Research Status and Development Trend of Bioheuristic Computing

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Abstract: Bio-inspired computation aims to study the biology function, characteristic and echanism of the various levels of nature from biological individual, population, colony until ecosystem, and set up a relevant model and computing method, so as to serve the scientific research and engineering application of human society. A few future directions and research challenges are presented, such as parallel bio-inspired computation, bio-inspired computation with reasoning and knowledge, bio-inspired dynamics computation, bio-inspired computation based on quorumsensing, artificialbrain, evolutionaryhardware, bigdata, swarmrobot, virtualbiological, cloudcomputing, etc.

1. Introduction
In the field of biological system research, various kinds of biological heuristic algorithms emerge one after another, with diverse forms, different ideas, modeling and analysis tools of their own characteristics. At the same time, since all kinds of biological intelligent computing modes are derived from “nature” and simulate the biological intelligent behavior rules in nature, they are always designed to solve certain kinds of computing and optimization problems, and these computing modes are relatively uniform[1][2].

Biological inspired computing research in nature is the purpose of the different levels of biological individual, population, community and even ecosystem functions, characteristics and mechanism, establish a corresponding simulation model and calculation method, to serve the scientific research and engineering application of human society. It has been proved that bioheuristic computing has good performance in solving problems difficult to be solved by traditional methods such as large-scale computation and NP difficulty. In addition, the biological inspired computing has potential parallelism, distribution and refactoring, can be easily applied to engineering calculation under the network environment, management, control, and division of labor.

2. Research status of bioinspired computing
With people's exploration of the biological world, new research results have been emerging in the field of bioinspired computing since the 1990s, showing vigorous vitality and bright academic research prospects. Bioheuristic computing is an interdisciplinary subject between lifescience and computational science. The theories of genetics, biological immunology, nervous system and endocrinology in life science, artificial intelligence in information science, adaptive theory, optimal control and cognitive science and basic mathematics all provide important theoretical support for the development of bioinspired computing, shown as figure1.[2-3]
2.1 Research status of bioinspired computing
In 1994, the first Computational Intelligence conference titled “Computational Intelligence: Imitating the life”, the theme of the seminar got scholars’ attention. Among them, bioinspired computing attracts many scholars to devote themselves to the research and development of this field because of its unique charm.

![Diagram of Bioinspired Computation Theoretical Origin and Supporting](image)

**Figure 1.** Bio-inspired computation theoretical origin and supporting.

2.2 Existing bio-inspired computing algorithms
As people understanding of society, especially in the past decade, biological heuristic calculation have been continuously developed, and derived a lot of new calculation method. The institute of computational technology, Chinese academy of sciences, tongji university, a university of electronic science and technology of China, Peking University, western jiaotong university and other research institutions have conducted research on bio-inspired computing, and published some monographs, such as simulated evolutionary computing of computational intelligence. Table 1 lists the proposed and widely studied biological heuristic algorithms and their heuristics. [4]
2.3. Research status of bioinspired computing

Existing biological heuristic algorithms have different objects of inspiration, but they all simulate the process of simple individuals cooperating to solve complex problems. Therefore, the internal structure of the algorithm has something in common: namely, within a certain geographical range, there are multiple individuals with simple capabilities, most of whom are isomorphic in structure and function; there is no central control in the population, and the cooperation among individuals is distributed. Individuals interact and collaborate by following simple rules. Moreover, the calculation mode of the above algorithm is relatively uniform, which is based on the adaptive behavior of evolutionary unit, and achieves the final goal through the iterative search method of “generation + test” feature. [5]

3. Prospect of application of biological heuristic computing

Since its inception, bioheuristic computing has been widely used in many fields of natural science and engineering science, and has shown great advantages and potential. Historically, the peak of bioinspired computing research was around 2010. At this stage, a variety of bio-inspired computational methods appeared, and the research content was gradually broadened and the application was gradually oriented to reality. But since 2015, research seems to have fallen into a slump. The reason is that the practical application of the algorithm has not been better used. But with big data, cloud computing and the urgent need to explore the complex world in the future, biologically-inspired

| EVOCATOR       | ALGORITHM NAME                  | BASIC IDEA                                                                 | PRESENTER AND SUBMISSION TIME                           |
|----------------|--------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------|
| molecular      | DNA computing                  | Biomolecular structures are simulated and computations are performed using molecular biotechnology | Adleman L M, US (1994)                                  |
| cells          | membrane algorithm             | A computational model that simulates the multilevel structure of cells        | Nishida T Y, Japan (2005)                               |
| immune         | artificial immune system       | Mimics how the natural immune system works                                  | Dougias D US (1998)                                    |
| Neural network | back propagation hopfield      | A multilayer feedforward network with error inverse propagation algorithm.   | Bryson A E and Ho Y C, US (1980)                        |
|                |                                | Considering the transmission delay of output and input in time, the          | Hopfield J J US (1982)                                  |
|                |                                | neural is clarified network and dynamics.                                    |                                                         |
| Biological     | evolutionary programming       | It simulates biological evolution from a holistic perspective,                | Fogel L J US (1963)                                    |
| evolution      | evolutionary strategies        | emphasizing species evolution                                                |                                                         |
|                |                                | The idea of biological evolution through natural mutation and natural       | Schwoefel H P, Germany (1965)                           |
|                |                                | selection                                                                   |                                                         |
| Ants           | ant colony optimization        | Ant pheromone foraging behavior                                             | Dorigo M, Maniezzo V, Italy (1991)                     |
| bird           | particle swarm optimization    | Flock flight and foraging behavior                                           | Kennedy and Berhart, US (1993)                         |
|                | swallow swarm optimization     | Swallows work in different roles to find food                              | Nafstad M, Sepiderham G and Sangolzaci M, Iran (2011)   |
|                | cuckoo search                  | Cuckoo parasitic breeding mechanism and levy flight search mode              | Yang X, Sand, Dub S, UK (2009)                         |
| fish           | artificial fish swarm algorithm| Fish feed and swim in groups                                                | Li Xiaolei, China (2002)                               |
| bacteria       | bacterial foraging optimization| Bacterial chemotactic foraging behavior                                     | Passino R, MUS (2002)                                  |
|                | bacterial colony chemotaxis    | Bacterial chemotactic foraging behavior                                     | Müller S D, Marchetto I, Sweden (2002)                 |
| fireflies      | glowworm swarm optimization    | Fireflies use their glow to attract mates or feed                           | Krishnamoorthy and Ghose D, India (2005)               |
| bees           | artificial bee colony          | The act of bees collecting honey                                            | Karaboga D, Turkey (2005)                              |
| human          | self-organizing migrating      | Group self-organizing migration behavior in social environment              | Zelinka I and Lampiainen J, Czech (2009)               |
| plant          | invasive weed optimization     | Simulate the process of weed invasion                                       | Mehrabian A and Lucas C, Iran (2006)                   |
computing with intelligent emergence mechanism will show great vitality in the following fields in the future.

3.1 Human Brain
The brain is one of the most complex system of nature, research and development of the human brain has always been a prospective research direction is of great significance. In 2014, the European commission announced the launch of the human brain project. In 2010, China launched a program on artificial brain research and related major guidance documents in the outline of medium - and long-term scientific and technological development. In 2013, the brain activity mapping project was launched in the United States. Countries such as Germany and Japan are also deploying brain science courses. Hugo DE garis, a computer professor at Utah state university, is the world's first inventor of an artificial brain. His CBM is a kind of brain manufacturing machine, using genetic algorithm to design the neural network, then the neural network modeling of electronic. In 2011, researchers at the university of southern California used carbon nanotubes to create a circuit that mimics the function of the brain's synapses. In 2012, scientists at the university of Waterloo in Canada designed a large brain called Spaun, made up of 2.5 million simulated neurons that perform eight different types of tasks. In 2012, IBM simulated a computing architecture with 530 billion neurons and 137 trillion synapses. Artificial brain manufacturing requires two levels of technical support: intelligent hardware technology that simulates brain nerves and intelligent computing technology that simulates brain thinking. Biological belongs to the behavior of complex systems and features can provide inspiration for the design of an artificial brain and evolution, adaptive, self-learning and self - grouping, highly parallel and interactive environment, can rearrange a new route, the study knowledge, discover new tasks and solve problems. [6]

3.2 Evolution hardware
Compared with the traditional fixed structure of the hardware, the hardware evolution (evolvable hardware, EHW) depends on the biological heuristic calculation, its hardware structure can be realized with the change of environment automatic hardware structure and function of refactoring. At present, the basic hardware architecture of the computer is still von neumann. Turing's Turing machine model laid the foundation for the logical working mode of modern computers. These two principles have been with computers for nearly 100 years. In contrast, evolutionary hardware is clearly a new technological baby with broader and better prospects. The computing, based on the biological heuristic evolutionary hardware research tasks include: evolutionary computation coding scheme, special application coding scheme, evolutionary computation algorithm parameters adaptive adjusting mechanism, the evolutionary computation fitness evaluation mechanism, the evolutionary computation fault-tolerant mechanism and parallel evolutionary computation, etc.

3.3 Big data
Big data is another revolution after mobile Internet, Internet of things and cloud computing. At present, there is a growing social forecasting, decision-making and business practices are based on the bjective analysis of large data. Effective analysis and processing of large data, for example, would bring huge economic value, promote social progress. The core value of big data is data analysis. Under the background of big data, data size and the difficulty of handling need analysis of the problems are extremely complex, with large scale and high dimension, strong constraints, strong dynamic and multi-objective characteristics. Faced with these characteristics, traditional data analysis methods are no longer applicable. At the same time, biological heuristic computation characteristic of the big data revolution brought great opportunities for biological heuristic calculations. At present, the international conference on large data, such as the IEEE conference on computing and big data services, ACM international conference on data management and domestic computer association of China's most influential and largest of the big data technology conference will be data analysis method, on the basis of included in this study, the biological inspired computing problem, pointed out that in
big data environment, biological inspired computing can be used to complete the following data analysis: a large-scale data analysis, high-dimensional data analysis, trend analysis, data analysis, strong constraint optimization of abnormal data category analysis, multi-scale analysis, extract feature selection, uncertainty of data analysis, etc.

3.4 Swarm robot

In the complex and changeable working environment, some single-task robots are unable to complete, while group robot systems can complete complex tasks that are difficult or impossible to complete by single robot systems with faster, more reliable, lower cost and better performance. Swarm robot's applications provide a wide range of applications and challenges for bioinspired computing. Future wars are increasingly fierce, and as military operations or other tasks require, single-platform uavs urgently need to develop toward multi-platform “clusters.” Cluster cooperative behavior and control method are the important basis of uav cluster. Currently, many countries around the world are using bioinspired computing to implement unmanned aerial vehicle (uav) swarm warfare, such as swarm warfare or Wolf warfare. In addition to cooperative uav operations, swarm robots can also complete environmental monitoring, hazardous environment operations, underwater and space exploration, hazard location, resource exploration and disaster search. Based on bioheuristic computation, the research tasks of collaborative work of swarm robots include: aggregation control, connectivity control, formation control, distribution control, path planning, multi-target tracking, multi-task division and multi-task coordination.[7]

3.5 Cloud computing

Cloud computing is an emerging computing mode developed by distributed computing, parallel computing and network technology, and is the core technology of the next generation network computing platform. The term “cloud” refers to a large pool of computer resources distributed on a network that are largely idle through virtualization. Through cloud computing, computing nodes can automatically access the resource pool, and all kinds of resource acquisition and services can fully realize dynamic autonomy without human participation. As cloud computing has massive, heterogeneous, distributed and diversified resources, it will involve many complex computing tasks in terms of resource optimization and data management. The implementation of these tasks needs to rely on bio-inspired computing. Based on biological inspired computing, realize the cloud computing environment complex computing tasks, task scheduling optimization, like a cloud resources (including digital resources, platforms, resources and performance, etc.) scheduling optimization, network performance optimization, the huge amounts of data analysis and forecast data management tasks such as research work includes the following: efficient real-time algorithm, dynamic multi-objective algorithm, adaptive dynamic algorithm, dealing with large-scale algorithm, parallel and distributed algorithms and efficient processing a np-hard problem and mass data of multivariate clustering algorithms, etc.[8]

4. Conclusion

Cloud computing is an emerging computing mode developed by distributed computing, parallel computing and network technology, which is the core technology of the next-generation network computing platform. The term “cloud” refers to the distribution of a large number of computer in the network resources, these resources through virtualization basically is in the idle state. Through cloud computing, computing nodes can automatically access the resource pool, and various resource acquisition and services can fully realize dynamic autonomy without anyone participating. Cloud computing is massive, heterogeneous, distributed and diverse resources, the resource optimization and data management will involve many complex computing tasks. The realization of these tasks depends on bionic computing. Based on bio-inspired computing, realize complex computing tasks in cloud computing environment, task scheduling optimization, such as cloud resources (including digital resources, platforms, resources and performance, etc.) scheduling optimization, network performance
optimization, a large number of data analysis and prediction data management tasks, such as research work includes the following: efficient real-time algorithm, dynamic multi-objective algorithm, adaptive dynamic algorithm, processing large-scale algorithm, parallel and distributed algorithm, and efficient np problem processing and multi-dimensional clustering algorithm of massive data.

References
[1] Holland J H 1995 How adaptation builds complexity (USA: Addlson-Wesley Publishing Company) p72-77.
[2] Holland J H 1992 Adaptation in natural and artificial systems An introductory analysis with application to biology, control and artificial intelligence (Cambridge, MA: MIT Press) p43-65.
[3] Parpinelli R S 2011 New inspirations in swarm intelligence A survey (Amsterdam: International Journal of Bio-Inspired Computation) p1-15.
[4] Xing B, Gao W J 2013 Innovative computational intelligence A rough guide to 134 clever algorithms (Berlin, Germany: Springer).
[5] Goh C K, Tan KC 2009 A competitive-cooperative coevolutionary paradigm for dynamic multiobjective optimization (USA: IEEE Transactions on Evolutionary Computation) p103-127.
[6] Oca M A M D, Garrido L, Aguirre J L 2005 Effects of inter-agent communication in ant-based clustering algorithms A case study on communication policies in swarm systems LNCS 3789: Advances in Artificial Intelligence (Berlin, Germany: Springer) p254-263.
[7] Garnier S, Gautrais J, Theraulaz G 2007 The biological principles of swarm intelligence Swarm Intelligence 1(1): p3 -31.
[8] Zhang J, Zhan Z H, Lin Y, et al 2011 Evolutionary computation meets machine learning A survey (USA: IEEE Computational Intelligence Magazine) 6(4): p 68-75.