on the other hand, are techniques that require less computational effort and thus can solve large problems. However, they can find solutions of good quality, but not necessarily the best solution (optimal).

The approach to computing problems in precision livestock is subject to how data will be captured and transmitted. It is necessary to dominate the technological use of such devices in real situations to consider various possible solutions using different types of mobility and mobile devices. The computational technologies related to mobility and mobile devices have been changing at a frightening speed in the last 10 years. The accumulation of a large number of mobile devices with different technologies coexisting together in the same market has imposed, paradoxically, a major limitation to expanding the use of mobility systems.

The high degree of specificity of these technologies is a challenge in developing software for mobile environments, it is very costly to establish teams capable of producing quality applications that meet a significant portion of devices on the market. In an environment of intense technology change along time and with short life cycles, the choice of a particular technology option can mean success or failure of any investment made in developing applications of this nature.

Another challenge in the use of mobile computing in precision livestock is the service availability and robustness of equipments, for they will be used in quite adverse conditions.

In this context the computational precision livestock production also represents an effort in order to popularize the appropriation of mobile technologies in rural production units and its integration with the existing computing environment.

The important thing is that Computational Precision Livestock offers solutions that are used by all actors in the production of meat, with good interface with the main mobile devices.

5. Concluding Remarks

To solve computing problems in precision livestock we have to take into account various aspects involved in agribusiness. There are applications of information and communication technology that should have existed in full operation in Brazil for many years. With them, many problems and even tragedies could be avoided, or at least better controlled. A concrete example is the environment monitoring. The main challenges include the availability of information and communication technology for agribusiness, the design and development of new technologies, in addition to the use of mature technologies in problems requiring urgent solutions.

The ability to innovate, particularly in the use and application of information and communication technologies, constitutes an important differential in the planning and implementing of public policies. Creating an environment conductive to innovation demands joint efforts by the organizations and the formulators of public policies. Many problems related to Agribusiness depend on innovative solutions that aggregate mobile device technology and also are integrated with new electronic government systems, with conditions to operate with new technologies.

Below we list several solutions developed by UFMS and UCDB together with Embrapa-CNPGC that help to produce quality beef. These solutions enable the sharing of information related to beef production for all producers, sanitary control, fiscal and planning organs. Some of these products were objects of software registration and others have pending patent requests.

- e-SAPI Bovis: a Web platform for Precision Livestock
- Obtention of the weight of (moving) cattle in the field
- Remote temperature measurement of cattle
- Electronic Emission of Animal Transit Guides
- System Based on Location
- Classification rawhide and web-blue using Computer Vision (Pistori et al., 2006)

Other problems are being studied, among them we highlight:

- Development and implementations of a case study of a Web Application on meat production;
- Installation of pilot projects in real time traceability of cattle with use of transponders (RFID);
- Implantation of unit reference in Precision Livestock;
- Installation of a pilot herd certification in real time;
- Usage of non-tripulated aircraft for herd management;
- Evaluation of pasture usage with satelite images;
- Datamining in genetic databases;
- Integration of cattle traceability procedures with traceability of leather aft slaughter;
- Flexible electromechanical structures to improve image capture in farms and slaughterhouses;
- Location of animals.

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