International Journal of Applied Information Systems (IJAIS) – ISSN : 2249-0868
Foundation of Computer Science FCS, New York, USA
Volume 12 – No. 5, August 2017 – www.ijais.org

Aerial Image Segmentation: A Survey

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ABSTRACT
Due to the advancement in recent times, aerial images have started gaining a widespread in every domain of science. The primary data for any region can be obtained through tables, maps, graphs, etc. but these are not sufficient enough to present a real time analysis. So, an aerial image fills in the missing element. The images obtained have to undergo a lot of processing steps to enhance their quality. One such processing is segmentation. The main goal of image segmentation is to cluster the pixels of the regions corresponding to individual surfaces, objects, or natural parts of objects and to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. In this paper, we have presented a study of various segmentation techniques applied on aerial images. The processes have been explained in detail followed by a comparative table.

General Terms
Image Processing, Remote Sensing

Keywords
Image Processing, Remote Sensing, Aerial Images, Image Segmentation

1. INTRODUCTION
Images are the finest way of transmitting any kind of information. Digital images are an assortment of pixels and each pixel in turn has some value to represent color, brightness, hue etc. Critical information can also be encrypted in digital images and transmitted. Image processing is the technique of altering or manipulating an image in such a manner so that quality of image can be intensified or some kind of valuable information can be extracted. Image processing with improved flexibility and adaptability is highly desirable in many areas such as image transformation, correction of distortion effects, noise purge, histogram equalization and more. An image can undergo several stages of processing in order to yield an improved output. One suchstage of processing is image segmentation. Image segmentation partitions the original image into discrete sections, each containing pixels with similar traits. An ideal segmentation is typically one in which:

- Pixels in the similar category form a connected region and have similar greyscale values,
- Neighboring pixels in dissimilar categories have dissimilar values.

Segmentation forms the vital step in image analysis. If segmentation is carried out well then the other stages are made simpler. Image segmentation algorithms [1] are generally classified into three major categories:

- Edge Based
- Region Based
- Clustering Based

We have focused our study on aerial images. These images are basically captured from any airborne vehicle. Since, aerial photographs reflect the current pictorial view as compared to the traditional means of data acquisition of a region; they are highly preferred as a tool to study the earth's environment. There have been growing research activities in use of aerial imagery for transportation management, disaster management, location services and others. This paper presents a comparative study of various techniques applied for image segmentation on different types of aerial images like forest fire image, remote sensing images, satellite image, SAR image and others.

The rest of the paper is organized in the following way: The next section discusses the various segmentation procedures carried out on aerial images followed by a section on their comparison. Finally the last segment concludes our work.

2. RELATED WORKS
We classify our research as per the role of aerial images played in different management systems.

2.1 Traffic Management Systems
For an effective traffic management system, the utility of the system is dependent on the accuracy of traffic flow estimation. Generally the ground based data obtained from fixed cameras do not divulge the spatial locations and movement of traffic beyond the field of view. Owing to its spatial scale and connectivity, aerial data is basically considered to enhance the quality of traffic estimation.L.I. Yu [2] in his research focused on extracting vehicles based on their geometrical configuration from high resolution UAV (Unmanned Aerial Vehicle) color imagery. He achieved this by following two levels of vehicle extraction. First, the color aerial image is segmented by a segmentation algorithm based on fuzzy c-partition in which the color histogram is used for color space analysis to obtain a proper initial estimate of center positions. Genetic algorithm is employed to optimally cluster the color space data point projected from the input color imagery, and hence optimal color segmentation is achieved. Secondly, the post-processing procedure is carried out on the segmented image by using binary mathematical morphology operators to extract the outlines of vehicles. The fuzzy c-partition matrix is calculated by the following formula:

$$p_{ij} = \mu(u_i,v_j)^{1/m-1} / \sum \mu(u_k,v_j)^{1/m-1} \ , 1 \leq k \leq c$$

where m ∈ (1, ∞) is the weighting exponent on each fuzzy membership. The fitness function for genetic algorithm is taken as: $1/c \sum p_{ij}$, $1 \leq i \leq c$, $1 \leq j \leq n$.

Similarly, in another research Rakesh Kumar et al. [3] worked on automatic traffic controlling system. They proposed an automatic multilevel thresholding method which optimizes the Automatic Thresholding Criterion (ATC) [9] with genetic algorithm and DWT. The proposed approach uses a new string representation of the chromosome. It is combined with a wavelet transform based technique in order to reduce the time computation. First, three RGB histograms are calculated separately. The histogram is then reduced using GA and wavelet [10], because a wavelet is a localized function that can be used to captive information, efficient and useful description of a signal. After evaluating all three threshold histograms, they are merged again in three dimensional space. At last, the post-processing procedure is carried out on segmented image by using mathematical morphological operators to extract the outlines of vehicles.

2.2 Forest Planning & Management Systems

Forests play an essential role in balancing the ecosystem. The forest management estimates its inventory based on aerial images. One such research to develop a forest inventory was put forward by S. Tuominen and R. Haapanen [5]. Their approach was based on interpretation of airborne laser scanning (ALS) data and digital aerial imagery using field sample plots as reference data. They carried out automatic stand delineation by segmentation of aerial photographs and ALS data interpolated to raster format. Then, segmentation was carried out in two phases: In the first phase, an initial segmentation was carried out employing local edge gradient. The objective of this was to find all potential segment borders. In the second phase the initial segments were processed using a region merging algorithm that was guided by parameters such as desiredminimum size of final segments and the similarity/dissimilarity of the segments to be merged. The merging of initial segments into larger spatial units was carried out on the basis of laser and aerial image data. The estimation method for k nearest neighbors was carried out by cross validation and accuracy of the estimates was measured by their root mean square errors (RMSE). The selection of imagefeatures was done by genetic algorithm and a total of 11 features were extracted for both grid elements and image segments. It wasfound out that the features extracted from grid elements worked better than features extracted from image segments in estimating forest attributes.

When managing the forests, appropriate precautions should be taken from forest fires as they take a heavy toll on the lives and the surroundings. To avert them or to mitigate the damage produced by them, researchers often take help of aerial images. One such work was produced by Sanqi Li et al. [2] to extract an area under forest fire based on its color characteristic. They defined that the area which was covered by smoke was the area of a forest fire in the early period. The smoke usually displays several specific colors in aerial images. The smoke area can be extracted from the images through the specific color detection. In natural light irradiation, smoke appears to be in white, black and gray. But in RGB space, the value of R, G and B components of these colors is basically equal. The following formula is used to calculate the variance and classify the area:

$$X = (R + G + B) / 3$$

$$\sigma^2 = [(R - X)^2 + (G - X)^2 + (B - X)^2] / 3$$

where R, G and B are the value of three color components respectively. X is the mean value of three color components. σ^2 is the variance of three color components.

The obtained image is first enhanced and changed to gray level. Using Otsu, an adaptive threshold value T is obtained. Now the enhanced color image is scanned from first line to last line for each pixel. The following formula is used to calculate the gray level t of the pixel:

$$gray = 0.299R + 0.587G + 0.114B$$

If t > T and the similarity between RGB of the pixel achieves a certain condition, the image pixel value in the corresponding position is changed to 1, otherwise to 0.

The binary image is obtained by the following formula:

$$g(i,j) = 1 \text{ , if } t_{i,j} > T \text{ and } \sigma^2 < 40 \text{ ; else } g(i,j) = 0 \text{ .}$$

2.3 Urban Planning

Aerial images give urban planners a clear spatial overview of a location thereby helping in to make calculations quick and easy. One such area of research to have a strong impact is the 3D reconstruction of buildings from aerial imagery. Mohammad Izadi and ParvanehSaeedi [4] carried out their research on 3D reconstruction of buildings from aerial images. They proposed a method to extract building profiles from rooftop images of buildings using a new hierarchical feature based segmentation method. Normally segmentation is parameter based but here feature based segmentation is used that incorporates an adaptive range for color resolution $h_c$to segment the image with no parameter variation. Using the mean shift segmentation algorithm [11], the input image (I) is segmented for Range Resolutions of $h_c = (T_l, T_l + \Delta T, \ldots T_l + (K\text{-}2)\,\Delta T, T_h)$. For each value of $i \in K$, $K = (T_h - T_l + 1) / \Delta T$, a segmented image S_i is generated including a set of regions R_{ij}: $S_i = \cup R_{ij}$ and $j = 1, \ldots\ldots, N_i$, where N_i is the no. of regions in S_i. Using these segmented images and their regions, a tree structure is established. This tree is utilized to identify the best Range Resolution for various regions of the image via a set of rooftop constraints.

2.4 Remote Sensing

Remote sensing [15] acts as an important data source for GIS. Several advanced research have been performed on these aerial data. We studied a few of the segmentation techniques based on remote sensing. SanghamitraBandyopadhyay et.al [6] proposed a multi objective optimization algorithm to tackle the problem of fuzzy partitioning of remote sensing images. Here, a number of fuzzy cluster validity indexes are simultaneously optimized and the resultant set contains a number of non-dominated solutions, which the user can judge relatively and pick up the most promising one according to the problem requirements. For K clusters, the centers encoded in a chromosome in the initial population randomly select K distinct points from the data set. The XB index [12] and J_m measure [13] are taken as the two objectives which need to be simultaneously optimized. For computing the measures, the centers $z_1, z_2, \ldots, z_K$ encoded in a chromosome are first extracted. Subsequently, the centers encoded in a chromosome are updated and the cluster membership values are recomputed. The XB index is defined as a function of the ratio of the total variation σ to the minimum separation *sep*, of the clusters. When partitioning is good and compact, σ should be low while *sep* should be high, thereby yielding lower values of the XB index. The objective is therefore to minimize the XB index for achieving a proper clustering. The non-dominated solutions among the parent and child populations are propagated to the next generation. J_m calculates the global cluster variance; the lower value of J_m implies better clustering solution. On the other hand, XB is a combination of local and global situations. These two terms may not attain their best values for the same partitioning when the datahave complex and overlapping clusters. Since the remote sensing data sets typically have such overlapping clusters, considering J_m and XB (or in effect σ and *sep*) will provide a set of alternate partitioning of the data.

In yet another research, B.K. Jeon et. al [7] presented a technique to detect roads from spaceborne SAR (Synthetic Aperture Radar) images using genetic algorithm. Roads can be modeled as curvilinear structures that possess width. These curved segments are extracted from the image using a curvilinear structure detector and the roads are detected accurately by grouping these curve segments. If the number of segments to be considered is large, then the input segments are reduced considering the fact that roads appear dark in SAR images. Thus simple thresholding is applied to exclude the regions of no interest before the extraction of the curvilinear roads. The segment grouping is done in 2 steps: initial grouping and main grouping using GA. In the initial grouping step, an initial seed was chosen , which is most likely to be found on the road by grouping base segments in a very strict sense and grouping is performed applying GA. The seed is then updated using grouped segments and the step is iterated until no base segment is found. In the GA grouping method, segments which are longer than the threshold are chosen as initial seeds. Multiple seeds are used so that the algorithm can detect road networks and grouping can be done around the two end points of the seeds using GA sequentially. The grouped segments of the current stage are used as the new seed of the next stage, and this procedure of region-growing is iterated N_{max}times in the same manner. Fitness function of the individual segment n is defined as:

$$F(n) = \alpha P(n) + \beta C(n) + \Upsilon H(n) + \delta L(n)$$

Here α, β, ϒ, δ are the four weighing factors for the fitness and are set to 0.5, 10.0, 1.0, 0.03 respectively and P, C, H, L are the proximity, co-curvilinearity, homogeneity, length of the segments. Finally, a post processing is done where Lai's snake model [14] is used. The snake is applied to gap regions between grouped segments. The points on the roads are detected by an energy-minimizing process, where initial control points of the snake are automatically chosen by interpolating grouped segments. Hence, the final roads consist of points from the segments grouped by the GA and points detected by the snake.

Ravindra K Moje and Chandrashekhar G Patil [8] used GA along with SVM (Support Vector Machine) to classify satellite images so that they will be close to the original images. At first, a procedure of image pre-processing is performed such as 5*5 median filtering and histogram equalization is carried out to improve the recognition rate of the image. Next different features related to the image such as Pixel level features, Local level features, Global level features are extracted. SVM employs optimization algorithms to locate the optimal boundaries between the classes. To make classification better than just having the raw spectral values as feature vectors, GA is used. The challenging task is to develop a fitness function to produce SVM parameters that are reliable and effective for SVM models. K-fold cross validation is applied to the GA fitness function. In k-fold cross-validation, training data T are randomly divided equally into k subsets $T_1 \ldots T_k$, a classifier is trained by k-1 subsets and tested using the remaining subset T_i (i=1,…, k). Training is iterated k times, and the final classification rate is the average of all the k classification rates. The k-fold cross-validation fitness function F is obtained by:

$$F = \frac{1}{K} \Sigma\, T_i \text{ rate}$$

whereT_i is the classification rate of T_i using the remaining k-1 subsets as the training set. This is the cross validation accuracy. The GA optimizes the image obtained from the SVM classifier using the above fitness function.

3. COMPARATIVE STUDY

S. No	Classific ation	Researc her(s)	Segmentation Technique	Objective	Different Techniques Used in the method	Parameters Taken for Segmentation	Results and Performance
1	Traffic Manage ment Systems	L.I. Yu	Histogram and Genetic Algorithm based fuzzy image segmentation.	Vehicle extraction	Fuzzy C partition, Genetic Algorithm, Colour Histogram Analysis	RGB histograms	Most vehicle outlines matched well with the original vehicles. Information can be used for traffic flow computation and vehicle classification.

2	Forest Planning & Management Systems	Sanqi Li, Wenbin Li, Jiangmig Kan, Yutan Wang	Image Segmentation Based on RGB Similarity of Segments	Forest fire area extraction	Otsu Thresholding, Histogram Equalization	Variance of RGB colourcomponents,Gray level of image colour	The technique divides image space into some meaningful areas that are corresponding to real scenes and thus, extracts the target fire area completely. The classification error rate is low, area consistent edge is clear, precise, and has good robustness.
3	Traffic Management Systems	Rakesh Kumar, TapeshParashar, Gopal Verma	Genetic Algorithm and DWT Based Multilevel Automatic Thresholding Approach	Vehicle Extraction	Histogram Thresholding, Genetic Algorithm, Discrete Wavelet Transform	RGB Histograms of Image	Almost all important components are preserved in the threshold images, since the homogeneous regions are well apparent and their outlines are very clear. Information can be used for vehicle classifications and traffic flow computation.
4	Urban Planning	Mohammad Izadi and Parvaneh Saeedi	Hierarchical Feature Based Image Segmentation	Automatic Building Detection	Hierarchical Segmentation using mean shift algorithm, Rooftop Verification	Building's context and geometrical features like total curvature, compactness, bounding prevention factor, dividability factor	Results showed the shape accuracy and completeness of 96%. Uses a number of geometrical/regional attributes to maximize a set of rooftop definition measures.
5	Forest Planning & Manage	S. Tuominn &R.Haapanen	Grid-based and segment-based estimation using airborne laser	Forest Attribute Estimation	Local Edge Gradient Algorithm, Region Merging	ALS height and intensity, Euclidean distances between	The features extracted from grid elements

	ment Systems		scanning and digital aerial imagery		Algorithm	the observations, Number of nearest neighbours	worked better than features extracted from image segments in estimating forest attributes producing the best automatic delineation of stands regarding their compactness, shape, correctness of borderlines.
6	Remote Sensing	S.Bandyopadhyay, U.Maulik, & A. Mukhopadhyay	Multi objective Genetic Clustering for Pixel Classification in Remote Sensing Imagery	Pixel Classification of aerial images	Fuzzy Clustering, Genetic Algorithm, Multi-Objective Optimization	Euclidean distance between point & cluster centre, Global cluster variance of Image	Results on numeric image data sets indicate that rather than considering these indexes individually, a better clustering performance is obtained if both of them are optimized simultaneously. It may be used in data mining applications also.
7	Remote Sensing	Byoung-Ki Jeon, Jeong-Hun Jang, and Ki-Sang Hong	Steger's Method[16] and Genetic Algorithm based Grouping	Road Detection	Genetic Algorithm, Perceptual Grouping	Proximity, Cocurvilinearity, Initial Grouping of image segments	Detects roads in the space borne SAR images with an accuracy of 92.2% and with an average error of only 0.13 pixels, which corresponds to 2.08 m and indicates high accuracy. Can detect roads regardless of landscape and texture because it utilizes information on the road structures in

							the scene. Practically, it can be utilized to update map information.
8	Remote Sensing	MojeRavindraK, PatilChandrashkhar G	Parameter Optimization using Genetic Algorithm	Satellite Image Classification	Support Vector Mechanism, Genetic Algorithm	Recognition rate of the image, Spectral Information of image pixels	Demonstrates that image characteristics such as texture, shape and pattern are helpful to the high resolution remote sensing images. It not only degrades the computational complexity, also can obtain a higher classification rate. Matching human performance is the ultimate goal of the system.

4. CONCLUSION

In this paper, various segmentation methodologies applied for image processing of aerial images have been explained. First, we have given a brief idea about image processing and its techniques and the importance of aerial photography in different fields. Then we have given a brief idea about the segmentation techniques on different types of aerial images aimed at achieving different goals. Finally we did a comparative study on the objectives and performance of these methods. We have also observed that these techniques can be applied in different fields to extract valuable information. On the whole, this survey gives us an idea on the importance of aerial images and how using different types segmentation techniques on them; we can achieve differentgoals faster and more efficiently.

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