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A Survey on Bio-Inspired Computing Algorithms and Application

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Abstract: *Nature is of course a great and immense source of inspiration for solving hard and complex problems in computer science since it exhibits extremely diverse, dynamic, robust, complex and fascinating phenomenon. It always finds the optimal solution to solve its problem maintaining perfect balance among its components. Nature inspired algorithms are Meta heuristics that mimics the nature for solving optimization problems opening a new era in computation. This paper presents a broad overview of biologically inspired optimization algorithms, such as Ant Colony Optimization (ACO), Genetic Algorithm (GA), Evolutionary Algorithm (EA) and Particle Swarm Optimization(PSO). By analyzing and investigating die rent approaches, this paper gives an overview about the researches on bio-inspired algorithm, its computations and human interaction.*
Keywords: *Ant colony Optimization, Evolutionary algorithm, Genetic algorithm, Particle Swarm intelligence, Stochastic Diffusion, Artificial ant colony.*

I. Introduction

Bio-Inspired computational has its roots based on the behavior of organisms in the nature for their survival, these behaviors are studied further to apply and find suitable solution of the complex computation which is a combination of computational intelligence and collective intelligence. These computational methods are used to solve complex problems, and modeled after design principles encountered in natural / biological systems, and tend to be adaptive, reactive, and distributed. The goal of bio-inspired computing is to produce computational tools with enhanced robustness, scalability, flexibility which can interface more effectively with humans.

These techniques are based on principles which are then converted into engineering models. In general, natural system presents remarkable capabilities of resilience and adaptability. Bio-inspired methods can solve different problems linked to the computer computations. It provides various optimization techniques such as group foraging of social insects, collective sorting and clustering division of labor etc.

Biologically inspired computing is a major subset of natural computation. Some areas of study encompassed under the canon of biologically inspired computing, and their biological counterparts:
•Genetic algorithms ↔ evolution • biodegradability prediction ↔ biodegradation
•Cellular automata ↔ life • emergent systems ↔ ants, termites, bees, wasps
•Neural networks ↔ the brain • artificial life ↔ life • artificial immune systems ↔ immune system
•Rendering (computer graphics) ↔ patterning and rendering of animal skins, bird feathers, mollusk shells and bacterial colonies •Lindenmayer systems ↔ plant structures
•Communication networks and protocols ↔ epidemiology and the spread of disease
•Membrane computers ↔ intra-membrane molecular processes in the living cell
•Excitable media ↔ forest fires, ―the wave‖, heart conditions, axons, etc. • sensor networks ↔ sensory organs

Computer science and biology have enjoyed a long and fruitful relationship for decades. Biologists rely on computational methods to analyze and integrate large data sets, while several computational methods were inspired by the high level design principles of biological systems.

II. Literature Review

Biologists have been increasingly relying on sophisticated computational methods, especially over the last two decades as molecular data have rapidly accumulated [1]. Computational tools for searching large databases, including BLAST (Altschul et al, 1990), are now routinely used by experimentalists. Genome sequencing and assembly rely heavily on algorithms to speed up data accumulation and analysis (Gusfield, 1997; Trapnell and Salzberg, 2009; Schatzet al, 2010). Computational methods have also been developed for integrating various types of functional genomics data and using them to create models of regulatory networks and other interactions in the cell (Alon, 2006; Huttenhower et al, 2009; Myers et al, 2009)[2-3].

BIO-INSPIRED COMPUTING AND AI The way in which bio-inspired computing differs from the traditional artificial intelligence (AI) is in how it takes a more evolutionary approach to learning, as opposed to what could be described as 'creationist' methods used in traditional AI [4-5]. In traditional AI, intelligence is often programmed from above: the programmer is the creator, and makes something and imbues it with its intelligence. Bio-inspired computing, on the other hand, takes a more bottom-up, decentralized approach; bio-inspired techniques often involve the method of specifying a set of simple rules, a set of simple organisms which adhere to those rules, and a method of iteratively applying those rules. For example, training a virtual insect to navigate in an unknown terrain for finding food includes six simple rules [6]. The insect is trained to

•Turn right for target-and-obstacle left; • turn left for target-and-obstacle right;

•Turn left for target-left-obstacle-right; • turn right for target-right-obstacle-left,

•Turn left for target-left without obstacle and • turn right for target right without obstacle.

The virtual insect controlled by the trained spiking neural network can find food after training in any unknown terrain [7].

Moreover, other techniques like Genetic algorithm, (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution as -described in[8]. Various challenges and its advantages are also discussed in this paper and it; focus on providing broad coverage of the existing literature. For each topic, we will start from a historical view, focusing on the pioneering efforts in the area. We continue with the most influential works, leading up to recent trends.

The main aim was to survey, if the bio inspired technique was,

- Adaptive to the varying environmental circumstances.
- Robust and resilient to the failures caused by internal or external factors.
- Able to achieve complex behaviours on the basis of a usually limited set of basic rules.

III. Inference from existing works on bio inspired computation

Bio-inspired Computing is the combination of computational intelligence and collective intelligence. These computational methods are used to solve complex problems, and modeled after design principles encountered in natural / biological systems, and tend to be adaptive, reactive, and distributed. The goal of bio-inspired computing is to producecomputational tools with enhanced robustness, scalability, flexibilitywhich can interface more effectively with humans.

Bio-Inspired computation algorithm is always the most research topics in artificial intelligence community. Biology is a perplexing source of inspiration for the design of intelligence artifacts that are capable of efficient and autonomous operations in unknown and changing environment it is difficult to solve computational problems, thus needing technique for control,optimization,prediction, design and security and so on. Bio-Inspired computational algorithms and the application is a collection that addresses this need. It integrates contrasting techniques of genetic algorithms, artificial immune system, particle swarm optimization Neurocomputing, DNA algorithm and so many other models to solve many real world problems.

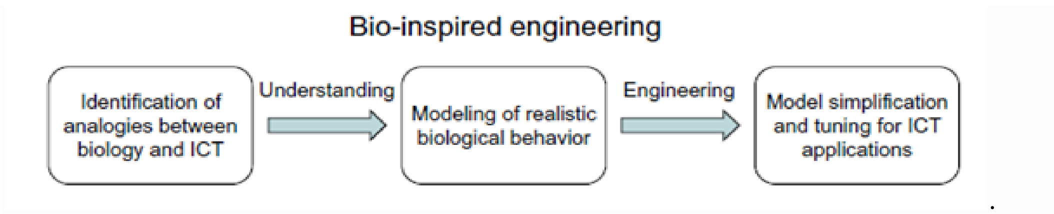

Figure 1: necessary steps to add up biological mechanisms to technical solutions

1.Identification of analogies
2. Understanding
3. Engineering

Three steps can be identified that are always necessary for developing bio-inspired methods that have a remarkable impact in the domain under investigation: 1. Identification of analogies – which structures and methods seem to be similar, 2. Understanding – detailed modeling of realistic biological behavior, 3. Engineering – model simplification and tuning for technical applications. The figure1 shows the overall general basic system architecture for modeling.

IV. Applications And Algorithm Based On Bio Inspired Strategies

The ideas from nature and biological activities have motivated the development of many sophisticated algorithms for problem-solving.

Applications of BioInspired Are:

1. Swarm intelligence (SI).
2. Nervous System.
3. Genetic Algorithm
4. Evolutionary Algorithms (EAs).
5. Artificial Neural Networks (ANNs).
6. Artificial Immune System (AIS).
7. Cellular Signaling Pathways.
8. Advances in Wireless Nano Sensor Networks and Communication.

These algorithms are broadly classified as evolutionary computation and swarm intelligence (SI) algorithms. Evolutionary computation is a term used to describe algorithms which were inspired by ‗survival of the fittest' or ‗natural selection' principles3; whereas ‗swarm intelligence' is a term used to describe the algorithms and distributed problems-solvers which were inspired by the cooperative group intelligence of swarm or collective behavior of insect colonies and other animal societies

1. Evolutionary Algorithm Evolutionary algorithms (EAs) are computational methods inspired by the process and mechanisms of biological evolution. According to Darwin's natural selection theory of evolution, in nature the competition among individuals for scarce resources results in the fittest individuals dominating over the weaker ones (i.e. survival of the fittest). The process of evolution by means of natural selection helps to account for the variety of life and its suitability for the environment. The mechanisms of evolution describe how evolution actually takes place through the modification and propagation of genetic material (proteins). EAs share properties of adaptation through an iterative process that accumulates and amplifies beneficial variation through a trial and error process. Candidate solutions represent members of a virtual population striving to survive in an environment defined by a problem-specific objective function. In each case, the evolutionary process refines the adaptive fit of the population of candidate solutions in the environment, typically using surrogates for the mechanisms of evolution such as genetic recombination and mutation

2. Genetic algorithms In the field of artificial intelligence, a genetic algorithm (GA) is a search heuristic that mimics the process of natural selection. This heuristic (also sometimes called a meta heuristic) is routinely used to generate useful solutions to optimization and search problems.[1] Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

The Canonical GA (pseudo code):

Choose initial population
Evaluate each individual's fitness
Determine population's average fitness
Repeat
    Select best-ranking individuals to reproduce
    Mate pairs at random
    Apply crossover operator
    Apply mutation operator
    Evaluate each individual's fitness
    Determine population's average fitness
Until terminating condition (e.g. until at least one individual has the desired fitness or enough generations have passed)

3. Swarm intelligence

Swarm intelligence (SI) is artificial intelligence based on the collective behavior of decentralized, self-organized systems. The expression was introduced by Gerardo Beniand Jing Wang in 1989, in the context of cellular robotic systems. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local interactions between such agents lead to the emergence of complex global behavior. Natural examples of SI include ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling. The application of swarm principles to robots is called swarm robotics, while 'swarm intelligence' refers to the more general set of algorithms.

Fig 2. Swarming of Birds

Fig 3. Swarming of ants

Swarm intelligence is the emergent collective intelligence of groups of simple autonomous agents. Here, an autonomous agent is a subsystem that interacts with its environment, which probably consists of other agents, but acts relatively independently from all other agents. The autonomous agent does not follow commands from a leader, or some global plan. For example, for a bird to participate in a flock, it only adjusts its movements to coordinate with the movements of its fock mates, typically its neighbors that are close to it in the fock. A bird in a flock simply tries to stay close to its neighbors, but avoid collisions with them. Each bird does not take commands from any leader bird since there is no lead bird. Any bird can be in the front, center and back of the swarm. Swarm behavior helps birds take advantage of several things including protection from predators (especially for birds in the middle of the flock), and searching for food (essentially each bird is exploiting the eyes of every other bird).

Two principles of Swarm Intelligence:
1. Self-Organization is based on:-
- Positive feedback(amplification)
- Negative feedback (for balancing)
- Amplification of fluctuations(random walks, errors)
- Multiple interactions

2. Stigmergy:-
- Indirect communication via interaction with environment.

Why is Swarm Intelligence interesting for IT?
- Analogies in IT and social insects
- Distributed system of interacting autonomous agents
- Goals: performance optimization and robustness
- Self-organized control and cooperation (decentralized)
- Division of labor and distributed task allocation
- Indirect interactions**.**

Properties of Swarm Intelligence
- Agents are assumed to be simple
- Indirect agent communication
- Global behavior may be emergent

- Specific local programming not necessary
- Behaviors are robust
- Required in unpredictable environments
- Individuals are not important

Some of the techniques based on bio-computing has discussed below:
1. **Ant Colony Optimization** Ant colony optimization (ACO) is a population-based metaheuristic that can be used to find approximate solutions to difficult optimization problems. In ACO, a set of software agents called artificial ants search for good solutions to a given optimization problem. To apply ACO, the optimization problem is transformed into the problem of finding the best path on a weighted graph. The artificial ants (hereafter ants) incrementally build solutions by moving on the graph. The solution construction process is stochastic and is biased by a pheromone model, that is, a set of parameters associated with graph components (either nodes or edges) whose values are modified at runtime by the ants.
2. Particle swarm optimization In computer science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. It solves a problem by having a population of candidate solutions, here dubbed particles, and moving these particlesaround in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position but, is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions
3. Stochastic Diffusion search Stochastic diffusion search (SDS) was first described in 1989 as a population-based, pattern-matching algorithm [Bishop, 1989]. It belongs to a family of swarm intelligence and naturally inspired search and optimization algorithms which includes ant colony optimization, particle swarm optimization and genetic algorithms. Unlike stigmergetic communication employed in ant colony optimization, which is based on modification of the physical properties of a simulated environment, SDS uses a form of direct (one-to-one) communication between the agents similar to the tandem calling mechanism employed by one species of ants, Leptothoraxacervorum.
4. Cuckoo Search Algorithm Cuckoo Search Algorithm (CSA) [9] is based on the obligate brood parasitic behavior of some cuckoo species in combination with the Levy flight behavior of some birds and fruit flies.CSA is a new meta-heuristic approach that models the natural behavior of cuckoos.
5. Artificial Bee Colony Algorithm Artificial Bee Colony Optimization was proposed by Karaboga in 2005.In the artificial bee colony (ABC) algorithm [7], the colony of artificial bees comprises three groups of bees: employed bees, onlookers and scouts. A bee waiting on the dance area for making decision to choose a food source is called an onlooker and a bee going to the food source visited by it previously is named an employed bee. A bee carrying out random search is called a scout.

V. Conclusion

This study has presented the variousmethods associated with the existing bio-inspired computations. It focuses on developing efficient solutions to overcome the computational problems. Self –Organization mechanisms for communication and coordination between computational systems need further more research and development.Biocomputing provides the very natural way to solve the problems for the human by adapting the animals behavior to solve the problem with the help of nature. The biggest problems here are to implements and form the computational methodology by the machine. There will be a promising domain for the computer science development via this bridge opening the new techniques for better problem solving. There are many objectives and many directions, but similar solutions can be derived.

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