A Method to Improve the Accuracy of Remote Sensing Data Classification by Exploiting the Multi-Scale Properties in the Scene

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Abstract. Land use mapping is one of the major applications of remote sensing. While most studies focus on the advanced remote sensing thematic classification algorithms for land use mapping, the scale factor in remote sensing data classification was less recognized. Previous studies showed that while the multi-scale characteristics exist in the remotely sensed data for land use classification, some classes are mostly accurately classified at a finer resolution, and others at coarser ones. Thus, it is helpful to improve the overall classification accuracy by mapping different land use classes at different scales. In this paper, a framework for improving the land use classification accuracy by exploiting the multi-scale properties of remotely sensed data is presented. Firstly, the remotely sensed data at original fine resolution was up-scaled to different coarser resolutions; Secondly, the up-scaled data were classified by independently trained Maximum Likelihood Classifier at every resolution, and the corresponding a Posteriori Probability of MLC classification was saved; Thirdly, the classification results at different resolutions were integrated by comparing the a Posteriori Probability of classification at every resolution. The final class of pixel was labeled as the class that has the maximum a Posteriori Probability. A case study on the land use mapping using Landsat TM data using this framework was conducted in the Dianchi Watershed in Yunnan Province of China. The land use was categorized into 6 classes. The classification accuracy was assessed using the Confusion Matrix. Comparison between the classification accuracy at multi-scale and that at original resolution showed an improvement of overall classification accuracy by about 10%. The study showed that by exploiting the multi-scale properties in the remotely sensed data, the accuracy the land use mapping can be improved significantly.

Keywords: remote sensing, classification, multi-scale characteristics, uncertainty, land use

1. Introduction

Land use mapping is one of the major applications in remote sensing. How to accurately acquire the land use information by classifying remotely sensed data have been extensively studied in the past decades of time. While most of the studies in land use classification focused on developing new classification algorithm such as artificial neural network and Support Vector Machine (SVM), some others focused on incorporating ancillary data into the classification feature space so that the classes can be more easily discriminated. While many features such as textures, NDVI et al., have been used for land use mapping, the multi-scale feature is attracting more and more interests.

Present satellite data are able to provide remotely sensed data with spatial resolution ranges from less than 1m to nearly 100 kilometres. When users try to use these remotely sensed data, it is natural that one has to choose the data with optimal spatial resolution so that the thematic information extracted from it contains the least uncertainty. Among the factors such as spectral resolution, training strategies and classification

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algorithm, the scale factor is one of the most important factors that influence the uncertainty of thematic information derived from remotely sensed data.

In remote sensing, the spatial scale refers to the spatial resolution of remotely sensed data. The effect of spatial scale in remotely sensed data classification has been recognized since 1980’s. Woodcock et al. (1987) analyzed the scale effect of remote sensing data classification by using the local variance analysis. It showed that the local variance reaches its maximum while the size the object is almost equal to the pixel size. Arbia et al. (1996) pointed out that the scale effect in remote sensing is a special case of the Modifiable Areal Unit Problem (MAUP) in scale research. He studied the scale effect in the Maximum Likelihood Classification of remote sensing data using the simulated imagery. The results showed that the classification error increase while the spatial resolution of remote sensing data become coarser. The scale effect is most significant in the boundaries between thematic classes. No single optimal spatial resolution exists for all classes in complex landscape classification (Marceau et al., 1994a; 1994b). Bo et al. (2003) explored the scale effect in remote sensing data classification by using the statistical separability of features and pointed out that, the scale effect of separabilities between classes were highly related to the spatial patterns of classes in the scene. Finer spatial resolution does not definitely lead to higher classification accuracy.

Due to the scale effect in remote sensing data classification, for the complex landscape, classification accuracy of some classes is high at high resolution, and some others at low resolution. Integrating multi-scale remote sensing data for classification is a natural way to improve the accuracy in land use mapping. Chen (2003) presented a strategy to integrating multispectral remote sensing data with different spatial resolution to improve the land use classification accuracy. However, acquiring remote sensing data with different spatial resolution increase the cost of land use mapping. In addition, because the satellite data with different spatial resolution also have different spectral band configuration and spectral resolution, the improvement of integrating multi-scale remote sensing data is hard to be rigorously evaluated.

In this paper, an approach to integrating multi-scale properties in remote sensing data for land use mapping is presented. Instead of using remote sensing data from different sensors, the multiple resolution remote sensing data was acquired by aggregating the high spatial resolution data to different spatial resolution. The benefit of the method is that the spectral band configuration and spectral resolution of original high spatial resolution data is preserved. The resampling method used in this paper is the cubic convolution resampling.

2. Principles and Methods
2.1 Acquisition of Multi-scale remote sensing data
Instead of using multispectral remote sensing data with different spatial resolution acquired from different sensors, the multi-scale remote sensing data were acquired by re-sampling the high spatial resolution data to different spatial resolution. The benefit of the method is that the spectral band configuration and spectral resolution of original high spatial resolution data is preserved. The resampling method used in this paper is the cubic convolution resampling.

2.2 Method of integrating multi-scale data for classification
The method of integrating multi-scale remote sensing data for classification has two basic steps. Firstly, the multi-scale remote sensing data obtained using resampling were independently trained and classified. Secondly, the classified results from multi-scale remote sensing data were integrated using an optimal decision method. To integrate the results from multi-scale data classification, an integration criterion should be premeditated. In this paper, the posteriori probability in the classification of every scale data was chosen as the integration criterion. The posteriori probability was obtained in the process of the Maximum Likelihood Classification (MLC) of remote sensing data. The pixel to be classified is labeled as the class that has the maximum posteriori probability. The integration method based on the posteriori probability is illustrated in Figure 1.
2.3 Integration strategy in multi-scale data for classification

To integrate the classification results of remote sensing data at multi-scale based on the posteriori probability, a “bottom-to-top” integration strategy was used. In this strategy, for a pixel to be classified, if the posteriori probability of the classification highest spatial resolution is equals to the maximum posteriori probability at all resolutions, the pixel was labeled using the label classified at the highest spatial resolution data. If the posteriori probability of the classification highest spatial resolution is less than the maximum posteriori probability at all resolutions, then the posteriori probability at the coarser resolution is compared to the maximum posteriori probability at all resolutions. The comparison process was repeated until find the scale at which the posteriori probability equals to the maximum posteriori probability at all resolutions, and the pixel was labeled using the label classified at the scale at which it has the maximum posteriori probability.

Assume the original multispectral remote sensing data was resampled to N resolutions. The spatial resolution was ranked from high to coarse as: R1, R2, ..., Rn. The classified results and the corresponding posteriori probability were noted as C1, C2, ..., Cn and P1, P2, ..., Pn respectively. Let Pmax=Max(P1, P2, ..., Pn), where the Max prefer to the Maximum of (P1, P2, ..., Pn). The integration strategy can be described as follow:

\[
\text{If } P_1 = P_{\text{max}} \\
\quad C = C_1 \\
\text{Else if } P_2 = P_{\text{max}} \\
\quad C = C_2 \\
\quad \ldots \\
\quad \text{Else if } P_i = P_{\text{max}} \\
\quad C = C_i \\
\quad \ldots \\
\quad \text{Else if } P_{n-1} = P_{\text{max}} \\
\quad C = C_n \\
\quad \text{Else} \\
\quad C = C_n \\
\text{End if} \\
\quad \ldots \\
\quad \text{End if} \\
\text{End if} \\
\]

3. Data and Results

To examine the effectiveness of the multi-scale remote sensing data classification in improving accuracy of land use mapping, the Lansat-5 Thematic Mapper data in Dianchi watershed, Yunnan Province, China was used to conduct the multi-scale classification. The data was acquired in 1990. the original data with 30m spatial resolution was resampled to the spatial resolution of 60m, 90m, 120m, 180m, 270m and 360m respectively by the cubic resampling technique. The multi-scale TM data was independently trained and classified using the Maximum Likelihood Classifier. besides the classification results, their corresponding posteriori probability were saved. The classification results were assessed by using the Error Matrix method.
The reference data in accuracy assessment is from the China Land Use Database. Because the classification were conducted at different scale, to compare the classification results and their posteriori probability, the classification results and posteriori probability have to be transformed to the original resolution. To preserve the value of the classification results and posteriori probability at different scale, the data were transformed to original resolution by splitting one pixel into N pixel without changing any pixel value. The transformation process was illustrated in Figure 2.

![Image](image1)

Fig. 2. Illustration of the information transformation from coarse resolution to fine resolution

![Image](image2)

Fig. 3. The classified results of the data with different spatial resolution

<table>
<thead>
<tr>
<th>Spatial Resolution</th>
<th>30m</th>
<th>60m</th>
<th>90m</th>
<th>120m</th>
<th>180m</th>
<th>270m</th>
<th>360m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa Statistics</td>
<td>0.4712</td>
<td>0.4402</td>
<td>0.4158</td>
<td>0.4349</td>
<td>0.4662</td>
<td>0.4154</td>
<td>0.4150</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>0.5593</td>
<td>0.5311</td>
<td>0.5113</td>
<td>0.5282</td>
<td>0.5537</td>
<td>0.5113</td>
<td>0.5113</td>
</tr>
</tbody>
</table>

Table 1. The accuracy of the classification at different spatial resolution

The classification results of the TM data at multi-scale were presented in Figure 3. The accuracy of the classification at every spatial resolution was shown in Table 1. Table 1 showed that the classification accuracy changes while the spatial resolution of the data changes, but high spatial resolution does not definitely lead to high classification accuracy.
The multi-scale classification integration experiments were conducted by integrating the classification at original TM spatial resolution with different number of coarser spatial resolution. The results and their accuracy were presented in Figure 4 and Table 2 respectively.

![Fig. 4. The classification results by integrating different spatial resolution data](image)

**Table 2. The accuracy of classification in integration of multi-scale remote sensing**

<table>
<thead>
<tr>
<th>Experiment No.</th>
<th>The spatial resolution of the data</th>
<th>Kappa Statistics</th>
<th>Overall Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30m, 60m</td>
<td>0.5097</td>
<td>0.5932</td>
</tr>
<tr>
<td>2</td>
<td>30m, 60m, 90m</td>
<td>0.5299</td>
<td>0.6102</td>
</tr>
<tr>
<td>3</td>
<td>30m, 60m, 90m, 120m</td>
<td>0.5603</td>
<td>0.6360</td>
</tr>
<tr>
<td>4</td>
<td>30m, 60m, 90m, 120m, 180m</td>
<td>0.6021</td>
<td>0.6695</td>
</tr>
<tr>
<td>5</td>
<td>30m, 60m, 90m, 120m, 180m, 270m</td>
<td>0.5513</td>
<td>0.6271</td>
</tr>
<tr>
<td>6</td>
<td>30m, 60m, 90m, 120m, 180m, 270m, 360m</td>
<td>0.5430</td>
<td>0.6186</td>
</tr>
</tbody>
</table>

Compare the Table 2 to the Table 1 shows that all the experiments of multi-scale remote sensing data classification integration can improve the classification accuracy. The overall accuracy and the Kappa Statistics can be improved by 4-11% and 3-13% respectively. Meanwhile, it was showed that more scale of data being integrated does not mean higher accuracy. When the number of scale of data is small, the classification accuracy increases with the number of scale of data increase. However, when the number of scale of data is larger than a threshold, the classification accuracy decrease with the number of scale continuously increases. This phenomenon is reasonable in theory. When the spatial resolution of data become coarser, the within class variance decreases so that the separability between classes increase and the...
posteriori probability of the classification increase, thus the classification accuracy increase. However, when the spatial resolution of data become coarser than a threshold, some objects in the imagery will aggregated with adjacent pixels and could be classified as other classes with high posteriori probability, which makes the accuracy of final classification that integrated very coarse spatial resolution data decrease. For a given landscape, there exists a threshold scale. In this experiment, the maximum classification accuracy appears in the integration of data with spatial resolution from 30m to 180m. When data with spatial resolution coarser than 180m was integrated, the final classification accuracy decreased.

4. Conclusions and Discussions

Because of the multi-scale properties of natural landscape, integrate multi-scale remote sensing data for is a promising way to improving the classification accuracy land use. In this paper, a “bottom to top” method was presented to integrate the multi-scale remote sensing data classification to improve the land use mapping accuracy. This method assume that when the posteriori probability of the classification at two resolution equals, the results at finer resolution is more reliable. the multi-scale remote sensing data was acquired by resampling the Landsat TM data to different coarser resolutions. The performances of integrating different number of resolution data were evaluated. It can be conclude that integrating the classification of multi-scale remote sensing data is a effective way to improve the land use mapping accuracy. However, integrating larger number of spatial resolution data does not definitely lead to higher land use mapping accuracy. There is a threshold spatial resolution exists. It was also testified that need not any other ancillary data, just scaling the remote sensing data to different scale and integrate the classification results at these scale could improve the final classification accuracy significantly.

5. Acknowledgement

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6. References