River Change Detection System Using Google Earth Satellite Imagery

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***Abstract*—Detecting changes from remote sensing data is essential to environmental monitoring. As the cultivation is central to the civilian economy in Myanmar, the lives of people in Myanmar depend heavily on water resources. Hence, it is required to monitor the changes in the river course flow. Detecting changes using remote sensing data reduces labor costs, time and raises the limits of ground surveys. In this paper, detecting the changes in rivers course using Google Earth satellite imagery is proposed. In this work, the riverregions and the sandbank regions are firstly segmented by means of heuristics according to the Sobel method and the threshold method. These segmented images are enhanced with contrast stretching. Then, HSV histogram features, color autocorrelation features, color moments features, Gabor wavelet features, and wavelet transform features are extracted from the segmented area. Next, multi-class Support Vector Machine (SVM) is applied to classify river areas, sandbank areas, and other areas based on derived features.Then, the classified river regions are detected for changes. Finally, the change rulesare applied to extract the change map of input pair of RGB satellite images between the years 2004 to 2017. Experimental results show that the proposed system provides good performance results in river change detection.**

***Keywords*—Google Earth images, multi-class Support Vector Machine, heuristic rules, color features, and texture features.**

I. INTRODUCTION

The surface of Earth is constantly changing due to the activities of various phenomena. Remote sensing is an area ofdetecting the Earth's surface without direct contact.It can also reveal interesting features that may not be on the ground and may not be affordable [1].In addition, remote sensing images provide the foundation for building an information system that supports the decision-making process based on land-cover changes.Thus, detecting changes in remote sensing data over times is an important and challenging topic.

Rivers support a variety of ecosystem services, and the riverside populationsare directly and indirectly dependent on the availability of water, the quality and quantity of the river water. Moreover, changes in rivers and water surface can affect the valuable features such as the damage of housing and farming productions. As the Ayeyarwady River is the lifeline of Myanmar's population and the agriculture is also the major source of income of Myanmar, water resources have the greatest impact on the lives of local peoplein this region. However, the river has become in a serious condition in recent year because of shrinking surface water and bank erosion. Moreover, detecting the river changes in ground survey can cost computation time and labor's effort. Therefore, this system is developed to identify the river changes using remotely sensed data.

The variation of the color values in the same river area and the similar color values in dissimilar areas (for exampleriver's color values and agricultural land's color values) are the biggest problems in the detection and extraction of river regions. In addition, detecting river changes from Google Earth imagery takes many challenges, as the additional multispectral bands are not included as Landsat imagery. Only color features and texture features can bederived. Therefore, this paper is aimed to determine the change in the Ayeyarwady River beside the Magway Division using Google Earth images based on the proposed method of extracting colors and texture features.The proposed system is implemented with MATLAB.

This paper is structured as following. In section I, the introduction of the proposed system are presented. The related researches are offered in Section II. An overview of the system is described in Section III, and the system methodologies are also presented in Section IV. The study areas and test results of the system are shown in Section V. The conclusions follow section VI.

II. RELATED WORKS

In change detection, differences in the state of an object are recognized by observing the object of the phenomenon at different times[2]. The several river change detection systems has been studied during the past decades. Lina Zhu et.al [3] proposed river change detection method and introduced a combination of wall is filter, pattern classifying, region growing, and morphology. Wallis filter was applied to enhance the image and suppress noises all at once. After that, each pattern was assigned to the minimum distance classes by using C-mean classifying. For image division, region growing method was used. In this system, seeds selection can be chosen by manual. In order to detect which parts of river changed, double-buffermethod was also applied. But, the implementation of this system can only detect the wider river merely.

Komeil Rokni et al. [4] proposed the extraction and detection of water features with multitemporal Landsat images. In this system, the principal components of the multi-temporal NDWI (NDWI-PC) was proposed and evaluated for the revealing of surface water changes.First, the NDWI was evaluatedusing multi-temporal Landsat data. Afterward, the resulting NDWI images has been arranged into a merged file. Finally, the principal components of the resulting multi-temporal NDWI was categorized and investigated for changes in the Lake surface. In order to categorize the resultant PCs, trial-and-error-based threshold technology was manually applied.

S.Venkata Lakshmi, K.Sathyamoorthy and T.K Senthil Kumar [5] presented a new approach for change detection in synthetic aperture radar (SAR) images by incorporating Markov random field (MRF) within the framework of Fuzzy C-means (FCM). The difference image was generated from log ratio and mean ratio images by image fusion technique. The minimum mean ratio method (MMRM) was applied to extract the change in the two images in spatial domain.

The authors in [6] also proposed a new methodology for detection of surface water changes. In this system,the combination of modified HIS, High Pass Filter, Gram Schmidt and Wavelet-PC techniques were examined by merging of multi-temporal Landsat images in order to highlight the changes. Classification techniquessuch as artificial neural network, support vector machine and maximum likelihood were applied to extract and map the highlighted changes. This system was tested with the tool in ENVI 4.8.

Satya Prakash Maurya, Akhilesh Kumar Yadav [7] introduced the system to delineate the historical changes of Ramganga river using Landsat MSS, TM, ETM+, LISS-III satellite images. Normalized Difference Water Index (NDWI) was calculated for water index extraction. ArcGIS 10.1 and ERDAS IMAGINE 2010 were used to analyze the collected images in this system.

The above-mentioned works on river change detection systems havebeen utilized various high-resolution satellite images. Detecting flow changes using very high resolution satellite imagery is more expensive and may not capture data for privacy reasons. To the best of my knowledge, river change detection system from Google Earth imagery has not been proposed. Therefore, this system applied open source Google Earth imagery. Moreover, this paper is intended to detect the Ayeyarwady River's changes using remotely sensed data in the period 2004-2017.

III. OVERVIEW OF THE PROPOSED SYSTEM

The following steps were performed to dothe river change detection: detection area definition, data acquisition, image preprocessing, river area detection, and change detection. In this system, RGB images are captured from Google Earth Pro. Next, a regional segmentation is performed for the segmentation of rivers and sandbanks. Then the segmented area is enhanced in order to acquire well features.

Thereafter, color and texture features are extracted from the enhanced image. Second, the river area, the sandbank area, and others are categorized by multi-class SVMs using the obtained features.The categorized river regions are then detected for changes using change rules. Finally, the change results and change map are obtained. The overview structure of the proposed system is illustrated in Fig. 1.

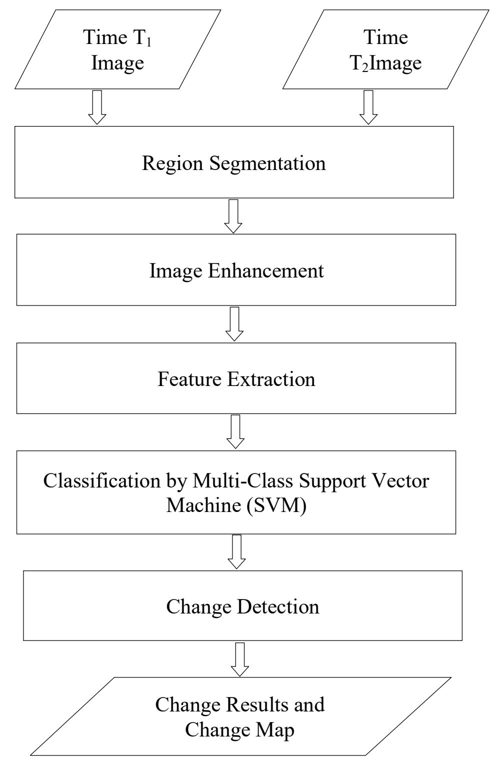


Fig. 1Overview structure of the proposed system

IV. METHODOLOGIES OF THE PROPOSED SYSTEM

In this section, the methodologies of the proposed system are described.

A. Region Segmentation

In satellite imagery classification, the regional segmentation is the key step for giving accurate classification results. The main task of region segmentation is to categorize the dissimilar things. In this step, resizing the input image is firstly performed to obtain the same sized input images. Then, color space conversion is applied for the transformation of input RGB images to grayscale image. Subsequently, the heuristics rules using the Sobel kernel and thresholding methods are utilized for thecalculation of gradient values of this image.

A gradient values which are greater than the threshold Th_1 are assumed to be the river area. And the largest area is extracted as river segment. Subsequently, a gradient values that are larger than the other threshold Th_2 are taken as sandbank regions and the largest eight surfaces are extracted as sandbank surfaces. Thereafter, the gray scale values which are bigger than the threshold Th_3 are extracted again as sandbank surface. Extracted sandbank areas are corrected by morphological operators such as closing, connected components extraction, and centroid finding [8].

B. Image Enhancement

Image enhancement is required to remove unwanted noise and to enhance the appearance of an image by enhancing the superiority of some features. In preprocessing step, the resultant river and sandbank areas obtained from the regional segmentation step are improved with contrast stretching. Contrast stretching expands the range of brightness values in an image to improve the contrast of the image[9].

C. Feature Extraction

On the way of obtaining the exact classification result, the features extraction step is vitalto acquire the significant features in satellite image classification. However, the main challenge of the river detection using Google Earth imagery is the color value diversity in water area. Therefore, color and texture features are extracted from the enhanced images in this system.Color is one of the most prominent perceptual features.Thus, the color feature extraction techniques: HSV histogram, color moments and color auto-correlogram are utilized for color features extraction in this system. As the color values variability in river area, the only color features can't provide the accurate classification result.Thus, textures features are also extracted.

Texture refers to the surface properties and appearance of an object resulting from the size, shape, density, placement, and proportions of the base parts. Extracting texture features from satellite images may support landscape index classification that have not sufficient spectral information.For texture features extraction,the transform based features extraction methods such as the Gabor wavelet and discrete wavelet transform are appliedin this system [9].

D. Multi-Class Support Vector Machine (SVM)

After extracting the features, all pixels in an image are categorized to obtain a given set of labels or land cover themes. In this work, river regions index are identified by the multi-class SVM. The former purpose of the SVM is to carry out the binary data classification. Nevertheless, numerous data type are needed to be categorize according to the requirements of current research fields. Therefore, SVM has been developed for the multiple class labelling. The main idea of this classifier is to provide the best hyper plane for new data categorization based on kernel function (K). In this system, the one-versus-all multi-class SVM is utilized for river regions, sandbank regions and other regions classification [9].

E. Change Detection

After the classified river regions are extracted, change detection step is performed. Change detection process is to identify the changed regions between the given image-pair observing the same scene at different time. The timely and precise recognition of surface features changes can support to become better interactions between human and natural phenomena, and also provide a basis for better resource management [10]. After river regions only are extracted from two same scene images at the different time, the change rule is applied to get the water area changes. The applied change rules for the system are presented as following.

$$If\ T_1Img \cap \overline{T_2Img}$$

$$then\ S(i) = 1$$

$$else\ if\ \overline{T_1Img} \cap T_2Img$$

$$then\ E(i) = 1$$

$$else\ C(i) = 0$$

$$end\ i=1,2,3,\ldots K. \qquad (1)$$

Final changes can be obtained from this operation$\overline{T_1Img} \cup \overline{T_2Img}$. Where S (i) denotes the shrink area and E (i) represents the expand area. The i is the same pixel of first and second images and K is the total number of pixel in the image. Where C (i) represents whether the river region is changed with 0 and 1 for non-change and change, respectively.

V. EXPERIMENTAL RESULTS

The experiment results and discussion of obtained results will be described in this section. The evaluation is performed on the dataset of 600 images. There are 400 images in training phase and 200 images in testing phase. In this system, input images are taken from the Google Earth with 2 minutes latitude and longitude points.

The satellite images are acquired during the summer season.The coverage area is approximately 44,818.96 km^2. The detection area is between 18° 52' 17.23' and 21° 35 ' 17 .23" N and between 94° 40' 17.23" and 95° 21' 6.36" E.The following figure describes the location map of detection area.

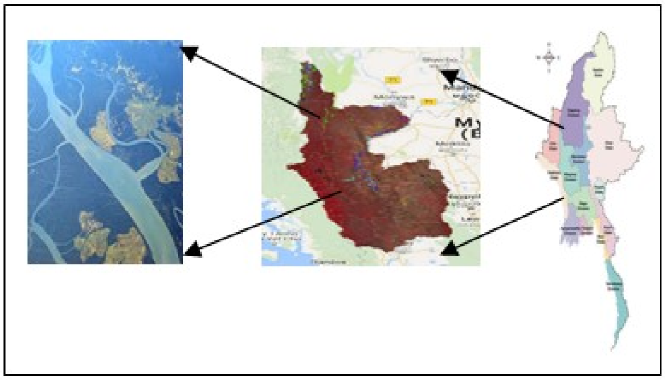
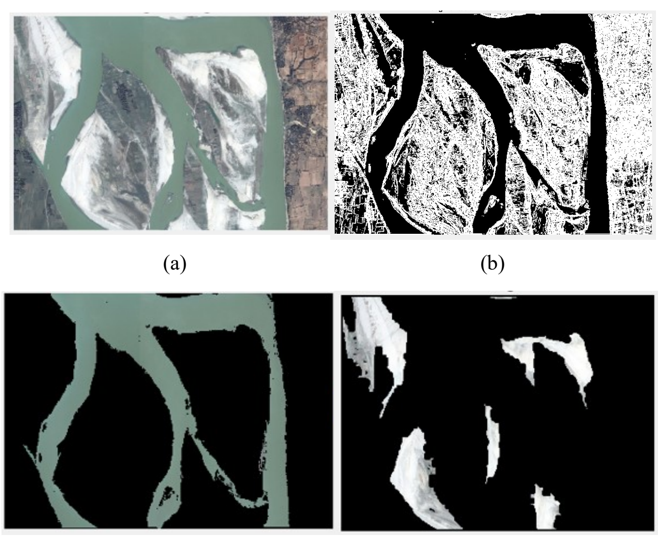


Fig. 2Map of Study Area

There are two phase in this system. The first one is river area classification and the second one is change detection. The RGB images with two minutes of latitude and longitudeare used as input images. The segmentation of input image into river and sandbanks regions is firstly performed. Then, these segmented images are transformed to high contrast image in the image enhancement step. Subsequently, the features are extracted from these improved images.



(a) (b) (c) (d)

Fig. 3 (a)The originalimage (b) Segmented image by gradient values (c) Extracted River regions bymulti-class SVM using color and texture features (d) Extracted Sandbank reiongs by multi-class SVMbased on color and texture features

In doing so, training data are automatically labelled with multi-class SVMs. Based on the extracted features, river area, sandbank area and other areas are categorized by SVM with multi class. The categorization results of the river area and the sandbank area are presented in Fig.3. The tested image revealed in Fig. 3 lies between latitude 20° 46' 17.33"N to 20° 44' 17.33"N and longitude 94° 41'6.36"E to 94° 43'6.36"E.

Theperformance of the proposed system is observed by calculating the evaluation measures such as specificity, sensitivity, precision and accuracy.

$$Specificity = \frac{TN}{TN + FP}$$

$$Sensitivity = \frac{TN}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

TABLE I. PERFORMANCE MEASURES OF K-NN CLASSIFIER

K-NN	River	Sandbank	Others
Specificity	96.75	78.75	94.5
Sensitivity (Recall)	60.5	92	95.5
Precision	94.03	68.4	93.2
Accuracy	86	83.17	93.17

In this experiment, the river area detection is also tested using the k-NN classifier. By applying with dissimilar k values, k value= 3 gives the more exact outcome for the system. The performance measurements of the proposed system tested with k-NN classifier are shown in Table I.

When testing system with multi-class SVMs, system classification using one versus all (OVA) methods is more accurate. Therefore, OVA multi-class SVMs is used for this system. Table II shows the performance results of the multi-classSVM for river regions classification.

Through the evaluation, the river detection system testing with the k-nearest neighbor (k-NN) classifier achieved 86% accuracy in the river region classification. For sandbank region classification, the system obtained 83.17% accuracy. The accuracy rates of other area classifications are 93.17% for k-NN classifier.

This system reveals the 92% accuracyfor river area classification and 93.5% accuracy for sandbank area categorization when multi-class SVM was applied. For other regions classification, 94.13% is obtained for multi-class SVM classifier.

The overall accuracy of the river are detection is approximately 87% for k-NN classifierand 93% for SVMs with multiple classes. Based on the results of testing with both classifiers, the proposed system obtained the higher accuracy rate when multi-class SVM is applied. A comparison between the classification results obtained by k-NN classifier and multi-class SVM is given in Fig. 4.

TABLE II. PERFORMANCE MEASURES OF MULTI-CLASS SVM

Multi-Class SVM	River	Sandbank	Others
Specificity	94.75	93	94.3
Sensitivity (Recall)	90.5	91.5	89.3
Precision	93.16	90.34	92.33
Accuracy	92	93.5	94.13

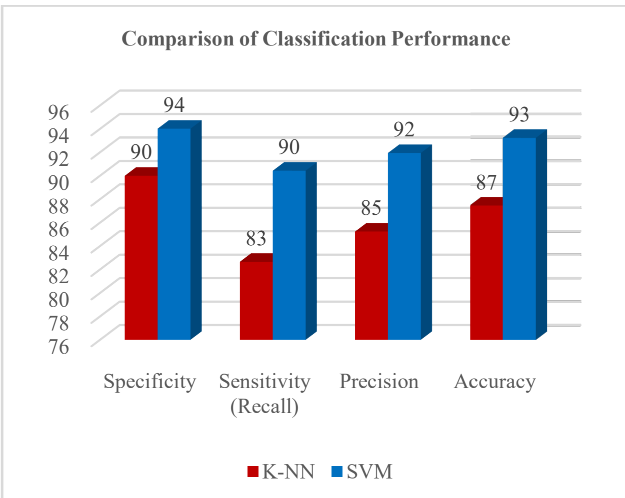


Fig. 4 Comparison of classification performance for two classifiers

Moreover, the proposed system has been also tried on the river satellite images which has been chosen from the public SIRI_WHU Dataset. The comparison of the performance measures of proposed system and that of SIRI_WHU Dataset ispresented in Fig.5. According to the experimental results, the proposed system obtained the satisfied accuracy result.

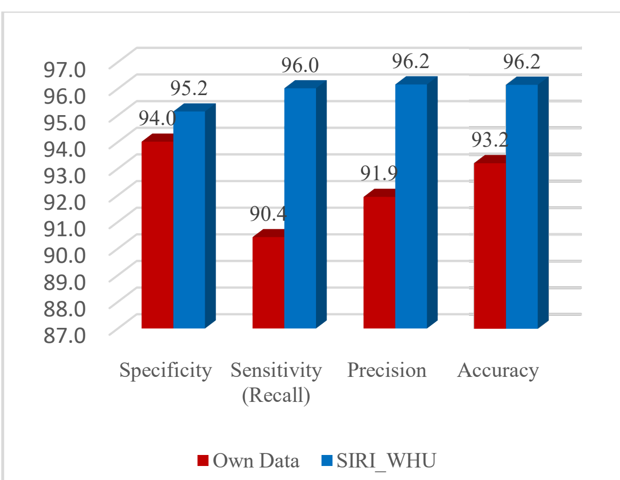


Fig. 5Comparison of classification accuracy for own data and SIRI_WHU public dataset

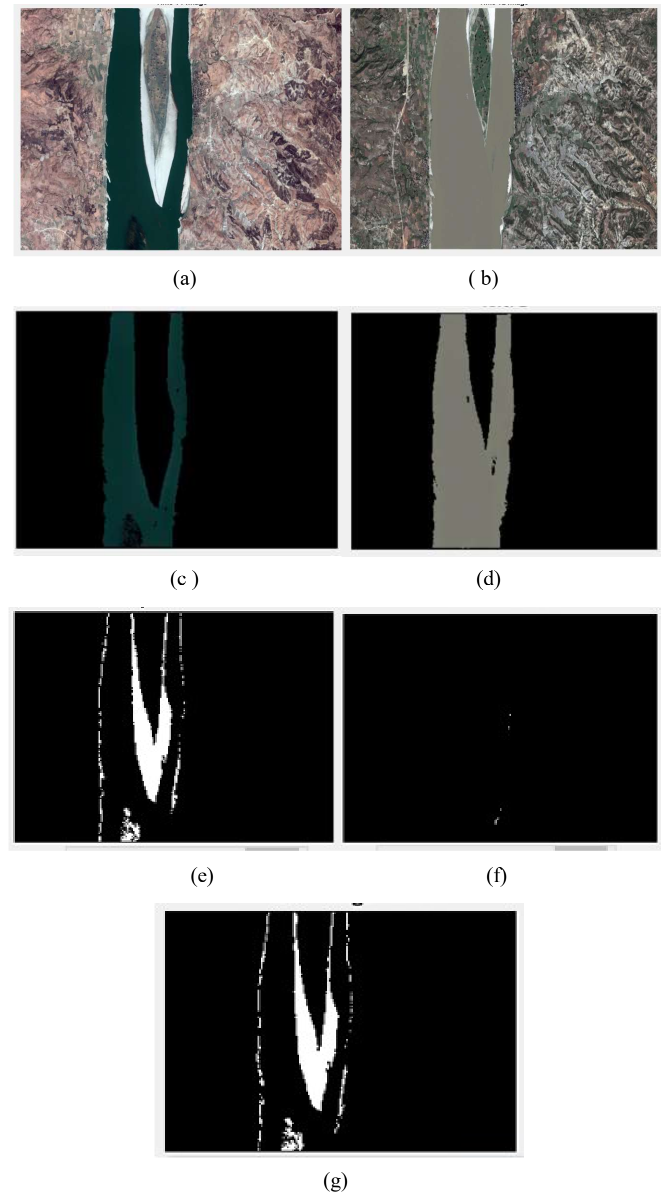


Fig.6 (a) The time t_1 image (2004) (b) The time t_2 image (2010) (c) Segmented river image of time t_1 image (d) Segmented river image of time t_2 image (e) Expanded area of river (f) Shrink area of river (g) Total river changes map

Furthermore, river change detection using satellite images is crucially dependent on the exact river detection. Based on the results of classification with multi-class SVMs, itmay be said that the resultant classification results canprovidethe accurate river change detection result. Therefore, the classified river regions are detected for changes using change rules.

The results of the change detection are shown in Fig. 6. The test image for change detection is between 19° 50' 18 .09" and 19° 52' 18.08" north latitude and 95° 7' 6.40" and 95 ° 11' 6.40" east longitude.The change detection accuracy of the proposed system is evaluated by the change detection results using ground truth images. Change detection performance measure of the proposed system are presented in Table III. According to the test results, the proposed system achieved an accuracy of 93.38 % for river changes detection.

TABLE III. CHANGE DETECTIN PERFORMANCE MEASURES

Specificity	Sensitivity	Precision	Accuracy
95.75%	65.70%	65.31%	93.38%

VI. CONCLUSIONS

In this article, we have presented a change detection system for the Ayeyawady River besides the Magway Division using Google Earth images. Sobel operators, thresholding, and morphological processing are applied for region separation in this system. Afterwards, color andtexture features are extracted. Then, SVM with multi classes is usedto categorize river, sandbank, and other regions. Subsequently, the resultant river regions from the classified step are applied for change detection using change rules.

According to the testing results, the overall accuracy of the river region detection for k-NN classifier is about 87% and for multi-class SVM is 93%. The system provides more accurate results when using multi-class SVM. Moreover, the evaluation is well performed on the public dataset SIRI_WHUand own data.The accuracy of the proposed system for detecting river changes is 93.38%.A qualitative and qualitative analysis of the changed detection results confirmed the effectiveness of the proposed system. Therefore, this system will support the water resource management and environmental management of the Ayeyarwady River in Magway region.

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