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DESIGN AND IMPLEMENTATION OF A HIGH SPATIAL RESOLUTION REMOTE SENSING IMAGE INTELLIGENT INTERPRETATION SYSTEM

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ABSTRACT

Very high spatial resolution remote sensing images have applications in many fields. However, research on the intelligent interpretation of such images is insufficient partly because of their the complexity and large size. In this study, a high spatial resolution remote sensing image intelligent interpretation system (HSR—RSIIIs) was designed with image segmentation, a geographical information system, and a data-mining algorithm. Some key methods such as image segmentation, feature extraction, feature selection, and classification algorithm for interpreting high spatial resolution remote sensing image have been studied. A land cover classification experiment was performed in the Zhuzhou area using a Quickbird multi-spectral image. The classification results were consistent with the visual interpretation results. In additional, the proposed interpretation method was compared with the traditional pixel-based method. The results indicate that the method proposed in the literature is more effective and intelligent than that used previously.

Keywords: High spatial resolution, Remote sensing, Intelligent interpretation, Mean shift, Land cover

1 INTRODUCTION

As important information sources, remote sensing images are playing an increasing role in many fields, such as environmental monitoring, resource investigation, precision agriculture, urban planning, and management. With the development of remote sensing technology, an increasing amount of very high-resolution imagery of astonishing quality provided by new space-borne sources has entered the remote sensing market. It is characterized by high user interpretability, rich information content, sharpness, accuracy, high image clarity, and integrity. The common remote sensing image processing software systems (for example, ERDAS IMAGINE, ENVI, PCI, ERMAPPER) are not suitable for high spatial resolution remote sensing images (Benz et al., 2004; Gu et al., 2005; Naumann & Siegmund, 2004; ShengTian et al., 2004). The traditional pixel-based classification method (see Figure 1) cannot provide satisfactory results and may reduce the classification accuracy, because the problem of mixed pixels is indeed reduced, but the internal variability and the noise within land cover classes are increased with the improved spatial resolution. Therefore, the object-oriented image analysis for extraction of information from remote sensing data has become of interest. Since the first commercially available software product, eCognition, for object-oriented image analysis was developed, it has been successfully utilized in many fields (Benz et al., 2004; Gu et al., 2005; Poon et al., 2005; ShengTian et al., 2004; Yin et al., 2005). The classification process is based on fuzzy logic, to allow the integration a of broad spectrum of different object features such as spectral values, shape, or texture for classification. It extracts labeled polygons from remote sensing images for updating GIS databases. The processing procedure in the image processing system does not do full justice to the GIS visual and man-machine interactive abilities.

The existing constraints on automated data interpretation are so profound that an efficient integration of remote sensing and GIS is still a matter for research and development. The automated allocation and extraction of real world geographic objects from high resolution remotely sensed data is the central challenge for both the remote sensing and the GIS communities within the next few years.

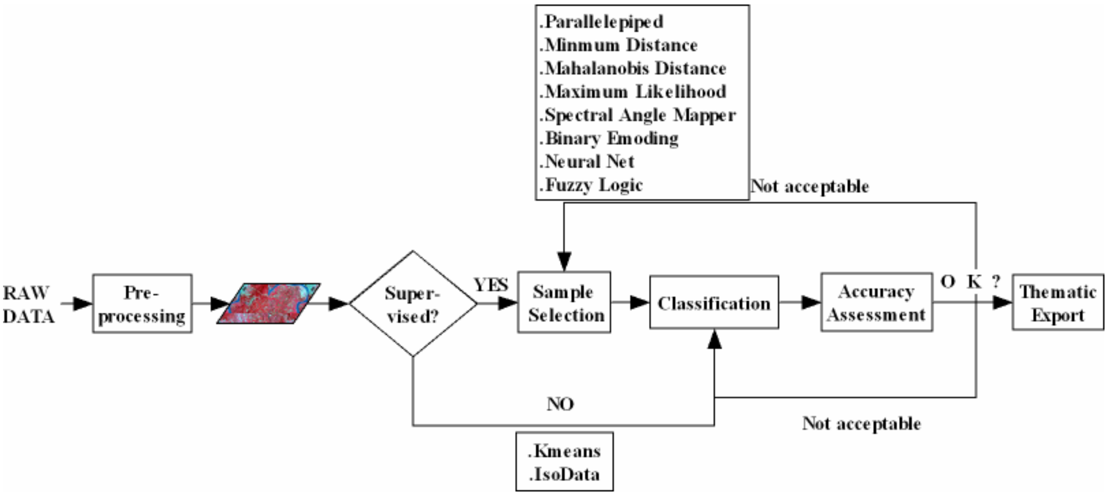

Figure 1. Traditional pixel-based classification basic flow

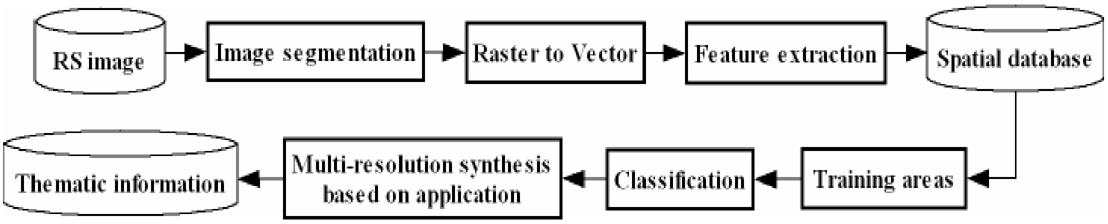

Figure 2. The general framework of Object- oriented image intelligent interpretation system

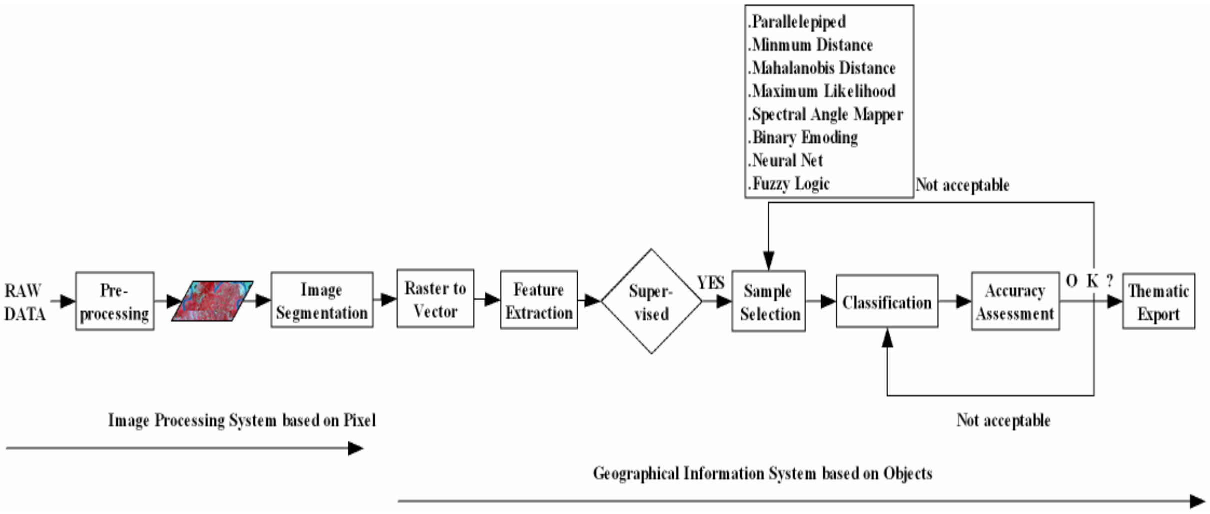

Figure 3. High-spatial resolution RS image intelligent interpretation system framework

In this paper, we present a new framework for an object oriented remote sensing image intelligent interpretation system. It synthesizes an image processing system (pixel-based), a geographical information system (vector-based), and data mining (intelligent computing) technology's strong points to interpret images from pixels to segments and to thematic information (see Figure 2 and Figure 3).

The rest of the paper is organized as follows. The next section looks at the image segmentation and introduces a robust and fast segmentation algorithm based on mean shift. Section 3 introduces the importance of feature extraction and selection and how to extract feature attributes from segments. Section 4discusses how data mining technology can be used for classification algorithms in geographical information systems; this work will add to the system intelligence. In section 5, in order to verify the feasibility and effectiveness of the system, we compare two different image interpretations for a Quickbird image. Finally, section 6 provides the conclusion and future directions of the study.

2 IMAGE SEGMENTATION

Image segmentation is the subdivision of an image into separated regions (Xu et al., 2004). For many years, procedures for image segmentation have been a main research focus in the area of image analyses, and many different approaches have been followed. However, few of them lead to qualitatively convincing results that are robust and applicable under operational settings. For example, region-growing algorithms cluster pixels starting from a limited number of single-seed points(Yu & Wang, 1999). These algorithms basically depend on the set of given seed points and often suffer from a lack of control in the break-off criterion for the growth of a region.

Among the various approaches for image segmentation, the mean shift algorithm has been actively regarded as one of the classic methods. It is an extremely versatile tool for feature space analysis because of its simplicity and robustness, and it is widely used in clustering, tracking, segmentation, discontinuity preserving smoothing, filtering, edge detection, and information fusion (Comaniciu & Meer, 1999; Comaniciu & Meer, 2002; Duan et al., 2004; Friedman et al., 2003; Li et al., 2005).

The mean shift procedure is an adaptive local steepest gradient ascent method. The mean shift vector is computed by the following formula:

$$m_{h,G}(\mathrm{X}) = \frac{1}{2} h^2 c \frac{\hat{\nabla} f_{h,K}(\mathrm{X})}{\hat{f}_{h,G}(\mathrm{X})} \qquad (1)$$

While $\hat{f}(X)$ is kernel density estimator, h is bandwidth parameter, $K(X)$ and $G(X)$ are kernel functions, The expression (1) shows that, at location X, the mean shift vector $m_{h,G}(\mathrm{X})$ computed with kernel G is proportional to the normalized density gradient estimate obtained with kernel K. the normalization is by the density estimate in X computed with the kernel G. the mean shift vector thus always points toward the direction of maximum increase in the density (Comaniciu & Meer, 2002).

An image is typically represented as a two-dimensional lattice of $p-$dimensional vectors (pixels). The space of the lattice is known as the spatial domain, while the gray level, color, or spectral information is represented in the range domain. When the location and range vectors are concatenated in the joint spatial-range domain of dimension $d = p + 2$, the multivariate kernel is defined:

$$K_{h_s,h_r}(\mathrm{X}) = \frac{C}{h^2{}_s h^p{}_r} k\left(\left\|\frac{\mathrm{X}^s}{h_s}\right\|^2\right) k\left(\left\|\frac{\mathrm{X}^r}{h_r}\right\|^2\right) \qquad (2)$$

where X^s is the spatial part, X^r is the range part of a feature vector, $k(x)$ the common profile used in the two domains, h_s and h_r the employed kernel bandwidths, and C the corresponding normalization constant. The quality of segmentation is controlled by the spatial h_s and the color h_r. The segmentation algorithm has two major steps:

the discontinuity preserving image filter and region fusion (Comaniciu & Meer, 2002). The precision of segmentation is controlled by three physical scale parameters（h_s - spatial scale, h_r - color scale, M- minimum area scale), with the scale parameters selected from bottom up, the regions are fused into bigger ones (see Figure 4).

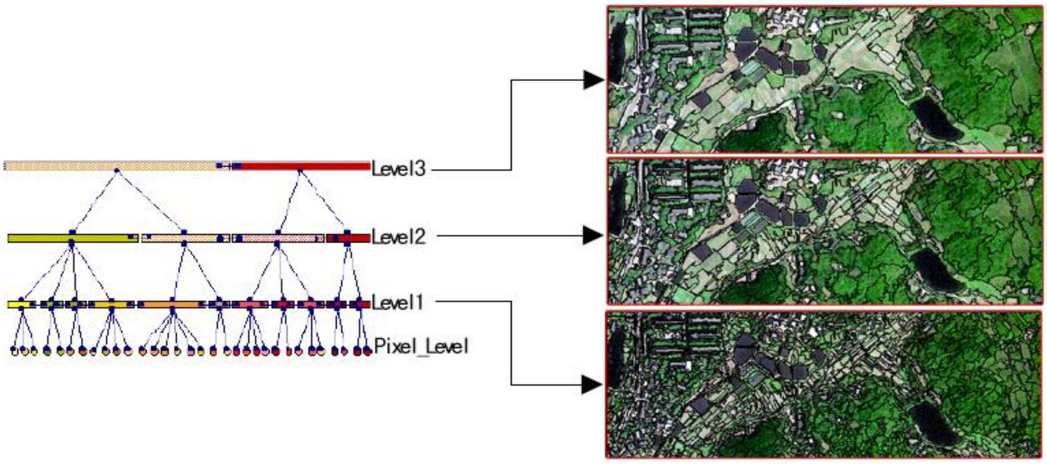

Figure 4. The hierarchical network of multi-scale segmentation image objects

3 FEATURE EXTRACTION AND SELECTION

Segmentation is not an aim in itself. The purpose of image interpretation can be a land cover classification or the extraction of objects of interest. However, objects of interest can in many cases be of considerable heterogeneity. The object oriented approach is therefore intended to focus on image object primitives, serving as information carriers for further classification. In this sense, the best segmentation result is one that provides optimal information for further processing.

In the HSR—RSIIIs, all the feature attributes are extracted in the geographical information system environment. The segmented image is converted into polygon features. Then with zonal analysis, statistical properties, such as histograms and max, min, mean and standard deviation features, are calculated for each polygon from raw raster and texture raster layers etc. Beyond spectral information, shape information, and texture information are extracted readily. Based on this already extensive set of features, arbitrary features can be combined using different arithmetic operations. Therefore, classification can address an astonishingly broad spectrum of different kinds of information. The raster image is a reference layer, and the vector polygons are the operated objects. As a HSR—RSIIIs main component, geographical information systems make a remote sensing image interpretation process in a visual and man-machine interaction environment, and the sample selection and training processing process is convenient and swift.

A major problem associated with image interpretation is the so-called curse of dimensionality; the number of features at the disposal of the designer of a classification system is usually very large, and there are several reasons to reduce the number of features to a sufficient minimum. Computational complexity is the obvious one. In the HSR—RSIIIs, the feature selection process is sample training for a specific application. The attribute database and spatial database are selected synchronously, which means “What You See Is What You Get.”

4 CLASSIFICATION

Classification methods can be separated into supervised and unsupervised methods. While supervised methods ask the user how the desired classes look, unsupervised methods are almost user independent. They rather can be seen as statistical grouping methods, sorting objects by their properties into clusters with similar properties. While unsupervised methods work almost automatically, supervised methods have to be trained by the user – usually either by taking samples or by describing the classes' properties. Therefore, the class-describing information must be as accurate, representative, and complete as possible, which is in most cases effectively impossible.

Data mining technologies are introduced into the HSR—RSIIIs to improve remote sensing image classification because of the shortage of clustering and classification algorithms in geographical information systems. Data mining will improve system intelligence.

In the HSR—RSIIIs, many kinds of classic classifiers (e.g. maximum-likelihood, minimum-distance, or parallelepiped) (Yoon et al. 2004). and many new methods such as neural network, fuzzy logic, support vector machines, etc. can be adopted readily. Segmentation drastically reduces the sheer number of units to be handled for classification. Even if a good deal of intelligence is applied to the analysis of each individual image object, the classification works relatively fast, and the object oriented approach, which first extracts homogeneous regions and then classifies them, avoids the annoying salt-and-pepper effect.

The higher interpretation level is a multi-resolution synthesis based on the application. For instance, the evergreen needle forest, evergreen needle-evergreen broadleaved forest, and broadleaved forest are forestland in the land cover classification.

5 A LAND COVER CLASSIFICATION EXPERIMENT

In order to verify the feasibility and effectiveness of the proposed interpretation method, a study area was selected in Zhuzhou city, Hunan province, P. R. China. A Quickbird image with 2.44 meter in multispectral bands and 0.61 meter in panchromatic band was acquired in august of 2002, under clear sky conditions. First, the pseudo color image was generated using 3 (2+4)/2 combined with 2 multispectral bands and sharpened with a panchromatic band (1024*1024) (see Figure 5). In order to compare the proposed method and the pixel-based method, only the spectral mean feature of objects was selected in the land cover information extraction. The proposed segmentation method based on mean shift generated 1106 segments with (h_s =10, h_r =6.5 and M =250); the classification was conducted by the Maximum Likelihood method. Five classes (e.g. water, grass, trees, buildings, concrete floors) were generated by the HSR—RSIIIs-based and pixel-based methods. The proposed method was a bit faster when applied to the Quickbird images and got a far more satisfactory result (see Figures 5-7).

Figure 5. Quickbird image of study area

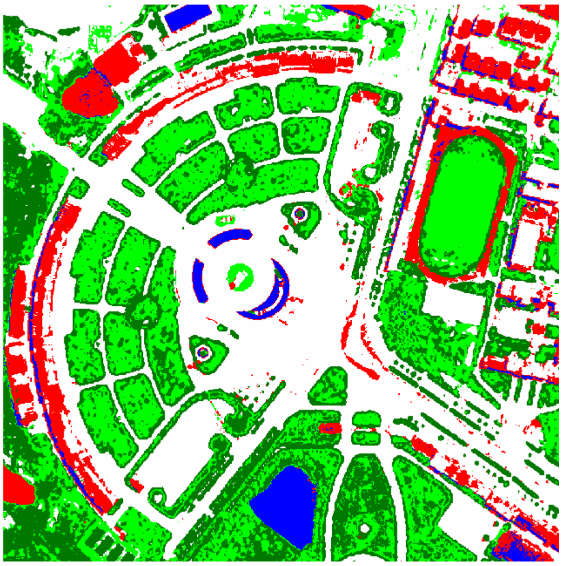

Figure 6. Pixel-based land cover classification

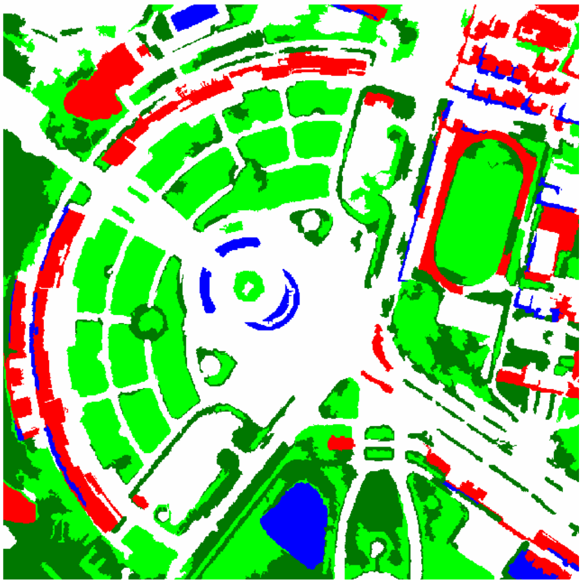

Figure 7. HSR—RSIIIs-based land cover classification

6 CONCLUSION

In this paper, a high spatial resolution remote sensing image intelligent interpretation system (HSR—RSIIIs) was designed combining image segmentation, a geographical information system, and a data mining algorithm using key methods such as image segmentation, feature extraction, feature selection, and a classification algorithm for interpreting high spatial resolution remote sensing images. Practices proved the HSR—RSIIIs is effective and intelligent. Compared with pixel-based classification; the proposed method is faster than the “salt and pepper” effect and the intelligent interpretation results are consistent with the visual interpretation ones. This method has great potential in high spatial resolution remote sensing information intelligent extraction, and it will be applied in many fields.

The geographical information system is HSR—RSIIIs' main component; it makes the remote sensing image interpretation process in a visual and man-machine interaction environment. Segmentation and data mining are very important, and they directly affect the interpretation accuracy. The next work is to choose and develop more promising segmentation and data mining algorithms for remote sensing intelligent interpretation.

7 ACKNOWLEDGEMENTS

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