Digital Modulation Classification Based On Chicken Swarm Optimization and J48 Algorithm

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Abstract. Automatic Modulation Recognition (AMR) has a significant impact in the military as well as civil applications. Recognizing the modulation of the received signal has been considered as an intermediate step between the detection and demodulation of the signal. Which is why, in many military and communication systems, the AMR is considered as part of the system. Presently, due to increasing digital modulations in military and civil applications. Digital modulation recognition is especially important. Usually for the AMR a small number of the received signal features are obtained and utilized. The choice of the suitable feature plays an important part in the increase of AMR efficiency. The presented paper indicates hybrid intelligent system for the recognitions of digital signal types, consisting of 3 major modules: classifier module, feature extraction module and J48 Classifier that was used for the first time in our research in the field of classification of modulated signals and optimization module by Chicken Swarm Optimization (CSO). To get better results of the system suggested optimization the features to discard weak or irrelevant features in the system and keep only strong relevant features Chicken Swarm Optimization. The results of simulation confirm the high accuracy of recognition that is related to the suggested system even at low SNR.

keywords: Hybrid System, Automatic modulation recognition, Chicken Swarm Optimization Algorithm, J48 Algorithm

1. Introduction.

Automatic Modulation Recognition the second stage which is used after detection of the embedded signals to demodulate them [1] is capable of recognizing the received signal’s modulation type between the pre-supposed modulation numbers. The automatic modulation recognition is of a significant impact on the military and civil applications in the present day, as a result of the increase in the digital modulations in the military and civil applications the recognition of the digital modulation is particularly important. Generally, for the automatic modulation recognition, a few features of the received signal will be obtained and utilized. The choice of suitable features is of a significant impact on the increase of recognition efficiency [2]. In [3] used the neural network algorithm choosing 10 modified signals (2-ASK, 4-ASK, 2-FSK, 4-FSK, 2-PSK, 4-PSK, 4-QAM, 16-QAM, 64-QAM). The existence of the Gaussian noise -5dB to 20dB. Results have shown an increase in the accuracy of recognition of the modification type. In [4] This study uses 2 convolutional neural network (CNN)-based DL models. The experimental results have demonstrated the considerable advantage of the performance and the feasibility of the applications of the DL-based method for the classification of the modulation. In [5] Suggested novel algorithm for distinguishing six types of digital: modulation approaches (2ASK, 2FSK, 2PSK, 4ASK, 4FSK, and 4 PSK) High-resolution result for new algorithms have been demonstrated even when SNR = 4dB. In [6] They proposed a data-based model to classify automatic settings without relying on expert features such as high-frequency moments. The accuracy of the results was 90% in the SNR variance ranging from 0dB to 20d In this research, the following
digital signals have been considered: (2ASK, 2PSK, 4PSK, 8PSK, 8QAM,16QAM,32QAM, 64 QAM, 128QAM, and 256QAM) is enhancing modulated signal features, which leads to the reduction of the properties of the signal by the increase of system accuracy in detections and identifications of the signal type with the use of the Chicken Swarm optimization algorithm. In The general outline of the present paper is: After introduction, features extraction and algorithms of the optimization will be reviewed in Section2 the classification will be provided in Section3. Section4 provides some of the simulation results, and finally, the conclusions of the present research will be provided in section5.

2. Feature Extraction and Optimization

The standard system of pattern recognition after carrying out some operations of the pre-processing usually decreases the raw data set size through the extraction of a group of the distinctive attributes that are referred to as features. The necessity for the feature extraction results from the potential incapability of using raw data. In the field of signal recognition, selecting good features results in enabling the classifier from distinguishing higher and more digital signals, as well as helping the reduction of the classifier’s complexity. A variety of digital signal types are known for different characteristics which is why they find the accurate features to identify them (particularly in the cases of the higher-order moment, cumulant) is a complicated task. according to the researches, statistical features present a good way to discriminate the types of the considered digital signals [7].

2.1. Moments

Probability distribution moments can be defined as a model of expected value and defining the character of the probability density function. Concerning digital signals the specification for $i^{th}$ the moment for finite length is specified via:

$$\mu_i = \sum_{k=1}^{N} (s_k - \mu)^i f(s_k)$$

(1)

Where $N$ can be defined as the data length, $s_k$ is the random variable, subscript $(k)$ is integer-valued, $\mu$ is the mean value of a random variable. Let the signal has a zero mean ($\mu= 0$), thus equation (1) becomes:

$$\mu_i = \sum_{k=1}^{N} S_k^i f(s_k)$$

(2)

The auto-moment regarding random variable is:

$$E_{s,p+q,p} = E[S^p (S^*)^q]$$

(3)

The $(p)$ represents the number of the non-conjugated terms $(q)$ represents the number of conjugated terms, $(p+q)$ represent moment order, and $(S)$ is a discrete random variable[8]

2.2 CUMULANTS

Cumulants are also statistical features. If the characteristic equation of a random variable $S$ with zero mean is:

$$F(t) = E[e^{tS}]$$

(4)

Expanding the Logarithm of equation (4) by applying a Taylor series we obtain

$$g(t) \log \left\{E\left[e^{tS}\right]\right\} = \sum_{n=1}^\infty k_n \left(\frac{jt^n}{n!}\right)$$

Where($k_n$) is called the cumulant, $(t)$ is time. The nth-order cumulant is comparable to nth order moment thus
\[ C_{s,p+q,p} = \text{Cum} \left[ s(t),...,s(t), S^*(t),...,S^*(t) \right] \]

The cumulants can be derived from moment :

\[ \text{cum}[s_1,...,s_n] = \sum_{q=1}^Q (-1)^{q-1} (q-1)! E\left[\prod_{j \in \mathcal{V}} s_j \right] \]

The summation will be implemented on partitions \( v = (v_1, ..., v_q) \) for the indexes \( 1, 2, ..., n \), \( q \) represents the number of elements in partition [1].

2.3 Optimization

To get better results of the system optimization is suggested to the features to discard weak or irrelevant features in the system and keep only strong relevant features, to check the accuracy of the system and comparing the results obtained from applying the feature optimization algorithm and without applying it algorithm used for feature optimization (BAT swarm).

2.4 Chicken Swarm Algorithm (CSO)

CSO may be characterized as an advanced intelligent approach that has been proposed to a lot of behaviors related to chickens cocks and hens in their process when they search for food. In the CSO the chicken swarm in the search space is mapped as a specific individual of the particle. The chicken particle swarm, cock particle swarm, and hen particle swarm have been organized according to the fitness value of the particle, and a variety of the search modes will be utilized by every one of the subswarms [9]. In this algorithm, more than a few particles with the best fitness are selected as the cock particle swarm which can be characterized as:

\[ (x)^{l+1}_j = (x)^l_j + \text{rand}nd(0,\sigma^2) \]

where \( x^{l+1}_i \) and \( x^l_i \) represents the position regarding j-the dimension of a particle i in t+1 and t iterations respectively \( \text{rand} \) can be defined as a uniform random \( 0, \sigma^2 \) represents the random number of Gauss distribution whose variance is \( \sigma^2 \). The parameter \( \sigma^2 \) could be computed via

\[ \sigma^2 = \begin{cases} 1, & \text{fit}_i < \text{fit}_k \\ \exp \left( \frac{(\text{fit}_k - \text{fit}_i)}{(\xi + \text{fit}_i)} \right), & \text{fit}_i \geq \text{fit}_k \end{cases} \]

where \( i, k \in [1, \text{size}] \) and \( i \neq k \). \( \text{size} \) can be defined as the number of cock swarms. \( \text{fit}_i \) and \( \text{fit}_k \) represents the values of the fitness regarding cock particle \( i \) & \( k \), respectively. \( \xi \) can be defined as a fairly small number. Moreover, most particles with the best fitness will be selected as the hen swarm. Its random search will be carried out by population cocks of hen and that of others, which may be given as:

\[ X^{l+1}_{1,j} = X^l_{1,j} + s2\text{rand} \cdot (X^l_{r1,j},X^l_{1,j}) + ... + s2 \cdot \text{rand} \cdot (X^l_{r2,j},X^l_{1,j}) \]

where \( X^l_{r1,j} \) and \( X^l_{r2,j} \) represents the position related to cock individual \( r1 \) in a population of the hen \( X_j \) and cock individual \( r2 \) in other populations, respectively. \( \text{rand} \) can be defined as a uniform random number over [0, 1]. \( S1 \) & \( S2 \) indicate the weight that is estimated by

\[ S1 = \exp \left( \frac{(\text{fit} - \text{fit}_{r1})}{(\xi + \text{fit})} \right) \]

\[ S2 = \exp (\text{fit}_{r2} - \text{fit}_i) \]

where \( \text{fit}_{r1} \) and \( \text{fit}_{r2} \) represents, fitness value regarding the cock individual \( r1 \) in hen population \( X^l_j \) and the cock individual \( r2 \) in other populations. Each one of the individuals, apart from a hen, swarm and cock swarm will be specified as chick swarm. Its mode of search follows the search mode of the hen swarm which has been provided as:

\[ X^{l+1}_{i,j} = X^l_{i,j} + FL \cdot (X^m_{i,j} - X^l_{i,j}), FL \in [0,2] \]
where FL represents a parameter, indicating that a chick will follow its mother to search for food. $X_{m,i}$ indicates the $i$th chick’s mother’s position ($m \in [1,N]$) [9].

3. CLASSIFIER

3.1 Classification Algorithms

Classification can be defined as a very important problem of data mining. Its input can be described as a data-set of the training record, where every one of the records got several attributes. Numerical attributes can be defined as the attributes that have numerical domains and categorical attributes, which are attributes that have non-numerical domains. In addition to that, there has been as well, a distinguished attribute which has been referred to as Class label. Such classification has been intended for the construction of a console model that may be utilized for the prediction of the future of the class label [10] unlabeled records. Numerous models of classification have been utilized and a method which is referred to as the called decision tree has been utilized in the present paper.

3.2. Decision trees

Decision trees are used for delineating the process of decision-making. It is a classifier that is embodied with a tree construction that is similar to a flowchart, which was used extensively for embodying the models of association, as a result of its graspable nature which holds to mind human reasoning. They have been used for categorizing the instances through sorting those instances down the 3 from origin to a small leaf node, running the instance association. Each one of the nodes is specifying an instance examination and each one of the divisions is corresponding to a potential advantage of that attribute. The decision tree in [11] performs the building of the regression or classification models as a tree structure. It performs a division of the data-set to smaller and smaller sub-sets as at a similar period a related decision tree has been developed incrementally. The final result is a tree alongside the leaf and the decision nodes. The decision node has 2 or more divisions and the leaf node embodies a decision or association. The topmost decision node in the tree, corresponding to the optimal predictor produced the origin node

3.3 DECISION TREE (J48)

One of the best algorithms of machine learning to examine the data continuously and categorically. J48 is utilized for the classification of a variety of applications and provide precise classification results: J-48 is a highly sufficient algorithm of machine learning which is utilized for the categorical and continuous examination of data C 4.5 (J-48) is one of the algorithms utilized for the generation of the decision tree, it has been advanced by R. Quinlan. C 4.5 is an extension of the earlier ID-3 algorithm by Quinlan. The C 4.5 actualizes (J 48) for the creation of a trimmed C 4.5 decision tree. All information aspects are split into smaller sub-sets to base a decision. J 48 considers the standardized data gain which is the result of splitting information through the selection of an attribute. In a summary, attribute extreme standardized data gained has been deployed. The smaller sub-sets are gathered again by the algorithm. Split strategies are stopped in the case where a sub-set has an index that has a similar class in every instance. J-48 produces a decision node with the use of expected class (J 48) estimations, the decision tree is capable of dealing with certain properties, the missing or lost data attribute estimations, and different attribute costs. Here the precision may be expanded with pruning [12, 13].

4. The Step of J48

Step1// Labeling of the leaf with a similar class in the case where instances are part of the same class.
Step2// For every one of the attributes, the possible data is figured and data gain will be obtained from the attribute test.
Step3// Ultimately, the optimal attribute is selected according to the current parameter of selection:
4.1 THE PROPOSED MODULATION CLASSIFICATION SYSTEM

The System which has been presented in This paper consists of 2 phases: Phase one: the electromagnetic signals. HOMs and HOCs were used for feature extraction (FE). MATLAB programs were designed to fulfill the tasks. the extracted HOMs and HOCs were obtained as a matrix of the dataset. Output FE was improved using the Chicken swarm optimization algorithm Phase 2: The outputs of the first stage are applied as inputs into the J48 to classify the signal and predict the signal type Fig. (1) demonstrates the diagram of the Proposed System.

![Figure 1. A diagram of the proposed method](image)

4.2 IMPLEMENTATION AND RESULT:

This section discusses the Results of using the Algorithm chicken Swarm Optimization and (J48) to classify 10 types of The modified signal (8 QAM, 16QAM, 32 QAM, 64QAM, 128 QAM, 256 QAM, 2PSK, 4 PSK, 8 PSK, 2 ASK Within the level of SNR (-2, -1,0,1,2,3,4,5,6,7, 8,9,10,11,12) dB and comparing these results when classifying without optimization the feature of signals in an algorithm (J48 decision tree) is for each type of signal and the accuracy of the rating as shown in Table 1 Each type of signal. The success rate in identifying signals after using the CSO algorithm is higher as indicated in Table 3 which means more system efficiency.

Results of classification accuracy using (J48 decision tree) without optimization where the accuracy ratio was 87% to the proposed methodology.

| Signal Type | Classification Criteria of Classification |
|-------------|------------------------------------------|
|             | Classification Accuracy | Re-call | F-Measure |
| 8 QAM       | %100                      | 100     | 100       |
| 16 QAM      | %100                      | 100     | 100       |
| 32QAM       | 86                        | 83      | 83        |
| 64 QAM      | 86                        | 83      | 83        |
| 128QAM      | 86                        | 83      | 83        |
| 256QAM      | %100                      | 100     | 100       |
| 2 ASK       | %100                      | 100     | 100       |
| 2 PSK       | 71                        | 73      | 75        |
| 4PSK        | 75                        | 100     | 100       |
| 8PSK        | 86                        | 86      | 83        |
Figure 2 The classification Accuracy without optimization

Represents results Accuracy using (J48 decision tree) with CSO where the accuracy ratio was 95 % to the proposed methodology.

| Signal Type | Criteria of Classification |
|-------------|-----------------------------|
|             | Classification Accuracy | Re-call | F-Measure |
| 8QAM        | %90                        | 100      | 100       |
| 16QAM       | %100                       | 100      | 100       |
| 32QAM       | 95%                        | 91       | 90        |
| 64QAM       | 88%                        | 88       | 86        |
| 128QAM      | %100                       | 100      | 100       |
| 256QAM      | %100                       | 100      | 100       |
| 2ASK        | %100                       | 100      | 100       |
| 2PSK        | 88%                        | 83       | 82        |
| 4PSK        | 93%                        | 93       | 92        |
| 8PSK        | %88                        | 87       | 86        |

Table-2. Represents Rresult's Classification criteria of the Proposed algorithm's with optimization

Figure 3 The classification Accuracy with optimization
Conclusions
In the present research, Ten digital signal types Modulated were generated in the MATLAB program in an SNR level that ranges within (-2, -1,0,1,2,3,4,5,6,7,8,9,10,11,12) dB. After that, statistical features have been extracted (Moment, Cumulant) of signals, above. Optimizing features with (CSO algorithm) Using the (J48 decision tree) as a classifier. The results showed higher classification accuracy when optimization the features by CSO up to 95% even at low noise levels compared to the classification accuracy without Optimize.

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