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Memetic algorithm with normalized RBF ANN for approximation of objective function and secondary RBF ANN for error mapping

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Abstract

Memetic algorithms (MAs) based on genetic algorithm (GAs) often require many evaluations of objective function. In applications like structural optimization a single evaluation of objective function can take from mere seconds to few hours or even days. Using artificial neural networks (ANN) to approximate the objective function can save computational time. To achieve required precision, certain number of training points has to be supplied. The time required to initialize and train the Radial Basis Function Artificial Neural Network (RBF ANN) depends on the number of training points and dimensionality, so it takes longer for more training points and more dimensions. More dimensions require more training points and so it is feasible to use the ANN approximation only for lower number of dimensions.

To evaluate the objective function of a solution from population of GA or for local search, the algorithm chooses either FEM or ANN, depending on the estimated precision of ANN in the particular area of the optimization space. This algorithm is using two RBF ANNs, the primary ANN is used to approximate objective function and the secondary ANN maps precision of the primary ANN over the optimization space. This allows the algorithm to use the primary ANN to approximate objective function in areas where it is precise enough and helps to avoid false approximations in areas with low precision.

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Keywords: memetic algorithms; radial basis function artificial neural networks; objective function approximation; structural optimization;

1. Introduction

Problems solved by structural optimization often require time consuming calculation of objective function. This is an important fact that has to be treated accordingly [1-6]. Many compromises have to me made due to time expensive objective function evaluation. The most affected areas include GA population size and local search frequency and depth. Parallel computing can significantly help to reduce the computational time, however even

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powerful computational hardware may not be sufficient for some problems. There are also other ways of reducing the computational time that can be used in combination with parallel computing. These options include the use of artificial neural network (ANN) for objective function approximation.

Using ANNs to approximate the objective function can save significant amount of computational time. However the ANN needs certain number of sample points to provide arbitrary precision. The number of required training points depends on the character and dimensionality of objective function. If the dimensionality is too high, it may not be feasible to use ANN for objective function evaluation at all.

2. Memetic algorithms (MA)

MAs represent a group of metaheuristic optimization algorithms combining biological and cultural evolution. The term meme was coined by Richard Dawkins in his book "The selfish gene", where he describes meme as an equivalent to gene in the process of cultural evolution [7]. MAs were introduced by Pablo Moscato as a hybrid of population based genetic algorithm (GA) and individual learning procedures used for local improvement [8]. The basic idea of MAs is that an individual or a solution can be improved both by genetic evolution and also by learning. These algorithms combine the strengths of global optimization methods and local search methods. Global optimization methods like GA or particle swarm optimization (PSO) help to explore the optimization space, maintain diversity and increase the probability of finding global optimum. The local search methods are used to improve few chosen solutions from the set of solutions of global search method in each iteration step of the global search method. As stated before, expensive evaluation of objective function can restrict the frequency and extent of local search, so it is inevitable to carefully choose which solutions will be improved, how often and how extensively.

3. Artificial neural networks (ANN)

Artificial neural networks are statistical models inspired by biological neural networks. Biological neural networks consist of multiple cells – neurons, which are connected by input and output connections. In both biological and artificial neural networks the strength of these connections varies and can change during a process called learning.

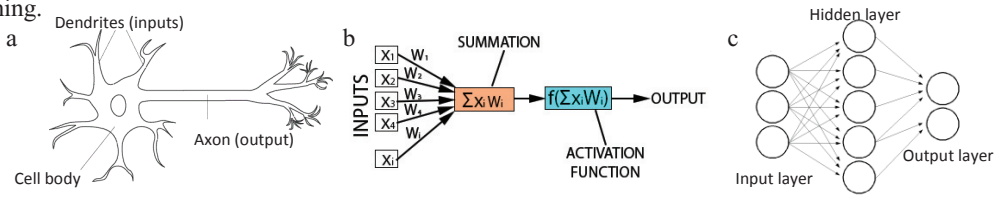

Fig. 1 (a) Organic neuron cell, (b) Artificial neuron, (c) Feed-forward artificial neural network.

In the artificial neuron which is depicted on the previous figure, the inputs are multiplied by weight coefficients W_i, followed by summation and processed by activation function producing single output. The weight coefficients are adjusted during learning, usually by method called back-propagation of errors. The type of activation function dictates the properties of the ANN, each activation function is suitable for different application.

When multiple artificial neurons are connected they form an artificial neural network. One example of such neural network is feed-forward neural network. In a feed-forward neural network all information flows in one direction. The ANN can be divided into layers, inputs form an input layer, outputs form an output layer and the other neurons form so called hidden layers [9].

4. Function approximation using radial basis function artificial neural networks (RBF ANN)

With enough sample points, the objective function can be approximated by artificial neural network. The time required to approximate the value of objective function using a neural network is relatively short, however the time