

# UML MODELLING: FROM A 2D TO A 3D CADASTRE

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## **Abstract**

The current cadastre registers rights on (2D) parcels. To reflect the 3D component of rights in the cadastral registration (for example a right of superficies that is established to hold a tunnel), the current cadastre needs to be extended. In this article two extensions are described: the registration of 3D right-objects and the registration of 3D physical objects, together with their UML class diagrams.

## **Introduction**

In intensively used areas there is a growing interest in building constructions on top of each other. Those situations are a challenge for cadastral registration, because traditionally cadastral registration is based on 2D parcels. In what way can a 3D approach of a cadastre help in complex situations? Complex situations refer to cases of multiple use of space: one parcel is used by several people (full owners and/or holders of limited real rights) each holding a right on the parcel, each right limited in the third (and second) dimension. For example a building is divided in several apartments and they belong to different owners. Or the owner of a railway line grants someone the right to erect an office block 10 meters above the tracks. Other examples of multiple use of space are tunnels, pipelines, cables and underground extraction of minerals.

To improve insight in the spatial component of rights established on 2D parcels, the current cadastral system needs to be extended. In the research '3D cadastre' that is carried out at our department in collaboration with the Netherlands' Kadaster, two extensions are studied:

- the registration of 3D right-objects
- the registration of 3D physical objects (as they occur in the real world)

In this article, these extensions are described as well as the UML models for the extensions, together with the UML model for the current cadastre.

## **Registration of 3D situations**

### *Registration of 3D Right-Objects*

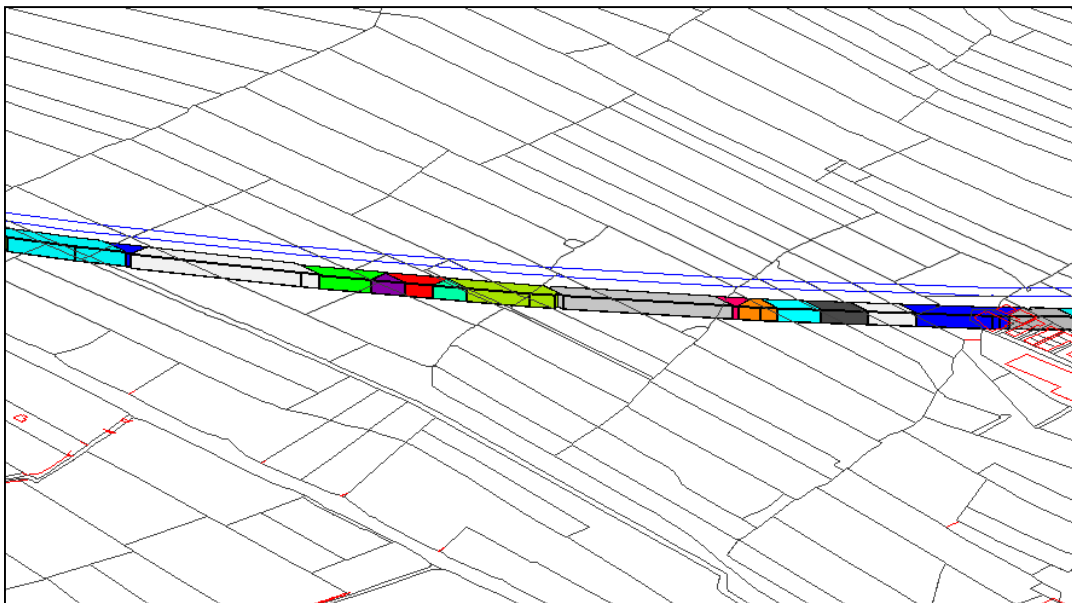
The least complex possibility to register 3D situations is to represent rights concerning 3D situations in 3D. A 3D right-object is a 3D representation of a right that is established on a 2D parcel and concerns a 3D situation, for example a right of superficies established for a tunnel that is limited in the third dimension (note that a 3D right is a different entity than the 3D right itself).

The boundary of the 3D representation starts usually with the parcel boundary and is extended into 3D by means of defining the upper and lower limits. When more detail is required, e.g. in case only part of a parcel deals with a complex situation, a more detailed 2D boundary or a new parcel boundary needs to be generated. For example if a cable crosses only part of a parcel, a smaller parcel is created to depict the location of the cable more precisely.

The 3D right-objects that are maintained are associated with a registered right and contain references to the whole spatial object (physical objects). Spatial and non-spatial characteristics of these physical objects may also be stored in (or outside) the DBMS. All 3D right-objects belonging to one 3D physical object can be derived, because they all refer to the same 3D physical object. You can also query which parcels contain a right or limited right related to a specific 3D physical object (this is an administrative and not a spatial query). To support this, a 3D right-object should have an attribute with the id of this 3D physical object. You cannot perform this query in the current cadastral system, as there are no references to the physical objects maintained. Neither can the 3D extent of a right be queried at the moment (to what height or depth does the right of superficies extend?).

A 3D right-object associated with a right on a parcel is only registered, when this is juridically required. That is in the case a limited real right is established on a parcel. In other cases it is voluntary, e.g. the parcel owner and holder of the 3D right-object are the same.

Figure 1 shows via visualisation the results of the implementation of the registration of 3D right-objects, applied to the 'HSL tunnel'. The HSL is a high-speed railway link between Paris and Amsterdam. Since this railway is passing through unaffected rural land, it was decided to drill a tunnel for this part of the railway. The realization of the tunnel is planned for 2006. To register the ownership of the tunnel, right of building and full ownership (by the expropriation of former landowners) are used. Parcels that only partially intersect with the tunnel are divided into new parcels, by which the 2D extent of the rights is limited in the second dimension. The (new) parcel boundaries coincidence with the 2D extent of the rights established for the tunnel.



*Figure 1: 3D right-objects as generated in the DBMS for the planned railway tunnel in the "Green Heart" of the Netherlands. The projection of the tunnel on the surface is also drawn. The 'new' parcel boundaries are the intersection between the 2D extent of the tunnel and the former parcel boundaries.*

Not the tunnel itself is registered, but the rights established for the tunnel together with their 3D representation. In our prototype for the 3D cadastre all data is maintained and generated in the DBMS (Oracle Spatial 9i) and visualized with MircoStation GeoGraphics. For the case of the HSL tunnel new (fictive) parcel boundaries are created, so that the parcel boundaries coincidence with the 2D extent of the tunnel.

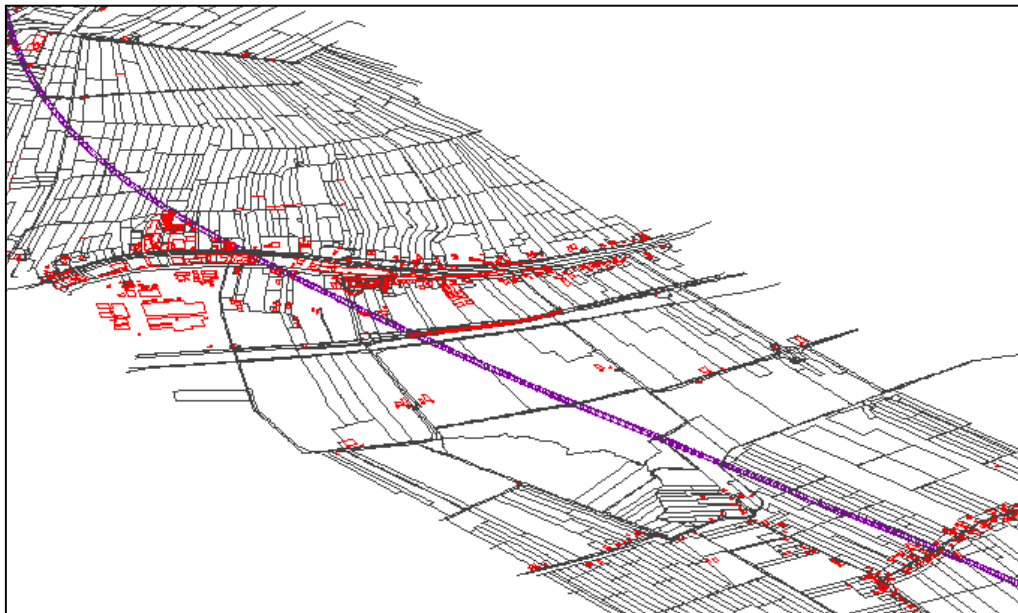
The ownership information in 3D situations can be found by finding the subject(s) that has (have) the right that is associated with the 3D right-object. From a juridical point of view, 3D right-objects do not need to be registered when the owner of the parcel is the same as the owner of the tunnel. This may lead to 'gaps' in the illustration above.

### *Registration of 3D Physical Objects*

A fundamentally different approach is to register the objects that are occurring in the real world themselves (tunnel, complex building). In this case the existence of a 3D physical object forms the base for registration. A registration of 3D physical objects needs to be organized and maintained and this registration will become a cadastral task. For the implementation of this registration a finite list of objects that need to be registered has to be made. It has to be decided whether this list can include 'empty space' objects or not (compare to 'air space parcels' in British Columbia (*Gerremo and Hannson, 1998*), '3D property units' in Sweden (*Julstad and Ericsson, 2001*) and 'construction property' in Norway (*Onsrud, 2002*)).

When 3D physical objects that are defined on the finite list occur, they have to be registered. To make the registration indisputable, a law is needed to make the registration obligatory. In the registration system spatial as well as non-spatial information on the whole 3D physical object is maintained. A 3D physical object can be queried as a whole. For example, which parcels are intersecting with (the projection of) a 3D physical object?; which rights are established on these parcels; who are the associated subjects?.

Figure 2 shows the implementation of this registration also applied to the same HSL tunnel. The spatial data is maintained in the DBMS. Apart from the parcels and outlines of buildings, the 3D physical object is maintained as one 3D object, which is the 3D representation of the tunnel.



*Figure 2: Registration of a 3D physical object (tunnel in combination with parcels).*

### 3D right-objects or 3D physical objects

The registration of 3D physical objects has a few drawbacks comparing to the registration of 3D right-objects. It requires more drastic adjustments in the current cadastre, as was stated above. Also generating data is easier when registering right-objects: the parcel boundaries that are already registered form (mostly) the basis for the 3D representation. The geometries of physical objects are much more complex, and mostly they will have to be provided by third parties. Since 3D right-objects are relatively simple objects, it is easier to represent them as polyhedrons in DBMSs. On the contrary, the advantage of registering the whole physical object is that gaps in the cadastral system can easily be traced.

### UML Models

Figure 3 shows the UML class diagrams of the cadastral data models described above. The current cadastral data model is based on three key entities: object, subject and right (figure 3A). A cadastral object is a parcel (and in some countries also a condominium right related to one or more ground parcels). Subjects are natural or non-natural persons with a right on a parcel. For every subject-object relationship a right is registered in the cadastral registration system. Between objects and subjects a n:m relationship exists via the right relationship: a subject can have a right related to more than one object (for example a person is owner of three parcels) and an object can have a relationship with more than one subject (for example one person has the right of property on a parcel and another person has the right of superficies on the same parcel).

For a full 3D cadastre the same data model applies. However, in this case cadastral objects are defined in 3D (3D parcel) and rights (right of long lease, right of superficies) are related to 3D parcels. A relationship between the surface parcels and 3D physical objects does not exist, since 2D surface parcels do not exist and 3D physical objects are not represented. Apartments will be cadastral objects, defined in 3D, on which a subject can have a right of property.

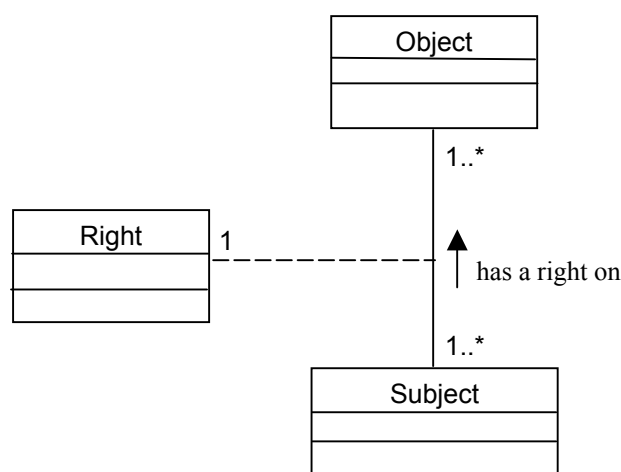


Figure 3A: UML class diagram of the current cadastre.

The UML class diagram for the registration of 3D right-objects is shown in figure 3B. For every right that is established on a parcel and that concerns a complex situation a 3D right-

object is maintained. This contains the 3D representation of the right, which is also maintained in the DBMS. One 3D right-object can be associated with more than 1 right: e.g. if a tunnel is held by two subjects with both a right of superficies.

All 3D right-objects belonging to one physical object can be found since they refer to the same 3D physical object. As you can see, this data model (figure 3B) needs some adjustment compared to the current cadastral model (figure 3A), but the principle of the 2D parcels as objects remains the same.

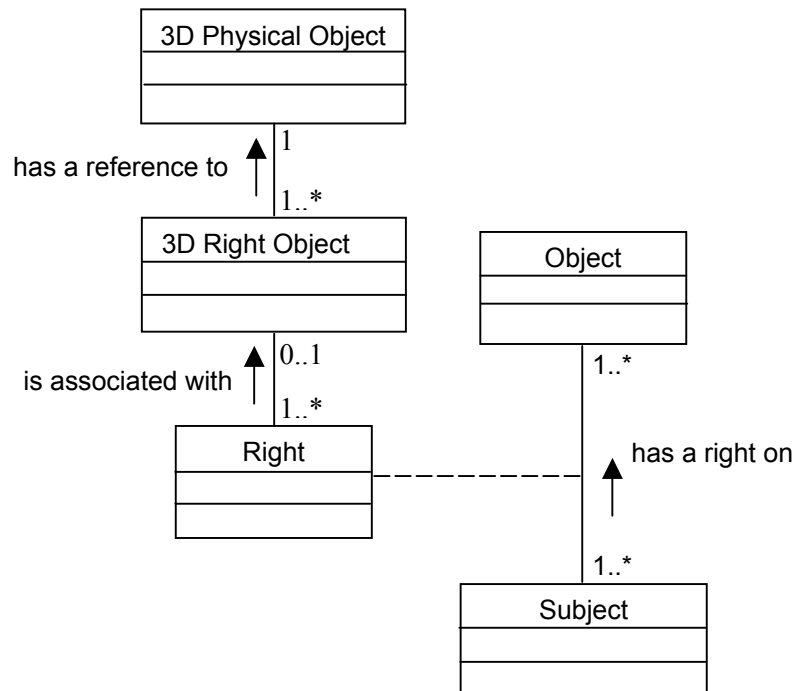


Figure 3B: UML class diagram for the registration of 3D right-objects.

For the registration of 3D physical objects the UML class diagram in figure 3C applies. Apart from parcels (Objects), 3D physical objects are also registered. The holder of the 3D physical object is a subject (or more than 1 subjects) with a right on a 3D physical object (factual ownership, which is not the same as the juridical ownership), by means of (limited) rights on the intersecting parcels. In general the holder of a 3D physical object is the person or organization who is responsible for the 3D physical object, and uses the object as if he were the owner. A 3D physical object is not a subset of a cadastral object, since 3D physical objects are maintained in addition to 2D parcels. Rights and limited rights are still registered on parcels. The only right that a person can get on a 3D physical object is that he can become the holder of this object.

Since both the 3D physical objects and the cadastral objects are spatially defined, the relationship between them can be obtained by means of spatial overlap functions and therefore this relationship does not need to be explicitly maintained. Juridical relationships between the 3D physical object and the parcels are not explicitly maintained. These relationships can be obtained by means of a common owner of the right: the subject who is holder of a 3D physical object is the same as the subject who should have some right on the surface parcel (if the registration is complete).

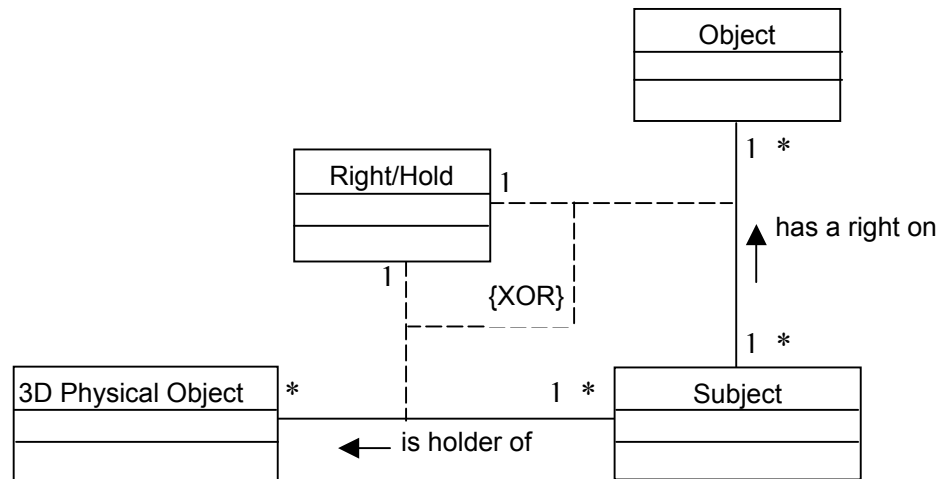


Figure 3C: UML class diagram for the registration of 3D physical objects.

## Conclusion

The current cadastre is capable to register complex situations adequately. In this way it is clear which persons have a right on a parcel. However, the spatial component of rights is not registered and therefore not available. Since 3D situations (“property” on top of each other) occur more often, a research has started in collaboration with the Netherlands’ Kadaster to look for the needs, constraints and possibilities of a 3D cadastre.

During this research, two extensions of the current cadastre are proposed to improve insight in the spatial component of rights: the registration of 3D right-objects and the registration of 3D physical objects. The registration of 3D right-objects requires less adjustment in the current cadastre.

The UML class diagram for the current cadastre was described as well as those for the described extensions. Further research will focus on the two proposed extensions, on both the concepts and the implementations, to come to the optimal solution for a 3D cadastre.

## References

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