

An uniform real-estate registration model for China

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Key words: uniform real-estate registration; 3D cadastre; modelling; land; building; property unit; rights; RRR; LADM

SUMMARY

The Interim Regulation on Real-Estate Registration (IRRER) was issued by the State Council of the People's Republic of China (SCPRC) in 2014 and took effect on March 1, 2015. This regulation stipulates that the Ministry of Land and Resources of the People's Republic of China (MLRPRC) will be responsible for the duties of real-estate registration, including the registration of land, houses and buildings, grassland, forest land, farmland, homestead land and sea areas, with the goal of unifying registration institutions, authorities, registration records and information platforms. However, the present-day real-estate registration model still relies on traditional 2D parcels, which are no longer suitable for modern land management and must consider 3D spaces for all the real estate. This paper presents a uniform registration model that fits uniform real-estate registration in China based on a comprehensive requirements analysis of uniform real-estate registration and the 3D forms of the real-estate objects.

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1. INTRODUCTION

Land is the most important basis of humankind's existence and production, and the utilization of land extends to the underground space and sky space because of the rapid development of urbanization. Traditional land-administration systems that are based on 2D cannot precisely record the spatial forms of real estate or effectively manage cadastral information (Drobez et al. 2016). Therefore, related theories, regulations and data models of cadastres and properties that are based on 3D have become a challenge that has attracted attention around the world (Gao et al. 2014, Geneva and Switzerland. 2012).

The Interim Regulation on Real-Estate Registration (IRRER) was issued by the State Council of the People's Republic of China (SCPRC) in 2014 and took effect on March 1, 2015. This regulation stipulates that the Ministry of Land and Resources of the People's Republic of China (MLRPRC) will be responsible for the duties of real-estate registration. Uniform real-estate registration (URER) is defined as a system that registration authorities use to register spatial and rights information for real estate in accordance with applicable laws and regulations. "Real estate" refers to immovable property as defined by legal provisions or natural properties and covers the entities and rights that are related to land, such as land, building, prospecting, and mining rights.

Real-estate objects exist in a geographical space. The Property Law of the People's Republic of China (PLPRC) (Guo 2012) regulated the implementation of a unified real-estate registration system, and the 136th article stated that the use rights of construction land can be created separately, either on the surface of the land or above/under the surface, and that newly established land cannot damage the rights/benefits of the real-estate object that had already been issued (Guo et al. 2012). Therefore, the contents of the rights legislation in China have been extended to the vertical direction of 3D space, which provides a legal basis to create, register and administrate real estate in 3D space. The basis of unified real-estate registration is to unify this geographic space into a single uniform 3D space, through which we can consistently represent and model immovable properties and further support unified management and registration (Guo et al. 2014). Some developed cities in China, such as Chongqing and Shenzhen, have already established independent land-utilization projects that set the rights on, above or under the surface land (Guo et al. 2010). However, existing real-estate registration that is based on 2D supports neither the modelling of different geographic objects nor the description and management of immovable 3D properties. Thus, a uniform real-estate model that is based on 3D space must be adopted. This paper proposes an URER model (Section 5) that is fitting for China's national conditions under the actual requirements of urgent progress (Section 2) and Chinese regulations (Section 3) to implement the URER system. The proposed model is based on an elaborate analysis of the spatial forms of Chinese real estate (Section 4) and the definition of a feasible unit of spatial property (Section 5).

2. RELATED WORKS

Before the IRRER was published, Chinese scholars performed a thorough analysis of the temporal situations, factors, drawbacks, rules and specifications of registrations from both theoretical and practical aspects (He et al. 2013, Lemmen et al.2015, Li et al, 2015). Separate real-estate registration, including house property and cadastres, has been conducted in many countries, but this type of registration mode has many drawbacks in terms of maintaining consistency between different real-estate objects. Therefore, Lin presented a 3D conceptual model that integrates housing properties with cadastral information based on the land usufruct (Lin and Guo 2006). Traditional cadastral registration is based on 2D parcels, while real-estate objects typically exhibit 3D shapes and should be basic registered units in 3D space, which makes the definition and representation of real-estate units (we use the term “property unit” hereafter) become very important. Rights, responsibilities and restrictions are the core of land administration, so property units could be defined and divided by their rights (Guo et al. 2014). In particular, 3D real-estate management is based on an inexorable trend (Gozdz 2014, Guo and Ying 2010) and some scholars presented a basic framework for converting 2D data models to 3D data models after analysing and summarizing the characteristics of spatial objects to utilize existing 2D cadastral data, and 3D cadastral data models have been contrasted based on object-oriented 3D models (Pouliot et al. 2016, Shi 2009). Other efforts included the automatic generation of 3D property objects(Guo and Ying 2010, Guo et al. 2011), the design of full 3D cadastral systems(Geneva and Switzerland 2012, Stoter 2014), and the modelling and visualization of 3D parcels (Van Oosterom 2013, Wang 2012).

The Land-Administration Domain Model (LADM) (ISO 19152) provides an extensible basis for the development and refinement of efficient land-administration systems and creates a standardized information service among different countries or apartments, and many scholars have since applied the LADM to real-estate registration in their country. Some countries (Poland and Netherland) have already established real-estate registration systems based on the LADM (Williamson 2010), and others began to explore the relationship between this model and the national land policies of their countries (Wu 2010). In China, the basic goal of unified registration is to unify registration authorities, institutions, information platforms and books. A LADM-based model that is suitable for the recombination of land and building data has been presented (Ying et al. 2015), and a prototype system was developed to verify this model’s feasibility (Ying et al.2017).

Existing 2D cadastral management systems, which are still the main method to manage land, cannot satisfy the current requirements of 3D property management. The need to implement an URER system has already become a reality because of the promulgation of relevant laws and regulations and the requirements of Chinese national conditions. At the same time, techniques for the management of 3D spaces and measurements have been widely developed, which provide a solid technical basis to construct an URER model. Thus, a 3D URER model must be introduced as soon as possible.

3. REQUIREMENTS FOR URER

Real-estate registration models are the key to bridge real-estate objects in the real world and their representations in a digital environment. In particular, such a model must express an understanding of real-estate objects in the real world (Shi 2009). The location and possession of 3D volumetric spaces are the most essential characteristics of real estate and are the key to distinguish and manage real-estate objects (Ying et al.2011). According to the IRRER, the term “real estate” refers to various land areas, sea areas, constructions and buildings/houses, forests and trees, and other appertaining properties. Generally, land and its attachments in China are handled in two scenarios: urban environments and rural environments. Collective land, farmland and homestead land are located in rural environments, while construction land is located in urban environments. In detail, the rights that are involved in real-estate registration include the following ten types.

- (1) Collective land ownership
- (2) Ownership of constructions and structures such as buildings
- (3) Ownership of forests and woods
- (4) Rights to the contracted management of farmland, forest land and grassland
- (5) Use rights of construction land
- (6) Use rights of homestead land
- (7) Use rights of water/sea
- (8) Easement
- (9) Mortgage rights
- (10) Other rights that require registration according to relevant laws

Before 2018, different departments are responsible for the registration of real estate (Table 1), the rules and regulations that are formulated by these relevant departments are not uniform. The data standards for the natural resources such as farmland, forest land, grassland, buildings and constructions in the housing and construction departments, land, agriculture, forestry, and water conservancy departments have been mixed, which leads much investigation works repeated. Therefore, Chinese government has carried out major government reforms and established the Natural Resources Department on March 14, 2018 to integrate the definitive rights and registration management responsibilities for natural resources such as land, minerals, waters, grasslands, and forests, with the goal of unifying registration institutions, authorities, information platforms and to further accelerate the speed of unified investigation ,supervision and registration management of real estate.

According to the IRRER, a property unit is the basic unit of real-estate registration. When a property unit is registered, required information should be registered and recorded, including the owner’s rights, use rights, and the characteristics of the natural source, such as the detailed locations, spatial boundaries, areas and attributes of the property unit (type, content, source, time duration, etc.). Based on the PLPRC and IRRER, URER management can be divided into three packages: parties, natural resource and RRR (rights, restrictions and responsibilities). The key to the unified registration management of natural resources lies in the unified construction of the property rights system, the unified definition of the spatial boundary of real estate, and the unified implementation of property registration certification.

Therefore, building a unified real estate registration model base on the unified spatial metric can more effectively and accurately describe, express and manage real estate.

Table 1. Real-estate registration management institutions

Managed objects	Institution
Housing/buildings	Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD)
Land registrations Land cadastral data	Ministry of Land and Resources of the People's Republic of China (MLRPRC)
Farmlands	Ministry of Agriculture of the People's Republic of China (MAPRC)
Forest lands/ Grasslands	State Forestry Administration of the People's Republic of China
Water areas	Ministry of Agriculture, Fisheries Bureau of the People's Republic of China
Sea areas	State Oceanic Administration of the People's Republic of China

4. OBJECT ANALYSES OF URER

The main function of a uniform real-estate model is to confirm the spatial position of registered objects and describe the ownership, use rights and other rights or obligations that are associated with real-estate objects. Users can consistently locate and represent the entities of real-estate objects within a uniform geographic space to insure that consistent rights are imposed. Real-estate objects occupy their own 3D space without overlap (Figure 1). The basic purpose of real-estate registration is rights verification. The essential precondition of market transactions is the unambiguous demarcation of the rightful position of real estate. Deep analysis regarding the spatial forms of real-estate objects is the basis to understand the spatial occupation and locations of real-estate objects because of their complexity. According to the spatial morphology of land and building shapes, the spatial forms of property units can be categorized into three different types: open, semi-delimited and fully delimited (Yu et al. 2017). The requirements for an URER, which were described in Section 3, indicate ten types of property rights for various property objects, which are described in detail in this section.

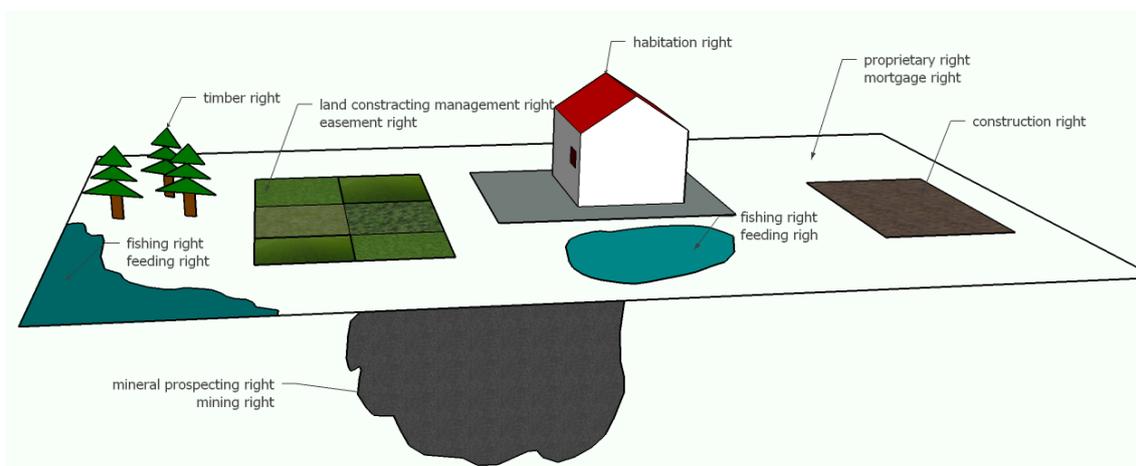


Figure 1. Relationship between spatial objects and rights

The information within an UREER should include 1) attributes such as a unique identification number, the type of the real estate, its location, boundaries, 2D spatial boundaries, 3D delimitation, acreage, approved usages and so on, and 2) rights information such as the owner, type, contents, source, term, change and other real-estate rights that are common to all registered objects. Other disparate contents of real-estate registration should also be included in the registration according to the unique spatial locations and characteristics of the real-estate objects.

4.1 Collective Land

Collective land is located in rural environments. The ownership of collective land belongs to farmer collectives. Housing sites, privately farmed plots of cropland and hilly land are owned by the collectives. Collective land is physically located on the Earth's surface in 3D space with an up and down surface (Figure 2); however, such land is officially typically represented by flat 2D parcels (Figure 3). These parcel map certificates, which exhibit 2D pictorial forms, describe only the location (coordinates) and boundaries of the 2D parcels and cannot fit or provide the precise details of various 3D land shapes. For example, the hilly land in Figure 2 has different surface land than the flat 2D projective area.

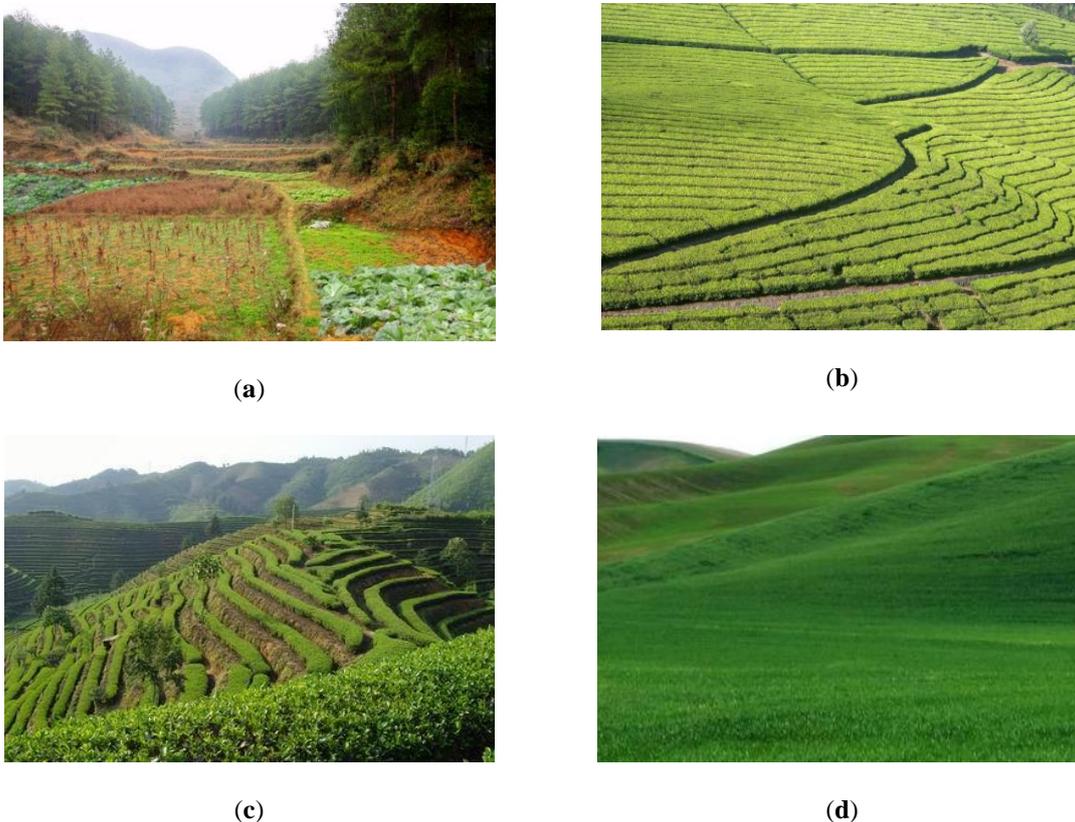


Figure 2. Typical spatial forms of collective lands: privately farmed plots of cropland (a and b); privately farmed plots of hilly land (c and d). (Figure source: <http://www.nipic.com>)

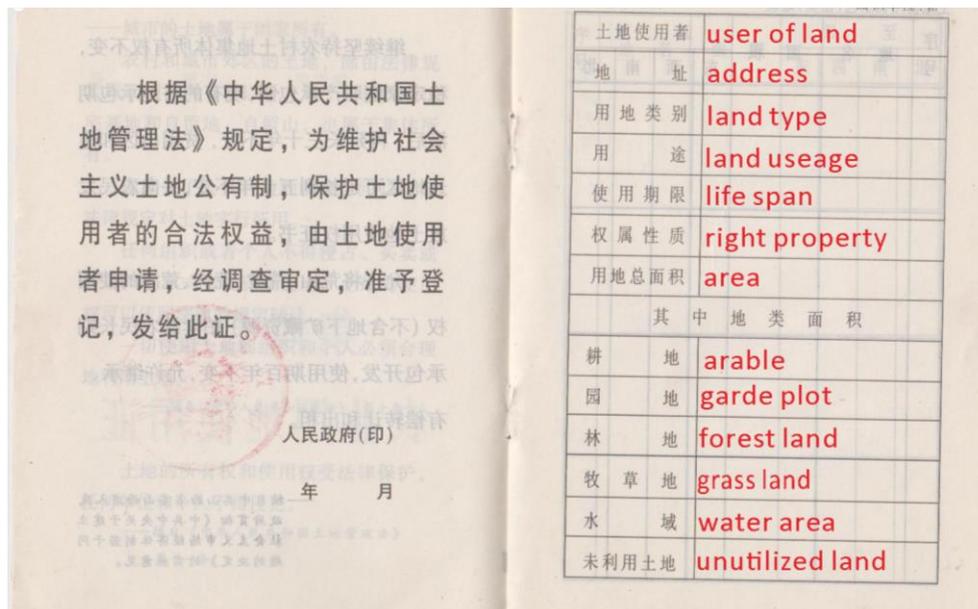


Figure 3. Certificate of collective land ownership (Figure source: <http://www.sinosuntop.com>)

Although the spatial forms of most collective lands are irregular, the ownership of such properties is unified. Therefore, collective land can be regarded as “open type” properties. Consequently, this 3D entity can be expressed by a projective plane on a 2D surface. The holder of this real estate should be registered as the collective that owns this land.

4.2 Buildings and Constructions

The difference between buildings and constructions is that the constructions (water towers, ponds, biogas digesters, and so on) can't provide living functions and accommodations, while buildings often do.

A certificate of building ownership in an urban area is shown in Figure 4, which lists basic textual information for the building. However, this certificate does not express the real estate with a matching land-parcel map. Furthermore, the spatial forms of realistic urban buildings are more complex; 2D parcel maps cannot completely illustrate their shapes and spatial information.

以张三在安徽省 XX 市购置的一套新建商品房登记为例，内页填写范例如下：
皖（2015）XX 市不动产第 XXXXXXXX 号

party	权利人	张三
share	共有情况	房屋单独所有
address	坐落	安徽省 XX 市 XX 小区 1 号楼 602
real estate number	不动产单元号	340XXX 002002 GB00151 F00010002
type of right	权利类型	国有建设用地使用权/房屋所有权
right property	权利性质	出让/商品房
useage	用途	城镇住宅用地/住宅
area	面积	共有宗地面积 5980.7 平方米 / 房屋建筑面积 148.15 平方米
life span	使用期限	国有建设用地使用权 2010 年 10 月 24 起 2080 年 10 月 23 日止
additional information	权利其他状况	分摊土地使用权面积：15.93 平方米 房屋结构：钢筋混凝土结构 专有建筑面积：117.31 平方米，分摊建筑面积：30.87 平方米 房屋总层数：12 层，所在层：第 6 层 房屋竣工时间：2014 年 01 月 01 日

Figure 4. Ownership certificate of an estate building (Figure source: <http://bbs.ccgoufang.com>)

Most constructions in urban areas can be considered as “open type” properties because their spatial forms are regular and their property ownership is unified, these 3D entities can be expressed by a projective plane on a 2D surface.

Buildings in urban areas should be considered “fully delimited type” properties because of specific spatial constraints during the development and utilization of underground spaces. From the perspective of spatial-rights management, buildings can be divided into 2 types: regular buildings and irregular buildings. Condominiums (Figure 5(a)) are typical regular building and can be defined as “fully delimited type” property because the property rights are owned by different individuals within a single construction (residential building). However, the property rights of underground portions may be separate from the property rights of aboveground portions, as demonstrated in Figure 5(b). These distinctions should be clarified during registration. Irregular buildings (Figure 5(c)(d)) can be regarded as “fully delimited type” properties because the property rights of these buildings may intersect and overlap with each other in vertical space. However, the complicated design of their aboveground portions makes URER more difficult, as illustrated in Figure 5(b). Therefore, more mature technologies are required to build 3D property units for irregular buildings.

A realty registration incorporates the following information: (1) the physical conditions of the construction, such as the land location, boundaries, four neighbours, acreage, unique identification number, structure of existing construction, number of floors, area, intended use, and so on, and (2) construction-rights information, such as the owner, type, contents, source, area of interest, transaction date, rights duration, business licenses, and so on.

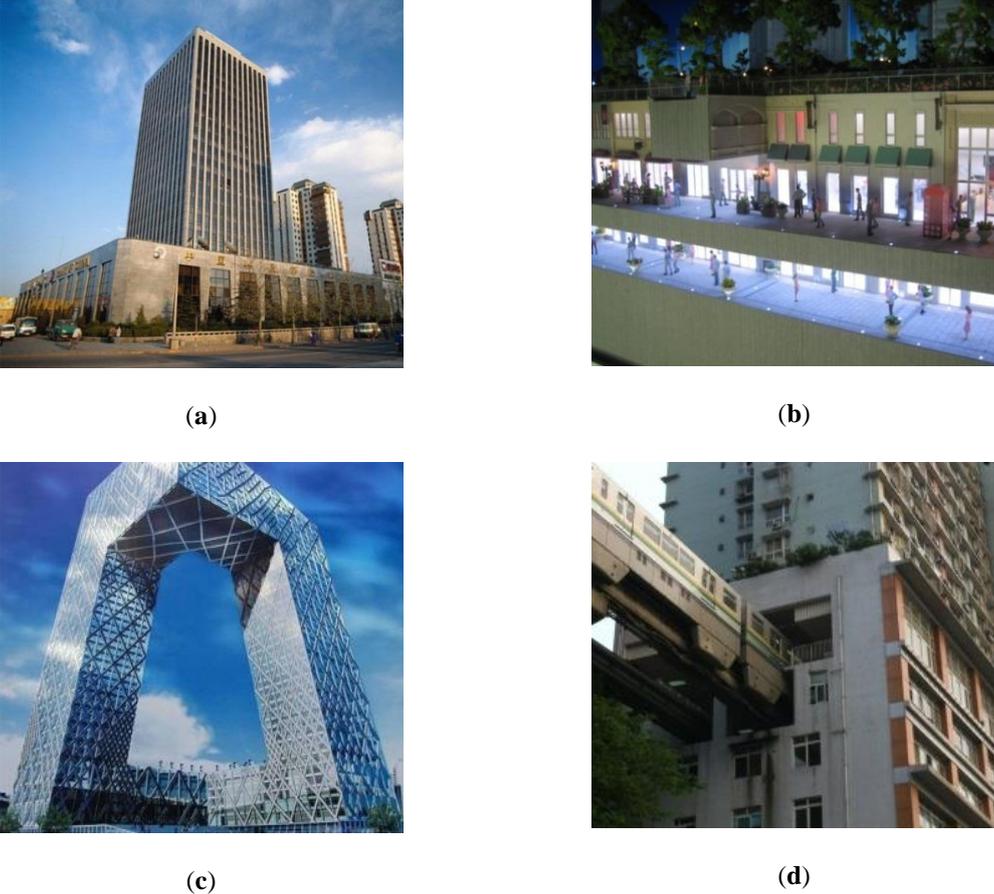


Figure 5. Spatial forms of buildings in urban areas (Figure source: <http://www.image.baidu.com>): regular building (a and b); irregular building (c and d)

4.3 Farmland, Forest Land and Grassland

According to the Status of Land Use Classification (SLUC), “farmland” refers to land on which crops are planted in rural areas. According to the FLPRC, “forest land” means land that is covered by wildwood, secondary forests or artificial forests, including commercial forests, economic forests, protected forests, firewood forests, etc. “Grassland” refers to lands that are mainly covered by herbaceous plants, including both natural grassland and artificial grassland. The range of property rights for farmland, forest land and grassland does not include other types of properties, for instance, water areas, buildings and so on. A full consideration of the spatial locations of property units should be included during registration.

Figure 6 shows a current certificate of forest rights from the People’s Republic of China. Spatial information regarding the boundaries, four neighbours, or acreage is not provided in

pictorial form. Furthermore, the spatial forms of farmland, forest land and grassland are complex in reality. Traditional 2D parcel maps cannot thoroughly illustrate this real estate because most real estate physically exists in 2.5D or 3D form. Therefore, current forest-rights certificates cannot represent forests and woodlands, and detailed information regarding forests and woodlands cannot be obtained based on these certificates.

森林、林木、林地状况登记表
0430225203204JDSYMSY00592 No 1

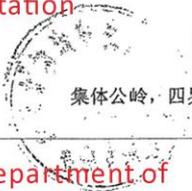
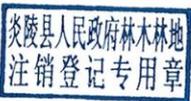
land ownership	林地所有权 权利人	坪坑村月形组	林地使用权 权利人	坪坑村月形组	processor
woods ownership	森林或林木 所有权权利人	坪坑村月形组	森林或林木 使用权权利人	坪坑村月形组	woods usufructuar processor
address	坐落	湖南省 株洲市 炎陵县 下村乡 田心村			
toponym	小地名	横垅里	林班 / 小班	1	
area	面积	1890.0亩	主要树种	中生阔叶树	chief species of tree
number of trees	株数	/	林种	防护林	types of tree
life span	林地使用期	40 年	终止日期	2052-09-06	expiration date
four boundaries	四至:	东:山顶倒水 南:山顶倒水 西:本竹山口 (即原瓦厂更与牛烧登交界处进山的山口) 北:山顶倒水			
annotation	注记:	  集体公岭, 四界内竹山已落实到户			
department of filling certificate	填证机关	经办人: 张伟平	负责人:	 2012年 08月 13日	

Figure 6. Certificate of forest rights from the People’s Republic of China (Figure source: <http://wiwz.anqing.gov.cn>)

Farmland and grassland can be regarded as “open type” properties, while the property units of forest lands should be regarded as “semi-delimited type” properties because their spatial forms can be separated into parts above and under the ground (as demonstrated in Figure 7). Aboveground trees are one component of the property unit (assuming the average height of tree as the height of cube), while the underground rhizome is another component of the property unit (assuming the average depth as the height of the cube); this restricted spatial region may intersect with other property units, such as water and mines. Thus, the latter region should be regarded as adjoining, sharing common boundary surfaces with other property units.

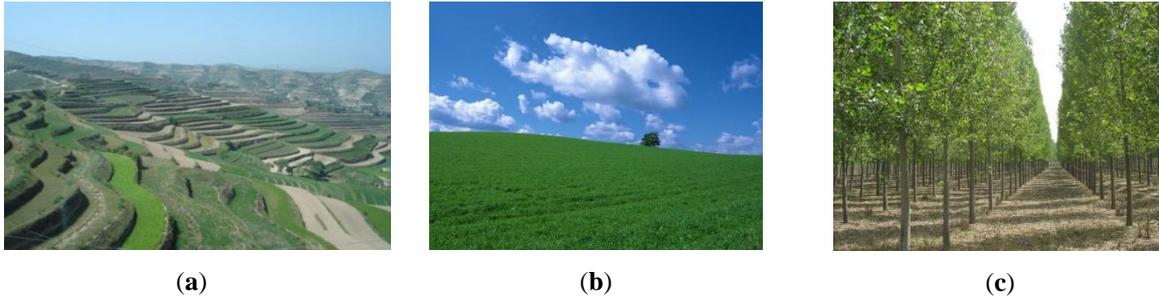


Figure 7. Spatial forms of property units (Figure source: <http://www.nipic.com>). (a) farmland; (b) grassland; (c) forests

The registration contents of this real estate should include the grade information of the land in addition to the common physical information and rights information. The calculation method of the area should be different among flat ground, sloped ground and terrace fields. If the spatial form of sloped land is a continuous curved surface, then the property unit can be approximated by several adjacent flats and the final acreage can be expressed by the sum of the area of every projective plane. If the form is a terrace field, the final acreage can be expressed by the sum of the acreage of all the projective polygons.

4.4 Construction Land

According to the LALPRC, “construction land” means land on which constructions and structures are built, including residential land in urban and rural areas, public facilities, and land for mining, industry, and transportation.

Figure 8 shows a registration chart for construction land. However, this registration simply demonstrates the construction land in a 2D model; details of spatial entities and components of the construction that are underground are not included in the current registration.

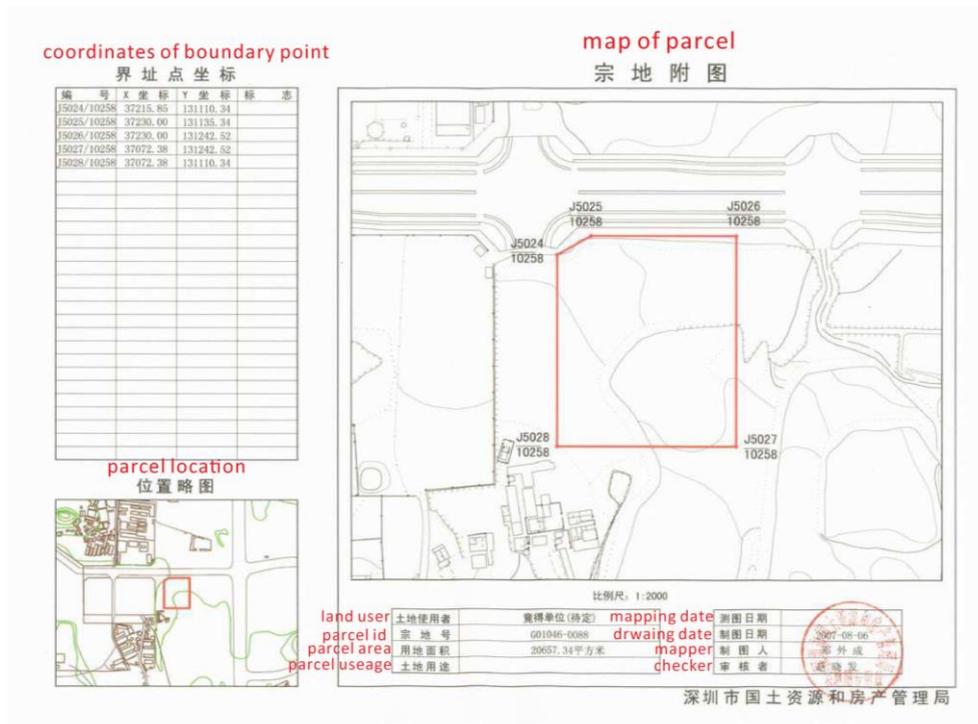


Figure 8. Parcel map of construction land (Figure source: <http://www.bjgtj.gov.cn>)

Examples of construction land are demonstrated in Figure 9. Construction land for specific usages, for instance, land for mining and industry and residential land in urban areas, should be separated into aboveground and underground components. The spatial forms of aboveground areas are typically irregular. However, these property units can be considered “open type” properties. These realty registrations should incorporate physical conditions and rights information. The basic unit of mining areas should be defined by its longitude and latitude according to the Rules for the Implementation of the Mineral Resources Law of the People’s Republic of China. The spatial forms of underground regions can be irregular in 3D space. Therefore, these forms can be considered “fully delimited type” properties because the ownership of the property is unified (distinctions between exploration rights and mining rights should be considered). If the underground regions of a mining area intersect with other property units, such as buildings or ponds, then these sections of the property unit should be regarded as adjoining, sharing common boundary surfaces.



Figure 9. Spatial forms of construction land (Figure source: <http://www.news.sina.com.cn>). (a) mining area; (b) building area; (c) construction land

4.5 Homestead Land

“Homestead land” is collectively owned land that is occupied and utilized as residential land by peasant households or individuals in rural areas. Three main types of homesteads exist: 1) land on which houses have been built, 2) land with roofless buildings that cannot provide living functions, and 3) land that is intended for houses.

Figure 10 shows a registration chart for a homestead; the registration form and contents are consistent with the registration chart of construction land. Furthermore, the spatial forms of realistic homesteads are very complicated. Therefore, this demonstration includes only the area of the homestead and a profile of the building; the details of spatial entities and underground components are not included in current registrations, and detailed spatial information for the homestead cannot be obtained based on these figures in contemporary registrations.

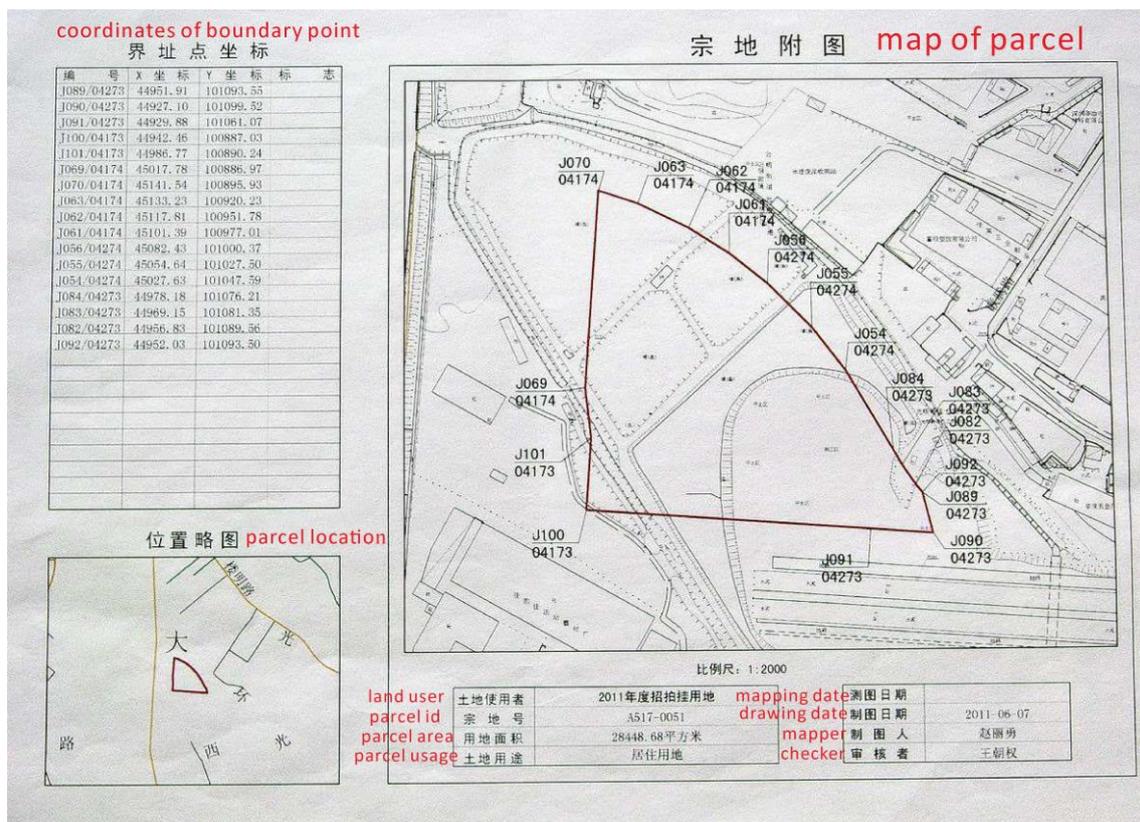


Figure 10. Parcel map of homestead land (Figure source: <http://www.hnlspd.com.cn>)

Homestead examples are shown in Figure 11. Homesteads should be regarded as “open type” properties because the ownership of the property is unified and the 3D entity can be expressed by a projective plane on a 2D surface. The land ownership and housing ownership of homesteads should be registered independently, and the contents of the registration should include the physical conditions and rights information (the specific contents of the registration should obey the Local Measures for the Management of Rural Homesteads).



(a)



(b)

Figure 11. Spatial forms of homesteads (Figure source: [http:// www.image.baidu.com](http://www.image.baidu.com)). (a)homesteads without building;(b) homesteads with building

4.6. Water Areas

A water area is a specific region that includes the scope and control limits of rivers, lakes, canals, channels, reservoirs, ponds and related constructions.

Table 2 shows the registration table for a water area, this table lists some information about the water area. However, the spatial forms of water areas are complicated in reality and detailed and visualized information for water areas cannot be obtained from current registration tables.

Table 2. Registration table of a water area (source: <http://www.ganyu.gov.cn>)

Applicant	Location	Geographical Coordinates	Acreage (Hectare)	Breeding Methods	Deadline of the Breeding Rights
/	/	34°55'20.68" 119°11'19.88"	1.332	Industrialization	2013-4-17 to 2058-10-31
		34°55'22.13" 119°11'21.23"			
		34°55'19.03" 119°11'30.26"			
		34°55'17.65" 119°11'28.73"			

Examples of water areas are illustrated in Figure 12. Water areas can be considered as “open type” properties if their ownership is uniformed, it can also be regarded as “semi-delimited type” properties when the ownership of resources under the water's surface is considered. Generally, the range of the property can be defined by the scope of the water area's surface, and the 3D entity can be expressed by a projective plane on a 2D surface. In this case, the realty registration should include the common information for real-estate registration. The contents of the registration should include the physical conditions and rights information. If the components of the property unit under the water's surface intersect with other property units, then these areas of the property units should be regarded as adjoining, sharing common boundary surfaces.



(a)

(b)

Figure 12. Spatial forms of water areas. (a) water area in city; (b) water area in countryside (source: <http://www.nipic.com>)

4.7. Sea Areas

“Sea areas” refers to specific ocean areas, including both above-water and underwater areas. According to the Law of the People’s Republic of China on the Administration of the Usage of Sea Areas (LPRCAUSA), sea areas in China include interior waters, the surfaces of territorial waters, water bodies, sea areas and subsoil. Interior waters lie between the extent of territorial waters and the coastline.

Figure 13 shows a registration table for a sea area. However, the spatial forms of sea areas are complicated in reality, so a traditional 2D parcel map cannot fully illustrate the real estate, and detailed visualized information for the sea area cannot be obtained based on current registration tables.

公 告

根据《中华人民共和国海域使用管理法》、《浙江省海域使用管理条例》、《浙江省海域使用权登记管理暂行办法》及相关规定，下列项目用海符合海域使用权登记要求，准予登记，现向社会公布。

登记号	项目名称	海域使用权人	海域使用权证书编号	用海位置	用海方式	用海面积	用海期限
330322-20170004	温州市域铁路S2线一期工程瓯江北口隧道工程(洞头段)	温州市铁路与轨道交通投资集团有限公司	2017C33032201218	位于乐清市柳市镇黄华堡村浙江海船厂有限公司厂区，下穿瓯江北口至洞头区灵昆街道九村村	跨海桥梁、海底隧道等	4.3853公顷	截止2067年03月28日

公民、法人或者其他组织认为海域使用权登记侵犯其合法权益的，可以根据《行政复议法》、《行政诉讼法》有关规定，提出行政复议申请或者向人民法院提起行政诉讼。

温州市洞头区海洋与渔业局
2017年5月5日

Figure 13. Registration table of a sea area (source: <http://hyj.dongtou.gov.cn>)

According to the LPRCAUSA, the registration (right of use) materials of specific realty such as sea areas should incorporate the intended use, coordinate graphs, functional zoning, boundaries, acreage, space, location and other sea-area properties.

Starting from March 1, 2015, the real-estate registration certificate(as shown in figure 14) issued by the Ministry of Land and Resources of the People's Republic of China will be formally applied, and the various types of real estate registration books used before will cease to be issued. However, the existing objects of real-estate registration are complicated, as shown in Table 3. Property rights are no longer restricted to 2D space but are increasingly becoming associated with 3D space. Therefore, the URER model in this paper must comprehensively express property units in 2D, 3D and hybrid space.



Figure 14. the real-estate registration certificate(source: <http://hj.dongtou.gov.cn>)

Table 3. Objects in the URER

Name	Types of spatial forms	Contents of registration	Spatial relationship with others
Collective land	Open type	Holder of the realty (collective), type of the real estate, contents of the rights, source of the rights, code, location, boundaries, spatial boundaries, acreage, usage, life span, change of the rights, etc.	Adjoin, Include
Construction	Regular Fully delimited type	(1) Physical conditions, location, boundaries, space, acreage, code, usage, etc.; (2) situation of the rights, holder of the realty, type of the rights, contents of the	Adjoin

	Irregular		rights, source of the rights, change of the rights, record date, term, etc.	
Structures		Open type	Holder of the realty, type of the real estate, contents of the rights, source of the rights, code, location, boundaries, spatial boundaries, acreage, usage, life span, change of the rights, etc.	Adjoin
Farmland, grassland		Open type	Holder of the realty, type of the real estate, contents of the rights, source of the rights, code, location, boundaries, spatial boundaries, acreage, usage, level, life span, change of the rights, etc.	Adjoin, Include
Forest land		Semi-delimited type	Holder of the realty, type of the real estate, contents of the rights, source of the rights, code, location, boundaries, spatial boundaries, acreage, usage, level, life span, change of the rights, etc.	Adjoin, Include
Construction land	For mining and residence	Over ground, open type; underground, fully delimited type	(1) Physical conditions, location (longitude and latitude), boundaries, space, code, acreage, usage, etc.; (2) situation of the rights, code of the rights, obligee, legal nature, life span, type of the rights, contents of the rights, source of the rights, change of the rights, etc.	Adjoin
	Others	Open type	Holder of the realty, code, type of the real estate, contents of the rights, source of the rights, name of the owner, location, boundaries, spatial boundaries, acreage, life span, usage, legal nature, change of the rights, etc.	Adjoin
Homestead		Open type	(1) Physical conditions, parcel code, figure code, acreage of the parcel, location, space, boundaries, house code, structure, usage, etc.; (2) situation of the rights, legal nature of the land, life span, obligee, source of the rights, name of the owner, type of the rights, contents of the rights, source of the rights, change of the rights, etc.	Adjoin
Water area		Open type	Holder of the realty, code, type of the real estate, location, boundaries, spatial boundaries, acreage, usage, life span, change of the rights, etc.	Adjoin
Sea area		Open type	Application of sea-area use, coordinate graphs of the sea area, functional zoning of the sea area, boundaries of the sea area, acreage, owner, term, change of the rights, etc.	Adjoin

5. CONSTRUCTION OF AN URER MODEL

The LADM focuses on the areas of land administration that are mainly connected to real properties, land ownership and the geometrical (spatial) components of real estate (ZARDINY and HAKIMPOUR 2015). This model provides a framework to extend property models to fit different administrative systems. In this case, a suitable URER model for the national conditions in China can be established based on people and land by extending the existing LADM framework. According to the requirements of real-estate registration (described in Section 3) and the analysis of the spatial forms of real estate in China (described in Section 4), the uniform real-estate model that is explained in this section can be separated into three core categories or classes: parties, natural resource and RRR.

The three basic classes of the uniform real-estate model and the relationships between them are demonstrated in Figure 15. The party class consists of group parties, non-natural persons and natural persons. The natural resource class primarily consists of 3D and 2D spatial elements; the latter can be expressed by 3D spatial elements via dimensionality reduction. The RRR class principally consists of proprietary rights, usufructuary rights and real rights for security (mortgages). Figure 15 demonstrates some of the significant attributes of each class, and it indicates that properties and legal spaces are correlated. Spaces can be described by geometrical objects and topological objects. RRRs can be added into the legal space. Only when the attributes of RRR are not equivalent to each other is geometrical partitioning required; meanwhile, the rights holder is the executor of the RRR class.

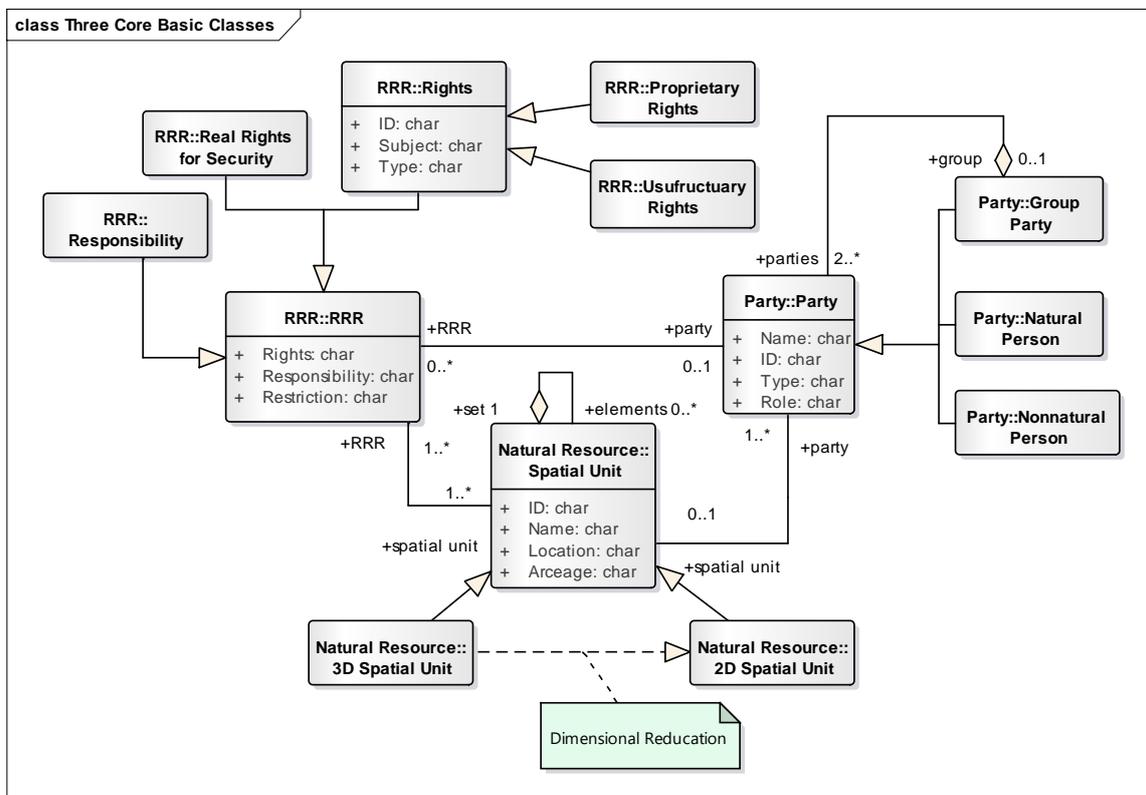


Figure 15. Relationships between the three basic classes of uniform real estate

5.1. Party

Ownership of land in China is limited to the state and collectives. According to the 118th article of the PLPRC, an individual or organization may possess, use and seek proceeds from natural resources that are owned by the state or used by a collective (but owned by the state) and those that are owned by a collective. Meanwhile, the 46th article states that mineral deposits, water and sea areas shall be owned by the state, the 123rd article states that mineral-prospecting rights, mining rights, water-intake rights and the right to use water areas or tidal flats for breeding or fisheries shall be under the protection of the law. Moreover, the 125th article states that the holder of the right to the contracted management of the land shall enjoy the right to possess, use and seek proceeds from the farmland, woodland, grassland, etc., under the contracted management thereof and the right to engage in planting, forestry, stockbreeding or other agricultural production activities.

Above all, the party of the URER model mainly includes natural persons and non-natural persons. Non-natural people include the state, collectives and other organizations in China. The real-estate rights holder will present different characteristics based on the rights that they own. For example, a rights holder who possesses ownership of a house may simultaneously be the holder of the right to use the land on which the house is located. A group party must contain two or more members. The aggregate association between a group party and party can be further categorized into an association of class “members”, in which certain characteristics of each member are maintained. The party class in model is presented in Figure 16.

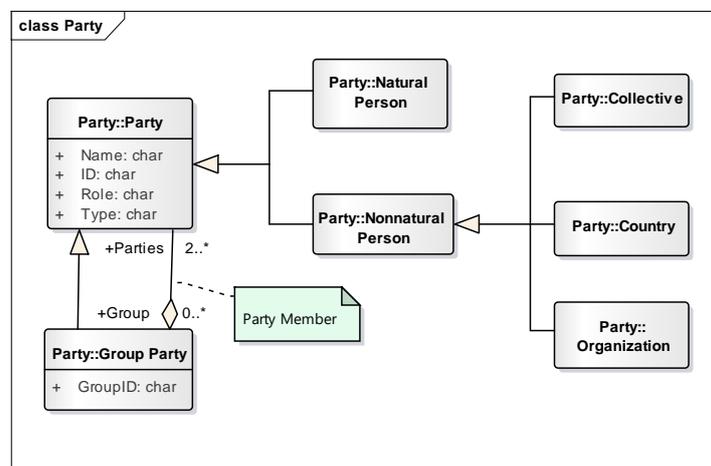


Figure 16. Rights holders in a uniform real-estate model

5.2. Natural Resource

Natural resources are higher-dimensional concepts than land resources and include land, infrastructure that is located on the land, living environments, and other areas such as water, forests, etc (Zhuo et al.2015, Zulkifli 2015). Real-estate objects involve areas both above and under the ground, for example, the right to use forests and land that is covered by these forests may not be owned by the same entity. Mining rights includes mineral-prospecting rights and mining rights, both of which must be registered. In this case, the real-estate objects must be registered as 3D elements because they exhibit both depth and area. The 70th article of the PLPRC states that the owner of apartments or commercial buildings shall enjoy ownership

over exclusive sections of the building but common ownership and management rights over the communal areas of the building. The 13th article of the IRRER states that land without houses should be registered as a parcel and recorded in the land portion of the registration book. Land with houses (or under construction) shall be registered as the basic unit. A “basic unit” is an area with fixed boundaries that can be utilized independently and can be a building or particular space with a clear and unique serial number (building number, room number, etc.). Villagers’ houses on collective land should be registered based on the independent construction (basic unit) that was built on the homestead. Meanwhile, villagers’ houses on common homesteads should be registered based on their areas and other spaces with fixed boundaries (basic units).

A natural resource class includes three components: a physical layer, a topological layer and a geometrical layer. The description of natural resource’ geometrical and topological information can reference those methods(YING et al. 2015, YING et al. 2011). The components of the natural resource class and the relationships between each component are demonstrated in Figure 17.

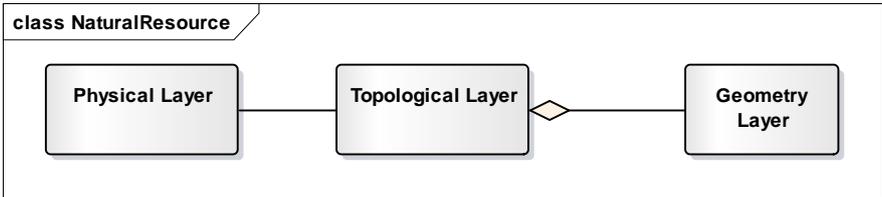


Figure 17. Components of the natural resource class

The physical layer mainly describes the real-estate objects. As mentioned before, real-estate objects can be separated into three types, these types can be characterized by 2D, 2.5D and 3D spatial forms. Individual real-estate objects can be divided into physical spaces and land spaces based on their forms. Physical spaces primarily include buildings and structures, while land spaces includes collective land, farmland, forest land, grassland, construction land, homestead, water areas, sea area, etc. The physical layer of the natural resource model is shown in Figure 18. Objects are framed by boundary points, boundary edges and boundary faces whether they are in 2D space or 3D space.

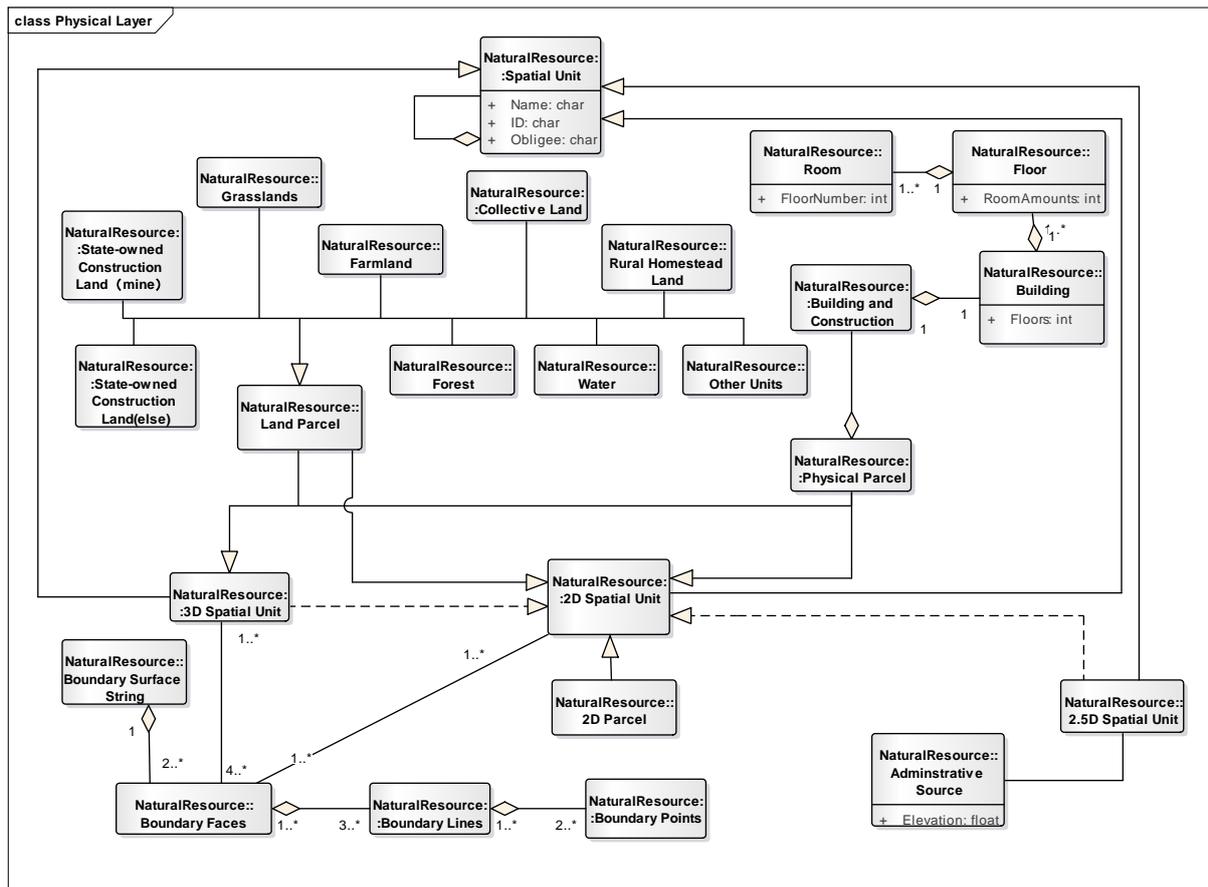


Figure 18. Physical layer of the natural resource class

The topological layer can establish and express relationships between geometry and entities. Specific topological relationships are required to precisely express complicated 3D objects and are helpful for deep data mining, such as spatial analysis and calculation (Zulkifli et al. 2015). Four types of topological elements exist in the topological layer, including nodes, edges, surfaces and bodies. In particular, 3D real-estate objects should be expressed by bodies, while 2D real-estate objects can be expressed by surfaces. The topological layer of the natural resource model is shown in Figure 19.

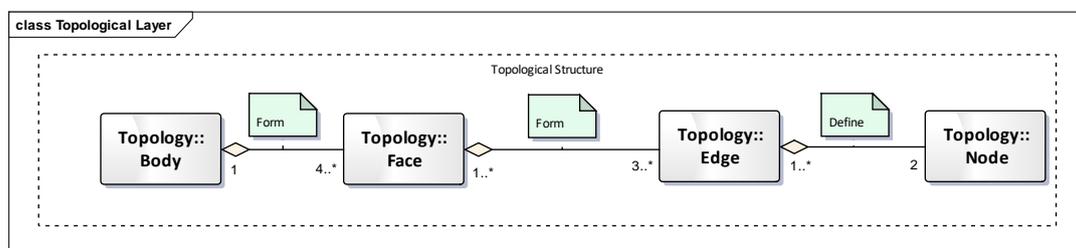


Figure 19. Topological layer of the natural resource class

The most basic geometrical data that are required to establish real-estate objects are described in the geometrical layer, which include point data (each data point includes X, Y and Z coordinates), Triangulated Irregular Networks (TIN) and Tetrahedral Networks (TEN). These

data can describe unique and complicated geometrical objects such as curved surfaces and irregular bodies. Real-estate objects such as forest land on a sloped surface can be expressed by TINs, and 3D bodies can use TENs to fulfil their tetrahedral subdivisions. Additionally, 3D space can be expressed by boundary surfaces to achieve the division of space. The boundaries of 2D space can be expressed by lines. Real-estate objects such as forests, water and construction land can be expressed as spatial units in different dimensions because of the different forms and requirements of their expression. The geometrical layer of the natural resource class is shown in Figure 20.

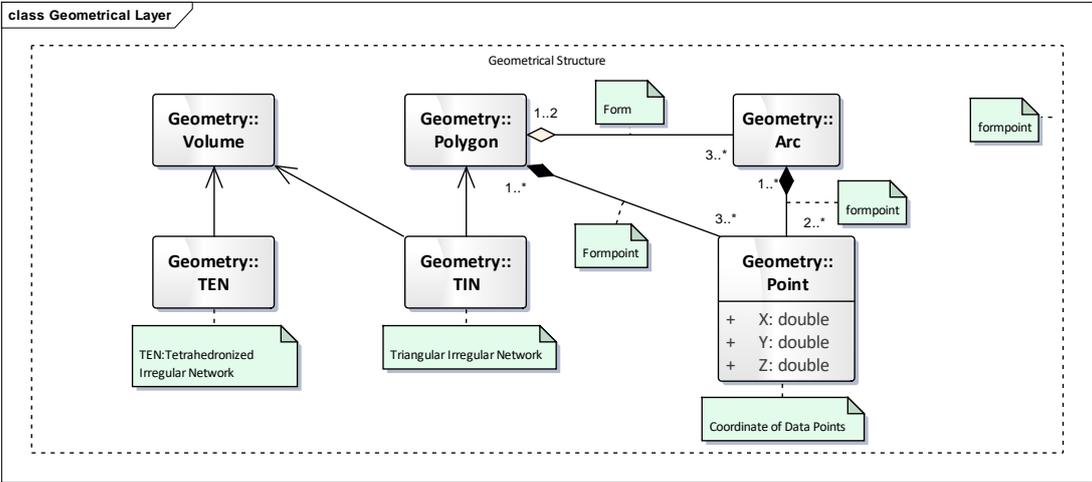


Figure 20. Geometrical layer of the natural resource class

5.3 RRR (Rights, Restrictions and Responsibilities)

According to the PLPRC and the IRRER, property rights can be summarized as ownership, real rights for the usufruct and real rights for security.

5.3.1. Ownership

Ownership in China mainly includes state ownership, collective ownership and private ownership. According to the relevant laws in China, all mineral resources, waters, forests, mountains, grassland, un-reclaimed land, beaches and other natural resources are owned by the state, or owned by the entire population, with the exception of forests, mountains, grasslands, un-reclaimed land and beaches that are owned by collectives in accordance with the law. Land in cities is owned by the state, and land in rural and suburban areas is owned by collectives, except for those portions that belong to the state in accordance with the law. Housing sites, privately farmed plots of cropland and hilly land are also owned by collectives.

5.3.2. Real Rights for the Usufruct

According to the 117th article of the PLPRC, a usufructuary rights holder shall enjoy the right to possess, use and seek proceeds from real property or movable property that is owned by himself according to legal provisions. Real rights for the usufruct include the right to the contracted management of the land, the right to use construction land, and the right to use house sites and easements. The 123rd article states that mineral-prospecting rights, mining rights, water-intake rights and the right to use water areas or tidal flats for breeding or fishery shall be under the protection of the law. The 124th and 125th articles of the PLPRC state that

the system of land-contract management shall be adopted for farmland, woodland, grassland and other land for agricultural uses that are owned by farmers' collectives and land that is owned by the state but used by farmers' collectives. The holder of the right to the contracted management of land shall enjoy the right to possess, use and seek proceeds from the farmland, woodland and grassland, etc., under the contracted management thereof and is entitled to engage in agricultural production activities such as planting, forestry, stockbreeding and so on. The 152nd article of the PLPRC states that the holder of the right to use a housing site shall be entitled to possess and use land that is owned by a collective and make use of that land to construct residential houses and their affiliated facilities.

5.3.3 Real Rights for Security

Real rights for security stand in contrast to the real rights for the usufruct. These rights exist to ensure the realization of creditor rights, whose contents are directly obtained from or dominate the exchange value of the property. Real rights for security can be seen as a type of restriction; at present, only mortgages belong to real rights for security. The 180th article of the PLPRC states that the following properties to which the obligor or third party has the right to dispose of may be used for mortgage: (1) buildings and other fixed objects on the ground; (2) the right to use construction land; (3) the right to the contracted management of barren land that is obtained by bid invitation, auction, public consultation, etc.; (4) manufacturing facilities, raw materials, semi-manufactured goods and finished products; (5) buildings, vessels and aircraft that are under construction; (6) means of communications and transportation; and (7) properties other than those that shall not be mortgaged according to any law or administrative regulation. A mortgagor may collectively mortgage all the properties in the previous paragraph. The 184th article of the PLPRC states that none of the following properties may be mortgaged: (1) land ownership; (2) the right to use farmland, house sites, land that is set aside for farmers to cultivate for their private use, hilly land that is allotted for private use, and other collectively owned land, unless otherwise prescribed by any law; (3) educational, medical, health and other public-welfare facilities of institutions and social groups with the aim of benefiting the public, including schools, kindergartens, hospitals, etc.; (4) properties whose ownership or use rights are unclear or controversial; (5) properties that are legally confiscated, seized or controlled; or (6) other properties that cannot be mortgaged according to any law or administrative regulation. The RRR class is presented in Figure 21.

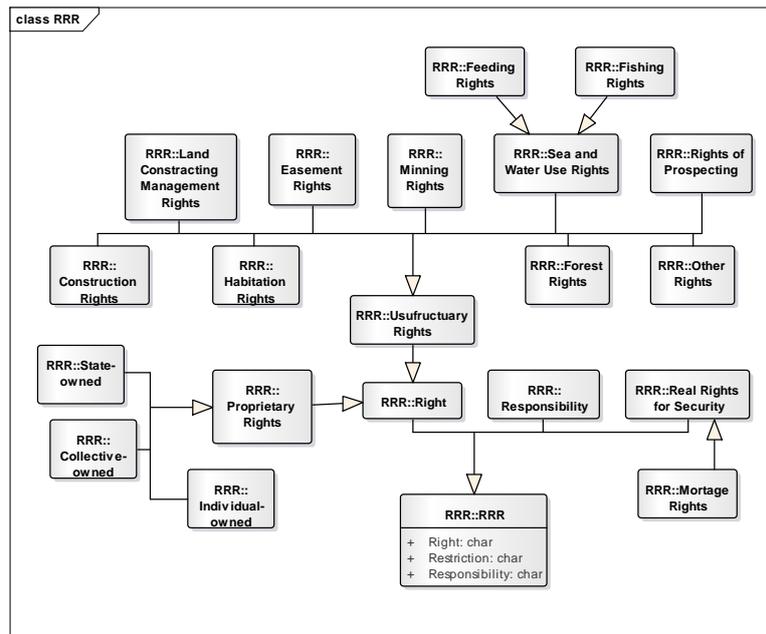


Figure 21. Rights, Responsibilities, Restrictions (RRRs) class

6. CONCLUSIONS

Contemporary real-estate registration models are still based on 2D parcels, which cannot satisfy the requirements of real-estate management in 3D space. This paper proposed a unified real-estate registration model that is suitable for China based on the needs of unified real-estate registration and an analysis of the spatial form of real estate. Combined with detailed descriptions and structures of the LADM, a number of classes and attributes were extracted from the aforementioned relevant laws and regulations, and this model mainly includes three packages: party, natural resource and RRR. What's more, the proposed concept model has been used tentatively for the registration and management of parcel and building in Shenzhen. In this model, the natural resource classes involve geometrical and topological information that is related to immovable objects and can describe natural resource's spatial information from 2D and 3D perspectives. Hence, this data model could utilize existing 2D cadastre data and adapt to 3D real-estate administration.

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BIOGRAPHICAL NOTES

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