rmAgro, a reference model for data exchange in precision agriculture

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Abstract

From the start of information technology onwards there is a need to exchange data between different software components and as soon as they are developed by different parties there is a need for standard methods. One of the successful standards is ISO11783 for data exchange between implements and towards Farm Management Information Systems. However, with the introduction of new sensor systems and IoT, independently developed advisory systems and requirements for tracking and tracing, there is a need for standards covering a wider scope as above mentioned one.

We started in the Netherlands in 2010 with as basis the first reference model for crop production, IMOT (1986). The data part of the reference model drmAgro, is set up as a Platform Independent Model (PIM) following UML. This PIM is transformed to specific models, like an XML model, a Java interface model and a DDL model for databases. Transformations to other languages are possible and a transformation to an OWL model is under development. The objective is to keep the specification of agricultural objects independent of the technology used for implementation. Care is taken that content of other models like ISO11783-10, AgroXML, Edaplos, Inspire and most recently ADAPT, is mappable to drmAgro.

The result is a public available platform independent reference model which is and will be in continuous development. It is set up with a generic package and branch specific packages like crop production, greenhouse production and animal husbandry. Crop production covers a wide range of use cases like planning and reporting of fieldwork, providing advice, soil sampling and analyses, application of crop growth models, scheduling of farm operations, auditing, etc. This reference model is the basis for standardised SOAP/XML messages exchanged between farm management systems and advisors, processors and the government in the Netherlands. It is also the basis for REST/XML data exchange through the FIspace platform developed as an EU project.

As mentioned above, there are different models intended as basis for standardised data exchange and many more proprietary interfaces defined. With globalisation of services in agriculture the need for one common basis will grow, while technology will continue to change. This requires a basis with clear semantics which is technology, platform, and independent.

rmAgro has proven to be a solid basis for implementation of standardised data exchange through SOAP webservices in the Netherlands, and REST based message exchange in the FIspace project.

Background

From the start of electronics and information technology onwards there is a need to exchange data between different hardware and software components. Early examples are the exchange of the quantity of concentrate feed from management information systems to concentrate feeders and the communication between onboard computers on tractors and implements. As soon as the market requires that those systems are delivered by different manufacturers, there is a need for standard methods. A successful standards is ISO11783 for data exchange between TaskControlers (TC's) on tractors and implements and from those TC's towards Farm Management Information Systems (FMIS). Also the exchange of data between FMIS's and processors of the produce like potato processors, mills and sugar companies required in an early stage standards for data exchange. The introduction of new sensor systems among which IoT systems like soil moisture sensors, independently developed advisory systems and requirements for tracking and tracing, there is a need for standards covering a wider scope as the above mentioned initial ones.

The Netherlands started in 1984 with a national plan to stimulate the use of information technology and information models were developed for the different branches of agriculture. One of them was the "Informatie Model Open Teelten", IMOT, the model for arable farming. This can be seen as the start of developing information and data models for agriculture which is shown in Figure 1.

Technologies for data specification and data exchange changed during the period that standards were developed and adapted. IMOT was developed as a process model and an entity relationship model and also ISO11783 part 10 is based on an entity relationship model as is AgroXML. CIA in the mid 90ties however was already based on object technology which is also the case for rmCrop and rmAgro following the UML specification. AgroXML changed to web ontology and is now specified as AgroRDF.

An ASCI based format, the Agricultural Data Interchange Syntax (ADIS) was developed for data exchange in Agriculture in the early days. In a later stage also EDIFACT was used, and during that period XML was introduced as a means for data exchange in agriculture. More recently we see JSON as an alternative for XML and the use of RESTfull API's like those published by John Deere.

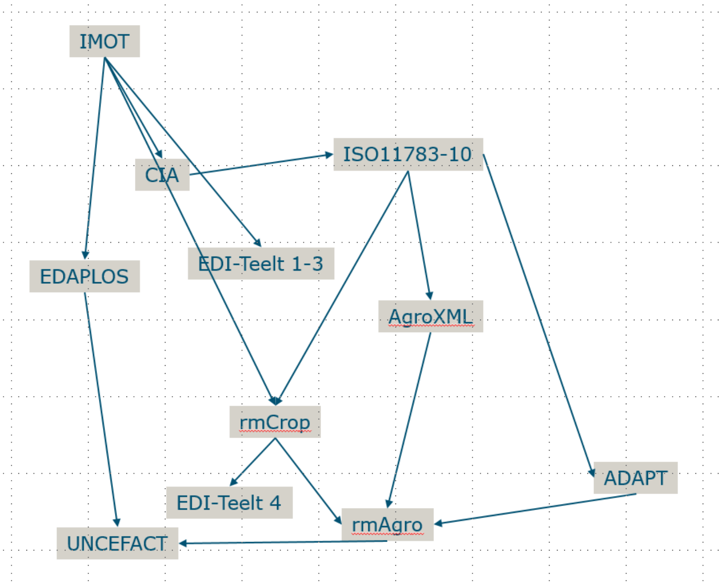

Figure 1. Relation between several data models in crop production.

As the most basic characteristic of a standard, clear definition of the identified data objects, their attributes and their mutual relation, is more stable over time, we decided to set up the data part of the reference model of rmAgro/drmAgro, as a Platform Independent Model (PIM) following UML. This PIM is transformed to specific models, like an XML model, a Java interface model, a Java implementation model, a DDL model for databases. Transformation to an OWL model is under investigation. Transformation to other implementation languages such as C#, C++ and PHP are possible. The objective is to keep the specification of agricultural objects independent of the technology used for implementation.

Over time also the scope of the standards for agriculture changed. Precision Agriculture and Geographic Information Systems didn't exist when IMOT started. This model paid on the other hand much attention to the different stages of planning: strategic, tactic and operational planning, which is not covered by more recent models. With CIA and ISO11783, the communication between FMIS and task controllers got much attention, but it was a seen as a batch process. With the introduction of wireless communication data exchange with machinery becomes much more dynamic and even real time data communication is required for machine to machine communication and managing a swarm of robots. Also operational planning becomes much more dynamic as progress of work in execution is known and regular updates on the weather forecast come in. Also tracking and tracing requires new functionalities and data objects.

In the Netherlands there came a need to align the different branches of agriculture. Arable crop production, greenhouse crop production and processors of produce require the same information for large scale vegetable production as for greenhouse production. Also processes around sampling of soil and products and the analyses of those samples have much in common among the different agricultural branches. This was the reason to extend rmCrop to rmAgro.

A number of organisations is working on standards for data exchange in agriculture. AgroConnect in the Netherlands, KTBL for several projects in Germany, Association 1901 in France, Europe with Inspire and several European projects, ISO/TC23/SC19 with ISO11783, AEF which prepares ISO standards, ADAPT initially in the USA and now also in Europe. OGC is important for geography aspects, their specification of sensor observations and has an intention to cover agriculture. Apart from those different organisations there are a large number of proprietary means of data exchange. We see also that an organisation changes the definition or scope of a class inherited form another organisation. An example is the PartField that originally was defined by one continuous surface, but in ISO11783-10 it allows for a multipolygon.

Methods

The Netherlands started in 2010 to develop a new generation information model for crop production with as basis the first reference model for crop production, IMOT (1986). As can be seen in Figure 1. IMOT influenced directly or indirectly quite a number of existing standards for data exchange in crop production.

Care is taken that content of other models like ISO11783-10, AgroXML, Edaplos, Inspire, E-Lab, GML, ISO19107, SensorML and most recently ADAPT, is covered by drmAgro. Apart from those other standards, the input of Dutch software houses and users of data is important, as well as some research projects of Wageningen UR. As much as possible use is made of published design patterns for which Gamma et al. (1995) is still a very useful source.

What we try to achieve is one model, with clear definitions, which is able to cover requirements that are visible from other standards and when possible mappable.

Some guidelines used by developing the platform independent domain model are:

- Camel based naming of classes and attributes
- No identifiers, part from global unique identifiers which are an attribute of appropriate classes. (They are generated in the transformation to the XSD model)
- No foreign keys, as this is implicitly defined by the associations. (they are generated in the transformation to the DDL model)
- Only generic datatypes, no platform (language) specific datatypes, they are result from a transformation.
- Many to many relations stay as they are, junction tables are only generated in the transformation to a DDL model.
- The expression “Type” is only used for datatypes, for classification of a class the expressions “Classification”, “Category” or “Group” is preferred.
- A class becomes a data type when it can be identified by the value of the attributes and does not need an identifier.
- Use enumerations only when one is convinced that the items in the enumeration are stable. In other cases use coding tables.

The level of abstraction to use in the domain model is a continuous weighting when to use inheritance, i.e. subclasses. An indication to formulate subclasses is when in the association with other classes one has to formulate restrictions depending on the category of the abstract class. A clear example is the class "DeviceElement" in ISO11783, which stands for many types of components of implements like Bin, Valve, Section, Connector, etc., which are specified by the DeviceElementType enumeration.
In ISO11783-10 there is a reciprocating relation, but it is clear that some relations do not make sense. In rmAgro we therefore would specify the different categories of components as a subclass. (They are actually independent classes with an association to DeviceElement, as the latter is specific for ISO11783 for addressing on the CAN interface and might not exist in other implementations)

Some complications occur when using GML as basis for the geographic objects. GML is an XML model based on ISO19107 which is an interface model. No platform independent model is available from OGC, so we had to formulate it as a sub package of drmAgro ourselves. Transformation to an XML model and an interface model is not necessary as they are already there. A problem is that GML is not completely following the structure of ISO19107, so mapping implementation objects to communication objects might require special attention.

In Agriculture there are some specific national or regional attributes. A clear example is "Ackerzahl" used in Germany and some eastern European countries, the EPA number in the USA and "RegulatorySoilType" from the Netherlands. Therefore we made Country specific sub packages which hold sub-classes for those classes that have country or region specific attributes.

Results

The model rmAgro has several packages:

- A Business Process Model, which specifies some processes from the European FiSpace project.
- Ontolgy, the OWL model as exercise for an OWL version of the domain model.
- Use Case model, with some use cases from ISO/TC23/SC19/WG5 on wireless communication aroun fleet management
- The domain model, which is the core of the reference model
- Dynamic view with some sequence diagrams from FiSpace
- DDL model, the database model as result of transformation from the domain model.
- External models, with specification of some third party models which could be imported in EA.
- External XSD's, with specification of some third party xsd specifications which could be imported from xsd file in EA
- Java model Agro, with a java interface model and a java implementation model as result of transformation from the domain model.
- Mapping, with diagrams in which some mapping of third party models is visualized.
- WSDL's, which specifies the messages used in the FiSpace project.
- XSD model Agro as result of transformation from the domain model.
- Deployment model used to specify some platform classes used in agriculture.

The domain model has a generic part drmAgro, which holds classes that are applicable for all branches of agriculture. It has separate packages for cropping, animal husbandry, greenhouse production, post-harvest processing and infrastructure. Apart from this branch specific sub packages there are sub packages for data types, enumerations, computer platforms, geometries, xsd types and swe (sensor web enablement) types.

In drmAgro and its sub packages there are diagrams for different scopes of the model. An example is given in Figure 2. For each class and attribute definitions are given, with eventual additional remarks and examples.

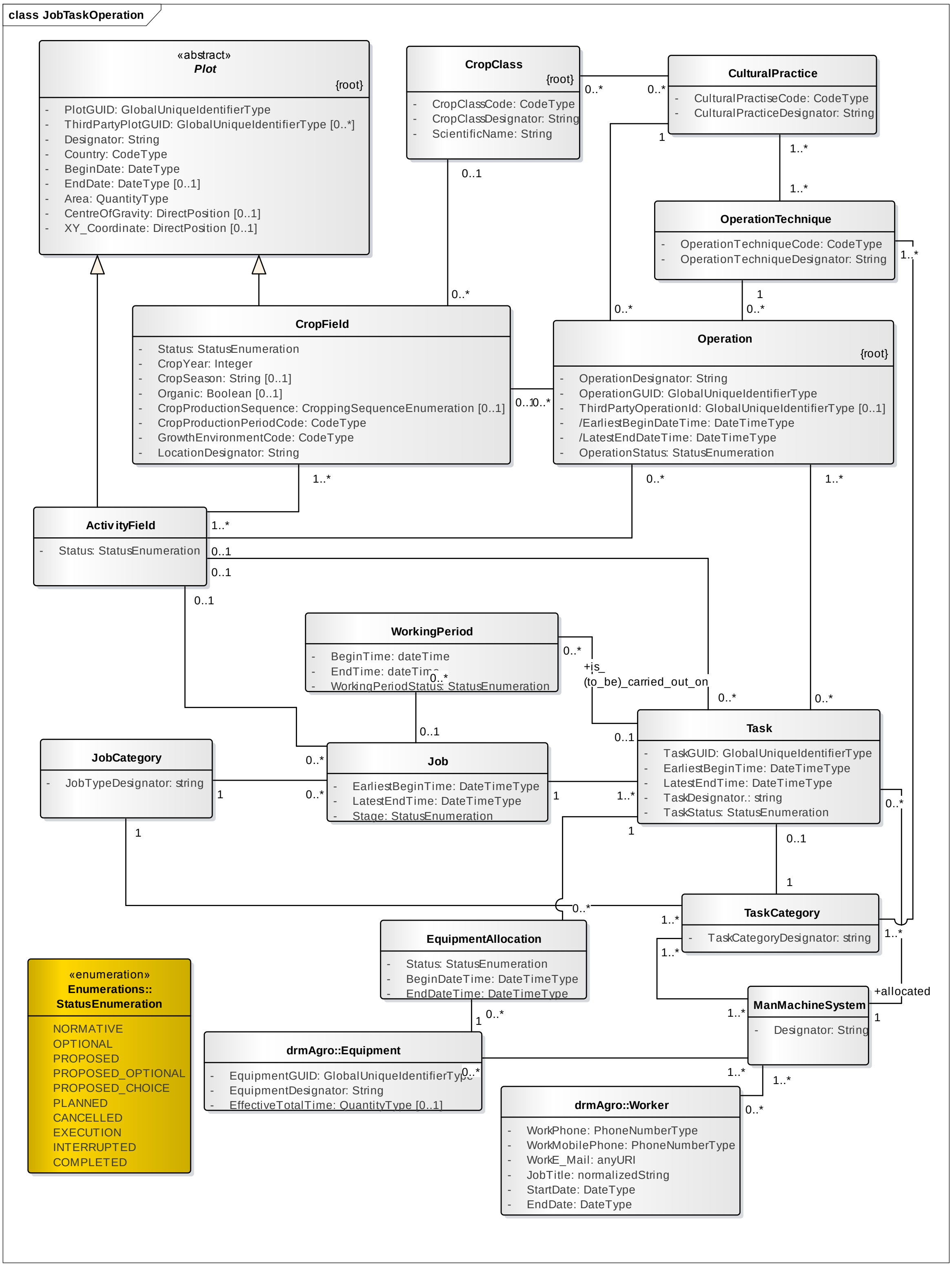

Figure 2. Diagram showing some classes of drmAgro/drmCrop representing fields and activities that are carried out.

The result is a public available reference model which is and will be in continuous development. In early 2017 drmAgro holds 38 generic classes and drmCrop 239 specific classes, but this package contained at that moment quite a number of classes which can be moved to the generic part.

Crop production covers a wide range of use cases like planning and reporting of fieldwork, advices, soil sampling and analyses, application of crop growth models, scheduling of farm operations, auditing, etc. This reference model is the basis for standardised XML messages exchanged between farm management systems and advisors, processors and the government in the Netherlands. It is also the basis for data exchange through the FIspace platform developed as an EU project.

Data exchange for crop production in the Netherlands is defined in Edi-Teelt 4.0 messages which are based on rmAgro. They are used to provide the government with data on crops grown on fields for the European regulations, a message to provide a cropping scheme to an advice service and a return message with an advice for crop protection or fertilizer recommendation. A message to order field operations by a contractor and the report on the executed operation is tested.

The most recent version of the model and background information is available on ftp://pragmaas.com/rmCrop/rmAgro_SNAPSHOT/

Discussion

As mentioned above, there are different models intended as basis for standardised data exchange and many more proprietary interfaces defined. With globalisation of services in agriculture the need for one common basis will grow, while technology will continue to change. This requires a basis with clear semantics which is technology, platform, and independent.

A large number of vocabularies is available at this moment. For agriculture about 300 relevant ones are published at http://vest.agrisemantics.org/ .

Conclusion

rmAgro has proven to be a solid basis for implementation of standardised data exchange through web services in the Netherlands, and REST based message exchange in the FIspace project.

The fact that rmAgro/drmAgro is set up as a platform independent model does not mean that it is stationary over time. We see that technical possibilities, functional requirements and the scopes develop over time, which means that a reference model for agriculture has to be extended continuously. In some cases this is a simple addition of some attributes, an additional class or subclass, but in some cases it has consequences for the structure, the mutual relation between classes which has far going consequences for database design and source code.

An overall discussion among organisations that work on standards for agriculture is desirable to agree on who is responsible for which domain or aspect of agriculture. Especially the maintenance of coding lists require attention. Crop characteristics including remote sensing variables, soil variables, crop classes and varieties, process variables for farm machinery, meteorological variables, require maintenance by organisations that are specialised in those aspects.

References

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