CONCEPTUAL MODELLING REPORT

BASIS FOR APPLICATION DEVELOPMENT

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Conceptual Modelling Report

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PREFACE

With the development of Galileo, a European Global Navigation Satellite System (GNSS), the European GNSS Supervisory Authority (GSA) aims to move Europe forward in the location based technology and stimulate innovation and new business. In order to examine potential uses and to prepare likely users for applications using the Galileo infrastructure and services, the GSA has initiated projects addressing various user communities.

This report has been prepared in the frame of the FieldFact project. The aim of FieldFact is the introduction and promotion of GNSS within the agricultural user community. The project is managed by the GSA and funded under the 6th Framework Programme. There are six consortium partners participating in the project - Alterra, Vexcel and PPO from the Netherlands, University of Warmia and Mazury (UWM) from Poland, Ekotoxa from the Czech Republic and the European Commission’s Joint Research Centre.

This report is the result of the Conceptual Modelling phase performed as the first activity in work package 3 of the FieldFact project, in which applications are developed that will serve as demonstrators in the FieldFact training and promotion activities. The purpose of the conceptual model described in this report is to serve as a thinking model or domain map that fits all applications of GNSS in agriculture and that is suitable for fitting in the Galileo discriminators. More specifically, for the FieldFact project it will be a blueprint for further elaboration of the FieldFact demonstrator applications.

This is issue 1.2 of the final version of the report. Review remarks from reviewer and FieldFact consortium partners have been integrated into this issue.

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EXECUTIVE SUMMARY

The conceptual modelling report describes the products that have been developed in the task "Conceptual Modelling" of the work package Application Development (WP 3) of the FieldFact project.

Through an iterative process of brainstorm sessions by a group of experts on spatial applications in the agricultural community, the relevant objects and relationships in the FieldFact application domain, being "the use of the Galileo GNSS in applications in the agricultural community", have been elicited. Using this expert knowledge and the information delivered from the work packages Stakeholder platform (WP 1) and Studies (WP 2), the conceptual model was composed.

The conceptual model is developed as a formal model describing the essential principles concerning the use of GNSS and in particular Galileo in agriculture. It describes the main object types related to the FieldFact application domain as well as relationships between those object types and architectural aspects. Its purpose is to serve as a thinking model or domain map that fits all applications of GNSS in agriculture and that is suitable for fitting in the Galileo discriminators. More specifically, for the FieldFact project it will be a blueprint for further elaboration of the FieldFact demonstrator applications.

The three sub models developed under this conceptual model form the basis for application development (FieldFact Domain Model), the development of spatial database and spatial objects (FieldFact Tempo-spatial Object Model) and the development of the technical architecture (FieldFact Global Architectural Model).

1 INTRODUCTION

1.1 Purpose and scope

In the framework of the FieldFact project, work package 3 (WP3), “Applications” aims at development of demonstrator applications for promotion of Galileo in agriculture. With the development of a Conceptual Model we aim at developing a model that clarifies the significance of using GNSS in general and particularly the added value of Galileo and EGNOS in the agricultural sector. It will be an important means for explaining the benefits of the use of Galileo and EGNOS in the agricultural community. The conceptual model will also be one of the instruments that we will use in order to communicate with stakeholders, to disseminate project results and to promote Galileo and EGNOS in agriculture.

The conceptual model is a formal model describing the essential principals concerning the use of GNSS and in particular Galileo in agriculture. It contains the main object types related to the FieldFact application domain as well as relationships between those object types and global architectural aspects. Its purpose is to serve as a thinking model or domain map that fits all applications of GNSS in agriculture and that is suitable for fitting in the Galileo discriminators. More specifically, for the FieldFact project it will be a blueprint for further elaboration of the FieldFact demonstrator applications.

The introduction chapter describes why and for whom this document is written. It also mentions associated project documents, references to literature and a list of important abbreviations and synonyms.

In chapter 2 the conceptual model is described. For the sake of clarity the model has been divided into 3 parts. The FieldFact domain model describes the objects and their relationships in the application domain of the FieldFact project: “the use of the Galileo GNSS in applications in the agricultural community”. Since the representation of spatial objects is of major importance in all GNSS applications, we have defined a separate model for this purpose. In this FieldFact tempo-spatial object model special attention is also given to the Galileo/EGNOS discriminators. As a third part of the conceptual model we have derived a FieldFact global architectural model, describing the global technical architecture of GNSS applications in agriculture.

In chapter 3 we have verified the conceptual model by matching two relevant GNSS applications in agriculture and describing how the defined model fits to these applications.

Chapter 4 describes the conclusions drawn from the conceptual modelling phase and recommendations for the subsequent project activities.

1.2 Intended audience / Classification

The intended audience of this document is twofold:

Designers/developers in the FieldFact Work package 3 – Applications

The conceptual model is a formal modal describing the essential principles concerning the use of the Galileo system in agriculture. It contains the main object types related to the subject as well as relationships between those object types and global architectural aspects. Its purpose is to serve as a thinking model or domain map that fits applications of GNSS and especially Galileo in agriculture. For designers and developers it will be a blueprint for further elaboration of the FieldFact demonstrator applications.

Other FieldFact consortium members

The second purpose of the document is to provide non IT-specialists within the FieldFact project with a framework that can be used as a basis to understand the application domain and to be able to translate and communicate some of the IT-specific aspects of the project to stakeholder groups. This will be especially useful in the numerous FieldFact activities that involve interaction with the various stakeholder groups (e.g. stakeholder platform, training, promotion).

Audience outside the FieldFact project

The conceptual modelling report is classified as a public document and is intended for dissemination to a broader audience than only the FieldFact consortium. Although the report will be publicly available (e.g. from the FieldFact website), it is expected to be read mainly by an audience that is interested in and well informed about Galileo developments and GNSS in agriculture.

1.3 Associated documentation

This list states the project documents that were used as input documents for the elaboration of this document:

1. Statement of Work. GALILEO Research and Development Activities, Second Call, Area 1A, GNSS for Special User Community. Ref.: GJU/04/2412-SOW/MM/fk, Issue 1, 26/05/2004. Galileo Joint Undertaking, Brussels;
2. FieldFact Proposal, Financial, Management and Administrative Tender. Introduction and Promotion of GNSS in Agriculture, version 1.0.1, July 2006. FieldFact consortium.
3. FieldFact Proposal, Technical Tender. Introduction and Promotion of GNSS in Agriculture, version 1.0.1, July 2006. FieldFact consortium
4. Critical Analysis Report (Draft version), the state and future of GNSS in Agriculture Europe 2007, version 1.0, January 2007. Ref.: FIELDFACT-WP2-EKOTOXA-DEL-2.1
5. Requirement Identification and Priority Report. Ref.: FIELDFACT-WP1-JRC-DEL-1.3, Issue 1.3.
6. Conceptual Model (Draft version), Basis for Application Development, February 2007. FieldFact consortium. FIELDFACT-WP3-ALT-DEL-3.1, Issue 1.0

1.4 Reference Documentation

1. Galileo Joint Undertaking, 2006. Next step in the Galileo program. Press release GJU/06/12307/HPM/rod, November 30th 2006.
2. Griffin, T. W., Lowenberg-DeBoer, J., Lambert, D.M., Peone, J., Payne, T. and Daberkow, S.G. 2004. Adoption, profitability and making better use of precision farming data. Staff Paper #04-06, Dept. of Agricultural Economics, Purdue University, USA.
3. Swinton, S.M. and J. Lowenberg-DeBoer 2001. Global Adoption of Precision Agriculture Technologies: Who, When and Why? In: Grenier, G. and Blackmore, S., eds., Third European Conference on Precision Agriculture, Montpellier, France: Agro Montpellier (ENSAM), pp. 557-562.

4. N. Pelekis, B. Theodooulidis, I. Kopanakis, Y. Theodoridis. Literature review of spatio-temporal database models. The Knowledge Engineering Review, 19: 235-274, Cambridge University Press, 2004;
5. M. Minout, C. Parent, and E. Zim ́anyi. A tool for transforming conceptual schemas of spatio-temporal databases with multiple representations. In Proc. of the IASTED Int. Conf. on Database Applications, DBA'04, pages 1–6, 2004.
6. T. van der Wal, P. Verweij, Th. Smits, J. Kuipers, Z. van Rijn, A. Luinstra, A. van Kampen. Wat, Waar en Wanneer bij Staatsbosbeheer: Een objectgerichte kijk op terreinbeheer (in Dutch), internal report, 2001;
7. N. Koncz and T. M. Adams. A Data Model for Multi- Dimensional Transportation Location Referencing Systems. Journal of the Urban and Regional Information Systems Association 14(2):27–41, 2002.

1.5 Abbreviations and Acronyms

CAP	Common Agricultural Policy
DGPS	Differential Global Positioning System
EC	European Community
EGNOS	European Geostationary Navigation Overlay Service
EU	European Union
FDM	FieldFact Domain Model
FGAM	FieldFact Global Architectural Model
FTOM	FieldFact Tempo-spatial Object Model
GIS	Geographical Information System
GJU	Galileo Joint Undertaking
GNSS	Global Navigation Satellite Systems
GOBLET	Geo-Object model Based on Location, charactEristics and Time
GPS	Global Positioning System
GSA	GNSS Supervisory Authority
IACS	Integrated Administration and Control System
PDOP	Position Dilution of Precision
RDS	Radio Data System
SIS	Signal in Space
VRA	Variable Rate Application
WP	Work Package

1.6 Use of GNSS and the added value of Galileo and EGNOS

On the modern farm gathering data about the production process has become more and more important. First of all this concerns data required to execute and improve the production process on the farm itself. Technical innovations on the fields of e.g. farm machinery and information technology, as well as the improvement of knowledge about the production process and the available agronomical models require more and better quality data as input for the process. Evidently the demand for information about the primary process from the production chain has become higher and higher in the light of for instance the demands for traceability in general, consumers demand for information and stricter guidelines for food safety. Last but not least, government and other public parties require farmers to deliver data about the production process. Again stricter legislation for food safety, cross compliance etc. are the drivers.

Using GNSS it becomes possible to automatically couple a process and the data collected in this process with the location (and time) at which the events occurred. Processing of such data leads to spatial datasets that provide a valuable source of information for the production process at the farm. Integration of spatial data in the farm management systems on the farm and in the automated processes on the field are opening up possibilities for new applications.

The Galileo system adds extra value to the utilization of GNSS by adding better accuracy, better availability and better reliability. The area of precision farming will benefit from high accuracy positioning and the high level of continuity and availability offered by Galileo. Since high accuracy services will be cost effective (e.g. in comparison to DGPS), regulated applications, like parcel measurement, will highly benefit from integrity (Signal in Space (SIS) authentication, integrity message) aspects of the Galileo SIS.

2 DESCRIPTION OF THE WORK CARRIED OUT

2.1 FieldFact deliverable input

The development of the conceptual model was fed by the preliminary results of work package 1 (Stakeholder platform) and work package 2 (Studies). Although at the time of development of this model not all final work package 1 deliverables were available, the stakeholder platform has provided us with the main directions, ideas and requirements for the use of GNSS and the exploitation of Galileo discriminators in the agricultural community.

From the Critical Analysis Review (performed in work package 2) we have learned about the types of applications used in the agricultural community, the nature of these applications and the specific applications that could benefit from the Galileo discriminators. Paragraph 1.3 shows a list of the associated documents for the conceptual model.

2.2 Methodology

The development of the conceptual model for the FieldFact project was carried out by a group of experts in the field of spatial applications in agriculture. With this group we went through a series of analysis and brainstorm sessions in which we developed the conceptual model incrementally.

Analysis

- Analysis of preliminary results and deliverables coming from the work packages “Stakeholder platform” (WP 1) and “Studies” (WP 2).
    - Draft Critical Analysis Report (Ref.: FIELDFACT-WP2-EKOTOXA-DEL-2.1)
    - Draft Report Requirements Identification and Priority (Ref.: FIELDFACT-WP1-JRC-DEL-1.3, Issue 1.3)
- Collection of documentation and experiences from previous projects

Definition

- Brainstorm sessions. In these sessions a group of experts elicited the relevant objects and relationships for the FieldFact application domain. With this information the conceptual model for the FieldFact application domain has been developed.
- Development of the FieldFact domain model, using the results of the brainstorm sessions.
- Extension of the conceptual model with a model for spatial information objects
- Development of a global technical architecture

Result analysis

- The results of the definition phase sessions were recorded in the conceptual modelling report.
- The developed models have been matched with some real world cases, derived from the list of priority applications that were identified in the Draft Critical Analysis Report (Ref.: FIELDFACT-WP2-EKOTOXA-DEL-2.1) as delivered in “Studies” work package (WP 2).

3 RESULTS OF WORK CARRIED OUT

3.1 Conceptual Model

3.1.1 Introduction

The conceptual model presented in this document describes the essential principles concerning the use of GNSS and in particular Galileo in agriculture. Its purpose is to serve as a thinking model or domain map that fits all applications of GNSS in agriculture and that is also suitable for fitting in the Galileo discriminators. More specifically, for the FieldFact project it will be a blueprint for further elaboration of the FieldFact demonstrator applications.

Since there are various aspects to GNSS use in agriculture we have found it valuable for the sake of clarity and comprehensibility to separate the conceptual model into three sub-models, the FieldFact Domain Model, the FieldFact Tempo-spatial Object Model and the FieldFact Global Architectural Model. Each sub-model describes a relevant aspect of the FieldFact application domain. Furthermore we have explained the relation between the sub-models in order to explain how these models fit together.

FieldFact Domain Model (FDM)

The application domain of the FieldFact project can be defined as: "*the use of the Galileo GNSS in applications on the farm in the agricultural community*".

The FDM describes the objects and the relationships between objects in this application domain. Describing the application domain clarifies the area of interest of the project. The object types in the application domain and the relationships between these object types are described on a high level. The FDM will serve as the basis for further application design and implementation.

FieldFact Tempo-Spatial Object Model (FTOM)

The use of GNSS is strongly connected to the collection, processing and utilization of localized information. Many of the object types that are defined in the FDM do in fact have a spatial component. Thus, modelling the spatial characteristics of objects should be part of any conceptual model describing this domain. A special point of attention in this sub model has been given to the capacity of the model to implement and explain the Galileo discriminators.

As stated, many object types identified in the FDM are in fact spatial objects and can thus be expressed in terms of the FTOM. This model should therefore be looked upon as a specialization of the FDM.

FieldFact Global Architectural Model (FGAM)

This sub model defines the relevant architectural components that are required when applying GNSS in agriculture. It is a global technical representation of the way a GNSS supported application can be set up. The model should be capable of capturing the FDM, including the spatial component as described in the FTOM. The objects described in the FDM, will be stored, processed and exchanged through an architecture as defined in this model. The FGAM will be the blueprint for the further design of the architectural model of the FieldFact project.

3.1.2 FieldFact Domain Model (FDM)

3.1.2.1 Introduction

In this paragraph we depict the FDM which describes the objects acting in the application domain and their relationships on a conceptual level. It states the object types relevant for applications involving the use of the Galileo GNSS in agriculture and the relationships between those objects. Figure 3-1 shows the developed domain model

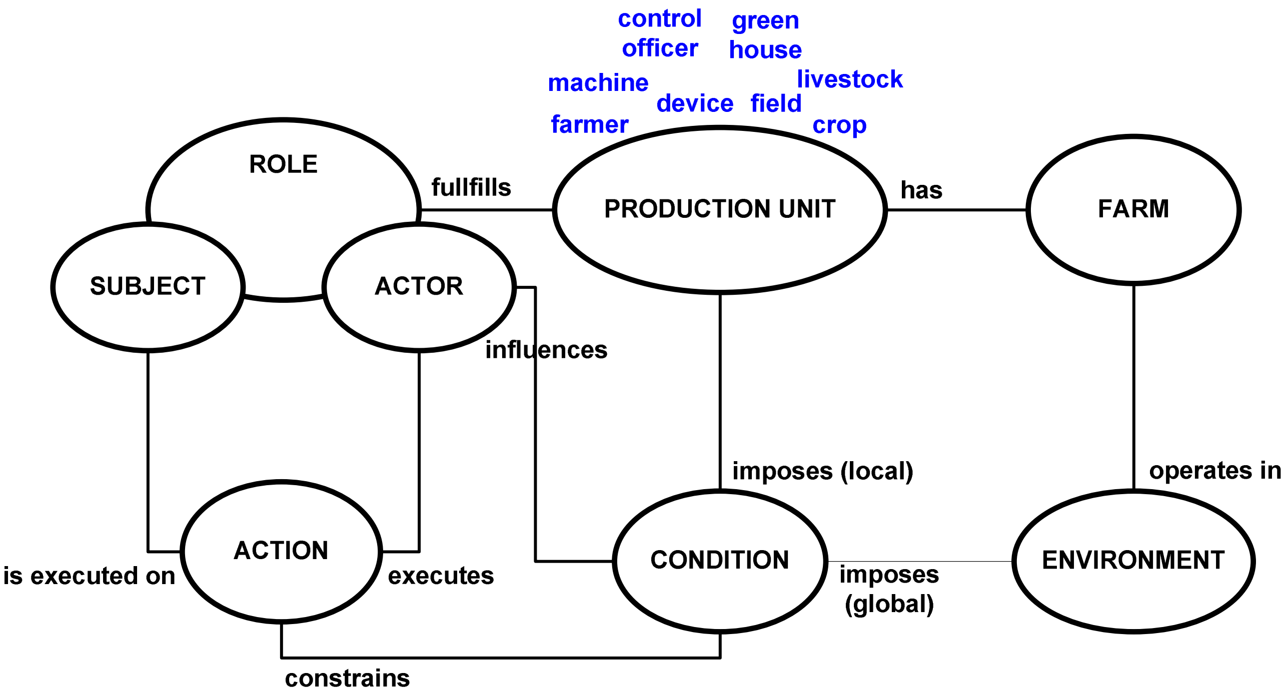

Figure 3-1 FieldFact Domain Model

In order to better understand this model, the descriptions of the object types in the domain model and the relationships between the object types will be described in the following paragraphs.

3.1.2.2 Domain model object types

Farm

In the FieldFact domain we are observing the agricultural sector at the farm level, where the primary agricultural processes occur. A farm is defined as a section of land devoted to the production and management of food, either produce or livestock. It is the basic unit in agricultural production. Farms may be an enterprise owned and operated by a single individual, family, or community, or it may be owned by a corporation or company. A farm can be a holding of any size from a fraction of a hectare to several thousand hectares (http://en.wikipedia.org/wiki/farm). The farm is the location where the actual work is carried out in our domain. This is also the spot where numerous data about the production process and the production environment is being collected, possibly supported by the use of Galileo.

Production unit

On the farm, the production units are the objects that are involved in the agricultural process are the production units. A production unit is an object involved in the agricultural production process on the farm, either in an active way, by performing (parts of) the agricultural production process or in a passive way, being the subject of the process. Examples of production units (that are for reasons of clarity also included as sub types in the domain model diagram) are the farmer, a field, livestock, agricultural crop, a greenhouse, machinery, a control officer, electronic measuring devices etc.

Environment

The farm functions as a part of its environment. The environment is defined as the agricultural production environment in its widest form. Apart from the physical environment (e.g. climate, landscape characteristics etc.), it also refers to the economical, social and political environment of a farm.

Condition

A condition influences if, when and how processes are performed on a farm. A condition is a characteristic of either the local circumstances at the farm or the environment of the farm. Such a condition either directly constrains the actions to be performed on the farm or influences the way the actor performs these actions. A local condition imposed by a production unit can for instance be the soil type of a field. Global conditions, imposed by the environment of the farm can be for instance the conditions stated by the government in the framework of legislation.

Action

An action is an elementary operation in the production process on the farm. An action is usually performed by someone (e.g. farmer, controller) or something (e.g. machine, device) aimed at something (a field, crop, livestock etc.). Typical examples of actions are spraying a field, transporting livestock or measuring a field or parcel.

Role

The role is a way of behaviour of an object. In the context of the FDM the role is used to express if the object behaves in an active (performing an action) or passive way (being the subject of the action).

Actor

An object (production unit) having an active role in the execution of an action. The object performs a specific operation, typically supported by knowledge and information that is collected during the operation and/or has been collected beforehand. The most evident example of an *actor* is of course a living human being the *farmer* or the *control officer* (e.g. measuring a parcel). However, the *actor* object could just as well be a piece of *machinery* or a *device (*e.g. performing variable rate application).

Subject

An object (production unit) having a passive role in the execution of an action. The object undergoes (is subject of) the action. A field that is measured by a controller or being fertilized by the farmer are examples of subjects.

3.1.2.3 Domain Model Relationships

A *farm* consists of a collection of *production units*.

The *farmer*, *control officer*, *machine*, *device*, *fields*, *livestock*, *crop*, *greenhouse* are (among others) possible types of *production units*.

A *production unit* might impose local *conditions* upon the agricultural production process.

A *farm* operates in an *environment*.

The farms *environment* imposes global *conditions* upon the agricultural production process.

A *production unit* fulfils a certain *role* when performing actions that are part of the production process.

The possible *roles* that can be fulfilled by a production unit in the FieldFact domain are *subject* and *actor*.

An *action* is executed by a production unit fulfilling the *actor* role in the context of this specific action.

An *action* is executed on a production unit fulfilling the *subject* role in the context of that specific action.

The *conditions* imposed locally (production unit) and globally (by the environment) influence the behaviour of the *actor* when performing actions.

The *conditions* imposed locally (production unit) and globally (by the environment) constrain the *actions* performed in the agricultural production process.

3.1.3 FieldFact Tempo-spatial Object Model (FTOM)

3.1.3.1 Introduction

Since many of the objects that play a role in the FieldFact application domain have a spatial component, it is evident that a conceptual model describing the application of GNSS in agriculture should also contain a means of describing the behaviour of spatial domain objects and the registration thereof in a database. We are dealing here with objects that change in time, in space and in their properties. Describing these kinds of objects requires the use of a tempo-spatial data model. Many useful designs for tempo-spatial databases are proposed in literature. Pelekis et al (2004) concluded that early attempts (80s and 90s) focused on capturing the state of real world objects or the physical events upon them, on the time line. This field has been developed since, including dynamic processes and changes in description/size/position/extent of entities. This has lead to models concerned with conceptual notation of tempo-spatial data. A list of useful requirements towards tempo-spatial conceptual models is defined. According to Minout et al. (2004) tempo-spatial conceptual models deal with:

- Objects have complex structure (e.g., non-first-normal form), generalization links, composition/aggregation links that should achieve full representational power in terms of data structures;
- Spatial objects with one or several geometries associated to different resolutions or user viewpoints;
- Alternative geometry features to support both discrete and continuous views of space;
- Temporal objects with complex lifecycle that allow users to create, suspend, reactivate, and eventually delete objects;

- Time stamped attributes that record their past, present and future values;
- Spatio-temporal concepts for describing moving and deforming objects;
- Explicit relationships to describe structural links as well as spatial (such as adjacency, inclusion, spatial aggregation etc), and synchronization links (such as before, during). The knowledge of the topological links between real-world entities is an essential requirement for applications;
- Causal relationships describing the causes and effects of changes that happen in the real world.

It is noted in a review of tempo-spatial databases that implementation of these models in databases concerned solving the complexity in just one application domain [Pelekis, 2004].

3.1.3.2 A conceptual model for tempo-spatial data

GNSS offers possibilities to automatically gather localized information during the execution of the production processes on the farm and to couple this information to other spatial or non spatial information sources. We are dealing with complex data objects originating from GNSS measurements that need translation to meaningful (real life) objects. For example, a parcel is described by its boundary and its area, both derived from a series of points. The conceptual model should be able to describe tempo-spatial objects on various scaling levels.

For FieldFact we propose to use a conceptual model for tempo-spatial data that is been developed in earlier work (e.g. van der Wal et al., 2001) and successfully applied in several databases. This model is based on the subject-specification concept where the instantiated object is separated from its characteristics concerning location, time and (other) properties. This conceptual model requires detailing when implemented, but it provides a useful and robust conceptual model responding to the requirements mentioned above.

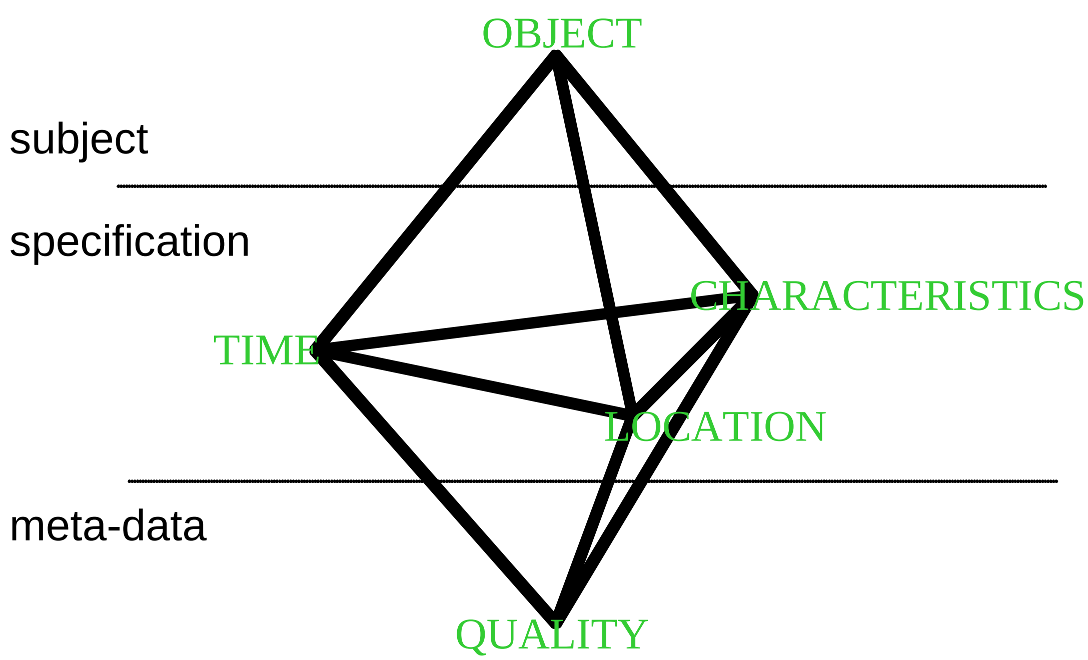

Figure 3-2 FieldFact Tempo-Spatial Object Model

The proposed conceptual model is called GOBLET (Geo-Object model Based on Location, charactEristics and Time). It consists of a three layered approach: the subject layer, the specification layer and the quality layer. The subjects are described by their specifications. Each specification can have a quality attribute, describing the relevant quality indicators for the given specification attribute.

We believe that all objects in FieldFact can be modelled by using this model. Figure 3-2 graphically depicts the GOBLET model. Time and Location are explicitly modelled in addition to other characteristics. Time and Location are considered important and relevant characteristics. In order to exchange and store data objects of different user views or origin, Time and Location must have explicit reference models, describing their datum and topology (Koncz and Adams, 2002). Quality attributes have been modelled separately in the model. Reason for this is that quality aspects of especially the geographical component play a very important role in the applications that will be build in the FieldFact domain to promote the use of Galileo. Quality aspects are of high importance, because the major discriminators of the Galileo system, like accuracy, availability, reliability and integrity are all related to the quality of the signal. This quality determines to a large extent the quality of the geographical information used in GNSS applications ergo the quality of the GNSS applications. We strongly believe that the advantages of Galileo/EGNOS can best be expressed by integrally modelling the spatial quality of these objects. Having quality attributes available on all scaling levels of spatial datasets and being able to show these attributes in an application will greatly facilitate the communication to stakeholders on the added value of using Galileo and EGNOS.

3.1.3.3 Processing spatial information

A model for spatial objects should not only express the elementary data collected through the Galileo / EGNOS SIS, but should also fit to the spatial objects that are used on other scale and aggregation levels. It should also cover spatial objects that are generated by processing data through for example agronomic models from rather ‘meaningless’ samples to integrated information sources that can be used in the agricultural production process or be exchanged with external parties.

Three steps can be distinguished in the process of integrating elementary samples derived from the Galileo system with other data sources:

1) Collection and storage of Galileo GNSS samples

The starting point for all Galileo based applications will be the collection of Galileo signal samples, basically being the recorded positions at a certain time. The spatial, temporal and quality aspects of these samples are directly derived from the Galileo signal. These GNSS samples can be seen as elementary spatial building blocks of any GNSS/Galileo based application.

Such an elementary Galileo based GNSS sample should be able to hold the following information:

- The location (x,y coordinates);
- Time (the time of sampling of the location);
- Quality attributes (the accuracy of the sample, integrity indicator, authentication etc.).

2) Derivation of spatial objects for Galileo GNSS samples

In the application these Galileo GNSS samples will subsequently be processed to coherent and meaningful spatial objects that are applicable on the application domain. A set of individual location samples (x,y) can for instance be processed to a line describing the track of a machine or a polygon describing the outline of a measured parcel. Again, these derived objects should fit into the conceptual model.

Such a spatial object derived from the elementary Galileo GNSS samples should describe:

- Geometry of the object (e.g. the outline of the parcel);
- Time information (e.g. this track started at time A and ended at time B);
- Characteristics (e.g. name of observer, receiver type etc, perimeter or area of the polygon etc.);
- Derived quality information (e.g. mean PDOP, integrity indicator of derived object).

3) Integration of Galileo GNSS based spatial objects with other data sources

Finally, the essence of Galileo based applications in FieldFact is that the Galileo based derived spatial objects can be combined with other spatial and non spatial information sources. Existing information sources can thus be enriched by adding and integrating the location based information delivered through Galileo. Both Galileo based and non Galileo based information sources can be processed by models, e.g. agronomic models, economic models etc. As a result such applications will again deliver new, enriched spatial information. The FieldFact tempo-spatial object model is able to describe these non Galileo based spatial objects as well as the processed information objects.

Again these higher level data sources that were generated by processing various GNSS and non GNSS information sources can be described in a similar means as the originating objects:

- Geometry (varying from simple elementary to complex geometries);
- Time information (even static objects like parcels have a “life time” and therefore time information);
- Characteristics, this can be all kinds of attributes, depending on the specific objects. A parcel for example can have a soil type; a harvester can have a harvesting capacity, weight etc.;
- Quality attributes for each specification.

Figure 3-3 shows how the FTOM, based on the GOBLET model, fits into the process steps described above. It shows a series of elementary Galileo based samples, collected by for instance a mobile application. Every single measured point has a coordinate, a timestamp and attributes regarding the quality of the signal at the time it was sampled, which can be expressed through the FTOM. The application uses customized spatial algorithms to process the samples to an aggregated object on the field scale. This object again has a geometry (in this case a polygon describing the outline of the object), time information (the data collection started at time A and ended at time B), quality attributes (some aggregated information derived from the quality attributes of the samples) and additional attributes (e.g. the area of the object). And again, this object can be described through the FTOM.

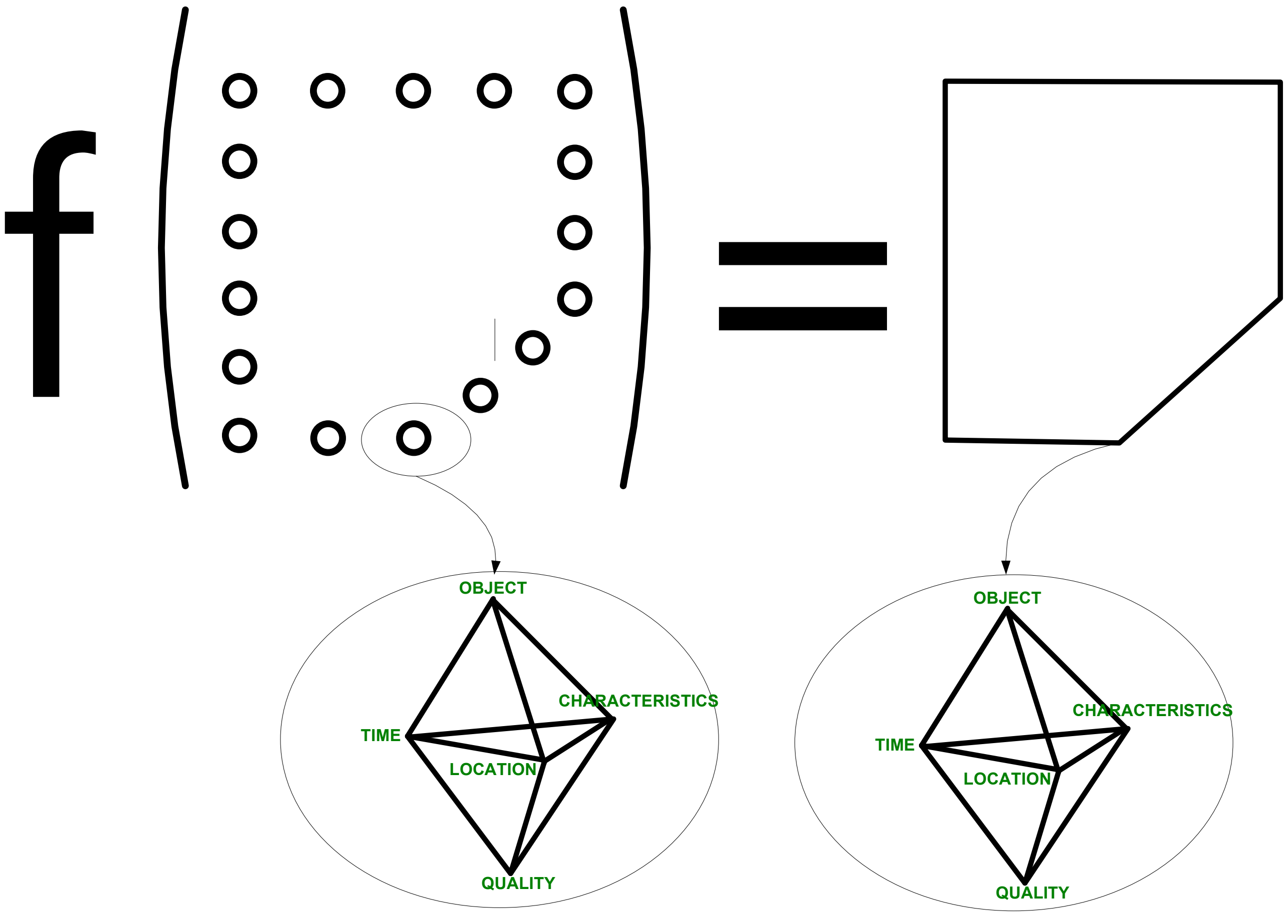

Figure 3-3 Transformation of tempo-spatial objects

Despite being objects on different scale levels, both elementary Galileo GNSS samples (being the lowest scale level) and derived Galileo based objects (usually at the Field level) can be represented by the FTOM.

This also counts for more complex and integrated spatial objects: Spatial objects can be derived from other objects by simple functions or complex models. Objects of different origin can be combined to produce new information or they can be aggregated to a higher scale. Still all resulting objects will fit into the GOBLET based FTOM.

3.1.4 FieldFact Global Architectural Model (FGAM)

The third sub model to be defined as part of the conceptual model concerns the global technical architecture of Galileo GNSS applications in agriculture. The infrastructure for the demonstrator applications will be set up using several building blocks. Figure 3-4 shows the components relevant in the set-up of the FieldFact technical architecture. The depicted global architecture will be further developed in the subsequent activities of WP 3 (Applications). In the deliverable D.3.5, Architectural Model Report the complete technical infrastructure will be described.

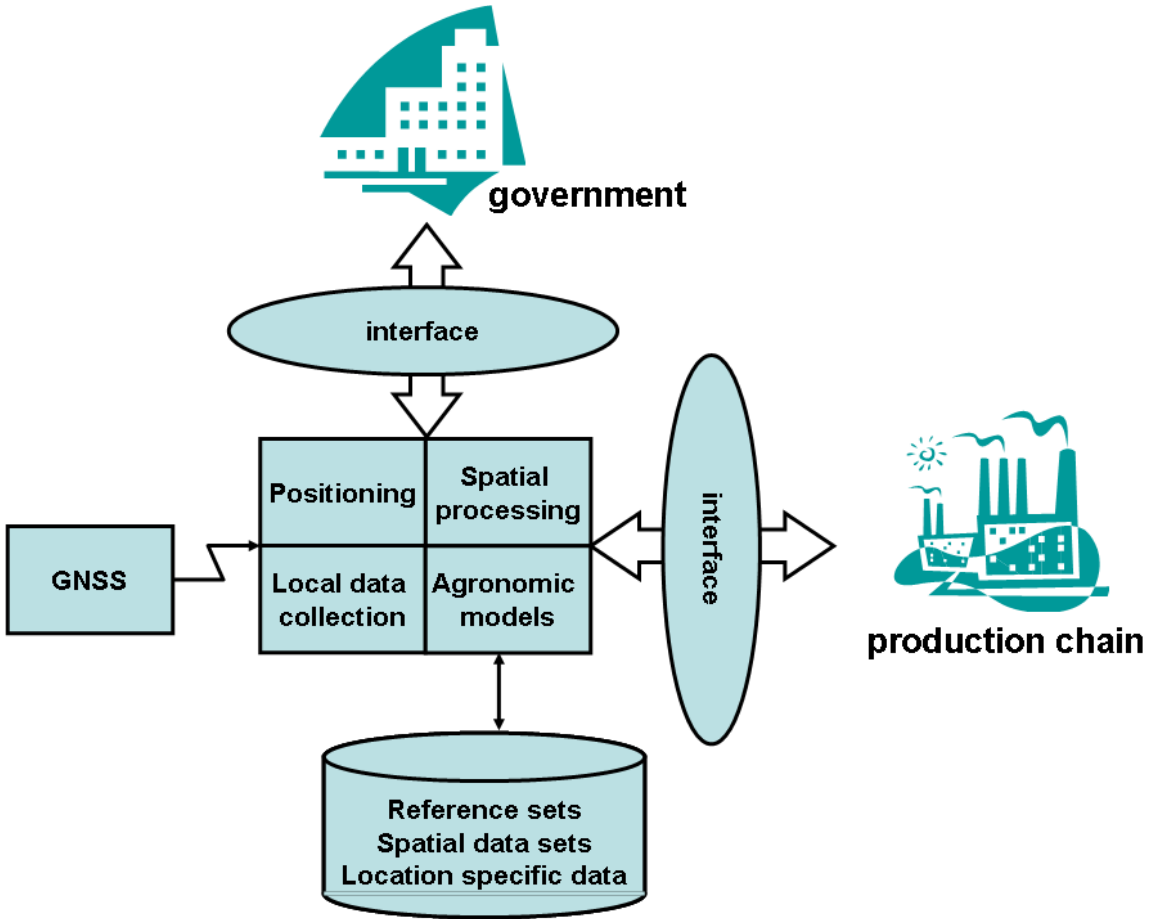

Figure 3-4 FieldFact Global Architectural Model

The FieldFact demonstrators need to be able through a positioning component to collect accurate spatial information at (sub-) field level. This component will use an external positioning system (GNSS, Galileo) and possibly additional precision enhancing systems. The infrastructure needs to provide receivers for the positioning signal and processing facilities for an augmentation system (online or post-processing).

A local data collection component will collect process data, including positioning samples. A spatial processing component (GIS), combined with specific domain knowledge of agronomic models, will aggregate and enrich the collected data and combine various data sources into new information applicable in the production process.

A communication infrastructure will provide functionality for central storage and processing of collected data-sets and for data exchange with external parties. Each building block will communicate through open interfaces with other building blocks, thus providing a means to exchange a physical implementation of a building block for another (better, more detailed, with extra functionality, etc.). Communication components provide interfaces to communicate with the outside world (e.g. government and production/logistic chain), again based upon open interfaces.

3.2 Model verification

3.2.1 Verification of the model: Parcel measurement

Through parcel measurement a farmer measures the dimensions of a parcel, for instance to be able to apply for subsidies within the framework of IACS. GNSS can support the farmer in collecting more accurate data. In the case of Galileo, an integrity message is added to the data, giving farmer and government “prove of evidence” of the validity of the measurement.

The *actor* in this application is the farmer, or maybe better, the field measurement application that is operated by the farmer. In this situation the performed action is the measurement of the parcel. The action consists of the sampling of separate points on the outline of the parcel, processing the separate samples to a parcel outline object and finally the upload of that object in a local repository (e.g. the farm management system), coupled with other information sources. The subject of the action is in this case the individual field or parcel.

Examples of *conditions* that constrain the parcel measurements are the following:

- parcel information must be delivered to the government every year in order to apply for subsidy (global condition, imposed by EU, government)
- accuracy of the measurement must be better than 2m (global condition, imposed by EU, government)
- Parcel measurement should have proven integrity ((global condition, imposed by EU, government)
- The yearly cost of parcel measurement should not exceed a maximum amount (local economical condition)
- A group of trees is positioned adjacent to the north side of the parcel (local physical condition)

All information that is produced by the parcel measurement application can be expressed as an instance of the FTOM. The parcel is the most evident example. The parcel measurement generates an information object that represents the parcel and some of its characteristics. It holds the polygon representing the outline of the parcel a spatial element. It also stores the time information about when the parcel was measured and the quality data necessary to prove that the measurement satisfies the quality conditions imposed by the government. Other attributes might be for example the area of the parcel, or the crop that is grown on the parcel.

The final goal of the parcel measurement application is the exchange of these parcel data with the national government in order to provide them with the necessary information for the CAP related subsidy application. An object representing the GOBLET model can be used to implement the interface between the farm and the government and can thus be used a carrier of the information generated by the application.

3.2.2 Verification of the model: Variable Rate Application

Variable rate application implies the application of resources on a field, dependent on the localized need for those resources. It might for instance be the automated localized dosage of fertilizer, controlled by relevant location specific data on the state of the soil and the crop.

The *actor* in the case of variable rate application (VRA) is the applying machine. The *action* performed here is the application of an amount of a resource on the field. This resource might be a fertilizer, but also a pesticide or a mixture of pesticides. The *subject* of the action is again the *field* or parcel.

The *action* in this case is the application of a substance to the field, controlled by location based *conditions*. Moreover, the *action* will also incorporate the collection of data concerning this *action*. It will thus produce location based information on applied amounts of fertilizer or pesticides. This information will be recorded and can in subsequent *actions* in time be used as an additional source of input (additional *conditions*).

Some examples of *conditions* that can be applicable to variable rate application are:

- Location based data on biomass, acquired by biomass monitoring.
- Location based soil sampling data
- Pesticides may not be applied on a determined buffer zone at the sides of a parcel (global *condition*, imposed by national of European legislation)

All information needed in variable rate application can be expressed in the FTOM spatial model described in this document. This counts for both the conditions (= input data) and the outputs of the action. Soil sampling data for instance can be expressed as a collection of simple GOBLETs that together form an aggregated spatial object, describing the localized state of the soil conditions of the parcel. Applied amounts of fertilizer of pesticide can be translated by the applying device to localized data expressing the amount of fertilizer applied at a certain location on the field at a certain time. Because all available data sources will be defined through the same spatial model, it will be relatively easy to process these data sources to input data sets for variable rate application or other field oriented actions.

The data sources involved in variable rate application (both input and output data) might also be used as a basis for communication with the outside world. By processing and aggregating these datasets, a farmer can for instance provide the government or the parties collaborating in the logistic chain with relevant information on the usage of resources in his production process. Thus he will be able to provide the necessary information needed to prove compliance with relevant national or European legislation or to for instance comply with quality and/or environmental certification systems imposed by parties in the logistic chain.

4 CONCLUSIONS & RECOMMENDATIONS

In the task conceptual modelling, a group of experts in the field of spatial applications in agriculture have developed the conceptual model for the FieldFact project. It describes the essential principles concerning the use of GNSS and in particular Galileo in agriculture. Its purpose is to serve as a thinking model or domain map that fits all applications of GNSS in agriculture and that is also suitable for fitting in the Galileo discriminators. More specifically, for the FieldFact project it will be a blueprint for further elaboration of the FieldFact demonstrator applications.

Three main products are part of the conceptual model

- The FieldFact Domain Model (FDM)
  The FieldFact Domain Model describes the relevant objects in the application domain of the FieldFact project. Describing the application domain clarifies the area of interest of the project: the use of the Galileo GNSS in applications in the agricultural community. This model describes the object types in the application domain and the relationships between these object types on a high level.
- The FieldFact Tempo-Spatial Object Model (FTOM)
  The GOBLET conceptual model for tempo-spatial objects serves as the basis for the development of the spatial objects in the FieldFact demonstrators
- The FieldFact Global Architectural Model (FGAM)
  This global architectural model describes the main building blocks of the FieldFact application architecture and will be the main basis for the development of the architectural model in the WP 3 task functional and non-functional analysis.

The developed models have been verified using two different application examples that have been derived from the list of priority applications as identified in the Requirement Identification and Priority Report (Reference: FIELDFACT-WP1-JRC-DEL-1.3).