World Engineering & Applied Sciences Journal 7 (2): 107-113, 2016
ISSN 2079-2204

DOI: 10.5829/idosi.weasj.2016.7.2.22623

A Generic Framework for Multiple and Multilevel Classification and Semantic Interpretation of Satellite Images

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Abstract: Remote sensing satellite images are rich, in providing information. Satellites are producing huge number of images and data at regular intervals. Satellite image classification is a powerful method to extract valuable information from massive satellite images. Satellite image classification is a process of grouping pixels/regions into meaningful categories. Many prominent researchers have proposed several satellite image classification methods. However, a hybrid approach of multilevel and multiple classifications would definitely produce more accurate results. The current research work describes ontology based multiple and multilevel generic framework for satellite image classification. The proposed framework has two phases 1) knowledge base construction 2) semantic interpretation using multiple and multilevel satellite image classification. First phase builds domain knowledge and rules through expert experiences. Ontologies are used to represent domain knowledge. Ontologies are, inevitable aspect of knowledge representation, processing, sharing and reuse and this itself is the essence and significance of ontology. Ontologies represent domain knowledge in machine understandable format. Second phase implements multiple and multiple image segmentation and group regions into meaningful categories with the support of domain knowledge and classification rules. Finally satellite image classification results are stored in RDF format. RDF provides a common structure and represents satellite image classification results in machine understandable format. RDF representation of classification results enables application interoperability, information exchange and semantic information retrieval etc.

Key words: Satellite image · Classification · Ontology · Knowledge Base and Semantic Interpretation etc

INTRODUCTION

The rapid development towards remote sensing technology became a major source of information [1]. Satellite images are rich in information. Satellite remote sensing technology collects data/images at regular intervals. The volume of data is growing at an exponential rate. The use of satellite data/images has increased in many application domains [2-4]: meteorology, agriculture, geology, forestry, regional planning, education, intelligence and warfare, oceanography, field study, environmental study, decision making and disaster management etc. Satellite remote sensing plays an important role in Geographic Information System (GIS).

To analyze, manage and retrieve satellite data, many prominent researchers have proposed several techniques. Satellite image classification is good technique to analyze, manage and retrieve satellite image. Satellite image classification is a task of grouping pixels or regions of satellite images into meaningful categories. Satellite image classification involves in interpretation of remote sensing images, spatial data mining studying various vegetation types such as agriculture and foresters etc. and studying urban and to determine various land uses in an area [5]. There are several satellite image classification methods, majority of the classification methods are automated. Experts use their knowledge and experiences to analyze and classify images. The expert knowledge is usually ambiguous. Formalization of expert knowledge, experiences and apply it in automated process is complex [6].

Semantic technology provides a powerful technique called ontology for effective and efficient representation of expert knowledge and their personal experiences. Ontology is a common, shared and formal description of concepts in specific domain [7]. Ontology provides

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domain vocabulary, domain knowledge, common understanding, sharability, information interoperability, reusability and supports semantic information retrieval. Ontologies represent knowledge in machine understandable format. Use of ontologies in satellite image classification improve the usability of satellite images and bridge the semantic gap between low-level features and high-level semantic concepts [8].

The current research work presents a semantic based generic framework for satellite image classification and interpretation. The proposed frame work has two phases 1) knowledge representation 2) satellite image classification and interpretation using multiple and multilevel classification process. Knowledge representation phase develops domain ontologies to represent spectral, spatial and temporal knowledge of satellite images of an application domain. The spectral knowledge describes pixel or region spectral information of various objects reside in the satellite image [9]. Spatial knowledge discusses relationship between pixels or regions of an image. Temporal knowledge describes factors such as season of the year, atmospheric effects on the satellite image. The proposed frame work interprets satellite image classification results in RDF [10] format. RDF provides a common structure for the classification information and presents in machine understandable format. It supports application interoperability and enables semantic retrieval on satellite images.

Rest of the paper is organized as follows. Section 2 describes current satellite image classification methods, limitations and open challenges. Section 3 illustrates proposed framework and section 4 gives conclusion and feature work.

Related Research Work: Satellite image classification is a task of grouping pixels into meaningful categories [11]. Many prominent researchers have proposed several satellite classification methods. Satellite classification methods can be broadly classified into three categories [12]: 1) Automated 2) Manual 3) hybrid. The major difference between three approaches is the way of grouping pixels into various meaningful categories. Automated classification methods classify satellite images without human intervention. In Manual methods, analyst involves in identifying grouping regions of image. Manual classification methods are time consuming, but produce more accurate results. Classification accuracy depends on the analyst knowledge about the area of study. Hybrid approach combines the best of both automated and manual classification method.

There are several satellite image classification methods. Majority of the classification methods fall under automated category. Automated classification methods further categorized into 1) supervised 2) unsupervised. Supervised classification methods classifies images pixels based spectral information obtained from training set [13]. Unsupervised classification groups pixels into unlabeled classes/clusters; further analyst assigns meaningful labels to the clusters. The current section discusses few recent automated satellite image classification methods.

[14] describes a satellite image classification and interpretation method. This method uses control knowledge for classification and interpretation. Controlled knowledge determines the level to be analyzed for the scene interpretation. The controlled knowledge is represented using predefined rules. It interprets satellite image by extracting spectral, spatial and temporal features and their corresponding labels. However, exchanging of interpretation is complex.

Xinwei Zheng *et al.,* [15] proposed a supervised satellite image annotation method using spatial relationship between image pixels. The method takes a set of images for every category as a training set. It groups image pixels into meaningful categories using by comparing pixel patterns in training set and spatial relation between pixels. The method uses multifeature joint sparse coding (MFJSC) technique to identify common pixel patterns in satellite images. MFJSC involves many complex calculations.

[16] describes ontology based supervised ocean satellite image classification method. This method illustrates power of ontology in ocean satellite image classification. The method extracts low level features from ocean satellite images and is represented in owl file format. Owl file is merged with domain ontologies and labeling rules. Labeling rules, training rules, binary decision tree rules and expert rules are represented using SWRL [17] language. The method produces classification results of ocean satellite image with the support of training, human expert, decision support and labeling rules. [16] also provides a tool, as plug-in for protégé ontology editor. The tool supports ocean satellite images with the support of domain ontologies. But the method is domain dependent.

G. Forestier *et al.,* [18] discussed a remote sensing image annotation and interpretation method for coastal images. The objective of the approach is to assign semantic labels to various regions of a satellite image. The method derives knowledge from experts on to different object classes, spectral information and is represented in an ontology. The method classifies regions in two phases.

Phase 1 classifies image regions based knowledge reside in the ontologies. Phase 2 checks the consistency of the spectral information and identifies mislabeled regions. The method revises annotation results in an iterative process to produce more accurate results. This method does not consider spatial and temporal knowledge in satellite image interpretation process and it is domain specific.

[19] Presents knowledge base building process for urban objects. The developed knowledge base is used to perform the interpretation of high spatial resolution satellite images and to convert segmented regions into semantic objects. The main motivation behind this method is to help urban planners to automatically map the land/regions to specific classes. This method is also domain specific and the knowledge base does not include temporal features.

[20] Discusses an approach that uses ontologies for remote sensing images. In these method ontologies describes concepts, spectral, pseudo-spectral and textural features of remote sensing images. The method uses image ontology. Image ontology describes image segments using spectral, pseudo-spectral and textural features. Remote sensing knowledge resides in the ontologies supports identification of regions of a class in the satellite image. Spatial and temporal features of satellite images are ignored in this method.

A detailed study on the recent satellite image classification methods concludes that though there are several classification methods. However, a hybrid approach of multilevel and multiple classifications would definitely produce more accurate results. Limitations of the current satellite image classification methods are:

- Many of the classification methods are domain specific
- Lack of semantics between low-level features and high-level concepts
- Exchanging classification results between applications is complex

The following are open challenges in satellite image classification.

- Improve satellite image classification accuracy
- Identifying most targeted regions of interest in satellite images [6].
- Semantic interpretation of satellite image classification
- Exchange of classification results between applications (Application interoperability)
- Semantic retrieval

The current research work proposes satellite image classification framework to address the above challenges. The proposed framework is a robust, generic, semantic based, multiple and multilevel classification method. It builds spectral, spatial and temporal knowledge using ontologies and applies on satellite image classification and interpretation.

Proposed Approach: The proposed satellite image classification framework is a generic and semantic technology based approach. It falls under supervised classification technique. Supervised Satellite image classification technique requires a training model to analyze and classify satellite images. The current framework uses expert/analyst knowledge for classification. It represents domain and expert knowledge using ontologies. Ontologies represent domain and expert knowledge in machine understandable format. Further ontologies guide the classification system.

The proposed classification framework can be divided into two phases. 1) Knowledge base construction 2) Multiple and multilevel satellite image classification.

Knowledge Base Construction for Satellite Image Classification: Knowledge base construction for satellite image classification is an iterative process. Fig. 1 Shows knowledge base construction process for satellite image classification. The knowledge base consists domain ontologies and rules. Domain ontologies defines concepts, concept hierarchy, semantic relationship between concepts, features of every concept (spectral, spatial and temporal) and their acceptable rages. Following are the steps involved in proposed knowledge base construction process.

Step 1: Concept Identification. This step includes identification of the following:

- Concepts of the domain
- Semantic relationship between concepts
- Spectral, spatial and temporal features of every concept
- Acceptable ranges for every spectral, spatial and temporal features

The concepts of domain can be obtained from domain experts. Concepts can also be derived from top-level ontologies.

Step 2: Define concept hierarchy and semantic relationship between concepts

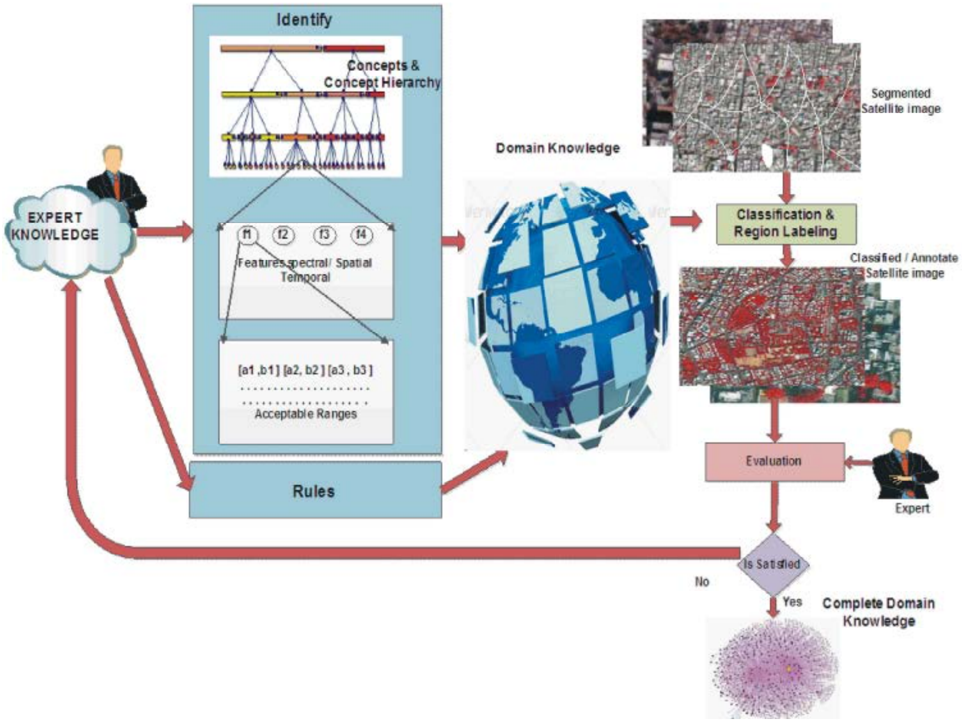

Fig. 1. Knowledge base build process

Step 3: Define association spectral, spatial and temporal features to every concept in the hierarchy and their acceptable ranges.

Step 4: Define rules to determine semantic concept for satellite image regions using experts experience. Rules use contextual and geometric information to determine edges of objects.

Step 5: The constructed knowledge can be applied for satellite image classification and region labeling.

Step 6: Evaluation of classification results. Experts evaluate accuracy of the satellite image classification.

Step 7: Building knowledge base is an iterative process and process needs to be continued until the results are satisfactory by taking concerns from domain experts.

Knowledge base construction process repeats until acceptable satellite image classification results are obtained.

Protégé [21] and Neon tool kit [22] are more popular ontology development tools [23]. Protégé and Neon tool kit are used to create ontologies and build knowledge base.

Satellite Image Classification and Semantic Interpretation: The main objective of the proposed satellite image classification and semantic interpretation provides robust and generic satellite image classification framework provides the below features:

- To provide better classification accuracy
- Multiple and multilevel classification of satellite images using spectral, spatial and temporal knowledge
- Semantic interpretation of classification results
- Represent classification results in machine understandable format
- Enable application interoperability
- Enable semantic retrieval

Fig. 2 shows framework of the proposed satellite image classification and semantic interpretation. The proposed framework takes input from satellite imagery. Multiple and multilevel classification method is applied on the raw satellite images with the support of predefined knowledge base and rules. Section 3.3 illustrates multiple and multilevel satellite image classification. Finally classification results are stored in RDF triple format. RDF [10] provides a universal format (triple) to represent image classification information. It represents data in machine

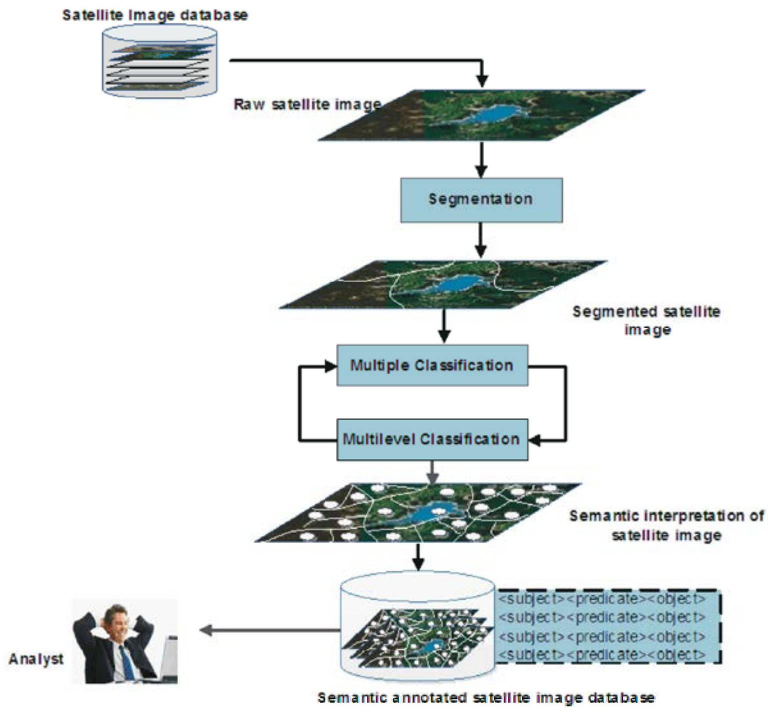

Fig. 2: Framework for satellite image classification and semantic interpretation

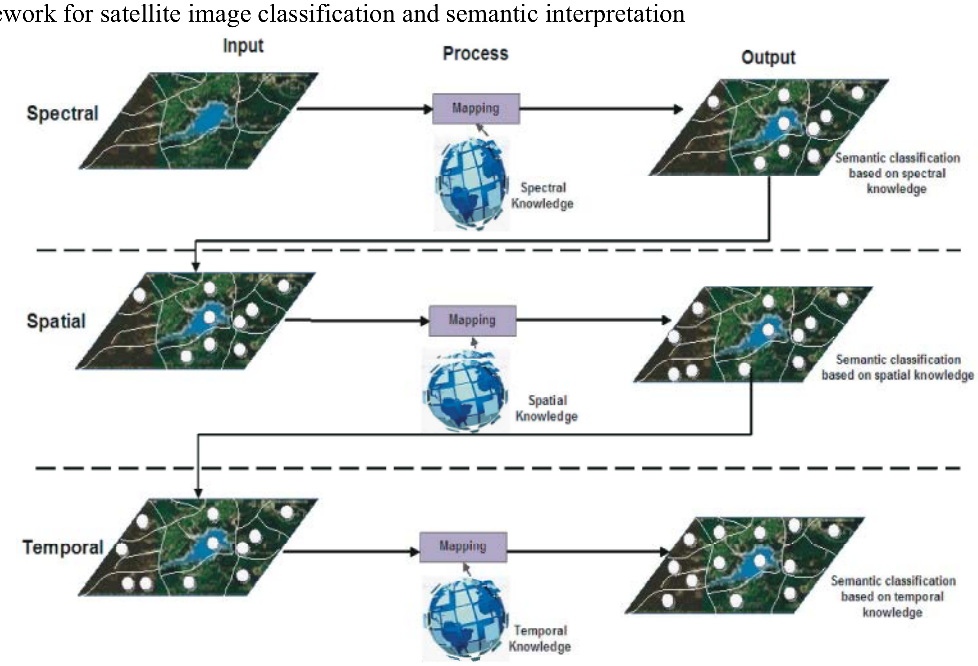

Fig. 3: Multiple segmentation and classification of satellite image

understandable format. RDF enables information exchange between applications, application interoperability and semantic information retrieval.

Multiple and Multilevel Classification: Multiple and multilevel classification of satellite image is an iterative process. Following steps illustrate multiple and multilevel segmentation process. Fig. 3 shows proposed multiple segmentation and classification process.

Step 1: Initially the classification takes raw satellite image, divides into various regions using any satellite image segmentation tool such as eCognition [24] and ERADAS Imagine [25] etc.

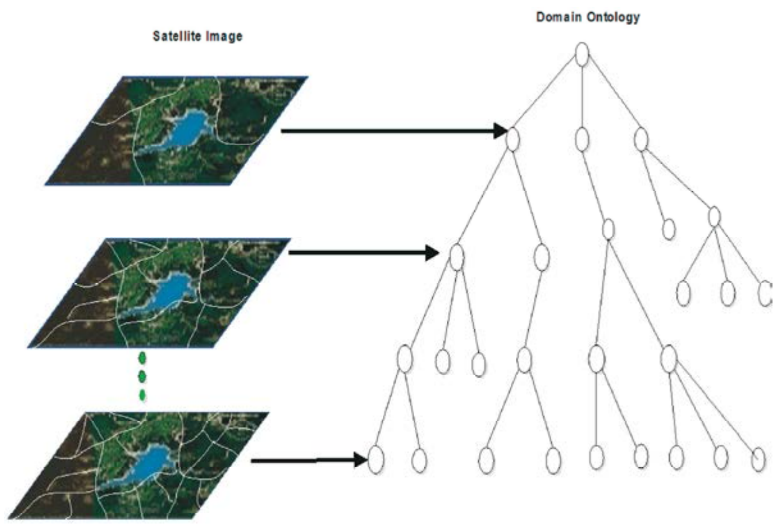

Fig. 4. Mapping Satellite Image Regions to Concepts

Step 2: Extracts spectral features of the regions and categorizes regions by comparing extracted feature values with the acceptable ranges of spectral features of domain ontology abstract concepts. This step identifies and groups homogeneous pixels based on spectral information [26].

Step 3: Extracts spatial features of the regions and categorizes regions by comparing extracted feature values with the acceptable ranges of spatial features of domain ontology high-level concepts.

Step 4: Extracts temporal features of the regions and categorizes regions by comparing extracted feature values with the acceptable ranges of temporal features of domain ontology high-level concepts.

Step 5: Classification method repeats this process for all the levels of concept hierarchy in the domain ontologies as shown in the Fig. 4.

The framework produces classified satellite image. In this all regions are associated with leaf/low-level concepts of domain ontologies. Semantic interpretation part of the proposed framework represents all region features in RDF format and maps to the respective domain ontology concept. It enables semantic inference mechanism on the knowledge base and semantic retrieval of satellite images.

CONCLUSION

The current research work describes a generic framework for ontology based satellite image classification and interpretation of satellite images. The proposed frame work uses spectral, spatial and temporal knowledge for satellite image classification. The framework represents domain knowledge using ontology. The framework introduced a multiple and multilevel satellite image classification method with the support of domain knowledge. The satellite image classification results are stored in RDF format. The framework represents classification information in machine understandable format and enables application interoperability, information exchange and semantic information retrieval on satellite imagery. Future research work includes implementation and evaluation of the proposed framework.

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