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Application of Image Fusion (Object Fusion) for Forest Classification in Northern Forests of Iran

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ABSTRACT

Forest classification on the basis of satellite images is a promising technique both for primary map production and for map updating and forest monitoring. For accurate forest classification into three classes, using mapping by canopy cover density "high spatial resolution satellite images have to be used in order to obtain the required spatial detail" [Schneider, 1999]. At the same time, the spectral information necessary for identifying certain class types can most economically be derived from multi-spectral images of medium spatial resolution. Fusion techniques have to be used to combine information from both sources. In this paper, a method was developed for object-level fusion of IRS-1C/1D pan images (5.8 m pixel size) and LANDSAT TM multispectral images (30 m pixel size) and subsequent classification to produce a canopy cover classification of the northern forests of Iran. The study area is located in Sari and its forest regions in 60,000Hec. (Figure 1) The individual processing steps included segmentation of a multi-band image consisting of both the high-spatial-resolution pan image band and medium-spatial-resolution multispectral bands, with proper weighting of the individual bands in the segmentation procedure in order to obtain both fine detail from the pan image and coarser boundary delineations which show up only in multispectral images. For classification, fuzzy logic membership functions were used. Verification of the classification was carried out and checked with error matrix and kappa calculation on a selected transect from a newly classified map. The results showed that employing object-based fusion procedure using medium- and high-resolution data was an appropriate method that improved classification. Comparing the hard work of creating a new topographic map, a pixel-based fusion procedure was demonstrated to be an acceptable method to create a satellite image map (Satmap) for visual monitoring activities and programs. The overall accuracy of the map produced was calculated as a topo-map of the region.

Keywords: Fuzzy classification, Iran's forests, Object fusion, Object oriented, Segmentation.

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INTRODUCTION

"The northern part of Iran, which is located to the south of the Caspian Sea, is covered with a small and narrow crescent of broad-leaved forests (nearly 1.8 million hectares or 1.1% of the country's area"). (Farzaneh, 1996) This Mediterranean ecosystem consists of various rare species of broad-leaved forests, which should be protected for purposes such as environmental protection, recreation and production. The study area, which is mainly covered by industrial forest, plays an important role in all human activities and projects of the region.

One of the approaches that indicates the qualities and quantities of forest, are canopy cover density classification, either using high resolution satellite images or by using large scale aerial photographs. Generally, the forest canopy densities have a direct relation to the qualities and quantities of forest, especially when they are sufficiently full-grown. That could be an indication of the sources of wood.

In other words, it means that where dense

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forest are occurr, it's good evidence of wood which is accessible and product able. Whereas in a semi-dense or disperse forest, due to any activities either human or natural impacts, the low density canopy cover means that lower quality and less wood production should be expected.

Most of these forests are facing severe destruction or changes either due to natural hazards like floods, earthquakes, storms, fire accidents, etc., or human activities. The best way of showing the location as well as the quantity and quality of these resources is by extracting information and presenting that information in the form of a classified map.

Thus, monitoring and recording these changes and degradation requires a rapid and fast method for recognizing and registering changes at least every ten years.

One possible way for obtaining accurate information is to use data from remote sensors such as high-resolution satellite images. But experience has shown that difficulties arise if one uses data from a single source. It is better to say that one satellite data source is not enough for such a study.

Image fusion can be performed at three different levels: at pixel level, at object (image segment) level and at decision (map object) level. (Schneider, 2000)

To overcome the shortcomings and limitations of satellite data, such as low spatial resolution, clouds and lack of image sharpness, a fusion technique may employed.

"Pixel-based", "object-based" and "decision level" fusion are new methods in advanced remote sensing and image processing.

Scientists and experts have defined fusion in remote sensing in many ways. However, the best recognized one that has been adopted by the majority is as follows:

"Image fusion is a combination of two or more different images to form a new image by using a certain algorithm". (Pohl, 1996)

Extracting concrete or single features like forest, non-forest, water bodies and etc., in remotely sensed data is not too difficult in itself. However, problems arise when man requires a detailed classification of a single feature, like a type of forest or classifying the different agricultural products in a large area of cropland.

"The conventional method used for processing remotely sensed data operates on a pixel basis and has a number of drawbacks". (Abkar, 1999) New developments can bring improvements. In the new methods of "object-oriented image analysis", the basic processing units are image objects or segments and not single pixels and classification is carried out on the basis of image objects. The idea of object-oriented analysis is to imitate the performance of human interpreters as far as possible.

In this paper, a method was developed for object-level fusion of IRS-1C/1D pan images 5.8 m pixel size) and LANDSAT TM multispectral images (30 m pixel size/ resolution) and subsequent classification to produce canopy cover classification of the northern forests of Iran in three classes: 1) dense forest, 2) semi-dense and 3) scattered trees.

The main goal of this study is to classify the forest density canopy cover in three classes, (dense, semi-dense and scattered forest) in order to achieve the quality and quantity of the forest of the region. Due to the problems set out above, the study area (Sari and its forest regions in 60,000Hec. Figure 1) was tested by employing the fusion of 2 satellite images: Figure 2, IRS-1C/1D pan Images (5.8 m pixel size) and Figure 3, LANDSAT-5 TM multispectral images (30 m pixel size). This fusion simultaneously increases the spatial resolution (IRS-C/1D) and also increases the spectral resolution (Landsat-5 TM) in a new data set. Thus assessing the capabilities of image fusion particularly (object fusion) in forest canopy cover classification is another sub-objective of this study.

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Figure 1. The study area.

MATERIALS AND METHODS

Study Area

The study area is located in Mazandaran Province in the northern part of Iran.

Mazandaran Province (Figure 1) covering an area of 46,456 km² accounts for 2.8% of the country's area. It lies from 35˚-47′ degrees to 38˚-5′ degrees northern latitude and from 50˚-34′ degrees to 56º-14′degrees eastern longitude from the Greenwich meridian. (Eshagi, 2000) The study area covers 60,000 hectares in four sheets of the topographic map at a scale of 1: 25,000.

In general, the study area is located in a mountainous region. The lowest points are at an elevation of -5 m (near the Caspian Sea), the highest points are up to 3,000 meters above sea level.

As demonstrated in the flow chart given in Figure 4, in the first steps of Digital Elevation Model (DEM) creation, Geometric correction and Radiometric calibration (only for Landsat-5) was carried out for both data sets. Geometric correction was used for data set correction. Radiometric calibration eliminates the effects caused by varying illumination due to varying sun height, terrain slope and exposition as well as the influences of atmospheric scattering and absorption. The resulting radiometrically calibrated images must have spectral signatures, which only depend on the terrain land cover, without unwanted disturbances, so that standardized classification methods can be applied.

The basis for radiometric calibration as applied at the Institute of Surveying, Remote Sensing and Land Information (IVFL) is given by the following formula:

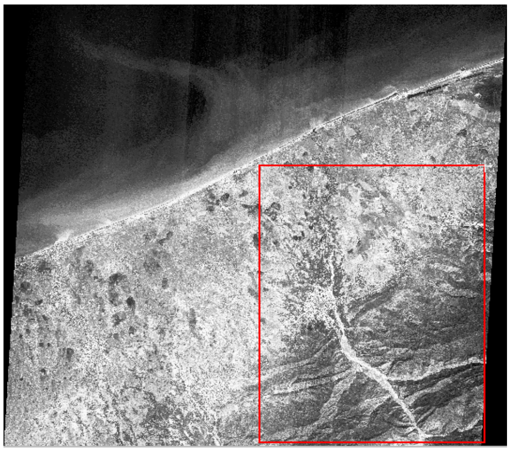

Figure 2. IRS-1C PAN study area (Acq. 1999-03-01).

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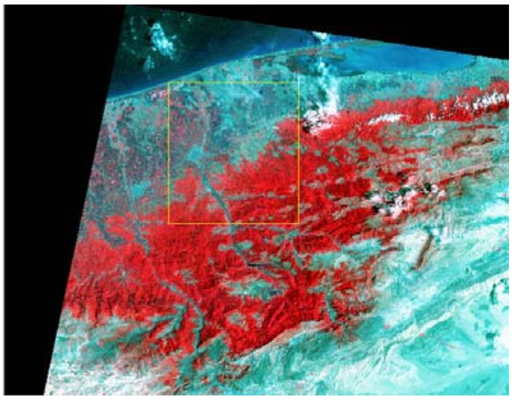

Figure 3. Landsat-5 TM study area (Acq. 1998-06-12).

DNcal=(DNorg-DNapr)/(Cs*cos I + (1- Cs))
DNcal = Calibrated digital number
DNorg = Original digital number
DNapr = Digital number due to atmospheric path radiance
Cs = Ratio of direct sun radiation
Cos I = Cosine of the angle between terrain surface normal and direction to sun.

The digital number of every pixel inside the image depends on the terrain illumination, terrain reflectance and the ratio of direct sun radiation to diffuse sky radiation. This procedure based on the above formula has been tested in IVFL's projects (IVFL, 2001). The same approach has been taken in this research.

At in this step, pixel based fusion is applicable. After using the IHS algorithm (Intensity Hue Saturation = HIS), we then followed with segmentation.

"Segmentation is the subdivision of images into separate regions. For many years, procedures for image segmentation have been a main research focus with regard to image analysis. Many different approaches have been adopted. However, few of them lead to qualitatively convincing results, which are robust and applicable under operational settings. One reason is that segmentation of an image into a given number of regions creates a problem with an astronomical number of possible solutions". (Baatz and Bernhardt, 2001).

The processing steps of segmentation of both high-spatial-resolution (pan) and medium-spatial-resolution (multispectral) image data were combined with the processing step of object level fusion by using the multi-resolution segmentation functionality of the eCognition software package.

The whole processing chain including georeferencing of the original data sets and radiometric-topographic calibration of the images was implemented in this work and demonstrated in Figure 4 as a flow chart for the test area data set.

The basic idea is to perform segmentation on a dataset combining both high-spatial-resolution IRS-1C-pan and low-spatial-resolution multispectral Landsat-5 data in different spectral bands. Weights are assigned to the different bands (layers) to control the degree to which the layers were taken into account for the homogeneity criterion.

Different levels of segmentation are used with different sizes of objects in such a way that a hierarchy of levels with decreasing mean segment size is created (levels of different scale, "scale levels").

Each segment boundary in a level with larger segments coincides with segment boundaries in levels with smaller segments. Size and shape of the segments in the different levels are controlled by the various parameters provided by eCognition software such as:

- Scale
- Color-shape
- Smoothness- compactness.

These parameters are optimized by trial and error to obtain a satisfactory result in which all landscape elements are displayed which:

- Show up in the pan layer with high contrast and fine detail (e.g. roads)
- Show up in the multispectral layers in contrasting colors without showing up in the pan layer (e.g. different vegetation types such as coniferous forest and deciduous forest).

The parameters governing the multi-segmentation process in eCognition were

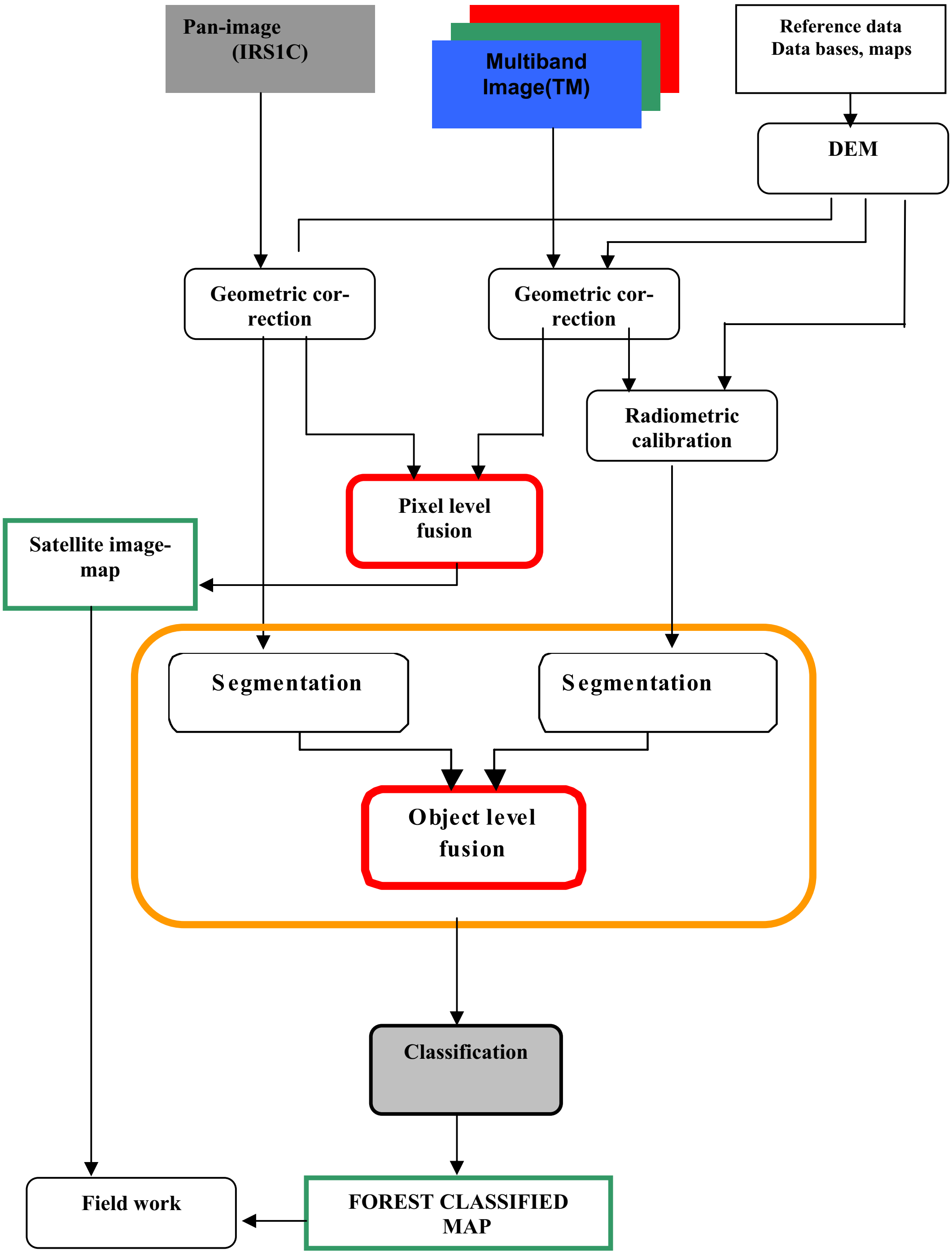

Figure 4. Flow chart of forest classification and map procedures.

Table 1. Setting parameters for object fusion.

IRS-1C single-band (pan)	*Lansat-5 TM multispectral*
Layer weight =1.5	Layer weight =0.1
Scale =30	Scale =30
Color = 0.8	Color = 0.8
Shape = 0.2	Shape = 0.2
Smoothness = 0.9	Smoothness=0.9
Compactness = 0.1	Compactness =0.1

optimized by trial and error so as to obtain a segmentation result showing the delineation of landscape elements in the most correct form. These optimal parameters are given in Table 1.

Considering the above parameters for segmentation, forests are classified into three types of forest using two approaches either manual or automatic. In fact, automatically it is down by computer analysis based on segmentation and manually by assigning the objects to their correct.

Classification

As a result of the previous processing step, a large number of image objects are available for classification. (Figure 5)

"Considering the multi-resolution approach, there are not only individual image objects, but a network of image objects within one scale level and among all levels. This hierarchical network allows for evaluating contexts – the relations of the local neighborhood of image objects on one level – and dependencies among levels." (eCognition User Guide, 2002).

Each image object has a larger number of characteristic properties called "object features". These are grouped into spectral features ("layer values"), measures for "shape", "texture" and "hierarchy" of the image object.

The most common "layer value" is the mean value of pixels within an image object called the "layer mean". However, other features such as the ratio between channels and higher order statistics are also available.

The following hierarchical system of categories was defined:

1. Forest (including woodland and shrub

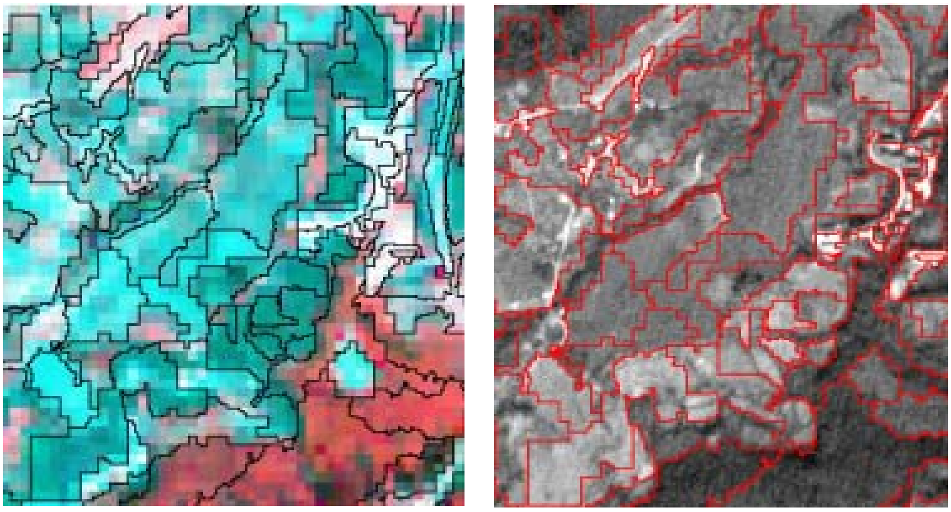

Figure 5. Superimposed boundaries from IRS(R) on TM (L).

land):

1.1 Dense canopy
1.2 Semi-dense canopy
1.3 Scattered trees.

2. Agriculture (dry farming and irrigated farms such as for rice or orchards.
3. Water bodies (rivers, riverbeds, swampy areas, reservoirs).
4. Infrastructure:

4.1 Densely built-up areas including roads and industrial areas
4.2 Scattered houses (mostly illegal) in forests.

In order to make this classification, 2 to 3 samples from each class were selected from the set of fused objects. Both the IRS-1C bands and the spectral bands from Landsat-5 TM are contained in this object set. For small and fine-scale objects such as roads, the IRS-1C based features are more visible and distinguishable than the Landsat-5TM features.

Processing and classification was carried out on all selected samples in two ways: statistically (sample-based) and rule-based.

In sample-based classification, a fuzzy approach of the nearest neighbor clustering is used. Since it is based on training samples, this clustering approach detects similar image objects in a multidimensional feature space. (Figure 6 shows four samples of forest classes in Bands 4 and 5 and vegetation index B4/B3).

	0	1	1	0
forest B2	2	3	4	6
forest B3	5	6	7	9
forest B4	90	92	100	108
forest B5	75	77	80	87
forest B7	22	23	24	26
veg.B4/B3	11	12	14	16

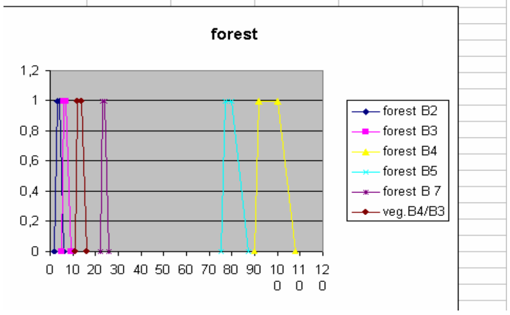

Figure 6. Fuzzy classification for a forest. The table gives the 4 inflection points of linear membership functions.

Rule-based classification allows easy integration of even vague and linguistic expert knowledge. The fuzzy rule base works on selected object features. The fuzzy sets are defined by membership functions.

The membership functions can be edited with a convenient graphical interface. These membership functions identify those values of a feature that are regarded as typical, less typical or not typical for a class in that they have a high, low or zero membership to the fuzzy set, respectively. The fuzzy sets are

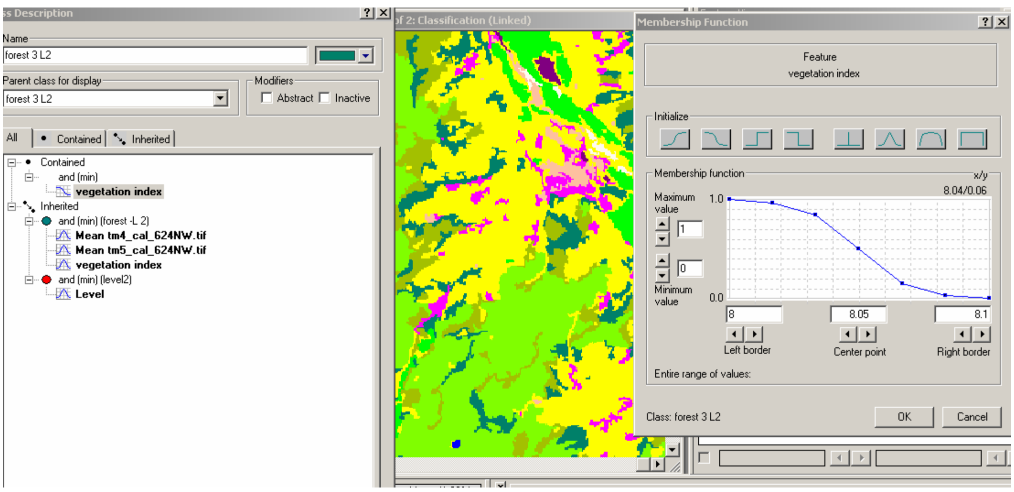

Figure 7. Fuzzy membership function used for canopy density.

combined with the logic operators ‘or’ and ‘not’ and there are several selectable implements to accommodate various concepts of these logical combinations. (Figure 7)
Considering forest canopy cover, processing and classification was carried out by employing samples on Bands 4 and 5 of TM. Then the fuzzy sets membership functions are defined for dens, semi and scattered canopy classes.

Verification

“At the completion of a classification exercise, it is necessary to assess the accuracy of the results obtained. This allows a degree of confidence to be attached to the results and will serve to indicate whether the analysis objectives have been achieved". (Darvishsefat, 1997]

The percentages listed in the table represent the proportion of ground truth pixels correctly and incorrectly labeled by the classifier. It is common to average out the percentage of the correct classifications and consider this as the overall classification accuracy.

Sometimes a distinction is made between errors of omission and errors of commission, particularly when only a small number of cover types is of interest, such as in the estimation of the area of a single crop in agricultural applications. Errors of omission correspond to those pixels belonging to the class of interest that the classifier has failed to recognize whereas errors of commission are those that correspond to pixels from other classes that the classifier has labeled as belonging to the class of interest. The former refer to columns of the confusion matrix, whereas the latter refer to rows.

Figure 8. Clipped classified map in transect form.

A transect (1*10km) selected from a classified map and checked in the same area in the field (ground truth) by employing GPS (Global Positioning System) and recent aerial photographs [in scale 1: 20000] is taken in order to ascertain the accuracy of the classification. (Figures 8 and 9).

The percentage of pixels from each class in the image labeled correctly by the classifier can be estimated along with the proportions of pixels from each class, which have been erroneously labeled into other classes. These results are then expressed in tabular form, referred to as a confusion or error matrix.

The following accuracy parameters are deduced from the error matrix:

Then error matrix was compiled by comparison of the ground truth data set and the automatically computer classified map. The results for the various parameters of thematic accuracy are:

Overall accuracy:	86.2 %
Kappa	78.2 %

Figure 9. Results of ground truth and visual interpretation of aerial photographs.

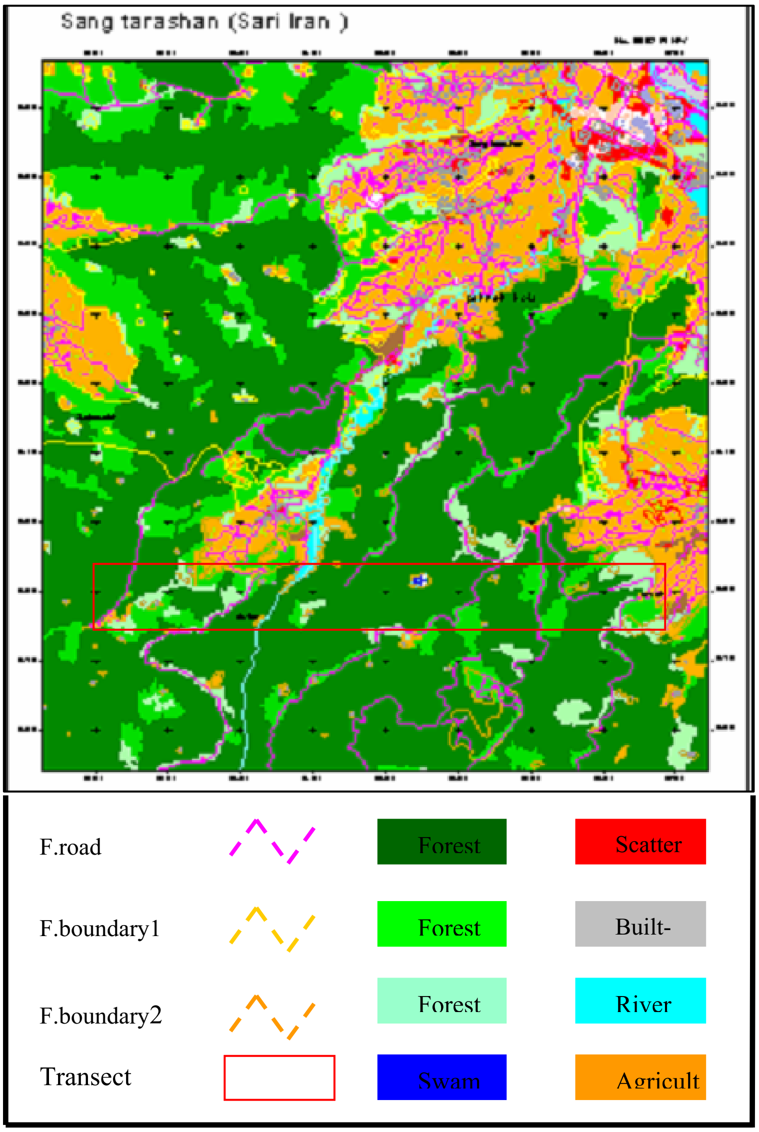

Figure 10. Forest canopy cover classification map scale: 1/25000.

Producer's accuracy:

	1	Forest1	88.1 %	
	2	Forest2	68.2 %	
	3	Forest3	74.1 %	
	4	Agriculture	77.3 %	
	5	Built-up areas	76.1 %	

User accuracy:

	1	Forest1	77.4 %	
	2	Forest2	97.4 %	
	3	Forest3	95.2 %	
	4	Agriculture	67.6 %	
	5	Built-up areas	67.9 %	

General Changes in the Region

According to a newly produced map, the following result in the table below shows:

A large valuable amount of information has been extracted by applying fusion methods. Table 2 shows clearly that agricultural land has decreased. Simultaneously, there has been an increase of forest type1, but a decrease of forest type 2 and, especially, type 3 which did not exist before. This is playing an important role in the new classi-

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Table 2. Changes in the region.

Map Classes	Old map/ha	New map/ha	Change/ha	%
Agriculture	4,681	3,374	-1,307	-28
Forest 1	5,466	6,902	1,436	26
Forest 2	4,775	2,667	-2,108	-44
Forest 3	----	1,174	1,174	100
Riverbed	117	557	441	377
Swamp	4	2	-2	-50
Infrastructure (roads, houses, etc.)	566	931	366	65
Total	15,609	15,609		

fication, and shows a decreasing trend in the forests of the region in general terms. The two recent types of forests are due to the application of a new method (object based fusion) and information extracted by gathering accurate field data, that was not available before.

"The author strongly believes that referring to old data and maps is not advisable because they were only estimations and undocumented"

According to this assessment, the new method confirms and explains the detail and gives further description of forest classes and sub-classes which is based on figures and the area tested in real nature, while there were no such data or methods available for former information. Thus, lack of up-dated data and vagueness of materials are a good justification for applying a new approach for forest classification and map creation.

RESULTS AND DISCUSSION

Image data from many different earth observing satellite sensors are available today. The sensors have different properties in terms of spatial and spectral resolution and temporal availability. Methods of analysis enabling flexible use of these sensors according to the requirements of the respective applications and the availability of the sensors are urgently required.

Three different methods for the fusion of image information from different sensors may be distinguished, according to the choice of objects for which attributes are to be combined from the different sensors, and according to the characteristics of these attributes: In pixel-based fusion, the objects are individual pixels. In object-based fusion, the objects are image segments (sets of adjacent pixels). In decision-level fusion, the objects are also segments, but they are already classified, and have been assigned to categories, i.e. they have attributes of a nominal level so that contradictions may occur when combining them.

Object-based fusion was found to be a proper tool for combining IRS-1C pan satellite images with 5, 8 m pixel size and Landsat TM multispectral images with 30 m pixel size for the purpose of land cover mapping and forest canopy cover classification. An appropriate method was developed taking as an example a test area in the Sari region of Iran. A forest classification could then be prepared.

For visual presentation purposes, pixel-based fusion of image data of the same sensors was found to be appropriate. The resulting satellite image map can be used for various planning and other purposes of public administration in the place of orthophoto maps. The attainable cost reduction compared to conventional orthophoto maps from aerial photographs is considerable.

Object-based fusion requires a preceding segmentation process (Baatz and Schape, 2000). The commercial software package eCognition was found adequate for performing segmentation and object-level fusion in one step, by applying multiresolution segmentation to a data set of geometrically registered bands from both sensors. The parameters governing the segmentation and fusion process are the relative weights of the spectral bands from both sensors, an inhomogeneity threshold up to which adjacent segments are merged (which, as a consequence, determines the size of the resulting segments), and parameters describing how the inhomogeneity measure is composed from spectral and spatial criteria.

The classification of the resulting segments is carried out through a knowledge-based method using fuzzy membership descriptions of the forest categories and their spectral properties. Spatial (e.g. size, density) and context characteristics of the forest canopy categories are also significant.

To avoid creating artefacts and defects in fusion processing and for better presentation, it is recommended that both data sets be of proper proportions in terms of pixel size. Considering high resolution and medium resolution of IRS-1C with 5.8 m resolution and TM with 25m or 30m resolution, respectively, this is not a good proportion. Possibly, 10m resolution by 30m or 15m by 5m, and so on, may yield better results.

It is highly recommended that the selection of data for the fusion process should be based on the objectives of the work and not primarily on data availability.

The satellite image map obtained by pixel level fusion seems to be adequate to partly substitute traditional survey processes in terms of land registration and rural cadastral mapping either for the private sector or for the governmental sector, due to its accuracy and speedy map production as well as for reasons of data reliability.

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Since this paper derived from my doctoral dissertation, I would like to express my special thanks again to the Institute of Surveying, Remote Sensing and Land Information (IVFL) of the Agricultural University of Vienna (BOKU).

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طبقه بندی تاج پوشش جنگل از طریق تلفیق تصاویر ماهواره ای (تلفیق شیء پایه) در جنگلهای شمال ایران

ع. فرزانه

چکیده

طبقه‌بندی تاج پوشش جنگل بر اساس تصاویر ماهواره‌ای یکی از روشهای پیشرفته طبقه‌بندی است که برای تولید نقشه‌های موضوعی جنگل و نیز بهنگام سازی نقشه‌ها و همچنین نظارت بر عملیات جنگلداری از آن استفاده میشود. بمنظور طبقه بندی دقیق تاج پوشش جنگل در سه کلاس تراکمی استفاده از تصاویر ماهواره‌ای با قدرت تفکیک مکانی بالا پانکروماتیک (Pan) ، همزمان تصاویر ماهواره‌ای با قدرت تفکیک متوسط چند باندی (Multy spectral) ، بمنظور افزایش تفکیک طیفی مورد استفاده قرار گرفت. تکنیک تلفیق (Fusion) در داده‌های ماهواره‌ای به سه طریق صورت می‌گیرد: (و ـ اشنایدر ۲۰۰۰) ۱. تلفیق پیکسل به پیکسل، ۲. شیء پایه ، ۳. تلفیق اطلاعات.در این مقاله بااستفاده از روش تلفیق شیء پایه (Object base fusion) در دو نوع داده مختلف ماهواره‌ای ، IRS1C/1D پانکروماتیک با قدرت ۵/۸ متر و داده ماهواره‌ای لندست Landset- 5TM با قدرت مکانی ۳۰ متر و چند طیفی، توانایی و قابلیت روش مذکور به منظور طبقه‌بندی تاج پوشش جنگلهای شمال کشور (در منطقه ساری) مورد بررسی قرار گرفت. مراحل پردازش تصویر با استفاده از قطعه‌بندی (Segmentaion) روی داده‌های چند باندی با قدرت تفکیک متوسط و همزمان در باند پانکروماتیک با قدرت مکانی بالا صورت گرفته است، و با تعیین وزن مناسب برای هر یک از باندهای ترکیبی از طریق تصویر چند طیفی، طبقه‌بندی جنگل انجام شده است. برای طبقه‌بندی این قسمت نیز از منطق فازی (نامعین Fazzy) استفاده شده است. بررسی دقت نقشه طبقه بندی شده در این مقاله با استفاده از جدول خطا (Error matrix) و محاسبه ضریب کاپا در یک برش عرضی از نقشه انجام گرفته است. نتایج بدست آمده نشان داد استفاده از روش Object base fusion (تلفیق شیء پایه) در طبقه بندی مؤثر است و طبقه‌بندی تراکمی جنگل با دقت بهتری انجام می‌شود. ضمناً مشخص گردید،روش Pixel base fusion (تلفیق پیکسل پایه) نیز برای تولید تصویر ـ نقشه (Sat-map) بسیار مناسب است که میتواند در برنامه‌ها و پروژه‌ها مورد استفاده قرار گیرد.

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