ADMINISTRATIVE CADASTRAL DATA IS FUN

Peter van Oosterom*

Preface

This contribution is dedicated to Theo Bogaerts, more than 25 years professor at the Delft University of Technology holding the chair 'Leer der Vastgoedsystemen' (Land Information Systems Technology). My personal contacts with Theo Bogaerts do not go that far back in history. About a decade ago I was very impressed by a presentation of Theo Bogaerts at a European GIS conference, because of his dedication to cadastral systems and specifically their (re-)establishment in Eastern and Central Europe. It is well known that cadastral systems contain both a geometric and an administrative (legal) aspect. Being more interested in the basic technology and less in application areas it was hard for me, at that time, to understand the passion of Theo Bogaerts for cadastral systems including the 'dull' administrative part. Later on, I got personally involved in the development of cadastral information systems at the Netherlands Kadaster. In this contribution the cadastral query tool is described together with several of its applications, which use both geometric and administrative cadastral data. Based on these experiences, I now can understand the source of Theo Bogaerts inspiration. Of course, his work must have been fun, otherwise it would not have been possible to work in this area for such a long period. I want to thank Theo Bogaerts for his cadastral systems inspiration and for his guidance he gave me during the last two years at the Department of Geodesy, TU Delft.

*** About the author**

Peter van Oosterom (1963), (MSc Technical Computer Sciences (1985) Delft University of Technology, PhD (1990) Leiden University). From 1985-1995 he worked as a computer scientist at TNO. In the period 1995-1999 he held the position of senior information manager at the Dutch Cadastre. On January 1st, 2000 he has been appointed to professor of GIS Technology at the Delft University of Technology, Department of Geodesy.

INTRODUCTION

Most information systems, both in past and present days, are of administrative nature. Nobody questions the usefulness of good administrative information systems for banking, social security, salary administration, insurance companies, and so on. However, they also have a dull and perhaps even boring reputation. This both from the point of view of the developer and from the point of view of the user. Specifically, users only complain when the administrative information system is not working; e.g. after the introduction of the new Baan software for project and financial administration at the TU Delft. Of course, 'specialists' know that administrative information systems can be very interesting. It is quite a big challenge to develop a secure and robust system to handle every day the huge amounts of financial transactions for a bank in a 7 times 24 hours economy. Also, modelling and maintaining the temporal aspect of administrative data sets is non-trivial and important if legal or financial consequences are involved: e.g. due to an error in the past a certain person did not receive enough money from the social security organization. However, correcting the past may be tricky as one would like to enforce business rules as integrity constraints and a change in the past may cause a 'Dr. Who' time ripple effect. Another challenge is to develop generic and flexible software, because administrative information systems are often strongly related to the law and regulations. It is not desirable to completely redesign a system when some rules change. However, developing generic and flexible software has its techniques and costs. Finally, all kind of (inter)net(work) developments do increase the potential access to the administrative information dramatically. Not only design of new interfaces is needed, but complete subsystems must be redesigned. Nevertheless, administrative information systems have a dull and boring reputation. This general opinion includes administrative cadastral data.

This contribution first shortly describes the scope of technical information systems, in contrast to the administrative information systems. This paper further reflects on a number of different types of research oriented applications with respect to querying cadastral information. Most applications require both geometric and administrative (legal) aspects of cadastral information. A short summary of the architecture of the query tool system is given, followed by an overview of the cadastral data model. Then, the research aspects of the six specific queries will be described in more detail. The paper is concluded with my revised opinion about administrative cadastral data.

TECHNICAL INFORMATION SYSTEMS

It was my personal opinion that administrative information systems are dull, when I joined the Kadaster of the Netherlands in 1995. Fortunately, my job was related to information systems handling spatial data: the cadastral map and the large-scale topographic map. Graphic or geographic information systems belong to another family of information systems: the technical information systems. Other members of this family are CAD/CAM (Computer Aided Design/Manufacturing), AI systems (Artificial Intelligence), vision and image processing systems, machine (robot) control and (route) planning systems, and so on. With these kinds of systems, often based on spectacular 3D graphic interfaces requiring specific hardware, challenging and high-tech operations are executed: e.g. sending an unmanned robot to Mars. It is clear that technical information systems are not dull and boring, but very interesting. The many interesting applications of geographic information within the Kadaster and customers of cadastral data in the Netherlands do support the same impression that these systems are attractive and intersecting: many types of colorful map presentations can be made and they look impressive on A0 plots. Internally the systems contain advanced (and not yet) standard techniques for spatial data clustering and indexing as the amounts of data to be dealt with are often huge. Further advanced geometric (or computational geometry) algorithms are implemented to perform all kinds of smart tasks: 'inpassen/vereffenen' (adjustment of the survey measurements to the existing geometric data), weighted node computation, topology construction, map overlay, generalization, compute re-allotment, and so on.

BACKGROUND QUERY TOOL

In this contribution the integration of cadastral geographic data sets and associated administrative legal data in one database is described. The relationship between the parcels on the cadastral map and the administrative data is realized through nation-wide unique parcel numbers. In the Netherlands, the cadastral maps are based on a topologically structured model. Manipulating area features in such a model requires navigation using the topology references to the boundaries. The topographic maps and the cadastral maps contain the full history since 1997. This is not (yet) the case for the administrative data. The next section introduces the basic data models for the geometric and administrative data. An earlier paper [1] described a prototype version of the query tool. The current version is in production since August 1999. In the query tool database the original data models (base tables) are not changed. However, database *views* are used to present the data in a more appropriate manner; see [2]. The views are used to:

1. integrate data from different tables in one view; e.g. geometric parcel and associated administrative objects,
2. visualize historic data; e.g. go back to a specific moment in the past or show changes over a specified period,
3. different geometric visualization of the same table; e.g. parcel as filled polygon or parcel as point with label,
4. derive default cartographic values, such as color, width, symbol type (which depend on attributes),
5. derive thematic aggregates without storing the result, and
6. present (encoded) attributes in a more clear way.

Examples of the latter are time stamps which are encoded with integers but visualized as readable strings such as '22-04-1998 09:52:50' or legal right codes which are short coded with two characters which can be represented better with a full string. The overall system architecture is displayed in Figure 1.

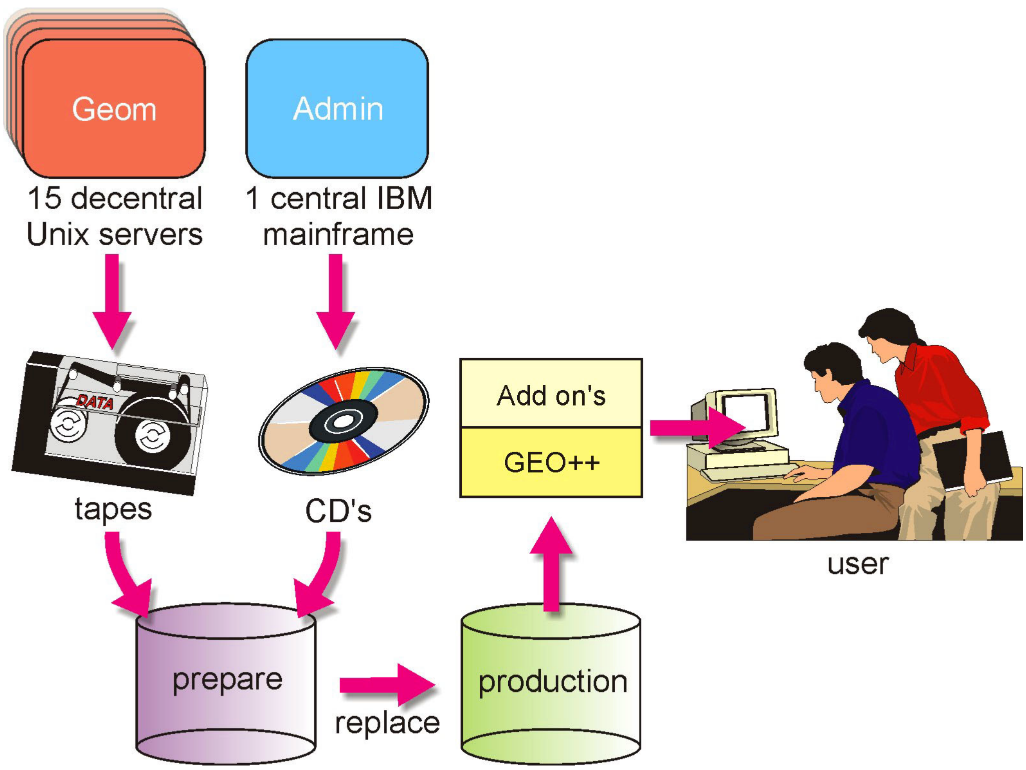

Figure 1. The overall architecture of the query tool.

The query tool system is currently based on the Ingres database management system (DBMS) [3, 4] and the GEO++ GIS package [5, 6, 7]. Specific addon's to these basic standard components of the architecture are described in [2]:

- *easier access to data:* just one button, instead of querying 4 tables;
- *analysis not possible in a relational DBMS:* e.g. intersection of a topologically structured area feature with a polyline;
- *introduction of new interface concepts:* e.g. the 'active set'.

Currently, the data is loaded two times per year into a single Ingres DBMS. Loading the data includes defining indices, computing geometric aggregates, collecting statistics (the basis to produce good query plans by the DBMS query optimizer) and making checkpoints. The whole process takes between three and four days on a (Compaq) AlphaServer 4100 with 1 CPU (598 MHz), 2 Gb main memory and about 500 Gb disks in the form of RAID5 (for the software) and RAID0+1 (for the data storage using striping and mirroring). The result is a 60 Gb database including the index structures. During loading, the previous version of the query tool database remains available to the users.
The query tool is nation-wide and available for analyzing and performing consistency checks on the cadastral data. One of the main goals is to improve the quality of the cadastral source data. The purpose is to create an environment with easy access to all data, in which the data can be analyzed, queried and filtered.

DATA MODELS

Currently, the large scale topographic and cadastral data are maintained by the LKI system (LKI stands for *Landmeetkundig Kartografisch Informatiesyteem* (in Dutch): 'Information System for Surveying and Mapping'), which stores the data in an Ingres database using OME/SOL (Object Management Extension/Spatial Object Library) [3, 4]. Legal and other administrative data related to parcels are maintained by the AKR (AKR stands for *Automatisering Kadastrale Registratie* (in Dutch): 'Automated Cadastral Registration') system, which stores the data in an IDMS database on an IBM mainframe. This database will be referred to as the *administrative* database in contrast to the *geometric* database.
The query tool has it own database, which contains a copy of all geometric and administrative data in their original data models. Therefore, a good understanding of the two data models is important. These data models contain structures, which can be found in many other applications; e.g. metric, topology and measurement information (date, accuracy, type of measurement) within the geometric data and hierarchies, n-to-m relationships, generalization/specialization structures within the administrative data. These

structures and their semantics are relatively difficult to deal with in a generic query tool environment. However, they have to be included in a query tool which is acceptable for users familiar with this cadastral data model.

Geometric model

The geometric model will be described very briefly as it has been published before quite extensively [4, 8, 9]. Since 1997 the geometric database keeps track of all changes over time, that is, it is a spatio-temporal database. The metric attributes of type point, polyline and box, are stored in the relational database together with the other attributes describing the measurement (date, accuracy, etc.). Every object is extended with two additional attributes: `tmin` and `tmax`. The objects are valid from and including `tmin` and remain valid until and excluding `tmax`. Current objects get a special `tmax` value: `TMAX_VALUE`, indicating they are valid now. The geometric data model for the cadastral *parcel* layer is based on winged-edge topology [10] as described in [4]; see Figure 2. In addition to the topologically structured cadastral parcel layer, this model also includes *topographic* layers, which are not (yet) topologically structured.

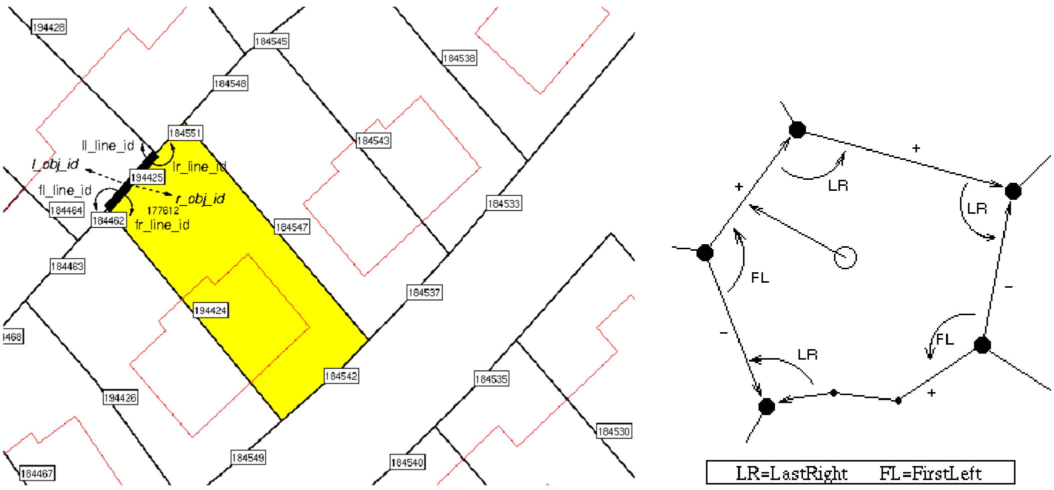

Figure 2: The topologically structured model.

Administrative model

The administrative data model is based on a few key concepts: *object*, *subject*, and *right*. Objects (parcels) and subjects (persons) have a n-to-m relationship via rights; see Figure 3: a subject can have rights related to several objects (e.g. a person owning three parcels) and an object can be related to multiple subjects. Two examples of the latter: an object is owned by two partners or an object is leased by one subject to another subject. There are two types of subjects: *natural persons* and *non-natural persons* (organizations), having some attributes in common, but also each having their own specific attributes.

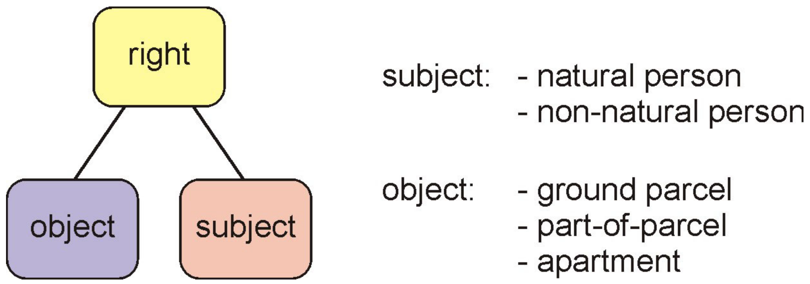

Figure 3. The core of the administrative data model: object, subject, and right.

In turn, the objects can be one of three basic types: complete *ground parcels*, *part-of-parcels*, or *apartments*. In the Netherlands a part of a parcel can be sold, as an object, before the surveyor has measured it. These part-of-parcels again can be sold in part. This results in an hierarchy which is represented by a tree structure with the root representing the ground parcel; see Figure 4. The rights are only related to the leaves in the tree, that is, part-of-parcels not being subdivided any further. The base parcel numbers of the identifiers of a ground parcel and a part-of-parcel are the same (number 12 in Figure 4).

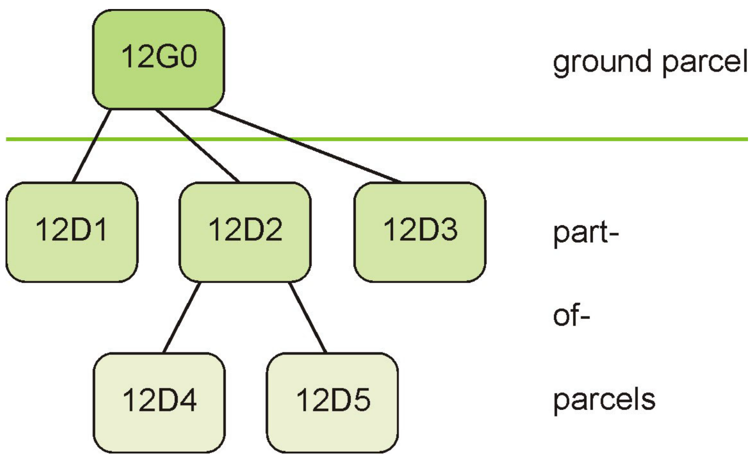

Figure 4. The tree structure representing the part-of-parcel hierarchy.

The difference can be found in the, so-called, *index* part of the identifier. For ground parcels this is always 'G0' for part-of-parcels this looks like 'D1', 'D2', and so on. The link between the geometric model and the administrative model is based on the ground parcel (number), which is present in both models.

Once the part-of-parcels have been surveyed, they become new complete ground parcels, with their own new base parcel number. The new base parcel number is no longer related to its original parent. Actually, the base part also includes the municipality and section codes in addition to the parcel number. An example of the complete identification of an object is 'WDB02B 02762G0000', a ground parcel in the municipality with code 'WDB02', section 'B ' and number '02762'. The municipality and section code are not shown in the figures for readability.

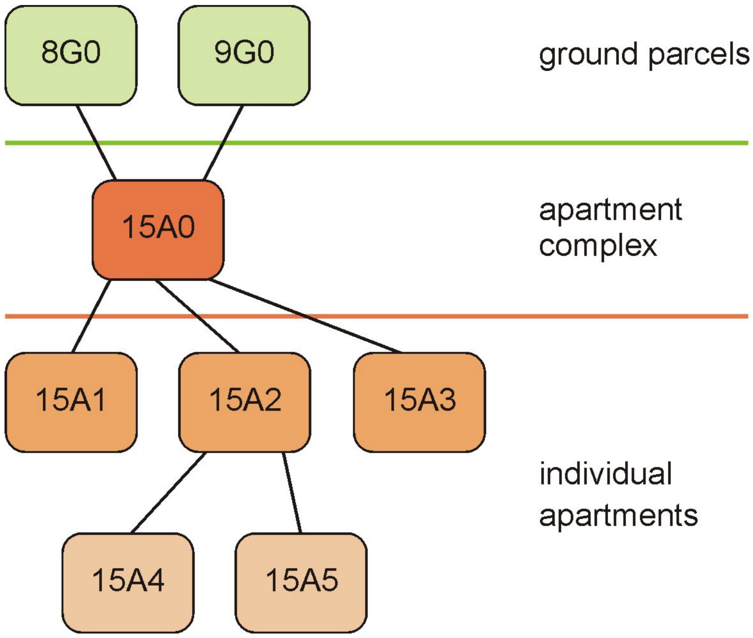

Figure 5. The structure relating ground parcels and apartments.

The apartment objects (rights) are related to an apartment complex in the same manner as part-of-parcels are related to a ground parcel, that is an hierarchical structure. The apartment complex itself can be composed of multiple (disconnected) ground parcels. The apartment complex is only based on complete ground parcels and not on part-of-parcels. The latter could theoretically occur if one tries to sell a part of the ground parcel, defining an apartment complex, before it is measured. However, in this case the ground parcel has to be surveyed first. Then it will be split into new ground parcels. After that the parcel can be removed from the apartment complex and can be sold. Note that the base parcel number of the apartment complex (number 15 in Figure 5) is different from the base parcel number of the related ground parcels (numbers 8 and 9 in Figure 5). The index part of the apartment complex identifier is always 'A0', the individual apartment objects have the same base parcel number and index parts which look like ‘A1’, ‘A2’, etc; see Figure 5.

Size of the database

A few numbers illustrate the size of the geometric data on 1 September 2000, including history, in the nation-wide database: 15,700,000 parcels, 41,100,000 boundaries, 51,900,000 topographic lines, 7,200,000 symbols and 7,400,000 text labels. The boundary and line entities are based on polylines and circular arcs. The total estimated number of different line segments in the database is over 400,000,000. The administrative databases contain the following amount of data (on 1 September 2001 without history): 7,700,000 objects (ground parcels, part-of-parcels, or apartments), 9,900,000 object addresses, 7,300,000 subjects (persons or organizations including their subject address), 10,600,000 right records (relationship between object and subject), 2,200,000 object limitations (legal notifications, restricting the use of the object due to some reason), etc.

When selecting a certain area the query tool displays the result with the same interactive speed for this nation-wide database as for a database with only a smaller region; e.g. a province. Also integrated views (e.g. showing the prices of the objects color coded on the parcel) are at the same speed as pure geometric views. The same is true for the historic views. It is interesting to note that the topology speeds up the visualization compared to a representation without topology, because in this case all coordinates are transferred twice from the database to the application. The key entries to the database are a region (usually a rectangle, sometimes just one point), parcel number, address and (subject) names. Whenever possible data is clustered based on spatial location. This is obvious for the geometric data using the spatial location code SLC [11]. However, this is also applied to the administrative data by clustering on parcel number, which contains a municipality and section code, or on postal/zip code. This enables spatial range queries to perform well in all situations including the integrated views. The other entries are supported by secondary indices (btree [12] or rtree [13]), because they usually return one or a few results.

APPLICATIONS

After the description of the query tool background and the cadastral data model in the previous sections, this section will now have a closer look at a number of applications. These applications were all triggered by an actual in- or external user question and in most cases both geometric and administrative

data were used to solve the question. The following applications will be described in this section:
1. find neighbors of parcels owned by the province of North-Holland,
2. check legal notifications due to NAM pipelines,
3. find potential agricultural parcels suitable for exchange,
4. find all agricultural parcels (that is parcels outside the urban polygons of DLG),
5. find the total length of all parcel boundaries in the Netherlands, and
6. analyze the number and concentration of parcels to be surveyed and split ('register 9 akteposten').

Example 1. Find neighbors of parcels

The province of North-Holland wants to have a single delivery of cadastral information from AKR related to all parcels owned (VE) by the province and the same for all the neighbor parcels. First, they want to receive a quotation based on the numbers of parcels (own parcels and neighbors). Therefore, the following request: please first provide the mentioned numbers of parcels within a couple of days, followed by two files with the involved parcels.

Later on a similar question, but now with respect to legal notifications, was posed. Find the parcels on which the province of North Holland has a legal notification of BZ(D) and also find the neighbor parcels. 'BZ' stands for a legal notification described as (in Dutch) 'Zakelijk recht als bedoeld in art.5, lid 3, onder b, van de Belemmeringenwet Privaatrecht'(real right which limits private property right in general interest based on public law). Two cadastral offices maintain the province of North Holland. Therefore, the province is indicated by two different subject numbers in the AKR databases. The result to the above stated questions was obtained by a mixture of interactive work with the query tool and direct DBMS access using SQL (Structured Query Language) script.

First, a SQL script finds the parcels on which the province has a legal notification of type BZ(D). The following SQL query uses the geometric parcel `lki_parcel` table and the administrative table with legal notifications `mo_obj_belemmering`. These tables are joined in the where clause on the parcel number `x_akr_objectnummer`. The other parts of the where clause select the proper type of legal notifications using the attribute `soortbelem` and only those related to the province using the attribute `belemmeraar`.

```
insert into select_parcel
select lki_parcel.*, object_key('0000000000000000')
from lki_parcel, mo_obj_belemmering
```

```
where
lki_parcel.x_akr_objectnummer=mo_obj_belemmering.x_akr_obje
ctnummer
 and ((mo_obj_belemmering.soortbelem = 'BZ') or
      (mo_obj_belemmering.soortbelem = 'BZD'))
 and ((mo_obj_belemmering.belemmeraar = '1603281134') or
      (mo_obj_belemmering.belemmeraar = '1100075010'));
```

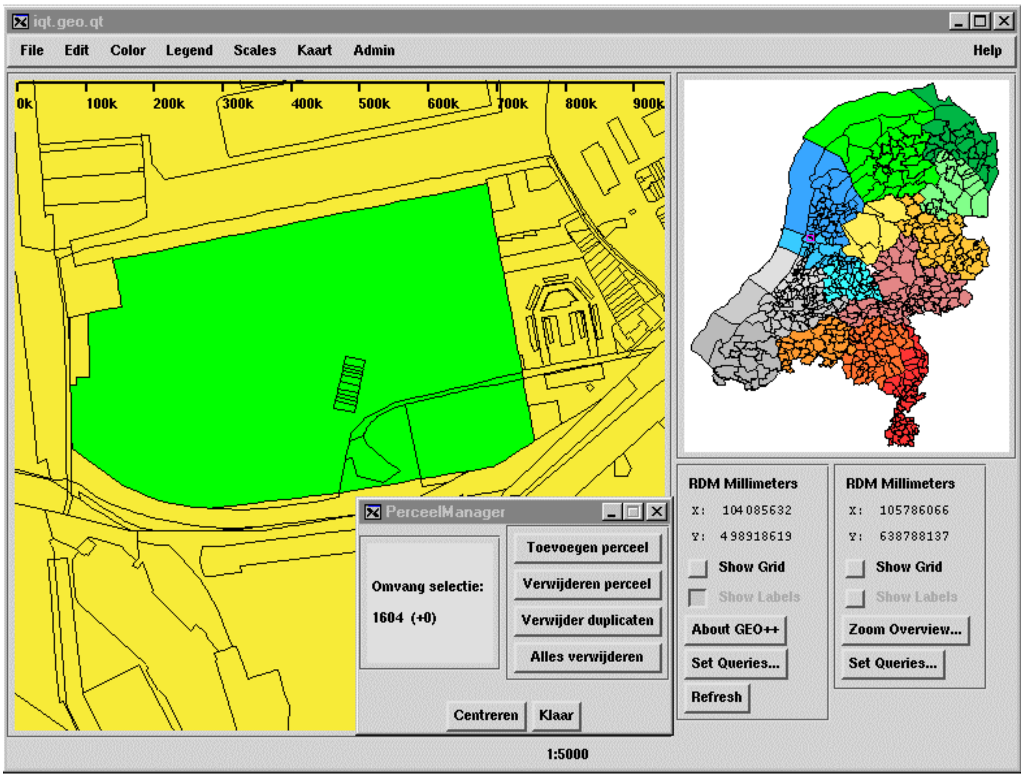

Figure 6. Some parcels for which there is a legal notification of type BZ(D) for the province of North-Holland.

This SQL query results in 1699 selected ground parcels select_parcel. Using the 'ParcelManager' of the interactive part of the query tool interface doubly selected parcels are removed. This results in 1604 unique parcels. Figure 6 shows some of the selected parcels. The graphic interface is used to find all neighbors of the 1604 selected parcels. This is the 'Selecteer buren' option. Now the total number of parcels is 4496 (without doubles); see Figure 7.

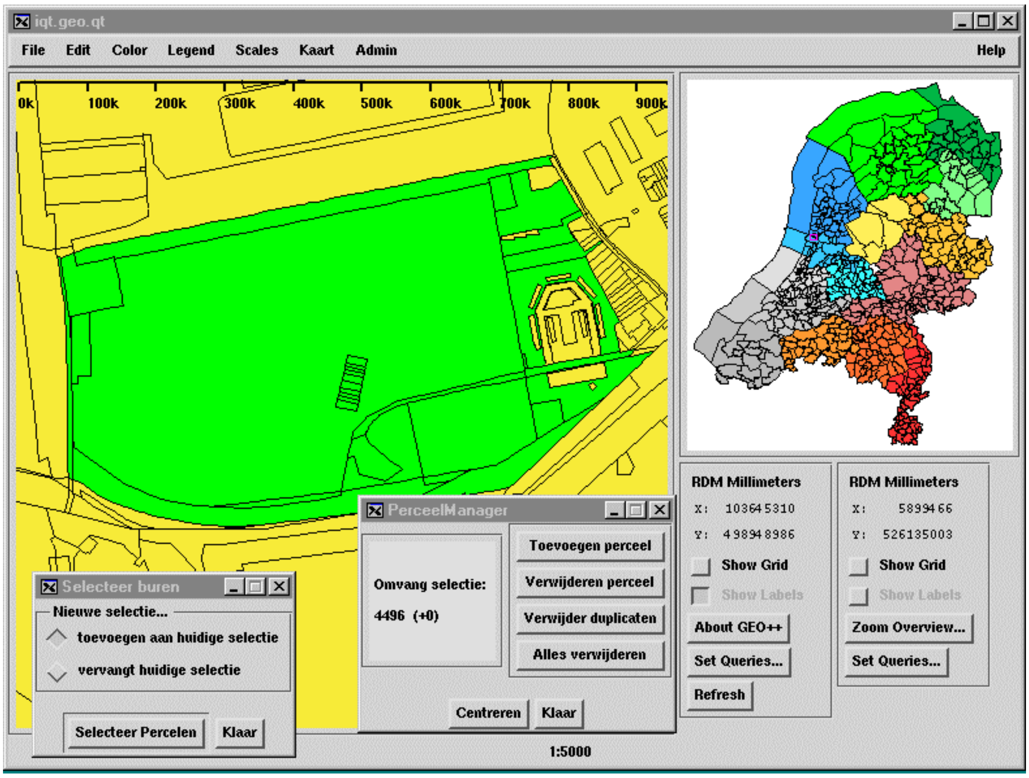

Figure 7. Neighbors of parcels for which there is a legal notification of type BZ(D) for the province of North-Holland.

Example 2. Legal notifications due to NAM pipelines

In this example application, which started as a pilot project, it was needed to import external geometric data in order to improve the quality of the registration of legal notifications due to NAM pipelines. (NAM stands for *Nederlandse Aardolie Maatschappij* (in Dutch), a company equally owned by Shell and Esso.) This question contains a generic aspect: how to deal with data from external parties. Later on this pilot project did get a follow up and quite a lot of requests followed, among others a question to make plots from the NAM and BP projects. These plots are needed to inform the KNB (Organization of Notaries of the Netherlands) about these projects.

First some background information. In addition to the registration of the basic rights, such as ownership, related to parcels (cadastral objects), the Kadaster also registers many types of legal notifications. These legal notifications restrict the use of a parcel by the owner due to some reason. An important type of legal notification is related to pipelines usually below the surface; see Figure 8.

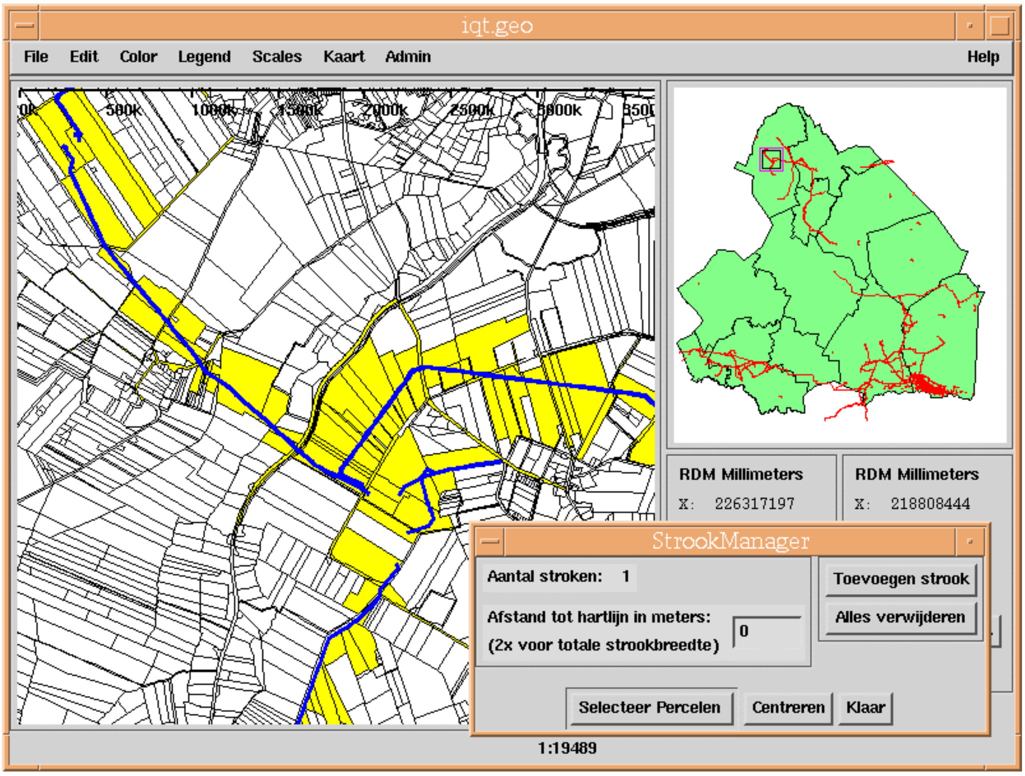

Figure 8. Pipelines of the NAM and the parcels they cross.

In order to protect these pipelines, the parcels crossed by a pipeline get a legal notification of the proper type. This is only done in the administrative part of the cadastral registration. It has to be done in an official manner described by law: a dead has to be drawn up by the notary and submitted to the Kadaster for registration. The pipelines are not available in the geographic part of the cadastral registration. Several types of problems became more and more visible during the last couple of years:

1. Whenever a parcel is split, all new parts inherit the legal notification. This is because the pipelines themselves are not registered at the Kadaster, so it is impossible to determine, which new parts are crossed by the pipeline. In order to be safe all new parts inherit the legal notification. This means that too many parcels have these legal notifications, which implies unnecessary costs for the owner of the pipeline.
2. It is very easy to forget a few parcels when trying to register the complete trace of a pipeline without the exact geometry of the parcels and the pipeline. This results in parcels without a legal notification. This is a dangerous (legal) situation as the pipeline crosses these parcels, but without the proper status.
3. The registration of basic rights always stores who (which subject) has a certain type of right on which parcel (object). In the early registration of legal notifications it was not registered who caused the specified type of

legal notification. Only the fact that there were one or more (types of) legal notifications was associated with the parcel. This makes the maintenance of this registration very difficult. Imagine that for some reason a pipeline does not need legal protection anymore, then it is dangerous to remove all legal notifications because they are 'anonymous'. It could very well be the case that another utility company has a pipeline crossing the same parcels.

In order to solve the problems mentioned above it was decided to start a quality improvement process. Going back to all the paper deeds is just too much work, so the query tool was used to select the parcels, which have these 'anonymous' legal notifications (these are of types BP, BG or OG, which stand for respectively 'Belemmering privaatrecht', 'BP-gedoogplicht', and 'Opstal olie/gas'). Using the list of selected parcels the paper deeds are now retrieved and the legal notification is associated with the proper organization ('owner' of the pipeline) and also the type of legal notification is changed to OL or BZ. 'OL' stands for a legal notification described as (in Dutch) 'Recht van opstal m.b.t. het leggen en houden van leidingen in, op of boven een onr. zaak' (right to construct and maintain pipelines/cables in, on or above a property based on private law). 'BZ' was already explained in the first example. This solves the third problem mentioned above. However, it does not solve the first two problems. A pilot project was started with the NAM, an important owner of pipelines in the Netherlands. The NAM delivered a digital version of their pipelines to the Kadaster, which were then entered into the query tool database and confronted with the parcels; see Figure 8. This was not a simple query in the database, because the geographic data model of the Kadaster is based on topology [4]. Within a relational database an overlap or cross operation based on parcels modelled with topology is impossible. Therefor this operation was implemented in the interface (front-end) part of the query tool; see the inset window of Figure 8. After the quality improvement of the legal notifications, the parcels with a legal notification of OL or BZ associated with the NAM can be displayed on top of the parcels crossed by a pipeline of the NAM. A few things can then be observed in Figure 9. *First*, not all parcels crossed by a pipeline have the legal notification. This can be correct in case the parcel is owned by the government; e.g. roads, in this situation a 'permit' is sufficient, but this is not registered at the Kadaster. However, there are several parcels crossed by a pipeline, without a legal notification and which are clearly not road parcels (so also without a 'permit'). This could be an old pipeline and has to be checked by the NAM. *Second*, there are parcels with a NAM legal notification, which are not crossed by a pipeline; see Figures 9 and 10. Again, this has to be checked by the NAM. It could be correct; e.g. the parcel might contain a NAM access road or some type of NAM location.

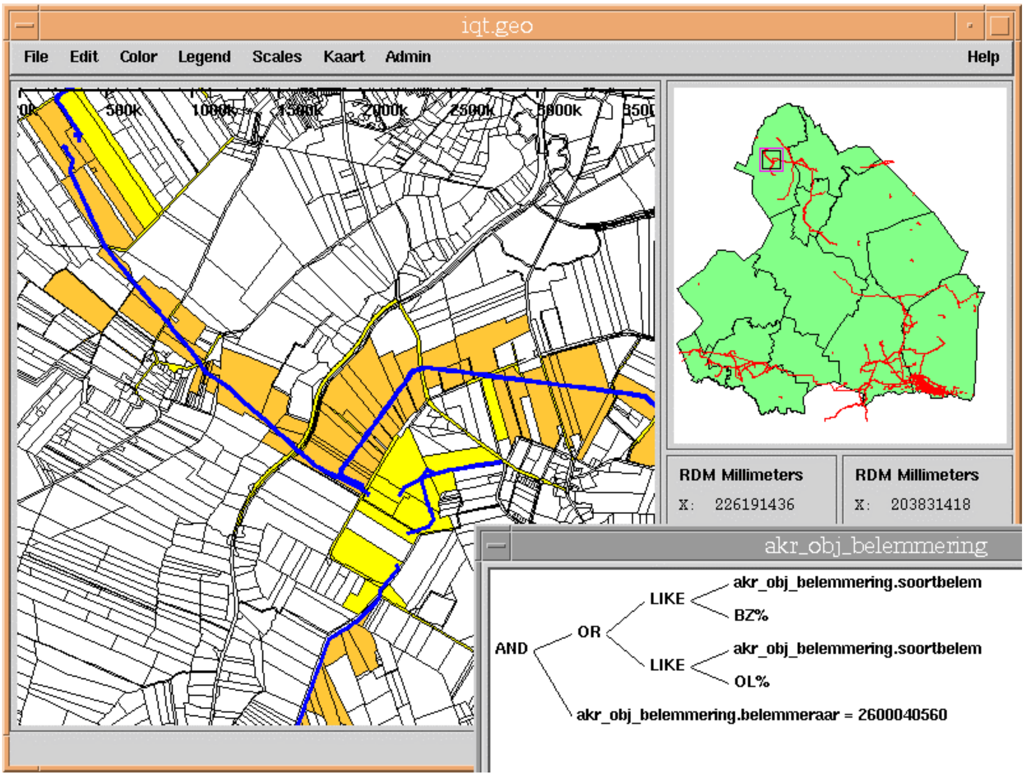

Figure 9. Parcels with a NAM legal notification of type OL or BZ.

Finally, it is interesting to check if the quality improvement process resolves all 'anonymous' legal notifications of type BP, BG or OG. Therefore all legal notifications of these types are selected and displayed with a label, indicating the parcel number, in Figure 10. In the project of quality improvement of legal notifications and the pilot project with the NAM, the query tool turned out to be very useful. As described, the query tool is used during several stages: before the process to inspect the situation and select the 'problem' parcels. During quality improvement to find the parcels crossed by pipelines. Finally, after quality improvement to check if indeed the results are correct; e.g. there are no more anonymous legal notifications. One final remark: there are many more types of legal notifications than the ones mentioned in this section. These were also quality improved, but are not discussed in this section.

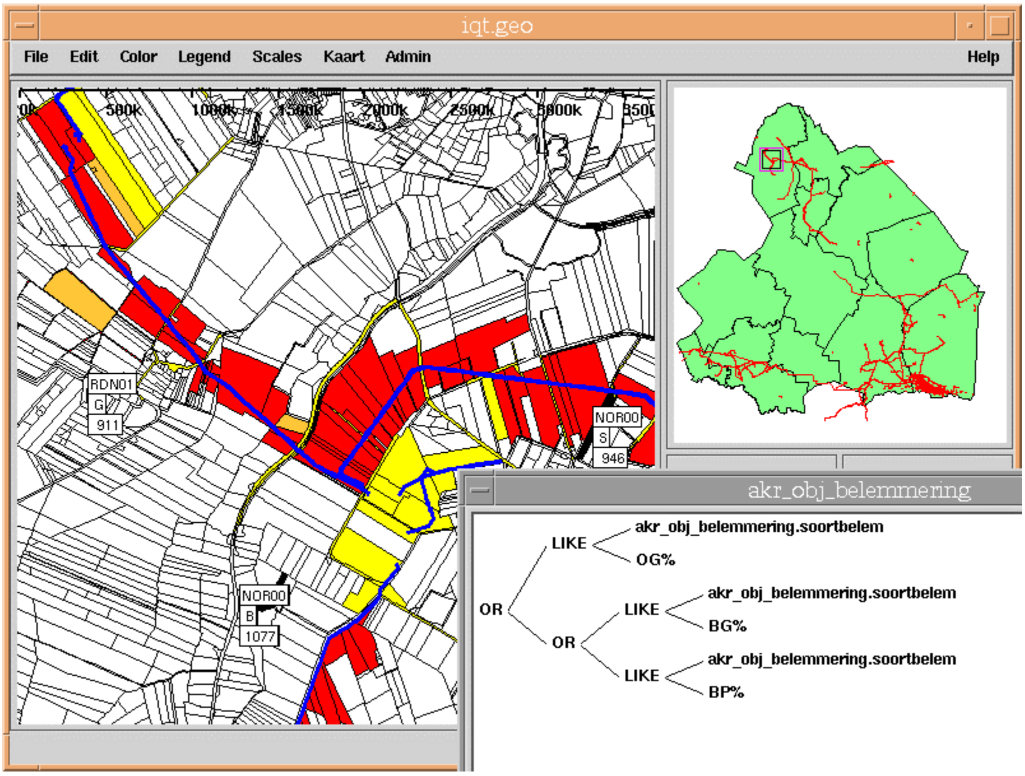

Figure 10. Parcels with legal notification of type BP, BG or OG are marked with a label.

Example 3. Exchange of agricultural parcels

In the province of Overijssel an organization called 'Stimuland' wants to find potential parcels owned by farmers which may be used for land exchange (lots at a large distance from the farm). Again, the research involved interactive use of the query tool and the development of a SQL/shell script. One of the tricky parts is that not only farmer subjects have to be considered but also married couples and groups of subjects. That is, if a partner has a suitable piece of land then this may be exchanged (even if the actual owner of the farm is somebody else). Further, a member of a group can also be married. These subjects are also taken into account. In theory the married partner could also be a member of another group, these group members are the 'last' to be considered as relevant.

In solving this question, first the distinct ground parcels and related subjects in the province Overijssel are selected from the nation-wide database. In AKR a group can have rights. These rights are 'transferred' to the members of the group. In a similar way also the partners of married subjects are treated. Then the number of rights (and related objects) is counted per subject via the group by clause using an aggregate query to create the table

```
stimuland_sel_aantal:
drop table stimuland_sel_aantal;
create table stimuland_sel_aantal as
  select gerechtigde, aantal=count(*)
  from stimuland_sel
  group by gerechtigde
  with nojournaling;
```

Only subjects with more than one right (object) are candidates for exchanging land, so the others are dropped. Then a location, object address, and subject address attributes are added from other AKR tables. The farm parcel has the same address for both the object and the subject address. The distances between the farm parcel and the other parcels of the same subject are computed. Now parcels at more than a certain distance from the farm are candiate parcels for land exchange. The parcels at distances larger than respectively 5 km and 10 km have been reported to Stimuland for further investigation and negotiation.

Example 4. Find all agricultural parcels for DLG

DLG (Ministry of Agriculture, Nature Management and Fisheries, Government Service for Land and Water Management) wants to obtain cadastral data related to all rural regions in the Netherlands. The normal procedure within the Kadaster does not work well to define the product(s) to be delivered. This is probably due to the huge number of involved parcels. Therefore, DLG supplies polygons of their regions of interest and the query tool is used to make a selection and to find all involved parcels. After answering this query, a second request was made to deliver mutations (changes) to the initial delivery, because DLG had supplied new polygons.
In fact it turned out that DLG did not deliver polygons of their areas of interest, but that they deliver polygons of urban regions (areas not of their interest); see Figure 11. The task is to find all agricultural/rural parcels, that is parcels outside the urban polygons of DLG. The polygons are delivered in Arc/Info ASCII export format. The polygon boundaries are first converted to Ingres DBMS. The selection of parcels outside the DLG urban polygons was now possible in one step for the whole of the Netherlands using the interactive interface of the query tool. As the parcels are topology based, this query could not be directly executed in the DBMS. At the customers request this result set was the divided into the individual provinces and/or cadastral offices.

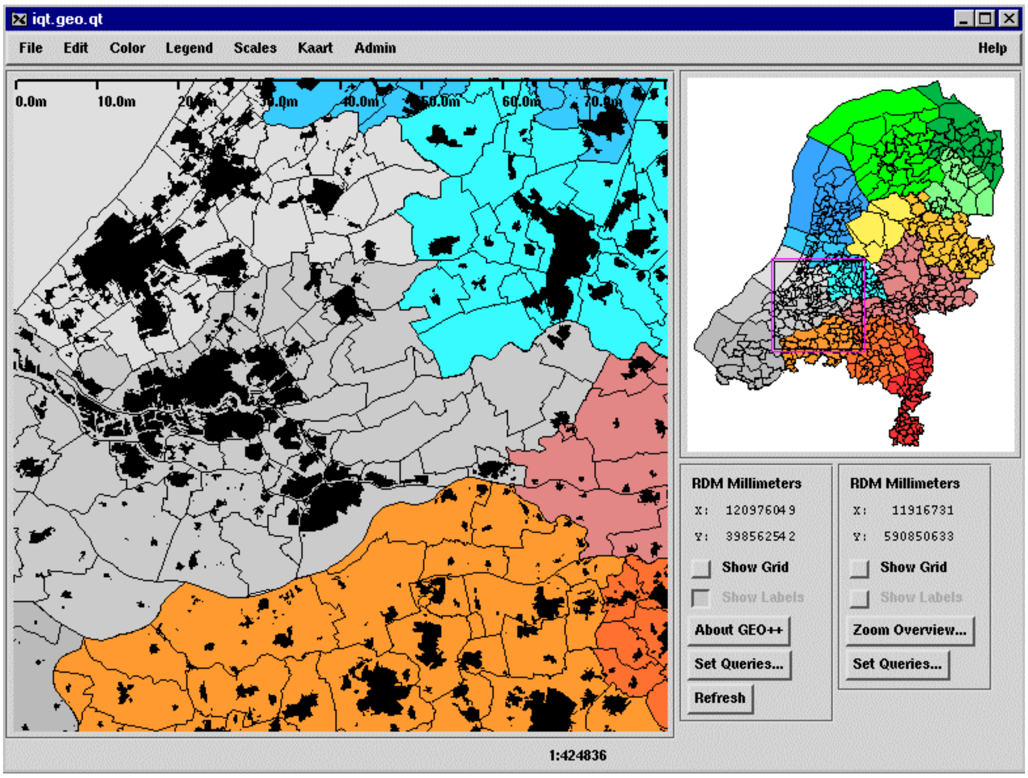

Figure 11. Overview of selection/filter polygons of urban areas.

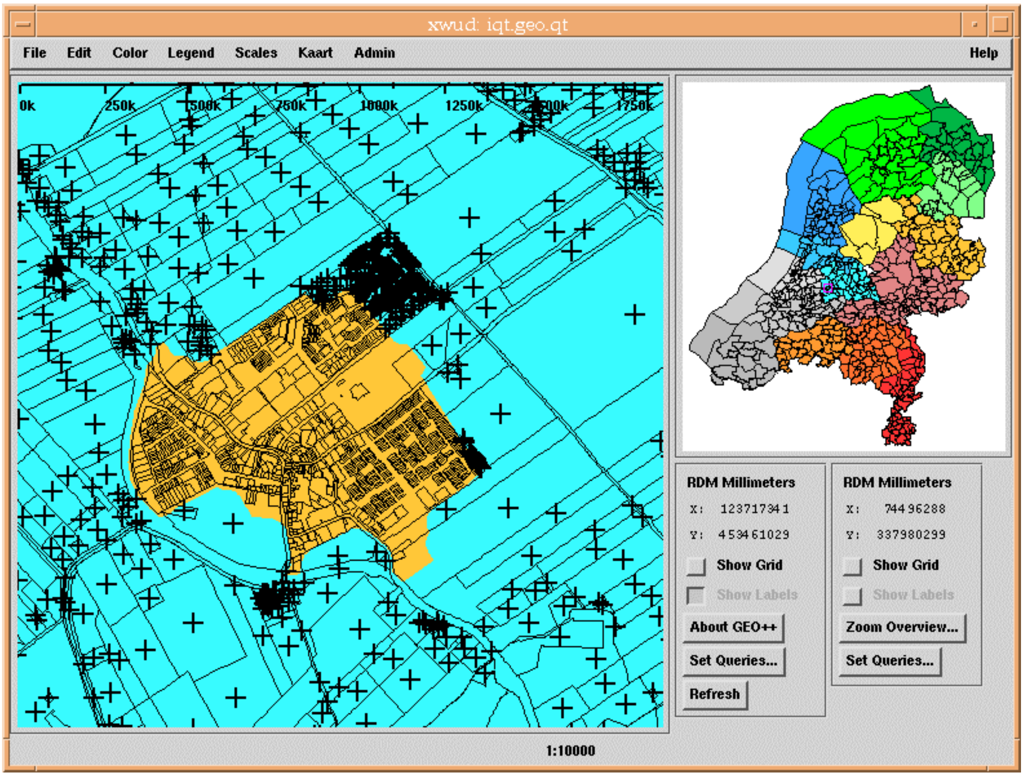

Figure 12. Some details of selected parcels, outside urban polygons (all marked with a +).

The result of the actual selection of the parcel per province/office can be seen in Figure 11. After the initial delivery of parcel numbers based on the selection with the DLG polygons, a new, more accurate set of DLG polygons was obtained. Basically, the old selection was saved and the same work was done again with the new polygons. In other to find the mutations (new or deleted parcel numbers), the differences per cadastral office between the old and the new selections are obtained and stored into two sets of files.

Example 5. Total length of all parcel boundaries

Determine the total length of all parcel boundaries in the Netherlands. This question was posed to the Kadaster in the context of a PhD research. Besides the total length, also determine the number of parcel boundaries and separate this per type of boundary: parcel, section, municipality, cadastral office (province) and country; see Figure 13.

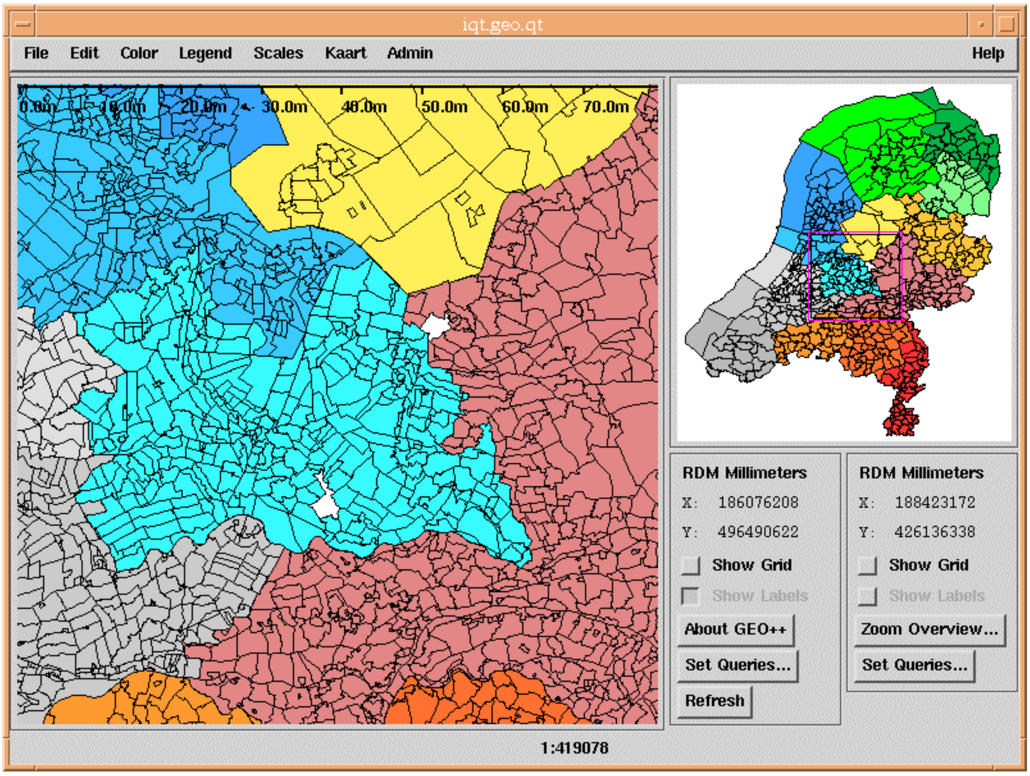

Figure 13. Cadastral sections in detail window and municipalities in overview window.

This is a relatively straightforward question for the nation-wide query tool database. The view `lki_boundary` is used, because it selects exactly one moment in time (which was in this case 1 Oct. 1999). Further, the unit length in LKI is millimeters. Therefore the `linelen` is divided by 1,000,000 to get kilometer units. To check if this division did not cause numerical problems (rounding off to zero), also a view based on meters (division by 1,000) was used. However, the results were identical. Total length of all valid (actual) parcel boundaries in the Netherlands (on 1 Oct. 1999) was 236,033.040 km (the number of boundaries was 19,664,704).

tot.length(km)	avg.length(m)	number	type
218623.599	11.51	18991509	parcel
8315.104	17.63	471621	section
2000.153	23.74	84270	cad muncip
4086.230	44.09	92683	muncip
2714.986	159.88	16981	cad province
287.156	38.00	7557	country

Example 6. Analyze parcels to be surveyed and split

Is it possible to visualize the number of planned future surveys and splits per parcel (in Dutch 'register 9 akteposten')? Urgent cases will become clear and also the spatial distribution can be mapped. This will support planning of the actual surveying per region. The additional question was related to aggregating this information to the cadastral section and municipality level (output requested in both map and tabular form). Note that one object (parcel) can have many 'register 9 akteposten' and that one 'register 9 aktepost' can involve many objects (parcels), that is a n-to-m relationship. Only the real number of 'register 9 akteposten' should be counted. In addition it would be useful if also the date (how old is a certain 'register 9 aktepost') could be involved in this analysis.

The concerned administrative information is contained in one AKR table, which holds the 'register 9 akteposten'. However, the first thing, which is not so easy to determine, is the unique identifier of a 'register 9 aktepost'. It turns out that the 'register 9 akteposten' are numbered per cadastral section. Therefore the unique identifier is the combination `municip, osection`, and `reg_9_nr`. The answers to the questions above are both simple and difficult. In the analysis two groupings have been defined. The first one is related to the age (date) of a 'register 9 aktepost'. This is defined by the following groups: <=6, 7-12, 13-18, 19-24, 25-30, 31-36, >=37 months.

The second one is related to the number of 'register 9 akteposten' per parcel, or in other words the concentration of 'register 9 akteposten': 1-4, 5-8, >=9 'register 9 akteposten' per parcel; see Figure 14.

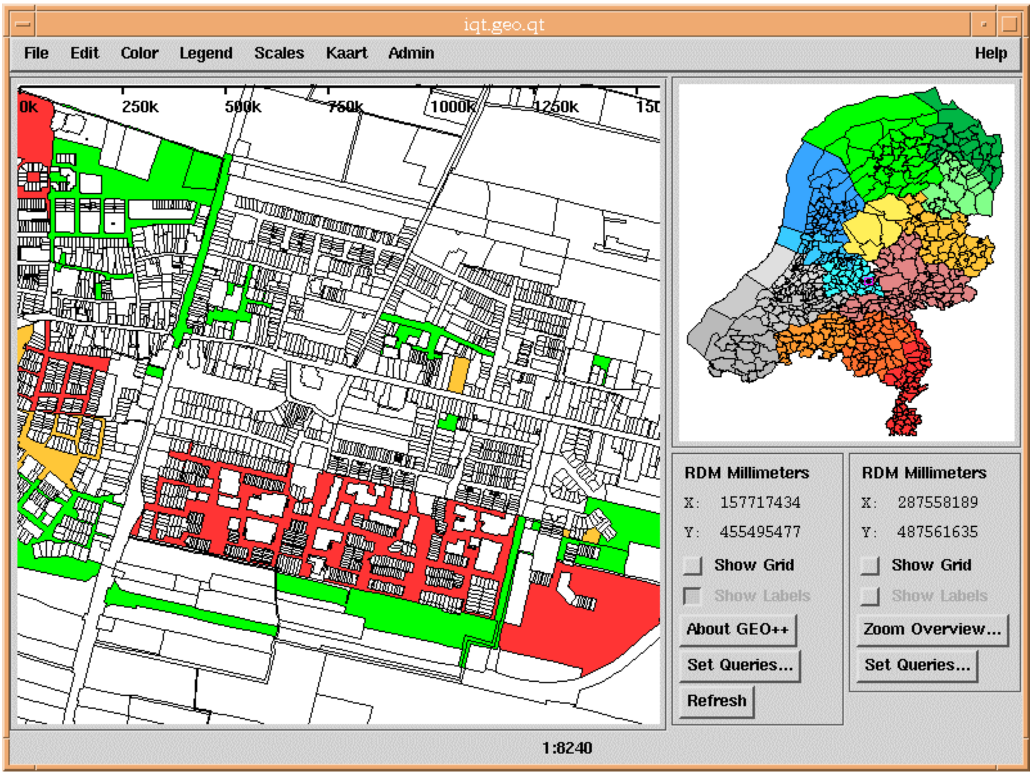

Figure 14. Parcels with more than 0/4/8 'register 9 akteposten' in green/orange/red.

Conclusion

Now, after being employed for about five years by the Netherlands Kadaster and little over two years by the TU Delft, I state that administrative (or legal) cadastral data is fun. Why did I change my mind about this? This was not (alone) due to the name of the chair of prof. Theo Bogaerts 'Leer der Vastgoedsystemen' (Land Information Systems Technology). The example applications showed the importance of integrated geometric and administrative cadastral data to both external (NAM, DLG, Stimuland) and internal users. Through these applications I could feel that the cadastral data reflect a very fundamental relationship: the one between mankind and land. It can be argued that this relationship goes much deeper than for example the relationship between mankind and money (although this is also very important). Because of the intense relationship between mankind and land, there is a whole story behind every administrative cadastral record: it can be a very happy moment when one buys a piece of land. The registration of these ownership rights in a reliable cadastral system forms the foundation of legal security. This results in save real estate transactions and is an important condition for investments needed for economic growth. Further, other cadastral registrations are very important. Take for example the legal notifications with respect to cables and pipelines. If these are not registered properly, the financial consequences and the damages may be enormous in case there is an incident. All fine and true, but is this the main reason why administrative cadastral data is fun? No! The main reason is that administrative cadastral data can be integrated with spatial data, because of the relationship with land. The administrative information can be visualized on interesting maps, which gives more insight in one picture than 10,000 administrative records together. Further, the map can be used as an entrance to the administrative records unlocking information in a very easy and natural manner. To most human beings space is a very natural organization, which can be easily understood, probably because we do live in space ourselves. Therefore the map as a metaphor is a very good way to organize information. The other way around: administrative information, such as a name or address can be an entrance to the map (and after that to other data). This is in a nutshell why administrative cadastral data is fun.

References

[1] Peter van Oosterom and Bart Maessen. Geographic query tool. In JEC-GI'97, Joint European Conference and Exhibition on Geographical Information, Vienna, Austria, volume 1, pages 177-186, April 1997.

[2] Peter van Oosterom, Bart Maessen, and Wilko Quak. Spatial, thematic, and temporal views. In SDH2000, 9th International Symposium on Spatial Data Handling, page 8b. 37-52, August 2000.

[3] ASK-OpenIngres. INGRES/Object Magemenent Extention User's Guide, Release 6.5. Technical report, 1994.

[4] Peter van Oosterom. Maintaining consistent topology including historical data in a large spatial database. In Auto-Carto 13, pages 327-336, April 1997.

[5] J.A. IJsselstein and A. P. Kap. Het kadastraal perceel: een stevig fundament! Nederlands Geodetisch Tijdschrift Geodesia, 37(7/8): 343-349, 1995. (In Dutch).

[6] Professional Geo Systems (PGS). The GEO++ system, version 2.80, Reference manual. Technical report, September 1996.

[7] T. Vijlbrief and P. van Oosterom. The GEO++ system: An extensible GIS. In Proceedings of the 5th SDH, pages 40-50, August 1992.

[8] Christiaan H.J. Lemmen, Ernst-Peter Oosterbroek, and Peter J.M. van Oosterom. New spatial data management developments in the Netherlands cadastre. In proceedings of the FIG XXI International Congress, Brighton UK, commission 3, Land Information Systems, pages 398-409, July 1998.

[9] Christiaan H.J. Lemmen and Peter J.M. van Oosterom. Effcient and automatic production of periodic updates of cadastral maps. In JEC'95, Joint European Conference and Exhibition on Geographical Information, The Hague, the Netherlands, pages 137-142, March 1995.

[10] Bruce G. Baumgart. A polyhedron representation for computer vision. In National Computer Conference, pages 589-596, 1975.

[11] Peter van Oosterom and Tom Vijlbrief. The spatial location code. In Proceedings of the 7th International Symposium on Spatial Data Handling, Delft, The Netherlands, August 1996.
[12] Douglas Comer. The ubiquitous B-Tree. ACM Computing Surveys, 11(2):121-137, June 1979.
[13] Antonin Guttman. R-trees: A dynamic index structure for spatial searching. ACM SIGMOD, 13:47-57, 1984.