AUTOMATIC ROAD FEATURE EXTRACTION FROM HIGH RESOLUTION SATELLITE IMAGES USING LVQ NEURAL NETWORKS

J.S.J. Wijesingha* , R.W.D.M. Kumara, P. Kajanthan, R.M.K.G.S.P.B. Koswatte, K.R.M.U. Bandara

Faculty of Geomatics, Sabaragamuwa University of Sri Lanka

P.O. Box 02, Belihuloya, 70140, Sri Lanka
Tel: +94(0)-452280031; Fax: +94(0)-452280010
Email: jayansrijeewantha@gmail.com, jsjw@sab.ac.lk

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Abstract: Accurate and up to date road data is very crucial for effective urban planning, infrastructure development, navigation applications, military purposes and for updating topographic GIS databases. Spatial resolutions of remote sensing images are rapidly increasing. It enables a good source for extracting road information. This research has developed a novel approach for sub-urban and rural road feature extraction from high resolution images. An Artificial Neural Network (ANN) based method has introduced by the study with self-organizing supervised learning neural network and compare its performance with typical pattern recognition neural network. The developed ANN models were trained and applied to a World View – II satellite's panchromatic image. The resulted raster binary images were evaluated using a completeness assessment compared with a digitized reference road layer. Final extracted road layer could be used to update a GIS database. Furthermore, the study has utilized the best learning parameters in developing Learning Vector Quantization (LVQ) and Patternnet Neural Network (PNN) to extract road from high resolution images. The successful results show the possibility of using the approach for automatic road feature extraction from high resolution images for updating GIS databases.

1. INTRODUCTION

Background

Linear feature extractions from spectral images were popular for many applications it is equally true for mapping and military applications. Linear features, such as roads, rail-roads, rivers, streams etc. are extracted from images to update maps and Geographical Information System (GIS) databases.

Roads are one of the important linear features existing in the terrain. Road data plays a key role in urban planning, traffic management, military applications, and vehicle navigation as well as for decision making in numerous applications. In the last few decades, the accelerated urbanization made the necessity of devising new methods for updating maps, which is impossible through conventional long term surveying and mapping techniques. Therefore, sufficient attainment has been made towards faster road extraction options from remotely sensed images.

Sensor systems have dramatically improved the spatial resolution of images in the recent past. Due to that, high resolution and very high resolution satellite images are available to be used for road feature extraction and other forms of detailed mapping.

Road feature extraction methods can be widely classified as semi-automatic method and fully automatic method. But there is no method for fully automatic road feature extraction from images, there may be at least little human interaction in all the current feature extraction methods.

Road feature extraction methods are growing since 1980 up to now, by implementing new sophisticated routes for extracting road features. In 1981, Fisher tried to tracked road by finding minimum cost path and in Steger developed a more sophisticated approach based on differential geometry in 1996 (Webno et al., 2001).

In past, low resolution images were used to extract road (linear) features (Albert et al., 2002). Roads are appeared as curvilinear structure in medium and coarse resolution images (10-30 m). To extract curvilinear structures used morphological operators, ratio edge detectors and Hough transformation (Lu, 2009).

Proportion to Lindi's (2004) review there are wide range of techniques used to detect linear (road) features in imagery. They are techniques of mathematical morphology, the Hough Transform (HT), classification-based feature extraction techniques, knowledge Integration, Artificial Intelligence (AI) approaches (Neural Network Techniques), Scale methods (Active Contour Model).

AI approaches usually based a model which includes rules with different weights (Lu, 2009). AI approaches are always combined Artificial Neural Network techniques, and fuzzy logic algorithms. Road feature extraction from images using Neural Network is currently ongoing research for reducing human input from the feature extraction method. Approaches based on fuzzy logic and mathematics was proposed to extract main road centre lines from VHR image (Amarsaikhan et al., 2009).

Different Neural Network algorithms or topologies are used to extract road features from the images. Most researches of feature extracting with ANN are applied feed forward ANN, Hopfield ANN algorithms. Those ANN algorithms are commonly used as fitting tools or clustering tools. Therefore, road feature extracting requires ANN algorithm which can be applied as classification and pattern recognizing tool.

In very high resolution satellite images, visual road identification is easier. But road feature extraction is more complex in suburban environment due to road type roads are hidden by crowns and trees.

Artificial Neural Networks (ANN)

The computer technology has been much developed over the last decade. But, still computers cannot perform some task that human brain can do. The human brain is consisted with millions of neurons. The most specific task is that the human brain can do than computers pattern recognizing and classification. All these are considered as intelligent tasks. The new technology attempts to make computer software to perform intelligent tasks. It is called Artificial Neural Network (ANN). Simply ANN is simulation of biological neural network.

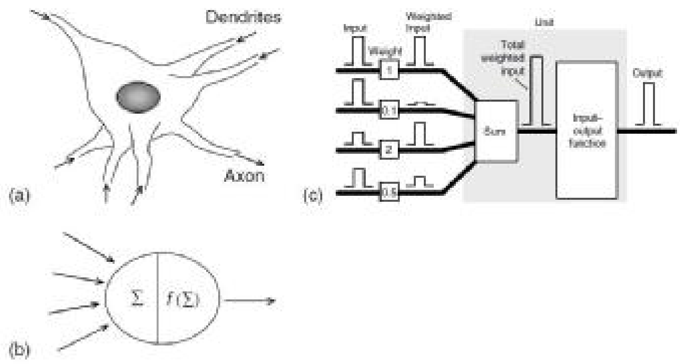


Figure 01: Biological Neuron and Its representation (Sandhya, 2006)
(a) Biological neuron (b) Neuron model (c) Detailed working of a single neuron

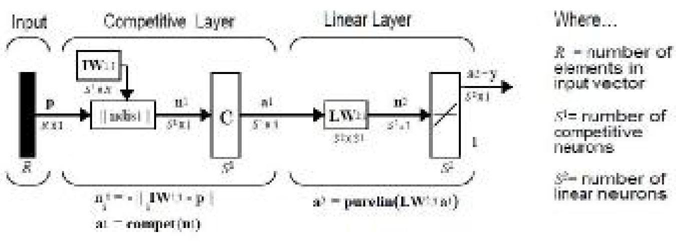
ANN is comparatively very simple network. It follows the same process like in biological neuron system. Basic features of an artificial neural networks, is similar to the real neuron. Figure 01 illustrates the similarity of the biological neuron and the artificial neuron. Inputs are alike to dendrites and output path alike to the axon. Processing element is similar to the cell body. If the total input exceeds threshold, an output will be present. It learns first and later identifies or predicts some pattern. There are two kind of learning namely supervised and unsupervised.

2. METHODS AND EQUATIONS

Pattern Recognition Neural Network

Pattern Recognition Neural Network is a feed forward neural network which can be used to classify inputs according to target classes. Feed-forward nets are the most well-known and widely-used class of neural network. Figure 02 describes the topology of feed forward network. In feed forward network, information flows in one direction along connecting pathways, from the input layer via the hidden layers to the final output layer. It contains nonlinear transfer function which allows the network to learn nonlinear relationship between input and output vectors. The linear output layer is most often used for function fitting problems. However for pattern recognition problems output layer should use a sigmoid transfer function. Equation (01) shows how to calculate outputs of feed forward network using inputs, weights and transfer function.

$$Y_{n\times 1} = f(W_{n\times m}\, X_{m\times 1} + \ b_{n\times 1}) ----------- \mathbf{Eqn\ (01)}$$



If the input **x** and the associated Voronoi vector/weight **w***I(***x***)* (i.e. the weight of the winning output node *I*(**x**)) have the same class label, then move them closer together from according to Eqn (03).

$$\Delta w_{I(x)}(t) = \beta(t)[x - w_{I(x)}(t)] ---------- \textbf{Eqn (03)}$$

Where $\Delta w_{I(x)}(t)$ is update value of wining node is is weight and x is inputs of network and $w_{I(x)}(t)$ is existing weight and β is learning rate of the network. Voronoi vectors/weights **w***j* corresponding to other input regions are left unchanged with $\Delta w_j(t) = 0$.

Methodology

Neural Network tool box of MATLAB is one of the tool boxes in MATLAB, which is help to implement the ANN for its application. The NN tool box provides many NN paradigms with Graphical User Interface (GUI) for designing and managing the network.

Initially, input data for network was prepared. Subset of panchromatic image and texture image of same area were used as input data of the network. Using the spectral signature of the sub urban roads defined the road class and the rest as another class (no road class). Then developed two different neural network systems with varying of its parameters and fed input data and trained and analyzed the confusion matrices. Table 01 represents the constant and dynamic input parameters of the each neural network. The networks were created using the Neural Network toolbox from MATLAB7.0 release 2011a.

Table 01: Created neural network and its configurations.

NN Name	Constant Parameters	Dynamic Parameter and its value
PN_01	Training Epochs = 25	No. of Hidden Layers = 10
PN_02		No. of Hidden Layers = 50
PN_03		No. of Hidden Layers = 100
LVQ_01	Training Epochs = 25 No. of Hidden Layers = 10	Learning Rate = 0.1
LVQ_02		Learning Rate = 0.01
LVQ_03		Learning Rate = 0.001

According to the confusion matrices values of each network, if classification accuracy of network is less than 90% redefined the network parameters and network was retrained.

Thereafter, trained network was simulated using another panchromatic subset image data and output image file was taken as a binary TIFF image which represented the extracted road as white (value 255) and other areas black (value 0). Resulted binary image was fine tuned using image enhancement tools in MATLAB and geo-referenced it using ERDAS Imaging 8.4. And manually digitized road vector layer was created for accuracy assessment. Finally, extracted road area and digitized road raster were compared in accuracy assessment phase. In the accuracy assessment overlaid two raster layers of roads which were extracted roads and digitized road, and evaluated number of pixels which were not belonging to road and calculated road extraction error using Eqn (04) in pixel based manner.

$$\textit{Road Extraction Error}\ \% = \frac{\textit{Number of non road pixels in extracted results}}{\textit{Number correct road pixel in manual extracted results}} \times 100\% -- \textbf{Eqn (04)}$$

3. RESULTS AND DISCUSSION

The approach was tested on Word View II panchromatic image of suburban area in Balangoda, Sri Lanka. The panchromatic image with spatial resolution of 0.5 m approximately covered an area around 127 x 102 m. Figure 04 shows the tested panchromatic image for extracting road features.

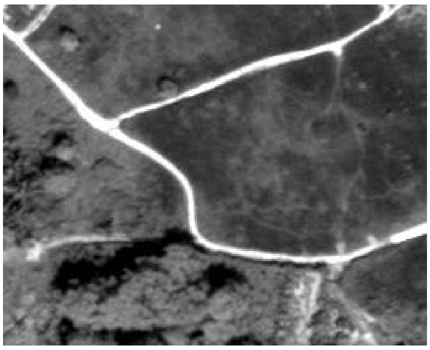


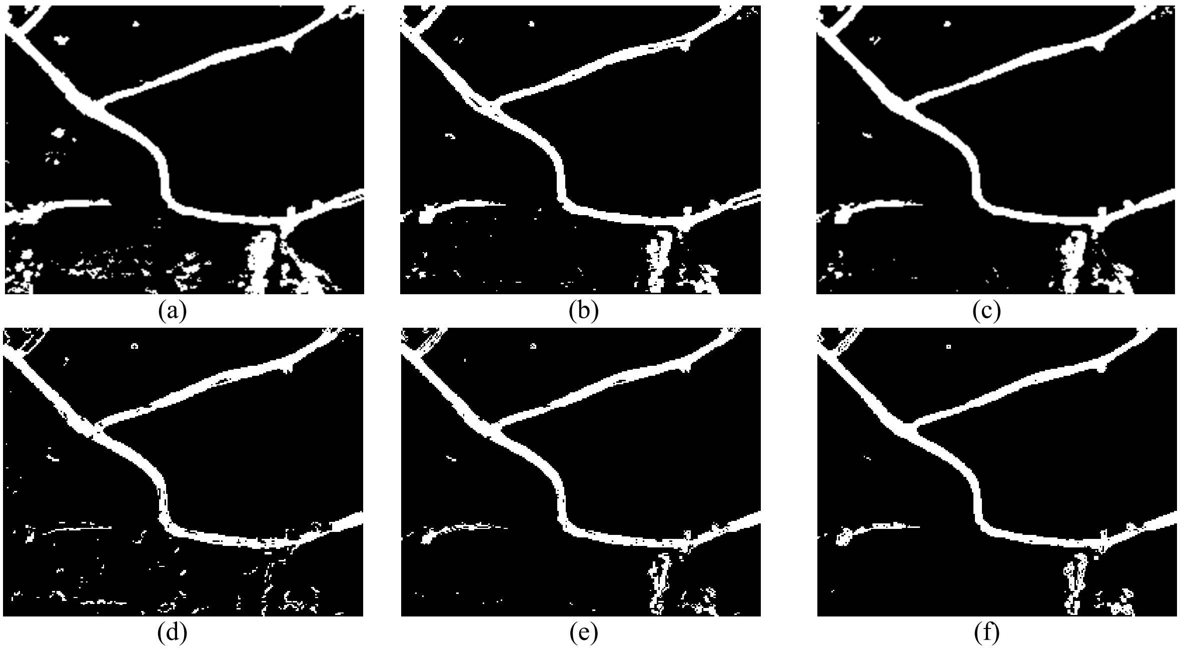
Figure 04: Tested World View-II panchromatic image

The resulting outputs of Neural Networks vary with several factors. They are topology of net, training algorithm, initial weights, neural net defining parameters and training parameters. In this research, the results were not analyzed by changing all the parameters. According to the methodology in this research, six different neural networks were trained and all the six neural networks were provided more than 90% accuracy in training phase. Table 02 describes the accuracy of created network using confusion matrices value and performance of each network using Mean Square Error (MSE) of training phase.

Table 02: Accuracy of trained networks.

NN Name	Confusion Matrix Accuracy	Performance (Mean Square Error of NN training phase)
PN_01	95.6%	0.0318
PN_02	96.1%	0.0312
PN_03	94.8%	0.0320
LVQ_01	91.9%	0.0739
LVQ_02	93.8%	0.0669
LVQ_03	95.1%	0.0528

Same subset image was simulated for each network and Figure 05 shows extracted road features respectively from defined six networks.



(a) (b) (c)

(d) (e) (f)

Figure 05: (a) extracted results of PN_01 network (b) extracted results of PN_02 network (c) extracted results of PN_03 network (d) extracted results of LVQ_01 network (e) extracted results of LVQ_02 network (f) extracted results of LVQ_03 network.

Extracted all road images contained more number of extracted pixels due to that area has same spectral signature as roads. Image Processing Toolbox of MATLAB was used to enhance the extracted results and Figure 06 displays enhanced extracted results of six different neural networks.

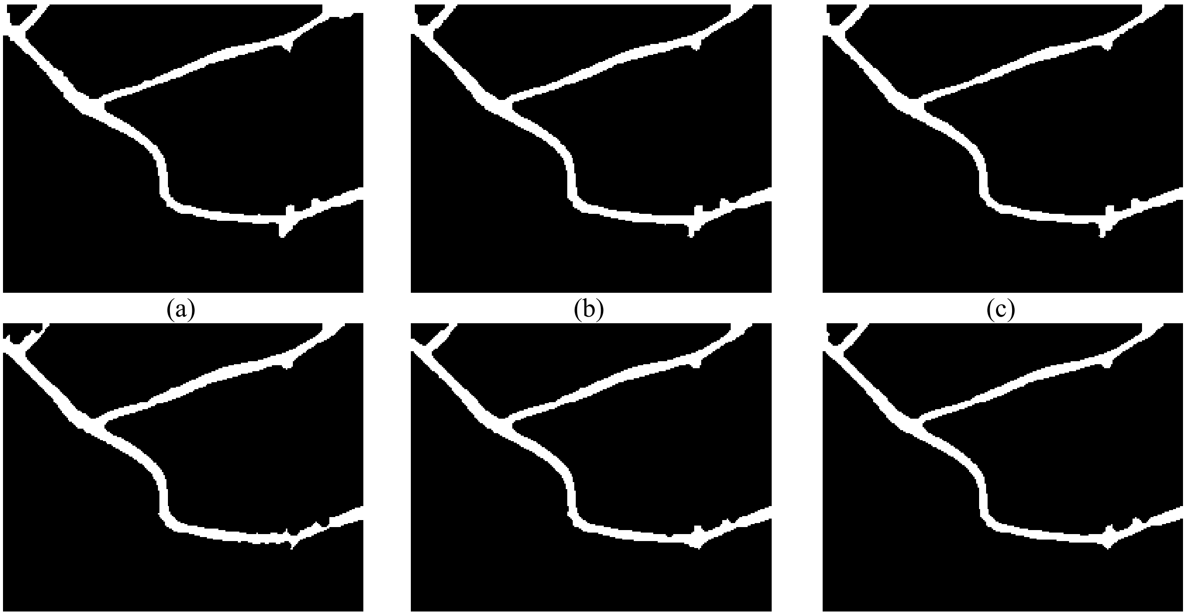


Figure 06: (a) enhanced results of PN_01 network (b) enhanced results of PN_02 network (c) enhanced results of PN_03 network (d) enhanced results of LVQ_01 network (e) enhanced results of LVQ_02 network (f) enhanced results of LVQ_03 network.

Manually digitized road layer was used for an accuracy assessment process. Figure 07 shows digitized road layer which was overlaid with original image.

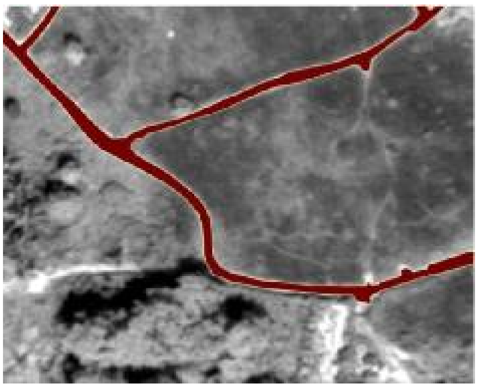


Figure 07: Digitized road layer overlaid with original image

According to accuracy assessment process, road extraction error was calculated for each extracted road results.

Table 03: Accuracy of simulated networks.

Network Name	PN_01	PN_02	PN_03	LVQ_01	LVQ _02	LVQ _03
Road Extraction Error (%)	26.50678	20.47965	21.01609	28.2739	19.24897	16.44052
Accuracy (100% - e%)	73.49322	79.20535	78.98391	71.72610	80.75103	83.55948

Table 03 describes the outcomes of the accuracy assessment process. The PN_02 network outperforms all other Patternnet Networks used in the system and it was 79.21% and accuracy of PN_01 network was the lowest. However in LVQ nets the highest accuracy value was given byLVQ_03 network and it was 83.56% and lowest value was given by LVQ_01 network. And also the highest accuracy value was given by LVQ_03 network when considering all six networks.

The research was successfully developed a semi-automatic method to extract sub-urban roads from high resolution satellite images using LVQ neural network algorithm.

4. CONCLUASION AND RECOMMANDATION

The main objective of this research was to develop an automatic method to extract rural and sub urban roads using neural network algorithm. It is successfully developed an automatic method to extract roads from very high resolution satellite images by using learning vector quantization neural network algorithm. The results prove that the approach is good enough for extracting roads from images using LVQ net than typical pattern recognition net. This novel approach efficiently integrates digital image processing with Neural Network, Remote Sensing and GIS technologies. It has great potential for updating old GIS data sets and uplifting the commercial value. Especially this new methodology can be applied to update road data in country side of Sri Lanka due to it has most gravel road with states like tea and paddy. Less clarity of concerned image is a limitation for automatic extraction of roads, which is the cause for errors in road extraction. Other reason for errors in road extracting is the availability of very similar pixels to roads in images which can be removed using filtering techniques. Automatic road extraction from remotely sensed imagery saves lot of time and money for GIS data collecting and updating tasks. In this research MATLAB was used to create ANN nets but it has some limitations, therefore future direction of this research is need to develop using typical computer programming languages like C++ or Java. By this research it has provided automatic road feature extraction method and has opened up the avenues for new software creation for automatic road feature extraction from satellite images.

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