Automatic water features recognition from Satellite images using an Artificial Neural Network

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Abstract— *Water body is a significant natural object and 70% of total Earth is covered with water. Out of which approx. 68% is saline water and is part of many water resources such as glaciers, oceans, sea, ponds etc. and only 2% is fit for drinking or portable water. Water body is an area that have well defined topographical boundary where the water accumulates, for example: river, ocean, sea, lake, reservoir etc. Mapping of water bodies is important in flood prediction, environmental monitoring, safe navigation, environmental protection, Geographical Information System (GIS) database updating, sustainable development & planning, watershed definition, evaluation of water resources and many more.*

Traditionally, mapping of water bodies in small areas are carried out using conventional field surveying methods or water bodies are manually delineated with a pencil on vellum paper overlaid on top of aerial photographs or traced with a cursor from digital remote sensing images on the computer screen. These methods are tedious, subjective and time-consuming. Automatic feature extraction is a beneficial method to get updated spatial data from aerial images, satellite images and Digital Surface Model (DSM) instead of traditional methods. Therefore, an effective technique is tested for automatic water features extraction from satellite images based on Artificial Neural Network (ANN).

Basically, the methodology has two stages as learning and application. In learning stage, defined ANN is trained using a small subset of the satellite image in study area and numbers of subset are simulated in application stage. Then, a shape file of the vector layer of extracted water bodies is provided automatically as the final output of the system. The methodology is tested for worldview-02 satellite images in the 'Samanalawewa' reservoir and the surrounding area of Belihuloya, Sri Lanka. The system is provided the accuracy as average completeness: 98.97%, correctness: 98.27% and quality: 97.28%.

Keywords— Artificial Neural Network (ANN), Geographical Information System (GIS) and Digital Surface Model (DSM)

I. INTRODUCTION

A. Background

The surveying is the science of determining the position, in three dimensions, of natural and man-made features on or beneath the surface of the Earth (Rusu and Musat, 2012). The surveying can be done by three possible options including; ground survey, aerial survey and satellite images (Ali, 2012). Traditionally, maps were prepared using plane tabling, sight rule, optical square, chain or steel measuring tapes as a ground survey (Rao et al., 2014).Traditional field surveying approaches were time consuming, very expensive and require lot of efforts as well as it was very difficult in remote areas especially in mountainous areas when the weather is very harsh (Onkalo, 2006 & Ali and Ahmed, 2013).

Then aerial photographs and past photogrammetry techniques (e.g. aerial triangulation, stereo orientations, and photo-interpretation, stereo-digitizing on stereo-model) were commonly used to produce geo-information (Tuladhar, 2005). The photogrammetry was not sufficient in surveying because inapplicable for large area, difficult to maintain the equipment, there are numbers of steps involved in the processing, expert are needed and time consuming due to manual digitization (Tuladhar, 2005).In this case satellite images were used as an alternative approach for spatial data acquisition (Ali and Ahmed 2013) and it is beneficial for surveying according to larger coverage, continuous capturing, and quick processing (Tuladhar, 2005).

Automatic feature extraction has been an active research topic in the field of digital photogrammetry and computer vision for many years (Lari and Ebadi, 2007). There is no method for fully automatic feature extraction from images, there may be at least little human interaction in all the current feature extraction methods (Wijesingha et al., 2012). Developing countries have advised to find the simply and low cost technologies to reduce the time and cost to complete mapping (Onkalo, 2006). There are a number of methods to extract the features from the satellite images for surveying, but most of them are semi-automatic.

The satellite images are having various natural objects in isolation or combination such as mountains, forests, vegetation, plains, plateaus, water bodies and many more. Water body is an important object that needs to be extracted automatically fromsatellite images. Automatic extraction of waterbody becomes a key component in order to assess the existing water resource and help in planning for various purposes.Therefore, a method should be developed to extract water features automatically from satellite images. The paper present a method to extract water features automatically from satellite images based on ANN.

B. Theoretical background

ANN is comparatively very simple network. It follows the same process as like as biological neuron system.The figure of a biological neuron is as follows.

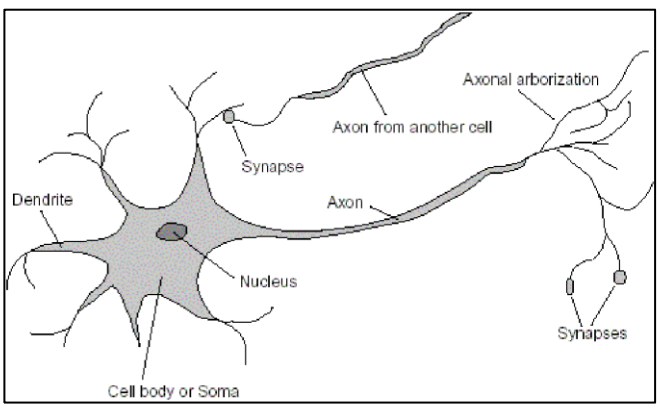

Figure1. A biological neuron

An ANN is composed of many artificial neurons that are linked together according to specific network architecture. Basic features of an ANN are similar to the real neuron. Inputs are alike to dendrites and output path alike to the axon. Processing element is similar to the cell body. The figure of an artificial neuron is as follows.

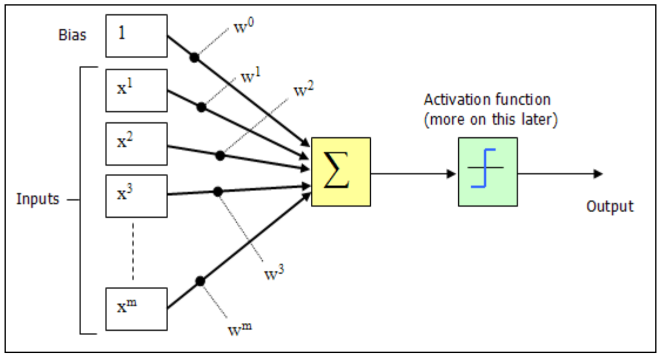

Figure2. An artificial neuron

The objective of the ANN is to transform the inputs layer into meaningful outputs layer via hidden layer.Typically, ANNs are adjusted or trained, so that a particular input leads to a specific target output.

II. METHODOLOGY AND EXPERIMENTAL DESIGN

A. Study area

The study area is the area which has UTM coordinate; upper right corner: 741478N, 479218E andlower left corner: 737805N, 473428E around the Samanalawewa reservoir, Belihuloya , Sri Lanka.

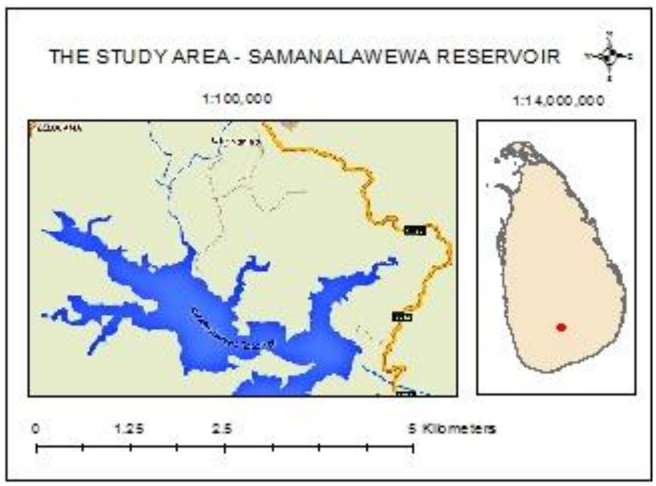

Figure3. Map of the study area

B. Data source

1) Satellite image

Wordview-02 satellite image of the study areawas used to develop the system. It has 0.5 m resolution (Panchromatic) and 2 m resolution (Multi spectral) and observation date is 23 February 2010. The satellite image is provided by Faculty of Geomatics, Sabaragamuawa University of Sri Lanka

2) Software

The neural network tool box in MATLAB is very important to develop an artificial neural network. Therefore MATLAB 7.10.0 (R2010a) with neural network tool box and Arc GIS 10.1 software was used to develop the system.

C. Method

The system was developed based on the methodology as shown in figure 04. Worldview-02 satellite images were used to develop the system. First, Digital Numbers (DN) of the satellite image were converted into spectral reflectance value for radiometric correction. Then, Normalized Difference Water Index (NDWI) was calculated using the following equation for enhancing the water bodies.

$$\mathrm{NDWI} = \frac{(\mathrm{Costal\ Band} - \mathrm{NIR2\ band})}{(\mathrm{Costal\ Band} + \mathrm{NIR2\ band})}$$

Learning Vector Quantization (LVQ) ANN was defined by applying a small subset of the image and network parameter such as number of hidden neuron, typical class percentage, learning rate and learning function etc. Then, the defined network should be trained by applying the subset, target classes of the subset and training parameter such as number of iterations and time period etc. The train network can be used to extract water bodies automatically on any number of subset taken from the image.

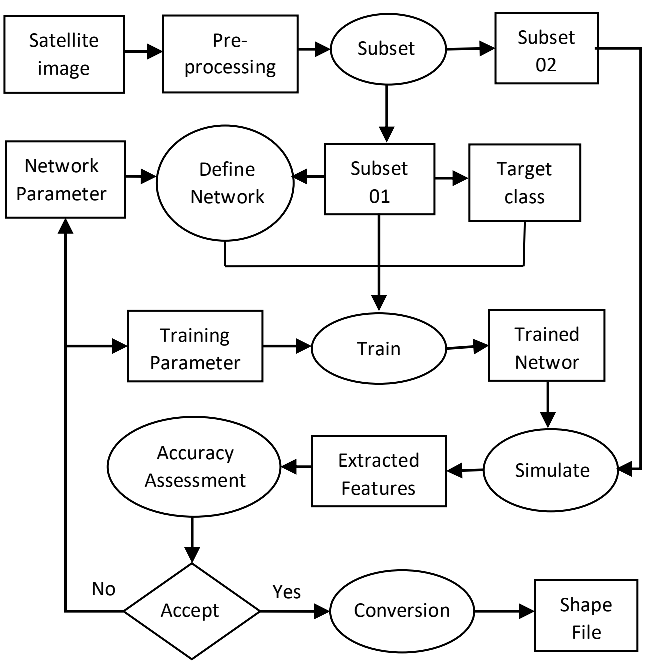

Figure4. The methodology

III. RESULTS

The system is tested using six subset taken from the satellite image and inputs & outputs of each subset have been shown from Figure 5 to Figure 10.

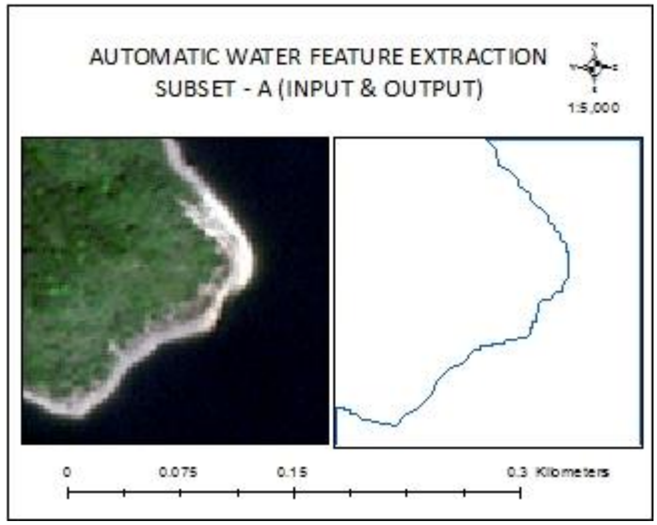

Figure5. The map of subset-A (input & output)

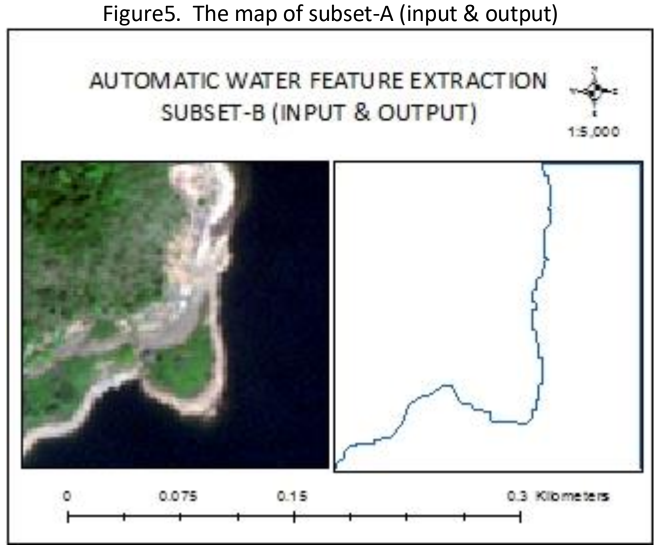

Figure6. The map of subset-B (input & output)

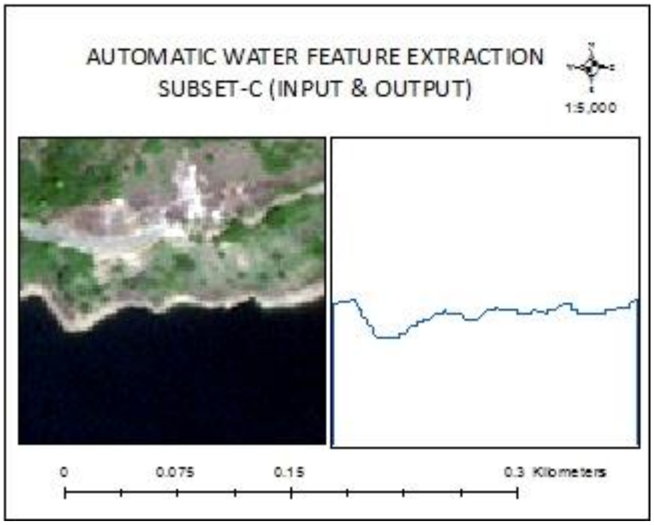

Figure7. The map of subset-C (input & output)

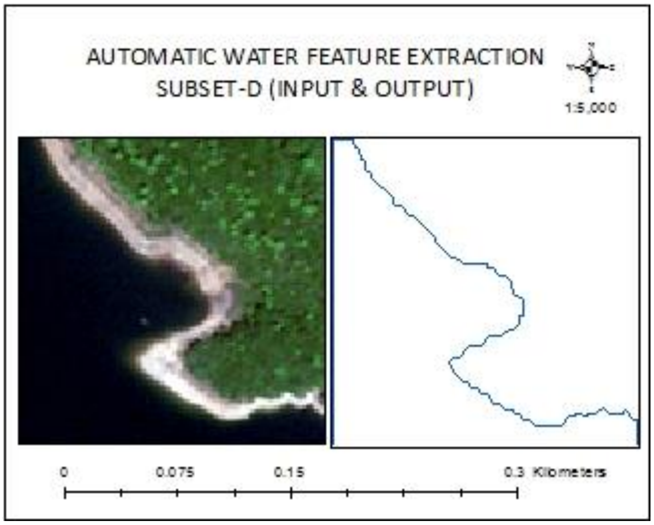

Figure8. The map of subset-D (input & output)

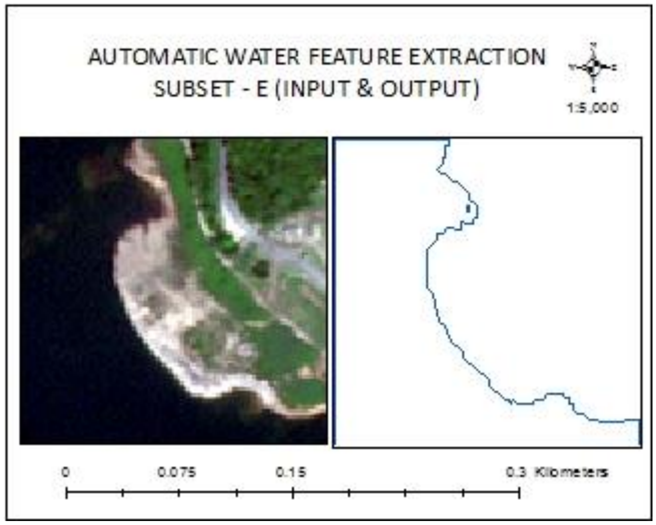

Figure9. The map of subset-E (input & output)

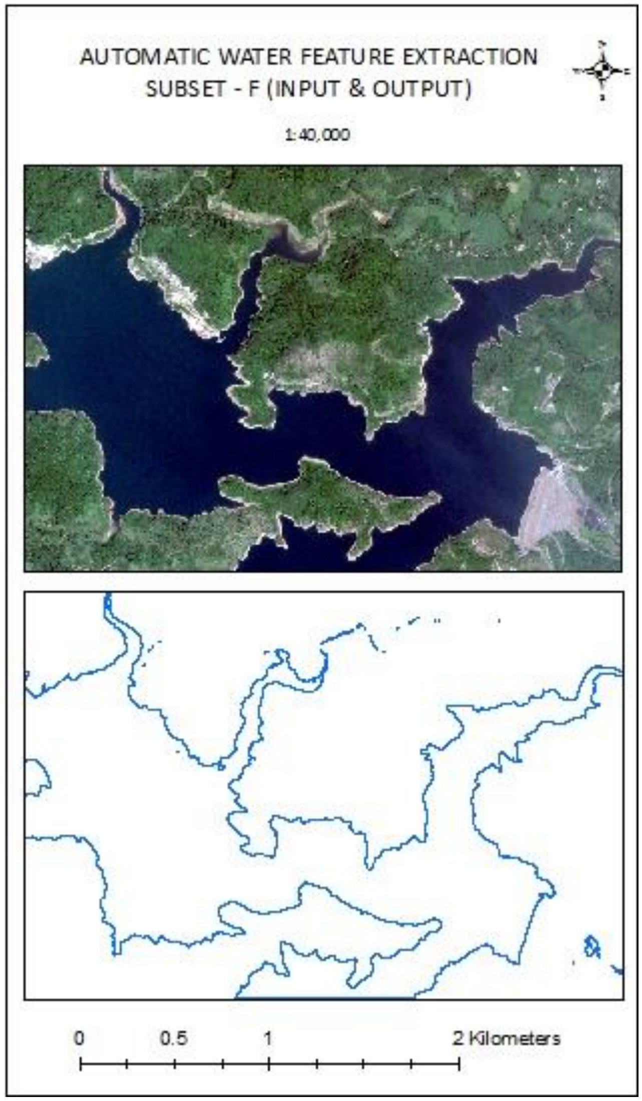

Figure10. The map of subset-F (input & output)

Table 1 includes the comparison of morphology of each subset at manual digitize method and the developed system.

Table 1. The comparison of morphology of each subset

Subset	Perimeter (m)			Area (Sq. m)		
	Manual digitize	By the system	Diff. (%)	Manual digitize	By the System	Diff. (%)
A	846.63	865.17	2.19	19331.64	19233.13	0.50
B	814.71	840.40	3.15	17515.37	17774.75	1.48
C	619.80	642.67	3.69	17463.34	17444.88	0.11
D	817.31	840.98	2.90	17746.91	18036.75	1.63
E	826.10	856.40	3.67	18653.85	18858.75	1.10

The completeness, correctness and quality of the system can be calculated based on following equations. The comparison of accuracy of each subset have been shown in Table 2.

$$\text{Completeness} = \frac{\text{Area of matched extraction}}{\text{Area of reference}}$$

$$\text{Correctness} = \frac{\text{Area of matched extraction}}{\text{Area of extraction}}$$

$$\text{Quality} = \frac{\text{Area of matched extraction}}{\text{Area of (extraction + unmatched reference)}}$$

Table 2. The comparison of accuracy of each subset

Subset	Completeness (%)	Correctness (%)	Quality (%)
A	98.59	99.10	97.72
B	98.76	97.32	96.15
C	99.35	99.45	98.81
D	99.10	97.51	96.65
E	99.06	97.98	97.08

The system is provided the accuracy as average completeness: 98.97%, correctness: 98.27% and quality: 97.28%.

IV. DISCUSSION AND CONCLUSION

The experimental results have shown the strength of ANN to recognize various objects in an automatic manner. The experiment shows good accuracy for automatic extraction of water body from satellite images.WorldView-2 products may need to be converted to top-of-atmosphere spectral radiance or spectral reflectancedepending on the application.Various types of spectralanalysis can be performed after applyingradiometric correctionsfor WorldView-2 imagery. NDWI is significant index for enhancing the water bodies on satellite images. Although waterbody extraction is a two class problem, LVQ ANN can be used for problems having more than two classes.The experiment can be extended in future for approaching multi class classification problem.

ACKNOWLEDGEMENT

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