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RESEARCH PAPER

Nature-inspired Computation — Effective Realization of Artificial Intelligence

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Abstract: In nature-inspired computation, different intelligent computation modes of agents usually have different extrinsic forms; but can they take on some relative uniform characteristics? To validate this idea, further systematic study on nature-inspired computation from a more macroscopical angle is made in this article and the uniform framework mode of nature-inspired computation is consequently summarized and presented, as well as described with feedback neural network and swarm intelligence algorithms. On the basis of the defined general mode framework, agents of the algorithms in a nature-inspired computation field can show a type of uniform intelligent computation mode.

Key Words: nature-inspired computation; general mode; uniform framework mode; neural networks; swarm intelligence

1 Introduction

The nature-inspired computation and interrelated study is becoming popular and has been acknowledged by the international evolution computation field[1], with an in-depth research of all kinds of intelligent computation modes in the field of artificial intelligence. Generally speaking, nature-inspired computation is this type of an intelligent computation mode that is coming from nature, especially the correlative function, characteristic, and action of some typical biological system and physical system. Moreover it is trying to obtain an intelligent information process mechanism through distilling relevant computing models and designing intelligent algorithms, as well as in virtue of the concurrent action of relevant modules, such as, information sensing and accumulation module, knowledge and method upgrading module, task scheduling and implement module, fixed-point information sensing module, and so on.

From the angle of topic research fields, nature-inspired computation pays more attention to the results in computational algorithms inspired from nature, including biological, ecological, and physical systems. It is an exciting and emerging interdisciplinary area, in which a wide range of techniques and methods are being studied for dealing with large, complex, and dynamic problems[2−4]. Specific areas include neural computation, quantum computation, evolutionary computation, DNA computation, information processing in cells and tissues, molecular computation, computation with words, fuzzy computation, granular computation, artificial life, swarm intelligence, artificial immune systems, and so on, with applications to knowledge discovery, finance, operations research, and more.

From the view of subject study, nature-inspired computation is a new intercross-subject of all relevant natural science (especially physics, biology, life sciences, etc.), computer science, and so on. This subject has a definite intercross with artificial intelligence, but this theme attends in depth to all relevant computing modes and the ideas of imitating nature and reconstructing nature, as well as, to the action mechanism of physics characteristics and life characteristics of each level in nature, which will provide helpful instruction in the design and application of all kinds of relevant computation models and algorithms.

2 General framework mode of nature-inspired computation

In nature-inspired computation, the information processing model is simulating the intelligent character of a biological organization and a biological system in nature, which is also the most essential characteristic of evolution computation. For example, the genetic algorithm (GA) is inspired and is simulating the genetic evolution phenomenon of organisms ubiquitous in nature, which use principles of natural evolution-like mutation, crossover, and selection, to obtain better solutions from the actual population of solutions. The artificial neural-network (ANN) is inspired by the structure of the human brain, and uses principles of neural information processing modes, which are the simplifications and abstract of the human brain. It is also inspired by the ant colony system (ACS) and particle swarm optimization (PSO), which are typical implementations of swarm intelligence, inspired by the foraging behavior of a flock of animals, such as ants or birds which cooperate to find better solutions. The authors are of the view that it is possible and necessary to set up an intrinsic and relative unitive framework to describe all computation models in nature-inspired computation, which will help to understand the intrinsic essence of intelligent modes

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of nature-inspired computation, and help to syncretize all kinds of intelligent algorithms and improve the performance of relevant algorithms.

In the process of dynamical computation, all kinds of algorithms and models of nature-inspired computation have distributed optimization characteristics without exception; however, it is restricted by a general framework of external uniform conditions. The general framework of nature-inspired computation can be looked upon as a hiberarchy model described in Figure 1, which is divided into four layers according to material problems to be solved, including the layer of macrostructure design and method improvement, the layer of task decomposing and corresponding, the layer of computation scheduling and information sensing, and the layer of movement process of controlled entities or objects.

In the layer of macrostructure design and method improvement, user and design module, knowledge and method upgrading module, and relevant knowledge and method repository are included. In the knowledge and method upgrade module, relevant knowledge, intelligent computation model and other design methods are collected. After being upgraded to system level by knowledge and method module, the knowledge and methods are stored to knowledge and methods repository to be transferred by the macroscopically design and decision-making distribution module. In the user and design module, the responding specific model frame and general parameters are determined, and information and related knowledge of the selected intelligent computation model according to practical problems to be solved are distilled; meanwhile, the distilling commands are sent to the knowledge and methods repository. The knowledge and methods repository then becomes a method repository which is not aiming at all-natural computing methods but special intelligent computation models. In the same sense, the knowledge and method upgrade module is aiming at a specific module.

In the layer of task decomposing and corresponding, the main operation is the decision-making distribution. According to the information of model frame and collectivity parameter presented by the layer above, and according to the macroscopical description, the description of task decomposing, and distributing and corresponding processes of tasks, collectivity objective order, and decision-making parameters are analyzed to the corresponding local task instruction, and then transmitted to the lower scheduling implement module. This task is an analysis of the macroscopical parameter to local task and instruction.

In the layer of computation scheduling and information sensing, the scheduling implementation module, information exchange module, and information sensing and accumulation module are included. According to the partial instruction passed from the upper level, relative commands can be carried out, distributed by the scheduling implementation modules of intelligent agents. Each intelligent agent can be a logic concept, or an entity concept, depending on the concrete problem to be solved. The necessary reference control signal of real movement can be formatted by each partial mission through real-time programming of tasks, real-time movement programming, real-time movement control, and real-time instruction propulsion. Information of the scheduling implementation module needed can be created by the information sensing and accumulation module, obtained through the extracted original information collection by fixed-point sensing, identification and conversion, and through signal processing optimization, information extraction and modeling, information accumulation and upgrading, and information systematization. The produced real-time information is distributed to each scheduling implementation module of agents through the information exchange modules, including information configuration, information requisition, information test, information conversion, and information delivery.

The layer of movement process of controlled object entity includes controlled movement process and controlled object entity, as well as, corresponding sensor system. In the controlled movement process, the controlled object receives real-time control signals of movement parameter from the computation scheduling implementation module of upper layer to implement the object's moving. The sensor system is able to collect the original information of objects and transfer the information to the above-layer information sensing and accumulation module.

In conclusion, decision-making distribution module, knowledge and methods upgrade module, and computation scheduling implementation, information exchange, sensing, and so on, for each agent, are independent in the general framework of nature-inspired computation. After completing the design and scheduling of tasks, the movement of a population of agents can be actualized in a distributed and independent computational environment, which takes on an essential characteristic of distributed artificial intelligence included in the idea of nature-inspired computation. Certainly, it is clear that nature-inspired computation is not absolutely equal to an independent physical system or biological population, but is an abstract framework idea that puts up a kind of relative uniform intelligent computation mode and is defined based mainly on review and home study of interrelated intelligence models.

3 Nature-inspired computation mode of feedback neural-network

First, the authors discuss feedback neural-network computation mode by using Hopfield neural-network, based on the instruction of the general framework model of nature-inspired computation. The mathematical model of Hopfield neural-network (for short HNN) can be found easily in correlative references [5–6], therefore, only the continuous model of HNN introduce simply as follows.

In the HNN, N nerve cells perform the energy function dynamic cooperation and optimization through a plane and fully interconnected mode. The standard energy function defines a uniform optimization object for the population of nerve cells to find the constringent results based on the standard interconnected framework. At the beginning, the designer should define energy function for different actual problems according to the standard energy function and the structural restriction of HNN. And then, comparing with standard energy function is performed and parameters for each nerve cell are designed. Consequently, the interrelated parameters of the nonlinear dynamic differential equation can be obtained, and the solution of the problem to be solved