Objected-oriented remote sensing image classification method based on geographic ontology model

Z Chu1,2, Z J Liu1 and H Y Gu1
1 Chinese Academy and Surveying and Mapping, Beijing, China
2 Liaoning Technical University, Fuxin, China
E-mail: chuzhao0601@163.com

Abstract. Nowadays, with the development of high resolution remote sensing image and the wide application of laser point cloud data, proceeding objected-oriented remote sensing classification based on the characteristic knowledge of multi-source spatial data has been an important trend on the field of remote sensing image classification, which gradually replaced the traditional method through improving algorithm to optimize image classification results. For this purpose, the paper puts forward a remote sensing image classification method that uses the characteristic knowledge of multi-source spatial data to build the geographic ontology semantic network model, and carries out the objected-oriented classification experiment to implement urban features classification, the experiment uses protégé software which is developed by Stanford University in the United States, and intelligent image analysis software—eCognition software as the experiment platform, uses hyperspectral image and Lidar data that is obtained through flight in DaFeng City of JiangSu as the main data source, first of all, the experiment uses hyperspectral image to obtain feature knowledge of remote sensing image and related special index, the second, the experiment uses Lidar data to generate nDSM(Normalized DSM, Normalized Digital Surface Model),obtaining elevation information, the last, the experiment bases image feature knowledge, special index and elevation information to build the geographic ontology semantic network model that implement urban features classification, the experiment results show that, this method is significantly higher than the traditional classification algorithm on classification accuracy, especially it performs more evidently on the respect of building classification. The method not only considers the advantage of multi-source spatial data, for example, remote sensing image, Lidar data and so on, but also realizes multi-source spatial data knowledge integration and application of the knowledge to the field of remote sensing image classification, which provides an effective way for objected-oriented remote sensing image classification in the future.

1. Introduction
Geographic ontology is the expansion and extension of ontology in the field of geographic information science, which mainly has been used to design geographic type and feature class on the geographical target domain, it provides a clear conceptual model for GIS filed so that people have better understanding of the geographical structure of the world, and avoids the great contrast existing data models and human spatial cognition, meanwhile through shared geographic concepts of a clear formal definition of geographic information sharing and interoperability, which has a wide range of applications on geographic information integration and geographic information services [1-4]. With the study of the geographic ontology, geographic ontology technology begins gradually to extend to the field of remote sensing image, which extracted the image feature information as the knowledge to build image feature base, build conceptual knowledge of geographic ontology model. For this reason some scholars use...
geographic ontology model in the field of remote sensing to carry out extensive research at home and abroad. Zhang Pu [5] uses geographic ontology as the basis, with sloping topography knowledge, build on the Loess Plateau landforms of ontology modelling, and model-based ontology established in accordance with the classification rules, implement to the extraction of the Loess Plateau landforms successfully; Mariana Belgium [6] based on geographic ontology and machine learning, using image feature information, constructed the building classification rules, based on geographic ontology and random forest, and realized urban building classification; G.Forestier [7] used image features to build geographic ontology, and implemented classified feature to treat the initial mark up through geographic ontology, to achieve certification marked feature of this method through expert knowledge built by the function of knowledge (Knowledge Functions) model achieved type of sea surface features of interpretation. As can be seen, to achieve remote sensing image classification at the level of knowledge has become the main trend in the field of remote sensing image classification, however, how to achieve the objective modelling of feature elements, how to achieve organization and expression of the knowledge characteristics effectively, such geographic entities can conceptualization and formal expression, in addition geographical entity having cognitive unity is the key problem to be solved based on the method of knowledge. This paper is mainly based on geographic ontology theory, the ontology has a geographical conceptualization, explicit, formal, sharing, etc. [8-10], combined with image features knowledge base, building geographic ontology model of the study area, to achieve conceptualization and formal expression of study area feature elements, to realize the study area of remote sensing image classification.

2. The introduction of geographic ontology model method

The method mainly analyzes the research need, extracts image feature knowledge and other additional knowledge such as elevation, build image feature model, decision tree model and expert rule model based on the research feature knowledge, and build geographic ontology knowledge structure of study region, imports the OWL file form of image object to the structure, the first it uses the decision tree model to construct the initial classification to obtain initial result, and then uses the expert rule model to construct the classification to obtain the final classification result. Specific technical route shows below.

![Figure 1: The classification flow chart of geographic ontology model](image)

As can be seen from Figure 1, the main steps based on geographic ontology model classification include the following:

- The first through the image segmentation, we can obtain image object of SHP format file, then through extracting feature for the image object, we can save them as CSV format file, the last we make CSV file and OWL file conversion of image object to implement OWL formal representation of image object.
For the study area, we could analyze ontology need, and make full use of the extracted feature knowledge to build feature knowledge base, then we should build geographic ontology structure including image feature model, decision tree model, expert rules model to get structure file and express it with OWL format.

We will import the image object of OWL format to geographic ontology structure and use the decision tree model and expert rules model to construct XQuery queries to implement the object identification of the study area. In addition, we need make OWL format file and SHP format file conversion to get the image object of SHP format.

3. Geographic ontology model of remote sensing image

3.1. Conceptual model of image feature
The image object feature is the origin attribute of remote sensing image. How to express the object feature relationship formally, how to make use of the extracted and mined feature information knowledge to implement image classification, which is the key problem that need to be solved in the field of remote sensing classification. This section mainly bases on the conceptual knowledge of image object and the OWL language to implement to build conceptual model of image feature and express the object feature relationship formally. We would consider research need and the data characteristics of the study area to define the feature and type of image object. The feature types include spectral feature property(Spectral_Property), texture feature property(Texture_Property), shape feature property(Shape_Property) and spatial feature property(Spatialfeature_Property).

3.2. Decision tree model
The method use decision tree in OWL format to build model, which is divided into four steps.

3.2.1. The description of related concepts.
It mainly include related concepts of decision tree algorithm and knowledge concepts of the study area. The decision tree concept includes Decision Tree, Root, Node and Leaf. The paper uses land cover as study object, therefore, the concept of study field mainly includes Building, Road, Water, BareLand, Vegetation.

3.2.2. Define classes and their relationships.
We define the class and the class hierarchy with top-down approach, the first we determine the base class—urban land cover class (City_Land), the second which could be divided into building class (Building) and low feature class (LowFeature) with the elevation, the third the low feature class would be divided into artificial feature class (ArtificalFeature) and natural feature class (NaturalFeature), the last the artificial feature class would be divided into road class (Road) and bare land class (BareLand) and the natural feature class would be divided into water class (Water) and vegetation class (Vegetation). We can build the structure diagram of tree and establish the relationships among classes.

3.2.3. Define attributes and attributes setting.
Because decision tree model mainly involves comparison of eigenvalues, the primary object properties defined include greater than (GreaterThan), greater than or equal (GreaterThanOrEqual), less than (LessThan) and less than or equal (LessThanOrEqual) four main attributes, and then we would set their domain and range of property.

3.2.4. Define individual.
According to class hierarchy and class definitions, we can create individual instances based on decision tree model. The paper uses the land cover as example, which mainly creates Node1, Node2, Node3, Node4, Node5, Node6 Node7, Node8 and Node9 etc. nine individuals. We would set each individual instance, which includes class setting, judging the individual belongs to class and attributes setting including object properties setting and data properties setting.

3.3. Expert rule model
Expert rule model mainly uses the semantic knowledge and concept of the field to create flag rule, which is basically the process of the image feature representation of semantic relations, then, according to
experts' flag rules and prior knowledge, we can get expert rules, and finally, according to the expert rules, we would use XQuery / XPath query language to implement ontology reasoning. We would use SWRL language combining with prior knowledge to express flag rules and expert rules.

3.3.1 Flag rule expression. Brightness(?x, ?y), lessThan(?y, 1000) -> DarkLight(?x) Elevation(?x, ?y), lessThanOrEqual(?y, 2) -> Low(?x) RectangularFit(?x, ?y), greaterThan(?y, 0.78) -> Regular(?x) Length_Width(?x, ?y), greaterThan(?y, 2.0) -> Strip(?x) NDVI(?x, ?y), greaterThan(?y, 0.40) -> VegetationIndex(?x) Elevation(?x, ?y), greaterThan(?y, 2) -> Height(?x) Brightness(?x, ?y), greaterThan(?y, 1500) -> BrightLight(?x) RectangularFit(?x, ?y), lessThanOrEqual(?y, 0.4) -> Nonregular(?x) Length_Width(?x, ?y), lessThanOrEqual(?y, 2.0) -> Planar(?x)

The formula means that when RectangularFit is greater than 0.78, the object is Regular, when it less than or equal 0.4, the object is Nonregular; when Brightness is greater than 1500.0, the object is BrightLight; when Elevation is greater than 2.0, the object is Height, when it less than or equal 2.0, the object is Low; when Length_Width is greater than 2.0, the object is Strip, when it less than or equal 2.0, the object is Planar.

3.3.2 Expert rule expression. DarkLight(?x), Low(?x), Strip(?x) -> Water(?x) Height(?x), Planar(?x), Regular(?x) -> Building(?x) Low(?x), Planar(?x), VegetationIndex(?x) -> Vegetation(?x) BrightLight(?x), Low(?x), Planar(?x), Nonregular(?x) -> BareLand(?x) BrightLight(?x), Low(?x), Planar(?x), Regular(?x) -> Road(?x)Where C (? X) represents X is a C class individuals, P (? X,? Y) represents the attribute, x, y is a variable. We use Road as example that the object has the nature of bright, low strip which should be seen as road.

4 Geographic ontology model of remote sensing image

4.1 Experimental data

The experiment selects DaFeng City as the study area. Dafeng City is a country-level city of Yancheng City, which is located in south of Yancheng, near to Yellow Sea, land area is 3059 square kilometers. Dafeng is the coastal plain, the city ground elevation is 1.9-4.5 meters, the southern part of the terrain is wide and the north is narrow. In this experiment, the flight area of Dafeng City things strip test, in order to take full advantage of Lidar data, we could select areas with relatively more buildings as a test area. The geographical location of the experimental area is shown in Figure 2.

![Figure 2](image_url)
4.2. Experimental result

In this experiment, we use the decision tree model and expert rule model to realize the classification of the features of the test area, the results is as shown in Figure 3(a), Figure 3(b).

![Figure 3(a) The decision tree model results](image1)
![Figure 3(b) The expert rules model results](image2)

By using the confusion matrix we evaluate the accuracy of the three, the results of the evaluation are shown in table 1, table 2.

| Vegetation | Water | Road | BareLand | Building | Sum | Production accuracy |
|------------|-------|------|----------|----------|-----|---------------------|
| Vegetation | 274   | 10   | 13       | 6        | 0   | 303                 | 90.43|
| Water      | 2     | 34   | 0        | 0        | 0   | 36                  | 94.44|
| Road       | 6     | 1    | 63       | 4        | 0   | 74                  | 85.14|
| BareLand   | 0     | 1    | 4        | 40       | 0   | 45                  | 88.89|
| Building   | 1     | 0    | 0        | 0        | 57  | 58                  | 98.28|
| Sum        | 283   | 46   | 80       | 50       | 57  | 516                 |        |
| User accuracy | 96.82 | 73.92 | 78.75 | 80.00 | 100 |                    |        |
| Overall accuracy | 90.70% | 85.20% |        |        |      |                    |        |

| Vegetation | Water | Road | BareLand | Building | Sum | Production accuracy |
|------------|-------|------|----------|----------|-----|---------------------|
| Vegetation | 273   | 6    | 8        | 5        | 0   | 292                 | 93.49|
| Water      | 1     | 38   | 0        | 0        | 0   | 39                  | 97.44|
| Road       | 3     | 0    | 69       | 4        | 0   | 76                  | 90.79|
| BareLand   | 2     | 1    | 4        | 44       | 0   | 51                  | 86.27|
| Building   | 1     | 0    | 0        | 0        | 57  | 58                  | 98.28|
| Sum        | 280   | 45   | 81       | 53       | 57  | 516                 |        |
| User accuracy | 97.50 | 84.44 | 85.19 | 83.02 | 100 |                    |        |
| Overall accuracy | 93.22% | 89.27% |        |        |      |                    |        |

According to the results of the classification of the experimental area, the classification results based on the geographic ontology model are significantly improved, especially in the classification of buildings, the use of Lidar data extraction of elevation information of the ontology model can be very good classification of the building, the user accuracy and production accuracy can reach more than 98%, the classification accuracy of the road, vegetation and water body is also higher than the traditional one, but there are some false classification, because the expert rule model is more complete in knowledge representation, the classification result is slightly better than the classification results of the decision tree model.
5. Conclusion
The paper focuses in the research of remote sensing image classification, for standardization and formalization expression of geographical entity unified cognition, solving the cognitive differences of geographical entity leading to inconsistencies of the classification results, we introduces the theory of geographic ontology, builds image data feature knowledge base, establishes geographic ontology model, implement feature elements conceptual and formal expression, research on the practical application of remote sensing images on the level of knowledge, carries out the experiment of remote sensing image classification based on geographic ontology. This method can objectively reflect the semantic information, and form the information of object elements, which provides an effective way for remote sensing image classification, and has a certain scientific and value.

- The paper could use the geographic ontology model to carry on the objective representation of the elements of the remote sensing image, realize the effective organization and utilization of the characteristic information of the image, express the semantic relations with the computer visual language, the objective nature of the information of object elements can be reflected more accurately.
- In this paper, OWL and SWRL are used to realize the decision tree rule modeling and expert rule modeling, to a certain extent, to achieve the classification of remote sensing image, but the relationship between the expression of object information is still flawed, in order to make up the deficiency of the existing model, more new data mining methods are introduced in the following research, at the same time, the establishment of expert knowledge of regional features, improve the expert knowledge, and gradually realize the model of universal.
- In this paper, the application of knowledge is more dependent on the image of the characteristics of knowledge, the image of the context knowledge, knowledge of the time, the geographical knowledge of the study area and the spatial relationship of knowledge related to the less, In the follow-up study, it is attempted to apply these knowledge to the framework of geographic ontology model, and to improve the construction of the model.

References
[1] Wang hong. Design and implementation of geographic information ontology based on domain knowledge[D]. WuHan University,2006.
[2] Huang yongqi. Research on spatial temporal query of agricultural geographic information based on geographic ontology and SWRL spatial temporal reasoning rules[D]. Institute of remote sensing applications, Chinese Academy of Sciences,2008.
[3] Hunag maojun, Du qingyun, Wu yunchao, Li fengdan. A preliminary study on geographic ontology and its application[J].Geography and Geographic Information Science,2004,20(4),1-5.
[4] Jing dongsheng. Research on ontology based semantic representation and service of geospatial information[D]. Institute of remote sensing applications, Chinese Academy of Sciences,2005.
[5] Zhang pu. Study on DEM extraction method of the typical landscape of the Loess Plateau driven by Ontology[D]. Lanzhou University,2013.
[6] Mariana Belgiu,Ivan Tomljenovic,Thomas J.Lampoltshammer,Thomas Blaschke. Ontology-Based classification of building types Detected from Airborne Laser Scanning Data[J].Remote Sensing,2014(6):1347-1366.
[7] G.Forestier,C.Wemmert,A.Pussant.Costal image interpretation using background knowledge and semantics[J].Computer&Geosciences,2013(54):88-96
[8] Zhang ying. Research on Geographic Ontology -- Research Progress and Application[J]. Standardization of Surveying and mapping, 2014,30(2):24-27.
[9] Li bin, Liu bin, Liu jiping. Review and Prospect of research on Geographic Ontology[J]. Science of Surveying and Mapping, 2015,40(4):53-57.
[10] Huang maojun. The formal representation mechanism of geographic ontology and its application in map service[D]. WuHan University,2005.

Acknowledgments
The paper was jointly supported by foundation support: Project of the National Natural Science Foundation of China (Item Number: 41371406)