Satellite Image Processing for Remote Sensing

Lalam Kiran Chandra[1], Laveti Komali[2], Lopinti Amrutha[3], Maddela Divya[4], Majji Subhashini[5]
GMR Institute of Technology, Rajam, Andhra Pradesh, India
20341A05A8@gmrit.edu.in[1], 20341A05A9@gmrit.edu.in[2], 20341A05B0@gmrit.edu.in[3], 20341A05B1@gmrit.edu.in[4], 20341A05B2@gmrit.edu.in[5]

Abstract: *In this study, image extracted from the satellite sensors are processed for remote sensing. Remote sensing is the science of gathering data about objects or areas from a distance. There are four main processing stages: image pre processing, enhancement, transformation and classification. In pre processing, some distortions need to be corrected before carrying out analysis and post-processing techniques. Radiometric, atmospheric and geometric corrections are one of the most used in satellite image pre processing techniques. There are different methods of satellite image enhancement which includes contrast enhancement, resolution enhancement, edge enhancement, density slicing and digital mosaics. Image transformation stage aims to identify particular feature of earth's surface using PCA and NDVI. Classification is a process of grouping the pixels, that produces effective thematic map of particular land use and land cover. Manual classification by using image interpretation technique requires more time and field experts. So in this paper, it is focused with efficient automatic satellite image classification. Convolutional neural network(CNN) is used for feature extraction and classification of satellite images.*

Keywords: Remote Sensing, Classification, Satellite Images, Pre Processing, CNN

I. INTRODUCTION

Remotely sensed images have been employed as the main data sources in many fields such as agriculture, urban planning and disaster risk management which also comprises of natural resource studies including land-use in general, biomass estimation, forests, plantation, soils, coral reefs, wetland and water resources and have been shown as an effective and critical tool to provide information. Remote sensing images provides critical information used to monitor and predict weather and climate change, land use changes at a macro scale and vegetation. The images acquired from the satellite vary as far as brightness, color, and wavelength. The resolution of an image determines the quality of the detail in the image pixel. So, the obtained images from satellite should be processed for remote sensing. Remote sensing image processing include tasks such as image preprocessing, image enhancement, image transformation and classification. Different processing methods were developed to address them, and they aimed to improve the performance and accuracy of the methods to address RS image processing. In this study, various machine learning and deep learning methods are studied at every stage of the satellite image processing to obtain better results in remote sensing they aimed to improve the performance and accuracy of the methods to address RS image processing. To denoise satellite images, the authors proposed various algorithms such as NLDE, optimization algorithm, and neural networks. PCNN and histogram equalization algorithms are used to improve the contrast and resolution of satellite images. Finally, satellite image classification is done by different classifiers, resulting in high accuracy and convolutional neural networks (CNN). This work provides a better approach to image processing of satellite images at various stages of processing.

II. LITERATURE SURVEY

1. de Oliveira, V. A., Chabert, M., Oberlin, T., Paulita, C., Bruno, M., Latry, C., & Camarero, R. (2022). Satellite Image Compression and Denoising with Neural Networks. IEEE Geoscience and Remote Sensing Letters, 19, 1-5.

- The publication's authors explain that satellite imagery is important for observing Earth and helping us understand the impact of human activity on economic activity and ecosystems. Denoising images acquired from the satellite facilitates satellite image classification. In this article, the author proposes his two approaches to compress and denoise his satellite images.

- The first proposed approach uses a single neural architecture to share onboard compression and noise reduction.
- The second pro_x0002_posed approach sequentially uses the first his neural architecture for onboard compression and the second neural architecture for ground noise reduction.
- This article aims to remove noisy data from satellite acquired images.

2. Shao, J., Guo, Z., Yao, W., Yan, D., & Wu, B. (2022). A Non-Local Diffusion Equation for Noise Removal. Acta Mathematica Scientia, 42(5), 1779-1808.Image quality is one of the most crucial influence factors when conducting biometric image-based human identification.

- In this paper, we propose a new nonlocal diffusion equation for noise reduction, derived from the classical Perona-Malik (PM) equation and the normalized PM-equation.
- Using image gradients and gradient convolution, the authors propose a new diffusion coefficient.
- However, the solution of the nonlocal diffusion equation may be discontinuous and belong to the bounded variation space.
- Experimental results show that this method has non-local performance, and outperforms the original PM and other methods.
- The purpose of this article is to suggest a better technique for denoising satellite images.

3. Ghous, M., & Khan, A. (2022). Efficient image enhancement using improved RIQMC based ROHIM model. Multimedia Tools and Applications, 1-25

- The authors note that contrast enhancement plays an important role in better visualization to achieve adequate results and improve image quality.
- In this study, the authors proposed a technique to enhance the contrast of both types of images: color and grayscale images.
- They used the best-fit histogram method based on RIQMC (Reduced Reference Image Quality Metric for Contrast Variation) and performed contrast enhancement using non-parametric histogram equalization.
- The purpose of this document is to provide techniques for improving the quality of satellite imagery by improving the contrast of the image obtained after removing noise from it.

4. Hariharan, K., Rajaan, N. R., Chelliah, P. P. R., & Deepika, M. (2021). The Enriched Feature Enhancement Technique for Satellite Image Based on Transforms Using PCNN. Wireless Personal Communications, 117(4), 2729-2744.

- The authors explain that satellite imagery is one of the agents that reflect earth surface features.
- This research paper provides a detailed investigation of two types of satellite imagery, panchromatic (PAN) and multispectral (MS).
- Using a Pulse Coupled Neural Network to stimulate low frequency pixels and applying a
- Morphological Filter to the edge detection image he finds features in the image.
- The purpose of this paper is to improve the obtained images.

5. Bindu, J. S., & Pramod, K. V. (2022). Texture and pixel-based satellite image classification using cellular automata. Multimedia Tools and Applications, 1-25.

- The author of this article provides a technique for classifying satellite imagery.
- Today, large amounts of satellite imagery are received in a fraction of a second, but processing such imagery to determine land cover and land use is considered a time-consuming process.
- To achieve this goal with high accuracy, this proposed approach introduces a Cellular Automaton (ACA) algorithm.
- Results show that texture-based His ACA classification provides higher classification accuracy (96.8%) than pixel-based His ACA classification (90.98%).
- The purpose of this work is to achieve high accuracy in image classification.

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III. METHODOLOGY/RECENT TECHNOLOGY

3.1 Method 1: Denoising with Cmdhho

CMDHHO is an improved differential evolution-driven multi-population algorithm that includes three main strategies: chaos, multi-population, and differential evolution strategies, and is proposed.

Strategy 1 (Chaos):

Apply chaos theory to the random search method to improve the effectiveness of random search. The proposed algorithm can use chaos theory's logistic mapping to generate a chaotic sequence as follows:

$cj+1 = \rho cj+1 \times (1 - cj), j = 1, 2, ., k - 1$

where ρ is the control parameter and k is the Harris-Hawks number.

Then a new population pc is generated based on the solution of population p with chaotic sequence c as follows:

$pc = cj \times p, j = 1, 2, . . ., k$

pc and p to determine the new fitness value. A new population is then created by choosing the fitness value solution. These steps must be repeated (K-1) times.

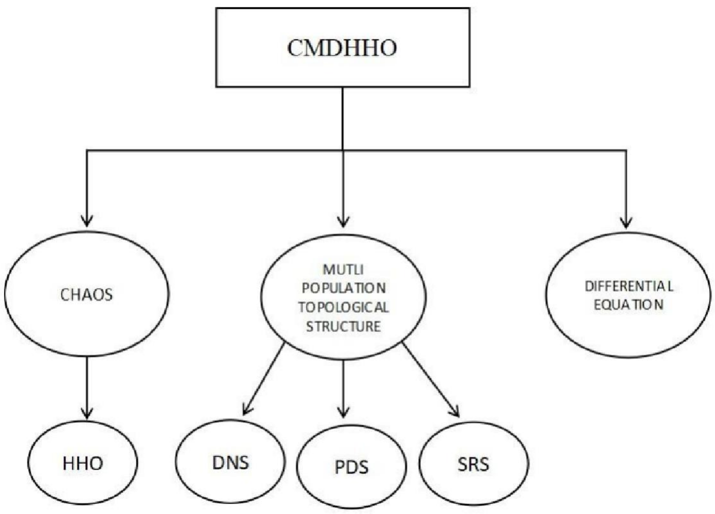
Strategy 2 (Topological Structure with Multiple Populations)

This structure plays a key role in establishing a balance between the exploration and development phases. In the first step of this strategy, distinct subpopulations are separated from the total population. All these subpopulations have the same population size. This feature of subpopulations provides a short and concise population structure and can also make the overall procedure simpler. By continuing the iterative process, the dynamic subpopulation numbering strategy (DNS) is designed to guide the process locally each time the subpopulation population size increases and the search volume decreases. fulfill. Additionally, we use a target detection strategy (PDS)to share information among subpopulations during the search process. On the other hand, PDS also improves the algorithm's ability to perform exploit drift. Finally, a subpopulation regrouping strategy (SRS) is applied when capturing the population at the local optimum.

Strategy 3 (Differential Evolution (DE))

To improve the local search ability of the Harris-Hawks optimization algorithm and the quality of the resulting solution, the proposed algorithm uses differential evolution. This strategy starts with remote sensing satellite image processing that uses a multiple population strategy to process the population creating a new population through three operations described below.

Step 1: Randomly select three characteristic individuals from the population.
Step 2: Measure the difference between the two people.
Step 3: Combine the differentiation vector with the third individual to obtain the final variant separately.



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3.2 Method 2: RIQMC based Rohim Algorithm

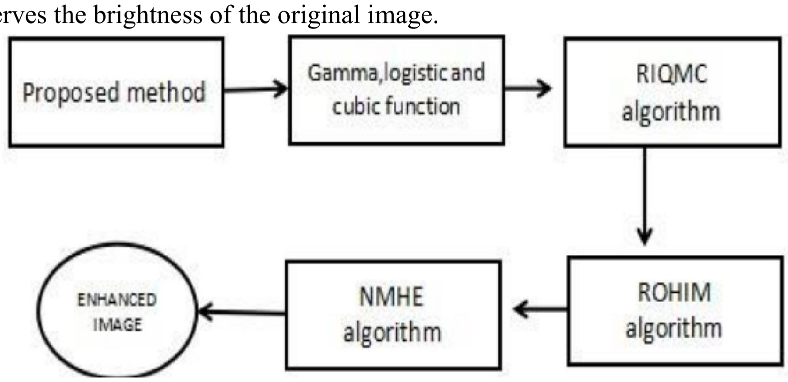
In this procedure, we consider a database of images obtained from the original images using the gamma transfer function, the cubic and logistic functions, and the synthetic function.

Gamma Transfer Function:

This function is known as the power law function. Positive Gamma Transfer Function and Negative Gamma Transfer Function. Positive gamma transfer function for $n > 1$ and negative gamma transfer function for $n \leq 1$. In this algorithm, phase congruence (PC)based values are obtained for database images. This includes his two strategies. We first quantify the similarity by computing the entropy difference between the output and input images. The comfort level consists of 1st, 2nd, 3rd and 4th order statistics. We also combine the above subjective and objective assessments to derive the RIQMC-based optimal histogram mapping (ROH IM).

This algorithm justifies its effectiveness compared to newly developed models. ROHIM also consists of his two stages of automatic contrast enhancement and performance comparison, which can enhance images better than new enhancement techniques.

Algorithm for improving image contrast according to RIQMC and ROHIM, but over-emphasizes the image. To eliminate this over-enhancement and image artifacts, the Non-Parametric Histogram Equalization (NMHE) algorithm is used. This method preserves the brightness of the original image.



3.3 Method 3: PCA and CNN Based Approach

In this method, raw satellite images are preprocessed by radiometric calibration, images are fused using the Brovey transform, principal component analysis is performed, and further classified by a convolutional neural network (CNN).

Radiometric Calibration

The image is calibrated using radiometric calibration, which allows the digital values to be converted to reflectance values via radiometric values by measuring emitting particles with the sensor.

Brovey Transform

The Brovey Transform is basically used to combine suggestive information from different bands into a single image for further processing with high resolution and good perceptibility.

Principal Component Analysis

PCA is commonly used for multispectral and hyperspectral satellite imagery. PCA is a statistical technique used for dimensionality reduction of data. PCA transforms the original set of correlated variables into a set of uncorrelated variables.

Convolutionary Neural Network:

CNN is which is a combination of multiple feature extraction stages in a multilayer architecture and 3 layers:

1) Convolutional layer - inner layer convolution
2) Pooling layer and
3) Fully connected layers.

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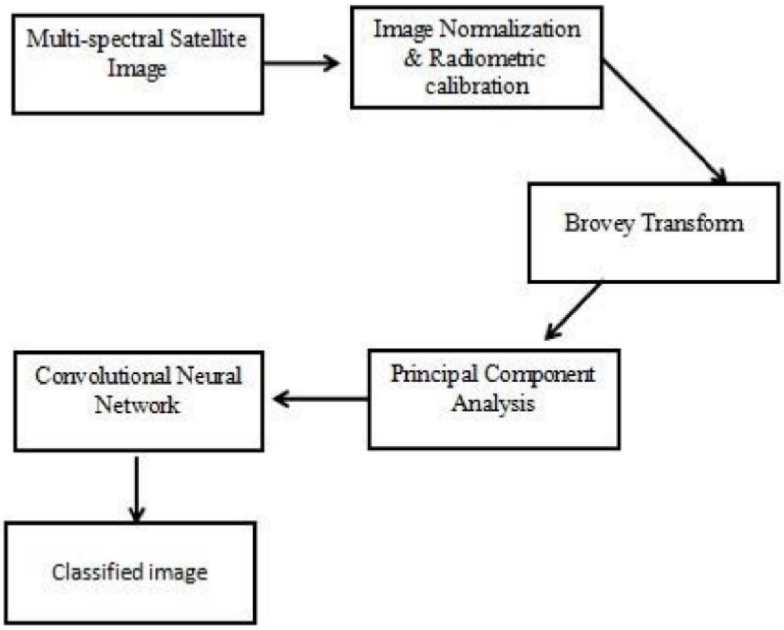
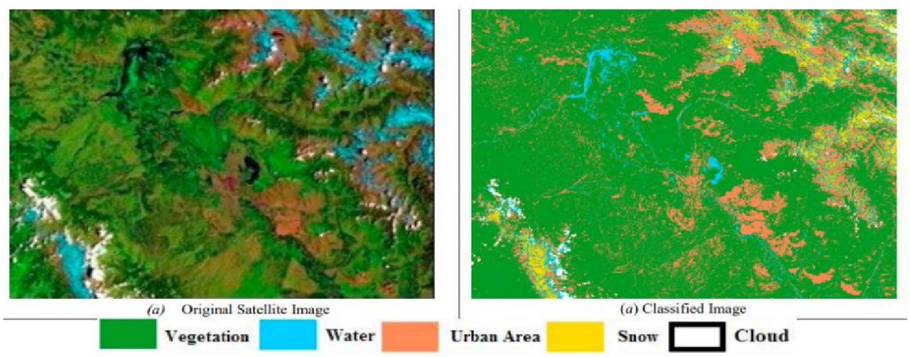
- **Convolutional Layer:** The convolutional layer is used to transform the 3D array input into a 3D composite feature output using filter k called the filter bank. The convolutional layer computes the output features on 3D arrays.
- **Nonlinear Layer:** This layer of the convolutional neural network has a nonlinear function for computing features in modified linear units called the activation function.
- **Pooling layer:** pooling layer is one of the main blocks of CNN. It is used to reduce the spatial size of the input data and works independently for each feature. Use a pooling layer, back propagation training to converge the nonlinear function to the objective function, and then classify the target output. Finally, a classified image is produced.

IV. RESULTS AND DISCUSSION



PCA AND CNN BASED CLASSIFICATION



V. PERFORMANCE METRICS AND EVALUATION

5.1 Denoising Method

Performance Metrics: Peak signal noise ratio(PSNR) - PSNR which is peak error where MSE is error which is cumulative and squared.

$$PSNR = 20log_{10}(\frac{255}{MSE^{\frac{1}{2}}})$$

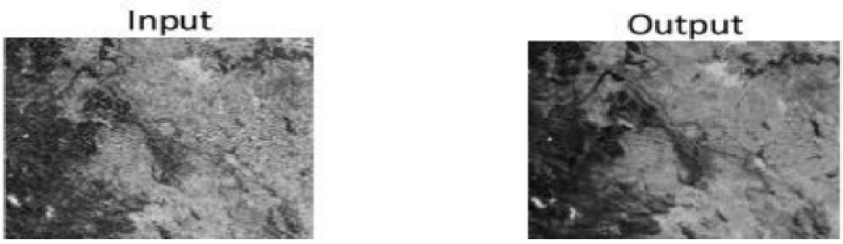
CMDHHO algorithm:

METRIC	ALGORITHM
PSNR	38.53

NLDE algorithm:

METRIC	ALGORITHM
PMS PSNR	31.5354
FEED PSNR	31.2055

The higher the PSNR value gives the better results of denoised images.



CMDHHO algorithm

From the above results CMDHHO algorithm gives better results giving high PSNR values.

5.2 Enhancement Methods

Performance Metrics: Mean square error (MSE) - mean square error gives the difference between the original image and the compressed denoised image.

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$$

Peak signal noise ratio(PSNR) - PSNR which is peak error where MSE is error which is cumulative and squared. For the better result of image it should have greater value of PSNR and smaller the MSE.

RIQMC based ROHIM algorithm:

METRIC	ALGORITHM
MSE	23
ENTROPY	6.17
PSNR	92

Transforms using PCNN algorithm:

METRIC	ALGORITHM
Mean input	134.809282
Standard deviation	0.233878
MSE	0.026926
RMSE	0.026926

From the above results of enhancement techniques RIQMC based ROHIM method gives best results.

5.3 Classification Methods

Performance Metrics: Kappa coefficient A discrete formula that evaluates the outcomes of the error matrix is the kappa coefficient. The kappa coefficient combines the off-diagonal rows and column observations and the diagonal observations to provide a more accurate accuracy assessment than any other calculation.

Accuracy: The ratio of total of True positive and True negative to total of True positive, True negative, False positive and False negative.

$$kp = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \ldots x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \ldots x_{+i})},$$

PCA and CNN algorithm:

METRIC	ALGORITHM
Kappa coefficient	0.89
Overall accuracy	94.5

ML algorithms:

ALGORITHM	OVERALL ACCURACY	KAPPA COEFFICIENT
Random forest(RF)	83.52	0.76
Support vector machine(SVM)	83.56	0.79

VI. CONCLUSION

Remote sensing images provides critical information used to monitor and predict weather and climate change, land use changes at a macro scale and vegetation. Satellite images are used for remote sensing but the images obtained from the satellite need to be processed. So, In this study we have mentioned the optimal and better process for processing the images obtained from the satellite. This involves various steps such as preprocessing, enhancement and classification. In the first step denoising techniques are applied in which CMDHHO algorithm gave the best results with 38.53 PSNR value. The second step is enhancement methods are applied for making classification easier in which RIQMC based ROHIM algorithm is used. Finally classification techniques are applied in which PCA and CNN algorithm given best results in terms of accuracy and kappa coefficient.

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