The Core Cadastral Domain Model:
A Tool for the Development of Distributed and Interoperable Cadastral Systems

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A standardized core cadastral domain model (CCDM), covering land registration and cadastre in a broad sense (multipurpose cadastre), will serve at least two important goals: 1. avoid reinventing and re-implementing the same functionality over and over again, but provide a extensible basis for efficient and effective cadastral system development based on a model driven architecture (MDA), and 2. enable involved parties, both within one country and between different countries, to communicate based on the shared ontology implied by the model.The second goals is very important for creating standardized information services in an international context, where land administration domain semantics have to be shared between countries (in order to enable needed translations). This paper presents an overview of the core cadastral domain model. The model has been developed in a set of versions, which were each time adjusted based on the discussions at workshops with international experts and the experience from case studies in several countries of the world (Netherlands, El Salvador, Bolivia, Denmark, Sweden, Portugal, Greece, Australia, Nepal, Egypt, Iceland, and several African and Arab countries). Important conditions during the design of the model were and still are: should cover the common aspects of cadastral registrations all over the world, should be based on the conceptual framework of Cadastre 2014, should follow the international ISO and OGC standards, and at the same time the model should be as simple as possible in order to be useful in practise. The heart of the model is based on the three abstract classes: 1. RegisterObject (including all kinds of immovables and movables), 2. RRR (right, restriction, responsibility), and 3. Person (natural, non-natural and group). The model supports the temporal aspects of the involved classes and offers several levels of Parcel fuzziness in bothe 2D and 3D space: Parcel (full topology), SpaghettiParcel (only geometry), PointParcel (single point), and TextParcel (no coordinate, just a description). The model is specified in UML class diagrams and it is indicated how this UML model can be converted into and XML schema, which can then be used for actual data exchange in our networked society (interoperability).

1. Introduction

Until today most countries (or states or provinces) have developed their own cadastral system because there are supposed to be huge differences between the systems. The one operates deeds registration, the other title registration, some systems are centralized, and others decentralized. Some systems are based on a general boundaries approach, others on fixed boundaries. Some cadastres have a fiscal background, others a legal one. However, it is also obvious that the separate implementation and system's maintenance of a cadastral system are not cheap, especially if one considers the ever-changing requirements. Also, the different implementations (foundations) of the cadastral systems do not make meaningful communication very easy, e.g. in an international context such as within Europe. Looking at it from a little distance one can observe that the systems are in principle mainly the same: they are all based on the relationships between persons and land, via (property) rights and are in most countries influenced by developments in the Information and Communication Technology (ICT). The two main functions of every cadastral system are: 1. keeping the contents of these relationships up-to-date (based on legal transactions) in a cadastral registration system and 2. providing information on this registration.

The UN Land Administration Guidelines (UN/ECE, 1996) speak about land administration as the 'process of determining, recording, and disseminating information on ownership, value and use of land when implementing land management policies'. If 'ownership' is understood as the mode in which rights to land are held, we could also speak about 'land tenure'. A main characteristic of land tenure is that it reflects a social relationship regarding rights to land, which means that in a certain jurisdiction the relationship between people and land is recognised as a legally valid one (either formal or non-formal). These recognised rights are in principle eligible for registration, with the purpose to assign a certain legal meaning to the registered right (e.g. a title). Therefore land administration systems are not 'just handling only geographic information' as they represent a lawfully meaningful relationship amongst people, and between people and land. As the land administration activity on the one hand deals with huge amounts of data, which moreover are of a very dynamic nature, and on the other hand requires a continuous maintenance process, the role of information technology is of strategic importance. Without availability of information systems it is believed that it will be difficult to guarantee good performance with respect to meeting changing customer demands. Organisations are now increasingly confronted with rapid developments in the technology, a *technology push*: internet, (geo)-databases, modelling standards, open systems, GIS, as well as a growing demand for new services, a *market pull*: e-governance, sustainable development, electronic conveyance, integration of public data and systems. Cadastral modelling is considered as a basic tool facilitating appropriate system development and re-engineering and in addition it forms the basis for meaningful communication between different (parts of the) systems.

Standardization is a well-known subject since the establishment of cadastral systems. In both paper based systems and computerized systems standards are required to identify objects, transactions, relations between real estate objects (e.g. parcels) and persons (also called subjects in some countries), classification of land use, land value, map representations of objects, etc. etc. Computerized systems ask for even further standardization when topology and identification of single boundaries are introduced (Van Oosterom, Lemmen, 2001). In existing cadastral systems standardization is limited to the territory or jurisdiction where the cadastral system is in operation. Open markets, globalisation, and effective and efficient development and maintenance of flexible (generic) systems ask for further standardization.

The guidelines of Cadastre 2014 (Kaufmann and Steudler, 1998) give an excellent modelling start, but it is a generic, or abstract, set of guidelines, which must be further refined into a more specific model. This is the aim of the CCDM. One could compare these two levels with the abstract and the implementation level of specification within Open Geospatial Consortium (OGC). The abstract level contains the most important knowledge, but this can be implemented in several different manners, which can all claim to be compliant (but the systems won’t support automated interoperability). The CCDM goes one step further and specifies an implementation level of the model, which means that different systems adhering to the core cadastral model will be interoperable.

2. Core Cadastral Domain Model

The three central classes of the CCDM are depicted in Figure 1, a Unified Modeling Language (UML) class diagram. The relationship between *RegisterObjects* (e.g. parcels) and *Persons* (sometimes called ‘subjects’) via rights is the foundation of every land administration. Besides rights, there can also be restrictions or responsibilities (***RRR***) between the real estate objects and the persons. A person can be involved in any number of RRR’s (indicated in the UML diagram with the multiplicity of ‘*’ at the RRR-ends of the association) and an RRR can involves exactly one person (indicated in the UML diagram by omitting the multiplicity, which means ‘1’). In the current model there is no direct relationship between Person and RegisterObject, but only via RRR.

A UML class diagram describes the types of objects and the various kinds of structural relationships that exist among them like associations and subtypes. Furthermore the UML class diagrams show the attributes and operations of a class and the constraints that apply to the way objects are connected (Booch, Rumbaugh, Jacobson, 1999). The proposed UML class diagram for the cadastral domain contains both legal/administrative object classes like persons, rights and the geographic description of real estate objects. This means in principle that data could be maintained by different organizations, e.g. Municipality, Planning Authority, Private Surveyor, Cadastre, Conveyancor and/or Land Registry. The model will most likely be implemented as a distributed set of (geo-) information systems, each supporting the maintenance activities and the information supply of parts of the dataset represented in this model (diagram), thereby using other parts of the model. This underlines the relevance of this model; different organizations have their own responsibilities in data maintenance and supply and have to communicate on the basis of standardized processes in so called value adding production chains. A RegisterObject is an abstract class, that is, there are no object instances of this object class. In a UML class diagram an abstract class is indicated by the italics used for the class name. RegisterObject has a number of specialization classes, in this case two: Immovable and Movable. In a UML class diagram the specialization classes point to the more generic class with an open headed arrow. The specializations are mutual exclusive as indicated by the 'ex-or' label between the arrows. The Movable objects, such as airplane, ship, train, car are outside the scope of the model.

3. Immovable Classes

The specializations of the Immovable class are represented in the 'blue' and 'light blue' package; see Figure 2. The Immovable objects are further refined into land, or in 3D space, objects (the 'parcel' family in 2D and 3D in 'light blue') and the other objects (in 'blue'). The different types of land (space) objects include ('light blue'): RegisterParcel, SpaghettiParcel, PointParcel, TextParcel, ParcelComplex, PartOfParcel. These classes can all have actual instances and these instances somehow describe a piece of land (in the case of 2D) or space (in the case of 3D). The other immovable register objects ('blue') include: Building, Unit, NonGeoRealEstate and OtherRegisterObject. All these specialisations of Immovable have associations with one or more Persons via the RRR class. There are parts, called ServingParcels in the model, which only have direct associations with two or more RegisterParcels. Characteristic of a ServingParcel is that it serves a number of other RegisterParcels, and that it is held in joint ownership by the owners of those RegisterParcels. However in most cases this kind of joint ownership (in French: *mitoyenneté*) applies only to constructions, like a party wall, or a joint sewerage, in some countries this kind of joint facilities such as a path, parking or playground are known (e.g. the Netherlands: *mandeligheid*). A straight line between RegisterParcel and ServingParcel in the UML class diagram depicts this association. It can be considered as a (special) kind of joint ownership via the RegisterParcels. The 'ServingParcel' principle could also be applicable to the common parts of apartment or condominium rights, if these common parts have been registered in the cadastral system as separate parcels. For the time being the 'ServingParcel' principle has not been applied to apartments (Building, Unit). To the contrary, perhaps even the ServingParcel itself could be removed from the model. In such a case a kind of 'fake' NonNaturalPerson (related to the RegisterObjects/RegisterParcels being served) should be used and have some kind of 'serving right' via RRR.

In the UML class diagram RegisterParcel, ServingParcel and NPRegion are specializations of the topologically structured Parcel, which all-together form the partition (subdivision without gaps and overlaps) of the domain (in 2D or 3D space). The Parcel class, just as the RegisterObject class, is an abstract class as there will never be instances of this class. Note that RegisterParcel is based on multiple inheritance (from Immovable and Parcel, both abstract classes). A ParcelComplex is an aggregation of RegisterParcels. The fact that the multiplicity at the side ParcelComplex is 0..1 (in the association with RegisterParcel) means that this is optional. A ParcelComplex situation might occur in a system where a set of RegisterParcels -could be in one municipality or even in another administrative unit- has a legal/customary meaning, for instance being the object of one mortgage. A RegisterParcel can also be subdivided in two or more PartOfParcel's. This case could occur when 'preliminary' RegisterParcels are created during a conveyance where the RegisterParcel will be split and surveying is done afterwards. It could also be helpful to support planning processes, based on cadastral maps, where establishment of RegisterParcels in the field is done later in time. Note that in the model a composite association is used, indication that the components (from the class PartOfParcel) have no meaning/right of existence without the aggregate class (RegisterParcel), this in indicated with the closed diamond. In case the multiplicity of a class in an association is one ('1'), then this is not explicitly shown in the UML class diagram as is the case at the site of the RegisterParcel. Further note that PartOfParcel is a specialization of RegisterObject (Immovable), making the unseparated piece of land (or space) a first class RegisterObject to which at least one Person is associated via RRR; e.g. in the form of ownership. Note that a ParcelComplex is a 'final' state (an aggregate of parcels, may be even disjoint, which together form one Immovable object), unlike a PartOfParcel, which is a kind of temporary object. So, ParcelComplex is not intended as a set of parcels to be merged into one new future RegisterParcel.

The model also offers the possibility to represent parcels not only based on a topological structure (faces of a planar partition in 2D or volumes of the spatial partition in 3D), that is, a set of cells without overlaps and without gaps, but also in alternative ways. A land (or space) Immovable/RegisterObject could (initially) be represented with a textual description, a single point or a spaghetti polygon, which is not adjusted with it neighbors in a topology structure. The whole domain is subdivided into two types of regions: 1. regions based on a partition (P) and 2. regions not based on a partition (NP). Together the P and the NP regions cover the whole domain. The object class Parcel is therefore also specialized into NPRegion, besides the specializations RegisterParcel and ServingParcel. Note that an NPRegion does not have any associated Person (or RRR), that is, it is not a RegisterObject. On the other hand, the land objects in Immovable class (specialization of RegisterObject) include the following specializations: TextParcel, PointParcel and SpaghettiParcel. These three 'alternative' non-topology representations of a land object can only exist in NPRegion areas (and does not influence involve the clean topology RegisterParcel and ServingParcel areas). This can be represented via an additional (geometric) constrained in the model. A parcel may change its presentation over time from TextParcel, to PointParcel to SpaghettiParcel to RegisterParcel (but not back). However, this does not need to be the case in situation that the TextParcel, PointParcel or SpaghettiParcel fulfils the needs. Perhaps, the text, point and spaghetti representation of a parcel should be interpreted as a parcel description with a certain fuzziness (all 'fuzzy faces' belonging to the same 'conceptual' partition of the surface).

As mentioned above, the other immovable register objects, the non-land (or space in 3D) subdivision objects, include: Building, Unit, NonGeoRealEstate and OtherRegisterObject (see Figure 2). The Building and Unit classes replace, as more general versions, the earlier ApartmentComplex and ApartmentUnit classes. In the CCDM there is no explicit association between Building and a parcel as this can be derived from the geometry and topology structures. In case this would not be possible, for example because a TextParcel (without geometry) is involved, an explicit association could be added in that specific country. Following the 'Cadastre 2014' principle of independent layers, it was decided not to include this association within the CCDM. There are two or more Units in a Building. Note that a Unit is intended in the general sense, not only unit for living purposes, but also for other purposes, e.g. commercial. In other words, all building units with legal/registration significance are included here. Also the model does not intend to exclude Units where the construction is very small, or in fact absent, like in cases of parking spots, etc.

In most cadastral systems a restriction is associated to a complete RegisterObject (RegisterParcel) and this is also reflected in the presented model: a Person can have a Restriction (specialization of RRR) on a RegisterObject. However, this may be inconvenient in some cases: one 'thing' may cause the restriction on many RegisterObjects and in such a case this information has to be repeated many times (with all possibilities for inconsistencies). Further, a restriction might also cover/affect only a part of the RegisterObject, but it is not (yet) registered which part this is. A better solution for this situation is to introduce a new layer (in addition of the planar partition of the Parcels) with own geometry (comparable with the layer concept of 'Cadastre 2014', Kaufmann and Steudler 1998). These can be considered as a kind of RegisterObjects 'overlapping' other RegisterObjects, from which they 'carve out' a part of the associated rights. We would suggest to maintain only the 'positive' rights, that is not explicitly store (for one Person) that another Person has a part of the rights, in the cases where the 'positive' right holder is known. This can be obtained via inspecting all rights associated with the RegisterObject and the overlapping OtherRegisterObjects. Note that OtherRegisterObjects are modelled as closed polygons in 2D or polyhedrons in 3D (and obtain their coordinates from SurveyPoint's, see section 4 and there is no explicit topology between OtherRegisterObjects, that is, they are allowed to overlap (and it is expected that they will not often share common boundaries as Parcels do). Typical examples of OtherRegisterObjects are: geometry of an easement (such as 'right of way'), protected region, legal space around a utility object. The class NonGeoRealEstate can be useful in case where a geometric description of the RegisterObject does not (yet) exist. E.g. in case of a right to fish in a commonly held area (itself depicted as a ServingParcel), where the holder of the fishing right does not (or no longer) hold rights to a land parcel in the area.

4. Surveying Classes

Object classes related to surveying are presented in pink colour; see Figure 2. A cadastral survey is documented on a Survey Document, which is a (legal) source document made up in the field. Most importantly, this document contains signatures; in a full digital surrounding a field office may be required to support this under the condition that digital signatures have a legal support. Otherwise paper based documents should be considered as an integral part of the cadastral system. Files with terrestrial observations -distances, bearings, and referred geodetic control- on points are attributes of SurveyDocument, the Measurements. The individual SurveyPoints are associated with SurveyDocument. From the multiplicity it can be recognized that one

SurveyDocument can be associated with several SurveyPoints. The SurveyPoints form the metric foundation of both the topology-based objects and the non-topology-based objects.

In case a SurveyPoint is observed at different moments in time there will be different SurveyDocuments. In case a SurveyPoint is observed from different positions during a measurement there is only one association with a SurveyDocument. One of the attributes of a SurveyPoint is the pointCode, which indicates the type of SurveyPoint; this could for example be a Geodetic Control Point (GCP). If the 'same point' is resurveyed several times and the location does change significantly the there are two options in the model: replace the old SurveyPoint with a new SurveyPoint (with a new id) and all associated classes (Building, but also Parcel node, edge,..) must be updated in order to refer to this new id. An alternative is to make a new version of the old SurveyPoint (keeps same id, but gets different time stamps tmin/tmax). The associated classes do not have to be updated, only the SurveyPoint itself: new time stamp, better, better coordinate and association to new SurveyDocument. Pervious locations of a specific SurveyPoint can be found via its id, which remains the same. In general the second option is preferred in case the location of the SurveyPoint is changed as this offers all the functionality with a relative small adjustment in the data set. Further, instead of a resurvey the could also be other reasons for changing coordinates, for example map improvement or switching to a different coordinate reference system (or new calculation of same reference system). Also in this case the second option, new version of SurveyPoint (keep id) is to be preferred.

5. Geometry and Topology: imported OGC/ISO TC211 classes

Object classes describing the geometry and topology are presented in purple; see Figure 3. The CCDM is based on already accepted and available standards *on geometry and topology* published by ISO and OGC. *Geometry* itself is based on SurveyPoints (mostly after geo referencing, depending on data collection mode: tape, total station, GPS, etc) and is associated with the classes tp_node (topology node), tp_edge (topology edge) and tp_face (topology face, only in 3D case) to describe intermediate 'shapes' points between nodes, metrically based on SurveyPoints.

Current cadastral registration systems, based on 2D topological and geometrically described parcels, have shown limitations in providing insight in (the 2D and 3D) location of 3D constructions (e.g. pipelines, tunnels, building complexes) and in the vertical dimension (depth and height) of rights established for 3D constructions (Stoter, 2004). In the CCDM 2D and 3D are treated in the same manner throughout the model; not only for Parcels but for all types of Immovables. It is important to realize that there is a difference between the 3D physical object itself and the legal space related to this object. The CCDM only covers the legal space. That is, the space that is relevant for the cadastre (bounding envelope of the object), which is usually larger than the physical extent of the object itself (for example including a safety zone). The registration of the 3D objects themselves (or even 2D or textual presentations) is outside the CCDM, but could be maintained in another registration (building, utility) to which the cadastral registration is linked via the GII.

The 3D legal spaces can represent the geometry associated with for example the right of superficies (*droit de superficie*, *Baurecht*), but also be related to full ownership. The solution of registering the legal space of 3D objects compensates many limitations of current cadastral registrations. For example, the surface parcels need not to be divided into smaller parcels. The spatial relationships between surface parcels and the (legal space of the) 3D physical object can be implicitly maintained with spatial overlay functions in the DBMS.

Parcels have a 2D or 3D geometric description. A Parcel corresponds one-to-one to the tp_face (or tp_volume in 3D) in a topological structure (as defined by ISO TC 211 and OpenGIS Consortium). A volume is bounded by faces. A face is bounded by its edges. Every edge has exactly two end points, represented in tp_nodes. In addition, an edge may also have several intermediate points. Both intermediate points and nodes are associated with SurveyPoints. The topological primitives tp_face, tp_edge and tp_nodes, have all a method ('operation') called 'boundary' which can be used to obtain a full metric representation. An edge (or face in 3D) may further be extended with additional (non-geometric) attributes describing properties only belonging to the edge (face) and not to the whole Parcel or individual SurveyPoints.

There are other geometry layers, which are not based on explicit topology structure, these can be found in respectively the classes PointParcel, SpaghettiParcel, Building and OtherRegisterObject (again 2D or 3D). As in the topology/geometry layer of PartionParcel, all coordinates are obtained from the SurveyPoints. There are methods available within the OtherRegisterObject class to return the complete and explicit geometry respectively gm_surface and gm_volume. In 2D a geometry area is defined by at least 3 SurveyPoints, which all have to locate in the same horizontal plane (of the earth surface). In 3D a geometry area is defined by at least 4 non-planar SurveyPoints; this would result in a tetrahedron, the simplest 3D volume object.

A coherent region with Parcels is either 2D or 3D, but not mixed. It is possible to mix 2D and 3D parcels according to the model, but not within the same region. It is noted that if the registration is based on 2D Parcels, this does also imply the 3D columns (but these are not explicitly represented). In case a region has an explicit 3D representation, the tp_volume_3D may be open at the bottom and/or top side (corresponding to infinite columns). The z-coordinate (height/elevation) can be specified relative to the earth surface or in an absolute reference system (similar to x and y). It is advised to use absolute height values, because it is dangerous to associate rights based on relative heights (as the earth surface may change). In case of 3D objects based on absolute heights, also the earth surface plays an important role, in order to decide if certain objects are above or below the surface (or both). Currently, the earth surface elevation is outside the CCDM, but it should be accessible via the Geo-Information Infrastructure (GII). Further, it is possible to model the parcels in 2D, while modelling in the same region OtherRegisterObjects in 3D (e.g. underground utilities).

The 2D or 3D (ISO/OGC) topology structures are valid at every moment in time. There are never gaps or overlaps in the partition. However, to edges belonging to different time spans (defined by tmin-tmax) may cross without a node. The temporal topology must also be maintained: that is no time gaps or overlaps in the representations. Therefore the structure is based on spatio-temporal topology.

6. Person Classes

The abstract class 'Person' (that is again a class without object instances) has as specialisation classes NaturalPerson or NonNaturalPerson like organisations, companies, co-operations and other entities representing social structures. If a Person is a NaturalPerson it cannot be a NonNaturalPerson and the other way around. That is, NaturalPerson and NonNaturalPerson are mutual exclusive. Besides the specialisations NaturalPerson and NonNaturalPerson, a third specialisation is added: GroupPerson. The difference between the NonNaturalPerson and the GroupPerson is that the first is intended to represent instances such as organisations, companies, government institutes (with no explicit relationships to other Persons), while the second is intended to represent communities, cooperations and other entities representing social structures (with possible explicit relationships to other Persons, optionally including their 'share' in the GroupPerson and associated RightsOrRestrictions to RegisterObjects). Note that a GroupPerson can consist of all kinds of persons: NaturalPersons, NonNaturalPersons, but also of other GroupPersons. In case of more informal situations the explicit association with the group member Persons is optional. Further, a Person can be a member of 0 or more GroupPersons. The composite association between GroupPerson and Person could be developed into an association class 'Members', in which for each Member certain attributes are maintained; e.g. the share in the group and the start and optionally end date of the membership.

7. Legal/Administrative Classes

Object classes presented in yellow cover the refinements in the Legal/Administrative side; see Figure 1. The main class in this package is the abstract class RRR with specializations Rights, Restrictions and Responsibilities. All RRR's are based on a LegalDocument as source. In principle legal data will not be changed without provision of a LegalDocument. The essential data of a LegalDocument are associated with ('can be represented in') the classes RRR and Mortgage. A single legal document may be the source of multiple instances of these classes and may even create of mix of these three types. In the other direction, a RRR or Mortgage is always associated with exactly one LegalDocument as its source. Because property and ownership rights are based on (national) legislation, 'lookup tables' can support in this. E.g., the right of 'ownership' might be 'Norwegian Ownership', 'Swedish Ownership', etc. etc. 'Customary Right' related to a region or 'Informal Right' can be included; from modelling perspective this is not an item for discussion. Of course, for the actual implementation in a given country or region, this is very important.

In addition to private law restrictions, many countries also have public law restrictions, which are usually imposed by a (local) government body. The 'holder' of the right is a 'fake' Person (either "the government" or "society-at-large") and usually they are primarily seen as restrictions. Some of them apply to a specific RegisterObject (or right therein) or a small group of them, for example most pre-emption rights, or the duty to pay a certain tax for improvements on the road, or the duty to repair damage or perform belated maintenance. Others have their own area of application, like whether there is soil pollution present, flood plains, (re) zoning of areas (esp. when urban development is made possible in a rural area).

Each non-ownership Right by a third part (be it government or a private Person) causes a Restriction. These Restrictions have their own place in the CCDM: they are modelled as views. That is, not intended to be stored, but to be derived on demand when needed. Public restrictions with their own areas can be recorded via the OtherRegisterObject class. Obviously the documents on which they are based need to be included (in the case of public restrictions this would be laws, regulations, decisions). Other restrictions should be indirectly be 'recorded' as rights in the name of the (positive side) holder. In certain countries some types do not explicitly state the holder (or the holder is a neighbouring RegisterObject, regardless of who holds that RegisterObject). In such cases the (positive-side) Right is recorded with a formal person indication the situation (e.g. neighbour Parcel; also see discussion in section 3 related to ServingParcels). Nevertheless, the most vital rights are usually in the name of a person, like ownership, leasehold or usufruct. Security rights differ between jurisdictions. Sometimes the holder of the right (e.g. bank) is recorded, in other cases there is only a 'restriction with a fake Person' recorded, informing others someone already has a security right on this RegisterObject (often only a defined, and often recorded, amount of money is secured, and a second or third Mortgage could be created). For every RRR it is important that it is made clear how it is recorded. In all cases the relevant source LegalDocument(s) should be associated. One should finally be aware that in most jurisdictions certain use rights and certain security rights can exist totally outside the registration system. These so called 'overriding interests' are valid, also against third parties, without registration. Examples can be rent contracts for shorter periods, certain agricultural tenancy agreements, and 'liens' by tax authorities.

Right (a specialization of the abstract superclass RRR) is compulsory association between RegisterObject and Person, where this is not compulsory in case of 'Restriction' and Responsibility (the other specializations of RRR). The class RRR allows for the introduction of 'shares of rights' in case where more than one Person holds a undivided part of a 'complete' Right (or Restriction or Responsibility). In current thinking and literature on cadastral and land administration issues usually the three R's of Rights, Restrictions and Responsibilities are used. A restriction means that you have to allow someone to do something or that you have to refrain from doing something yourself. Restrictions can both be within private law, especially in the form of servitudes, as within public law, through zoning and other planning restrictions as well as environmental limitations. Responsibilities mean that one has to actively do something. Not all legal systems allow such mandated activities as property rights (rights in rem), and this will also effect the question if they can (and have to be) registered. Obviously their impact can be substantial and their registration makes sense.

There is always at least one instance of Right (subclass of RRR) in which the type of right represents the strongest (or primary) right, for instance ownership, freehold or leasehold. Connected to this strongest right certain interests can be added, or subtracted from this strongest right. A point of discussion is how to represent the subtractions (Restrictions) as they are already implied by a non-primary right of a third party. The fact a neighbour is allowed to walk over your Parcel is an additional Right (appurtenance, positive-side) to the ownership of his property, where it is a Restriction (encumbrance, negative-side) to your property. In the present model both sides are represented, but it is the intention to only store the positive-side and derive (compute) the negative side when needed (compare Zevenbergen in FIG/COST, 2004). Therefore, Restriction is modelled as a view. Although some definitions of encumbrance seem to include the obligation to do something (as described under responsibilities before), we added it here as a separate specialisation Responsibilities (or obligations) to avoid any confusion on allowing the registration of responsibilities (if and when the legal system is tailored for that).

A mortgage is always vested on a RRR, and should never be seen as a separate relation between Person and RegisterObject. On the other hand a Mortgage is usually vested as collateral for loan. Therefore the one providing the money, the mortgagee, is connected to the Mortgage as MoneyProvider; one of the specialisations of the abstract class Person (see Figure 1). The fact that all the different (public law and private law) RRR's find their base in some kind of establishing or transacting document is represented by connecting them to LegalDocument which is now a specialisation of the abstract class SourceDocument (as is SurveyDocument). The one responsible for drafting the document (for instance a notary, lawyer or conveyancer) is connected to this as Conveyer; again a specialisation of the abstract class Person.

Land administration systems that have to underpin customary land tenure systems, informally arranged land use or conflicting claims to rights, and whose objects might not be clearly identifiable (fuzzy), not (yet) clearly identified or whose areas overlap are in need of other classes to allow for those type of situations (van Oosterom et al in FIG/COST, 2004). Often in such countries or jurisdictions both types of situations (strictly legal and formalized and more fuzzy and informal) are to be found in the same area, and should therefore be able to co-exist in the cadastral system, and thus in the core cadastral domain model.

8. Embedding the model in ISO/TC211

In the context of GIS and Spatial data there is currently a lot of effort to standardise the modelling and exchange of this type of data. Most of the standardisation effort is concentrated in the OGC Consortium and in ISO/TC211 and a combined effort has resulted in a harmonised model. This model is described in the ISO19100 standard series. Since most cadastral data is spatial the core cadastral model should be based on these standards. This will allow us to build on the rich model of geo objects as defined in these standards and ensures that the model fits well in GIS software. In order to adhere to the ISO standard a model has to adhere to certain modelling rules (ISO19109) and the spatial types as defined in (ISO 19107) have to be used. Other relevant parts of the standard are about: temporal modelling and geodetic coding.

One of the advantages of modelling in UML is that it gives the possibility to generate an exchange format for the data in a standardised way. The GML3 standard (ISO 19136) describes how to translate an UML model to an GML Applications Schema. This Application Schema uniquely defines an exchange format for data in the UML model. For the correct generation of such a schema the UML Model has to adhere to the encoding rules that are given in the GML Standard. Various tools exist that automatically convert an UML Model to an GML Application Schema. The ShapeChange tool (Portele, 2004) reads an UML Schema in the XMI exchange format and writes an XML Schema. The UML/INTERLIS Editor (Eisenhut, 2004) has an export button to generate a GML Application Schema.

9. Conclusion

A core cadastral data model should serve at least two purposes:

1. Enable effective and efficient implementation of flexible (and generic) cadastral information systems based on a model driven architecture, and
2. Provide the 'common ground' for data exchange between different systems in the cadastral domain.

The later one is a very important motivator to develop a core cadastral data model, which could be used in an international context; e.g. the EULIS project. The OpenGIS Consortium 'Property and Land Information Initiative', as announced in March 2003, underlines the relevance of standardisation. The CCDM ontology is very important for creating standardized information services in an international context (e.g. EULIS), where land administration domain semantics have to be shared between countries (in order to enable needed translations). It is not realistic to expect that involved countries will immediately change their registrations and adjust to the CCDM. However, the CCDM ontology can be used in translations from countries own registration terminology and concepts to the shared terminology and concepts (Hess/Schlieder, Hess/de Vries, and Tiainen in FIG/COST 2004). This enables creating meaningful standardized information services.

How to implement or use the CCDM within a country (or between countries), depends on the organizations involved and the preferred manner of working (and available or planned communication infrastructure). The model itself does not say that something should be centralized or decentralized. In fact, it supports both. In case of a centralized implementation, the model provides the relevant classes. In case of a decentralized implementation, the model provides the required semantics (needed for meaningful communication) and also provides the interface definitions between the different decentral systems (XML/GML encoding; see section 8). Many different implementation scenarios can be imagined. Two realistic, both decentralized, cases could be: 1. for every package of the model a different national organization is responsible for the maintenance of the information in classes within the package (Person, Legal, Parcel, Building, immovable/OtherRegisterObject, Survey) and consistent references between the packages, and 2. a local organization is responsible for the information in all packages within its territory, and has to take care of consistent references to and from data maintained in other territories. Many different implementation (or deployment) approaches are possible.

In this it has been tried to remain within the original scope of the cadastral domain and not extend it with related domain models of topography, geology, geo-technical and soil information, pipelines and cables, addresses, buildings, polluted areas, mining rights, fishing/hunting/grazing rights, cultural history, (religious) monuments. (non-)natural persons, ship- and airplane (and car) registrations, etc.

The foundation of the new CCDM is a 2D and/or 3D parcel with temporal attributes (actually four dimensions) with possible fuzzy boundaries. This does not mean that every cadastral system should have four dimensional fuzzy parcel, but the model gives the overall framework. The actual systems are in a certain sense 'special cases' of this general model.The new version of the model is intended to be an interoperable implementation specification version of Cadastre 2014 (which is at a more abstract level). Being at an implementation level, it will guarantee that different systems adhering to this specification of the CCDM will be interoperable. The actual communication could take place via XML/GML encoding of the CCDM. An XML schema can be derived of the UML class diagram of the CCDM. The current version of the CCDM is also 100% compliant with the ISO 19100 series of geo-information standards, including 'Rules for application schema' (ISO19109), 'Spatial schema' (ISO19107) and 'Geography Markup Language' (ISO19136). Finally, the list of future work includes:

- refine the current ontology/semantics by adding OCL to UML class diagram
- dynamic aspects of the involved processes
- true 3D/4D spatio-temporal parcels (if needed)
- highlight the layer structure in CCDM (by giving a number of examples)
- modeling of the field survey with more structure/attributes
- indicate which classes are part of the real obligatory core (also for attributes and relations)
- generation of a full XML/GML schema (not just an example fragment)
- test with real data (in EULIS context) and test data exchange
- harmonize with other domain models (topography, water, cables/pipes, etc.)

The CCDM has been reviewed by many experts in the field of cadastre and land registry. Co-operation with OGC and ISO in the further development of the model will be required. In addition to the cooperation with these organizations, a review and/or validation by a platform as EULIS, Eurogeographics or the Working Party on Land Administration should be performed. Finally, it is very important that also UN Habitat is involved in such a review and validation process.

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Appendix UML diagrams

The following three figures show the compete CCDM: Figure 1. the legal and person part of the model, Figure 2. the immovable object classes, and Figure 3. the Geometry and Topology classes from ISO TC211.

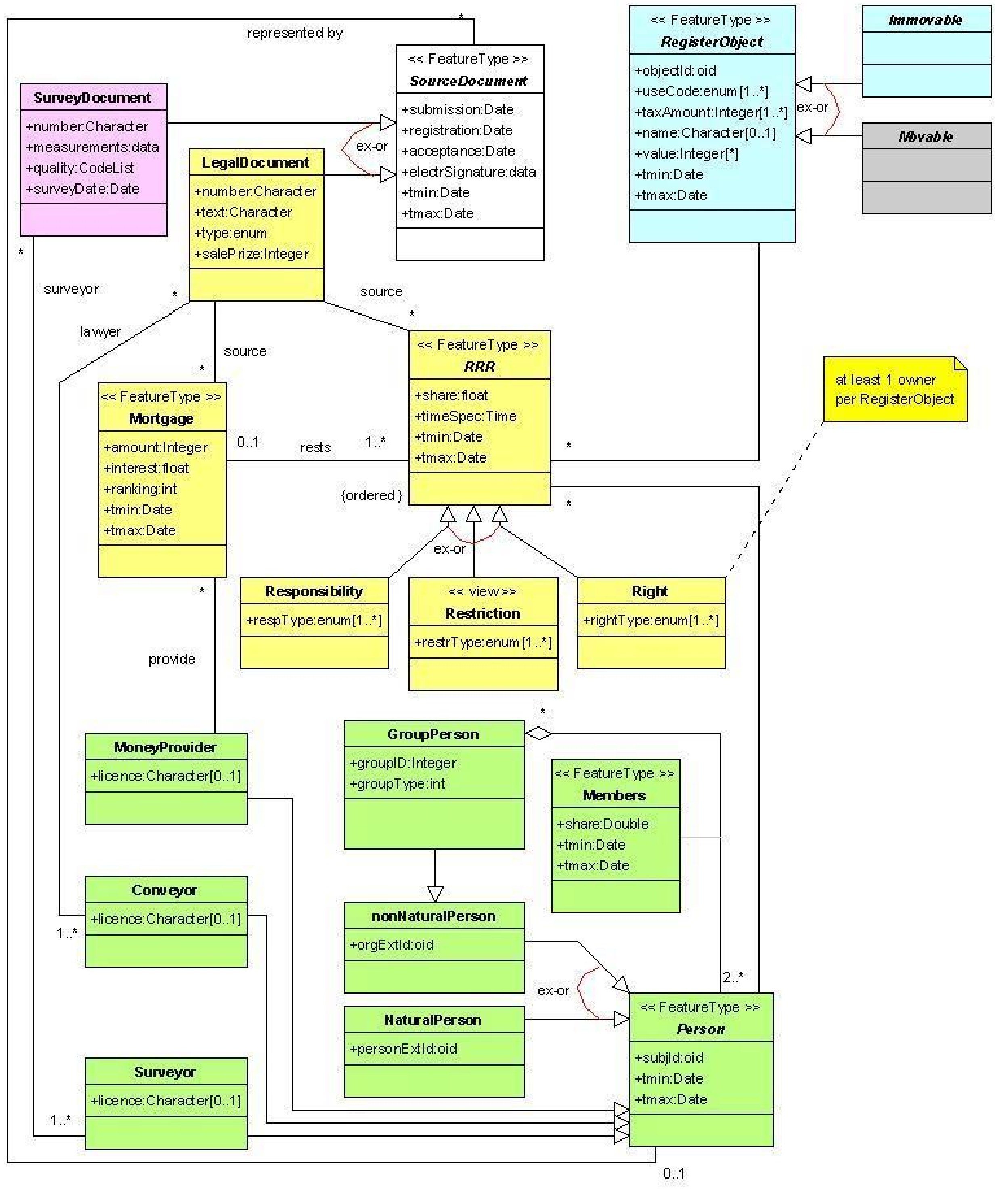

Figure 1: The legal/administrative and person classes

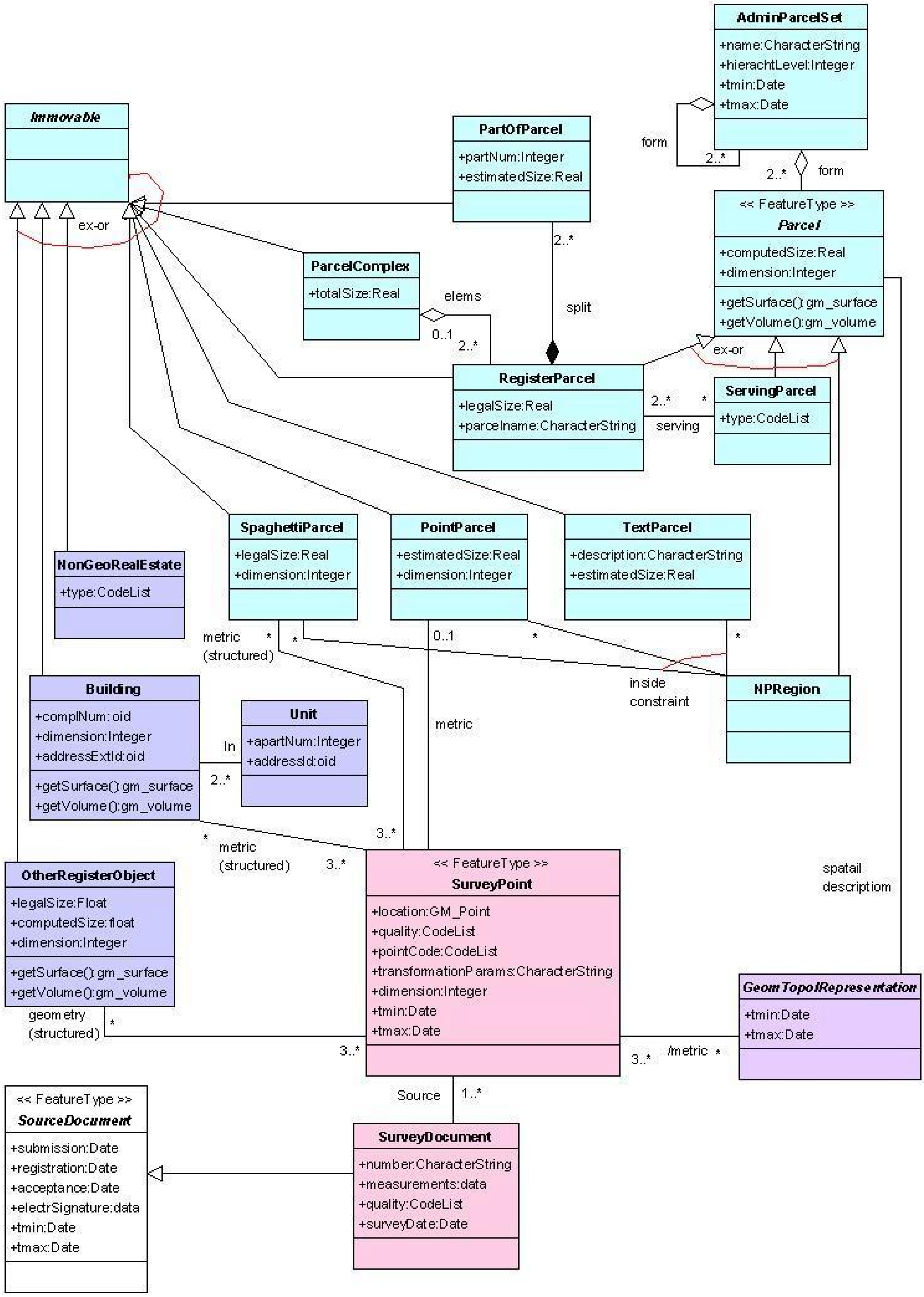

Figure 2: The different types of Immovable object classes

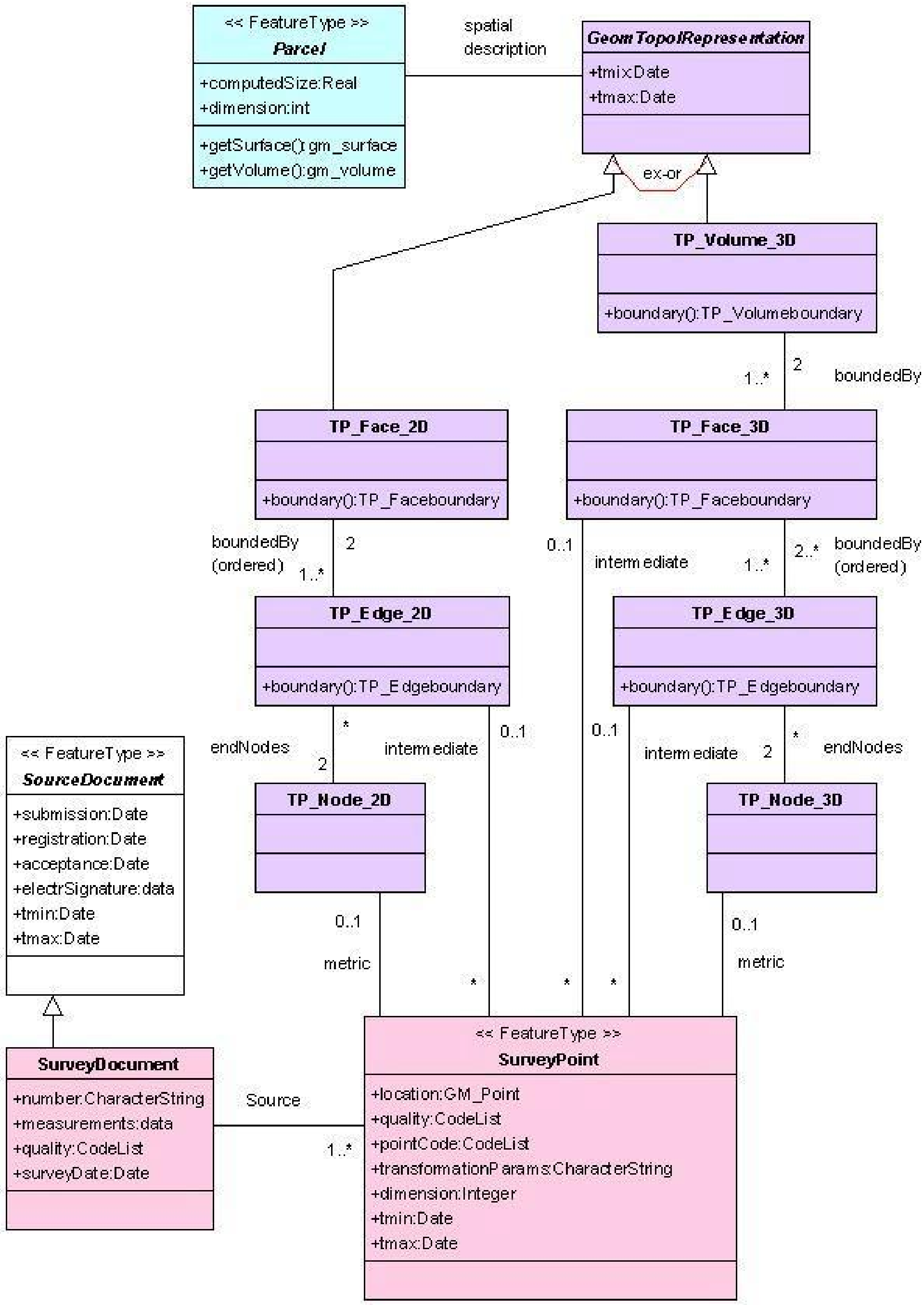

Figure 3. The Geometry, Topology and some related packages, purple