EVALUATION OF VARIOUS SEGMENTATION TOOLS FOR EXTRACTION OF URBAN FEATURES USING HIGH RESOLUTION REMOTE SENSING DATA

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ABSTRACT

The study involves segmentation of the image using the three segmentation modules of three software namely ERDAS Imagine, ENVI and eCognition to extract building features. The best parameters for segmenting buildings have been established. New method of evaluation has been presented for evaluating segmentation quality. The results of three segmentation modules are assessed using the proposed evaluation methodology and the results are discussed. A general comparison of the three tools is also provided at the end.

1. INTRODUCTION

With the launch of High Resolution satellite sensors offering high spatial and radiometric resolution, it has become easy to gather information about detailed land use map and urban features. High-resolution data helps in efficiently identifying man made objects and also provides additional advantage in mapping and planning activities (Srivastava and Raju, 2001). Application specific information can be gathered from the high resolution images. However, manual extraction of urban features from the high resolution satellite data at a detailed level over large areas is tedious and time consuming. Therefore there is a need of some methodology for semi-automatic extraction of urban features. A lot of research is going on in the field of automatic information extraction from high resolution data (Dong-Su Kim et. al., 2003, Fengliang Xu, et al., 2002, Baillard et al., 1995, Collins, et al., 1995). Many new and computationally expansive methods are being evolved for extraction of urban features involving high data requirements thus increasing the cost of gathering information much higher than the manual methods, without fully exploring the information extraction tools and methods available. Image Segmentation is one computationally inexpensive method, which, if applied on high resolution satellite data can prove to be a boon to the field of urban feature extraction, as it can reveal the shape of urban features. However, there are various segmentation methods, and the question arise as to which is best for extracting urban features, and indeed how to evaluate the meaning of “best”.

Some studies have compared segmentation algorithms. Meinel and Neubert (2004) ISPRS have tried to evaluate segmentation results, however they have used pan sharpened MSS image and used average difference in area, perimeter, shape index and visual quality as the parameters of evaluation.

2. OBJECTIVES

To answer the questions, addressed above, it is necessary that we evaluate the existing segmentation tools. Therefore this study has two objectives: (1) develop evaluation criteria; (2) use these to compare several popular segmentation algorithms.

A novel methodology for Evaluation of segmentation result:

Accuracy is the degree of conformity with a true reference. Wiedmann et al. (1997) has described some algorithms to check accuracy. Accuracy exhibits different parameters like error of omission and error of commission, completeness, correctness, quality. This concept was extended to the extraction of area features like buildings, and the following definitions were evolved:

Error of omission in case of an Area feature describes how many area features were omitted in the extraction and can be defined as the ratio of the unmatched reference features to the total reference area.

Error of commission in case of an Area feature describes how many area features were wrongly committed in the extraction and can be defined as the ratio of the unmatched extracted features to the total extracted area.

Completeness of an Area feature describes how complete an area layer is and can be defined as the ratio of the correctly extracted area to the total reference area.

Completeness ? {0;1}

Correctness of an Area feature describes how correctly the area features are extracted and can be defined as the ratio of the correctly extracted area to the total area extracted.

Correctness ? {0;1}

Quality of an Area feature combines completeness and correctness to give a measure of final result and can be defined as the ratio of the correctly extracted area to sum of total area extracted and within reference data.

Quality ? {0;1}

Segmentation Modules Compared:
Segmentation Modules of three most common and commercially available software, namely ERDAS Imagine, eCognition and ENVI/RSI were evaluated. The present section describes in short the segmentation methodology used by the three modules:

1. ENVI 4.0 (Research Systems Inc., USA): ENVI uses a region based approach to segment the image into areas of connected pixels based on the pixel DN value. Option is available to enter a single DN or a range of DN values to use in the segmentation. Only pixels that fall within the entered DN range will be considered in making the segmentation image. All other pixels will have an output value of 0. Either four or eight adjacent pixels are considered for the connectivity. Minimum number of pixels in a region can be specified. Each connected region, or segment, is given a unique DN value in the output image. If only one value is entered, the data minimum or maximum is used as the other end of the threshold.
2. eCognition 4.0 (Definiens Imaging GmbH, Munich Germany): Multi-resolution segmentation used by eCognition is a bottom up region merging technique to extract homogeneous image object primitives in a chosen resolution achieve image objects, by minimizing weighted heterogeneity using tone and shape as the parameters to calculate heterogeneity. The users can specify several parameters like scale parameter, layer weights and the mixing of the heterogeneity criterion based on tone and shape. Adjusting the scale parameter indirectly influences the average object size. eCognition uses two definitions of neighborhood (plane and diagonal).
3. ERDAS Imagine (Segmentation Module developed by USDA Forest Service, Remote Sensing Applications Center, Salt Lake City, Utah): Image segmentation in ERDAS is like ISODATA, in a sense that image segmentation partitions imagery into unique spectral groups, however image segmentation includes a spatial component (Unlike ISODATA). A requirement of image segmentation is that all pixels in a group (or segment) are spatially contiguous. The main input parameters to the segmentation module are Spectral Threshold Distance for limiting the growth of the region and the Minimum Region Size, which defines the size for the minimum region. The unit value is in pixels. All regions less than or equal to this value will be merged with the most similar adjacent region. There is also option to set the block size, to increase speed of the module and to avoid artificial lines resulting in the output. However, there are tradeoffs with the block size. The larger the block size, the faster the program runs but the more memory it uses. The segmentation module also provides facility to vectorise the segmented result in arc coverage.

Data used:

Panchromatic IKONOS image (1m ground resolution and 11 bit radiometric resolution) of test area of Dehradun City, Uttaranchal State, India (30O19’N and 78O20’E), (Figure 1) were segmented by the three above mentioned segmentation modules. Each test area had a size of 400 by 280 pixels, representing urban area**.**

Figure 1: Test Image

3. METHODOLOGY

Establishing best segmentation parameters for extracting buildings:
Several parameter combinations were used in all the three modules for extraction of building features, were established with focus to extract building objects from the image. The table 1 presents the optimum (best) parameters in the three modules for extraction of buildings:

Table 1: Optimum parameters for extraction of buildings

S. No.	Parameter	ENVI	eCognition	ERDAS
	Min	550		
	Max	900		
	Min Population/ Min Region size/ Spectral threshold Distance/ scale parameter	50	50, 50	50
	Block Size			100
	Shape		.7	
	Compactness		.5	

During the analysis of segmentation result, a comparison was established amongst parameters of segmentation in the three modules and it was found that Min Population of ENVI was functioning similar to what scale parameter was doing in eCognition and what Min Region size and Spectral threshold Distance of ERDAS were doing, as all the parameters in three software were deciding the growth and size of the region. For this reason, this value was kept constant to have uniformity in result based on this parameters.

In ENVI, the selection of range was done based on the analysis of DN values for building objects. The selection of range was tricky as expanding the range was including unwanted regions, and compression of range on the other hand was ignoring the building features, due to the similarity of DN values of building objects with other features having same tome like roads, parks etc. Building objects with very dark roof tops created difficulty in selection of parameters. Minimum size of the building was one important deciding factor in selection of minimum population.

In case of eCognition, the apart from the scale parameter, which indirectly decided about the size of the object, which was kept constant as discussed above, the shape and compactness were decided based on the hit and trial method. A balance was achieved first in weights to tone and shape with view to extract building objects, and thereafter a tradeoff between the compactness and smoothness was decided.

ERDAS did not give much opportunity to differentiate building objects form other objects except that we analyzed range of building objects in the image and decided about the spectral threshold distance based on building objects.

While ENVI was flexible in its segmentation module as it gave opportunity to define the range, eCognition had an additional advantage of utilizing the shape parameters of the objects for performing segmentation. But ENVI did not have any vectorisation tool to convert the segmented result immediately after segmentation. So the result was taken to ERDAS Imagine for vectorisation for further analysis. To avoid non uniformity in vectorisation results, no smoothening was used during vectorisation, as the ERDAS and eCognition perform this smoothening differently.

Evaluation of Segmentation Result:

No extraction is complete until its accuracy has been assessed (Lillian, 2001) and misuse of statistics may mislead the accuracy assessment. Thus having a correct method of evaluation is very important. As no concrete and complete method was available for accuracy assessment for segmentation of area objects, first a new evaluation methodology was evolved for quantitative evaluation of the segmented result.

The accuracy of the segmentation results was checked both qualitatively and quantitatively. To perform the evaluation of the segmented result, they were first vectorised and brought to one common platform where first the results were analyzed visually and then a detailed quantitative analysis was performed to judge the quality of segmentation, based on proposed method of evaluation and then a general comparison was also done of all the software tools under study.

Qualitative Analysis:

The Qualitative analysis included visual survey with respect to the reference (Figure 2) overlayed over IKONOS of the original segmentation result (Figure 3) overlayed over IKONOS) as well as of the segmented result corresponding to building objects extracted with respect to reference layer (Figure 4), overlayed over IKONOS. All the results were compared based on criterion of distinct delineation of building objects from other similar objects like roads, footpaths, open ground and vegetation; Object shape and size with respect to the building objects in the reference, inclusion of non building objects and exclusion of no building objects and also mixing/ segregation of objects in the corresponding reference building object.

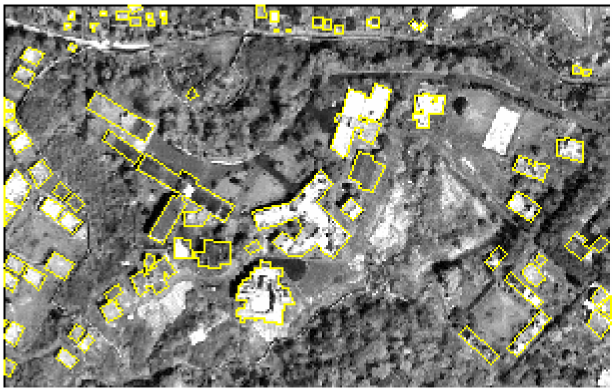
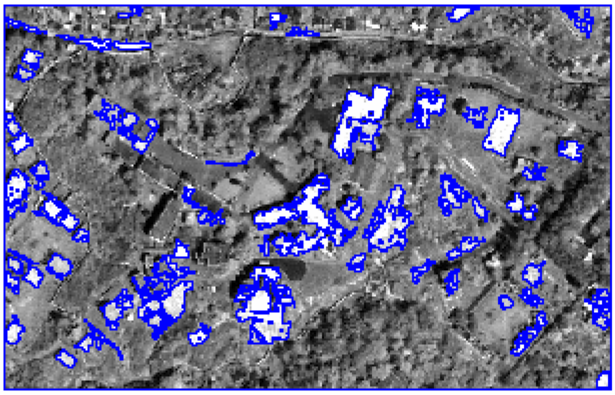
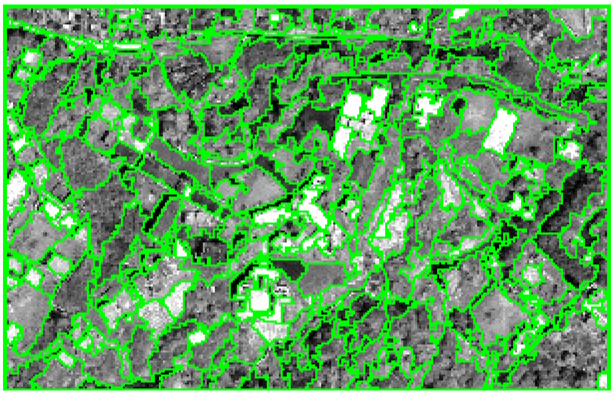


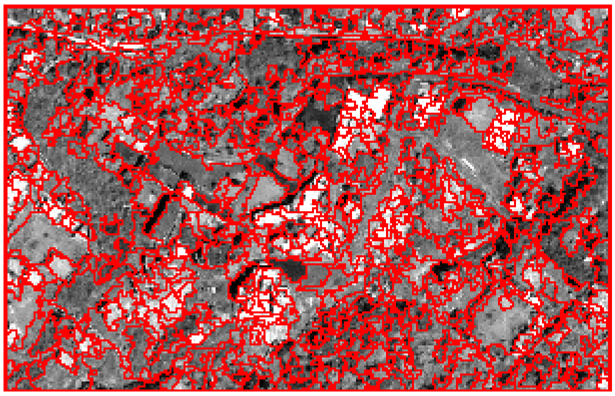
Figure 2: Reference



(a) ENVI

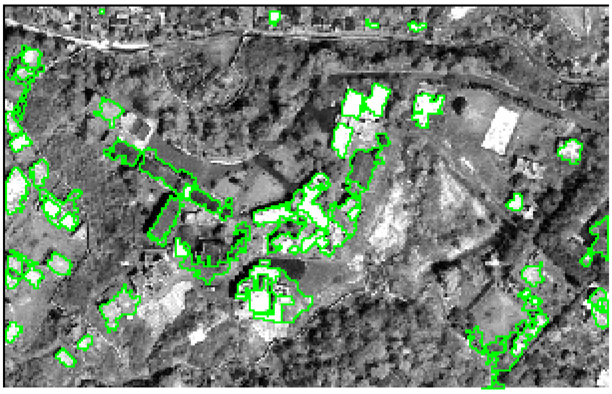


(b) eCognition

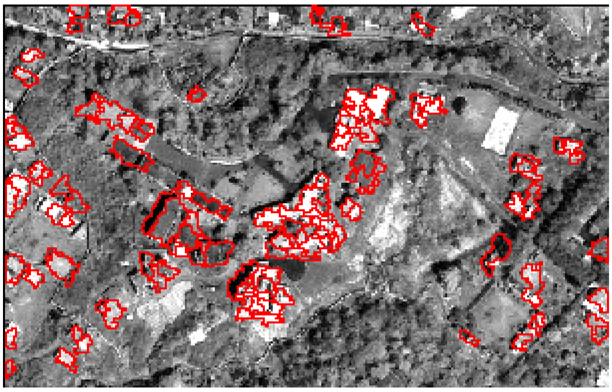


(c) ERDAS

Figure 3: Original Segmentation Result



(a) eCognition



(b) ERDAS

Figure 4: Segmentation Result (Building Objects Only)

Quantitative Analysis:

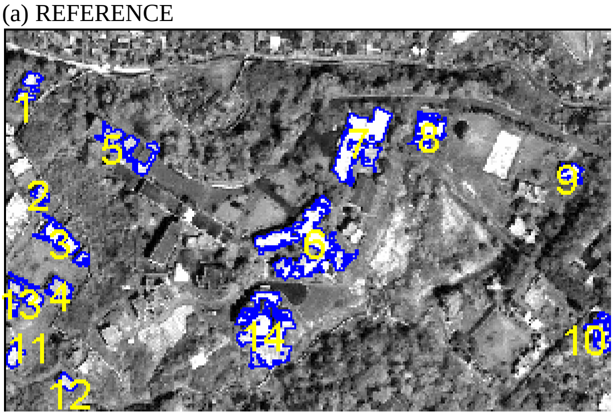
A methodology was evolved for exhaustive quantitative comparison of segmented result, and then subsets were created of the three results having only building objects and 14 samples were selected and their statistics was computed based on the methodology evolved. An over all quantitative comparison was also done of the total statistics of building objects in the three software.

A detailed quantitative comparison was done on the segmented result pertaining to building objects and total statistics was generated (Figure 3a and Figure 4 segmented buildings, overlayed over IKONOS). Secondly 14 samples were selected in all the three segmentation results having a correspondence with the reference layer (Figure 5 segmentation result buildings-14 samples, overlayed over IKONOS). And complete statistics of evaluation was generated based on the proposed evaluation method (Table 2, Figure 4). The results were also compared on the over all statistics of the 14 selected samples.

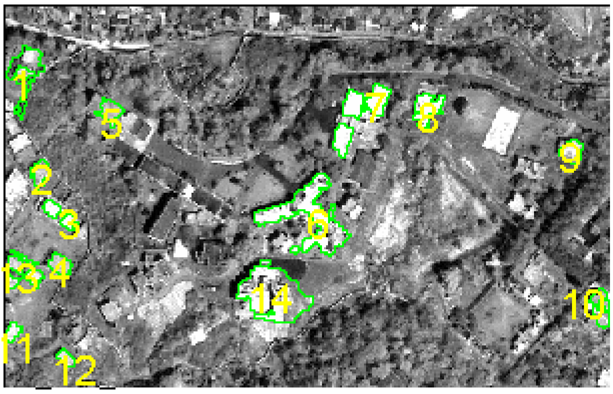
Results and Discussion:

Several quality parameters were developed to evaluate the result of segmentation. With this research question in mind, the author has tried to do an exhaustive qualitative and quantitative evaluation of Segmentation Modules available. Mainly three segmentation tools were used from three most popular software, namely ERDAS, ENVI and eCognition. The IKONOS Panchromatic image has been used for the evaluation purpose. The study involves segmentation of the image using the above three segmentation modules to extract building features. The best parameters for segmenting buildings have been established. New method of evaluation has been presented for evaluating segmentation quality. The results of three segmentation modules are assessed using the proposed evaluation methodology and the results are discussed, finally concluding with the remarks about the segmentation modules. A general comparison of the three tools is also provided at the end.

(a) REFERENCE

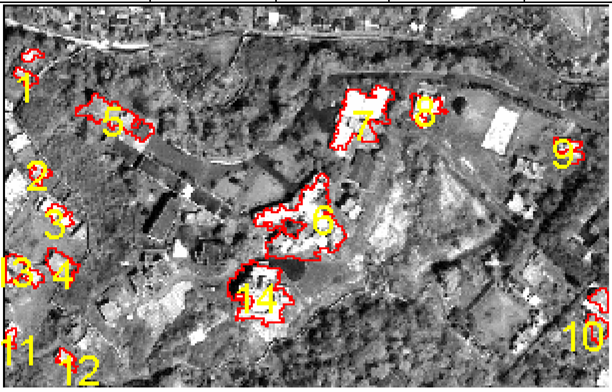


(B) ENVI



(C) eCognition

	Reference	ENVI	eCognition	ERDAS
Completeness (min, max, average)	-	0.388, 0.892, 0.708	0.279, 0.705, 0.890	0.468, 0.925, 0.759
Correctness (min, max, average)	-	0.590, 0.998, 0.841	0.329, 0.989, 0.862	0.597, 0.942, 0.776
Quality (min, max, average)	-	0.310, 0.855, 0.624	0.273, 0.876, 0.630	0.389, 0.760. 0.621
Shape Index (min, max, average)	105.93, 3107.48, 781.77	142.07, 8406.00, 1990.85	131.58, 4083.01, 975.07	118.44, 5194.38, 1181.48



(D) ERDAS

Figure 5: Segmentation Result for selected 14 samples

With the findings that image fusion distorts the image radiometry thus modifying the original DN values, we have used IKONOS PAN image for evaluation. We also However in our study we present more exhaustive parameters such as completeness, correctness, quality, error of omission, error of commission, shape index as the main parameters for comparison.

Qualitative Analysis

ENVI segmentation module was flexible enough to incorporate the range of pixel values for building objects and we could nicely separate most of the building objects from other objects at the segmentation stage itself. Most of the building objects were nicely extracted, except for the cases where the building roofs were dark (due to the shielding by tar sheet to protect from leakage) and was having intensities very less as compared to other building objects (Figure 3a). There were also some unwanted non-building objects like roads and open grounds due to their mix with the intensities of building objects. In case of eCognition and ERDAS (Figure 3b, 3c), it was not possible to differentiate building objects from other objects due to the limitation of choice in segmentation parameters. In case of eCognition because of the adapting segmentation parameters suitable to building objects, the border of the building objects was smoother than that of ENVI and ERDAS, and at the places where ENVI and ERDAS further divided the building object due to the within object variability of intensity, eCognition gave better results in terms of size of the object still maintaining shape of its outer boundary. ERDAS had difference in its object size, extracting bigger objects where the spatial frequency was low, and smaller objects in case of high spatial frequency, where as ENVI objects were of comparatively smaller size than the reference objects, and had on an average the matching sizes with the reference buildings, except for building objects with highly frayed boundaries.

Table 2: Quantitative Comparison of buildings extracted from three segmentation modules using the newly evolved methodology

Quantitative Analysis:

The results of quantitative analysis over 14 selected samples are summarized in Table 2. The completeness and Quality values show that the highest values of the two variables were observed in case of ERDAS, while the lowest in eCognition, but on an average, building extracted using eCognition were more complete and had a high value of quality as compared to other two. In case of correctness, the value was highest in ENVI and lowest in eCognition but average value of correctness was highest in case of eCognition again. In case of shape index, the quantitative analysis shows that on an average eCognition performed better that the other two modules. The completeness and quality values of the three modules depict that even though there might be cases where ERDAS and ENVI might have performed, on an average, for most of the objects, eCognition performed better than the other two. The difference in the shape index for all the three modules was due to saw-tooth effect of the segmented polygons as no smoothening technique was applied to the segmented results.

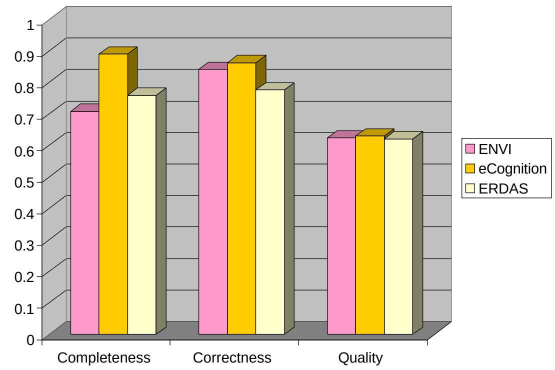


Figure 5: Quantitative Comparison of three segmentation modules

A General Comparison of the three Segmentation modules:

An overview of various segmentation modules and their general comparison was done, as summarized in table 3.

Table 3: General Comparison of the three segmentation modules

Segmentation Module	***ENVI***	***eCognition***	***ERDAS***
Algorithm	Region Growing	Region	Region

Segmentation Module	*ENVI*	*eCognition*	*ERDAS*
		Growing	Growing
Basis of Segmentation	Tone	Tone, shape	Tone
Output Statistics of Segmented Object	DN Value	Exhaustive statistics (207 features) on Object related features, class related features and global features	Limited (Grid code, ID, area and perimeter)
Parameters	3 (Min, Max Min.Population)	3 (Scale Parameter, Shape, Compactness)	3 (Block Size, Spectral Threshold Distance, Min. Region Size)
Max Image size handled by segmentation (pixels)	-	10000 by 10000	2000 by 2000
Retain map projection, geo-referencing information	Projection, datum	Not applicable	Projection, spheroid, datum
Vectorization of Segmentation Result	Not possible at Segmented stage/ to vectorise the segmented image	Yes	Yes
Options/ flexibility of vectorization	Not Applicable for segmented image	Allows for smoothening	Allows for smoothening
Output Vector Format	Not Applicable	Shape file	Arc Coverage
Availability	Commercial	Commercial	Freeware
Input Image Formats for Segmentation	ENVI File format	ecw, asc, img, jpg, jp2, pix, png, tif, bmp	Tiff, IMG
Usage of segmented result in classification	Yes	Yes	No

The segmentation module of ENVI offers specifying probable range of DN values which had a competitive edge over all other segmentation modules as at the segmentation stage itself, it was possible to differentiate most of the building objects from other objects. The other two modules did not provide this feature. However the eCognition segmentation module gave a better flexibility to consider shape in addition to colour, which probably was the reason for the better results from eCognition.

4. CONCLUSIONS

This paper presented a novel approach for segmentation to extract buildings using completeness, correctness and quality parameters. Three segmentation based modules namely ECOG, ERDAS, and ENVI were used for this purpose. Qualitative and quantitative comparisons of the three algorithms were made. ENVI showed best performance in terms of correctness, ERDAS showed highest level in terms of completeness and quality parameters. However, Ecognition performed better than other software in terms of all the parameters in an average.

The use of parameters namely completeness, corrected and quality provide sufficient help to evaluate the segmentation and extraction of urban features

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