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Biogeography and geo-sciences based land cover feature extraction

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ABSTRACT

This work proposes a biogeography and geo-sciences based soft computing technique which is an extension of original biogeography based feature extraction algorithm using the concept of entropy inspired from the geo-sciences phenomenon of mantle convection and dynamics of the earth. This algorithm uses surface entropy in the relevant band of multi-spectral images as the basis of calculating the habitat suitability index which in turn forms the basis of identifying different terrain features in the satellite image. The proposed work has been primarily developed for the purpose of finding the applications of geo-sciences in developing computationally intelligent models. This may lead to another concept of process randomization, generation of virtual scenarios, etc. which are important ingredients in battlefield assessment. The proposed feature extractor algorithm has been applied on the datasets of Alwar region in Rajasthan and Patalganga area in Shivalik ranges. The results indicate that our proposed geo-sciences based classifier is highly efficient in extracting land cover features. Further when integrated with hybrid bio-inspired intelligent classifier proposed in our previous work, it improves its classification efficiency and outperforms the earlier probabilistic classifiers, recent soft computing classifiers such as membrane computing, hybrid FPAB/BBO, extended non-linear BBO, etc. and the very recent hybrid ACO2/PSO/BBO classifier proposed by us [16,21]. Our results conclude that the classifier based on our proposed model is the best known classifier developed till date. The proposed model is flexible and can adapt itself to suit to a large number of classification problems including mixed pixel resolution, face recognition, pattern recognition, etc. whereby entropy can be simply calculated in any other band or according to its standard definition and hence feature extraction can be made.

1. Introduction

Currently, many soft computing techniques like fuzzy sets, artificial neural network, rough set theory, ant colony optimization, particle swarm optimization, genetic algorithms, membrane computing and biogeography based optimization are being used for feature extraction or image classification, ground water detection, etc. [33,34] for which satellite remote sensing has been recognized as a valuable tool that views, analyzes, characterizes and makes decisions about the environment [44,48]. Artificial neural networks can handle non-convex decisions. The use of textural features in ANN helps to resolve misclassification [2]. The rough sets were basically designed for synthesis of approximation of concepts from the acquired data [42,43]. The genetic algorithm searches a space of image processing operations for a set that can produce suitable feature planes, and a more conventional classifier which uses those feature planes to output a final classification. Fuzzy measures show the detection of textures by analyzing the image by stochastic properties. The fundamental stochastic properties of the image are isolated by different kinds of stochastic methods, by non-linear filtering and by non-parametric methods [39]. The swarm intelligence techniques of ACO [12,13], PSO [8,14] and BBO [9,45] and membrane computing [23] are based on the concepts of image clustering and heuristic method implementation and are more accurate when working with low spatial resolution images. Enhanced versions of these techniques have also been used for solving various engineering problems such as the improved PSO called as the immunity enhanced particle swarm optimization (IEPSO) for damage detection [28] wherein a damage detection method based on combined data of static and modal tests using particle

Abbreviations: ACO, ant colony optimization; BBO, biogeography based optimization; PSO, particle swarm optimization; LISS, linear imaging self scanning; RS1, Radarsat-1; RS2, Radarsat-2; DN, digital number; I, maximum immigration rate; HSI, habitat suitability index; SIV, suitability index variables; NIR, near infra red; MIR, middle infrared; DEM, digital elevation model; E, maximum emigration rate; ANN, artificial neural networks; EA, evolutionary algorithm; GA, genetic algorithm; BBO-GS, biogeography and geo-sciences based optimization; IEPSO, immunity enhanced particle swarm optimization; RCGA, real coded genetic algorithm; DE, differential evolution; PBIL, probability based incremental learning; SGA, stud genetic algorithms; ES, evolutionary strategy.

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swarm optimization (PSO) is discussed. To improve the performance of PSO, some immune properties such as selection, receptor editing and vaccination are introduced into the basic PSO and an improved PSO algorithm is formed. The BBO technique has been adapted and modified for economic load dispatch analysis [6] to solve both convex and non-convex economic load dispatch (ELD) problems of thermal plants involving constraints such as transmission losses, ramp rate limits, valve point loading, multi-fuel options and prohibited operating zones. The GA has been modified in the form of the real coded genetic algorithm for target sensing [41] wherein an evolutionary soft-computing technique of real coded genetic algorithm is applied to solve the system of linear equations. This paper demonstrates the evolution of a new soft computing paradigm for satellite image classification using the concept of entropy inspired from the geo-sciences phenomenon of mantle convection and dynamics of the earth thereby presenting the modified version of the original biogeography based land cover feature extraction technique [40].

Our motivation is the absence of geo-sciences based approaches as contributory domains to computational intelligence. Till now, the domains like philosophy, psychology, cognition, logic and bio-sciences all have been used as contributory domains for the development of computational intelligence techniques, however, geo-sciences have never been used as applied sciences for developing a computational model. Also, the computational intelligence techniques [2] can be divided into techniques based on modelization of human mind and nature inspired intelligent techniques as the techniques that have been used till date for solving the problem of land cover feature extraction. However, it has been observed that geo-sciences which fall under the category of nature inspired intelligent techniques have never been used for the purpose. Hence, we propose a computational model inspired from the earth's dynamics as a geo-sciences based nature inspired intelligent technique which can be used to improve the original BBO technique [45] and develop an enhanced algorithm for land cover feature extraction. The proposed model is flexible to be applicable to a large number of classification problems wherein entropy can be calculated in any other band in case of applications where the dataset is terrain multi-spectral images for example, mixed pixel resolution, design of hybrid classifiers, etc. or simply formulating the entropy function according to its standard definition and evaluating the fitness function for applications where the dataset are normal images, for example, in case of face recognition application, pattern recognition, etc. Below, we summarize the main contributions of the paper:

[1] The proposed biogeography and geo-sciences based hybrid intelligent classifier, the hybrid (BBO-GS)/ACO2/PSO, extends the taxonomy of soft computing feature extraction techniques and improves the intelligent hybrid bio-inspired classifier, the hybrid ACO2/PSO/BBO classifier, demonstrated in our previous paper [19,21] wherein the strengths of the ACO2/PSO technique were combined with the characteristic strengths of BBO.
[2] Our proposed model uses surface entropy in DEM band as the measure for designing the fitness function. This entropy is the driving force leading to the formation of heterogeneous regions called as plates (texture analysis), similar to the convection forces in the mantle of the Earth. Hence, our classifier is able to classify the homogeneous regions (the regions with the lower entropy), more efficiently than the other hybrid classifiers presented in our previous works [17,21].
[3] This also validates the theory established in our paper [19] which states that the classification efficiency of biogeography based extractor on a given land cover feature is proportional to the degree of entropy for that feature.

The paper is organized into six sections, the section following the introduction illustrates the concepts of biogeography and geo-sciences. The third section describes the parameter settings, the hypotheses development and the proposed methodology of the biogeography and geo-sciences based feature extraction algorithm. The fourth section presents the implementation results and discussion for two different datasets. The fifth section presents the classification comparison of the results of the other recent soft computing classifiers with the proposed classifier on a standard dataset to prove its effectiveness. The last section concludes and summarizes the future work.

2. Basics of biogeography and geo-sciences

This section presents the concepts of geo-sciences which can be adaptively applied for building the modified version of the original BBO for solving the problem of land cover feature extraction more efficiently [7,40].

2.1. Biogeography based land cover feature extraction

BBO is a population based algorithm motivated by the migration mechanisms of ecosystems. It is based on the mathematics of biogeography. In BBO, problem solutions are represented as islands, and the sharing of features between solutions is represented as emigration and immigration [45]. In BBO, each individual is considered as a habitat with a HSI [45], which is analogous to the fitness function of other conventional algorithms, to measure the individual fitness. Also, an SIV which characterizes the habitability of an island is used. A good solution is analogous to an island with a high HSI, and a poor solution indicates an island with a low HSI. High HSI solutions tend to share their features with low HSI solutions. Low HSI solutions accept a lot of new features from high HSI solutions [9,45]. Thus, BBO is a swarm intelligence technique based on the concept of information sharing as discussed in our paper [20]. From our paper, we know that the concepts of sharing information in BBO can be adapted to suit to the problem of land cover feature extraction where it has been mentioned that BBO is well suited for natural terrain feature elicitation application and hence we modify the original BBO and adapt it to the problem of feature extraction. Fig. 1 presents the algorithm for biogeography based land cover feature extraction [40].

2.2. Geo-sciences

There are two underlying concepts which form the base of the geo-sciences phenomenon, the first being the dynamics of the movement of earth's plates and the second is the crust formation [9,22,35]. We consider that it is the entropy or the degree of disorder of the earth's mantle convection which is the driving force of the mechanism of plate dynamics. Fig. 2 shows that the plate dynamics is considered as analogous to the clustering of similar pixels which is accomplished through texture analysis using rough sets in our proposed algorithm and resulting crust formation is considered as analogous to the presence of mixed pixels in an input plate. Hence, the underlying concepts of geo-sciences can be adapted to integrate with the original BBO technique for feature extraction in the satellite image. This paper is an attempt to modify the original biogeography based feature extraction technique using an analogy between biogeography and geo-sciences phenomenon of earth's dynamics as shown in Fig. 3 and some of the ideas of which were first presented in our paper [18].