Towards an open development environment for recording and analysis of dairy farm data

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Abstract
A description of the current "in field" situation regarding information exchange in the dairy farming sector will be presented. Based on an analysis carried out in the EU-funded project 'agriXchange' current developments and issues will be discussed in relation to intra (on farm) and inter chain interactions. Organizing information sharing will be a main issue in this context. This is a complex issue because many aspects and dimensions play a role. In this respect lack of standardization of information systems is largely responsible for inefficient use and exchange of the recorded data. As a big challenge for the future the adoption of new technology by means of open innovations is also mentioned.
In a recently started project in the Netherlands 'Smart Dairy Farming (SDF)', companies in the dairy chain cooperate in the development of sensor technology and decision support models for on farm/cow application and the exchange of relevant information between the chain partners. The structure for recording, storage and analysis of farm and cow data, which is aimed to restrict new developments as little as possible, will be explained. This comprises an in-depth requirement analysis of the different sensor-actor-based processes which are continuously in operation for managing feeding, milking and reproduction of the dairy herd.

Keywords: information, livestock, management, sensor

Introduction

This paper consists for a larger part of a condensed representation of mainly livestock farming items, published by Holster et al. (2011) as part of the work carried out in the agriXchange project. AgriXchange is an EU-funded project; it is a coordination and support action to set up a network for developing a system for common data exchange in the agricultural sector. Here we describe the current "in field" situation regarding information exchange in livestock farming. Developments and issues are discussed in relation to intra-enterprise ('on farm') and inter-enterprise data exchange levels. Current issues and future challenges are summarised and discussed in relation with the new project initiative Smart Dairy Farm (SDF).

State of the art of information exchange in livestock farming

First an overview of the state of the art of information exchange in livestock farming, derived from literature, will be presented. This is combined with an overview of current new developments. The state of the art is described on the inter-enterprise integration level ('in farm' and on the inter-enterprise integration level ('in the chain').

Intra-enterprise integration

Process automation technology on the farm is mainly applied in dairy cattle, housed in free stall barns. The technology controls in particular processes around the animal. An overview of this technology is given in Table 1.

Table 1. On farm (process) automation technology; first generation and new developments.

Technology	First generation	New developments
Electronic identification	Approach and treat each animal individually	RFID for traceability of animals (EU regulation?)
Automatic concentrate feeder	Supply feed depending on yield	New software techniques: dose-response analysis
Sensors	Milk yield, milk conductivity, animal activity	Combining data from different sensors; (bio-) components in milk; wireless technology
Farm management systems	On farm storage of relevant farm and cow data	Centralized storage of data; PDA usage

An important break-through was the introduction of electronic identification in the mid-seventies. This offered the possibility to approach and treat each animal in a herd individually. On farm level radio frequency identification (RFID) for feeding concentrates to individual dairy cows is already in use for decades (Rossing, 1976). Experience gained during the foot-and-mouth disease epidemic in 2001 highlighted the need to establish traceability systems for cattle based on electronic identification of individual animals. Since January 1st 2008 electronic identification is obligatory for sheep and goats (Regulation (EC) No 21/2004). In Denmark electronic tagging of cattle is already mandatory from June 2010 (Hansen, 2010), more countries are expected to follow in the next years.

Identification systems as applied for concentrate feeding offer possibilities to record information from individual cows. Using this information offers possibilities for new software tools, that are about to be introduced in practise. For example a tool for the optimization of the amount of concentrates based on dose-response analysis (André, G., et al., 2007) and provides the potential to integrate economics with daily management feeding decisions.

Meanwhile, many more sensors are used in dairy farming, such as to record milk yield, milk conductivity and animal activity (Hogeveen, H. & Ouweltjes, W., 2003). In combination with software tools these are mainly used for monitoring milk quality and production and the health and reproductive status of individual animals. Technology makes it possible to increasingly take into account individual differences, offering shaping and controlling husbandry conditions for each animal.

An important mile-stone in the further development of individual cow management was the introduction of automatic milking systems. It is the ultimate example of how technology can be highly adapted to the cow. At the end of 2009, there were over 8000 commercial farms worldwide using one or more AM-systems to milk their cows (Koning, K. de, 2010).

Meanwhile, first systems are on the market for on-line analysis of certain bio-components in milk (Blom & Nielsen, 2009). The information is subsequently used for daily feeding and health management activities on the farm.
Currently, on-going research is identifying possibilities for clever agricultural applications of technologies that are already widespread in our daily lives (mobile phones, navigation systems). These wireless sensor technologies will again expand the available information about the production environment (climate, weather, housing) and production factors (animals, feed).
In farm management systems all relevant farm and cow data are stored. In some cases connections are made with external databases for relevant data exchange. External storage and development of service will increase data exchange. Market forecasts (Stormink & van Buiten, 2009) speak about developments towards external storage of farmers data in the coming years. The Internet will be used to have entrance to all the data, knowledge and services from all kinds of knowledge providers. Information for farmers will be more and more tailor-made in forms like benchmarking, complex decision support models (Mol, R. de, et al., 2007). This way of interactive use of data processing will encourage more and better registration and data collection and data interchange on the farm and chain. Farmers information systems storage is now moving to central location. An example of this is a sheep information system which uses handheld computers in the field, communicating through 3G mobile network over the air. Benefits of centralized systems are evident, looking at the decrease of risks of storage damage, but more the availability of the data for other partners in the chain.

Inter-enterprise integration

The traditional data-and information flows between the dairy farm and chain partners are generally well mapped and textured (Kuipers et al., 2005). The external processing of business data into specific management support information has an important position in dairy farming. Table 2 gives an overview of parties with whom farms exchange information .

Table 2. Information exchange between farm and chain partners.

Chain partner	Information
Accounting office	Economic business indicators; Tax information
Dairy processor	Milk deliveries, composition, quality and payments; quality assurance scheme
Animal health organisation	Monitoring animal diseases
Breeding organisation	Fertility, milk production and composition per cow; information of sires
Specialized labs	Forage, soil, manure composition and supplies
Feed manufacturer	Feed ration and concentrate composition
Governments	Identification and registration of bovine animals; Mineral (nitrate and phosphate) flows; Animal treatments and feeding (organic regulations)

In many countries farmers are required by the dairy processing industry to participate in a quality assurance schemes.
Animal health service organizations play a major role in monitoring animal diseases. The registration of contagious animal diseases like FMD, BSE, tuberculosis, brucellosis and leucosis are statutory duties.
Various data are collected on farm, processed and made available to the farmers via the Internet. Fertility and milk production data at the cow level are the starting point of the services of breeding organizations to farmers. This information is often shared with other service providing experts like veterinarians or feeding advisers. Data on composition and quality of milk delivered by dairy farms to dairy companies are determined by laboratories and used for payment.
The composition and quality of home-grown forage is on many farms determined by specialized laboratories. This information is used by the farmer or feeding adviser for optimizing the feeding ration for the dairy herd.
Feed manufacturers provide the service to compose concentrates based on forage quality and milk yield and composition data. Invoices from the feed suppliers can be viewed via the Internet and can be retrieved as an XML message and stored in the farm management system or forwarded to the accountant.
Several EU regulations require the farm to deliver information to the authorities. This refers for example to information for identification and registration of bovine animals (Regulation (EC) No 1760/2000), for keeping track of mineral flows (Nitrate Directive - EC Directive 91/676/EEC) and for organic farms for detailed documentation about animal treatments as well as the feeding (EC Regulation 834/2007 and EC Regulation 889/2009).
On dairy farms the farm management system is increasingly used for exchanging electronic messages with external data sources. Standards are for example available for exchanging information about individual cow milk monitoring, animal identification & registration events, insemination events, veterinary treatments and milk delivered to dairy processor.
Important information issues for the dairy chain partners, now and in the near future, are food safety, animal health and welfare and sustainability. Dairy producers and processors need to take the lead in providing the consumers with the essential information.
To protect public health, more efforts are needed to reduce the presence of undesirable residues of pharmacologically active substances in food of animal origin. An important aim in the field of antibiotics is the reduction of antimicrobial resistance. To achieve this, more information about the application of antibiotics in general but also on the level of individual farmers and veterinary surgeons should become available (Bondt et al., 2009).
Facing the increasing societal demand, initiatives at national or European level have been developed for the protection of farm animals (European project Welfare Quality®). The processing industry agrees that welfare and sustainability are interesting issues. Any new developments around data and information exchange on these topics between producers and processing companies should offer better opportunities for ensuring the product quality, animal welfare and sustainability.

In many cases creation of smart links between existing data bases could provide the required information. In such system each party can make information or data available. Parties remain themselves responsible for the quality of the supplied data.
Concluding the state of the art for livestock production, the quantity of data exchange are numerous and various. Data exchange exists between farmers and several service providing organizations. Different EU regulations result in flows between farmers and the governments. The increasing use of automatic devices on farm results in an increasing need for communication between devices and with farm management information system. Within the farm system, especially in dairy operations, there is a need to integrate data from different systems: feeding, milk performance, milk composition (quality), reproductive performance, health, heifer rearing (again, feeding, performance, reproduction). In the future, the situation could become more complicated with the introduction of new technologies (biosensors, wireless sensors). Sensors can produce large amounts of data. Current software tools mainly signal when there are deviations from expected or normal values. Further developments should not only focus on signalling deviations but should also give advice for a treatment or in the next phase even lead to an automated action.

Integration issues

Data integration is the alignment of data definitions in order to be able to share data and to provide the technical infrastructure to enable communication between hardware components (Wolfert et al., 2010). In Table 3 different levels of integration are defined. Main issues for each integration level are given.
As shown in Table 3 there are many issues in the different integration levels for information exchange. Here, only some will be highlighted a little further.
The number of devices and sensors are exploding, making the problem of interoperability even worse. But also making the free choice of farmers more difficult and hence not stimulating market competition (keeping the cost price high). In fact, interface standards (like USB in PC devices industry which gave a boost to innovations) are missing or not widely adopted by industry on a hardware level.
Data integration and data sharing are highly dependent on the availability of broadband internet in less easy area's like the rural environment and in house (stable) situations. The availability of mobile data communication structure plays an extremely important role for innovations based on mobile solutions.
For several reasons a more open data market infrastructure is needed or at least helps innovations. The lack of regional or domain specific (and interconnected) collaborative infrastructures is now often hampering. But it also makes it almost impossible to create an accurate private-public infrastructure where public (even EC) can efficiently connect to the private data (with great benefits for private).

Table 3. Review of levels of integration with main issues.

Integration level	Issues
Physical infrastructure	Lack of interoperability of devices, sensors and other techniques
Interface standards	Maturity of new technology, including costs
Communication standards	Availability of (broadband) internet infrastructure
	Lack of collaborative (EU) data infrastructure
	Embedded systems are limited in handling data and standards
	Adopting standards
Data exchange	Bad integration of data standards in countries
	Poor alignment of data definitions and data dictionaries
	Data quality and security
	Availability of public data sets and schemas (authentic databases)
Application	Local vs. centralized storage of applications data
	Adoption of open web services
	Open standards by software industry
Business	Business Process modelling as new skill for developers
	Process approach only picked up in new areas
Organization	Trust
	Adoption of new technology
	Limited investment possibilities (small domains)
	Lack of public involvement in collaboration (private-public)
	CAP implications

Although standards are widely implemented, they are not in all countries and not always in a very good integrated way implemented all over the added value chain. Data standards are very common based on bilateral messaging of data, which means that a few business partners are making agreements on the exchange of data entities (and its definitions) rather than on the business processes and data.

Nowadays application integration based on web services technology is emerging. Web services are autonomous, reusable software components based on XML message technology. Data doesn't need to be stored at a central location, but it helps in collecting data from several input locations and in linking the data to other external applications. Definitely, web services are coming up in agri-ICT as they can have a major impact on the development of data exchange since they can be rather simple and open to communicate. It would help if there was a bit more of a directive, from industry platforms and or from national or international governments (also playing a role on the 'information' market as demander for data).

The final integration is around the integration of processes (alignment of tasks) by coordination. Therefore, activities and interactions between processes must be defined in process and data models. There are several reference process models that support the design of integrated intra- and inter-enterprise business processes (Verdouw et al., 2010). Agri-ICT developers are sometimes rather small businesses and have to invest in modern and new tools. Additionally, innovations and improvements do have a strong dependency on social and organizational issues. Awareness and trust on the impact of a change (i.e. by research, implementing new technology and accompanying standardization) are important for business efficiency. Learning and further developing of services and products (based on the technology) in a rather safe innovation environment (pilots for example), and co creation by more stakeholders are other critical success factors.

Not only private collaborations but also the involvement of the public can be a key factor. The European common agricultural policy implies the control of several main themes like animals and its movements, mineral management, land parcel usage, food safety. Even animal health care and welfare and ways of responsible production of food and feed are already or will be monitored in near future. The implication of this is that the EU is a market player on the field of information sharing. In some countries, like The Netherlands, national government invest in open standardisation, publishing public data models (probably in future even data schemas) of the obligate data inquiry.

Implications new project initiative Smart Dairy Farm (SDF)

In a recently started project in the Netherlands 'Smart Dairy Farming (SDF)', companies in the dairy chain cooperate in the development of sensor technology and decision support models for on farm/cow application and the exchange of relevant information between the chain partners. From a research point of view one of the main objectives for this project should be to build a structure for recording, storage and analysis of farm and cow data, in which the recommendations from the agriXchange project (Table 4) are as much as possible fulfilled.

Table 4. Recommendations for ICT agri- and food business.

Recommendations for ICT agri- and food business
- Investing in awareness and trust
- Adoption of new technology by means of open innovations
- Join in developing new collaborative and service-oriented infrastructure
- Implementing business process standards and service-oriented approach
- Choosing the standards

Industry and business should take the responsibility investing in increased trust and awareness. Learning and further developing of services and products (based on the technology) in a rather safe innovation environment (pilots for example), and co creation by more stakeholders are other critical success factors. Open innovation is the keyword in an increasing complicated system. Private, and even public business, should invest in new collaborations and collaborative infrastructures. New data structures should be developed where data can be gathered, distributed, used for producing (new) services. Further attention has to be paid at the pre-competitive and more secured commercial layers to provide a means of securing property rights in an open space. Authentication and authorisation should be handled in a proper way.

As data integration would become more and more complicated, linking to several processes (and organisations) at the same time, the business process modelling approach will have evident benefits on a longer term. The same for service orientation. On both sides its very worthwhile to invest in knowledge and collaboration.

In ICT-agri, especially at the inter-enterprise (farming) level, the process modelling is so far only introduced in new data exchange areas. In the SDF project one partner (TNO) has experiences with the application of large scale sensor infrastructures. The so-called AnySenseConnect platform can be used as Application Programming Interface (API) to request for data and meta data of sensors and other "observers" over the internet. This HTTP REST interface can be used by third party applications to, for example, build apps for mobile devices, websites, control rooms, etc. In the IJkdijk project (www.ijkdijk.eu), the focus was on the development, testing and validation of sensor systems in water defences. It investigates the use of this sensor network technology to support early warning systems and emergency management.

The structure for recording, storage and analysis of farm and cow data, which is aimed to restrict new developments as little as possible, has to be worked out in more in more detail. This comprises an in-depth requirement analysis of the different sensor-actor-based processes which are continuously in operation for managing feeding, milking and reproduction of the dairy herd. These diagrams are made for all processes that provide information for actors (herdsman, veterinarian, etc.) or other processes. In Figure 1 the process 'concentrate intake' is given as a 'use case' diagram.

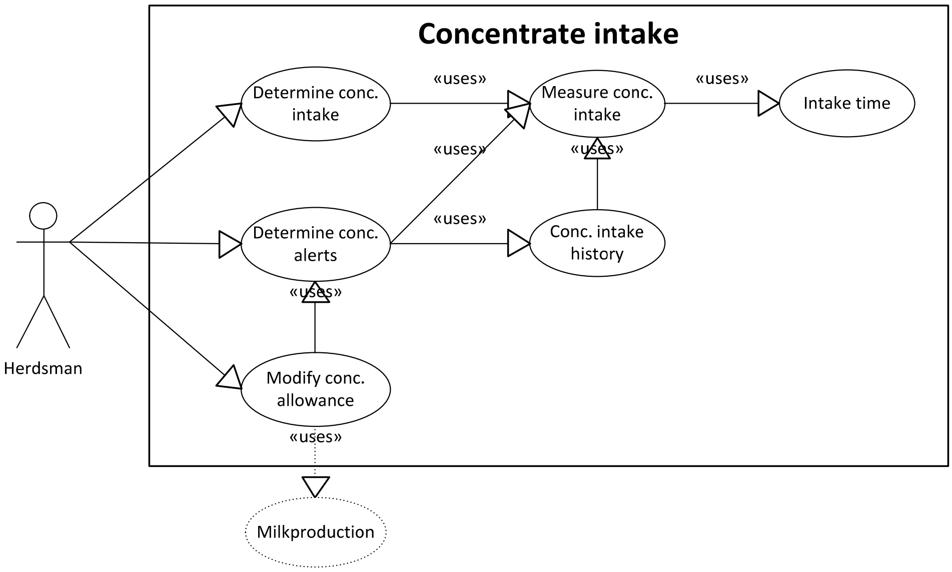

Figure 1. Use case diagram of "Concentrate intake"

A use case is a narrative, textual description of the sequence of events and actions that occur when a user participates in a dialog with a system during a meaningful process. A use case diagram illustrates a set of use cases for a system, the actors, and the relation between the actors and use cases. Use cases are illustrated in ovals; actors are stick figures.

In the next step a database structure will be built, in which external storage of farm and cow data is foreseen. The Internet will be used to give under certain conditions access to the data to all kinds of knowledge providers.

Concluding

For the next years Wageningen UR Livestock Research aims to use the SDF project for developing new possibilities for collecting, exchanging and applying information. These developments should take place in close cooperation with the other partners within the project, including farmers. A big challenge is the adoption of new technology by means of open innovations.

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