LEVEE ANOMALY DETECTION USING SYNTHETIC APERTURE RADAR IMAGERY

Lalitha Dabbiru*, James V. Aanstoos, Nicolas H. Younan, Robert J. Moorhead
Mississippi State University
Email: lalitha@gri.misstate.edu

ABSTRACT

- Unstable slope conditions can lead to slump slides, which weaken the levees and increase the likelihood of failure during floods.
- On-site inspection of levees is expensive and time-consuming, so there is a need to develop efficient automated techniques based on remote sensing technologies to identify levees that are more vulnerable to failure under flood loading.
- The main focus of this research is to detect vulnerabilities on the Mississippi river levees using remotely sensed Synthetic Aperture Radar (SAR) imagery.
- Synthetic Aperture Radar technology, due to its high spatial resolution and potential soil penetration capability, is a good choice to identify problem areas along the levee so that they can be treated to avoid possible catastrophic failure.
- This research analyzes the ability of detecting the slump slides on the levee with NASA JPL's Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) data using supervised and unsupervised classification techniques.
- The main contribution of this research is the development of a machine learning framework to:
    - detect anomalies on the levee sections
    - provide early warning of impending levee failures
    - develop efficient tools for levee health assessment

STUDY AREA AND DATA USED

Slump slides are slope failures along a levee, which leave areas of the levee vulnerable to seepage and failure during high water events. The clay soil on the levees shrinks during dry weather periods and gains moisture during wet periods resulting a loss in shear strength which can lead to failure. NASA JPL's UAVSAR data acquired on June 16, 2009 was used in this study as there were active slides during the time of image acquisition.

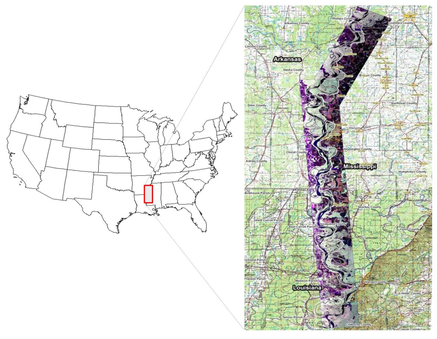

Fig 1: Polarimetric UAVSAR 3 band (HH, HV, and VV) data shown in color composite along the lower Mississippi River. Image swath width is 20 km; total flight line length is 230 km.

Fig 2: A Slump slide on the levee adjacent to Chotard Lake, MS, USA.

AUTOMATED LEVEE TARGET RECOGNITION SYSTEM

- Surface roughness is an important property that can be used to distinguish slump slides as the radar backscatter is strongly influenced by the surface roughness.
- Therefore, textural features derived from Synthetic Aperture Radar imagery using the discrete wavelet transform (DWT) technique have been used in the classification tasks.
- Supervised and unsupervised classification algorithms have been applied to SAR data for efficient land cover classification.
- The RX Detector (RXD) unsupervised classification algorithm was implemented on the extracted features of the SAR data.
- The support vector machine (SVM) supervised classification algorithm was implemented on the DWT features with the ground truth data and the performance has been evaluated by the classification accuracies.

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CLASSIFICATION APPROACH

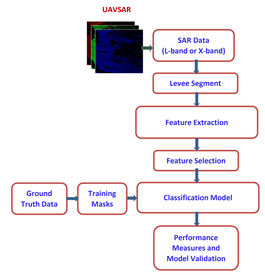

Fig 3: Block diagram of Classification approach

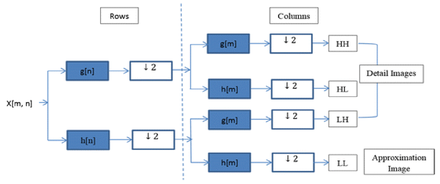

Fig 4: Schematic diagram of one-level 2-Dimensional DWT image decomposition process

RX ANOMALY DETECTOR – UNSUPERVISED CLASSIFICATION RESULTS

The RX Detector (RXD) unsupervised classification algorithm was implemented on the extracted features of the SAR data. The output generated by RXD is a grayscale image; the larger the value of the pixels, the more anomalous the pixels would be. For visualization purposes, the range of values of the output are color-coded. A threshold is used to identify the true positives, which are the slide pixels.

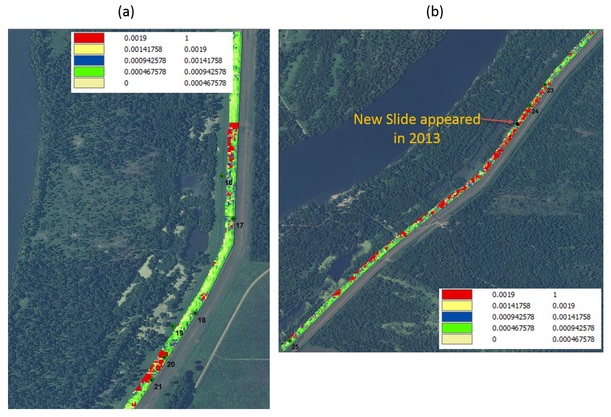

Fig 5: (a) RX Anomaly detector classification output for active slides 20 – 21 at the time of UAVSAR image acquisition on 16 June 2009. The slides were color coded as dark red in color based on the threshold as shown in the color map. Slides 17 and 18 were appeared in October 2009, after the image date. (b) Lower part of the levee segment which contain three slides (23 – 25) active at the time of image acquisition on 16 June 2009. A new slide appeared later at a location flagged as anomalous during the 2009 image analysis.

SUPPORT VECTOR MACHINE – SUPERVISED CLASSIFICATION RESULTS

Wavelet features were extracted with different window (block) sizes: 4, 8, and 16 and the SVM algorithm was implemented on the extracted texture features of the SAR dataset using a Gaussian radial basis function (RBF) kernel and the performance of the classification was tested with different values of the kernel parameter σ. The results showed that the SVM classifier performed well in detecting the slump slides with the highest accuracies of 94.5% for the slump slide class and 95.6% for the healthy levee class.

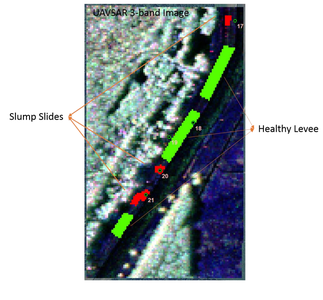

Fig 6: Training mask for UAVSAR subset with two ground truth classes: 1. Slump slide and 2. Healthy Levee with 3-band UAVSAR (HH, HV, and VV) image at the background.

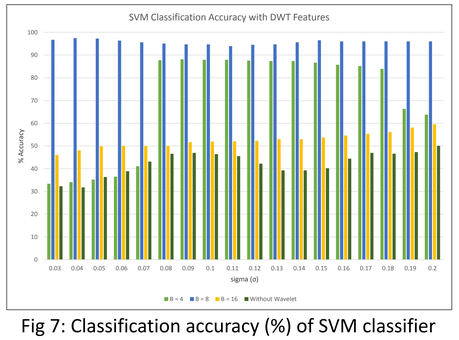

Fig 7: Classification accuracy (%) of SVM classifier with DWT features and with different block / window size (B).