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Artificial memory optimization

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ABSTRACT

To solve some complicated optimization problems, an artificial memory optimization (AMO) is constructed based on the human memory mechanism. In AMO, a memory cell is used to trace an alternative solution of a problem to be solved; memorizing and forgetting rules of the human memory mechanism are used to control state transition of each memory cell; the state of a memory cell consists of two components, one is the solution state which associates with an alternative solution being traced; another is the memory state which associates with the memory information resulting from tracing results, where the memory residual value (MRV) is stored; the states of memory cells are divided into three types: instantaneous, short- and long-term memory state, each of which can be strengthened or weakened by accepted stimulus strength. If the solution state of a memory cell has transferred to a good position, its MRV will increase, and then the memory cell is not easily to be forgotten; when the solution state of a memory cell is at sticky state, its MRV will decrease until the memory cell is forgotten; this will effectively prevent invalid iteration. In the course of evolution, a memory cell may strive to evolve from the instantaneous, short-term memory state to long-term memory state, it makes search to be various. Because AMO has 6 operators at the curent version, it has wider adaptability to solve different types of optimization problems. Besides, these operators are automatically dispatched according to their executing efficiency. Results show that AMO possesses of strong search capability and high convergence speed when solving some complicated function optimization problems.

1. Introduction

Nature-inspired algorithms are often used to find global optimum solutions of some complicated optimizations, these problems are always assumed to be without any restrictions on their objective functions and constraints, which can be continuous or discontinuous, differentiable, non-differentiable, concave or convex, neither concave nor convex, or even their mathematical expressions not known [1]. The existing nature inspired algorithms are always established based on some simple behaviours of animals or phenomena in nature, these algorithms include Genetic Algorithm (GA) [2–4], Ant Colony Algorithm (ACA) [5,6], Particle Swarm Optimization (PSO) [7–9], Artificial Fish Swarm Algorithm (AFSA) [10,11], Biogeography-based Optimization (BBO) [12,13], Differential Evolution (DE) [14–16], Artificial Immune Algorithm (AIA) [17–20] and Evolutionary Strategy (ES) [21,22], Bat-inspired Algorithm (BAT) [23,24], Cuckoo Search (CS) [25,26], Glowworm-inspired Agent Swarms (GAS) [27,28], Artificial Bee Colony (ABC) [29–31], Epidemic Dynamic Model-based Optimization (SISA) [32] and SIRQVA [33] and so on.

After a thorough investigation into existing nature inspired algorithms, we find out there are 4 common traits among these algorithms [33]:

(A) Synergy: Synergy of individuals in a population may be cooperation, competition, interaction, role changing, state transition, operation dispatching, task assignment and so on [4,10,15,24,29,32,33];

(B) Information exchange: information exchange among individuals can cause individuals to evolve better [29–33];

(C) Diversity: diversity of individuals may enable evolution of individuals to be lively, and then reducing the probability that evolution drops into sticky state [32,33];

(D) Evolution: there exists evolution in a population, each individual has instincts to make itself to grow better or become stronger [2,4,6,12–16,32,33].

Synergy can be transferred into logic structure of a population-based optimization algorithm; information exchange can be transferred into operators of the algorithm; diversity can make search to develop along different directions; while evolution and instincts of each individual will enable each individual to evolve

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toward better fitness so as to arrive at global optima at higher probability [32,33].

Based on the above-mentioned discussion, we can develop a population-based intelligent optimization algorithm under much wider view. If a natural phenomenon, animal activity or society activity possesses of synergy, information exchange, diversity and evolution, then it can be transferred into a population-based optimization algorithm [33]. For example, a food-chain system in sea or ocean, a war battle, a sports game or even a TV play can be transferred into a population-based optimization algorithm. In other words, when we are watching a sports game or a love drama on computer, the game or the sitcom is actually solving a quite complicated optimization problem.

In the past researches, activities and behaviors of human itself are always excluded out of natural-inspired algorithms. Human is a kind of cleverest animals in nature, then whether can we make use of human's wisdom to design a nature-inspired algorithm to solve some very complicated global optimization problems? The answer is YES [8,34,35]. Article [8] uses extended human memory to make simulation analysis on PSO; article [34] uses human memory to invent a forecasting method, but the memory mechanism used by article [8] and [34] is different from the real human memory mechanism; article [35] uses the human memory mechanism to build a simple nature-inspired algorithm, but the memory mechanism of the algorithm is greatly simplified, and its parameters are very difficult to configure.

Cognitive psychology has pointed out that human's wisdom is tightly associated with his memory [36], if a man has good faculty of memory, he may be very clever; on the contrary, if a man is very clever, he must have good faculty of memory. Therefore, human's liquid intelligence (brain) is actually equivalent to his memory [36]. Up to now, many researches have been achieved on human's memory mechanism in cognitive psychology [36]; many interesting phenomena on human memory have been found, many interesting experiments and observations have been made, and many famous mathematical models have been created about the topic. These achievements have laid solid foundation for our research.

In the article, a special nature-inspired algorithm to use the real human memory mechanism is created; it is called artificial memory optimization (AMO). The motivation of the article is summarized as follows:

(A) Try to build a nature-inspired algorithm that human utilizes ingeniously his memory to solve very complicated function optimization problems.

(B) The nature-inspired algorithm has solid foundation of some mathematical theories.

(C) The algorithm can integrate many operators, which can be dispatched automatically and efficiently according to optimization problems to be solved.

(D) The parameters of the algorithm can be set and adjusted automatically without the help of manual configuration.

(E) The algorithm has good potentiality of development because there are many disciplines such as the associative memory theory, emotional memory theory, memory neural network theory, and so on to support improvement of the algorithm.

There are many and many stories that human uses his memory to solve problems existed in nature and society. The algorithm can provide basis to transfer these stories into nature-inspired algorithms with different purposes.

2. Mathematical model for memory updating and forgetting

Human memory theories explores human memory mechanism, types of memory including sensory, short- and long-term memory, transformation among different types of memory and memory retrieval of human brain system [36–41].

Sensory memory (SM), also called instantaneous memory (IM), is a direct image of material stimulation or original information through one or several sensory organs into instantaneous memory storage; its storage capacity is physiological limit of sensory organs, and can also be defined as information maintaining time limited by decay [42–50]. The information in sensory memory will enter into short-term memory (STM) after preliminary selection.

Short-term memory, which is composed of current information in the brain, is often called as working memory (WM); its information is from both instantaneous memory, and retrieval and extraction of long-term memory (LTM) [50–53]. For storage of short-term memory, there are two features or limits: one is the instantaneity of depositing, only the information that has been selected and processed sufficiently can enter into long-term memory; the other is the limit of storage capacity (i.e., memory span or STM capacity). The average capacity of short-term memory is 7 ± 2 blocks [54,55], this number is relatively stable Short-term memory encoding consists of acoustic (sound) coding, visual (shape) coding and semantic coding [56,57]. The information that has entered into short-term memory can get better conservation after further being processed, and then transfers into long-term memory.

2.1. Memory controlling and forgetting

Inductive valve controls the strength that signals are accepted and short-term memory accepting ability is influenced directly. When a brain nerve cell is excited by stimulus, its synapses are ascending or inductive valve is descending, synapses of brain nerves excited repeatedly by stimulus have stronger signal sending and accepting ability than rarely excited and stimulated. At this time, inductive valve is sensitive to process low energy signals; on the contrary, if inductive valve can't accept signals for a long time, it will rise, and accepting ability becomes low and looks like more inaction.

Forgetting plays a great role in human memory. Based on intrusion of new events, the forgetting mode of putting old events out of memory is called elimination. The capacity limit of sensory memory depends on time progress, the longer some events stay in memory, the weaker they are in memory, until they disappear. Information disappears from memory as time elapses; it is the forgetting time theory, that is to say, the strength of obtaining trace of events decreases every minute. The Ebbinghaus's forgetting curve [36,54,55] is discovered by Germany Psychologist after long time research at the end of the nineteen century, the curve shows that the newer an event is remembered, the quicker it is forgotten; the longer an event is kept in memory, the slower it is forgotten. The Ebbinghaus's forgetting curve is shown as Fig. 1.

From the viewpoint of modern cognitive psychology, memory is the process of memorizing, maintaining, recognizing and recalling information of the objective world. The mutual relationship among instantaneous, short- and long-term memory is shown in Fig. 2 [36,50–53].

Information enters into instantaneous memory storage through sensory organs, it is original appearance of outside stimuli; in instantaneous memory, information recognizing and filtering complete. Short-term memory is a limited capacity buffer, from which information is transferred into long-term memory storage; current brain information is constructed in the buffer; the information plays important roles on decision-making. Long-term memory is results of short-term memory being stimulated for a long time; it can reflect relatively stable information of the objective world; it makes human to recall past information, by which human can make reasoning and resolve unknown problems. Forgetting refers