Pixel Classification of SAR ice images using ANFIS-PSO Classifier

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Abstract— Synthetic Aperture Radar (SAR) is playing a vital role in taking extremely high resolution radar images. It is greatly used to monitor the ice covered ocean regions. Sea monitoring is important for various purposes which includes global climate systems and ship navigation. Classification on the ice infested area gives important features which will be further useful for various monitoring process around the ice regions. Main objective of this paper is to classify the SAR ice image that helps in identifying the regions around the ice infested areas. In this paper three stages are considered in classification of SAR ice images. It starts with preprocessing in which the speckled SAR ice images are denoised using various speckle removal filters; comparison is made on all these filters to find the best filter in speckle removal. Second stage includes segmentation in which different regions are segmented using K-means and watershed segmentation algorithms; comparison is made between these two algorithms to find the best in segmenting SAR ice images. The last stage includes pixel based classification which identifies and classifies the segmented regions using various supervised learning classifiers. The algorithms includes Back propagation neural networks (BPN), Fuzzy Classifier, Adaptive Neuro Fuzzy Inference Classifier (ANFIS) classifier and proposed ANFIS with Particle Swarm Optimization (PSO) classifier; comparison is made on all these classifiers to propose which classifier is best suitable for classifying the SAR ice image. Various evaluation metrics are performed separately at all these three stages.

Keywords- SAR, Speckle Noise, Particle Swarm Optimization, Ice Images

I. INTRODUCTION

SAR processing is widely used for various radar imagery applications. One of its main applications is monitoring sea ice. Sea ice monitoring has been the main mission objectives for satellite programs such as RADARSAT, European Remote Sensing satellite (ERS) and ENVISAT [1]. Since sea ice has an important role in the heat exchange between the ocean and the atmosphere, it has an impact on the water temperature, heat circulation and ecosystem in Polar Regions. Sea ice is a threat to the navigation and oil exploration, because it can make damage to ships and oil platforms in the sea [2]. Sea ice monitor is useful to know the regions around the ice infested area. It covered with many regions which include sea, vegetation, land etc. For route planning in ship navigation classification of sea ice is an important one.

In this paper pixel based classification is performed where three stages are considered in classifying SAR ice images. It includes Preprocessing, Segmentation and Classification. SAR images are affected by speckle noise thus preprocess stage attempts denoising of speckle noise. Various speckle filters from image processing and wavelet family types are compared in which Daubechies method in wavelet family gives better results in removing noise from SAR ice images. Segmentation process is done by comparing the K-means and Watershed algorithm in which K-means clustering algorithm gives best result in segmenting SAR ice images into various regions. Finally at the classification stage, pixel based classification on the SAR ice images is performed using various supervised learning classifiers such as Back Propagation Neural Network, Fuzzy Classifier, Adaptive Neuro Fuzzy Inference Classifier (ANFIS), and ANFIS with PSO (Particle Swarm Optimization). Experiments at various stages are conducted to obtain results.

Following Table.I show the Origin of the dataset collected for the SAR ice classification.

TABLE I.   ORIGIN OF THE DATASET

No. of Images	Image Location	Satellite	Government
1	Strait of Georgia	SEASAT	Canadian Space Agency, Government of Canada
2	Ward Hunt ice Shelf	RADARSAT-1	Canadian Space Agency, Government of Canada
3	Mouth of the Columbia River and the Oregon coastline	ASF(Alaska Satellite Facility)	NASA, Government of USA
4	Isla Cedros, Baja California	ASF(Alaska Satellite Facility)	NASA, Government of USA
5	Grays Harbor and Willapa Bay in Washington State	ASF(Alaska Satellite Facility)	NASA, Government of USA
6	Early winter sea ice in the Beaufort Sea	RADARSAT-1	Canadian Space Agency, Government of Canada

II. METHODOLOGY

Methodology of SAR ice classification includes three stages. The following Fig.1 shows the overview of the methodology.
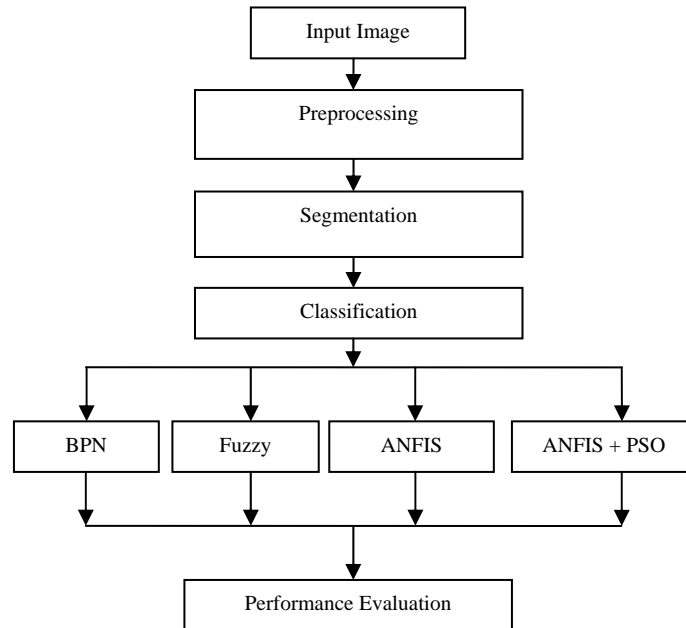

Figure 1.   Overview of methodology

A. Preprocessing

SAR images are affected by speckle noise due to the coherent nature of processing the signal [3]. Speckle noise is a coarse noise that is usually evident in and degrades the quality of the active radar and synthetic aperture radar (SAR) images. Speckle noise is commonly observed in radar sensing system and images, although it can be observed in most types of remotely sensed images utilizing coherent radiation. Speckle noise in radar data or images has multiplicative error and must be removed before the data can be used otherwise the noise is merged into and degrades the image quality [4].

In this paper the filters considered are standard speckle removing filters and filter method from wavelet family. This paper involves a comparative method which includes the families in wavelet filter. Through the analysis of this comparison, Daubechies (dB) in wavelet family have proved the best in denoising the image when compared to all other filters. All the filter algorithms are evaluated using software tools called ENVI 4.7 and IDL 7.0. Following Table.II shows the various filters taken for removing speckle noise in SAR ice images.

TABLE II.   SPECKLE REMOVAL FILTERS

S. NO	Image processing Filters for speckle control
1	Median Filter
2	Lee Filter
3	Enhanced Lee Filter
4	Frost Filter
5	Enhanced Frost Filter
6	Gamma Filter
7	Kaun Filter
8	**Wavelet Family**
	Symlet
	Coiflet
	Haar
	Daubechies

The objective results for the preprocessing are given in the following Table.III.

TABLE III.   OBJECTIVE RESLUTS FOR SPECKLE NOISE FILTER COMPARISON

MF	LF	ELF	FF	EFF	GF	KF	SM	CM	HM	DM
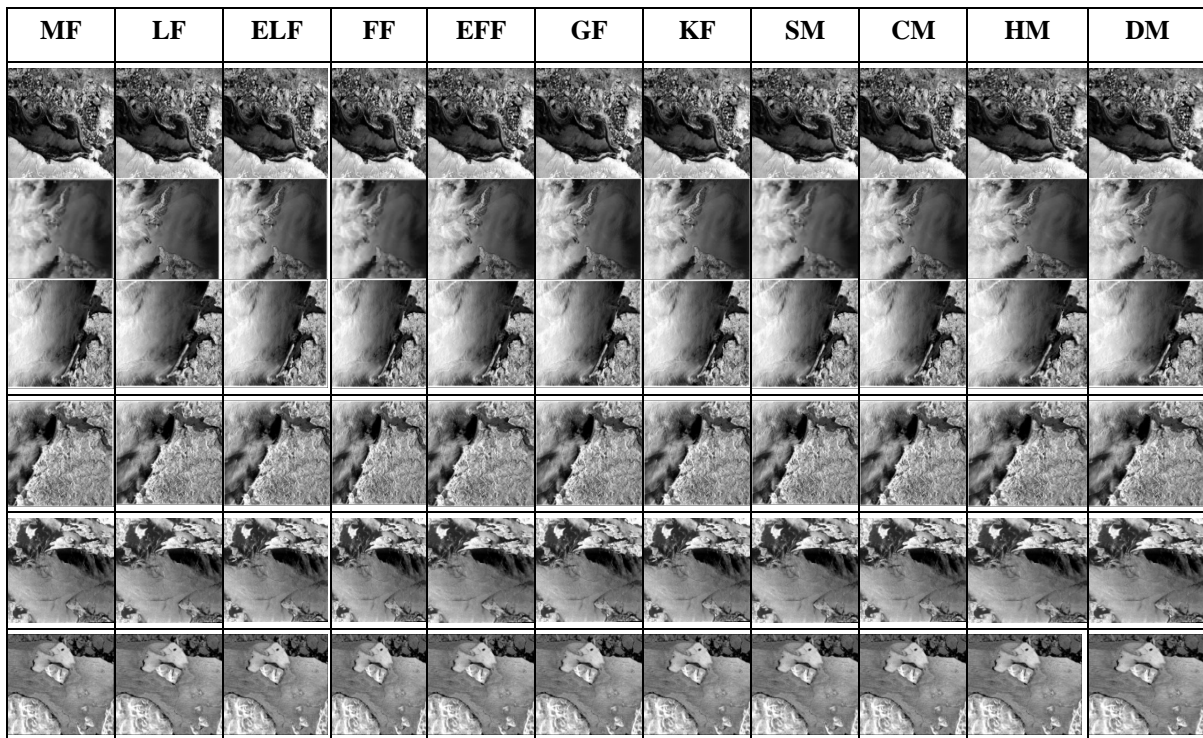
MF- Median Filter, LF- Lee Filter, ELF- Enhanced Lee Filter. GF- Gamma Filter, KF- Kaun Filter, SM-Symlet Method, CM- Coiflet Method, HM- Haar Method, DM- Daubechies Method

B.   Segmentation

Image segmentation plays a very important role in the interpretation and understanding of SAR images. It has received an increasing amount of attention over the last few decades [5]. The segmentation procedure is to find the better positions of the shape points according to the appearance information [6]. The purpose of image segmentation is to cluster pixels of an image into image regions.
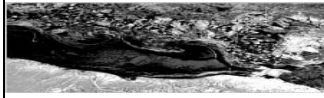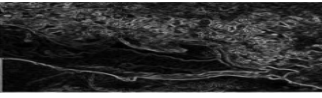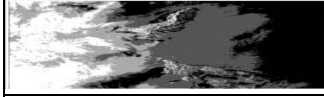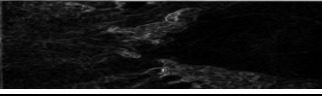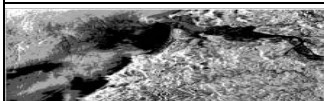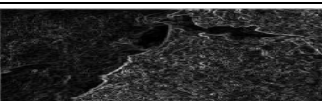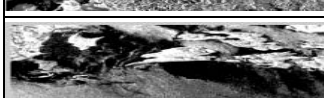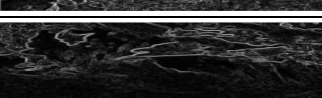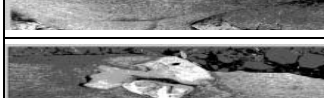
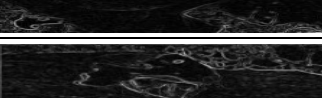To classify the SAR ice image it is first needed to segment the regions, further these segmented regions are then identified in the stage of classification. In this paper segmentation of SAR ice images are done using two algorithms namely K-means algorithm and Watershed algorithm. These two algorithms are most promising in segmenting remote sensing images. Comparison of these two algorithms is performed and the result shows that

K-means are more efficient in segmenting the images than watershed algorithm. Some of the drawbacks which are find out in Watershed algorithms during the experiment are:

- It produces over segmentation.

- It is highly sensitive to the local minima

- Considerable effort for defining the algorithms takes place for every marking of the watershed.

- It exhibits the neck line on every region to estimate the number of objects in the given cluster. Errors are produced while exhibits the line on regions.

K-means clustering concept gives more advantages in grouping the pixels of an image to the corresponding classes. In this paper, for segmentation comparison is made in terms of segmentation metrics such as True Positive area ratio, False Positive area ratio and Similarity Index area ratio. The Objective result for comparative analysis between these two segmentation algorithms is given in the following Table.IV.

TABLE IV.　　OBJECTIVE RESLUTS FOR COMPARISON OF K-MEANS AND WATERSHED SEGMENTATION ALGORITHMS

K-Means segmented image	Watershed segmented image

C. Classification

Classification process is the main phase in performing SAR ice classification. Classification helps in finding out the features of the ice images such as water, vegetation, land and ice. In classification the segmented regions are identified and predicted. It groups the features based on supervised learning. This process automatically creates a classification model from a set of records called a training set. Once a model is induced, it can be used automatically to classify records belonging to a small set of class that is predefined called a testing set. Training refers to building a new model by using historical data and testing refers to trying out the model on new, previously unseen data to determine its accuracy [7].

In this paper four supervised learning algorithms are performed in the classification of SAR ice images. The comparative analysis between these four classifiers are performed to predict proposed classifier of ANFIS with PSO which gives best classification result in terms of Accuracy, Validity Index (VI), Network sensitivity, Time complexity and Error complexity. Following section gives brief explanation about the classifiers which are performed in this paper.

1. Back Propagation Neural Network

Back propagation neural classifier is the most simple and best classifier from neural network. It is widely applied for all the classification problems in image processing. The Network Structure of ANN should be simple and easy. There are basically two types of structures recurrent and non recurrent structure. The Recurrent Structure is also known as Auto associative or Feedback Network and the Non Recurrent Structure is also known as Associative or feed forward Network [8].

The Following Figure 2 shows the Architecture of the Back Propagation Network.
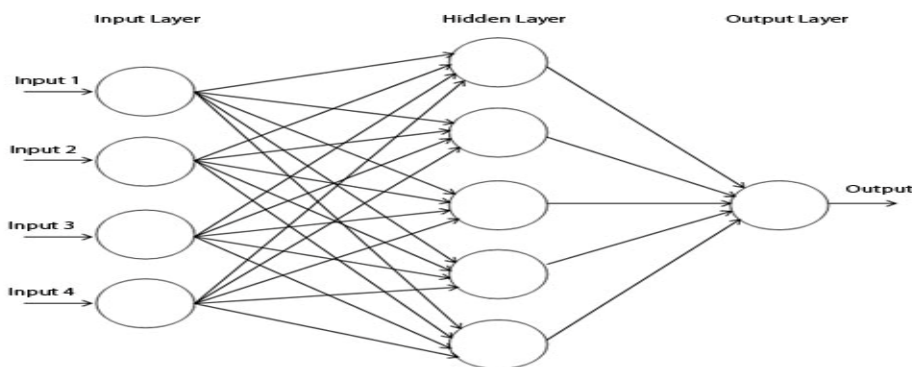

Figure 2.   Back Propagation Neural Network Architecture

In this paper, 3-layer Back Propagation network classifier with one output unit is used for the classification purpose. The steps performed in both training and testing process includes,

Step 1: Defining a structure Corresponds to the input and output.

Step 2: Image pixels are given to the network as an input.

Step 3: Assigning the targets according to these inputs.

Step 4: According to the network parameters set, network simulation is performed and an input pixels are trained and store in a file.

Step 5: Target pixels are called and network simulation is presented to the system.

Step 6: During the testing process network simulation is used to compare the test image which is currently selected with the trained pixels.

Step 7: Pixels in a groups are identified if the selected image pixel values are matched with the existing trained pixels.

Step 8: Identified regions are separated and represented with annotations.

During the training process image pixels are given to the network as an input. Targets in which each pixel is stored are assigned. After the training process, classification process is preceded with testing the segmented image with the trained pixel. If training process is correctly done it identifies every region according to the pixel values of an image. The Back Propagation Classifier gives a correct classification rate of 77.14% on the test set images. The experimental results for BPN classifier are given in Table.VII to Table XIII. Below are some limitations of BPN classifier, they are,

- It creates the structure for every incoming input. It does not adjust the incoming inputs with existing structure.
- Larger number of structure gives complexity in structure. Understanding the concepts will be tough because of its complexity.
- Errors are increased if the structures are getting increased.
- Training the pixels takes more time.
- Parameters need to be assigned to the network to train. Setting the parameter rate is the biggest deal.

2. *Fuzzy Classifier*

To overcome the disadvantages in the BPN classifier and to give a highest accuracy in SAR ice classification Fuzzy classifier is considered. Over the past few decades, fuzzy logic has been used in a wide range of problem domains. Although the fuzzy logic is relatively young theory, the areas of applications are very wide: process control, management and decision making, operations research, economies and, for this paper the most important, pattern recognition and classification. The natural description of problems, in linguistic terms, rather than in terms of relationships between precise numerical values is the major advantage of this theory [9]. There are numerous advantages are noticed in fuzzy classifier during the experiment, those are,

- Fuzzy classifier does not create a new structure for its every incoming input. It adjusts the previous structure according to the incoming inputs.
- The complexity is very less compare to the BPN.
- Training taken lesser time compare to BPN.

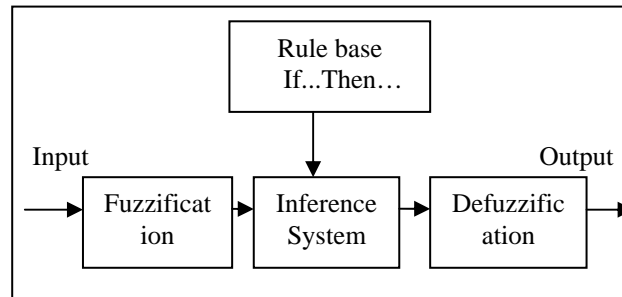Fuzzy Inference System diagram is presented in Figure 2.2.

Figure 3.   Fuzzy Inferenc System

Fuzzy algorithm steps for SAR ice classification are summarized as follows.

Step 1: Defining the input is the first step. Here the inputs are the pixel values.

Step 2: The rules with IF, THEN condition are defined in this step. These rules are defined logically to the system in which it can be easily find out the need of the user.

Step 3: Third step is defining the membership function that gives the representation to input. Membership function allocated in this paper is the targets in which the pixels should be stored.

Step 4: Finally during the testing process original segmented images are compared with the rules which are given to the fuzzy system. At the classification stage features are extracted and represented with annotations.

SAR ice classification using fuzzy classifier makes use of the rules and produces the result accordingly. Training the fuzzy classifier make use of the pixel values of six images. Testing process uses k-means segmented images. Defining a rule gives a better definition for the need of classification. Thus it provides efficient classification which leads to better accuracy than BPN classifier. Fuzzy classifier for SAR ice gives the accuracy rate of 86.6%. Experimental results of fuzzy classifier are given in the Table.VII to Table XIII. Fuzzy classifier has limitation and it is listed below.

- Defining the rules in linguistic manner is the only problem in fuzzy classifier.
- Wrong rules can lead to wrong classification.

3. Adaptive Neuro Fuzzy Inference Classifier (ANFIS)

ANFIS classifier combines both BPN and Fuzzy classifiers advantages. It overcomes the limitations and which gives the better accuracy in classifying SAR ice than other two algorithms discussed above. The combination of fuzzy logic with the design of neural network led to the creation of Neuro- Fuzzy systems which has benefit of the feed forward calculation of the output and back propagation learning capability from the neural networks. Because of crisp consequent functions, ANFIS uses a simple form of scaling implicitly. The ANFIS composes the ability of neural network and fuzzy system [10].

There are some numerous advantages found in ANFIS classifier they are,

- Finding of membership function and appropriate rules in one system can leads to minimize the error.
- BPN can introduce the learning to the fuzzy system which leads to the efficient classification.
- When combining these methods fuzzy system will set a rule for its every input vectors which is then used to calculate the output value.
- Designing a way such that fuzzy system will gets the learning ability of neural network and optimizes its parameters.

i)   ANFIS Structure

Designing the ANFIS structure for the SAR ice classification is the initial step to perform the classification. Defining the inputs, rules, membership functions and output for the system is separated according to the five layers. In this paper structure of the ANFIS consists of six inputs and single output. The six inputs represent different pixel values of the images. Each of this training set forms the fuzzy inference system with rules. In fuzzy inference system, fuzzification will take the rules for every input signal. Defuzzification is used to select one particular output signal to the corresponding selected image. Image will be selected during testing process. The basic structure of the ANFIS classifier is presented in the below Fig 4.
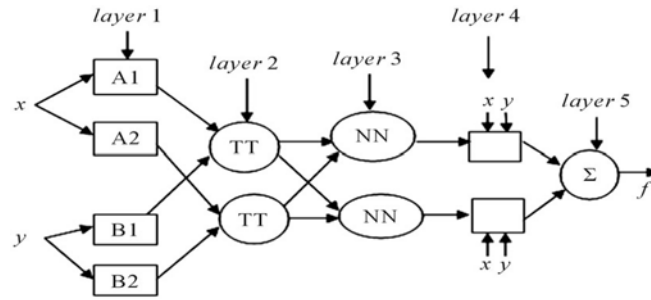
Figure 4.   Structure of ANFIS

Summarization of these five layers according to the SAR ice classification includes as follows,

Layer 1: In Layer 1 fuzzification process are taken place in which an input of pixels are assigned.

Layer 2: In Layer 2 execution of the fuzzy rules are taken place. Rules are assigned according to the inputs and its output.

For ex, if the input = 2.354 (image pixel value) then

Output = Resultant image (corresponding annotations according to the pixel regions are given)

Here an annotation represents as the color representations.

This part is the main one in fuzzy inference system. The rule which is not defined linguistically can lead to wrong output.

Layer 3: In Layer 3 normalization of membership functions are performed. Membership functions given here are the targets in which each pixel can be stored.

Layer 4: In Layer 4 execution of the fuzzy rule is performed. Execution of rules with the membership function is taken place here.

Layer 5: In Layer 5 summing up the output of the layer 4th and produces the output for the ANFIS system is taken place. Extraction of the rules according to the test image selected is displayed in the output.

ANFIS training gives better results as it combines both the benefits of neural network and Fuzzy systems. ANFIS classifier gives better performance than other two algorithms namely BPN and Fuzzy classifier in terms of its accuracy and speed to produce the output. It takes less time to generate the result. ANFIS classifier gives accuracy rate of 90% on SAR ice classification. Experimental results of ANFIS classifier is given in the Table.VII to Table XIII.

ANFIS classifier has some limitations which are listed below.

- It creates a new structure for every incoming input since it combines the neural network structure.
- Assigning the targets is another problem in ANFIS classifier. These targets should be analyzed and identified according to the problem which we going to perform.
- Time which is taken for training the pixels is higher.
- Rules must be linguistically defined.
- According to the back propagation error rate, weights should be change until no errors are found.

4. *Proposed Adaptive Neuro Fuzzy Inference System (ANFIS) with Particle Swarm Optimization (PSO) Classifier*

To overcome the limitations found in the above discussed classifier a new novel method have been developed for SAR ice classification. Proposed method involves optimization technique which is combined with the previous classifier called ANFIS. PSO is an optimization method which is used to search for global optimized solution but time must be uncertain. The work starts with randomly initialized population for every individuals.PSO operates on the social behavior of particle. The global best solution is derived by adjusting each individual position with respect to global best position of particle with the entire population. Each individual is adjusting by altering the velocity with its observation of the particle and by its experience in search space. According to fitness function the new local best position and global best position will be calculated [11]. There are some numerous advantages of ANFIS with PSO classifier during the experimental, these are:

- Finding *fitness function in terms of optimized value*

In ANFIS both the neural network and fuzzy classifier are combined. Training process is worked as neural network technique in which targets has to be given to the network. In combination of ANFIS with PSO, PSO will find its fitness function by using its optimized value. Fitness function is further used as the target.

- Structure

        In ANFIS new inputs are added to its network system as its works as neural networks it creates a new structure for its every incoming input. PSO does not create any new structure for newly coming inputs. It is used to update the new one with the same structure itself.

- Computational Time

        PSO will optimize its input according to the computational time; it produces the fitness result according to its optimized value so that the large amount of time will be reduced when training ANFIS.

- *Error*

PSO aims to find out optimized vales, when it gets combined with ANFIS there is no possibilities of errors in training a network.

- Defining Rule

PSO's optimized fitness value will be given to the rule set for ANFIS system. There is no need to set the rules in a linguistic manner as seen in the fuzzy and ANFIS system. To define a rule to perform the classification, calling fitness out put itself enough. For example, if fitness (1) then output=result.

The summarization of steps performed with ANFIS with PSO is given below.

    Step 1: Assigning Inputs: input is taken are the pixel values of an image. There is no need to assign the targets in proposed work.

    Step 2: Parameter initialization: PSO training parameters are initialized such as number of iterations, number of particles, number of swarms etc. These are initialized with empty matrices. During the training process the values are gets loaded for each iteration.

    Step3: Fitness function: After the training process over the outputs are produced this is said to be fitness function. This can be assigned as a target to the ANFIS system.

    Step 4: Rules: According to the fitness function rules are defined. The great benefit in defining a rule is, is no need to define a rule linguistically. Just calling of fitness function is enough.

        For ex, rule can be defined as,
        If Fitness = 5.235 (image pixel value)
        Then output = result (within this annotations are specified)

    Step 5: Output: According to this value the output of classified image will be displayed.

In this paper, PSO is added to the ANFIS at the stage of training. Pixel values are given at the fuzzification process in proposed classifier. PSO optimize all these pixel values of SAR ice image and rearrange the membership function called as fitness function (here the optimize value taken are the input pixels). It gives the fitness value result according to the time of execution. The results which are produced from the PSO are given to the fuzzy rule generation, in which efficient manner of defining a rules are taken place. This leads the system to easily generate the output in less time and accurate manner. Compare to all other three classifiers proposed method gives better accuracy rate of 93.33%. The experimental results for ANFIS with PSO classifier is given in the Table.VII to Table XIII.

III. RESULTS AND DISCUSSION

    This paper proposes a new classification algorithm called ANFIS with PSO for SAR ice classification. It has also presented various filter methods, segmentation algorithms and classification algorithms. The comparative study between all these methods is performed and it predicts the best one in all the three stages. The results are presented in the following paragraphs.

A. Preprocesin g Results

    Preprocessing stage aims at removing speckle noise from SAR ice images. There are various filters are performed such as, Median Filter, Lee Filter, Enhanced Lee Filter, Frost filter, Enhanced frost filter, Kaun filter and Gamma filter are from standard image speckle filter category and Symlet, Coiflet, Haar and Daubechies from wavelet family. All these filters performances are evaluated using following metrics.

- Signal to noise ratio
- Mean Absolute Error
- Root Mean Square Error
- Universal Image Quality Index

1. Signal to Noise Ratio (SNR) is used to measure the level of original signal affected by the level of back ground noise.

2. Mean Absolute Error (MAE) is used to measure how close the prediction to the actual outcome.

3. Root Mean Square Error (RMSE) is used to measure the difference between the prediction and observed outcome.
4. Universal Image Quality Index (UIQI) is used to measure the quality of an image after removing the noise. The following Table.V shows the subjective results for the comparison of speckle filters.

TABLE IV.   SUBJECTIVE RESLUTS FOR SPECKLE FILTER COMPARISON

Early winter sea ice, Beaufort					Islo Cedros			
Filters	*SNR*	*MAE*	*RMSE*	*UIQI*	*SNR*	*MAE*	*RMSE*	*UIQI*
Median Filter	5.682	7.145	12.457	0.874	8.987	8.244	8.254	0.874
Lee Filter	7.254	4.857	9.547	0.457	7.214	7.254	8.247	0.745
Enhanced Lee Filter	6.254	6.547	8.254	0.874	7.124	8.214	10.247	0.457
Frost Filter	4.257	7.654	7.254	0.598	8.578	6.214	7.024	0.789
Enhanced Frost Filter	4.896	9.354	7.547	0.578	8.254	9.254	5.456	0.457
Gamma Filter	8.257	5.254	8.574	0.754	3.254	5.254	7.254	0.459
Kaun Filter	6.578	8.254	7.254	0.874	4.256	6.547	11.657	0.687
Symlet Method	8.547	7.254	5.257	0.547	4.257	6.201	8.244	0.784
Coiflet Method	4.578	6.578	6.254	0.654	5.325	7.896	9.217	0.745
Haar Method	8.257	5.254	5.254	0.814	9.254	5.214	7.247	0.852
Daubechies Method	9.945	4.521	4.251	0.995	10.247	3.457	4.478	0.986

Grays harbor and willapa Bay					Mouth of Columbia river			
Filters	*SNR*	*MAE*	*RMSE*	*UIQI*	*SNR*	*MAE*	*RMSE*	*UIQI*
Median Filter	7.254	7.245	12.248	0.204	5.245	5.328	6.215	0.457
Lee Filter	8.254	8.576	9.247	0.235	4.247	7.244	7.215	0.587
Enhanced Lee Filter	6.254	7.214	9.244	0.257	6.245	7.248	6.425	0.665
Frost Filter	6.257	6.247	5.241	0.368	5.247	8.245	6.430	0.228
Enhanced Frost Filter	5.254	8.247	8.242	0.345	8.254	9.247	10.412	0.784
Gamma Filter	6.254	8.248	7.245	0.456	7.289	9.244	8.825	0.578
Kaun Filter	5.241	9.248	10.247	0.745	9.235	9.254	7.252	0.874
Symlet Method	9.254	6.254	5.245	0.457	11.287	11.245	12.254	0.247
Coiflet Method	9.954	6.147	5.426	0.425	9.974	11.247	6.212	0.578
Haar Method	10.214	5.247	4.255	0.245	11.987	12.278	5.214	0.784
Daubechies Method	11.247	4.578	3.112	0.894	12.624	5.124	4.024	0.987

Strait of Georgia					Ward Hunt			
Filters	*SNR*	*MAE*	*RMSE*	*UIQI*	*SNR*	*MAE*	*RMSE*	*UIQI*
Median Filter	7.247	4.275	9.254	0.579	5.272	8.287	9.382	0.124
Lee Filter	8.254	4.457	7.157	0.654	8.242	7.285	7.285	0.698
Enhanced Lee Filter	7.546	8.424	6.247	0.654	4.252	8.285	11.284	0.845
Frost Filter	6.242	4.248	7.257	0.789	7.472	9.385	7.285	0.174
Enhanced Frost Filter	8.245	5.452	8.254	0.657	7.552	7.284	12.524	0.213
Gamma Filter	5.245	8.427	9.475	0.694	7.282	8.274	5.965	0.125
Kaun Filter	4.575	7.427	7.851	0.378	6.274	9.281	9.382	0.368
Symlet Method	5.282	4.462	7.854	0.721	8.392	8.262	7.254	0.542
Coiflet Method	4.122	5.457	8.254	0.324	8.145	6.254	5.282	0.284
Haar Method	8.572	7.152	9.247	0.654	9.261	8.154	5.254	0.896
Daubechies Method	9.204	3.757	5.214	0.854	10.235	5.251	4.282	0.964

SNR- Signal to Noise Ratio, MAE- Mean Absolute Error, RMSE- Root Mean Square Error, UIQI- Universal Image Quality Index

Daubechies method uses overlapping windows, thus the results reflects changes between its pixel intensities. Daubechies of D4 transform has four scaling coefficients. The sum of all these scaling coefficients is also one, so the calculation is depended over four adjacent pixels. Subjective results have shown that Daubechies from wavelet family has given a low error rate in MAE and RMSE parameters and higher rate in SNR, Universal Image Quality Index (UIQI) parameters.

B. Segmentation Results

Segmentation stage aims at separating the image into various regions. This paper aims at classifying the SAR ice images to know the regions around it. Thus segmentation includes dividing the images into four regions using K-means and Watershed algorithms. The area error segmentation metrics are used to evaluate the performance of these two algorithms is as follows,

- True Positive Area Ratio
- False Positive Area Ratio
- Similarity Index (SI)

Following Table.VI Shows the subjective results for comparison of K-means and Watershed segmentation algorithms, True Positive area ratio should be higher and False Positive area ratio should be lower and Similarity Index ratio should be higher in best segmentation algorithm. K-means has proven best in all these evaluation metrics.

TABLE V.　　　SUBJECTIVE RESLUTS FOR K-MEANS AND WATERSHED COMPARISON

No. of Images	K-means			Watershed		
	TP in mm	*FP in mm*	*SI in mm*	*TP in mm*	*FP in mm*	*SI in mm*
1	17.2	8.9	16.5	9.1	16.2	8.1
2	15.2	8.8	14.2	8.9	15.1	7.8
3	17.5	7.7	16.5	8.9	17.3	6.7
4	16.2	7.6	15.8	8.9	16.1	6.6
5	16.9	8.2	16.5	8.9	16.7	7.2
6	16.5	6.3	14.2	8.9	15.2	5.3

TP- True Positive area ratio, FP- False Positive area ratio, SI- Similarity Index

TP area error ratio is used to measure the areas which are segmented correctly. FP area error ratio is used to measure the areas which are not segmented correctly. Similarity Index is used to measure how similar the segmented image to the original image.

C. Classification Results

Classification aims in identifying the regions in SAR ice images. The regions which are extracted can be identified as ice, water, vegetation and land. These areas can be represented in color options to know the different between the regions. There are four supervised classifiers such as BPN, Fuzzy classifier, ANFIS and ANFIS with PSO is considered in classification stage. All these classifiers performances are evaluated through following metrics.

- Accuracy
- Validity Index
- Sensitivity
- Time Complexity

Following Table.VII shows the subjective results for these classification algorithms.

TABLE VI.　　　SUBJECTIVE RESLUTS FOR CLASSIFICATION ALGORITHMS

Classifiers	Accuracy in %	Validity Index in %	Sensitivity in %	Time in Sec
BPN	77.14	0.0514	4.8913	6.11827
Fuzzy	86.6	0.0867	-	5.30179
ANFIS	90	0.0900	5.6604	3.54808
ANFIS +PSO	93.33	0.0933	5.8577	0.27243

Accuracy rate is used to define the overall performance of the classifiers; Validity Index is used to measure the performance of the network. Sensitivity is used to calculate the sensitivity on the parameters when it changes during training. It can be applied for BPN, ANFIS and ANFIS with PSO classifiers since all these classifiers uses network parameters to train a network, it is not suitable for fuzzy classifier since it does not uses parameters for training. Time complexity measure is used to predict the overall time has taken by the classifiers during the training.

Among all other classifiers ANFIS with PSO classifier gives higher rate in Accuracy, Validity Index, and Sensitivity and the lower rate in time complexity. Following Tables shows the classification results for all the classifiers included in SAR ice classification.

TABLE VII.   EARLY WINTER SEA ICE CLASSIFICATION RESULT
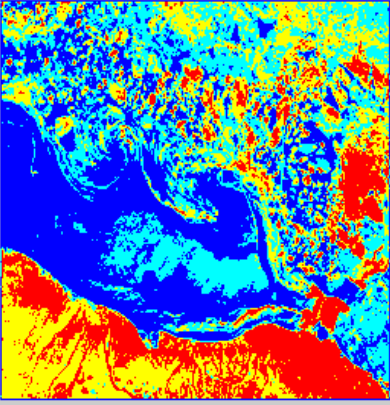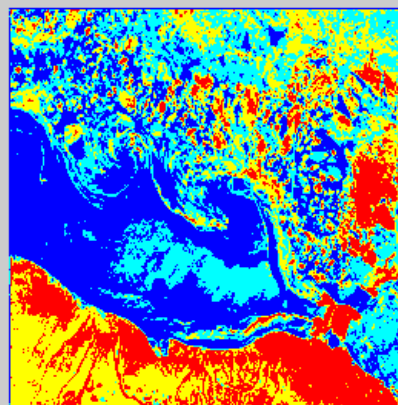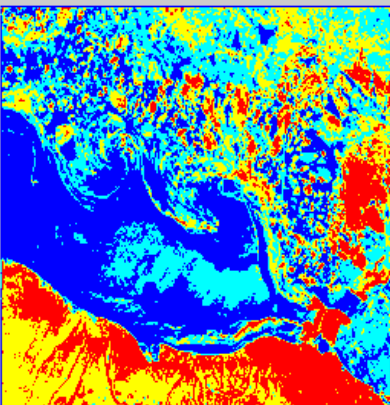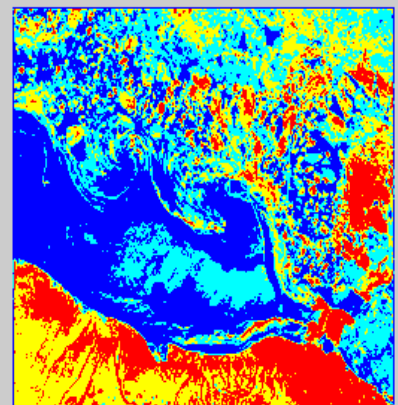
Classified Image of Early winter sea ice, Beaufort using BPN, Fuzzy, ANFIS and ANFIS with PSO

TABLE VIII.   ISLO CEDROS CLASIFICATION RESULT
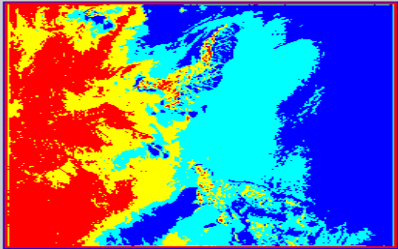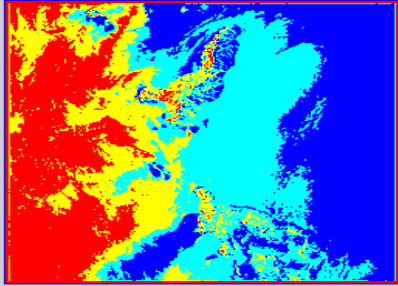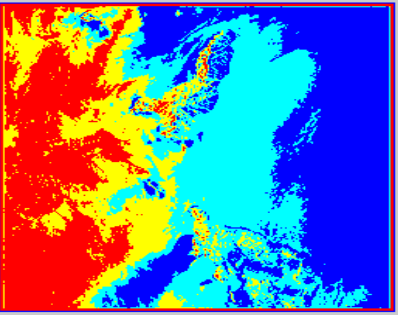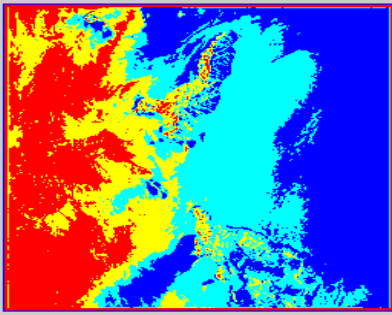
Classified Image of Islo cedros using BPN, Fuzzy, ANFIS and ANFIS with PSO

TABLE IX.   GRAYS HARBOR AND WILLAPA BAY CLASSIFICATION RESULT
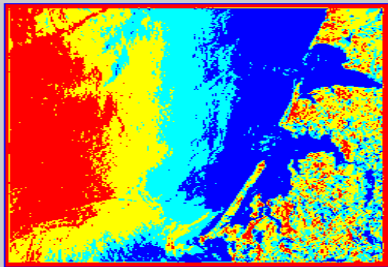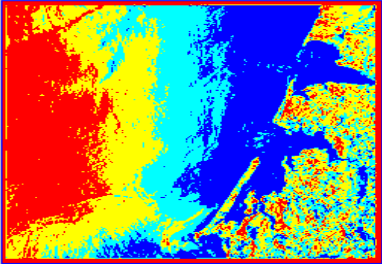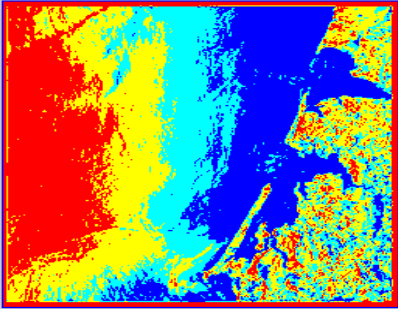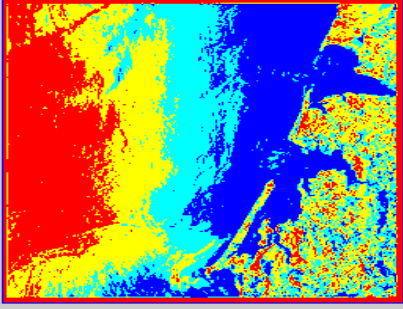
Classified Image of Grays Harbor And Willapa Bay using BPN, Fuzzy, ANFIS and ANFIS with PSO
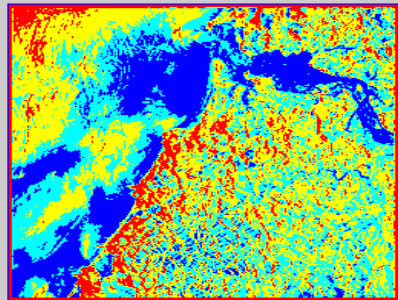
TABLE X.   MOUTH OF COLUMBIA RIVER CLASSIFICATION RESULT
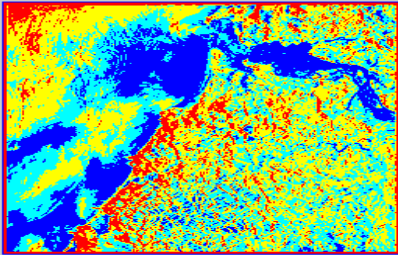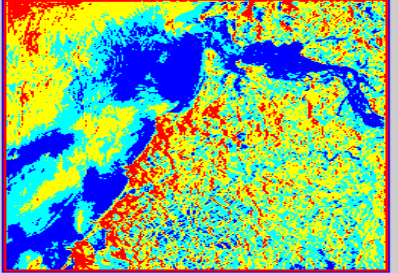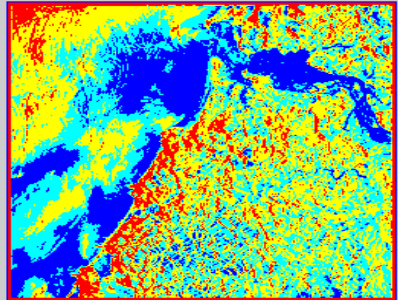
TABLE XI.   STRAIT OF GEORGIA CLASSIFICATION RESULT
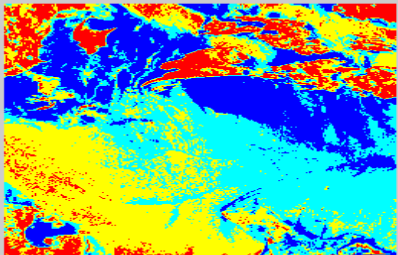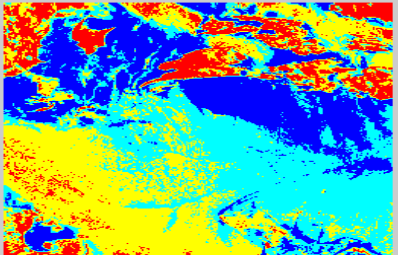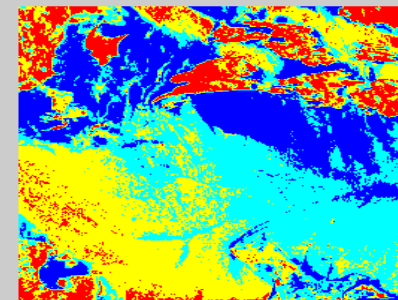
TABLE XII.   WARD HUNT CLASSIFICATION RESULT

Classified Image of Ward Hunt using BPN, Fuzzy, ANFIS and ANFIS with PSO
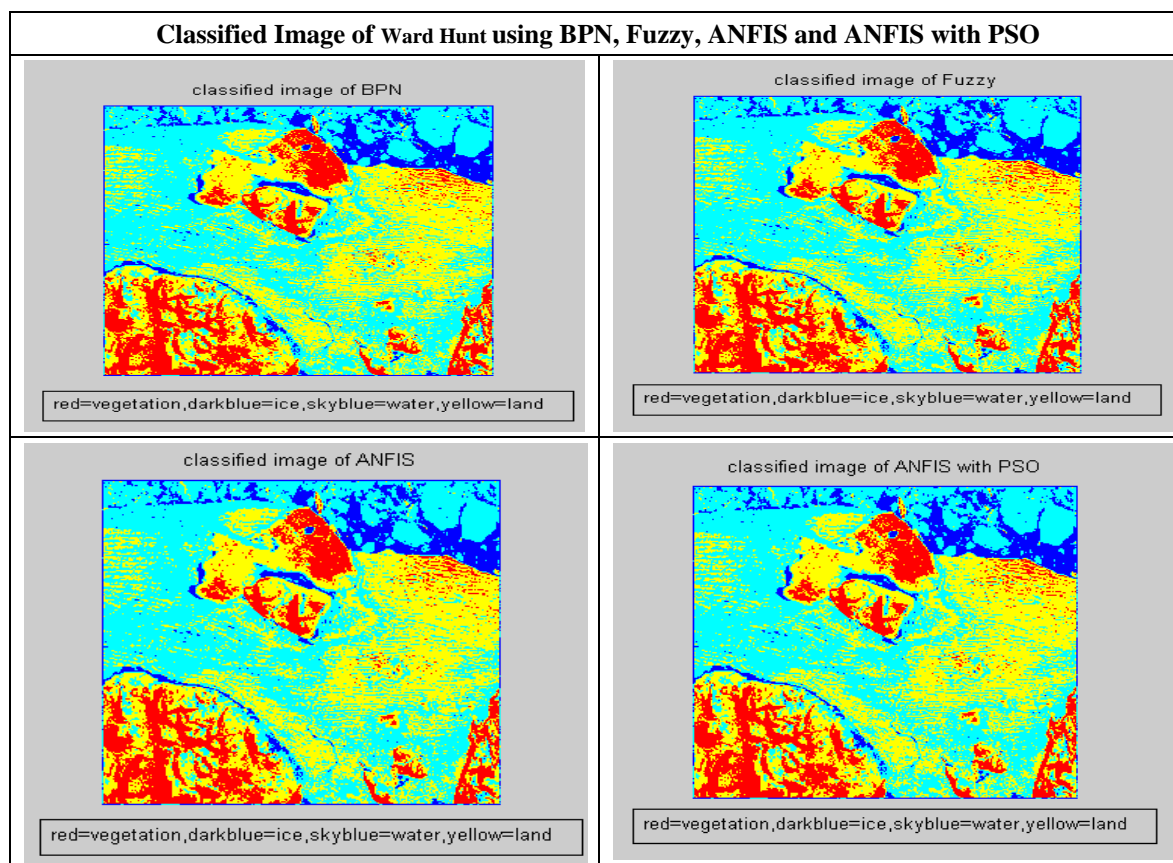
IV.   CONCLUSION

In this paper, pixel based classification on SAR ice images using supervised learning classifiers are performed. SAR images are affected by speckle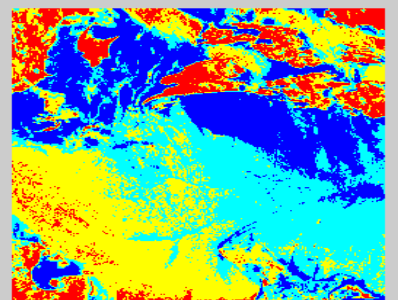 noise due to its backscattering nature of radar signals. This work is initialized with Denoising a speckle noise images using a Daubechies method in wavelet filter with the comparison of all the speckle filters. After the preprocessing stage segmentation is preceded. Comparison of K-means and Watershed algorithm are done and K-means is selected as a best segmented algorithm. Image was divided into the regions after the segmentation process has completed. Four classifiers namely, back propagation neural network (BPN), Fuzzy Classifier, Adaptive Neuro Fuzzy Inference System (ANFIS), and ANFIS with Particle Swarm Optimization (PSO) are performed. Above classifiers are the single classifier used to compare the accuracy of classification in SAR ice. Various regions called Vegetation, Land, water and ice are extracted by these classifiers. In this paper only four classifiers are performed for SAR ice classification, in future, fusion based classification can also be considered. It was focused on performing pixel based classification in future objective based classification can perform in fusion based classification.

REFERENCES

[1]   Natalia Yu. Zakhvatkina, Vitaly Yu. Alexandrov, Ola M. Johannessen, Stein Sandven, and Ivan Ye. Frolov "Classification of Sea Ice Types in ENVISAT Synthetic Aperture Radar Images" IEEE Transactions on Geoscience And Remote Sensing, Vol. 51.
[2]   LIU Huiying , GUO Huadong and ZHANG Lu "Sea ice classification using dual polarization SAR data" 35th International Symposium on Remote Sensing of Environment (ISRSE35) IOP Conf. Series: Earth and Environmental Science 17 (2014) 01211.
[3]   S. Parrilli, M. Poderico, C.V. Angelino, G. Scarpa, and L. Verdoliva, "A non local approach for SAR image Denoising" IEEE July 2010.
[4]   Klogo GriffithS.,GasonooAkpeko and Ampomah K. E. Isaac "On The Performance of Filters for Reduction of Speckle Noise In SAR images off the Coast Of The Gulf of Guinea" International Journal of Information Technology, Modeling and Computing (IJITMC) Vol.1,No.4,November 2013
[5]   Miao Ma , Jianhui Liang, Min Guo, Yi Fan, Yilong Yin "SAR image Segmentation based on Artificial Bee Colony Algorithm" Elsevier: Applied Soft computing Volume 11, Issue 8, December 2011, Pages 5205–5214.
[6]   Ashraf A. Aly, Safaai Bin Deris and Nazar Zaki, "Research Review for Digital Image Segmentation Techniques" International Journal of Computer Science & Information Technology (IJCSIT) Vol 3, No 5, Oct 2011.
[7]   Pushpalata Pujari and Jyoti Bala Gupta, "Improving Classification Accuracy by Using Feature Selection and Ensemble Model" International Journal of Soft Computing and Engineering (IJSCE) 2012.
[8]   Vidushi Sharma, Sachin Rai and Anurag Dev, "A Comprehensive Study of Artificial Neural Networks" IJARCSSE 2012.
[9]   Vini Malik, Aakanksha Gautam, Aditi Sahai, Ambika Jha, AnkitaRamvir Singh, " Satellite Image Classification Using Fuzzy Logic" International Journal of Recent Technology and Engineering (IJRTE) 2013.

[10] V.Seydi Ghomsheh, M. Aliyari Shoorehdeli, M. Teshnehlab, "Training ANFIS Structure with Modified PSO Algorithm" Mediterranean Conference on control & automation, July, 2007.

[11] Sarita Mahapatra , Alok Kumar Jagadev and Bighnaraj Naik, "Performance valuation of PSO Based Classifier for Classification of Multidimensional Data with Variation of PSO Parameters n Knowledge Discovery Database" International Journal of Advanced Science and Technology 2011.

[12] Shuhrat Ochilov and David A. Clausi, "Automated Classification of Operational SAR Sea ice Images" Canadian Conference Computer and Robot Vision, pp- 978-0-7695-4040-5, IEEE 2010.

[13] Huawu Deng and David A. Clausi "Unsupervised Segmentation of Synthetic Aparture Radar sea ice imagery using a novel Markov Random Field model", IEEE transaction vol. 43, no. 3, march 2005.

[14] S. Parrilli, M. Poderico, C.V. Angelino, G. Scarpa, and L. Verdoliva, "A non local approach for SAR image Denoising" IEEE IGARSS: IEEE Geoscience and Remote Sensing Society, July 2010.

[15] K. Thangavel, R. Manavalan, Laurence Aroquiaraj, "Removal of Speckle Noise from Ultrasound Medical Image based on Special Filters: Comparative study", ICGST GVIP: Journal emphasizes on graphics, vision and image processing Vol. 9, Issue: 3, pp. 25-32, June 2009.

[16] Klogo Griffith S, GasonooAkpeko and Ampomah K. E. Isaac, "On the performance of filters for reduction of speckle noise in SAR Images off the coast of the gulf of guinea" IJITMC: International Journal of Information Technology, Modeling and Computing Vol.1, No.4, November 2013.

[17] Bala Prakash, Venu babu, Venu Gopal, "Image Independent Filter for Removal of Speckle Noise" IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 5, No 3, September 2011.

[18] Jyoti Jaybhay and Rajveer Shastri, "A study of speckle noise reduction Filters" Signal & Image Processing: An International Journal (SIPIJ) Vol.6, No.3, June 2015.

[19] Asli Ozdarici and Zuhal Akyurek, "A Comparison of SAR Filtering Techniques on Agricultural Area Identification" ASPRS: American Society of Photogrammetric and Remote Sensing 2010 Annual Conference San Diego.

[20] Jaspreet kaur, Rajneet Kaur, "Biomedical Images denoising using Symlet Wavelet with Wiener filter" International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 3, May -Jun 2013.

[21] Meenakshi Cahudary and Anupama Dhamija, "A Brief Study of Various Wavelet Families and Compression Techniques" Journal of Global Research in Computer Science Volume 4, No. 4, April 2013.

[22] Sangeeta Arora, Yadwinder S. Brar and Sheo Kumar, "Haar Wavelet Transform for Solution of Image Retrieval" International Journal of Advanced Computer and Mathematical Sciences ISSN 2230-9624 Vol 5, Issue2, 2014.

[23] Mohamed I. Mahmoud, Moawad I. M. Dessouky, Salah Deyab and Fatma H. Elfouly, "Comparison between Haar and Daubechies Wavelet Transforms on FPGA Technology" International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol: 1, No:2, 2007.

[24] Ashraf A. Aly, Safaai Bin Deris and Nazar Zaki, "Research Review for Digital Image Segmentation Techniques" International Journal of Computer Science & Information Technology (IJCSIT) Vol 3, No 5, Oct 2011.

[25] K.M. Sharavana Raju, Dr. V. Karthikeyani, "Improved Satellite Image Preprocessing and Segmentation using Wavelets and Enhanced Watershed Algorithm" International Journal of Scientific & Engineering Research, Volume 3, Issue 10, October-2012

[26] Sim Heng Ong, Kelvin W.C Foong, Poh-Sun Goh and Wieslaw Nowinski, "Medical Image Segmentation Using K-Means Clustering and Improved Watershed Algorithm", IEEE Research gate Conference paper February ISSN 1-4244-0069-4/06 2001.

[27] Johann Schumann and Yan Liu "Performance Estimation of a Neural Network-based Controller".

[28] Stein Sandven and Ola M. Johannessen "Ers-L Ice Monitoring of The Northern Sea Route" Proceedings of the First ERS-1 Pilot Project Workshop, Toledo, Spain, 22-24 June 1994.