Enhancement of Image using Fuzzy Inference System for Remotely Sensed Multi-Temporal Images

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Abstract - *Remote sensing has an important role in a wide variety of fields including research. This paper proposes a spectral resolution enhancement method (SREM) for remotely sensed multi-temporal images using the Fuzzy Inference System. Improving the quality of the images for better human perception is called Image enhancement. Using different image enhancement techniques, the impulsive noise can be reduced. By using an image enhancement technique, the quality of the original image can be increased for better analysis by a machine or a human. Fuzzy image enhancement is one of the image enhancement techniques. Fuzzy logic deals with approximation rather than fixed and exact reasoning with studying of possibility logic or several valued logics. It handles partial truth, where the truth values may either be in between of completely false value or true values are also considered as the important application areas of the fuzzy domain. Using triangular membership function and fuzzy rules from the fuzzy inference system the contrast of the original image is been increased. First, Fuzzy rules are applied to the original image and then defuzzification is done on the same to get the enhanced image. Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) have been calculated for enhanced images. The approach was tested with eight image datasets, and the spectra-enhanced were compared by visual interpretation and statistical analysis to evaluate the performance. The experimental results demonstrated that the Fuzzy Inference System produces good image data which will greatly improve the range of applications for remotely sensed data.*

Key Words: Multi-temporal, Fuzzy set, Fuzzy inference system, Membership function, Fuzzy if then rules.

1. INTRODUCTION

Remote sensing is playing an increasingly important role in a wide variety of fields, such as military target identification [1], precision agriculture [2], forest research [3], mineral exploration [4], earth science research [5], environmental monitoring [6] and mining [7].

There is a trade-off between the spectral and spatial performance of remotely sensed images in terms of the signal-to-noise ratio (SNR) and data acquisition rate because of difficulties with instrument design [8]. As a consequence of this, remotely sensed images have more bands but low spatial resolution and narrow swath. It becomes difficult to obtain wide data coverage and high spatial resolution with a higher spectral resolution.

In recent decades, a wide range of satellite data has been used in military, civil, and research areas. For different types of studies different spectral, spatial and time-resolved data are required [9]. Applications such as mineral exploration, crop disease detection, land cover mapping, and vegetation research usually need remotely sensed data with higher spatial resolution and wider coverage [10]. The scope of research in these areas is usually limited to a relatively small range, and better results can often be obtained with higher spatial resolution. However, a massive amount of accumulated remotely sensed data has been collected around the world.

To convert the image so has to be better suited for analysis by a human or a machine or to improve the visual appearance of an image there are many techniques that are sought in the area of image enhancement. For improving the image quality and contrast of the image enhancement is used. The fuzzy image enhancement includes linguistic variables which include fuzzy based rules in the form of sentences for image processing and membership functions which convert the image into a fuzzy membership plane from pixel plane. The range has been set for both input and output Membership function [11].

Fuzzy is a system of knowledge representation, it processes human knowledge in the form of fuzzy rules and the Fuzzy image processing enhances image contrast very efficiently. It also manages the ambiguity and vagueness of the image effectively. Measuring the amount of blur in an image is a function which increases when the sharpness of its image decreases is known as fuzzy entropy. The intensification parameter, fuzzier and crossover point are the three parameters that are considered. Using contrast minimization technique, the degraded image representing light objects in a dark background is enhanced. A cross over point is considered, which is associated to stop fluctuation and a histogram is used to covert Shannon entropy to fuzzy entropy also the parameters of the images are calculated. Then selecting cross over point, membership function is modified with respect to cross over point and the Gaussian membership function is for used membership value modification [12]. Initially, the maximum intensity pixels' values to 1 and minimum intensity pixel value of the input image will be assigned to 0. Using membership function the intensity mapping functions map the fuzziness or uncertainty regarding low contrast from intensity plane to fuzzy plane and the pixels are grouped with respect to their intensities. Finally, by defuzzification image is converted from a membership plane to a fuzzy plane [13]. The different ranges of different noises in the image are removed by using different filters and for the comparative study purpose, different filters are applied. The filter removes different noise efficiently also the filter with different threshold values is applied on the noisy image for the different range of noise levels in a noisy image initially the filters are applied and the applied filters are of different window sizes. The most size of the window is limited to keep away from the severe blurring of image details at large noise levels. The filter removes every pixel which is having the same values or equal to the minimum or maximum values in a window used, and then it calculates remaining or the neighbouring four pixels the mean value of the pixels. Noisy pixels are replaced by the average pixel value of the filter or median value is used to replace the corrupted pixels. By improving its contrast, useful information about the image is improved and the noise present in the image is decreased. Further Membership functions are used to convert image from pixel plane to transform plane and fuzzy logic is used to process knowledge in the form of fuzzy “if-then” rules. Fuzzification, defuzzification and fuzzy rules are included in the enhancement process. Two parameters PSNR and MSE of enhanced images are calculated After enhancing the quality of the image.

2. METHODOLOGY

The eight remotely sensed image datasets are input for the system. The acquired image is in the jpeg or png format, which is further processed for image enhancement.

2.1 Fuzzification

The concept of assigning required membership functions on an image, which transforms the image from a pixel plane to a fuzzy plane is called fuzzification. Characteristic function in crisp collections are the Fuzzy collections having membership functions which are unique scenarios and the characteristic function of crisp collections is unique scenarios of the membership functions of the fuzzy sets. By using membership function the acquired degraded color image is transformed to membership plane where its values vary from the interval 0 to 1 and the membership function can take infinite values between the intervals 0 to 1. To convert image from pixel plane to membership plane triangular membership function is used. The ranges for each membership function are adjusted by using the membership function editor toolbox and three membership functions for both input and output are selected at three intensity levels of the image respectively. The ranges of both output and input membership functions are mainly considered while defining fuzzy rules for the system and dragging the selected membership function in the toolbox can vary the ranges of membership function for both input and output.

2.2 Triangular Membership Function

Three triangular membership functions are used for both input and the output namely mf1, mf2 and mf3 as shown in figure.2. Dark region is represented by mf1, the gray region represents mf2 and white region represents mf3 of the image respectively. The range of the mf1 is 0 to 100, mf2 is having the range from 25 to 225 and mf3 is having the range from 150 to 250 respectively as shown in the figure and the fuzzy rules are added in the rule editor toolbox by considering parameters of these three membership functions. In that X-axis indicates the pixel intensity values and the Y-axis indicates the degree of members assigned to the pixels with respect to their intensity variation.

2.3 Membership Modification

The membership values are modified using a fuzzy inference system (FIS) toolbox. It is categorized into types i.e. Mamdani type FIS and Sugeno type FIS. FIS is a toolbox of MATLAB consists of the rule editor, FIS editor, rule viewer, surface viewer, and membership function editor and for both input and output variables, FIS consists of inbuilt membership functions. Setting a membership value for the gray level of the image where the variance between the gray levels, maximum gray level and minimum gray level are defined. Membership values are assigned to the pixels based on variation in their intensity level and The new membership values are defined for the pixels with respect to their gray level intensity values.

2.4 Fuzzy Rules

Using linguistic variables fuzzy rules are expressed and these are variables whose values are sentences or words. The non-numeric which may be a compound or atomic sentence generally used to express the rules and facts linguistic variables can be modified and variables usually take numerical values in mathematics and it consists of fuzzy if-then rules. Fuzzy rules for the modified membership values with respect to the pixel intensity are defined and while defining the rules fuzzy operators are used. The fuzzy rules are added using a fuzzy rule editor toolbox, where rules can be deleted or added with respect to the membership functions selected and to their range of mapping.

2.5 Defuzzification

The main purpose of the defuzzification process is to locate one single crisp value that summaries the fuzzy set which enters it from the inference system and it is the inverse procedure of fuzzification. The images are transformed back to the pixel plane from the fuzzy plane and new membership values are set for the system while doing defuzzification. The defuzzification method is initially chosen in the fuzzy inference system toolbox while doing the fuzzification and the centroid defuzzification method is used for the system.

2.6 MSE AND PSNR

Images with different sizes are taken initially for the system and then the images are enhanced the peak signal to a ratio (PSNR) and mean square error (MSE)of the enhanced images are calculated. Low MSE and high PSNR values indicate efficient contrast enhancement of the image and the parameters calculated values are tabulated for different images.

3. IMPLEMENTATION

3.1 Image Acquisition

Eight Remotely Sensed Image is acquired from the Mangalore region that is taken for system and images with different sizes have been considered.

3.2 Fuzzy Inference System

Using different fuzzy inference tool boxes the image is processed. The process of mapping from a given input to output can be done by using fuzzy logic which becomes a basic foundation for decisions to be made or patterns discerned. Fuzzy inference system consists of the following parameters: Fuzzifying the input variables, Applying the fuzzy operator, Aggregating the rule outputs and defuzzifying.

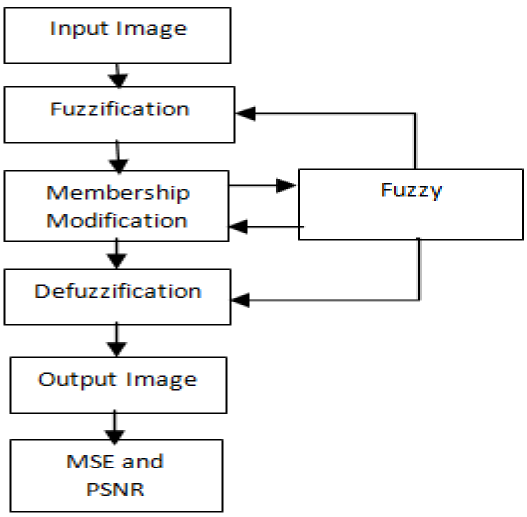

Fig -1: Block Diagram of Fuzzy Inference System

Figure 1 shows the block diagram of the Fuzzy Inference System. The fuzzy inference system editor displays information about FIS and the FIS Editor tool allows editing the utmost level characteristics of the fuzzy inference system, likewise the number of input and output variables. It consists of other various editors to operate on the fuzzy inference system and the FIS editor allows easy access to all other editors by providing more importance on maximum flexibility for communication with the fuzzy system.

3.3 FIS Editor

The basic structure of the FIS is shown in figure 2. The output variable is on the right side of the FIS and input variables are at the left side of the FIS editor as shown in the above figure, the boxes showing membership functions shown using icons and they do not represent any type of membership functions. Fuzzy operators namely AND and OR are selected, range and also defuzzification method for the system is selected in this editor. Membership function editor for output and input variable of the system can be obtained respectively by double-clicking on to the pixel icon provided an inference system is selected for the system. The important features of the fuzzy inference system are modified using the FIS editor tool, which is a type of membership function, ranges of the membership function, the number of output and input variables required and the defuzzification method. The FIS Editor provides the high level display for any fuzzy logic inference system and due to which other different editors are made to operate on FIS. Its ranges are set in this toolbox.

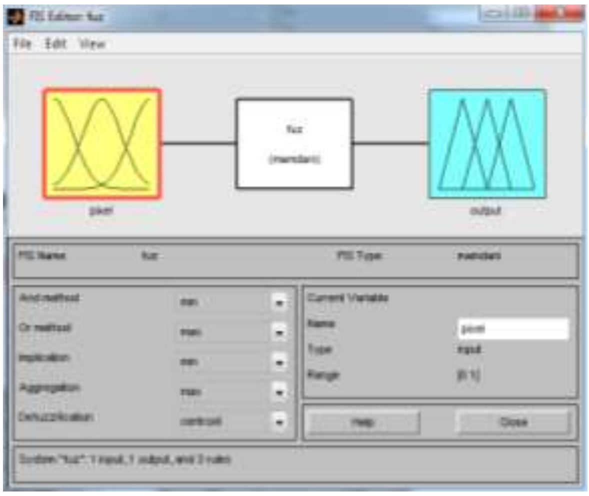

Fig -2: FIS editor tool box

3.4 Membership Function Editor

Changes are done to the type, name and to other variables for all membership functions. Built-in membership functions are provided in the toolbox and the display range and membership functions are chosen in this toolbox. For both output and input membership functions and their parameters are selected in the toolbox and the image is transformed to a fuzzy plane from pixel plane with x-axis indicating pixel range and for y-axis indicating degree of membership for the respective pixel.

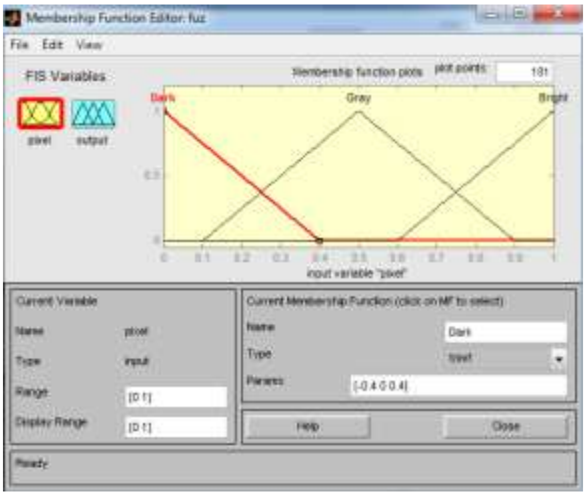

Fig -3: Membership Function Editor

The tool used to edit the membership functions for the input variable as well as for the output variables for use in the entire fuzzy inference system is shown in figure 3. Similar features are found between FIS Editor and membership function editor. In the membership function editor toolbox built-in membership functions are Available. Membership functions are defined in this tool box and the type and range of the membership function for both output and input is selected in this tool box. X-axis and Y-axis represent the pixel range and the degree of membership for the corresponding pixel respectively. Also, the triangular membership function is selected for the system.

3.5 Fuzzifying The Input Variables

Converting crisp values into a degree of membership intended for linguistic variables of fuzzy sets is the main process consisting. Degree of membership values are found out for the intensity variation of each pixel also membership functions are defined using a fuzzy inference system toolbox [5].

Following equations sets the membership function

(2) P (i, j) = (1 + (X max- x 11 (i, j) / Fe)) ^ Fd)

Where P (i, j) = i rows and j columns Resulting image pixel

x11 (i, j) = i rows and j columns Image pixel

X max = Maximum gray level

3.6 Rule Editor

Using the rule editor in FIS editor the fuzzy rules are modified. By using a fuzzy inference system, the applied rules are checked and edited and by using rule editor it is possible to add rules for all the input and output variables. The fuzzy rules can be changed, created and deleted by using this toolbox [11]. The process of image-enhancing the contrast of a grayscale image the fuzzy rules: IF a pixel is gray, THEN make it gray: IF a pixel is bright, THEN make it brighter: IF a pixel is dark, THEN make it darker. The fuzzy inputs are processed to the antecedents of the fuzzy rules and If fuzzy rule obtained is having multiple antecedents, then fuzzy operator (AND or OR) is used to gain a single number which indicates the result after the evaluation of antecedent [12] and OR fuzzy operator is used to calculate the disjunction of the rule antecedents.

$$\mu_A(Z) \cup \mu_B(Z) = \max[\ \mu_A(Z), \mu_B(Z)] \qquad (5)$$

Where $\mu_A(Z) \cup \mu_B(Z)$ is union of two fuzzy sets A and B

$\mu_A(Z)$ is degree of membership of subset A

$\mu_B(Z)$ is degree of membership of subset B

To evaluate the conjunction of the rule antecedents AND fuzzy operators are used.

$$\mu_A(Z) \cap \mu_B(Z) = \min[\ \mu_A(Z), \mu_B(Z)] \qquad (6)$$

is intersection of fuzzy sets A and B

$\mu_A(Z)$ is degree of membership of subset A

$\mu_B(Z)$ is degree of membership of subset B

Obtaining the union of the outputs of every rule by taking the membership functions of all rule results and combines them into one fuzzy set is described using the aggregation of Rule Outputs. Input for the aggregation process is the list of membership functions. One unique fuzzy set for all output variables is the input and output of the aggregation process.

Fig -4: Rule Editor

The tool where modification of the rules of a FIS structure can be done is shown in figure 4. Using this toolbox, the rules used by FIS for the system are inspected. The fuzzy rules for the system are modified i.e. added, changed and deleted in this editor by the range and the type of membership functions is used and the rules are added considering both input and output with respect to each other.

3.7 Rule Viewer

The fuzzy inference diagram for a FIS is described by the rule viewer. The entire implementation process from beginning to the end is viewed using the rule viewer. By moving around the line indices that correspond to the inputs and later watch the system readjust and compute the new output. The tool which is used to verify the output surface of an FIS for every number of inputs is known as the Surface viewer and it is a read-only editor because of this it will not alter the fuzzy system or its related FIS structure at any cost. The selection of two input variables given to the two input axes (X and Y), similarly output variable is assigned to the output (or Z) axis with the help of drop-down menus. Using the plot points identity membership functions, the creation of a smoother plot, are evaluated by input and output range.

The rule viewer describes the fuzzy inference diagram for a FIS is shown in figure 5. The surface viewer is shown in figure 6. It is a tool that is used to verify the output surface of a FIS for all the number of inputs. It is a read-only editor and at any cost, it will not alter the fuzzy system or its related FIS structure. The two input axes (X and Y) the selection of two input variables given with the help of drop-down menus and the output variable is assigned to the output (or Z) axis.

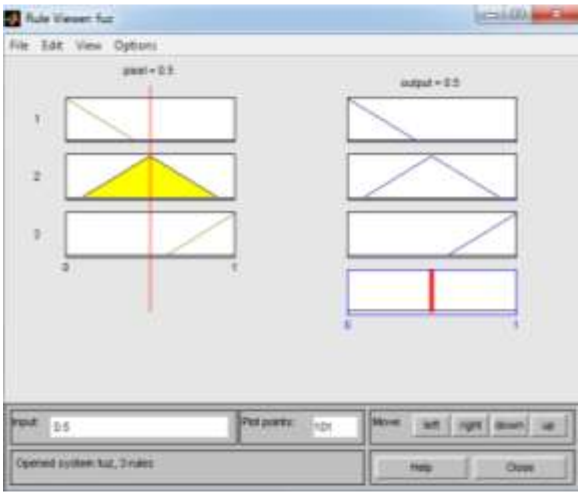

Fig -5: Rule Viewer

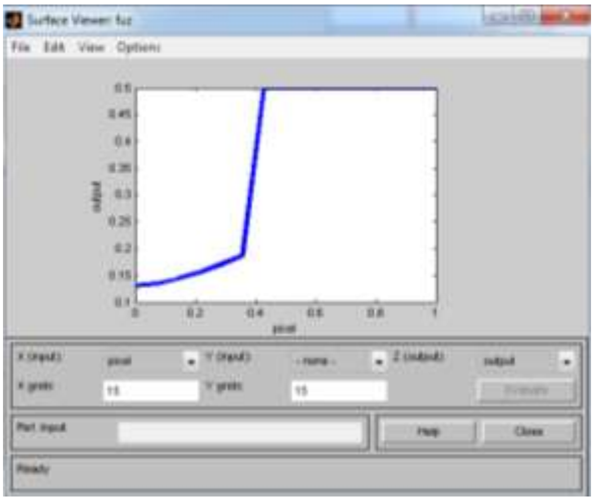

Fig -6: Surface Viewer

3.8 Defuzzifying

In the fuzzy inference system, it is the final step involved. Fuzziness is used to evaluation of the rules used and always the fuzzy system output is a crisp number. Aggregated output fuzzy collection and the output is a single crisp number to do defuzzification process [10]. The point representing the center of gravity of the fuzzy set is found in Centroid Defuzzification Method Mathematically, Center of gravity is represented as follows:

$$COG = \frac{\int_a^b \mu_A(Z)Zdz}{\int_a^b \mu_A(Z)dz} \quad (7)$$

Where COG is Centre of gravity
Z is a fuzzy set
A is a subset of Z
$\mu_A(Z)$ is degree of membership of subset A

3.9 Enhanced Image

Using a fuzzy system Contrast of the degraded input image is enhanced and it is the process of where characteristics of an image are changed which made it possible to get a new image with more suitability for any particular application. By using the equation enhanced image can be obtained.

$$I(i,j) = X_{max} - Fe * ((1/P(i,j))^{\wedge}(1/Fd) - 1) \quad (8)$$

Where,
X_{max}= maximum gray level
Fe= Exponential Fuzzifier
Fd= Denomination Fuzzifier

3.10 MSE AND PSNR

Comparison between the estimator and what is estimated is done and MSE measures the mean of the "errors":

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - k(i,j)]^2 \quad (9)$$

Where m, n indicates the number of row size and column size and i, j indicates current pixels' row and column number. PSNR is a difference between the maximum intensity level of the image to the capacity of distorting noise which affects the accuracy of the image and PSNR is always expressed in terms of the logarithmic decibel scale thus

large PSNR usually shows i.e. the reconstructed image is having better quality:

$$\text{PSNR} = 10\log_{10}\frac{MAX_i}{MSE} \quad (10)$$

MAXi is the maximum achievable pixel intensity value of the image and the pixels are represented using 8 bits, then MAXi is 255.

4. RESULTS

We used eight sets of remote sensing data to test the enhancement of the image using the Fuzzy Inference System. The dataset images cover the same region but obtained at a different time. The image showed an urban site with several kinds of urban factors, which was freely available google earth which includes the ground truth reference data needed for the assessment.

The study area of the eight datasets was located in Mangaluru in the south region of Karnataka state in India and was part of the coastal area (see Fig. 3). Datasets covering the study area were collected between 2012 to 2018.

The results evaluation carried out based on visual interpretation, statistical characteristics, and classification effects.

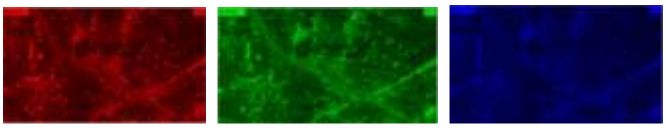

Fig -7: RGB composites of the Mangaluru urban study area

(a) (b)

Fig -8: Mangaluru Urban study area. (a) Noisy Image (b) Denoised Image

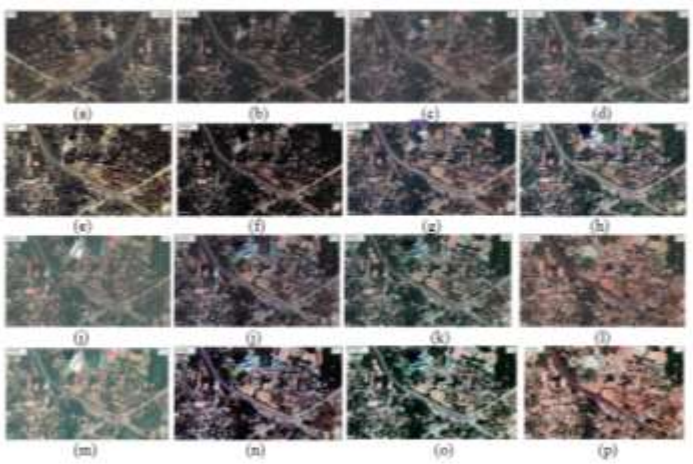

Fig -9: Visual comparison between input and enhancement of multi-temporal images in Mangaluru urban study area:

(a) to (d) show the input images of 2012, 2013, 2014 and 2015 respectively.

(e) to (h) show the enhanced images of 2012,2013,2014 and 2015 respectively.

(i) to (l) show the input images of 2016,2017,2018 and 2019 respectively.

(m) to (p) show the enhanced images of 2016,2017,2018 and 2019 respectively.

Table -1: Test results of proposed Fuzzy Inference System MSE and PSNR calculation.

Year	PSNR	MSE
2012	13.66	2798.29
2013	16.49	1458.57
2014	12.47	3679.38
2015	13.31	3028.24
2016	14.68	2211.67
2017	15.41	1870.36
2018	17.18	1244.71
2019	15.31	1912.08
Average value	14.81	2275.41

5. CONCLUSION

Enhancing the contrast of the image using the fuzzy image enhancement technique is the main focus of the paper. Images with different variations in the contrast and sizes are taken for the system. Fuzzy rules and fuzzy membership functions are applied for the same which is a knowledge-based system. To convert image from pixel plane to fuzzy plane and fuzzy rules Triangular membership function is used and is applied after the modification of membership values by using a fuzzy inference system. It is able to get over the drawbacks of methods like histogram equalization, frequency-domain methods, spatial domain and threshold and results in increases of the contrast of the image also the low contrast image is efficiently enhanced using the fuzzy technique.

REFERENCES

[1] Qingxi Tong, Yongqi Xue, and Lifu Zhang, "Progress in Hyperspectral Remote Sensing Science and Technology in China Over the Past Three Decades", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 7, No. 1, Jan. 2014, pp. 70-91.

[2] Wei Yang , Ce Yang , Ziyuan Hao , Chuanqi Xie and Minzan Li, "Diagnosis of Plant Cold Damage Based on Hyperspectral Imaging and Convolutional Neural Network", IEEE Access, Vol. 7, 2019, pp. 118239-118248.

[3] Yan Zhang, Yanguo Fan and Mingming Xu, "A Background-Purification-Based Framework for Anomaly Target Detection in Hyperspectral Imagery", IEEE Geoscience and Remote Sensing Letters, 2019.

[4] Jean-Baptiste Féret and Gregory P. Asner, “Tree Species Discrimination in Tropical Forests Using Airborne Imaging Spectroscopy”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 51, No. 1, Jan 2013, pp. 73- 84.

[5] Dawa Derksen, Jordi Inglada and Julien Michel, “Spatially Precise Contextual Features Based on Superpixel Neighborhoods for Land Cover Mapping with High Resolution Satellite Image Time Series”, Geoscience and Remote Sensing (IGARSS), IEEE International Symposium , 2018, pp. 200 – 203.

[6] Lifu Zhang, Xuejian Sun, Taixia Wu, and Hongming Zhang, “An Analysis of Shadow Effects on Spectral Vegetation Indexes Using a Ground-Based Imaging Spectrometer”, IEEE Geoscience and Remote Sensing Letters, Vol. 12, No. 11, Nov. 2015, pp. 2188- 2192.

[7] Richard J. Murphy, Anna Chlingaryan, and Arman Melkumyan, “Gaussian Processes for Estimating Wavelength Position of the Ferric Iron Crystal Field Feature at ~900 nm from Hyperspectral Imagery Acquired in the Short-Wave Infrared (1002–1355 nm)”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 53, No. 4, Apl. 2015, pp. 1907- 1920.

[8] Xiao Xiang Zhu, Claas Grohnfeldt and Richard Bamler, “Exploiting Joint Sparsity for Pansharpening: The J-SparseFI Algorithm”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 54, No. 5, May. 2016, pp. 2664-2681.

[9] Ziyao Li, Rui Wang, Wen Zhang, Fengmin Hu and Lingkui Meng, “Multiscale Features Supported DeepLabV3+ Optimization Scheme for Accurate Water Semantic Segmentation”, IEEE Access, Vol. 7, 2019, pp. 155787-155804.

[10] Yonghao Xu, Bo Du, Liangpei Zhang, Daniele Cerra, Miguel Pato, Emiliano Carmona, Saurabh Prasad, Naoto Yokoya, and Bertrand Le Saux, “Advanced Multi-Sensor Optical Remote Sensing for Urban Land Use and Land Cover Classification”, 2018 IEEE GRSS Data Fusion Contest”, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 12, No. 6, Jun. 2019, pp. 1709-1724.

[11] Abdullah Amer Mohammed Salih, Khairunnisa Hasikin and Nor Ashidi Mat Isa, "Adaptive Fuzzy Exposure Local Contrast Enhancement”, IEEE Translations, Vol. 6, 2018, pp. 58794-58806.

[12] Mario Versaci, Francesco Carlo Morabito, Giovanni Angiulli, “Adaptive Image Contrast Enhancement by Computing Distances into a 4-Dimensional Fuzzy Unit Hypercube”, IEEE Access, Vol. 5, 2017,pp. 26922- 26931.

[13] Toufique Ahmed Soomro, Ahmed J. Afifi, Ahmed Ali Shah, Shafiullah Soomro, Gulsher Ali Baloch, Lihong Zheng, Ming Yin and Junbin Gao , “Impact of Image Enhancement Technique on CNN Model for Retinal Blood Vessels Segmentation”, IEEE Access, Vol. 7, 2019, pp. 158183- 158197.