Semantically Enriching and Reconstructing the Cadastral Map of the Netherlands – An LADM Approach

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Key words: Dutch Cadastre, Cadastral Mapping, Survey Documents, Data Modelling

SUMMARY

The Dutch Cadastre (Kadaster) is the organization in the Netherlands that registers and maintains all legal rights concerning properties. One of its products is a land covering cadastral map, which is digital available as open source. It displays by approximation all parcels in context to each other including its geometry and parcel numbers. The map serves as an entry to the original survey documents, which contain accurate descriptions of parcels and boundaries.
The existence of two different products leads to miscomprehension in the actual location of boundaries by laymen. The cadastral map is easy accessible and simple in use, while survey documents are complex by the in depth details.
The Kadaster has the aim to reduce this ambiguity and misinterpretation by improving the cadastral map in two stages. At first the cadastral map will be semantically enriched by data for the survey documents and secondly this data will be used for dedicated algorithms to recalculate the cadastral map. The ultimate goal is to accomplish a map with very accurate described boundaries.
A first step in this process is to redesign the current data model from parcel level to the more specific boundary level in order to accomplish an unambiguous connection between cadastral objects and its related survey data.
Challenges in this transformation are the dynamics of the cadastral situation, the different survey procedures and data acquisition over time and the appearance of survey documents in digital and paper format. Additionally the current survey documents only describes changes in a parcel, thus different boundaries of a parcel are related to different survey documents.
The new data model takes the sub package survey and representation of the LADM (Van Oosterom et al, 2011 and Soffers, 2017) into account for solid solutions in their design challenges. The basic structure of spatial sources, points, boundaries and parcels, all with their own identification, enables to store relevant data, like coordinates, quality descriptions and metadata, as attributes to these objects. Further new relations can be established while previous ones are maintained. The superclass versioned object enables the maintenance of different appearance of the same object in adjustment and reconstruction process.
The strive of the Kadaster to reconstruct the boundaries of the cadastral map offers new perspectives for the sub package of LADM by tighten the survey and representation part of the sub package; The cadastral map will not only be the visual representation of the survey document, it is actual a survey document by itself.
The concept of the reconstruction map and the information map will bring new insights to relate the different cadastral objects in the in a more dedicated way.

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1. INTRODUCTION

Since 1832 the Dutch Cadastre (Kadaster) is the national organization that registers and maintains all legal rights concerning land property in the Netherlands. It is organized as an independent, but public organization, which is supervised by the Minister of Internal Affairs.

About 15 years ago the Dutch Mapping Agency and Kadaster merged and forms a combination of National Mapping Agency, Public Register (of deeds) and Cadastre. The Kadaster has adopted the service where links to utility companies are provided to everyone who has digging activities in a certain area. They are obliged to ask for this information (maps with the location of the underground objects) which will be provided by the companies.

From this point the Kadaster has developed to a National portal of geo-information where all kinds of information are provided to the users. The Kadaster does not only provide its own data like cadastral information and small-scale topographic maps but also data that is maintained by other organizations like the Dutch communities (large scale topographic map). Besides to this key-activities the Kadaster provides taylormade GIS-products to authorities for applications like spatial development plans and share knowledge with other countries by a specialized department known as Kadaster International.

This article focusses on is the description of parcels. These descriptions can most of the time be found as boundary descriptions because in the Dutch work process only new established boundaries are descripted and existing boundaries remain untouched. This descriptions can be found in deeds (drafted by a notary, in words and sometimes also as a simple sketch in the map), in survey documents and of course in the Cadastral map. So the geometric description of a parcel must be derived by collecting all the source data of the surrounding boundaries or simply by looking in the cadastral map.

Nowadays more and more people get aware of the digital map. They are able to combine it with an aerial photograph, zoom in and take wrong or opportunistic conclusions about the exact location of a boundary, due to the limited geometric quality. The desire to limit this misunderstandings led to an innovation program where the desired new products and processes create a need for a better data structure. The Kadaster decided to use the LADM as an important inspiration in order to stimulate future cooperation. In this article the Dutch Cadastral process and products will be presented, further on the innovation program, the needed functionalities and the consequences this has for the data structure in relation to LADM.

2. THE DUTCH CADASTRAL MAP & SURVEY DOCUMENTS

2.1 History

The legal base of the Dutch Cadastral System is conformity between neighbours at both sides of a boundary. At the start of the cadastre in 1832 all parcels that belong to particular persons were mapped and related to registered owners for tax purposes. Areas without a known owner like woods, rivers, etc. where left out and a lot of these maps where so called “Island maps”. From that moment on every change in a parcel (when it was split up) has to be described in presence of and defined by the owners at both sides of a boundary. A change in a parcel has namely only two flavors: to split up in two of more parcels or getting united with one or more other parcels. Only the splitting of a parcel leads to new boundaries.

2.2 Process of defining new boundaries

The described process is very important and is called in Dutch “*de aanwijs*”. The owners say and show to the surveyor where they think the new boundary has to be established, and the surveyor make adequate notes in a survey-document in order to be able to mathematically describe the boundary by surveying the boundary in connection with his environment and with high geometric quality. A special aspect of the Dutch cadastral process is that in general no attention is paid to the already existing boundaries, only in the mapmaking process the connection is made and the new parcels will be formed. In most cases owners *visit a notary* before this process takes place to legally define in a deed that a piece of a parcel does change of owner.

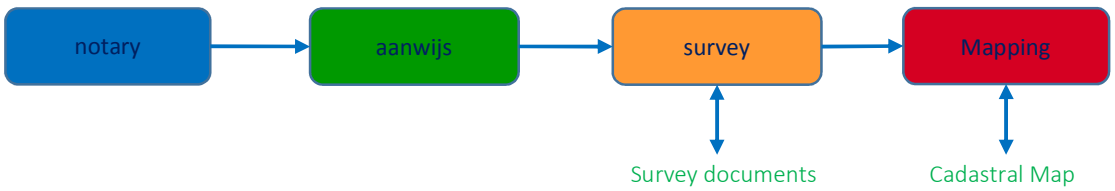

Figure 1. The different steps to implement a new boundary

2.3 Two main products

The Dutch Cadastral procedure does produce and maintain two main products: *the cadastral map* and the *archive with survey documents.* As shown in figure 1 the survey document occurs after the *survey process* and is meant for future precise reconstruction of the boundary in the terrain. For that purpose a lot of specialised survey information is stored, both as figures, texts and numbers. In its current form also coordinate lists are stored in a special archive. An innovation of this archive into a more structured database is taking place under the name “terrestric registration”. Only the boundary coordinates that come from the measurement will be entered in the cadastral map by a *mapping process* where the new lines will be connected with the existing boundaries (cutting, extending, etc.) and form the new parcels.

2.4 Closer look at the cadastral map

The Dutch cadastral map is a free available digital map, which offers a general impression of the location of all parcels in the Netherlands. It is a 100% complete map which means that all the current parcels in the Netherlands can be found on the map in a topologic correct way. The map is also seamless which is a great advantage when searching specific parcels. The map forms the index to the archive of survey documents. Since the location of boundaries are indicative given, no rights can be derived on boundary locations in this map. For a precise spatial description of boundaries, the survey documents need to be consulted. Nevertheless it is guaranteed that the map has a precision of 20 cm in urban areas and 40 cm in rural areas for 95% of the data. The Dutch cadastral map depicts the boundaries of each parcel, the cadastral identification of each parcel and relevant building outlines, which are derived from the national topography map. In the Netherlands topography is used to refer survey data to its environment. Further contains the polygon based map additional information about parcels, like area. No additional information is (yet) given for the cadastral boundaries.

2.5 Making of the digital cadastral map

The cadastral map is derived from former local cadastral maps, which where digitized and merged to a land covering map. In order to build this digital map all the maps have been connected with a lot of work in connecting corresponding lines. Furthermore, to make a reliable connection to the national coordinate system (RD) a large-scale topographic have been build first (started in the 70th-s). In the first years of this millennium this digital map has been build. New boundaries are adapted to its adjacent cadastral objects in the map to keep the map topologically correct and complete.

2.6 Survey documents

These documents contain the most accurate spatial description of cadastral objects and are drafted by the land surveyor and contain the notes about his/her observations in the field. The document is identified by an own identification number and the related parcel numbers. These parcel numbers in combination with the municipality code and section are the reference between the documents and the cadastral map. Since survey documents only contain changes, in most cases many survey documents need to be consulted before all relevant documents for a specific parcel is collected. An example is demonstrated in figure 2; Survey document 3, 2 and 1 need to be consulted in order to have the complete survey data for parcel 71.

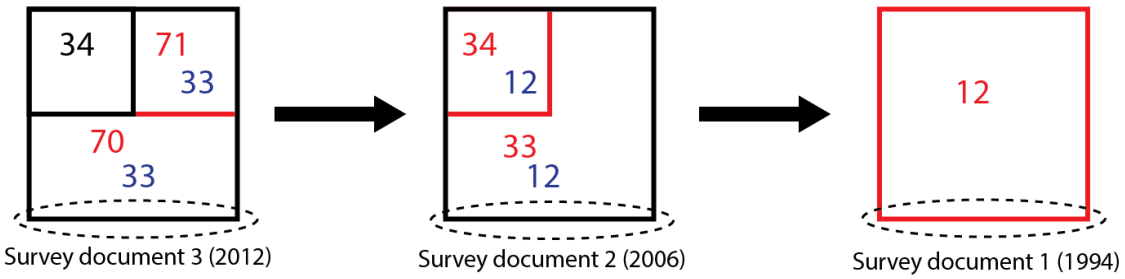

Figure 2. Multiple survey documents for the boundaries of one parcel

Although currently the survey document are drafted and stored digitally, the main part of the archive consists of paper documents, which are scanned and stored in a digital database.

3. THE CADASTRAL MAP IMPROVEMENT PROGRAM

3.1 Goal

The existence of both a cadastral map and an archive of survey documents results in complexity and incorrect use of the cadastral map as the single source of truth by customers. Therefore the Kadaster has the aim to reduce this ambiguity and misinterpretation by improving the cadastral map in such a way that it is more and more harmonized with the information on the survey documents. The ultimate goal would be to fabricate a cadastral map that corresponds object-to-object (in a semantical and geometrical way) to the information on the survey documents. In that case the cadastral map gives valuable information with which one can determine to location of a boundary in the terrain.

In two steps the new map will be build: at first the cadastral map will be semantically enriched by data from the survey documents and secondly this data will be used in dedicated algorithms to recalculate the cadastral map. The ultimate goal is to accomplish a map with adequate described and very accurate boundaries.

3.2 Two problems that need to be solved

Before building the new map two major challenges need to be accepted. At first the scanned survey documents need to be transformed into a digital readable format. Recent research projects have proved that an semi-automatic tool can read a high percentage of the stored measurements. This tool contains OCR for handwritten numbers and deep-learning systems for self-improvement. This is needed to reduce manual labor and costs.

The second challenge is restructuring the survey data structure of the Kadaster from a parcel based structure into a boundary based structure. Since survey data primarily describes boundaries, it is essential for further map improvement to store the survey information linked with the cadastral object it actual belongs to. In order to achieve such a structure, survey documents need to be parsed to boundary level, taking the different formats of survey documents and the different used techniques into account. This restructure of the cadastral data requires a new and more detailed data model.

3.3 Information map

Both challenges will create the ability to improve the cadastral map. This will be executed in two steps, as it is demonstrated in figure 3. At first the objects of the current cadastral map will be semantically enriched by the survey information, the so-called *information* map. All boundaries are given a quality label, based on the survey information. This quality label could be expressed in a cartographic way or by adding it as an attribute. Also the textual description of boundaries can be added to the map. This will put the interpretation of the location of boundaries in the terrain in better perspective. A last it is the aim to present the actual survey data of the object in the cadastral map or in a linked digital environment. It need to be notified that in geometrical way the information map runs completely synchronously to the current cadastral map.

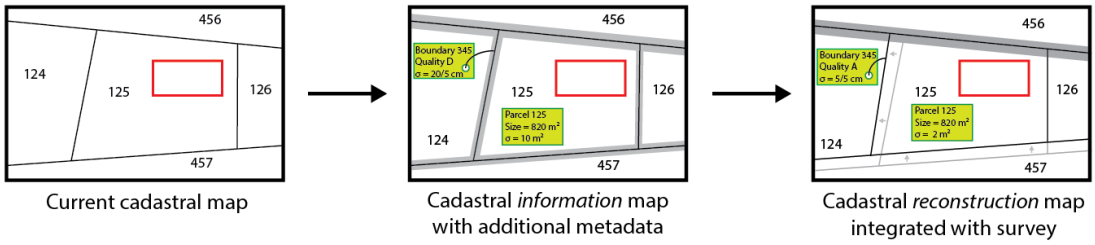

Figure 3. The information map and the reconstruction map

The main benefits of the information map are a better and unambiguous access to the survey archive and a dedicated quality overview of the objects in the cadastral map.

3.4 Reconstruction map

A second phase in the improvement of the cadastral map is by recalculating the boundaries, this results in the so-called *reconstruction* map. This map is demonstrated in figure 3. Custom-made algorithms will reconstruct the current cadastral map by using the data from the survey documents. Once the data is acquired it is connected to data from the "neighbour" documents by mutual points. For the calculation the 'Delft method' is used, which forms the base of the surveying work at Kadaster. The adjustment and testing routines make sure that every single detail is treated correctly and with respect to its quality. Every single measurement is tested to make sure that errors can be found and eliminated. Historic measurements can for instance easily be combined with modern GNSS data. The result is a better geometry and metadata about this quality.

3.5 Reasons to have two maps for some period

The reasons to have stability in the map are:

1. the change of area sizes will cause much resistance, but have to be done at some time. Therefore it is wise to wait until all new sizes are clear;
2. the current cadastral map is widely used in combination with other maps. Users do not want unexpected movements.

3.6 Results

The achievement of such an improvement will put the cadastral map in a new perspective; the accurate location of boundaries can be presented in a custom-made way, a dedicated estimation of the area of a parcel can be given and the cadastral map can be combined in a legal way with other open source maps, having a similar quality or other maps can use the geometry of the cadastral map for own purposes.

3.7 Production process

The process needed to build the two maps is displayed in figure 4. Building the *information* map is nothing more than adding default labels (2) with the designed quality and, if possible, to assign labels with higher quality when the process of area analysis (1) give rise to. More complex will be the process of recalculation which results in the reconstruction map and where sometimes very old survey networks are linked together and recalculated (3-6). Special attention is needed for process 4 and 5 where we aspect a lot of manual labour. Process 7 is a legal process where more communication and less technical challenges are excepted.

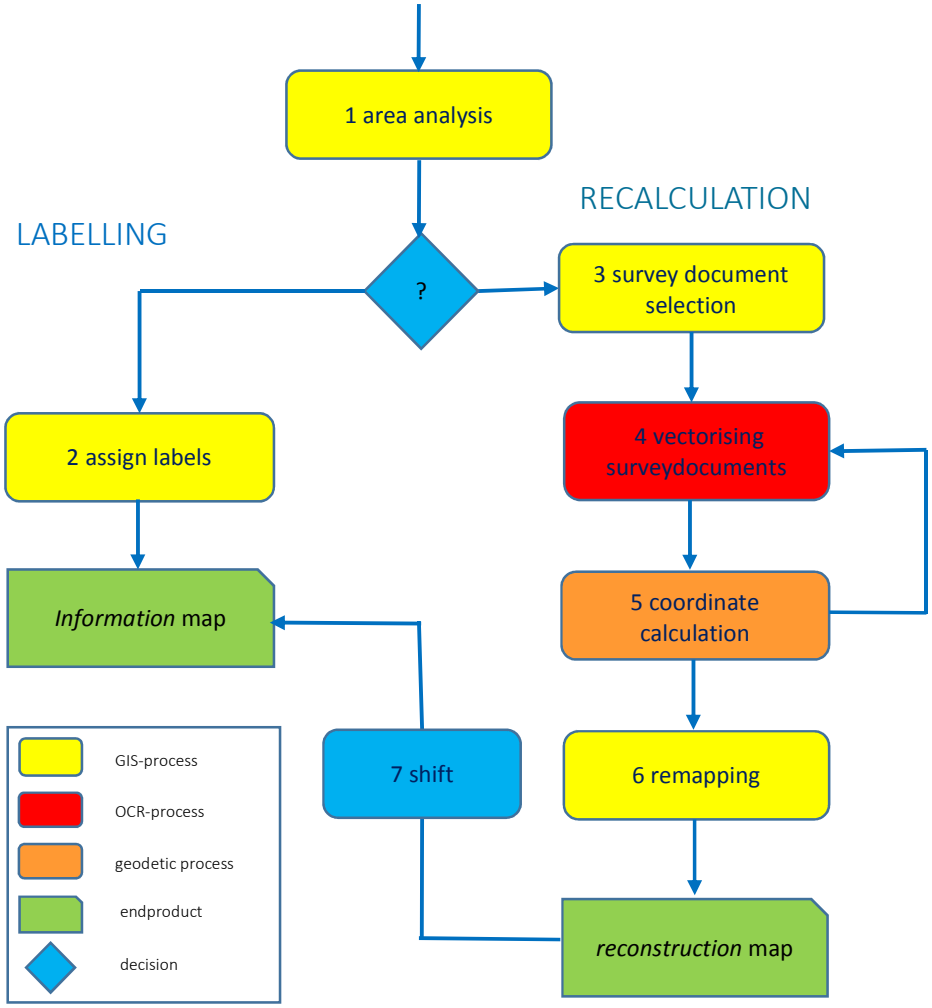

Figure 4. The cadastral map improvement processes

3.8 Lessons learnt

Most of the content presented here are near-future plans, the Kadaster is speeding up the development. What have been proved are the remarkable results of the attempt to automatically read old survey-documents: at least 60% and probably up to 80% of the needed information can be automatically required. It is still unknown if the recalculation and remapping can be automated to a high extent.

4. REQUIREMENTS

In order to provide all the tools and infrastructure, a reconsideration of the current data model is necessary. This is accommodated in the project 'Terrestric Registration', which has the aim to design a cadastral database, which stores survey data in a structured way. The project takes the LADM sub package survey and representation as template to benefit from its expertise and offered solutions. The approach results in a clear and broadly supported data model.

In the current situation there exists only a connection between the survey documents and the parcels in the cadastral map: this should be specified to a more detailed level, where all relevant cadastral objects should be considered as own entities. A proper definition of objects and a precise explanation of their mutual connection are very important.

The new data model have to meet the following requirements:
- all cadastral objects in the data model should have a direct connection with their related survey document. This will result in an unambiguous access to the survey data and it provides the data for the information map and the reconstruction map;
- boundaries should be considered as own entities, since survey information is primarily describing boundaries. Special attention need to be paid the distinction between boundaries in the cadastral map and boundaries surveyed in the field;
- points should be considered as own entities, since survey information exists of a collection of points. All these points are processed together in the cadastral system, but represent different elements, like a part of a boundary description or topography;
- all different data formats (paper and digital) and all different survey methods used by the Kadaster overtime should be incorporated;
- the topological relation between the different cadastral objects should be maintained, even after the production of the reconstruction map;
- the data model should incorporate a history model, since the cadastral map is subjected to dynamics, since the cadastral situation is constantly changing.

5. IMPLEMENTATION OF THE SUBPACKAGE SURVEY AND REPRESENTATION IN THE DATA MODEL

The LADM subpackage survey and representation includes 5 classes; LA_SpatialSource, LA_Point, LA_BoundaryFaceString, LA_BoundaryFace and LA_SpatialUnit. For the transformation to the Kadaster data model the prefix “NL_” is used. The data model is displayed in figure 5. The structure of the LADM considers points, boundaries and parcels all as own cadastral objects and they are all related to each other. The benefit of this structure is to store the specific information to the object it actually describes. The class LA_BoundaryFace is ignored, since 3D registration at the Kadaster is still in a development stage. The classes of the data model have their own ID. Having multiple cadastral objects in the data structure asks for a different approach in identification. Currently parcels are marked based on their cadastral context of the Kadaster. If this approach would be applied on points and boundaries as well, this would mean that every mutation in the cadastral map end ups in a chain reaction of changing ID’s for the surrounding object. If a parcel changes, its boundaries and points are forced to change as well, while the object itself haven’t been changed at all. The ID should not be based on its cadastral context and the relation with the surrounding cadastral objects should be registered on attribute level.

Survey documents exist of observations in the field. These observations are transformed in a collection of points by several processes. The different steps are captured by the super class VersionedObject to which the class NL_Point inherits. Recalculated objects from the reconstruction map are implemented in via this superclass.

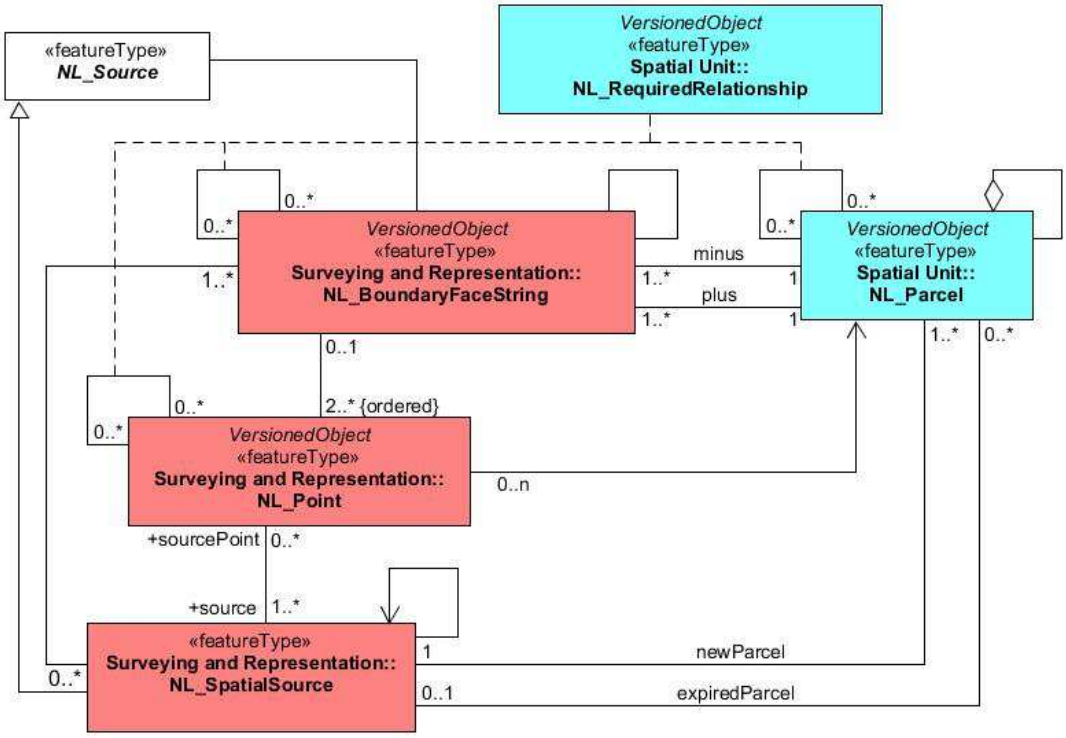

Figure 5. Implementation of the LADM subpackage

A boundary is represented by a subset of the collection of points, but points could also represents topography to place the survey data in the environmental context. In some cases the link between survey data and points is not one-to-one, but makes a detour. If a boundary is defined by two points, these points are surveyed on a random location on the boundary line. Implementing this boundary in the cadastral map generates a line, which is extended until it intersect with other boundaries. This results in intersection points, identifying the start and end of a boundary in the cadastral map. These points have a cartographic background. These intersection points are based on surveyed points, but they are not identical objects. This is a different case when a boundary is defined by a collection of 3 or more points. These boundaries contain midpoints, which do have a corresponding object in the cadastral map.

The class NL_BoundaryFaceString represents boundaries. In the data model a distinction have to be made between surveyed boundaries and cartographic boundaries. Surveyed boundaries are identified by a collection of points and appear in a single moment of time; the mutation of the cadastral registration. Cartographic boundaries are the representation of these surveyed boundaries in the cadastral map. Cartographic boundaries runs from node to node, having one parcel at the left and one parcel at the right. This result in a complete collection of all unique boundaries in the current cadastral registration. Due to the cadastral dynamics, cartographic boundaries are mutable objects. Implementing a new boundary has the effect that the adjacent boundaries are split in two, while the aggregation of two adjacent parcels results in the aggregation of the adjacent boundaries. In the data model the boundary class has a self-inheritance, based on a parent-child structure. A cartographic boundary could be derived from

multiple cartographic boundaries and vice versa. This results in a fragmented relation between cartographic boundaries and surveyed boundaries.

At first sight it seems that every object is defined by only one survey document, but there are some considerations in this assumption. The Kadaster has a service for reconstructing cadastral boundaries in the field. In most cases this involves old boundaries, measured with less accurate techniques, while related topography, like ditches or walls are gone or replaced. The boundary reconstruction is an opportunity to update the description of the cadastral boundaries to the present circumstances. A boundary reconstruction does generate a new survey document with a lot of detailed information. However due to the legal issues it is currently no option in the cadastral map to replace the original boundaries by the more accurate, reconstructed boundary. If it would be, than should the NL_SpatialSource class inherits the superclass VersionedObject as well. In any case the updated information of the boundary reconstructions are very usefull material as supplement for the information map and the reconstruction map. The data model can provide an alternative for this by declaring reconstructed boundaries as 'equal' to their original boundary object via the NL_RequiredRelationship class. This enables a history registration of documentation over time for a specific cadastral object.

Another issue comes with the reconstruction map project. This project will use dedicated algorithms to combine multiple survey documents to recalculate cadastral objects. By connecting the survey documents via corresponding features a more accurate and more detailed description can be generated for cadastral objects. This approach result in the fact that an object is not described by a single survey document, but is calculated via a collection of survey documents.

6. CONCLUSION

This article discusses the aim of the Kadaster to improve its cadastral map by linking the survey documents to its cadastral objects. This process will be established in two phases; at first by semantically enriching the current cadastral map based on the survey data and secondly the Kadaster will recalculate the cadastral map by applying dedicated algorithms to the survey data.

As a basis for these projects a new data model will be designed, which facilitates the tools and infrastructure for such operations. This data model is inspired by the LADM sub package 'survey and representation' to benefit from its expertise and solutions.

The sub package is a general model, which can be applied on many cadastral systems. The map improvement program of the Kadaster brings the implementation of the sub package into a new perspective, since the survey part and representation part are more integrated.

Before the integration of the survey documents with the cadastral map is achieved, there are still many challenges to be solved. The Kadaster is open for contributions abroad to support the program with solutions based on comparable issues.

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BIOGRAPHICAL NOTES

Pieter Soffers holds an MSc in Geomatics from TU Delft. He is currently working for Kadaster in the Product and Process Innovation Department. He is involved in the cadastral map improvement program and the Terrestric Registration project.

Eric Hagemans graduated with a degree in Geodesy from TU Delft in the 1980s. After working for several engineering companies, he became a professor in geodesy and photogrammetry and manager at the University of Applied Sciences in Utrecht. For the past three years he has been working at Kadaster where he is responsible for the cadastral map improvement programme as well as geodetic innovation within the Survey Department.

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