Knowledge-Based Systems 89 (2015) 420–445

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Two-phase anticipatory system design based on extended species abundance model of biogeography for intelligent battlefield preparation

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ARTICLE INFO

Article history:
Received 14 April 2014
Received in revised form 18 July 2015
Accepted 20 July 2015
Available online 26 July 2015

Keywords:
Anticipatory system
Enemy base station
Biogeography based optimization
Ant colony optimization
Particle swarm optimization
Troop deployment strategies

ABSTRACT

This paper presents an extended model of biogeography based optimization (BBO) as opposed to the classical BBO wherein the HSI value of a habitat is not solely dependent upon the emigration and immigration rates of species but the HSI value is a function of different combinations of SIVs depending upon the characteristics of the habitat under consideration. The extended model also introduces a new concept of efforts required in migration from a low HSI solution to a high HSI solution for optimization in BBO. Hence, the proposed extended model of BBO presents an advanced optimization technique that was originally proposed by Dan Simon as BBO in December, 2008. Based on the concepts introduced in our extended model of BBO and its mathematics, we design a two – phase anticipatory system architecture for intelligent preparation of the battlefield which is the targeted optimization problem in our case. The proposed anticipatory system serves a dual purpose by predicting the deployment strategies of enemy troops in the battlefield and also finding the shortest and the best feasible path for attack on the enemy base station. Hence, the proposed anticipatory system can be used to improve the traditional approaches, since they lack the ability to predict the destination and can only find a suitable path to the given destination, leading to coordination problems and target misidentification which can lead to severe casualties. The designed system can be of major use for the commanders in the battlefield who have been using traditional decision making techniques of limited accuracy for predicting the destination. Using the above natural computation technique can help in enabling the commanders in the battlefield for intelligent preparation of the battlefield by automating the process of assessing the likely base stations of the enemy and the ways in which these can be attacked, given the environment and the terrain considerations. The results on two natural terrain scenarios that of plain/desert region of Alwar and hilly region of Mussourie are taken to demonstrate the performance of the technique where the proposed technique clearly outperforms the traditional methods and the other EAs like ACO, PSO, SGA, SOFM, FI, GA, etc. that have been used till date for path planning applications on satellite images with the smallest pixel count of 351 and 310 respectively. For location prediction application, the highest prediction efficiencies of the traditional method on Alwar and Mussourie was only 13% and 8% respectively as compared to the proposed method.

1. Introduction

In this modern warfare era, it has become necessary to have the ability to anticipate the likely actions of the enemy's maneuver and the troop mobilization strategies. The ability to accurately predict the deployment strategy of the enemy troops –to identify the most likely location for the enemy to position their forces and finding a feasible route is of critical importance to the commanders in the battlefield [38]. To understand and simulate the best available routes for attacking the enemy forces and to predict the ability of the enemy to position forces and mount attack, this paper has put forward natural computation algorithm. Natural computing refers to computational processes observed in nature and human designed computing inspired by nature.

ACO, PSO, BBO, Swarm intelligence, and artificial neural networks are some of the techniques under natural computation. For our military application, we have used the combination of

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http://dx.doi.org/10.1016/j.knosys.2015.07.023
0950-7051/

Abbreviations

SIVs	Suitability Index Variables	SOFM	Self Organizing Feature Maps
HSI	Habitat Suitability Index (Similarity Threshold)	FI	Fuzzy Inference Mechanism
PSO	Particle Swarm Optimization	P_{ij}	Probability of choosing 'j' as the next city when at city 'i'
ACO	Ant Colony Optimization	E	Maximum Emigration Rate
BBO	Biogeography Based Optimization	I	Maximum Immigration Rate
T_{ij}	Pheromone value	S_{max}	Maximum No. of species = Maximum No. of SIVs in the feature habitat
N_{ij}	$1/d_{ij}$	SGA	Stud Genetic Algorithms
D_{ij}	Distance between city 'i' and city 'j'	GA	Genetic Algorithms
F_{ki}	Feasible neighborhood of the ant 'k' when being at 'i'		
ES	Evolutionary Strategy		

three natural computation techniques of ACO, PSO and BBO, which are all a part of population based optimization. The reason for the selection of these techniques is the versatile and distributive nature of the soft computing techniques of swarm intelligence. The main aim of the work done in this paper is to enhance the decision capability which will enable the commanders in the battlefield to make better strategies to combat the actions of enemy.

ACO is a class of Swarm Intelligence Technique which means it is the study of the collective behavior of decentralized, self-organized systems. It is in the nature of ant colonies to discover and travel upon the shortest from their nest to the food source. This search for the shortest path is based on a heuristic function and update of pheromone values upon each iteration [6]. PSO is a stochastic, population-based computer algorithm for problem solving. It is a kind of swarm intelligence that is based on social-psychological principles and provides insights into social behavior, as well as contributing to engineering applications. The particle swarm optimization algorithm was first described in 1995 by James Kennedy and Russell C. Eberhart [20]. The particle swarm simulates social influence and social learning. A problem is given, and some way to evaluate a proposed solution to it exists in the form of a fitness function. The swarm is typically modeled by particles in multidimensional space that have a position and a velocity. These particles fly through hyperspace and have two essential reasoning capabilities: their memory of their own best position and knowledge of the global or their neighborhood's best. So a particle has the information to make a suitable change in its position and velocity. BBO, first introduced by Dan Simon in December 2008 [36,37] is a class of biology based optimization technique and is an optimization technique based on the geographical distribution of the biological species. Geographical areas that are well suited for biological species are said to have a high habitat suitability index (HSI). The variables that characterize the habitability are called the Suitability Index Variables (SIVs). SIVs are the independent variables and HSI the dependent variable. The migration of SIVs from bad to good solutions raises the quality of those solutions which is the main mechanism of optimization in the said technique. BBO has been used in a variety of applications one of them being biogeography based land cover feature extraction [31].

In our application, the base stations (habitats, according to the algorithm) that best suit the military purpose of the enemy troops for positioning their forces (depending upon certain influential parameters called the Suitability Index Variables) are assigned high HSI values than the other less suitable stations. Each of the suitable base stations can be considered as a candidate solution to the problem of finding the best suitable base station. High HSI solutions resist change more than low HSI solutions. High HSI solutions tend to share their features (SIVs) with low HSI solutions. Poor solutions accept a lot of new features (SIVs) from good solutions. With probability P_{mod}, we modify each solution based on other solutions. If a given solution is selected to be modified, then we use its immigration rate to probabilistically decide whether or not to modify each suitability index variable (SIV) in that solution. If a given SIV in a given solution S_i is selected to be modified, then we use the emigration rates of the other solutions to probabilistically decide which of the solutions should migrate a randomly selected SIV to solution S_i. This addition of new features to low HSI solutions may raise the quality of those solutions hence in turn leading to the best solution. This approach to problem solving is basically what is called the biogeography-based optimization that will eventually lead to the best solution which represents the best base station for the enemy troops, in our military application.

Hence, we find the best suitable base station for the enemy (with a very high probability since we have found the most probable solution) to position its forces and mount attack. Having found the destination, now we proceed to find the shortest and the safest path to this base station using a hybrid of the extended BBO technique with the ACO Technique [6] and the PSO [20] techniques. PSO path extraction and ACO path planning algorithm is used for the purpose [9,19]. To make a path more smooth morphological operations are implemented to minimize the effects of shadows, trees and inconvenient areas so that an optimized path can be more quickly planned even in a complex environment by effectively extracting the obstacles and finding the shortest and safest path. Thus, the proposed anticipatory system integrates the process of finding the shortest and the best feasible path to a destination after fixing the most feasible destination. Deciding efficient routes has so far been an intuitive and a cognitive process for the troop commanders. Automated simulation of the terrain (of the war area) and of the available routes, will allow the commanders to understand the implications of the terrain for effective maneuver. When simulated on the enemy's terrain coupled with the provision for the automated prediction of the enemy base station, the system will help to predict the intents of the enemy's troop deployment and the ways of attack.

Section 2 presents the related work section. Section 3 basics of biogeography based optimization technique. Section 4 presents the proposed problem solving framework based on extended form of biogeography based optimization. Section 5 discusses the proposed two-phase anticipatory system architecture design based on the proposed model of biogeography based optimization. Section 6 presents the design and implementation of the proposed two-phase anticipatory system on synthetic scenarios. Section 7 presents the performance comparison results of the two-phase anticipatory system with the traditional decision making techniques as well as the other recent optimization techniques. Section 8 presents the conclusion and future scope of the work.