Ph.D. Research Proposal

Doctoral Program in "Department Name"

Difference Thresholding Mediated Capsule Network For Feature Fusion And Classification For Remotely Sensed Images

by

<Name of the Candidate>

<Reg. No of the Candidate>

<Supervisor Name>

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I. INTRODUCTION / BACKGROUND

Image fusion is an emerging task in both computer vision and image processing research that uses ***multiscale analysis and multisensor processing.*** It integrates the significant information from a given set of images and forms a single image and thereby, the resultant image is found to be more superior to the initially obtained images. Image fusion is performed at three different processing levels according to the stage at which the fusion takes place:

1. Pixel level fusion
2. Feature level fusion
3. Decision level fusion

- Pixel level fusion represents fusion at the lowest processing level referring to the merging of measured physical parameters
- Fusion at feature level requires the extraction of objects recognized in the various data sources, e.g., using segmentation procedures.
- Decision- or interpretation level fusion represents a method that uses value-added data where the input images are processed individually for information extraction.

Image Classification is the process of assigning land cover classes to pixels. For e.g. classify images into forest, urban, agriculture and other classes

- Image classification generates thematic maps from remotely sensed images.
- Generated maps represent different objects on earth surface like vegetation, buildings and roads.
- Different satellite sensor produces different quality images.
- Accuracy of classification dépends on satellite image quality.

Image classification can be done using supervised classification and unsupervised classification. Prior knowledge about study area is required for supervised classifier. In supervised classification image analyst select the training pixels. These pixels are used to obtained different land cover features. Using these features the classification is done. Unsupervised classification does not require any prior knowledge of study area. In this classification large number of pixels that are unknown are examined which are further divided into different classes depending on natural groupings of images.

1.1 Research Outline & Scope

Image fusion and classification are the primarily roles for remotely sensed images. In this work, diverse features are required to improve the accuracy for land cover type classification.

1.2 Research Objectives

The main aim of our proposed model is to fuse the images with minimum errors and classify images with high classification rate. The major objectives and contributions of this research work are:

- To propose image fusion and classification model
- To propose novel approach for image fusion and classification
- To compare the proposed methodology with conventional image fusion methods and state-of-the algorithms

II. RESEARCH GAPS

2.1 Common Problem Statement

Image fusion and classification are the major process in remote sensing. It is very difficult to identify land cover classification manually from a satellite image due to the insufficient spatial and temporal information. There are certain crucial challenges in this field such as High computational complexity during sub band Selection, Existing approaches used a small amount of training data, Single classifier does not scale well for large scale images, and Noisy attributes,

which are not useful for classifying fused data, and Increases memory overhead when the dimensionality of the data becomes larger.

2.2 Problem Definition

Authors [1] proposed a new saliency-driven fusion method using complex wavelet transform. Initially, an adaptive saliency detection method using spectral dissimilarity and clustering is proposed to compute the saliency factor for representing diverse needs of the two kinds of regions resolutions. Second integrate nonlinear intensity –hue-saturation transform with multi resolution analysis using dual-tree complex wavelet transform (DTCWT). Therefore, the saliency factor is presented to satisfy different needs of different regions.

Problems

- DTCWT provides useful characterization of image structure, multi resolution, higher degree of shift variance, and sparse representation makes the DTCWT superior than DWT while preserving details (Edge and Texture). However, the number of decomposition directions can increase while ensuring shift variance translation.

Proposed Solutions

- We proposed Tunable Q-Factor based Wavelet Transform for Decomposition. 5^{th} level decomposition is considered for Image Fusion

Authors considered multisource remote sensing data (Synthetic Aperture Radar –SAR, and Optimal Imagery) in [2] to classify the land-cover types with the support of support vector machines (SVM) and genetic algorithms (GA). However, the selection of SVM kernel parameters is difficult which affects the classification accuracy performance. Hence, GA is combined to SVM for parameter optimization and feature selection. A Thaichote (THEOS) and RADARSHAT-2 (RS2) SAR multispectral image is considered for performance evaluation. In this model, two criterions were employed to compute the fitness function including the number of features in the selected subset and the classification accuracy

Problems

- In this paper, GA is considering for SVM kernel parameters selection. However, the optimization time is high for genetic algorithm.

Proposed Solutions

- In this work, we employed J48 with Rule mining is proposed which is the combination J48 algorithm and also association rule mining

Image enhancement is an important task in remote sensing images. This paper [3] concentrated on image enhancement from Indian Remote Sensing (IRS) Satellite P6 LISS IV remotely sensed data such as Near Infrared Band. For that presented four filtering techniques like Median Filter, Bilateral Filter, Wiener Filter, and Gaussian Homomorphic Filtering to remove the noises (salt & pepper noise and Gaussian noise). Finally, concluded that homomorphic filter outperforms than the other three filters because it's normalize the brightness of the image and increase the contrast.

Problem

- However, the main challenge of the filtering approaches are regarding time CPU time that is high while dealing with normal denoising utilize greater time for large scale images

Proposed Solution

- An emerging need of the optimized filters can enable the image denoising effectively. Thus, we proposed Difference Thresholding based Adaptive Switching Filter for noise reduction. The inference engine performs well as we remove the salt & pepper noises and Gaussian noises.

To improve the classification accuracy of remote sensing images [4], scalar wavelet based contourlet frame based features are used. Multiwavelet is an extension to scalar wavelets which provides higher degree of freedom and also its given two or more scaling function and wavelet function. This paper considers multiwavelets such as Chui Lian (CL) and Geronimo-Hardian-Massopust (GHM). Finally, authors have concluded that the CL based multicontourlet frame

based features are improving the classification accuracy because it contains directional filter banks. Principal Component Analysis (PCA) is considered for feature reduction and Gaussian Kernel Fuzzy C Means classifiers considered to improve the classification accuracy.

Problems

- PCA support for dimensionality reduction. In order to build the predictive model, we needs to gather more information from variables , but PCA produces noisy attributes, which are not useful for classifying fused data

Proposed Solutions

- To overcome the PCA, Hill Climbing is used for feature reduction which reduces useful information and ranks variables

Zhang et al. [5] have proposed a multi-source data feature fusion which is a new framework for feature level fusion. The source of the proposed work is implemented for landsat operational land imager images and also advanced land observing satellite-2 images. For evaluation, Chongqing (Karst Mountain) is focused and also the overall accuracy (OA) is better than previous approaches in 85% and the Kappa Coefficient value is 0.845.

Problems

- Considered only contrast features, which is not sufficient to find land cover type and classification

Proposed Solutions

- There are four types of features are considered for accurate classification

III. RESEARCH CONTRIBUTIONS

This research work is considered two approaches on input digital images, **Image Fusion and Image Classification**. There are six major phases are incorporated into our proposed works that are:

- Pre-processing
- Wavelet Decomposition
- Best Coefficients Selection
- Feature Engineering
- Feature Selection
- Image Classification

For image fusion process, we considered two sources of images such as PAN and MS images.

The first is pre-processing in which we perform two steps:

- Color Models Conversion (RGB to HSV and HSI)
- Denoising: We remove the salt& pepper noise and impulse noise using switching filter with difference thresholding. The noise removed in Diagnonal direction using switching filtering.
- Next, wavelet decomposition is performed using Tunable Q-Factor Wavelet Transform
- In order to fuse the image effectively, we have selected best coefficients using Di-Distance formula such as Hassanat Distance and Canberra Distance. Based on the majority similar values, best coefficients are selected.
- Thus, the coefficient with minimal distance is attaining the high priority than the other coefficients. In this way, the fused image is reconstructed.

Improving classification accuracy, we invoking two steps of processes

1. Feature Engineering
2. Best Feature Selection

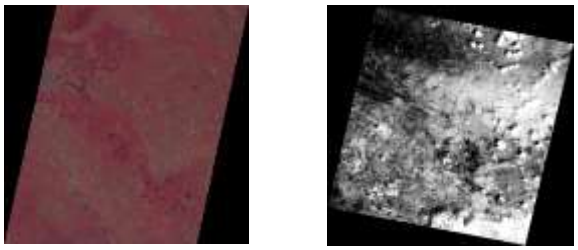
Feature Engineering: The multiple features including spectral, shape, global and local features are extracted by Capsule Networks.

Best Feature Selection: Then we have given these pooled features into Hill Climbing with Random Restart for finding best of top features.

Finally, we classified the decision with 8 classes using J48 classifier with Rule Mining is proposed that are follows:

- Wetland
- Grass land
- Urban
- Roadways
- Vegetation
- River
- Forest
- Bareland

Dataset Description: LISS IV images (PAN, and MS Images). This image was captured by the IRS P6/LISS IV Satellite/Sensor which has a resolution of 5.8 m. The bands with spectral resolution is 0.52-0.59, 0.62 – 0.68, and 0.76 – 0.86, respectively. The image scale is 1: 50 000 approximately.



(a) (b)

Fig.3.Original LISS IV image from IRS P6 Satellite

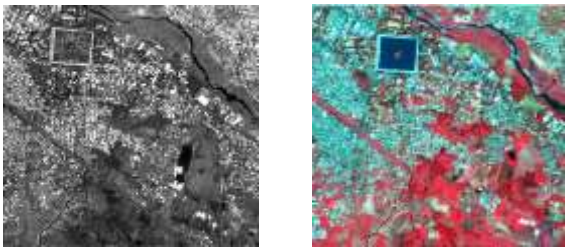


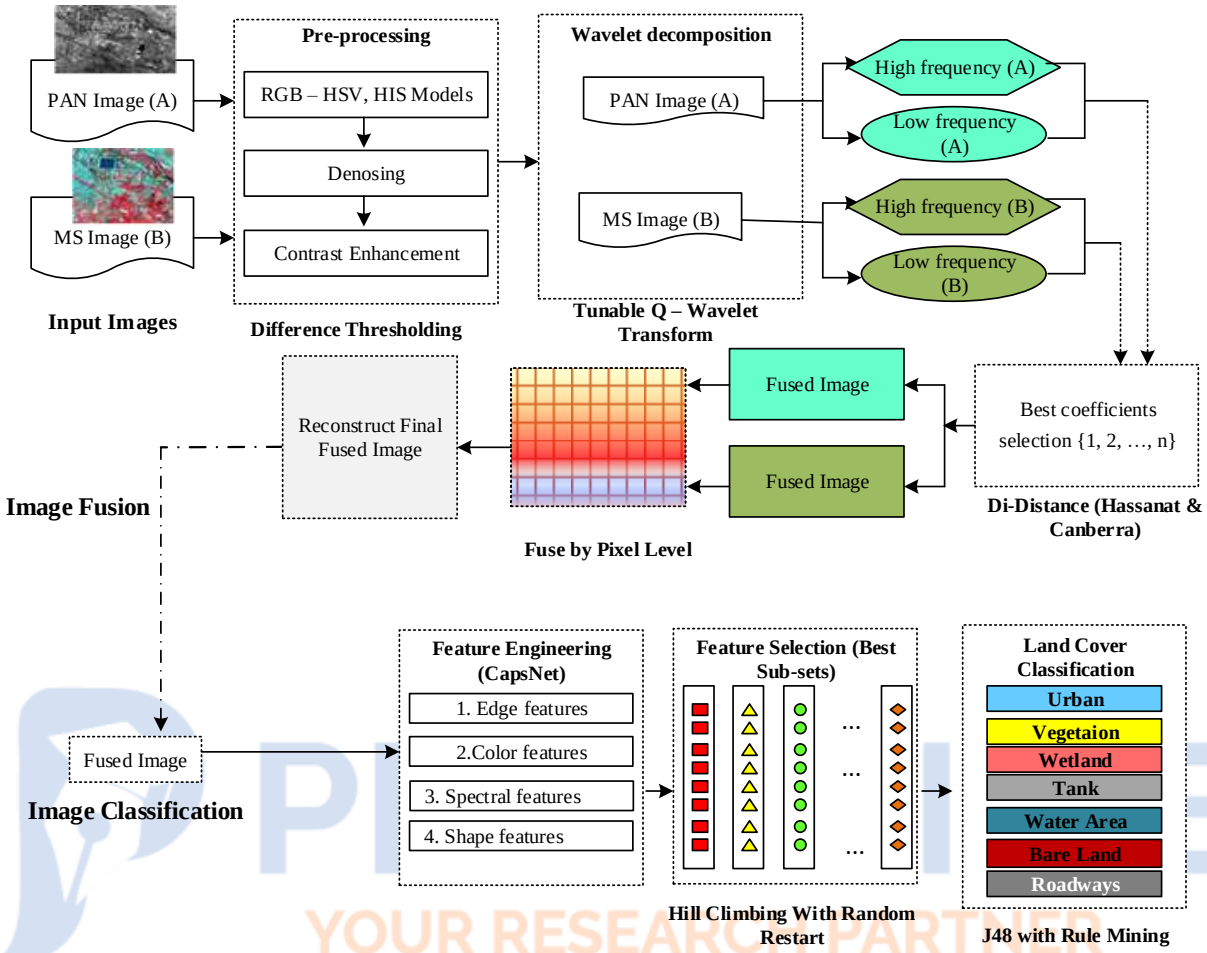
Fig.5.Cropped LISS IV Images (PAN and MS)

Performance Evaluation

Finally, the performance is evaluated in terms of the following metrics

- Spectral Angle (SA)
- Overall Accuracy
- Running Time
- Kappa Coefficient
- User Accuracy
- Producer Accuracy
- Normalized Cross Correlation (NCC)
- Feature Mutual Information (FMI)
- Peak Signal to Noise Ratio (PSNR)
- Structural Similarity Index Matrix (SSIM)
- Root Mean Squared Error (RMSE)
- Correlation Coefficient (CC)

SYSTEM ARCHITECTURE



IV. PREVIOUS WORKS & LIMITATIONS

PAPER 6

Title - Enhanced Dictionary based Sparse Representation Fusion for Multitemporal Remote Sensing Images

Concept -

In this paper, authors have presented an enhanced dictionary based sparse representation (EDSR) for multitemporal fusion. A local adaptive dictionary is constructed which contains patches extracted from both source images. The image reconstruction is performed using maximum absolute coefficients using learned dictionary.

Limitations

- However, the dictionary based learning approach is not suitable for large scale images. Mostly, satellite images are diverse for different sensors which lead to less accuracy and unsatisfactory result.

PAPER 7

Title - Image Fusion Techniques for Accurate Classification of Remote Sensing Data

Concept –

In this paper, the image preprocessing techniques like noise reduction and color conversion are applied to improve the image fusion performance. When complex remote sensing data can be processed, then the accurate image fusion techniques must be needed to preserve image classification

PAPER 8

Title - Remote Sensing Image Fusion via Wavelet Transform and Sparse Representation

Concept –

Authors have presented sparse representation and wavelet transform for remote sensing image fusion. The curvelet transform, discrete cosine transform, discrete wavelet transform, principal component analysis, ridgelets transform, shearlet transform are the existing methods used for fusing images. Using spatial frequency maximum the high frequency sub-images with prolific detail information is established using fusion measurement indicator.

PAPER 9

Title: SIFT-FANN: An Efficient Framework for Spatio-Spectral Fusion of Satellite Images

Concept –

Authors have introduced SIFT-FANN image fusion method which combines the Scale Invariant Feature Transform (SIFT) and Fast Approximate Nearest Neighbor (FANN) for automatic registration of satellite images. For image fusion, two kinds of feature information are considered i.e. spectral and spatial features. If these feature similar to each other, image fusion is performed.

Limitations

- This method produce higher accuracy but still speed for automatic image fusion remains challenging issue. However, for huge amount of data, speedup is more important for a higher precision.

PAPER 10

Title: A Review: Image Fusion Techniques and Applications

Concept – Different image fusion techniques have been proposed and the comparisons have shown in this paper. The techniques are HIS (Intensity-Hue-Saturation) transform, PCA, Pyramid techniques, high pass filtering, wavelet transform, artificial neural networks, and discrete cosine transform. Finally, the fuzzy let fusion algorithm shows the better results in terms of PSNR and RMSE value. But the general fuzzy logic system is not adoptable for all cases. Generally, the sensors are produces images with a rich spatial resolution but a poor spectral resolution

PAPER 11

Title: A Computationally Efficient Algorithm for Fusing Multispectral and Hyperspectral Images

Concept – In this paper, computationally efficient algorithm for fusing multispectral and hyperspectral images with a low computational effort. Fusing images for classification is another

major task in remote sensing applications. The multispectral (MS) and panchromatic (PAN) images construct multiscale representation (low-frequency and high frequency sub-images). For low frequency sub images, the fusion rule is applied

Limitations

- The integration of sparse and spectral information does not extract the local structure information of images.

PAPER 12

Title: A Generalized Metaphor of Chinese Restaurant Franchise to Fusing Both Panchromatic and Multispectral Images for Unsupervised Classification

Concept – Authors have presented a unified Bayesian model to discover semantic segments from panchromatic image and then allocate cluster labels for the segments by multispectral images. These remote sensing images are captured on the same geographical area at different acquisition dates are merged to attain a fused image for further analysis.

Limitations

- However, Bayesian approach leads to high computational cost especially in frameworks with a large number of parameters.

PAPER 13

Title: Effective Sequential Classifier Training for SVM based Multitemporal Remote Sensing Image Classification

Concept –

In this paper have proposed SVM (Support Vector Machine) classifier for multispectral images classification. The SVM approach applied sequentially to image data, with only a small number of training samples being required from each image. Hence, this method can preserve the spatial detail information and spectral information.

Limitations

- The single classifier does not produce high accuracy results especially, when using SVM the kernel parameter selection is much difficult for remote sensing images.

PAPER 14

Title: Image Fusion for MODIS and Landsat Images using Top Hat based Moving Technique with FIS

Concept -The moderate and landsat resolution images are taken from artificial satellite is generally not distinguishable in perfect. This paper presented top hat based moving technique with fuzzy inference system (THBMT-FIS) to obtain the image accuracy and clarity. The black top hat (BTH) and white top hat (WTH) techniques remove the dark and light character of the image. Then the image fusion is performed using fuzzy inference system. Hence the proposed method is used to retrieve satellite images which are highly informative techniques. The resultant fused image consists of more information than the input images. Entropy is the measure of the information content of the image, the increase in entropy represents that better fusion has been done.

Limitations

- Fuzzy Inference System does not scale well for large scale images

Paper 15

Title: Hyperspectral image classification based on Joint Spectrum of Spatial Space and Spectral Space

Concept - This paper proposed a novel feature extraction method that invokes local histogram in spectral space (pixel spectrum) and spatial space) for hyperspectral classification. The final feature is extracted based on affine transform and 3D spectrum model, which is given to the input of widely used for Support Vector Machine (SVM). This model is iteratively choosing the

subbands with subspace projection and posterior probabilistic fusion strategy for HSI classification.

Limitations

- However, the selections of kernel parameters are difficult and it is more complex for remote sensing satellite data

PAPER 16

Title: Practical Remote Sensing Image Fusion Method based on Guided Filter and Improved SML in the NSST domain

Concept - A novel remote sensing image fusion scheme called non-subsample shearlet transform (NSST) is proposed. This is an enhanced scheme used to solve the insufficiency of spatial detail in multiresolution analysis (MRA) based methods after the HIS color space (Intensity-Hue-Saturation) transform. Next, during the NSST fusion process, a guided filter based low frequency coefficient fusion rule and an enhanced sum-modified Laplacian (SML) based high frequency coefficient fusion rule are presented. The guided filter is an edge preserving smoothing filter which avoids the ringing artifacts. It is successfully adopted for many image processing tasks such as image defogging, enhancement and matting. The final fused image such as the resultant image can be obtained through the inverse NSST transform and inverse HIS transform.

Limitations

- A guided filter based low frequency coefficient fusion rule and an enhanced SML based high frequency coefficient rule are presented in this paper.
- The common limitation of the guided filter is it may exhibits “Halos” near some of the edges. A halo represents the artifacts of unwanted smoothing of edges. It is unavoidable for local filters when the filters are forced to smooth some edges
- Similarly, NSST is an extension of the NSCT. It is also leads to high computational complexity

PAPER 17

Title: Remote Sensing Image Fusion Method based on PCA and Curvelet Transform

Concept- This paper proposed a new remote sensing image fusion algorithm using Curvelet Transform and Principal Component Analysis. To fuse two registered multi-spectral and panchromatic image, PCA transform first principle component PC1 of MS image is extracted through PCA transform. At the same time, the morphology hat transform on the PAN image and segment the transformed PAN image using the PCNN segmentation algorithm. Finally the resultant image such as the fused image is obtained using inverse curvelet transform and PCA transform.

Limitations

- Most commonly, the remote sensing images are large in size and this method is not effective during real-time image fusion. Both the PCA and Curvelet Transform leads to high computational complexity

PAPER 18

Title: Deep Learning Classification of Land Cover and Crop Types using Remote Sensing Data

Concept- Recently, deep learning is a powerful in image processing particularly in remote sensing images. This paper illustrates a multilevel deep learning architecture that targets crop type classification and land cover from multisource and multitemporal satellite imagery. The convolutional neural network (CNN) is proposed for land cover and crop type's classification. The target accuracy of CNN is reached to 85% for major crops such as wheat, sunflower, sugar beet, maize, and soy beans. The major advantage of using CNN than MLP and RF is that it enables to build a hierarchy of sparse and local features derived from temporal and spectral profiles.

Limitations

- When using CNNs for small objects classification in the remote sensed image, it is not effective and not accurate

Paper 19

Title: A Combined Detail Enhancing Algorithm and Texture Feature Extraction Method for Supervised Classification of Remote Sensing Images

Concept - A supervised classification approaches are widely used in multispectral satellite images in terms of feature extraction and classification. Firstly, image is decomposed into low-pass approximation and high pass multi-directional subbands using wavelet based contourlet transform. Most commonly, high pass subbands can easily interfere or affected by noise. Using the normal shrink technique, thresholding is applied in high frequency images to remove the noise in satellite images. The Gray Level Co-occurrence Matrix is computed to form the co-occurrence features on training and testing images. Finally the classification is performed using the Mahalanobis distance classifier.

Limitations

- Less accuracy which leads to Mahalanobis distance classifier because it's increases memory overhead when the dimensionality of the data becomes larger [Does not scale well to high dimensional data $O(10^6)$ for many satellite images] and it only works for linearly separable data

PAPER 20

Title: A Novel Image Fusion Algorithm using an NSCT and a PCNN with digital filtering

Concept - In this paper authors proposed a nonsubsampled contourlet transform (NSCT) and a pulse-coupled neural network with digital filtering in a novel manner. Initially, decompose two original images into a low-frequency and a series of high frequency subband coefficients using the NSCT. Next, each low frequency subband coefficient in different levels in the frequency domain for both images was duplicated. Different levels of low-frequency subband coefficients from two different images are processing using a Laplacian Filter. This filter can improve the

performance of both texture and edge representation and also average filter can implement image smoothing for creating a superior reconstruction of an image through the low-frequency subband coefficients of the frequency domain. Further, the coupling coefficients from different images are fused into one new image using the PCNN.

Limitations

- A reconstructed fused image based on low and high frequency subband coefficients were not improve the efficiency of the fused image since NSCT has high computational complexity.

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