e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:03/Issue:07/July-2021 Impact Factor- 5.354 www.irjmets.com

REMOTE SENSING OF SATELLITE IMAGES USING DIGITAL IMAGE PROCESSING TECHNIQUES: A SURVEY

Shilpa Kaman*1, Dr. Aziz Makandar*2

*1Research Scholar, Department Of Computer Science Karnataka State Akkamahadevi Women's University Vijayapura, India.

*2Professor, Department Of Computer Sceince Karnataka State Akkamahadevi Women's University Vijayapura, India.

ABSTRACT

Remote sensing is gaining prominence as a result of its wide range of applications, including weather prediction, monitoring natural disasters, infrastructure planning, agriculture, forestry, mineral exploration, and many more, which can facilitate public and private operations and decision making to benefit society. Remote sensing system captures the portion of earth's surface, hence the output produced will be images representing the scene being observed. To process and extract useful data from these images, we need to apply different techniques of digital image processing. Basic image processing methods for remote sensing applications are as follows: Preprocessing, Image Enhancement, Transformation and Image Classification. This paper aims to provide an overview of the fundamental principles of techniques for remote sensing and image processing.

Keywords: Remote Sensing; Image Processing; Resolution; Multispectral; Hyperspectral; Satellite Images.

I. INTRODUCTION

Remote sensing is a technique for obtaining images from an airborne viewpoint and electromagnetic radiation reflected or emitted from the earth's atmosphere in one or more electromagnetic spectrum fields are used to provide knowledge about the earth's ground and water surfaces [1]. Let us look at some of the advantages of Remote sensing.

- It provides a synoptic view and unbiased recording. Which means satellites cover large part of the earth and they provide recording of data without any human intervention.
- Global Coverage: most of the satellites cover different or all portions of the earth irrespective of some of the countries having earth stations and some may not to record this data.
- Repeatability: some satellites keep covering the same portion of the earth depending on their resolution, swath, width and orbit. For example, satellites like NOVA AVHRR cover 4 times in a day twice day time and twice night time.
- Multispectral: Sensors can measure energy at wavelengths beyond range of human vision i.e., in Near Infrared, Infrared, Thermal Infrared and even in passive microwave regions which is otherwise not possible.
- Multi-resolution: Same Satellites can have different sensors of different resolutions which helps in capturing atmospheric conditions at different resolutions.
- Data is collected in Near Real time which is very essential in disaster management. Allows systematic data collection as we know the timing of satellite capturing data at fixed location with particular properties.
- Remote Sensing is the only solution sometimes for otherwise inaccessible areas. For example, in mountains, terrains, dense forest areas where humans cannot reach.
- Provides generic data which can be applied to many applications in different areas like weather forecasting, mineral exploration, civil engineering, agriculture and many more.
- It is Cost effective because once the satellite is launched it may last for 5years, 6years or 10 years sometimes. Initial cost is much more but once satellites is launched it may work with little operational costs like for recording, achieving, analysis and interpretation of data. Hence it is cost effective compared to traditional methods like ground-based survey.

Organization of paper: Section I gives introduction and advantages. Section II is briefings on the fundamentals of remote sensing. Section III we address various image processing methods used in remote sensing. Section IV is the Conclusion.

II. BASIC CONCEPTS OF REMOTE SENSING

The process of remote sensing involves seven major components as depicted in the following Fig. 1. Where A is the energy source required to capture target of interest, B is radiation and atmosphere, C is interaction with target, D is sensor to collect and record electromagnetic radiation, E is process of energy transmission, reception and processing, F is interpretation and analysis process to extract information from satellite images, G is application of data to a specific problem domain.

The distribution of electromagnetic radiation depending on the frequency and wavelength is electromagnetic spectrum. It ranges from shorter to longer wavelengths i.e., from gamma, x-rays to microwaves, radio waves. This electromagnetic spectrum has many regions that are useful for remote sensing including Ultraviolet radiations, Visible spectrum, Reflected Infrared, Thermal Infrared and even microwave regions.

Passive sensors are called remote sensing devices that monitor energy which is naturally visible. This will take place with all reflected light only at the period that the Earth is lit by the sun means in the direct sunlight. On the other hand, for illumination, active sensors have their own energy source. The sensor emits radiation directed at the target that needs to be measured. The sensor senses and analyses the radiation reflected from the target [2].

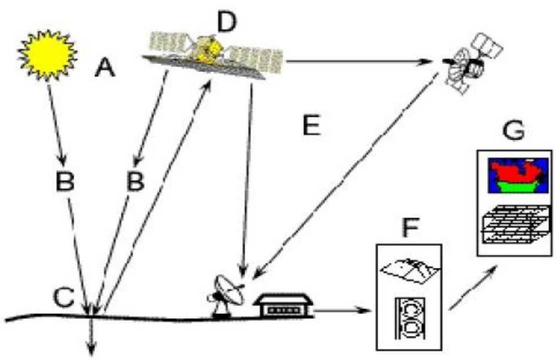

Fig. 1: Components of Remote Sensing System [2].

In order to absorb and record energy reflected or released from a target or surface, sensors must be mounted on a stable base. Remote sensing platforms can be deployed above the atmosphere, on the ground, on an aircraft or a balloon, or on a vehicle or satellite.

Resolution is one of the important characteristics of satellite images that refers to potential details provided by the imagery. In remote sensing there are 4 types of resolutions.

Spatial: The dimension of the smallest visible object is referred to as spatial resolution. We believe a picture has high resolution because we can see small details in it with great precision. The smaller the object that can be distinguished in an image, the higher the spatial resolution [3].

Spectral: The ability of a sensor's spectral resolution to identify fine wavelength intervals in an electromagnetic spectrum is known as spectral resolution. As a result, higher the spectral resolution, narrower the wavelength range of a given band [4].

Temporal: The time it takes a satellite to revisit the same location at the same viewing angle is known as absolute temporal resolution. This applies to the amount of time a satellite takes to complete one full orbit loop [4].

Radiometric: The number of digital levels used to reflect the data obtained by the sensor is referred to as radiometric resolution [3]. Radiometric resolution helps us to distinguish objects with high and low-level contrast in an image. Radiometric resolution specifies the brightness, contrast, lighting patterns and other information of an image [4].

III. IMAGE PROCESSING TECHNIQUES

Digital Image: Remote sensing images are represented in digital form produced by electro optical sensors. Pixels are a rectangular series of tiny equivalent areas or picture components that make up a visual image. Each pixel has a digital number (DN) that reflects the brightness or intensity of the image at that particular point. Here object reflecting higher energy is given higher number and vice versa. If 8-bit sensor is used then these values range from 0-255, where 0 is the value of darkest element and 255 is the value of brightest element. This is all about hypothetical image which is single band and also called as panchromatic image. But remote sensing data produced is multispectral image which means, the image of same area is captured in different spectral bands. Here a pixel is referred by its row, column and band number. Following fig. 2 shows the structure of these images.

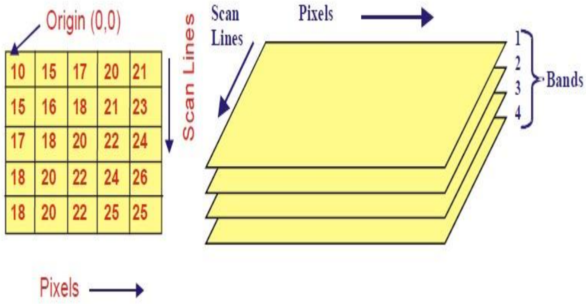

Fig. 2: Structure of a digital image and multispectral image [5].

Basic Digital Image Processing Operations performed in Remote Sensing systems on satellite images are as follows:

A. Preprocessing

Remote sensing systems may not function perfectly at all the times as the objects captured by sensors are complex like land, water and due to atmospheric disturbances also there may be chances of errors during data acquisition, which may degrade the quality of remotely sensed data. There are 3 possible errors called radiometric, atmospheric and geometric distortions. Preprocessing operation corrects these errors before further processing of information. Image Rectification is another name for image preprocessing.

1) Radiometric correction

Detector imbalances and atmospheric defects cause radiometric errors. The value of DN is changed which may degrade the image. Radiometric corrections are carried out to maximize the image's optical quality and are thus often referred to as aesthetic corrections. Most commonly occurring radiometric errors are

a) Line or column drop outs (periodic/partial): If detector fails to function properly entire line or column data will have no spectral information means line has value zero. A simple thresholding algorithm can be used for correction.

b) Line or column striping: Instead of line completely being missed detector response may shift towards higher or lower end that causes horizontal and vertical banding patterns. Corrections can be made by modelling linear relationship between input and output.

2) Atmospheric correction

There are 3 types of atmospheric errors.

a) Haze: As a result of scattered light from the atmosphere touching the sensor. It's an exponential effect that lowers

contrast. These errors can be corrected by histogram minimum or dark object subtraction method.

b) Skylight: The multiplicative effect is caused by dispersed light touching the sensor after being transmitted from the earth's surface.

c) Sun angle: The multiplicative effect is produced by the seasonal effect of shifting the atmospheric direction. The correction is implemented by dividing each DN pixel value in the scene by the size of the angle of solar elevation for a given time and picture position.

3) Geometric correction

Geometric corrections include correcting geometric distortions caused by improvements in sensor-Earth geometry and converting details to real-world coordinates on the Earth's surface (e.g., latitude and longitude) [2]. That's the method of fixing an image geometrically so that it can be interpreted on a planar surface. It is

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:03/Issue:07/July-2021 Impact Factor- 5.354 www.irjmets.com

crucial because accurate calculations of position, time, and direction must be made from imagery. Two basic operations must be performed to geometrically rectify the remotely sensed image.

a) Geometric Transformation coefficient computation: The geometric relationship between the position of input pixels (row and column) and the corresponding map coordinates of the same point is defined by this method. It involves using the least square technique and fitting polynomial equations to select Ground Control Points (GCPs).

b) Intensity Interpolation or Resampling: It is used to determine the pixel brightness value i.e., the DN value to be filled in the rectified output grid extracted from a location in the input image created after transformation. This results in input line and column numbers as real numbers not integers. Hence, we need to use any of the following methods for assigning brightness values.

- **Nearest Neighbor:** Assign the value of the nearest input pixel to the output pixel, which ensures the values are rounded to the nearest integer value.
- **Bilinear:** Takes the weighted average of 4 nearest pixels to assign value to the output pixel.
- **Cubic Convolution**: Similar to bilinear but take the weighted average of 16 nearest pixels instead of 4. Image produced is much smoother than bilinear.

H. Bagheri et al. [5] suggested a scheme for geometric correction of the Worldview-2 satellite image using various modelling techniques, with the goal of providing an overall estimation of the influence of different possible models for a design image of an urban region like Tehran. Artificial intelligence approaches such as genetic algorithms and neural networks were used for further optimization.

An image-based correction method that eliminates Stray-Light-Driven Radiometric Inflation (SLRI) without an independent reference, so that the Geostationary Ocean Color Imager (GOCI) method can be used for operational data processing is proposed by W. Kim et al. [6]. It uses SLRI correction algorithm that removes the stray-light-driven Inter Slot Radiometric Discrepancy (ISRD) using the Minimum Noise Fraction (MNF) transform. The relative radiometric calibration model based on side-slither calibration data that is not only effective to the linear response system but also to the nonlinear response system is proposed in [7] by Yan Li et al.

Y. Iikura et al. [8] proposes an effective method for correcting the Landsat TM image's space-varying atmospheric impact the technique was developed by taking into account the variations in atmospheric effects between visible and infrared bands. S. Özsarac et al. [9] proposed atmospheric correction system, that consists of geometry estimation method and atmospheric effects removal. The advantage of the proposed system is that it has achieved good accuracy with the detailed consideration of the radiometric relationships and physical measurements.

B. Image Enhancement

Improving the presentation of an image to make it more interpretable for a specific use. Image Enhancement is necessary for better understanding and easier visual interpretation of imagery as satellite images give lot of inadequate information where useful data is often available in small portions. Contrast stretching increases the tonal difference between different features, while spatial filtering enhances or eliminates unique spatial patterns in an image [2].

1) Contrast Enhancement

Also called as radiometric enhancement where point operations are performed that modifies the brightness value of each pixel in image independently and brings out the contrast. This requires the maximum spectrum of sensitivity of the display system to be used instead of the initial input values.

a) Linear contrast enhancement:

Input and Output values follow linear relationship. DN value in low range values are assigned to black, high range values are assigned to white and remaining values are distributed linearly between these values as shown in fig. 3.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:03/Issue:07/July-2021 Impact Factor- 5.354 www.irjmets.com

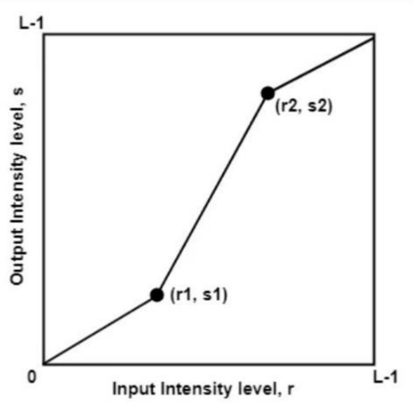

Fig. 3: Linear contrast transformation where r1=s1 and r2=s2

b) Nonlinear contrast enhancement

Input and output values are not linearly distributed and are related via transformation function which can be mathematical, statistical or trigonometrical function.

- **Logarithmic Stretch:** One example of contrast enhancement is logarithmic stretch. Here log values of inputs are linearly stretched to get desired output values.
- **Histogram Equalization:** The histogram of an image is distributed to generate uniform population density, making it one of the most commonly used contrast enhancing techniques. This is accomplished by grouping neighboring grey layers. As a consequence, the output has fewer grey levels than the input. Contrast is increased at most populated range of brightness values.

2) Spatial filtering

Often known as spatial enhancement, this method involves performing local operations on pixel values dependent on the values of adjacent pixels. It's a technique for breaking down an image into its constituent spatial frequencies and selectively changing those spatial frequencies by suppressing and forwarding on certain spatial frequencies to emphasize specific image characteristics. Filtering is done by using convolution mask of size 3x3, 5x5, 7x7 and so on and considering values of neighboring pixels.

a) Low pass filters: Allow low frequency by blocking high frequency components. It has smoothening effect on image blur the image at edges. Used to remove noise, especially noise of the salt and pepper. Three most common type of low pass filters are mean, median and mode filters.

b) High pass filters: These focus on fine information while preserving high frequency and removing slowly varying elements. Used for edge improvement and tracking. The Laplacian filter, which senses edges in all directions, is the most widely used filter.

Bhandari et al. [10] proposed a novel strategy for optimizing low-contrast satellite images based on the DCT-SVD (Singular Value Decomposition) domain. The fundamental enhancement is due to the scaling of singular DCT coefficient values. Proposed technique provides better results in terms of contrast as well as brightness of the enhanced image.

Image Enhancement is one of the most important Digital Image Processing standards for rendering an image usable for a variety of purposes in the areas of digital imaging, nursing, geographic information systems, industrial inspection, law enforcement, and a variety of other digital image applications. F. M. Abubakar et al. [11] suggested a system to increase the accuracy of digital images by integrating Histogram Equalization and Spatial filters, and the results are displayed in a MATLAB version 7.12.0.635 (R2011a) program, which displays the performance of each step.

H. Demirel et al. proposed Singular Value Decomposition(SVD) as a new strategy for optimizing satellite image contrast based on the Discrete Wavelet Transform (DWT). The protocol decomposes the input image into four frequency sub bands, calculates the singular value matrix for the low-low sub band image, and then reconstructs the improved image using inverse DWT.

For the enhancement of low contrast satellite images, A.K. Bhandari et al. [13] have a Contrast Enhancement approach. The proposed approach is based on the Artificial Bee Colony (ABC) algorithm, which uses Singular Value Decomposition and Discrete Wavelet Transform (DWT-SVD). The ABC approach is used to learn the adaptive thresholding function parameters necessary for optimal enhancement.

In [14], Fuqin Li et al. use the MODTRAN 5.4 radiative transfer model to apply atmospheric correction to Landsat 8 images at a site in Northern Queensland where ground aerosol and water reflectance measurements are available from an AERONET site to create a matched data set. The atmospheric corrections included aerosol and Rayleigh scattering, gas and aerosol absorption, and sky and sun glint effects.

C. Image Transformation

Multiple bands are manipulated from a single multispectral image or from two or three photographs of the same region obtained at differing times (multitemporal data). Image transformation generates new image by highlighting particular features and produce better output image. Some image transformations like image addition used for line striping error corrections, image subtraction is used in change detection, image multiplication useful in masking and the most useful mathematical transformation is image division. Let us discuss some of the transformation techniques.

1) Band Ratioing

Image division operation is also called as band ratioing were pixel by pixel division is done and resultant data are used to fill the range of display device. Here division by zero is avoided by assigning denominator value to one whenever it is zero. Band ratioing is used to avoid undesirable effects caused by variations in the topography due to which interpreter may not correctly identify the surface material. The vegetation index is calculated using band ratioing. The Normalized Difference Vegetation Index is the most widely used vegetation index (NDVI).

2) Image fusion

The majority of sensors have two modes of operation: multispectral and panchromatic. The spectral resolution of multispectral mode is higher, while the spatial resolution of panchromatic mode is better. Two different sensor-signal fusion methods are used to incorporate the benefits of both spatial and spectral resolutions. Different techniques used for image fusion are Band substitution, Statistical, Mathematical techniques, Color Space transformations (RGB, IHS).

3) Principal Component Analysis (PCA)

Since multispectral data bands are often highly correlated, they can contain similar details. Hence, we need to transform original band to new bands that gives more information than the original bands. PCA is a technique to uncorrelate the correlated datasets.

Y. Byun et al. [15] suggest an area-based image fusion algorithm for combining SAR (Synthetic Aperture Radar) and optical images. Until the images are merged, the proposed registration procedure is used to co-register the two images. The SAR texture image is then segmented into active and inactive areas for selective injection of the SAR image into the panchromatic (PAN) image.

Hybrid method of image segmentation, salient area recognition, and image fusion are proposed by Shanthini. C et al. [16]. It uses the superpixel segmentation method to divide the image into subareas and the difference of Gaussian and local binary patterns from the salient regions for feature extraction.

Forest disturbance identification has been done using time series data. Unlike multi-temporal shift analysis, time series analysis not only describes regions of change but also measures time of change. For the Ayuquila watershed in Jalisco province, Mexico, Y. Gao et al. [17] present forest disturbance identification using time series NDVI data for the years 1998 to 2018.

Pansharpening is a hybrid technique for generating a high-resolution multispectral image by combining a high spatial resolution panchromatic image with lower spatial resolution multispectral image images. In the case of image fusion, eight different approaches are compared to show how well they can combine multitemporal and multisensor images. As a panchromatic substitution, a sequence of eight multitemporal multispectral remote sensing images is combined with a panchromatic Ikonos image and a TerraSAR-X radar image. Spectral aspect preservation and spatial enhancement was visually and quantitatively measured in the merged images.

Proposed fusion outperforms all other algorithms studied, and it is also the only approach that maintains excellent color conservation over all dates and sensors. et al. [18] proposed by Ehlers.

Principle Component Analysis (PCA) is applied by S. Réjichi et al. [19] for feature extraction to boost the Very High Resolution (VHR) Satellite Picture Time Series multitemporal classification approach (SITS). The enhanced multitemporal classification is able to distinguish between different activities (stable, intermittent, etc.) in areas, which is very helpful in land cover monitoring. Turgay Celik et al. [20] propose a system for unsupervised shift identification in multitemporal satellite images based on PCA and k-means clustering.

K. V. Sharma et al. [21] introduced a new fusion algorithm called the Intensity Transformation Fusion Mode (ITFM) for LANDSAT8 panchromatic (PAN) and Land Surface Temperature (LST) images. The ITFM method improved the spatial accuracy and visual distinctiveness of LST images while still preserving the LST information.

D. Image Classification and Analysis

The aim of this process is to remove features from remote sensing data by converting it into more concrete categories that reflect surface groups and conditions. Image classification methods can be classified broadly into following categories.

1) Supervised Classification

Training sets or areas are used as numerical interpretation keys, which are provided to computer to do the classification. Pixel categorization or classification is being supervised via human intervention. Some of the important supervised classification algorithms are Minimum distance to means classification (Chain method), Gaussian maximum likelihood classification, Parallelepiped classification so on.

2) Unsupervised Classification

It is the process of aggregation into natural spectral groups or clusters. Here minimum human intervention is required while classification is being performed on digital image processing software. No prior knowledge is required about thematic classes. It is quicker but requires large human intervention in various steps. Clustering algorithms include K means, Texture Analysis etc.

3) Object based Classification

Classification techniques that we have discussed so far are pixel-based classifications i.e., processing entire image scene pixel by pixel. Object-oriented classification helps researchers to use the multi-resolution image segmentation procedure to decompose the scene into several relatively homogenous image objects or fragments.

N. Vijaranakul et al. [22] suggest an approach that uses supervised machine learning methods including Decision Tree, Naive Bayes, k-Nearest Neighbors (kNN), Random Forest, and Gradient Boosting to determine air quality using satellite images. Using the deep system, A. Chatterjee et al. [23] suggest an unsupervised learning algorithm to cluster hybrid polarimetric SAR images and dual-polarized SAR images. For instruction, it employs an entropy-based loss function and Adam, an efficient learning rate optimization algorithm. The patches are divided into three categories: surface, volume, and double-bounce, both of which are described using SAR scattering characteristics.

E. zlem et al. [24] used multi-temporal Sentinel-2 photographs from multiple seasons and applied rule-based object-oriented classification techniques to the images. To help classify certain land use groups and improve overall classification quality, thematic opensource data was introduced into classification. G. Danneels et al. [25] suggested an automatic method for detecting landslides from multi-spectral remote sensing images. Depending on the type of landslide, the criteria for detecting slope instability can vary. In the first step, predefined input parameters obtained from the images are used in a supervised pixel classification algorithm.

IV. CONCLUSION

This paper provides a concise overview of the various image processing methods used to process satellite imagery in remote sensing. This paper emphasize on how preprocessing is done using radiometric, geometric and atmospheric corrections. Enhancement using contrast stretching, spatial filtering and wavelet transform.

IRJMETS

e-ISSN: 2582-5208

International Research Journal of Modernization in Engineering Technology and Science

(Peer-Reviewed, Open Access, Fully Refereed International Journal)

Volume:03/Issue:07/July-2021 Impact Factor- 5.354 www.irjmets.com

Image transformations using band ratioing, image fusion and PCA. Different image classification techniques. How these techniques are used in implementation of remote sensing applications.

V. REFERENCES

[1] JAMES B. CAMPBELL, RANDOLPH H. WYNNE, Introduction to Remote Sensing, New York: The Guilford Press, A Division of Guilford Publications, Inc., 2011.

[2] A CCRS – Canada Center for Remote Sensing Remote Sensing Tutorial. Fundamentals of Remote Sensing, 2004.

[3] L. Fonseca, L. Namikawa, and E. Castejon, "Digital image processing in remote sensing," in Proc. Tutorials 22th Braz. Symp. Comput. Graphics Image Process., 2009, pp. 59–71.

[4] Sowmya DR, Shenoy PD, Venugopal KR (2017), "Remote sensing satellite image processing techniques for image classification: a comprehensive survey". International Journal of Computer Applications 161(11):24–37.

[5] H. Bagheri and S. Sadeghian, "Geometric Rectification of High Resolution Satellite Images using Mathematical Intelligent & classical Modelling", February 2014 Iranian Conference on Intelligent Systems (ICIS).

[6] W. Kim, J. H. Ahn, and Y. J. Park, "Correction of stray light driven inter Slot Radiometric Discrepancy (ISRD) present in radiometric products of Geostationary Ocean Color Imager (GOCI)," IEEE Trans. Geosci. Rem. Sens. 53(10), 5458–5472 (2015).

[7] Li, Y., Zhang, B., He, H.: Relative radiometric correction of imagery based on the side-slither method. In: 2017 2nd International Conference on Multimedia and Image Processing, (2017)

[8] Y. Iikura, "Atmospheric correction of satellite images over rugged terrain," in Geoscience and Remote Sensing Symposium. IEEE, 2012, p. 0002340.pdf.

[9] S. Ozsara¸c and G. B. Akar, "Atmospheric effects removal for the infrared image sequences," ¨ IEEE Transactions on Geoscience and Remote Sensing 53, pp. 4899–4909, September 2015.

[10] Bhandari, A. K., Kumar, A., & Singh, G. K. (2012b). SVD Based Poor Contrast Improvement of Blurred Multispectral Remote Sensing Satellite Images. In Proceeding IEEE 3rd International Conference on Computer and Communication Technology (ICCCT-2012), 156-159.

[11] Abubakar, F.M. Image enhancement using histogram equalization and spatial filtering. Int. J. Sci. Res. (IJSR) 2012, 1, 105–107.

[12] Demirel H, Ozcinar C, Anbarjafari G., " Satellite image contrast enhancement Using discrete wavelet transform and singular value Decomposition. IEEE Geosciences and remote sensing letters", 7 (2), pp. 333-337, 2010.

[13] Bhandari, A. K., Soni, V., Kumar, A., & Singh, G. K. (2014b). Artificial Bee Colony-based satellite image contrast and brightness enhancement technique using DWT-SVD. International Journal of Remote Sensing, 35(5), 1601-1624.

[14] F. Li, D. Jupp, S. Sagar & T. Schroeder, "Atmospheric correction and water surface issues for aquatic Applications of Landsat 8". IEEE International Geoscience and Remote Sensing Symposium (IGARSS), July 2019.

[15] Y. Byun, J. Choi, Y. Han, An area-based image fusion scheme for the integration of SAR and optical satellite imagery, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 6 (5) (2013) 2212–2220.

[16] Shanthini.C and Anitha.J, "Satellite image registration using hybrid salient region detection method", International Conference on Circuit, Power and Computing Technologies (ICCPCT), March 2016.

[17] Y. Gao, A. Quevedo and J. Loya, "Forest Disturbance Detection By Landsat-Based Ndvi Time Series For Ayuquila River Basin, Jalisco, Mexico", IEEE Latin American GRSS & ISPRS Remote Sensing Conference (LAGIRS), March 2020.

[18] M. Ehlers, S. Klonus, P.J. Astrand and P. Rosso, "Multi-sensor image fusion for pansharpening in remote sensing",March 2010, International Journal of Image and Data Fusion 1(1):25-45.

[19] Réjichi, S.; Chaabane, F. Feature extraction using PCA for VHR satellite image time series spatio-temporal classification. In Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Milan, Italy, 26–31 July 2015; pp. 485–488.

[20] T. Celik, "Unsupervised change detection in satellite images using principal component analysis and k-means clustering," IEEE Geosci. Remote Sens. Lett., vol. 6, no. 4, pp. 772–776, Oct. 2009.

[21] K. V. Sharma, S. Khandelwal and N. Kaul, "Principal component based fusion of land surface temperature(LST) and panchromatic (PAN) images", Spatial Information Research, May 2020.

[22] N. Vijaranakul, S. Jaiyen, P. Srestasathiern, and S. Lawawirojwong, "Air Quality Assessment Based on Landsat 8 Images Using Supervised Machine Learning Techniques," no. March 2019, pp. 96– 100, 2020.

[23] A. Chatterjee, J. Saha, J. Mukherjee, S. Aikat, and A. Misra, "Unsupervised Land Cover Classification of Hybrid and Dual-Polarized Images Using Deep Convolutional Neural Network", May 2020 IEEE Geoscience and Remote Sensing Letters PP(99):1-5.

[24] E. O. Yilmaz, B. Varol, R. H. Topaloglu, and E. Sertel, "Objectbased classification of Izmir Metropolitan City by using Sentinel-2 images," in 2019 9th International Conference on Recent Advances in Space Technologies (RAST), pp. 407–412, Istanbul, Turkey, June 2019.

[25] G. Danneels and E. Pirard, "Automatic landslide detection from remote sensing images using supervised classification methods", IEEE Xplore Conference: Geoscience and Remote Sensing Symposium, IGARSS, August 2007.