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Dissemination Level

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Executive Summary

Following the determination of the user requirements and the functionalities, the technological infrastructure of the FMIS must be selected. It can be concluded that a single proprietary monolithic software system cannot meet all the identified requirements, and thus, a web-based approach to the implementation of an FMIS that fulfils these additional requirements are presented. By adopting such an approach, the system has a so called core FMIS that includes basic functionalities (like FMIS logic) and a central database. In addition to the core FMIS, the concept of the envisioned future FMIS also includes a set of modular elements (like Rules manager and Rules Application), which can be software components as well as manual or automated services linked to the system, providing tailored functional features. The FMIS has a web interface so, that its components e.g. database can be accessed via the Internet from different locations and by different authorised users.

An important part of the quantification of the designed management information system is to derive a reference information model. A reference information model expresses the data content needed in a farm management information system and provides an explicit representation of the semantic and lexical connections that exist between the information carried in the fields of exchanged messages. A reference information model is essential for increasing precision and reducing implementation costs. AGROVOC thesaurus should be further developed to perform also as a reference information model of future FMIS and to meet the data exchange needs.

By inferring from the FMIS functionalities to the actual FMIS architecture, a network of distributed web services which offer the required functionality comes up as a possibility. The implementation of these services may vary and will depend on elaborated information flows. A major requirement would be that all services communicate via well defined and agreed upon vocabularies. In one case, the functional requirements could be addressed by standard (non SOA) software architectures; however the functionality range of these services (financial, agronomic, optimisation, modelling, etc) renders such an approach unlikely. A scenario where specialised services are implemented by companies competing against each other, by governmental or non-profit organisations would be more likely.

The overall conclusion is that there is need to integrate emerging FMIS services with a well defined reference model depicting vocabularies. As part of a distributed architecture, an efficient data exchange is needed so that interpreters at various intersections can be avoided and it will be possible to have a cost-efficient implementation of the architecture.
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1 Introduction

The conceptual model of a future farm information management system was described in deliverable 3.1 and published in Soerensen et al. (2010). Figure 1 illustrates the model and its entities, and it shows the dispersed nature of the components influencing the farm management. The grey dashed line captures the in-farm components.

During the course of the FutureFarm project, actors and information flows (deliverable 3.2, Sørensen et al. 2009), usage processes and data elements (deliverable 3.4, Sørensen et al. 2010) have been modelled and analysed, and functional requirements of FMIS have been determined (deliverable 3.5, Pesonen et al. 2010). The outlined system elements and requirements are very complex and diverse depending on the farm production type, level of automation and inherent business processes. When looking to the future, external services as decision making assisting features will become an important part of FMIS concept. At the moment, the utilisation of scientific models together with the large amounts of data in different formats produced by modern farm machinery, sensors located within the farm, remote sensing, etc. is still an open area of research and new methods are developed continuously. The seamless incorporation of new functionality and assisting features into an existing FMIS is of paramount importance.

2 FMIS architecture

Following the determination of the user requirements and the functionalities, the technological infrastructure of the FMIS must be selected. It can be concluded that a single proprietary monolithic software system cannot meet all the identified requirements, and thus, a web-based approach to the implementation of an FMIS that fulfils these additional requirements has been presented (Nikkilä et al., 2010, Figure 2). By adopting such an approach, the system has a so called core FMIS that includes basic functionalities (like FMIS logic) and a central database. In addition to the core FMIS, the concept of the envisioned future FMIS also includes a set of modular elements (like Rules manager and Rules Application), which can be software components as well as manual or automated...
services linked to the system, providing tailored functional features. The FMIS has a web interface so, that its components e.g. database can be accessed via the Internet from different locations and by different authorised users. Also, the different functional modules can provide real-time updated functional features through the web-services (deliverable 4.2, deliverable 4.3). This kind of web-based FMIS is also capable of linking to the other web-services (Steinberger et al. 2009), and connecting to e.g. “Future Farm Portal” (deliverable 2.2, Chatzinikos et al., 2010 ) using so called Service Oriented Architecture (SOA, Erl, 2005; Murakami et al., 2007; Wolfert et al., 2007; Wolfert et al., 2010). As ultimate solution, the entire FMIS and its functionalities can be provided as an external service to the farmer, in which case the farmer does not have any maintenance or updating work or responsibility for the system.

Wolfert et al. (2010) extended the concept of SOA-based FMIS’s to architecture for the entire agri-food supply chain network (AFSCN). Here FMIS, described in this paper, plays an active role in a network of services participating the business in agri-food branch. This pursued approach was based on a three-layer SOA architecture which included (Figure 3):

- A business process management layer, coordinating the execution of business services: this is a functional integration layer that groups services from the underlying business service layer into business processes. The process services are typically implemented through generic enactment engines, that execute workflows defined in languages like BPEL or BPML.
- A business services layer, delivering information services to the business processes. The business services implement the information processing functions of the actual business processes. Business services may be either straightforward data registration or reporting services, or complex services based on extensive business logic.
- A business application layer, executing the application logic and data storage. Applications are wrapped in application services, offering a standard web service interface to the business services, thus enabling enterprise application integration.
Figure 3. Three-layered SOA architecture with some illustrative examples of components from the arable farming sector (Wolfert et al., 2010)

Service oriented system architecture seems to solve most of the problems encountered when determining the architecture of the future FMIS. But it has to be noted that it is necessary to be aware also of the special risks that web-based systems encompasses, like audit and compliance risks, security risks, information risks (e.g. intellectual property) and billing risks. Risks related to web-based FMIS that need special attention include:

- performance and availability risks, especially in terms of the availability of sufficient powerful internet connections, e.g. mobile internet
- interoperability risks, especially in terms of backup plans in case a certain important service changes
- contract risks in terms of agreements on who owns the data, what happens if the service fails or the provider goes out of the business, etc.

3 Data presentation, transmission and transformation in multi-agent networks

Loose coupled web-based managed and Service Oriented Architecture based information systems provide a solution for interoperability and connectivity between different (existing) proprietary IT systems. However, in order to perform cost efficiently, standardised methods to exchange agricultural data are needed.

Several initiatives for data exchange within the agricultural domain exist. The most prominent ones are on the one hand the ISO initiatives ISOBUS (ISO11783-10:2007) and ISOagriNet (DLG, 2009). ISOBUS is the common specification of the manufacturers on the uniform application of the International standard ISO 11783 Serial control and communications data network. It is a bus system for the data communication between tractor, implement, virtual terminal and personal computer (PC) and machinery and allows for logging work activities and loading processing instructions onto controllers on agricultural machines. This standard defines an open communication protocol at physical and application layer level and is based on Controller Area Network (CAN) protocol (ISO 11898-1, 2003).
Parts of ISOagriNet are internationally standardized, the data dictionary accompanying it is divided into an international and a national set of entities. Those entities currently cover mainly livestock farming. Due to large scale applications in milk recording, the data dictionary in this area is especially well worked out. ISOagriNet provides a complete protocol stack for record-oriented data exchange, suitable for very large data volumes and hardware low on resources such as micro-controllers.

AgroXML (Martini et al., 2007) is a standardized language for data exchange in plant production and covers most of the aspects necessary for exchanging arable farming data. It is based on the worldwide standard eXtensible Markup Language (XML) and is used in communication between farm management information systems and external partners and information providers. It was developed mostly by KTBL (The Association for Technology and Structures in Agriculture, promoted by the German Federal Ministry of Food, Agriculture and Consumer Protection), that provides and maintains an infrastructure consisting of a source code, management system and documentation.

Other standards include: AgXML (Chituc et al., 2008) and AgrisAP (FAO, 2005) for general agriculture data exchange, PALM for the precision agriculture domain, AgroEDI a standard data-processing format of exchange for the agricultural and agro-industrial sectors (Verdouw et al., 2010), GeoFarms an application of geo-information and digital communication in the agro sector that aims to develop a standardized digital exchange platform that enables farmers and the government to exchange geo-information, agriXchange (www.agrixchange.org) that aims at merging some present standards like agroXML, AgroEDI, ISOBUS etc., ADIS (Agricultural Data Interchange Syntax) and an X400 mailbox-system for the exchange of data between computer applications, as well in mobile as in stationary equipment.

4 Reference information model

Vocabularies, or dictionaries define the concepts and relationships (also referred to as “terms”) used to describe and represent an area of concern. Vocabularies are used to classify the terms that can be used in a particular application, characterize possible relationships, and define possible constraints on using those terms. Vocabularies are the basic building blocks for inference techniques on the Semantic Web. There exist several vocabularies in connection to different data exchange standards. To get harmonised data exchange cost efficiently common vocabularies would be preferable.

AGROVOC is a multilingual structured thesaurus of all subject fields in agriculture, forestry, fisheries, food and related domains (e.g. environment), which represents a degree of consensus regarding terminology (Sini et al., 2008). It was developed by FAO (Food and Agriculture Organization of the United Nations) and the Commission of the European Communities, in the early 1980s and extensively used for indexing and retrieving data in agricultural information systems. It is updated by FAO roughly every three months (changes on the AGROVOC website).

An important part of the quantification of the designed management information system is to derive a reference information model. A reference information model expresses the data content needed in a farm management information system and provides an explicit representation of the semantic and lexical connections that exist between the information carried in the fields of exchanged messages. A reference information model is essential for increasing precision and reducing implementation costs. AGROVOC thesaurus should be further developed to perform also as a reference information model of future FMIS and to meet the data exchange needs.

As an example of the future needs of FMIS, three domain-specific knowledge hierarchies were built as the basis for the reference information model for three different standards, which the FMIS should be able to check the compliance with. Three hierarchies have been constructed and presented to demonstrate the process of formulating a directive or standard, namely, the agricultural standards hierarchy, the Nitrate Directive hierarchy, and the Globalgap hierarchy. The first one concerns the standards of the main agricultural management strategies, cross compliance, organic farming, and integrated crop management, while the other two were constructed regarding the Nitrate Directive and Globalgap voluntary standards and they had as initial list of terms, the
vocabulary coming from the checklist of the Nitrate Directive and the Globalgap categorized checklist, concerning only the spraying and fertilising as field operations.

As a first step in the hierarchy construction is to find the category names, top name category, which are generic terms that should be expressed consistently and represents the most general classes. It is important to distinguish between class and its name, since classes represent concepts in the domain and not the words that denote these concepts (Noy et al., 2001). The superclasses, top classes, will encompass all the relevant sub-classes. The class hierarchy represents an “is-a” relation for example, Agri-environmental measures is a subclass of Environmental and land management, and the Environment friendly farming methods is subclass of the Agri-environmental measures and this taxonomy is going on.

The first hierarchy, Agricultural standards hierarchy, concerns the standards of the main agricultural management strategies, Cross Compliance, Organic Farming and Integrated Crop Management. This hierarchy used as knowledge source for the concepts the rules and requirements that farmers must or should follow when a particular management strategy is followed. The superclasses Environmental Management, Public, animal and plant health and Animal welfare are concepts derived from the standards of Cross Compliance regulations, most of which are mandatory rules for agriculture production. The superclass Environment and land management is a concept that encompasses standards which are legally-regulated voluntary rules for products like the organic standards and the agri-environmental measures of rural development programmes. At last, the superclass Quality Management Systems is a concept coming from the private standards of voluntary requirements for agriculture production, implemented by private organisms like Globalgap. The hierarchy of Agricultural standards is given in Annex 1.

Another two hierarchies were also constructed regarding the Nitrate Directive and Globalgap voluntary standards and they had as initial list of terms, the vocabulary coming from the checklist of the Nitrate Directive and the Globalgap categorized checklist, concerning only the spraying and fertilization field operation. Regarding the Nitrate hierarchy (Annex 2), the hierarchy describes terms that are defined or used in the nitrate directive. We start ‘building’ the hierarchy having as a first step the superclasses: Water resources, Water management, Water pollution, Soil type, Soil condition, Land management, Agricultural management, Environmental law. Then each term in the list it is classified as subclasses in the already defined superclasses: Surface water, and Ground sources are subclasses of the superclass water resources, also Water supply, Water use and Water conservation are subclasses of the superclass Water management. The same methodology has been followed for the construction of the Globalgap hierarchy (Annex 3), where we used as repository of concepts the list of terms from the checklist vocabulary. We defined the superclasses and the relevant subclasses.

5 Specification of adoption requirements

A Farm Management Information System (FMIS), in order to be adopted from the participants, should be covering the fundamental quality characteristics. These quality characteristics are the same used as in Software Requirements, because FMIS is a kind of on-line software. These quality characteristics are the following (IEEE, 1998 & Lauesen, 2000):

Correct: The conclusions and results from the preferences of FMIS users should be connected with real data and information. This information and data are taken from the regulations, standards and the recorded data from the field

Unambiguous: The information that is provided by FMIS should be unique. FMIS must contain information or data that can be interpreted in one way only (IEEE,1998). This means that depended on the data that are provided by the user should show information or data that are unique for him/her preferences.
Complete: A FMIS is complete when it covers the requirements as functionality, performance, design constraints and external interface. This means that users would use it without finding any problems or missing data (Vie, 2000).

Consistent: FMIS capability functions and performance levels are compatible, and the required quality features (security, reliability, etc.) do not negate those capability functions (Vie, 2000).

Verifiable: A verifiable FMIS is consistent from one level of abstraction to another. Most attributes of an information system are subjective and a conclusive assessment of quality requires a technical review by experts (IEEE, 1998).

Modifiable: A FMIS is modifiable when it is possible to make changes on the structure of it. These changes are mainly from new technologies that are introduced in agriculture and from new standards that are covering the new necessities (IEEE, 1998 and Vie, 2000).

Valid: A valid FMIS is one in which all parties and project participants can understand, analyze, accept, or approve it. In order to be in a comprehensive way, FMIS should be written in natural language that the groups of people that are participants can understand (Vie, 2000).

6 Summary and Conclusions

A domain-specific knowledge hierarchy as the basis for the reference information model composed by three hierarchies (Agricultural Standards, Nitrate Directive, and Globalgap hierarchies), the adoption requirement for the proposed farm management information system, and the on-line control and real-time requirements, as part of the proposed fleet management system, of the system have been presented. As in the other approaches developed in related deliverables, the presented approach were centred around the farmer as the principal decision maker and involved external entities as well as mobile unit entities as the main information producers, as a way to extend the general proposed farm management information system design into automated decision-making. Furthermore, for the better process control as well as an improved capability of documenting the quality of farming farmers would be able to gain increased insight into their production processes and would able to evaluate the performance of the chosen technology.

The envisioned assisting services will be arranged as a manual/personal service, involving possibly semi-automated parts or it will be fully automated (software implementations) depending on the level of knowledge modelling of the relevant decision process as well as the level of data quality and availability.

By inferring form the FMIS functionalities to the actual FMIS architecture, a network of distributed web services which offer the required functionality comes up as a possibility. The implementation of these services may vary and will depend on elaborated information flows. A major requirement would be that all services communicate via well defined and agreed upon vocabularies. In one case, the functional requirements could be addressed by standard (non SOA) software architectures; however the functionality range of these services (financial, agronomic, optimisation, modelling, etc) renders such an approach unlikely. A scenario where specialised services are implemented by companies competing against each other, by governmental or non-profit organisations would be more likely.

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http://agrovoc-cs-workbench.googlecode.com/files/Final-322881-1.doc


Annex I: Agricultural Standards Hierarchy

+Environmental Management
  - Wild birds
  - Natural habitats and wild flora and fauna
  - Groundwater
  - Sewage sludge
  - Nitrate
+Environmental Agriculture
  + Soil erosion
    - Minimum soil cover
    - Minimum land management in site specific conditions
  - Retain terraces
  + Soil organic matter
    - Crop rotation
    - Arable stubble management
+ Soil structure
  - Machinery use
+ Minimum level of maintenance
  - Permanent pastures
  - Landscape features
  - Unwanted vegetation on agricultural land
- Minimum livestock stocking rates
- Habitats
- Olive tree maintenance
- Vegetation in olive groves and vines
+ Water
- Buffer strips
- Authorization
  - Permanent Pasture
- Public, animal and plant health
- Animal welfare
+ Environment and land management
  + Agri-environmental measures
  + Environment friendly farming methods
  + Organic Farming
  + Input reduction
    + Fertilizers/fertilizing (synonyms)
      - Compost
    + Manure
      - Livestock/animal manure
      - Green manure
    - Crop residues
    - Biosolids
  + Soil conditioners/soil amendments
    - Natural nutrients
- Lime
- Clay

- Soil inoculants

- Pest, disease and weed control
  - Preventive methods
    - Biological control
  - Cultural control
  - Mechanical / Physical control
  - Authorized plant protection substances
    - Authorized disinfectant products
    - Authorized chemical synthesized products

+ Soil management

- Minimum tillage

+ Soil fertility
  - Cover cropping
  - Incorporation of crop residues

+ Crop rotation
  - Green manure crops
  - Legumes-fix nitrogen crops

+ Biodiversity enhancement

+ Polycultures
  - Intercropping
  - Strip-cropping/multi-cropping
  - Crop rotation

- Hedges, trees,
- Meadows
- Natural waterways
- Native vegetation, trees

+ Grassland Maintenance
  - Meadows
  - Pastures

+ Landscape management
  - Arable land management
  - Catch crops
  - Bio-belts

- Natural Handicaps (Less Favorite Areas)
- Natura 2000 and Water Framework Directive
- Animal welfare
- Non-productive investments
Annex II: Nitrate Directive Hierarchy

+Water resources
  +Surface water
    +Inland waterways
      -Lakes
      -Rivers
      -Streams
    -Estuaries
  +Freshwater
    -Drinking water
    -Water springs
  -Coastal water
  +Ground sources
    -Groundwater
    -Aquifers
+Water management
  +Water supply
    -Water harvesting
  +Water use
    -Water reuse
    -Water conservation
+ Water pollution

+ Groundwater contamination

+ Landfill leachates
  - Nitrate groundwater enrichment

- Seepage liquids
- Silage effluents

+ Surface water contamination

+ Eutrophication of fresh and salt water

+ Agricultural runoff
  - Nitrogen, phosphorous-rich fertilizer run-off
  - Nitrogen-rich manure run-off

+ Drinking water quality
  - Excess Nitrate level

+ Run-off liquids/effluents
  - Urban runoff
  - Sewage effluents

Soil type

+ Soil condition

- Water Saturated ground
- Flooded ground
- Frozen ground
- Snow-covered ground

+ Land management
  - Farmland preservation
  + Land use
    - Land use change
  + Zoning
    - Special protection areas
    - Specific Area of conservation
  - Pasture management
  - Grassland management

+ Agricultural management
  + Soil management
    + Soil conservation
      - Soil erosion
    + Soil amendments / Soil conditioners
    - Tillage
  + Irrigation
    - Irrigation water
    - Irrigation systems
  + Crop management
    - Crop residue management
+Cropping systems
 - Continuous cropping
 - Crop rotation
 - Intercropping
 - Multiple cropping

+Nutrient management
 + Natural nutrients
   - Phosphorus
   + Nitrogen
     + Natural nitrification
       - Soil inoculants (Nitrogen-fixing organisms such as Rhizobia, algae)

+Fertilizers/ artificial nutrients
 - Compound fertilizers
 - Liquid fertilizers
 + Inorganic fertilizers
   - Phosphorous fertilizers
   + Nitrogen fertilizers
     - Nitrate fertilizers
     - Ammonium fertilizers

+ Organic fertilizer
   - Compost
   - Biofertilizer
   - Green manure
+ Fertilizer application
  - Foliar fertilization
  - Irrigation

+ Animal manure management
  + Manure storage
    - Livestock manure storage vessels
    - Manure handling

+ Environmental law

+ Nitrate Directive
  + Nitrate allowed concentration
    - Surface freshwater
    - Groundwater
    - Eutrophic bodies of water

+ Nitrate Vulnerable zones (NVZ)

+ National Action Programs
  - Monitoring

+ Measures
  - Rules of farming practices
    + Fertilizer application
      - Prohibited periods
  - Limits on livestock manure
    - Capacity of manure storage vessel
    - Specification of manure application
Codes of good agriculture practice
- Mandatory application
- Voluntary application
Annex III: Globalgap Hierarchy

+Nutrient management
  +Nutrient analysis
    +Crop nutrition requirements
      -Crop analysis
    +Soil nutrient status
      -Soil analysis
      -Crop off takes
    +Fertilizer analysis
  +Fertilizers/artificial nutrients
    +Organic Fertilizer
      -Green manure
      -Stirry
        -Farmyard manure
        -Livestock manure
      -Sewage sludge
    +Inorganic Fertilizer/ synthetic fertilizer
      +Chemical content
        +Heavy metals
        +Nutrients
          -Phosphorous
          -Nitrogen
+Fertilizer application
  +Fertilization type
    - Soil fertilization
    - Foliar fertilization
    - Fertigation
  + Field Records
    - Application date
    - Application quantity
    - Application machinery
  + Fertilizer storage
    - Storage conditions (clean, dry area)

+ Plant Protection
  - Biological plant protection
  - Disease control
  - Pest control
  - Weed control
  + Integrated control
    - Integrated pest management
  + Plant Protection Products (PPP)/ Biocides
    + Pesticides
      - Fungicides
      - Herbicides
      - Insecticides