A composite Hybrid Technique of Crop Classification Using Multi-date AWiFS Data

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Abstract:
The paper presents the methodology developed for classifying Rabi crop using NDVI time series derived from multi-date IRS AWiFS data. The study area covered the part of Chandrapur District, Maharashtra State. Multi-date IRS P6 AWiFS data for Three Rabi seasons (2011-12 to 2013-14) were used in this study. The classification technique is based on multi-stage classification of multi-date dataset by unsupervised Iterative Self Organizing Data Analysis Technique (ISODATA), assignment of classes based on existing temporal spectral profiles of different Rabi crops, local interpolation and decision rule based integration for final classified image. This hybrid classification technique takes advantage of inherent clustering tendency of land use / land cover classes in feature space with existing temporal dimension added to it in terms of NDVI time series data and it also makes use of signatures of known crop classes for assigning the class clusters. The estimated Rabi acreage of study area is needed to be compared with the existing crop acreage estimation of agriculture department. The large number of linear image features (like canals and roads) that were correctly classified using this technique. This technique is simple, time saving, less subjective and requires less expertise compared to hierarchical classification technique.
Keywords: multi-date IRS AWiFS data, Self Organizing Data Analysis, NDVI time series data, Rabi, Maximum Likelihood (ML) algorithm.

Introduction:

Classification is a technique by which labels or class identifiers are attached to the pixels making up a remotely sensed image on the basis of their characteristics. These characteristics are generally measurements of their spectral response in different wavebands. They may also include other attributes (e.g., texture) or existing temporal signatures. This class assignment process is implemented through pattern recognition procedures, the patterns being vectors of pixel characteristics. The most commonly used classification methodologies used in remote sensing are unsupervised procedures such as ISODATA and supervised methods, the most popular of which is the Maximum Likelihood (ML) algorithm. The precise filtering of the information registered on imageries and the sorting out of the surface objects is carried out with image analysis algorithms. Our capability relies on them to automatically recognize similarities and discriminate among different surface objects. Moreover, the detail and success of discrimination that can be achieved by the use of these classification algorithms constitutes one of the limiting factors for the effective usage of remote sensing products. Each method of image data classifications has its own advantages. The supervised classification method involves a training stage, which allows the input of analysts' experience into image data classifications. A number of algorithms for grouping pixels into information classes are available from regular image data analysis software packages. The unsupervised classification method can automatically generate a very high number of spectral classes, which are based on spectral foundations for generating information classes. In contrast to the supervised classification, unsupervised classification requires very few inputs into the classification processes. The algorithm selects natural groupings of pixels based on their spectral properties. An unsupervised classification algorithm still requires user interaction, however it is required after the completion of classification. In unsupervised classification, the user has to assign information classes to the spectral classes created by algorithm. The ISODATA clustering algorithm compares the radiometric value of each pixel with predefined number of cluster attractors and shifts the cluster mean values in a way that the majority of the pixels belongs to a cluster. The user in this case interacts with the procedure at the beginning indicating the number of the predefined clusters to be created and the iterations to be carried out at the end, where user decides which class represents which surface objects and merges or rejects the classes with non-realistic representatives (Manakos et al., 2000). There exist some ground features that are spectrally similar and can't be separated using ISODATA clustering. Researchers have used various classifiers for classifying the RS data for different applications (Tateishi et al., 1991; Friedl and Brodley, 1997; Hastings, 1997; Friedl et al., 1999). Multi-date AWiFS data have been used for various agricultural applications including cropping pattern change monitoring, crop yield modelling and crop classification (Rajak et al., 2002; Rajak et al., 2005; Oza et al., 2008). In the present study, a hybrid technique of multi-date RS data (IRS AWiFS) classification based on two-stage unsupervised classification (ISODATA) and visual vector polygon classification has been presented. It takes advantages of the natural groupings of pixels based on their spectral properties by way of ISODATA clustering and discrimination of spectrally similar classes by way of visual vector polygon analysis.

Study Area And Data Used

The study was carried out over a part of Chandrapur District , Maharashtra state, that belongs to marginal Rabi crop growing area. The major rabi (crops that are usually sown in winter and harvested before summer) crops grown in the area are wheat,pulses,Cereals, Lakh, Peanut etc. Most of the agricultural land is non-irrigated in the study area. The data set used in this study comprised of multi-date IRS AWiFS data, ground information collected and district boundaries vector polygons. The IRS AWiFS data covered Three rabi seasons i.e. 2011-12, 2012-13, and 2013-14

Methodology

The methodology consists of multi-date AWiFS data analysis for crop acreage estimation may be briefly described in the following major steps:

Multi-date AWiFS Data Geo-referencing

Two images can be registered to each other by registering each to a map coordinate base separately or one image can be chosen as a master to which the other, known as the slave, is to be registered. The second method is fast compared to the first method. Multi-date RS data analysis needs a high degree of accuracy in image-to image registrations. All the registrations were carried out to meet the accuracy requirement in terms of root mean square error less than 0.5 pixels.

Radiometric Corrections

The raw digital numbers (DN) images from AWiFS data were converted to radiance images using the calibration coefficients. The relationship between DN and radiance (L) is given by:

$$L = L_{min} + DN * (L_{max} - L_{min}) / DN_{max}$$

Where Lmin=minimum radiance
Lmax=saturation radiance/maximum radiance
DNmax = Radiometric resolution
The values of Lmax and Lmin for different spectral bands of the two sensors are given in Table 1. The levels of DNmax were taken as 1024 (10 bit data i.e. 0 to 1023) for AWiFS.

NDVI and Time Series Data Preparation

Normalized Difference Vegetation Index (NDVI) derived from the radiance values of two spectral bands, is defined as:

$$NDVI = \frac{LNIR - LR}{LNIR + LR}$$

LNIR is radiance value for NIR band and LR is radiance value for RED band. The value of NDVI ranges from –1.0 to +1.0, but for simplicity, it was scaled in range 0 to 200 multiplying by 100 and adding 100.

Table. 1- Calibration coefficients used for computing radiance values

Sensor	Spectral Band	Band λ Range (μm)	L max	L min
AWiFS	Green	0.52 - 0.59	57.0*	0
AWiFS	Red	0.62 - 0.68	42.0*	0
AWiFS	NIR	0.77 - 0.86	31.7*	0
AWiFS	SWIR	1.55 - 1.70	07.8*	0

* Source: NRSA, 2003.
# Lmax in mw/sq.cm/str/micron
ScaledNDVI = 100 +100x(NDVI)

The NDVI images for multi-dates of each season were stacked together in time sequence to form time-series of NDVI data. In this way three NDVI stacked images were formed for the three crop seasons.

ISODATA clustering and Assigning of Classes:

There are several unsupervised classification algorithms commonly used in RS data analysis. Two of the most frequently used algorithms are the K-mean and the ISODATA clustering algorithm. Both of these algorithms are iterative procedures. The ISODATA algorithm allows for different number of clusters while the k-means assumes that the number of clusters is known a priori. The standard ISODATA clustering algorithm was chosen as the unsupervised classification method for this dataset. The algorithm starts by randomly selecting cluster centres in the multidimensional input data space. Each pixel is then grouped into a candidate cluster based on the minimization of a distance function between that pixel and the cluster centres. After each iteration, the cluster means are updated, and clusters are possibly spilt or merged depending on the size and spread of the data points in the clusters. In the present study, two-stage ISODATA clustering has been carried out. In the first stage, time-series NDVI data is subjected to ISODATA clustering with 50 clusters to be created. The unsupervised clusters were compared with the ground truth database to assign classes. The unknown classes are assigned to two categories i.e. pure 'non-crop class' (includes water bodies, built-up, roads, canals, waste lands, rock outcrop, sand, forest, plantations, shrubs, other vegetation etc.) and 'other class' (includes pure crop class as well as mixed class). In the second stage, the time-series NDVI data for the pixels of only 'other class' was subjected to ISODATA clustering and the classes created were assigned to four categories i.e. pure 'non crop class' (includes water bodies, built-up, roads, canals, waste lands, rock outcrop, sand, forest, plantations, shrubs, other vegetation etc.), 'other crop class' (includes potato, vegetables etc), 'Cereals class' and 'mixed class'.

Visual Analysis of Vector Polygons

The pixels belonging to well identified classes ('non crop class', 'other crop class' and 'other class') were masked out and the remaining classified image was converted to vector polygon layer. These polygons of 'mixed class' were superimposed over different dates FCC images, visually analysed (by visually comparing temporal patterns of NDVI) and edited to classify into the three classes i.e. 'non crop class', 'other crop class' and 'other class' (the area specific knowledge of dominant crops helps in separation of classes).

Integration for Final Classified Image Preparation

The final classified image was prepared by assembling all the pixels belonging to the three classes ('non crop class', 'other rabi crop class' and 'other class') by taking union of the classified image of second stage of ISODATA clustering and the classified vector polygons of the visual analysis.

Rabi Crop Acreage Estimation

The district boundary vector polygons were overlaid on the final classified image and the numbers of pixels belonging to the three classes were determined for the district. The district-wise rabi crop acreages were estimated.

Results and Discussion:

The temporal NDVI patterns of major land use / land cover classes of the study area, the spectral patterns of rabi crops are clearly different from that of non-crop classes. This wide difference in temporal profiles of non-crop classes from that of crop classes helps ISODATA clustering in separating non-crop clusters from crop clusters. The analyst could easily assign the following three land use / land cover (LULC) classes to the unknown clusters using basic knowledge of feature signatures and comparing the spatial distribution of unknown classes with respect to False Colour Composite (FCC) images of different dates. The three LULC classes assigned to unknown classes were:

1. Non-crop class: It included water bodies, built-up, roads, canals, wastelands, rock outcrop, sand, forest, plantations, shrubs, other vegetation etc.
2. Crop class: It included cereals, pulses, wheat potato, vegetables etc
3. Mixed class: It included all classes that could not be assigned to 'non-crop class' or 'crop class' with full confidence.

The pixels under crop and mixed classes were further subjected to ISODATA clustering (second stage unsupervised classification) and thus resulted unknown clusters were assigned to four LULC classes by visually matching the temporal

NDVI graphical patterns of unknown classes with the known patterns. The four LULC classes assigned to unknown classes were:

1. Non Crop Class
2. Other Crop class: It included potato, sugarcane, vegetables etc.
3. Rabi Class : Oilseeds. cereals, pulses, wheat etc
4. Mixed class: It included all classes that could not be assigned to any of the above three classes with full confidence (In case, all the clustered could be assigned to known features, this class won't exist The clusters of pixels under mixed class were converted to vector polygons. The polygons were manually compared with FCC images of different dates, inspected for their spatial distribution, edited (wherever needed) for sub-division and assigned to Non-crop, Other crop or Rabi class. An integrated final classified image was prepared by assembling all pixels belonging to Rabi class in classified image of stage two ISODATA clustering and Rabi polygons of vector analysis. The Rabi crop acreage for the study area (parts of Chandrapur district) was found to be 64200ha for 2011-12, 61865 ha for 2012-13, 72786 ha for 2013-14.

Conclusion:

The hybrid technique of multi-date RS data classification integrated two-stage ISODATA clustering and visual classification of unknown vector polygons. The two-stage ISODATA clustering yielded in a classified image having 93 to 98 percent pure-class pixels and 2 to 7 percent mixed-class pixels. The class assignment of unknown classes in first stage clustering was based on analyst's knowledge of basic signatures of land use / land cover classes. The pixels belonging to non crop classes were masked out before the second stage clustering. The class assignment of unknown classes of the second stage clustering was based on visual graphical matching of temporal NDVI patterns of unknown classes with those of known crops in the study area. The mixed classes after second stage clustering were vectorised and then class polygons were manually edited for assigning pure crop classes to them. The final classified image was prepared by integrating the pure classes from second stage clustering output and edited vector output. The Rabi crop acreage estimated from the final classified image for the study area comprising part of Chandrapur district of Maharashtra state was found to be 64200 ha (2011-12). The hybrid technique of multi-date AWiFS data classification developed in the present study is simple, more objective and requires less expertise than hierarchical classification.

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