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An Enhanced Approach of Building Extractionfrom Satellite Images Using SOFM & MRF Model

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Abstract—Extracting Building features from satellite imagery is a vital research area in digital remote sensing field. Building detection & extraction is one of the complex and challenging task in GIS database. But this technique is useful for urban planning and obtaining more timely and accurate information during natural disasters like Earth quakes, Cyclone etc..At the first appearance, buildings are visible as easiest objects to detect and extract. But many difficulties meet on extracting buildings accurately, comprising various outlook angles, roof top complexity, environmental objects(Trees, Roads, vehicles etc) and additional objects which ambiguous the boundaries of the buildings that can be detected. Because of these reasons many algorithms deliver less quality of building extraction and also much time taken for detection. To solve this problem, integrating many efficient algorithms provides better results than individual algorithms. In this study, an enhanced approach for rising the quality and accuracy in detecting & extracting building textures with various and complex angles of roofs from urban area satellite images is proposed. First, an unsupervised image segmentation approach based on SOM(Self organizing maps) is applied to detect roof top regions. Then, the SOM combines with MRF(Markov Random field) spatial constraints for improved segmentation outcomes. This Hybrid approach of SOM and MRF used less data samples in training set. Experimental results obtained that the proposed method achieved excellent result in detecting and extracting rooftops in complex satellite images**.**

Keywords—Self Organizing Feature maps; Markov random field; GIS data

I. INTRODUCTION

Semi automatic and Automatic building extraction has been one of the major research areas in digital photogrammetry, remote sensing fields for many years. Automatic extraction methods are needed to reduce database development time and cost.Buildings are one of the significant Geographical features and building detection is to be a useful technique in city planning & management[water distribution, utility transportation, drainage systems of urban areas], Pollution modeling, calamity monitoring[flood,forest fire etc] and many other types of urban models.A Large number of Building extraction methods with many algorithms have been developed for building extraction from satellite imagery. However, a high accuracy & successful building detection remains a demanding goal in research. A wide range of these algorithms are combing for oblong structure extraction and different viewing angles identification using data samples like geometric structure[1],edge based methods[2] that includes linear attribute verification, shadow[3] etc.Due to high spatial resolution, building detection and extraction was focused on aerial images or 2D images in Earlierresearches. This field depend on line or edge detection. Unfortunately, these methods failed to detect textured roof tops in buildings. Saeedi and Zwick(Saeedi and Zwick,2008) developed a hybrid approach of edge information and graph based segmentation. GS(Geometric snakes) is used by Region-based Active Contour Model is one of the most acceptable technique for aerial images, as they focused on intensity, texture and statistical features of the image regions[4].Lee et al.(2008) has classified building detection techniques under three categories such as Algorithms for 1.2D or 3D Satellite imagery ,2.LIDAR data 3.Both LIDAR data & Satellite imagery. Cheng et al (2008) introduced a method for separating buildings from other objects in satellite images hold more detailed information with the shadows.This approach is even more complicated in 3D images. Unfortunately raw or interpolated data can influence the detection performance which leads poor accuracy for building edges.

Sirmacek and Unsalan (2010) developed an algorithm for building detection in various environments.Wei and Zhao[5] proposed an approach using Artificial Neural network algorithm(unsupervised learning method) for clustering the satellite image with the shadow data to identify the building components.Haalaetal (Haala and Brenner,1999) introduced a novel approach to reconstruct building roof tops using surface models detected from DEM data. In this approach building boundaries were detected automatically by classifying DEM data and corresponding color image. Functional minimization [6] is a major factor of DEM-based building detection. Mayungaa[7] worked on active contour model for semiautomatic building extraction method in which thealgorithm creates the border of all buildings when user selects the estimate middle of each building. This method are tested on aerial images with only rectangular buildings ,not on more complex shapes.ZahraLari and Hamid Ebadi [8] evaluated automatic building extraction of structural and spatial data combined with ANN(Artificial Neural Network) algorithms. This method required set of trained samples prior to initiating the proper building extraction.In this proposed method, automatic building extraction in satellite imagery is obtained with acceptable accuracy. The proposed methodology for building extraction is a combined technique of self organizing feature maps and Markov random field technique.

II. RELATED WORK

Image segmentation defines to the process of image partition into several groups of homogenous pixels in order to several criterion. The adjacent regions must not intersect with each other groups , because they are heterogeneous. Finally segmentation means partitioning an image in to meaningful groups. At earlier stage, many segmentations methods are supervised. A Supervised method needs a prior knowledge for proper segmentation results. But sometime it is not possible to get the prior information. Recently several unsupervised approaches are introduced.Mason,Pieeczynski(1993) described an approach of unsupervised method which required many parametricmetrices and it resulted noisy & sensitive data.To overcome the difficulties ,Kohonen's proposed a novel approach self organizing maps is an unsupervised network used to partition high resolution satellite images.(2001).This method focused on to convert the high resolution pattern in to two dimensional pattern.but it was not known by all. R.Ruskone et al(1997)..proposed a method for automatic road detection.This method which has two processing steps to extract the road segment and production net. S.Hinz developed a method for road extraction in city areas.Zahralari and Hamid ebadi introduced an approach for automatic building extraction from high resolution satellite images using ANN(Artificial Neural Networks).This method used spectral snd structural information based on Ann and provided better results. This method required set of trained samples prior to initiating the proper building extraction.Zhou et al.,(2007) proposed a hybrid approach of K-means and SOM for satellite image segmentation.Here K-means algorithm is used to segment an image in random scale and SOM did resegment in that image of fine scale.It required pre-partitionalclusters.Awad el al(2007) provided SOM based genetic algorithm for different satellite image segmentation.It resulted high accuracy,However performance of the segmentationremains a problem. Lili Yun ,Keiichi Uchimura developed a semi-automatic method for road network extraction from high resolution IKONOS imagery using interpretation of self organizing maps(2007)[9].It defined learning process using grayscale images and implicit connection rules.The SOM process provided an approach to road centerline delineation from IKONOS imagery that is not included the edge defection.In this method obtained results were satisfactory in all case ,but some part of the road network were missed.Lizyabraham,M.Sasikumar (2012) proposed an automatic method for satellite images building extraction using ANN.It is mainly used for very high resolution urban area building were extracted. It required a only one panchromatic image for detecting the buildings. Even though It is used for complex image extraction, the resultant image not shown the perfect shape of buildings roofs.[10].

III. METHODOLOGY USED

The proposed hybrid method is illustrated in the sketch (sec D).First neighborhood pixels is identified by SOM trained data set. Second, using MRF model improves the segmentation without having more training set. Finally Buildings are extracted from high resolution satellite images using Matlab 7 code.

A. Self Organizing Maps

Kohonen's Self organizing Feature maps (SOM) is an unsupervised ANN(Artificial Neural Network) method. It transforms high dimensional input model into two dimensional arrays of neurons. SOM retainsneighbouring input neurons. The basic SOM model includes an input layer and an output layer. All input neurons are considered as input data dimension and organized as two-dimensional array of output neurons.The SOM describes a method for map the input data Sn into a standard 2-dimensional array of neurons. For each input node i, is represented by vector w_i€Sn. The array of data is defined as rectangular pattern type. A weight w_i evaluated with an input node x_1€Sn and the more similar match is found and mapped onto this position. This is represented as" restort".The array vector and the location of the retort(input image) are presented as image display.

Let x_1€Sn be a random input dataset and small random values assign as weights w_i.The minimum Euclidean distances $||x - w_i||$ is computed by more similar matching nodes(best matching unit), The term "u" represents minimum Euclidean distances among the nodes :

$$dk = \|x1 - wc\|$$

$$u = \min_i \, dk(t) \quad (1)$$

Thus x_i is mapped onto the node u relative to the parameter values w_i. For every iteration of winning process, the weight vector and its neighbour vector is to be updated using the following learning equation:-

$$w_i(t+1) = w_i(t) + \alpha(t)[x(t) - w_i(t)] \quad (2)$$

The following Fig.1 clearly shows the winning neuron process from several iteration .

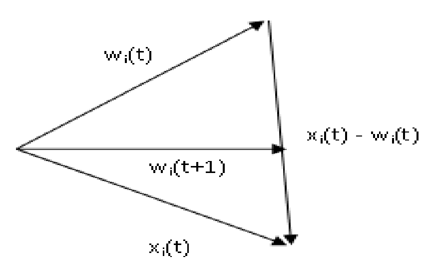

Fig.1. Winning Process Iteration

where t1 is time coordinate integer value, and α(t) is the neighborhood vector at the starting of the traningset.It may be a function of time in linear/non-linear form. In the array , α(t) = l(||ru - rv||, t1), where ru€R2 and rv€R2 are the center vectors of nodes u and v, respectively, when increasing ||ru - rv||, and α€0. So the implementation of the SOM based segmentation method is used to reduce the time of segmentation.It can be implemented with two major steps:

In the first step we generate a SOM (ANN) with xi*n*put neurons and k outputs.. The n vectors were prepared from the n non-overlapping blocks of the image. These non overlapping blocks will reflect all the textures in that image. The neural network will be self organized to map the k types of texture blocks. This phase needs training. In the second step, the similar neural network is mapped with number of input patterns (pattern vectors) into h partitions. Since the neural network is already organized for k types of patterns ,this phase will not require any training. Each input neurons is mapped through weights to every output nodes The weights are adjustable for each iteration. Let $X=[x0,x1,x2\ldots\ldots xn-1]^T$ be the set of N number of input data in Sn and gerenates each x_i N dimensions. Let $Y=[y0,y1,y2\ldots\ldots yn-1]^T$ be the set of N number of output nodes and W denotes the set of weights $Wj = [w0j,w1j,\ldots\ldots w(n-1)j]^T$ and consider as reference vectors.The weight vector $Wi^{[k}]$ representsthe weight for node i at iteration h.The input node is denoted by xi connected to the output node yj via Wij.It is the weight adjustmentvalue from i^{th} input node to the j^{th} output node.The weights are updated by the winning entity and the neighborhood be nearer to the accessible input node. Any inputs in SOM method is calculated only for output units in a limited neighborhood whose distance dij is in least value. AnEulidean distance is measured by d_{ij}, as follows:

$$d_{ij} = \min_j \left\| x_i - w_{ij} \right\|^2 \qquad (3)$$

Let be a learning rate, $\alpha_{ij}(t)$,is also essential to reduce in instance. The weight updating rule is defined as:

$$w_{ij}(t_1+1) = w_{ij}(t_1) + \alpha_{ij}(t_1)[x_i - w_{ij}(t_1)] \quad (4)$$

The methodology for image extraction using proposed Algorithm(SOFM).

1. Open the Image which is to be segmented.
2. Prepare a Single column texture block matrix for each pixel in the image and convert the texture blocks as multidimensional data points (sliding neighborhood operation).
3. Create a SOM and train it with some randomly selected dataset.
4. Make Clusters out of the all the feature vectors using the newly trained SOM.
5. After that we will have the cluster labels for each pixels in the image.
6. Decide the gray levels of each segments by averaging the pixels corresponding to the class labels in each groups.
7. Display the Segmented image.

While doing slidingneighbourhood operation, the output values may be computed by assuming that the input image is surrounded by additional rows and columns of zeroes. But in our implementation the border pixel inside that particular radius of operation is discarded. So the output image is little bit smaller than the original. (shown in separate column in the output table in results section).

B. The Markov Random Field Model

We can include the more spatial constraints into SOM training algorithm for enhanced segmentation results. SOM training algorithm can update the connection weights by adding the Markov Random Field model. For each pixel, pixel intensity & its label is indicated by i, $s_i$andg_i.$g_i = c_i$ respectively. Each pixel i belongs to its region c_i.Let G-{g_i} indicates the image segmentation not including the i^{th} pixel i(g_i).A region process which generates the spatial connectivity which is modeled by a MRF(Markov Random Field) as:

$$P(g_i \mid G - \{g_i\} = P(g_i \mid g_j, j \in N_i \quad (5)$$

Here N_i indicates the neighborhood of the pixel i..Gibbs density produces the density of g which makes the equation as given below:

$$P(g_i \mid g_j, j \in N_i) = \frac{1}{Z}\exp\left\{-\sum_{c_i} V_c(g_i)\right\} \quad (6)$$

Here Ci indicates possible no of cliques that contain i^{th}pixel.$V_c(g_i)$ is clique potentials and Z is a partition constant (i.e) $Z = \sum_{g \in G} e^{-\sum_{c \in C} v_c(g)}$.

The value of $V_c(g_i)$ depends on the local configuration on the cliques.Here energy function MRF is

$$U(g_i) = \sum_{c_i} V_c(g_i) \quad (7)$$

The function, $U(g_i)$ is a sum of clique potentials $V_c(g_i)$ over all possible cliques C.The Clique potentials using 2-point are defined below:

$$V_c(g) = \begin{cases} -\xi(s_i - \mu_{gi}) & if \quad g_i = g_j \; and \quad j, i\varepsilon C \\ 0 \quad if & g_i \neq g_j \quad and \quad j, i\varepsilon C \end{cases} \quad (8)$$

Here ,0< ξ<1 and mean intensity μ_{gi} is computed for the region g_i.

C. The Alternative SOM Algorithm with MRF Function

By taking Equation (7) and hybrid SOFM weight connection update with MRF rule is:

$$w_{ij}(t_1+1) = w_{ij}(t_1) + \alpha_{ij}(t_1)[x_i - w_{ij}(t_1)] + U(g_i) \quad (9)$$

Here $U(g_i)$,is integrated to classify the regions based on spatial clustering of pixels . It provides prior spatial information regarding the dimension, contours, direction and angle of the regions to be segmented. Each spatial constraint evaluates for the natural contiguity of pixels belonging to the same type of image region. If a pixel is a specific type, the neighbour pixels would have a high possibility of being the same type.

In the training set, the Markov Networks progresses the segmentation results without adding more data samples.The Modified SOFM Neural network is segmented the Buildings from satellite images with different levels.The Satellite images used in this paper are obtained from Global area images(Mumbai).It is viewed that the spatial constraints (MRF) need not be measured as the major feature for the Segmentation.It is used to remove the result of noise and flat boundaries.The segmentation error is different in each individual segmented Image ,Because no of pixels are different in each Image.

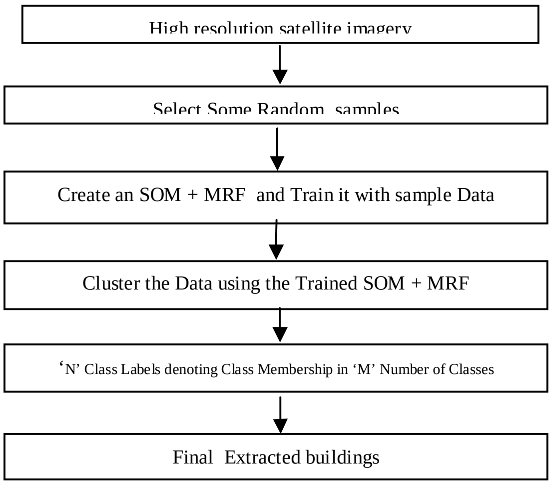

Fig. 2. System Sketch: Image Segmentation Steps of SOFM and MRF

D. System Sketch

The proposed system(SOFM and MRF) consists of four main parts that each of them have specific process shown in Fig.2.In the first part ,some random samples are selected.In the second part,Modified SOM algorithm generated using of MRF and trains the sample data.In the third part,Cluster the Data using the Trained SOM .In the Fourth Part, the system segments the Buildings based on Feature extracted using 'N' Class Labels denoting Class Membership in 'M' Number of Classes.

IV. Result and discussions

After training the unsupervised network used in this system, we can recognize the degree of its success in building extraction. This images used in this study are subsets of Globalregion(Mumbai) images .Its spatial resolution is 0.61 panchromatic layer and 2.44 for the multispectral ones and 256X256 pixels are taken for implementation. The Modified SOFM Neural network is segmented the Buildings from satellite images with different levels.It is viewed that the spatial constraints (MRF) need not be measured as the major feature for the Segmentation.It is used to remove the result of noise and flat boundaries.

Here the learning factor taken as α(t) which is applied for many Iterations(0.2,0.3,0.4). More training iterations can improve the results ,but it needs much longer training time. This method is executed two tasks 1) the right structured buildings has to be found and 2) The structure of the buildings has to be detected. Mean square Error is computed to determine the internal accuracy of the measurement. Therefore ,buildings even from high dense areas can be detected with considerable degree of accuracy and also hybrid approach of SOFM with MRF with different training data set, insignificant buildings which cannot be distinguished from the background features are able to extract. For performance evaluation ,the same images are evaluated with K-means and Fuzzy C-means methods.(shown in Table 1).The proposed results are compared with K-means and Fuzzy C-means algorithms. The output results shows that the segmented image of proposed method contains more edges of the input images.

A. Result of Different Segmented Images

The following Fig.3shows various Global images with segmented output.

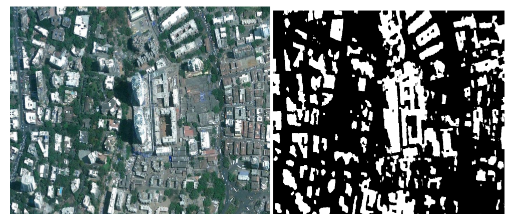

Image **(a)**

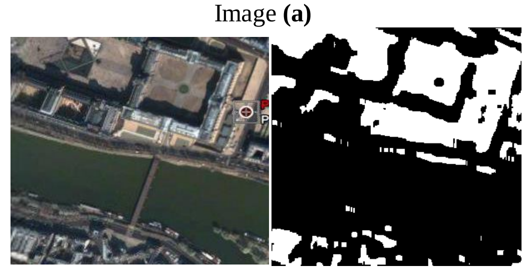

Image **(b)**

Image **(c)**

Image (d)

Image **(e)**

Fig. 3. Original, Segmented results of Five Globalregionimages

B. Overall Performance of proposed method

The following Table .1 shows the average performance of K-means[11], Fuzzy C-means[12] and SOM. The numbers were the average values obtained from repeated tests with different

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Satellite images if uniform size (256 X 256) in different segmentation levels.The proposed SOM based algorithm, the performance in terms of speed was so good and the same quality of segmentation

Segmentation Level : 1 and 2
The Input Image format : TIFFimage
The Number of Repetitions : 10
Time Taken for Data Preparation : 100 Sec

The Table.1 shown below,compares performance in terms speed in Different Segmented Methods of Mumbai region images.

Table 1

Sl No	**Images**	**Time Taken For Segmentation**		
		K-Means (Seconds)	***Fuzzy C-Means (Seconds)***	***Proposed Method(SOM+MRF) (Seconds)***
1	Image a	4.436000	4.707000	1.742000
2	Image b	4.867000	5.057000	1.802000
3	Image c	13.740000	12.027000	1.883000
4	Image d	26.287000	21.601000	4.066000
5	Image e	17.341000	15.616000	2.322000

C. Performance Chart

The following chart shows the average performance of the three segmentation algorithms under evaluation. The numbers were the average values obtained from repeated tests with uniform Satellite image size (256 X 256). As we see in the chart, obviously, the arrived results were more significant and comparable. The Proposed SOM based algorithm performed very well in terms of speed. If we note the segmented output images in the previous pages, we can realize the better performance of the algorithm in terms of visual quality also.Fig.4shows performance in terms of speed in adapted SOM (SOM+MRF) compared with K-Means and Fuzzy C-Means Algorithms.

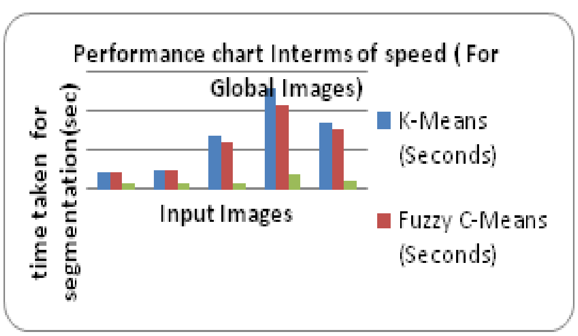

Fig.4. Performance chart of the Global images using various segmentation methods

V. Conclusion

In this research, a combined approach of self organizing Feature maps and Markov random field based building extraction from high resolution satellite imagery is proposed. The approach leads improvement to building extraction accuracy by adding the energy function of MRF with existing SOM algorithm. The proposed algorithm includes more spatial information about a pixel region by using Markov Random Field(MRF) model. The MRF term improves the segmentation results with less trained samples set. This verifies that the neighboring pixels need to have uniform segmentation assignment unless they are in the boundary of different regions. The proposed method has significantly reduced the time taken for segmentation.

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