ORGANIZATION AND REPRESENTATION OF OBJECTS IN MULTI-SOURCE REMOTE SENSING IMAGE CLASSIFICATION

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ABSTRACT:

Compared with the traditional remote sensing image processing system based on pixel, there are some unique characters in the object-based classification: various operations on objects; variety of objects features; complicated relationships among objects; high-dimensional feature set. All of these increase the difficulty of the organization and representation of objects. Therefore, the effective organization and representation of objects plays a key role in this system. This paper proposes a synthetic dynamic representation method of objects. The characteristic of the method lies in: the objects are represented in both the vector and raster format; the high-dimensional object features are dynamically recorded; the complicated relations among objects are recorded based on hierarchal object network. This method considers the characters of the object-oriented multi-source remote sensing imagery classification system. It effectively solves the problems of object representation and meets the demands of the multi-source remote sensing imagery classification.

1. INTRODUCTION

The integration of multi-source remote sensing imagery for classification is a research hotspot currently. It makes full use of the distinctive features of multi-source images to reduce the uncertainties inherent in the remote sensing data and improve the accuracy and reliability of classification which will benefit the large-scale application and research of remote sensing data. At present, the multi-source imagery classification methods are mostly pixel-based. They are effective in the classification of the low spatial resolution remote sensing images. However, with the development of the high spatial resolution remote sensing technology, high spatial resolution remote sensing images (HSRI) show more detailed spatial information about ground objects, such as shape, structures, texture etc, which is not efficiently and fully used in the traditional pixel-based image classification methods. In contrast, the object-oriented image processing technology appears as an effective approach to make full use of the rich spatial information inherent in HSRI. With these facts, we initiate a research to develop an object-oriented classification system of multi-source remote sensing data. In the object-oriented system, the multi-source data are processed based on objects. To make full use of the complex object attributes extracted from the multi-source data, the effective organization and representation of objects becomes very significant.

Compared with the traditional pixel-based remote sensing image classification system, there are some unique characters in the object-oriented classification system:

1. Various operations on objects. There are multifarious operations of objects in object-oriented classification for multi source remote sensing data, including the ineluctable transferring of object geometric definition among multi-source data and the topological analysis between objects.
2. Various types of objects feature. The objects features extracted from multi source is various in the type. It includes the numeric data, semantic symbol data as well as the pixel-based features such as spectral features and object-based features such as shape, texture.
3. Complicated relationships among objects. The relationships among objects are used in the classification. In the hierarchal object network, the topological relationships, such as adjacency and cover, among objects of the same scale and.
4. High-dimensional attribute set of the objects. The high-dimensional object attribute set consists of multiple kinds of features including gray value, texture, geometric features extracted from multi-source data.

All of these increase the difficulty of the organization and representation of objects in the process of classification. This paper proposes a synthetic representation method of objects. In this method, objects are synthetically represented in different ways according to the characteristic of features, and the dynamical mechanism is used to solve the problems of object representation in the multi-source remote sensing imagery classification system. The focus of the method lies in:

1. The representation of object in both the vector and raster formats.
2. The representation of distinctive object features
3. The dynamical representation of the high-dimensional object attributes.
4. The representation of the topological relationships among objects in the hierarchal object network.

The paper details the method in the following five sections: the frame of the method (section 2); the representation of the basic object attributes (section 3); the dynamical representation of the high-dimensional attributes (section 4); the representation of the topological relationships among objects in the hierarchal object network (section 5); the conclusions (section 6).

2. FRAME OF THE METHOD

In the object-oriented multi-source imagery classification system, the object features extracted from multi-source data include spectral, texture, shape, surface features and so on. As shown in table 1, object features extracted from multi-source is various in the type. And the object features are divided into two types: the inherent object features and the topological features among objects. The inherent object features are extracted from the multi-source images to represent the individual object, while the topological features among objects represent the topological relationships among different objects. In this paper, the inherent object features are divided into two parts: the basic features and the extended features (EX Features). The basic features mainly consist of the geometric features extracted from the image segmentation results of the pan image and the original spectral features from the pan and multi-spectral images. The EX Features are features extracted based on the basic features, such as the texture and the shape features, and the features extracted from other special images, such as the surface roughness and the complex dielectric constant from SAR.

Feature type	Features	Data source
Layer features	Mean	Pan Multi-spectral images
	Brightness	
	Standard deviation	
	…	
	Surface roughness	SAR
	complex dielectric constant	
Shape	Height, width, area, perimeter	Pan
	Shape index	
	density	
	Symmetry	
	…	
Texture	Homogeneity	Pan Multi-spectral images
	Dissimilarity	
	Contrast	
	Entropy	
	…	
Topological relationships	Adjacency, including	Pan
	Relationships among layers	

Table 1. Features from multi-source data

Then the objects characteristics and their representation methods in the multi-source remote sensing imagery classification system are respectively introduced in the following three parts.

a) The representation of the basic object features. In the representation of the geometric features, both the vector and raster formats are used. And the spectral features are represented by the regional features other than the pixel-based features. In the paper, the regional feature of each spectral band is described by the statistic result of the pixel values of each object including the mean value, the standard deviation value, and the maximum and minimum values.

b) The representation of the extended features. As mentioned above, the extended features are extracted based on the basic features or from other special images. Due to the expandability of such kind of features, they are generally various in types and high-dimensional. The integration of these features can improve the accuracy and reliability of the classification results. Because of data redundancy, it is always inefficient and can't meet the demands of high precision to assemble such features simply in the classification system. For the purpose of improving the accuracy and efficiency of the classification, the corresponding features should be selected for different purposes. Therefore, this paper uses a dynamic recording method, which only records the features that contribute to the classification.

c) The representation of the complex topological relationships among objects. Multi-scale analysis of the objects is demanded, and the complex relationships among objects at the neighbour scales should be represented to implement the classification task. In this paper, the hierarchal object network is established. In the network, the topological relationships among objects at the same scale and the relationships among objects at the neighbour scales are represented. The latter relationship is represented by recording both the parent object and the son object.

As mentioned above, the object features are structured as shown in Figure 1.

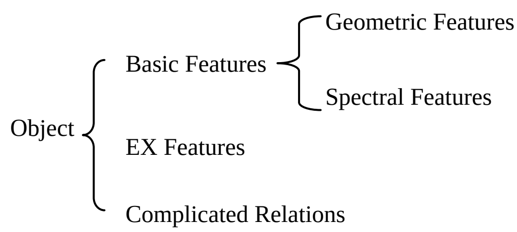

Figure 1. Structure figure of the object features

3. REPRESENTTATION OF THE BASIC FEATUERS

3.1 Representation of geometric features

For the purpose of expressing the geometrical information of objects, they can be represented in the vector or raster formats. The vector data is used in the topological analysis among objects while the raster data is used in the overlay analysis of objects. These two types of data are connected by the unique ID of the object.

In the vector recording of object, the unique ID, arc list and the number of arcs are recorded. Each arc is composed of nodes and represented by the number of the nodes, the node list, and the ID of the left and right objects of this arc. The structure is shown in Figure 2.

- Object
  - ID
  - Arc
  - Arc List
    - Nodes
    - Node List
    - Adjacent objects

Figure 2. The structure of the vector data

In the raster recording of objects, the unique ID, pixel lines (PL), pixel line number are recorded. The pixel line denotes the sequential pixels in one line and the pixels belong to the object. To represent each PL, we record the begin column, the end column of the PL and the row which the PL locates at (Figure 3).

- Object
  - ID
  - PL Number
  - PL List
    - Row
    - Begin Column
    - End Column

Figure 3. The structure of the raster data

3.2 Representation of spectral features

In the pixel-based classification system, the spectral features are represented by the gray values of each pixel, whereas in the object-oriented multi-source imagery classification system, the spectral features are linked to objects and represented by the regional spectral features of the object. In the spectral feature record, the mean value, the standard deviation value, and the maximum and minimum values are included. Table 2 shows the record structure of the spectral features. For the purpose of getting knowledge from the feature information, the feature information is recorded in the feature information table (It is shown in table 3). The feature information can be searched according to feature code and region feature code in the feature information table. In the feature information table, the feature code, region feature, importance, the feature information, the value type and the value range of the feature are recorded. Among them, the feature information includes the source, characteristic and use of the feature. The features are divided into four types including the continuous feature, the discrete feature, the feature set and the Bool type feature.

Object ID	Spectral Feature Code	Region Feature Code
	T1	mean
		Standard deviation
		Maximum Minimum
	…	…
	Tn	mean
		Standard deviation
		Maximum Minimum

Table 2. The structure of spectral feature record

Spectral Feature Code	Region Feature Code	Value Type	Value Range	Inform-ation	Import-ance

Table 3. The feature information table

4. DYNAMICAL REPRESENTATION OF EXTENDED FEATURES

The extended features extracted from multi-source remote sensing images are various and high-dimensional. Due to the correlations among the extended features, some of the features are redundant in the classification. Representation of all the extended features will reduce the efficiency of the system. Therefore, this paper uses a dynamical representation method. In the method, only the features related to the classification are represented. These features, which are needed to classify the object, are selected according to the basic spectral features of the object and the sample set. In this method, the features selected vary with the object. The data structure of the object represented by the dynamical method is shown in Figure 4. For each object, the object ID, the number of the features selected and the feature list are recorded. The feature list comprises of the name and value of each feature.

- Object
  - ID
  - Feature Number
  - Feature List

Figure 4. The data structure of the object represented by the dynamical method

In the selection of the extended features, the sample set is used to acquire the classification related features for each object. The process mainly consists of three steps:

1. All the features are extracted for the objects in the sample set. Then rule set is built up according to these features.
2. For each object, the features related to classification are selected by its basic spectral features and the rule set.
3. The selected features excluding the basic features are used to represent the object by recording their number and feature list.

In step 2, the features related to classification of each object are selected according to the rules which the object matches by the basic feature value of the object. For each rule, if the object matches it, the object may be classified to the corresponding class of that rule. If there are more than one rules which the object matches, the object may be classified to the corresponding multiple classes. Therefore, the involved features of the rules should be recorded in the representation of the object. The rule set table is shown in table 4. From it we can see that there are four kinds of features in the table: Feature1, Feature2, Feaure3, and Feature4. In the column of each kind of features, the feature values are recorded. Similarly, in the column of "Class" and "Rule Index", the corresponding class codes and the rule indexes are recorded. There may be some blanks in the table, which indicates that the corresponding feature is not involved in the corresponding rules. For example, the blank 1 (row1, column 4) and the blank 2 (row 2, column 4) are null, and that indicates that Feature 4 is not involved in rule 1 and rule 2. Let Feature1 and Feature 2 be the spectral features, Feature3 and Feature4 be the extended features. Take an object as an example, if the Feature 1 value of the object is 1, the Feature 2 value 1, then the matched rule indexes are 1 and 2. So the object may be classified to class 1 and class 2. From the table we can see that the rules 1 and 2 connect with Feature 3, Feature 1 and Feature 2, therefore Feature3 is selected to represent the extended feature of the object.

Feature 1	Feature 2	Feature 3	Feature 4	Class	Rule Index
1	1	1		1	1
		2		2	2
	2	4	1	1	3
			3	2	4
		5	2	2	5
	3		1	1	6
			3	3	7
			2	2	8
2	1	1		2	9
					10
		2	1	2	11
			2	3	12
	….				
…					

Table 4. Rule set table

5. REPRESENTATION OF THE COMPLEX RELATIONSHIPS AMONG OBJECTS

In the multi-source remote sensing imagery classification system, to meet the needs of the classification, multi-scale objects should be extracted by multi-scale image segmentation. A hierarchal object network can be established based on these different scale objects. It is shown in Figure 4.

In the real world, the relationships among objects are very clear and useful. In the hierarchal object network, the relationships among objects reflect the relationships among objects in the real world. Therefore the relationships among objects in the object-oriented remote sensing imagery classification system are useful for the automatic interpretation of the images. They should be clearly represented to get the valuable information for the image interpretation. At the same time, to meet the requirements of the hierarchal object network, the multi-scale segmentation should follow the two rules listed below.

1. Object borders must follow borders of objects on the next lower level.
2. Segmentation is constrained by the border of the object on the next upper level.

Therefore, in the representation of objects, the representation of the relationships among objects and the representation of the multi-scale objects should be taken into account. The two parts are discussed in the following text.

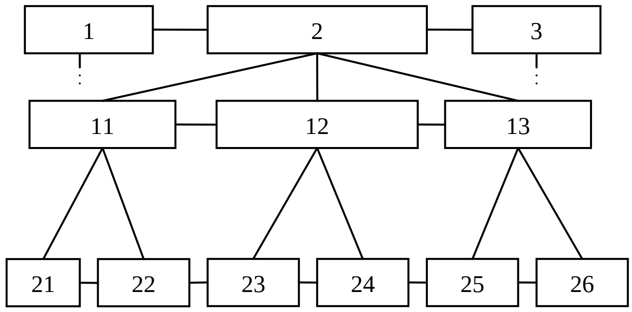

Figure 4. Three-level hierarchical network

5.1 Representation of the relationships among objects

There are two types of relationships in the hierarchal object network, one is the relationships among objects at the same level, and the other one is the relationships among objects at the different levels.

The relationships among objects at the same level mainly consist of the adjacency and including relationships. The including relationships refer to the condition that the represented object include the other objects. If the represented object is included in the other object, the relationship between them is regarded as an adjacency relationship of the represented object in the paper. As shown in Figure 5, the adjacency relationships among objects at the same level are represented by recording the number of objects which are adjacent to the object and these objects' ID. And the including relationships are represented in the same way.

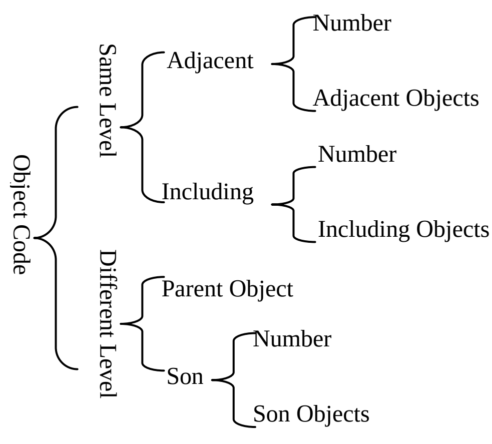

Figure 5. Object Relations

As shown in Figure 4, between two objects of the different scales there is parent-son relationship. For example, object 12 is the son object of the object 2, while object 2 is the parent object of object 12. Therefore, for the objects at the middle layers in the hierarchal network, two kinds of objects are recorded: the parent object at the upper level and the son objects at the lower level; for the objects at the top layer, only the son objects are to be recorded; for the objects at the bottom layer, only the parent object is to be recorded. Because for each object there is only one parent object, so the parent object is represented by the object ID. But for the son objects, both the number of son objects and the object ID are recorded, because for each object there are always many son objects. For example, in Figure 4, the parent object of object 12 is represented by recording the parent object ID 2, while its son objects are represented by recording the number of the son objects which is 2, and the object ID of each son object: 23 and 24. The structure of the representation is shown in Figure 5.

5.2 Adjusting Representation

In the course of the multi-scale segmentation, objects may be over-segmented or under-segmented. Therefore, objects which can not meet the requirements should be adjusted by two methods: merge and split. In the representation of object the two operations should be considered. The merge operation of objects is to combine some objects into one object, while the split operation of objects is to divide the object into many objects. For the convenience of representation, the merge and split operations should follow the two principles listed below.

1. The objects to be merged should have the same parent object.
2. The border of the object to be split should be consistent with the border of the son objects at the lower level, which means that the border of the son objects should not cross with the border of the object.

In the merge process, a new object is created. Then the son objects of all the merged objects are recorded as its son objects and the parent object of the merged objects is recorded as its parent object. As shown in Figure 4, if object 11, 12, 13 are merged to create a new object O, then the son objects of object O are object 21, 22, 23, 24, 25, 26, and the parent object is object 2.

In the split process, suppose the object is divided into n objects: O_1, $O_2 \ldots O_n$. Then the parent object of O_i is the split object, i = 1, 2… n. And the son objects of the new objects are recorded as their son objects. As shown it Figure 4, if object 2 is split into two objects, one of the objects O_1 includes the son object 11; the other object O_2 includes the son objects 12, 13. Then the parent object of the two objects is object 2, and the son object of O_1 is object 11 while the son objects of object O_2 are object 12 and object 13.

6. CONCLUSION AND FUTURE WORK

This paper studies the characteristics of objects and the problems of object representation in the object-oriented multi-source remote sensing imagery classification system and proposes the object representation method that represents the objects in a synthetic dynamic manner. It is valuable for the system to represent the objects in this method: because of representing the objects in vector and raster formats, the topologic analysis among objects and the transferring of object geometric definition among multi-source data become easy; the dynamic representing reduce the data redundancy and it improve the efficiency of the classification; by representing the complex relations among objects based on hierarchal objects network, the difficult of topological representing vanishes and we can get the semantic knowledge more effectively. In the method proposed in the paper, the representation of objects in the hyper spectral images is not involved. The hyper spectral images can provide very important information for the classification, the representation of them will be studied in the future.

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