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Optimum design of short journal bearings by enhanced artificial life optimization algorithm

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Abstract

This paper presents an optimum design of high-speed short journal bearing using an enhanced artificial life algorithm (EALA) to compute the solutions of optimization problem. The proposed hybrid EALA algorithm is a synthesis of an artificial life algorithm (ALA) and the random tabu search method (R-tabu method) to solve some demerits of the ALA. The emergence is the most important feature of the artificial life which is the result of dynamic interaction among the individuals consisting of the system and is not found in an individual. The artificial life optimization algorithm is a stochastic searching algorithm using the feature of artificial life. The feature of R-tabu method, which prevents converging to the local minimum, is combined with the ALA. One of the features of the R-tabu method is to divide any given searching region into several sub-steps. As the result of the combination of the two methods, the EALA not only converges faster than the ALA, but also can lead to a more accurate solution. In addition, this algorithm can also find all global optimum solutions. We applied the hybrid algorithm to the optimum design of a short journal bearing. The optimized results were compared with those of ALA and successive quadratic programming, and identified the reliability and usefulness of the hybrid algorithm.

Keywords: Optimum design; Artificial life algorithm; Emergent colonization; Random tabu search method; Journal bearing

1. Introduction

Artificial life, as a scientific term, was first used around September 1987 at the first workshop on artificial life, which was organized by Christopher Langton, who has contributed greatly to the studies of artificial life. He defined artificial life as follows: 'Artificial life is the study of man-made systems that exhibit behavior characteristics of natural living systems" [1,2]. The research motive of artificial life was originated from the intention to understand the true meaning of life through the synthesis of the life that makes it superior to the existing life in nature.

Existing optimization methods for the differentiable irregular function consist of Newton method, and sequential quadratic programming (SQP) among others [3]. All these methods need the gradient information of the objective function to the design variables. Even though the above methods have the merit of convergent speed and accuracy, they also have the risk of trapping in the local optimums because they depend on the initial estimated value. The random tabu searching method (R-tabu method) which has problem in converging to the local minimum, was proposed by Hu [4]. It was also identified that this method has a demerit for the optimization problems with the broad search space or multivariable problems [5].

The authors proposed an artificial life optimization algorithm (ALA) that can be applied to the irregular function independent of the initial value [6]. The technique is also applied to the optimization of the journal bearing and to verifying the work listed in [7]. The artificial life has an important feature called emergence. The emergence is the result of dynamic interaction among the individuals in

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Nomenclature

D_0	initial value in order to set the neighbor region
E_e	internal energy being given to the individuals having high fitness when they move randomly in the elite reservation strategy
G_e	increasing internal energy when the individuals intake the wanted resources
I_e	initial internal energy of each individual
L_e	decreasing energy according to increasing age
L_i	minimum internal energy for survival
N_a	number of survived organisms (individuals) at any generation
N_c	maximum number of searching in each sub-step
N_{in}	number of initial individuals
N_{opt}	optimum number of individuals
N_{off}	number of offspring generated during one generation
N_s	number of sub-steps in the neighbor region
N_{sp}	number of species
R_a	minimum age for reproduction
R_e	minimum energy for reproduction
R_{f,N_s}	radius of innermost sub-step at the final generation
R_p	probability of reproduction determining whether the individuals reproduce themselves or not
$R_{p,min}$	minimum probability of reproduction
R_r	radius ratio of inner sub-steps to the outer sub-steps
α	radius parameter determining the reduction of the neighbor region through a generation

the system and is not found in an individual. The colonization is one of the most important and widespread emergent phenomena in biological systems. In the ALA, the emergent colony is the fundamental mechanism to search the optimum solution. Emergent colonies being accomplished through the metabolism, movement and reproduction among artificial organisms appear at the optimum locations in the artificial world. The locations are optimum solutions in the optimization problem. The ALA then focuses on the searching for the optimum solution in the location of emergent colonies and can achieve a more accurate global optimum. The ALA is a stochastic searching algorithm using the feature of an artificial life [6].

The ALA has a demerit that after it has congregated at the neighborhood of optimum solutions, not only does the convergent speed become very slow, but also the solution accuracy is poor. Moreover, to decide the locations of a waste of metabolism, destination of random movement and the offspring in the reproduction has an important influence on the efficiency of the ALA which remained to be improved [8].

The optimum design for hydrodynamic journal bearings carried out by a number of authors: for example, Rohde [9], Asimov [10], Beightler et al. [11], Seireg and Ezzat [12], Hashimoto et al. [13–15], Lin and Noah [16] based on various kinds of optimization techniques, such as the direct search method, genetic algorithm, and successive quadratic programming.

Thus, this paper proposes a hybrid artificial life optimization algorithm which introduced the R-tabu method into the ALA to solve these remaining location problems mentioned above. The technique can improve the convergent speed and accuracy, and can be applied to enhance the distinguished efficiency in the multivariable and the multimodal problems. We compare the performance of the EALA with the results of the ALA for the optimum design of a short journal bearing. The results show the superiority of the technique and illustrate the performance of the EALA.

2. Proposed artificial life algorithm

In the conventional ALA [6], the formation speed of the colony at the location for optimum solution can be made is one of the most important factors in determining the performance of optimization. Also, the amount of individual density that the individuals located in the colonies had for the area of the colonies is an important factor which determine the accuracy of the solution. These determine not only the efficiency of the concentrated search but also the level of solution accuracy. The timing of colony formation and the individual density basically depend on the following three decisions of location problem. The bottom line is how to decide the new location efficiently.

- To decide the location of the waste in metabolism
- To decide the location of random movement, if the individuals did not find the wanted resources
- To decide the location of the next generation in reproduction

In the ALA, the possible searching space of each individual is defined by the neighbor region, C as shown in Eqs. (1) and (2), in which organisms can perceive [6]. The ALA randomly searches the solution in this region

$$C = \{X \in R^n | \|X - X_s\|^2 \le D\} \quad (1)$$

$$D = D_0\, e^{-(t/T)\alpha} \quad (2)$$

where X_s is the location of an individual, t is the generation number, T is the last generation number, α is the radius parameter and n is the dimension of the artificial world and/or the number of design variables. The ALA has the searching ability of the global optimum solutions and the merit of much higher searching speed. But the individual density of colonies in the ALA is diverged as shown in