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Optimum Feature Selection for Efficient ISAR Image Classification

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Abstract

Objective: To identify optimum features from the initial feature set to classify ship ISAR images with good accuracy. The optimum feature selection brings down the computational complexity and also removes the redundant features in the feature vector. **Methodology:** Colour moments computed from R, G, B, RG, GB, RB component images are taken as one feature vector. The average wave energy values of horizontal, vertical and diagonal details of images decomposed up to five levels using wavelet transform are considered as second feature vector. The ship ISAR images measured with high resolution Radar are used as data set to test the classification performance of the two feature sets, which is explored uniquely in this work. Genetic algorithm and particle swarm optimization techniques are used to find the optimum feature sets. Probabilistic neural network is used to compare the classification accuracy achieved with full length feature vectors and optimum feature vectors of the two considered feature sets. **Findings:** Data set of two ships is taken. The data of each ship is divided in to two parts training data and test data. The feature vectors computed from training set are used to train the classifier and that computed from test set are used to test the classification accuracy. The number of variables (number of features in the feature vector) of optimization algorithms Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) is varied to find the optimum feature set to classify the ship ISAR image data. The function that computes the classification accuracy is used as the objective function of the optimization algorithms. From the initial feature vector of thirty colour moments a set of four features is identified that gives 100% accuracy for both the targets considered. From starting set of fifteen average energy levels, a set of four energy levels identified by PSO and the set of three energy levels are found to be more effective in classification of the ship ISAR images with classification accuracy of 66.6% for the first target and 75% for the second target. Both the optimization techniques performed in similar way. Other optimization algorithms can be explored to find feature combinations that classify ship ISAR images with better accuracy. **Application:** Classification based on ISAR images has application in automatic non-cooperative target recognition, development of monitoring systems for surveillance along transportation corridors etc. to avoid illegal immigration. **Future Work:** Different classifiers Self Organizing Maps, Support Vector Machines etc. can be used to study the possibility of obtaining optimum solution in smaller time.

Keywords: Classification, Feature Selection, ISAR image, Optimum Feature Set, Optimization Techniques

1. Introduction

Inverse Synthetic Aperture Radar (ISAR) image classification is being extensively used for recognition and classification of air, sea and geographic targets. ISAR images are acquired from a moving target through high resolution radar. Highly focussed ISAR images give useful information about the target. Radar is a very popular sensor to detect and classify targets at very large distances. When the size of the dataset is huge and the computation of feature vector is computationally intensive, the size of the feature vector is very crucial. Also it may not be true

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that all the features in the feature vector contribute for classification. So, it is necessary to find the optimum number of features that form the feature vector and improve the classification accuracy. Optimization techniques Genetic algorithm and particle swarm optimization are used to find the optimum features that give good classification accuracy. These two optimization techniques are also in use for optimum feature selection in classification problems like medical diagnosis, face recognition, image retrieval, gender classification etc. The function that calculates the classification accuracy is the objective function. In this paper, ship ISAR image classification problem is studied with two feature vectors. One is Colour moments. Colour moments initially thirty in number are taken and both the optimization techniques GA and PSO are used to find the optimum number of features that give maximum classification accuracy. Similarly, wavelet transform is applied to decompose the ship ISAR images up to level five. Study is carried out on feature vector formed by fifteen average wave energy values computed from the three horizontal, vertical and diagonal detail components of each of the five wavelet decomposition levels of the images.

Literature survey indicates that feature selection using optimization algorithms is playing a good role in classification problems of present day research. In face image classification, GA is used to select a subset of Eigen features computed by Principal Component Analysis and Linear Discriminate Analysis and compared[1]. A subset of shape, texture, statistical properties, and discrete cosine transform coefficients of region of interest of digitized mammographic images is selected with GA for mammogram classification[2]. In skin cancer detection problem grey level co-occurrence matrix and RGB colour features are used for classification and the weights of artificial neural network are optimized using GA[3]. Reduced feature set size is achieved applying GA to acoustic signatures of real land mines. In this paper the feature subset is represented by a binary string with the length equal to the total number of features N where each bit represents the presence or absence of corresponding feature[4]. Genetic algorithm is used to remove the redundant features from the feature vector in separation of brain haemorrhage regions from other parts. Error resulted in classification is used as feedback to the feature selection algorithm[5]. Statistical characteristics of grey level co-occurrence matrix and fractal dimension obtained from fracture surface images are represented as a binary vector and genetic algorithm is used to select an optimum feature set to discriminate fracture surfaces[6]. GA is used to select a subset of features that contain significant information about gender required for gender classification from face images using SVM classifier[7]. About 71 in number features like GLCM, intensity features, Gabor and Laplacian of Gaussian features computed from MR images are taken. GA is used to choose the most informative features for brain tumour classification[8]. GA based feature selection is used for discrimination of targets from clutter using Bayesian classifier[9]. Multi objective algorithm is used to select an optimal subset of statistical texture descriptors to represent and retrieve ultra sound medical images[10]. Particle Swarm Optimization is used to extract and select optimum feature set from first order and second order statistical features extracted from the lung CT scan images[11]. PSO is used for feature selection in thermal face recognition using features computed by scale invariant feature transform. Minimum distance classifier acts as objective function[12]. Binary PSO is used for feature selection from discrete cosine transform features in face recognition using Support Vector machine[13]. The velocity and position updating rules of PSO, the crossover and mutation from GA are used for feature selection in road detection or different types of land covers using SVM since SVM gives good classification accuracy for high dimensional data even with a limited number of training samples[14]. Discrete cosine transform is used to extract global features from each face as a whole. Local features computed from prime parts of face like eyes, nose, mouth etc are fused with global features and used for gender classification of face image database. Hybrid PSO and GA is used for feature selection. The performance of GA is enhanced by applying the PSO for each generation[15]. PSO and GA are used for feature selection and compared in classification of abnormal retinal images with self organizing feature map based classifier. In the paper it is inferred that the PSO outperformed GA since it increased the classification accuracy[16]. Genetic neuro approach is used for Tuberculosis disease classification. A database consisting of data of nine features for each one of 539 patients. Back propagation based neural network is used for classification. Genetic algorithm is used to select the most effective feature seven features that improved classification accuracy from 86.4% to 96.3%[17]. Sentiment analysis of social web data being natural language processing task is very tedious. Different online databases based on product reviews, Internet Movie database, twitter data etc. and different nature inspired optimization techniques PSO, Artificial Bee Colony (ABC), Ant Colony Optimization (ACO) and their combinations are used for feature selection to achieve improved sentiment classifier[18]. In present study GA and PSO are applied for optimum feature selection for the efficient ship ISAR image classification.

2. Feature Extraction

In this paper features based on colour moments and wave energy levels are studied. Inverse Synthetic Aperture Radar images are colour images. In our previous work the feature vector based on colour moments is studied for its suitability in ship ISAR image classification. First R, G and B components are obtained from ISAR images represented in RGB format. The colour moments mean standard deviation of R, G, B component image matrices are taken as one feature vector and those of combined RG, GB and RB image matrices are taken as another feature vector. Mean and standard deviation computed from RG, GB & RB matrices are found to form a good feature vector and have given classification accuracy of 91.6% for target one and 75% for the second target[19]. In this work about five moments mean, median, standard deviation, variance and skewness computed from individual and combined R, G, B image matrices are taken as a initial feature set from which a suitable subset of features is selected. To obtain another feature vector, wavelet transform is applied to the ISAR images to decompose up to five levels. At each decomposition level average wave energy values are computed and considered for optimum feature selection.

2.1 Colour Moments

The Colour moments mean, median, standard deviation, variance and skewness are computed from each of the R, G, and B component images obtained from ship ISAR images and from each one of the combinations RG, GB and RB. Thus a number of thirty moments are computed for each image in the data set. Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) are applied to the feature vector of thirty colour moments to select a smallest set of features that gives maximum classification accuracy. The set of colour moments taken for finding the optimum feature set is given below:

[mean_R^{1}, mean_G^{2}, mean_B^{3}, median_R^{4}, median_G^{5}, median_B^{6}, std_R^{7}, std_G^{8}, std_B^{9}, var_R^{10}, var_G^{11}, var_B^{12}, skewness_R^{13}, skewness_G^{14}, skewness_B^{15}, mean_RG^{16}, mean_GB^{17}, mean_RB^{18}, median_RG^{19}, median_GB^{20}, median_RB^{21}, std_RG^{22}, std_GB^{23}, std_RB^{24}, var_RG^{25}, var_GB^{26}, var_RB^{27}, skewness_RG^{28}, skewness_GB^{29}, skewness_RB^{30}].

The right most super script gives the position of the feature in the feature vector.

2.2 Wave Energy levels

The wavelet energy is a measure for how much the signal is in order or disorder. It provides useful information of the dynamical process within the signal. Wavelet transform is applied to ship ISAR image dataset to decompose the image in to approximation, horizontal, vertical and diagonal details up to five levels using the MATLAB function given below:

[C,S] = wavedec2(X, N,'db1')

Where wavedec2 is a two dimensional wavelet analysis function which returns the wavelet decomposition of the image matrix X at level N using the wavelet named Daubechies. The outputs are the decomposition vector C and the corresponding book keeping matrix S. At each level, the wave energy level values are calculated for approximation, horizontal, vertical and diagonal details with the MATLAB function shown below:

$$[E_a\ E_h\ E_v\ E_d] = \text{wenergy2}(C, S)$$

Where wenergy2 returns E_a, E_h, E_v, E_d that represents the percentage of energy corresponding to the approximation, horizontal, vertical and diagonal details. At each level of decomposition three features are obtained. The average energy level of each of the three details horizontal, vertical and diagonal details up to five levels of decomposition form the fifteen features in the feature vector. An optimum set of average energy values that gives good classification accuracy is identified using GA and PSO techniques. Optimum average energy values are selected from the wave energy values given below:

$$[avgE1_h^{1}\ avgE1_v^{2}\ avgE1_d^{3}\ avgE2_h^{4}\ avgE2_v^{5}\ avgE2_d^{6}\ avgE3_h^{7}\ avgE3_v^{8}\ avgE3_d^{9}\ avgE4_h^{10}\ avgE4_v^{11}\ avgE4_d^{12}\ avgE5_h^{13}\ avgE5_v^{14}\ avgE5_d^{15}]$$

Where $avgE1_h^{1}$, $avgE1_v^{2}$, $avgE1_d^{3}$ denote the average energy values of 1st level decomposition horizontal, vertical and diagonal details resp. The right most upper super scripts 1, 2, 3 denote that they are the first, second and third features in the feature vector. Similar notation is used to represent the average energy values of horizontal, vertical and diagonal details of remaining five decomposition levels of ISAR images.

3. Feature Selection

In this paper two optimization techniques genetic algorithm and particle swarm optimization are applied for feature selection to the two feature sets considered for ship ISAR image classification problem. Optimum combinations of features are identified that give maximum classification accuracy. Every optimization problem is associated with an objective function. The value of the objective function is used for evaluating the suitability of the feature combination for classification. The ship ISAR image classification problem is a mono objective optimization problem where the classification accuracy calculation acts as an objective function.

Any optimization algorithm involves generation of initial population of individuals where each individual represents a potential solution to the problem at hand. The quality of each solution is evaluated using a fitness function. After each iteration, a new population is formed using a selection process. Only the fit individuals will form the new population. Individuals are altered using operations like mutation and cross over. The procedure is repeated until convergence is reached.

3.1 Genetic Algorithm

In this technique the possible solutions of an optimization problem are called chromosomes. A chromosome is formed from genes. The genes are represented by numeric values, binary, symbols or characters depending on the optimization problem. A collection of chromosomes is called the population. These chromosomes undergo a process called objective function to find the most able chromosomes. These able chromosomes participate in crossover, mutation and produce offspring chromosomes. The process continues until maximum number of generations is reached. The fit chromosome is the one that has maximum fitness function value in a maximization problem. For a minimization problem, the chromosome that has minimum objective function value is selected for next generation. The chromosome having highest fitness value in each generation has the highest probability of being selected for reproduction or next generation. The chromosome that has highest fitness value over all the generations is the final optimum solution of the problem. Let j^{th} chromosome is given by c_j and its probability of selection $P_{sel}(c_j)$ is given by

$$P_{sel}(c_j) = f(c_j)/\Sigma_j f(c_j) \tag{1}$$

Where $f(c_j)$ is the fitness function value of the j^{th} chromosome

3.2 Particle Swarm Optimization

In PSO a population of candidate solutions or particles for the problem is initialized. These potential solutions are called particles. These particles move in search space according to simple mathematical formulae for the particle's position and velocity. The movement of each particle is influenced by its personal best position and guided towards the best known positions in the search space that is the global best position. All the particles have fitness values that are evaluated by the fitness function. The algorithm runs for N independent trials. At each trial an initial population is generated. For each particle, the position and velocity are initialized with random values. The fitness function is evaluated for each particle to assign a fitness value. This fitness value is compared with the personal best. If the current fitness value is found to be better than the personal best the current fitness value is assigned to personal best. The particle position and velocity are altered with the following formulae:

$$V_j^{t+1} = w * V_j^t + c_1 * r_1 * (p_{j\,best} - X_j^t) + c_2 * r_2 * (G_{best} - X_j^t) \tag{2}$$

$$X_j^{t+1} = X_j^t + V_j^{t+1} \tag{3}$$

Where,

X_j^t – Current Position, V_j^t – Current velocity, X_j^{t+1} – New position, V_j^{t+1} – New velocity, p_{jbest} – Particle's personal best known position, G_{best} – Swarm's (global) best known position, r_1, r_2 – Random values generated by MATLAB, c_1, c_2 – Acceleration coefficients, w – Inertia weight, $(p_{jbest} - X_j^t)$ – Cognitive component, which represents the particle's own experience as to where the best solution is, $(G_{best} - X_j^t)$ – Social component, which represents the belief of the entire swarm as to where the best solution is.

4. Discussion

The colour moments specified in Section 2.1 computed from ship ISAR image data set are taken as genes to form a chromosome of length 30. The length of chromosome is varied from 12, 10, 8, 6, 4 and 3. That means the number of variables of the optimization problem are changed. For each length of the chromosome, the algorithm is run for 100 generations. Probabilistic neural network based classifier is taken as an objective function to find the classification accuracy achieved with each chromosome and compared with that of others, to rank the fitness of chromosomes. MATLAB GA tool box is used. Particle swarm optimization is also applied by varying the length of the colour moments feature vector by setting the parameters social attraction c2 as 1.25 and cognitive attraction c1 as10.5, number of generations 100 and stall generations also 100. Population type is taken as double in both the optimization techniques. Similar study is carried out with the feature vector having fifteen number of average wave energy values as features using the two optimization algorithms.

The number of features in the optimum feature set achieved with the two optimization algorithms applied to the two feature vectors considered, the most suitable features and the classification accuracy achieved are given in Table 1 and 4.

From Table 1 and Table 2, it is understood that the feature vectors of length of six, five, four and three selected from thirty number colour moment features have given 100% classification accuracy for both the targets in case of genetic algorithm. So the feature vector of length four is the optimum colour moment feature set. The length of optimum colour moment feature vector computed using PSO is also four. For wave energy level features, the length of optimum feature set selected by GA is three and that by PSO is four as shown in Table 3 and Table 4. The comparison of classification performance with the feature set of six colour moments used in our previous work and the feature sets of three and four colour moments obtained after optimization using GA and PSO is given in Table 5.

In case of both the feature vectors the colour moments and wave energy levels, different combinations of the optimum features that give maximum classification accuracy of the data set can be identified by running the optimization algorithms GA and PSO multiple times. It is also observed that the performance of GA and PSO is similar in choosing the subset of features from both the colour moments and wave energy levels.

Table 1. Optimum colour moment features selected by GA and classification accuracy

Length of optimum feature set	Optimum Colour Moment Features Selected using GA	%Classification accuracy achieved	
		Target1	Target2
12	1,8,14,16,17,18,20,22,23,24, 28, 30	100	91.6
10	8,13,14,17,18,22,23,24,29,30	100	91.6
8	1,5,8,15,19,22,23,24	100	91.6
6	8,9,13,15,18,24	100	100
5	8,15,18,22,23	100	100
4	8,9,18,24	100	100
3	8,18,22	100	91.6

Table 2. Optimum colour moment features selected by PSO and classification accuracy

Length of optimum feature set	Optimum Colour Moment Features selected using PSO	%Classification accuracy achieved	
		Target1	Target2
12	3,5,7,8,13,15,17,22,23,24,28,29	91.6	91.6
10	8,13,15,18,19,20,22,23,24,28	100	91.6
8	3,8,13,15,17,22,23,24	100	100
6	3,8,14,19,22,24	100	100
5	1,8,13,18,22	100	100
4	8,9,18,24	100	100
3	3,8,23	100	91.6

Table 3. Optimum wave energy features selected by GA and classification accuracy

Length of optimum feature set	Optimum Wave energy level Features Selected using GA	%Classification accuracy achieved	
		Target1	Target2
10	1,2,3,4,6,8,9,10,11,12	66.66	75
8	2,3,5,7,8,9,11,12	66.66	75
6	2,3,5,6,10,12	66.66	75
4	2,7,10,11	66.66	75
3	3,4,10	66.66	75

Table 4. Optimum wave energy features selected by PSO and classification accuracy

Length of optimum feature set	Optimum Wave energy level Features Selected using PSO	%Classification accuracy achieved	
		Target1	Target2
10	1,2,3,4,5,8,9,10,11,12	66.66	75
8	1,2,3,5,6,7,8,10	66.66	75
6	3,6,7,9,10,11	66.66	75
4	4,10,11,12	66.66	75
3	1,4,13	58.3	83.3

Table 5. Classification accuracy achieved with colour moments before and after optimization

Length of feature set	Colour moments in feature set before and after optimization	%Classification accuracy achieved	
		Target 1	Target 2
6	Mean RG,std_RG, mean_GB,std_GB, mean_RB, std_RB (previous work of authors [Reference 19]	91.6	75
4	Std_G, std_B, mean_RB, std_RB (computed with GA and PSO)	100	100
3	Std_G,Mean_RB,std_RG (computed with GA) Mean_B,std_G,std_GB (computed with PSO)	100	91.6

5. Conclusions

In this study, colour moments and wave energy levels are used as feature vectors for classification of ship ISAR images. Genetic algorithm and Particle Swarm Optimization techniques are applied to the both feature vectors considered and optimum feature sets of length four in case of colour moments. In case of wave energy levels, optimum feature vector of length three and four that give best classification accuracy are identified with GA and PSO respectively. In case of colour moments, the features standard deviation of G component image, standard deviation of B component image, mean and standard deviation of combined RB image are the features identified by both GA and PSO to give the best classification accuracy. Whereas in case of wave energy levels, the average energy of diagonal detail of level one decomposition, horizontal detail of 2^{nd} and 4^{th} level decompositions are identified as optimum features by GA. Average energy values of horizontal detail of level 2 and level 4, vertical and diagonal detail of level 4 are the features computed with PSO. Other optimum combinations of features that give the same classification accuracy and optimum length are identified by running the GA and PSO for a number of times.

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