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RESEARCH PAPER

Identification of flooded area from satellite images using Hybrid Kohonen Fuzzy C-Means sigma classifier

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Abstract A novel neuro fuzzy classifier Hybrid Kohonen Fuzzy C-Means-σ (HKFCM-σ) is proposed in this paper. The proposed classifier is a hybridization of Kohonen Clustering Network (KCN) with FCM-σ clustering algorithm. The network architecture of HKFCM-σ is similar to simple KCN network having only two layers, i.e., input and output layer. However, the selection of winner neuron is done based on FCM-σ algorithm. Thus, embedding the features of both, a neural network and a fuzzy clustering algorithm in the classifier. This hybridization results in a more efficient, less complex and faster classifier for classifying satellite images. HKFCM-σ is used to identify the flooding that occurred in Kashmir area in September 2014. The HKFCM-σ classifier is applied on pre and post flooding Landsat 8 OLI images of Kashmir to detect the areas that were flooded due to the heavy rainfalls of September, 2014. The classifier is trained using the mean values of the various spectral indices like NDVI, NDWI, NDBI and first component of Principal Component Analysis. The error matrix was computed to test the performance of the method. The method yields high producer's accuracy, consumer's accuracy and kappa coefficient value indicating that the proposed classifier is highly effective and efficient.

1. Introduction

Natural disasters are major adverse events which result from earth's natural processes. Natural disasters pose a serious threat to life and property, the extent of damage is directly related to the vulnerability of the affected area. The number of occurrences of natural disasters in the last few years has greatly increased. The major disasters include tsunamis, floods, volcanic eruptions, earthquakes etc. Floods are one of the most frequent and devastating natural hazards that occur worldwide. Floods occur due to excessive rainfall in a short duration of time and consequent high river discharge causes a large amount of damage. Flooding results in huge economic losses, destruction of ecological resources, food shortages and

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starvation of millions of people. Thus one of the major concerns of various countries is to monitor flooding so as to reduce the effect of floods. In the era of satellites, remote sensing data are used effectively for assessment, identification and management of flood disaster (Manjunath et al., 2007). Traditionally, field surveys or ground inspections were used for damage assessment. The limitation of these methods is that at the time of disaster it becomes difficult to reach the actual site. Remote sensing is a reliable way of providing coverage for wide areas in a cost effective manner and also it overcomes the limitation of surveying the ground in an extreme hydrological event. Satellite images are widely used for monitoring urban expansion and land use cover changes at a medium or large scale, to help better observe and understand the evolution of urbanization and advance the sustainable development process. The application of satellite imagery for flood mapping began with the use of Landsat Thematic Mapper and Multispectral Scanner, the Satellite Pour l'Observation de la Terre (France and Hedges, 1986; Jensen et al., 1985; Watson, 1991; Barton and Bathols, 1989), the Advanced Very High Resolution Radiometer (Gale and Bainbridge, 1994; Rasid and Pramanik, 1993; Sandholt et al., 2003), the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), MODIS, and Landsat-7 sensors (Brakenridge et al., 2003a,b; Smith, 1997; Stancalie et al., 2006; Wang, 2004; Wang et al., 2002). The pre and post flood Landsat 7 TM images were used to identify water and non-water features to identify flooded areas (Wang et al., 2002). Flooded areas and damaged buildings due to the 2011 Japan tsunami were identified based on the difference of backscattering coefficients from the pre and post tsunami TerraSAR-X intensity images (Mori et al., 2011). Flood monitoring in Bangladesh is done using a supervised classification technique using RADARSAT data (Hoque et al., 2011). A recent paper proposed a hybrid neuro fuzzy classifier known as Fuzzy Kohonen Local Information C-Means (FKLICM) Clustering for Remote Sensing Imagery (Singh et al., 2014). FKLICM is a hybridization of KCN with FLICM. Celik and Lee commented and proved that due to the design of the objective function of FLICM, the local minimizers do not converge to the correct local minima (Celik and Lee, 2013). The objective function of FKLICM is the same as that of FLICM and after conducting a thorough evaluation of the method it is revealed that the limitation associated with FLICM prevailed in FKLICM too. The proposed classifier is a hybridization of Kohonen Clustering Network (KCN) with FCM-σ clustering algorithm. It overcomes the limitations of FKLICM. The advantages of HKFCM-σ have been discussed later. In September 2014, heavy rainfall occurred in Jammu and Kashmir area which caused disastrous flooding and landslides all over the area including Jammu and Kashmir and adjoining areas of Pakistan also. In this paper, a method for identification of flooded areas using the proposed novel HKFCM-σ classifier is presented. The method classifies the pre and post flooding images using HKFCM-σ into different land cover classes and then using post classification comparison a classified change map is obtained which shows the flooded areas. The method is applied on areas of Kashmir to identify the flooding that occurred in September 2014.

2. Site description and satellite data used

Pre and Post flooding Landsat 8 Operational Land Imager (OLI) images acquired on 25th August 2014 and 10th September 2014 respectively are used for the study [http://glovis.usgs.gov]. Landsat 8 is an earth observation satellite launched on February 11, 2013. Landsat 8 Operational Land Imager (OLI) images consist of eleven spectral bands with a spatial resolution of 15 m for PAN band, 30 m for Bands 1–7 and 9. The band characteristics of Landsat 8 are given Table 1.

The study area covers around 7578.3814 sq km area of parts of Jammu and Kashmir including Handwara, Bandipora, Sopore, Pattan, Srinagar, Pahalgam, Poonch and other nearby areas. Fig. 1 shows the location of the study area. The geographical coordinates of Jammu and Kashmir are 33.4500° N, 76.2400° E. The false color composite pre and post flooding images are shown in Fig. 2.

3. Methodology

The flow chart of the proposed method is shown in Fig. 3. These steps are as follows:

3.1. Image preprocessing

The input images are preprocessed to obtain accurate results and remove any sort of distortions. The study area covers mountainous regions and therefore there is brightness difference due to image acquisition under different sun illumination conditions. Thus to compensate for this difference, the Top of Atmospheric (ToA) reflectance of the images is computed. Quantitative comparison of multi-temporal images requires

Table 1 Band Characteristics of Landsat 8 OLI.

Bands	Wavelength (m)	Resolution
Band 1 – Coastal aerosol	0.43–0.45	30
Band 2 – Blue	0.45–0.51	30
Band 3 – Green	0.53–0.59	30
Band 4 – Red	0.64–0.67	30
Band 5 – Near Infrared (NIR)	0.85–0.88	30
Band 6 – SWIR 1	1.57–1.65	30
Band 7 – SWIR 2	2.11–2.29	30
Band 8 – Panchromatic	0.50–0.68	15
Band 9 – Cirrus	1.36–1.38	30
Band 10 – Thermal Infrared (TIRS) 1	10.60–11.19	100 * (30)
Band 11 – Thermal Infrared (TIRS) 2	11.50–12.51	100 * (30)