Texture-based forest segmentation in satellite images

S V Sai, E V Mikhailov

Pacific National University, 136, Tikhookeanskaya st., Khabarovsk, 680035, Russia

E-mail: sai1111@rambler.ru

Abstract. NDVI images are often used to segment vegetation areas in satellite images. Unfortunately, NDVI lack information to effectively separate forest regions from grass regions, as it is computed basing solely on spectral characteristics of red and infrared bands, and both forest and grass display similar spectral characteristics. On the other hand, forest areas are visually distinguishable, as they contain a lot of small shadows or dark spots in satellite images, while grass areas look flat. In the paper, we use this observation by extracting simple texture features from the panchromatic band. In our case, it was enough to compute standard deviation for a sliding window to separate forest from grass.

1. Introduction

A normalized difference vegetation index (NDVI) is often used to analyse satellite images to detect vegetation areas. NDVI is based on spectral information from red band and near-infrared band images [1]. It is easy to compute and it produces reliable results even if combined with simple thresholding. Although, NDVI is also applied for quantitative analysis of vegetation areas and is used as an indicator of vegetation density, biomass, etc. [2, 3, 4], NDVI is not sufficient to reliably segment forest from dense grass. NDVI is an old method and does not fully utilize modern satellites, which produce high resolution imagery. For example, WorldView-2 produces 0.5 meter resolution panchromatic images and 2 meter resolution multispectral images. As seen in figure 1, forest and trees are clearly distinguishable from grass even in a panchromatic image, because trees have light and dark spots, and grass looks flat. The problem is that NDVI uses only spectral information, while spatial information is required to distinguish.

To make the proposed method aware of spatial information, computation of texture features is added [5, 6]. Even simple features such as standard deviation for a sliding window combined with NDVI thresholding is enough to reliably segment forest areas.

2. Method overview

General steps for the proposed method are as follows.

1. Compute top of atmosphere reflectance (ToAR) for each band [7, 8, 9].
2. Compute NDVI based on red and near-infrared images.
3. Extract texture features from a panchromatic image. In the paper, standard deviation for a sliding window is used.
4. Combine NDVI thresholding and texture features image thresholding to segment forest areas.

Source images are shown in figure 1. Those are images of a small area in Khabarovsk made by the WorldView-2 satellite. Calculation of NDVI requires using reflectance data, but initial source images values are just digital numbers which do not have physical meaning. More importantly, images for
different bands are not properly weighted against each other. First spectral radiance response and scaling factors are taken into account to produce top of atmosphere radiance. This step just requires to weight images of different bands by some fixed band-specific values. Given radiance registered by satellite sensors, known as solar spectral irradiance and current position of the scene and the sun, it is possible to calculate ToAR values. The last step depends on the image generation date and time, as well as on geographical position of the region. The whole procedure is satellite specific, so one usually should refer to satellite technical documentation.

![Source images: a – panchromatic image; b – multispectral image (rgb); c – red band; d – near-infrared band.](image)

**Figure 1.** Source images: a – panchromatic image; b – multispectral image (rgb); c – red band; d – near-infrared band.

After ToAR images are computed, it is possible to compute NDVI images. NDVI is derived from red band and near-infrared band images, and then NDVI can be used to segment vegetation areas by simply applying threshold. This segmentation method is based solely on spectral information, so it cannot effectively distinguish grass and forest. To improve this result, an additional step is proposed, so that the method can utilize high resolution of the satellite. This step is based on extracting texture features from the panchromatic image, so that the method becomes somewhat aware of spatial information. More information on NDVI images and texture feature extraction is given in the following sections.

3. NDVI image
The idea of NDVI is based on spectral characteristics of plants, as it is mainly used to analyze satellite images and check whether a region contains green vegetation or not [1, 10]. Plants convert energy of visible light into chemical energy through photosynthesis. The main leaves pigment used in photosynthesis is chlorophyll, and it strongly absorbs red and blue light, so that healthy plants appear to be green in visible light. Photons at infrared wavelengths do not transmit enough energy for photosynthesis, and plants strongly reflect it to prevent overheating. Based on that information one could expect vegetation areas to be bright in the near-infrared spectrum and dark – in the visible red spectrum, as it is clearly seen in figure 1. NDVI exploits that observation and it is computed as follows:

\[
NDVI = \frac{NIR - VIS}{NIR + VIS},
\]

(1)
where NIR and VIS are reflectance in near-infrared and visible red spectrums, respectively. The range of NDVI values is between -1.0 and 1.0. For vegetation areas, VIS should be near zero and an overall value of expression should be near 1.0. Usually, condition NDVI>0.6 is a strong indicator of dense vegetation. Bare land and soils have slightly above zero NDVI values and water areas have negative NDVI values or zero. Buildings, roads and other artificial regions have quite a wide range of NDVI values, but usually they appear to be similar to soils NDVI values or below zero.

Figure 2.a shows the results of computing NDVI for the area of interest. Both grass and forest areas appear to be bright (values near 1.0), while other areas appear to be dark (values near zero or negative values). Using threshold NDVI>0.6, we can easily separate vegetation areas from soils and roads as seen in figure 2.b. NDVI thresholding also identifies correctly a small water body to the left of the region as a non-vegetation area. On the other hand, NDVI is ineffective if one needs to separate forest from grass, as it can only estimate vegetation density and not plants height.

![Figure 2](image.png)

**Figure 2.** Segmentation of vegetation areas using NDVI: a – NDVI image; b – dense vegetation areas (NDVI>0.6).

4. **Texture features and forest segmentation**

Although we cannot use NDVI to separate forest from grass, one can visually distinguish forest areas in panchromatic images, without even considering color image. As seen in figure 1, grass areas usually appear to be flat as it contains pixels of almost the same brightness. Forest usually has a lot of height variation, which results in a lot of small dark (tree shadows) and bright (actual trees) spots. Moreover, these spots usually have certain size, which roughly equals to an expected tree crown diameter. As a result, in order to find forest in satellite images, we need to consider spatial information, and NDVI is only aware of spectral information.

To address this issue, we propose extracting simple texture features [5, 6, 11]. These features should be computed for a sliding window big enough to contain at least one tree with a shadow. Small windows observe high frequency spatial information, and they are suitable for highlighting edges, so a sliding window should not be too small. Moreover, it is preferable to remove high frequency noise before feature extraction. A sliding window also should not be too big, as grass areas over big regions also contain some brightness variation and big windows are more suitable for detecting low frequency spatial information. Given a proper window size, it is enough to use even simple texture feature to separate forest from grass, and we use standard deviation for a sliding window. Overall, the extraction of texture features goes as follows.

1. Pre-process the panchromatic image by removing high frequency noise. For that, we use Gaussian blur to remove features smaller than a tree.
2. Compute standard deviation for a sliding window. The window size should be slightly bigger than that of a tree.
3. Post-process the image of texture features with blur. As distance between trees varies, we also want to include small grass area near trees into forest regions. A blur window should be bigger than a tree.
4. Threshold the resulting image to segment forest.
A panchromatic image is used as a source to compute texture features, as it is usually has a higher resolution. The first two steps are used to find regions with a certain spatial structure to highlight areas with spots of a tree size. Generally, we want to avoid small or thin areas of grass or forest, so we apply the third step. It is possible to replace it with more aggressive post-processing, such as morphological image processing of the final result. The final result after texture feature thresholding combined with NDVI thresholding is shown in figure 3. As compared to figure 2, the final result excludes grass in the lower part of the image and represents the forest area more accurately.

Figure 3. The final result of forest segmentation.

5. Conclusion
NDVI on its own is not sufficient to segment forest areas, as it does not consider spatial information, so the proposed method combines it with texture features extraction and the method is capable to effectively separate forest from grass.

The further work should consider more complex texture features, such as Gabor filters, texture features of the second order and others, as simple standard deviation is not particularly aware of spatial information. These new features might allow for better classification, for example it might be used not only for separating forest, but for estimating tree density, tree height and other parameters.

The proposed method also requires selecting thresholds. Although the process is straightforward for NDVI, it becomes tricky, when it comes to thresholding on more complex features, such as texture features. So it is better to automate thresholding by deploying some machine learning algorithms.

References
[1] Rouse J W, Haas R H, Scheel J A, and Deering D W Proceedings, 3rd Earth Resource Technology Satellite (ERTS) Symposium 1 48–62
[2] Todd S W, Hoffer R M, and Milchunas D G 1998 International Journal of Remote Sensing 19(3) 427–438
[3] Carlson T N and Ripley D A 1997 Remote Sensing of the Environment 62(3) 241–252
[4] Moleele N, Ringrose S, Arnberg W, Lunden B, and Vanderpost C 2001 International Journal of Remote Sensing 22(5) 741–756
[5] Newsam S, Kamath C 2004 Proceedings of SPIE 5433 21–32
[6] Zhang C, Guo X, Wilmshurst J and Sissons R 2006 Canadian Journal of Remote Sensing 32(4) 281-287
[7] Chavez P S 1996 Programming Engineering and Remote Sensing 62 1025–1036
[8] Chandler G, Markham B L, Helder D L 2009 Remote Sensing of Environment 113 893-903
[9] Parente C 2013 Proceedings in EIC 2(1)
[10] Tucker C J 1979 Remote Sensing of Environment 8(2) 127-150
[11] Srinivasan G N, Shobha G 2008 Proceedings of World Academy of Science, Engineering and Technology 36 1264-1269