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Nature Inspired Algorithms: A Survey of the State of the Art

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Abstract: ***Nature has been a constant source of inspiration for humans since centuries. Scientists across different domains have formulated various theories by observing the processes that occur in nature. Nature-inspired computation is a relatively new area of research which focuses on developing algorithms that takes inspiration from natural phenomenon for solving complex optimization problems. In this paper, a systematic review of the classical well-established, as well as less popular, recently developed nature inspired algorithms is presented. The nature-inspired algorithms are classified into broad categories, and some of them are described in detail. A discussion on the recent trends and challenges in the field of nature-inspired algorithms is also given.***

Keywords: ***Nature-Inspired Computation, Bio-Inspired Algorithms, Swarm Intelligence, Evolutionary Algorithms, Genetic Algorithms, Survey.***

I. INTRODUCTION

Real-world optimization problems are often very difficult to solve and involve multi-objective optimization. Most of them are NP-hard problems, which cannot be solved using the traditional deterministic algorithms. Nature-Inspired algorithms (NIAs) have been proven to be excellent methods to address these complex optimization problems, and have been applied to solve many such problems belonging to different domains. Over the past few decades, various NIAs have been developed, taking inspiration from the biological swarms, natural evolution, physical, chemical, and geographic processes that occur in nature [1-3].

In the current literature, there are more than fifty such algorithms. Some of the classical and popular NIAs are Particle Swarm Optimization (PSO) [4], Genetic Algorithms (GA) [5], Ant Colony Optimization (ACO) [6], etc. Apart from these well-renowned classical algorithms, many other NIAs have also been proposed recently.

In this paper, a broad classification of the NIAs is presented and an endeavor is made to cover as many algorithms as possible, keeping the manuscript simple and easy to understand. The rest of the paper is organized in the following manner.

In section-2, NIAs are classified into broad categories. Section-3 discusses the various application areas of the NIAs. In section-4, different challenges and limitations in the field of NIAs are described. Section-5 concludes the findings of the survey and discusses the scope for future enhancement.

II. CATEGORIZATION OF THE NIA

Depending on their source of inspiration, NIAs can be broadly classified as represented by fig.1. Fig.2 represents the various sub-classes of NIAs in the form of a Venn diagram. It is clear from the Venn diagram that the 'Swarm-Intelligence' algorithms are a sub-class of the 'Bio-Inspired' algorithms, which itself is a sub-class of the 'NIAs'.

Similarly, algorithms inspired by physics and chemistry belong to the main class of 'NIAs', but are different than 'Bio-Inspired' algorithms. Now, let us discuss each category of the NIAs in detail.

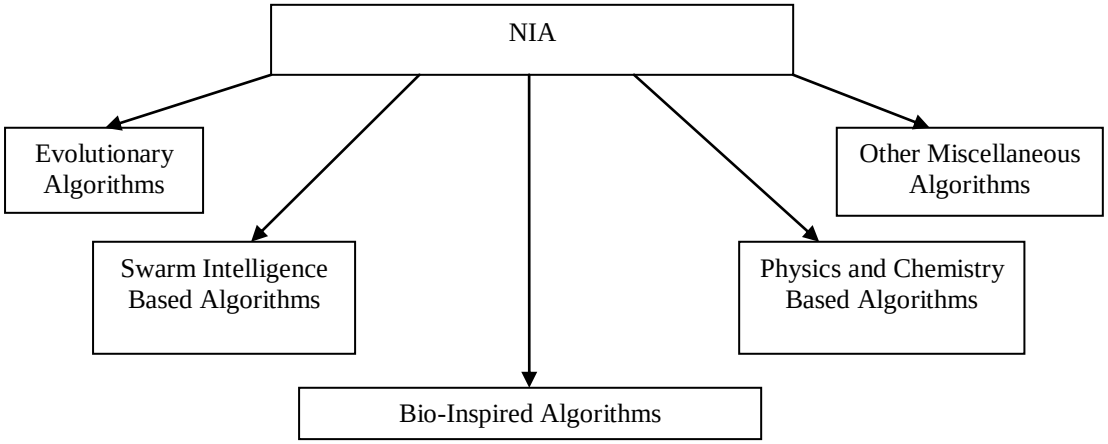

Fig.1 Broad Classification of the NIAs

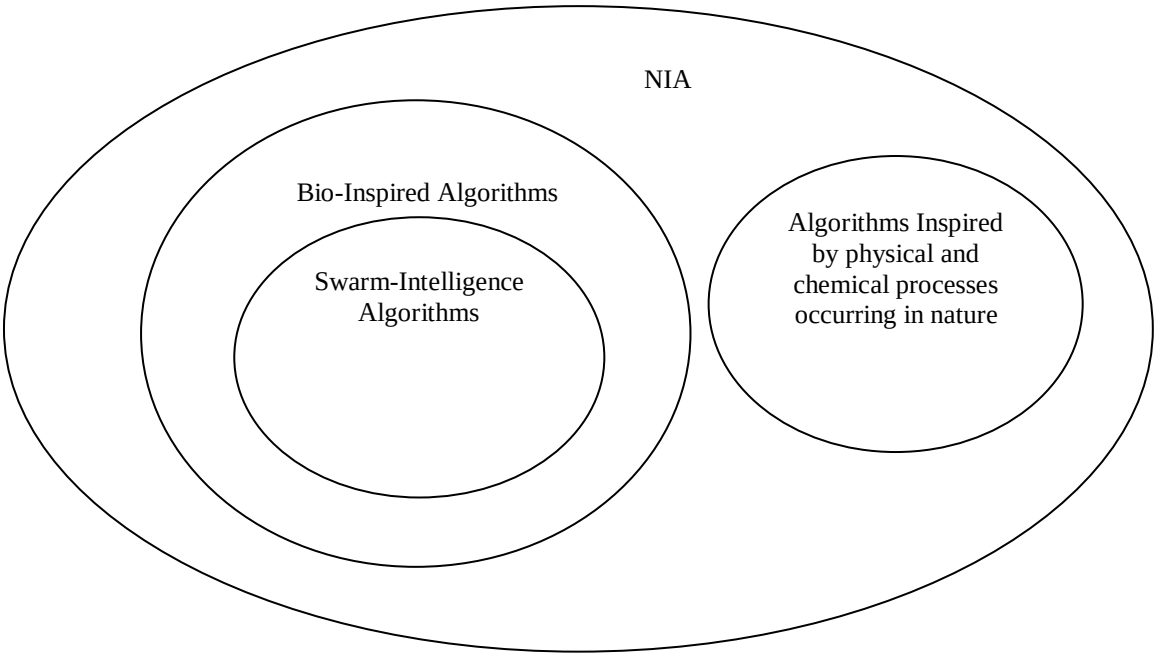

Fig.2 Venn diagram representing the various categories of NIAs

A. Evolutionary Algorithms

Evolutionary algorithms are widely used to solve complex real-time optimization problems. Evolutionary algorithms can be divided into the following categories as represented by fig.3.

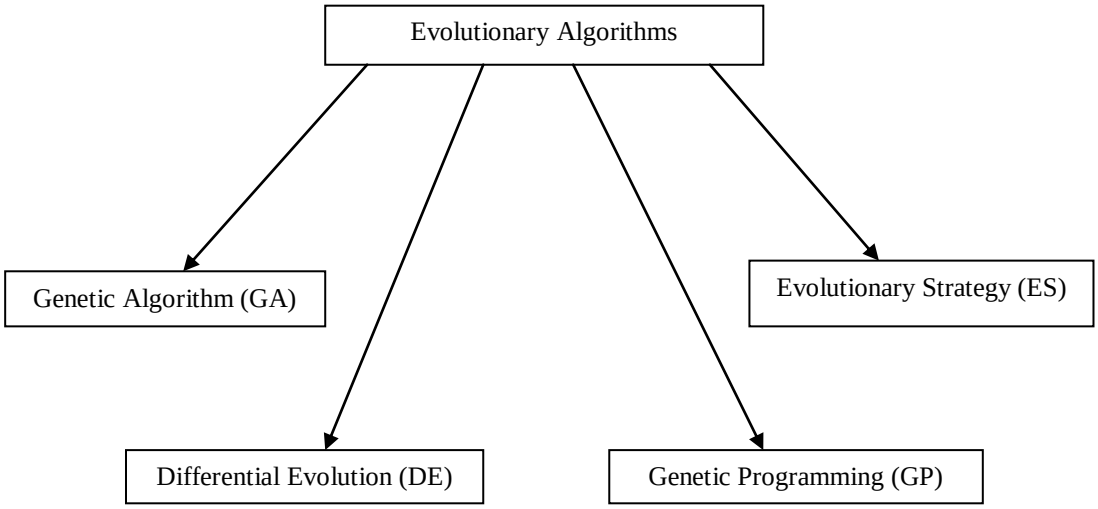

Fig.3 Classification of the Evolutionary Algorithms

1) *Genetic Algorithms*: Schema theory forms the foundational basis for the success of genetic algorithms [7-11]. The key operators used in genetic algorithms are selection, crossover and mutation.

2) *Differential Evolution*: It is a technique that optimizes a given function by continuously improving the solution.

3) *Genetic Programming*: It is a very popular evolutionary technique. In a basic genetic program, a variable-sized tree of functions and values is used.

4) *Evolutionary Strategy*: In evolutionary strategies, a fixed-length real-valued vector is used. Like in genetic algorithms, here also each position in the vector represents a feature of the individual.

B. Swarm intelligence based algorithms

Excellent survey papers on the bio-inspired algorithms could be referred from [12-13]. Most of the NIAs are inspired by the swarm behavior of various species like: birds, fishes, ants, bees, fireflies, cats, monkeys, etc. and are termed as 'Swarm intelligence based algorithms'. These algorithms are represented by fig.4 as shown below.

C. Bio-inspired algorithms

There are many algorithms that are inspired by the biological phenomenon other than the swarm behavior. Various algorithms that belong to this category are depicted by fig.5.

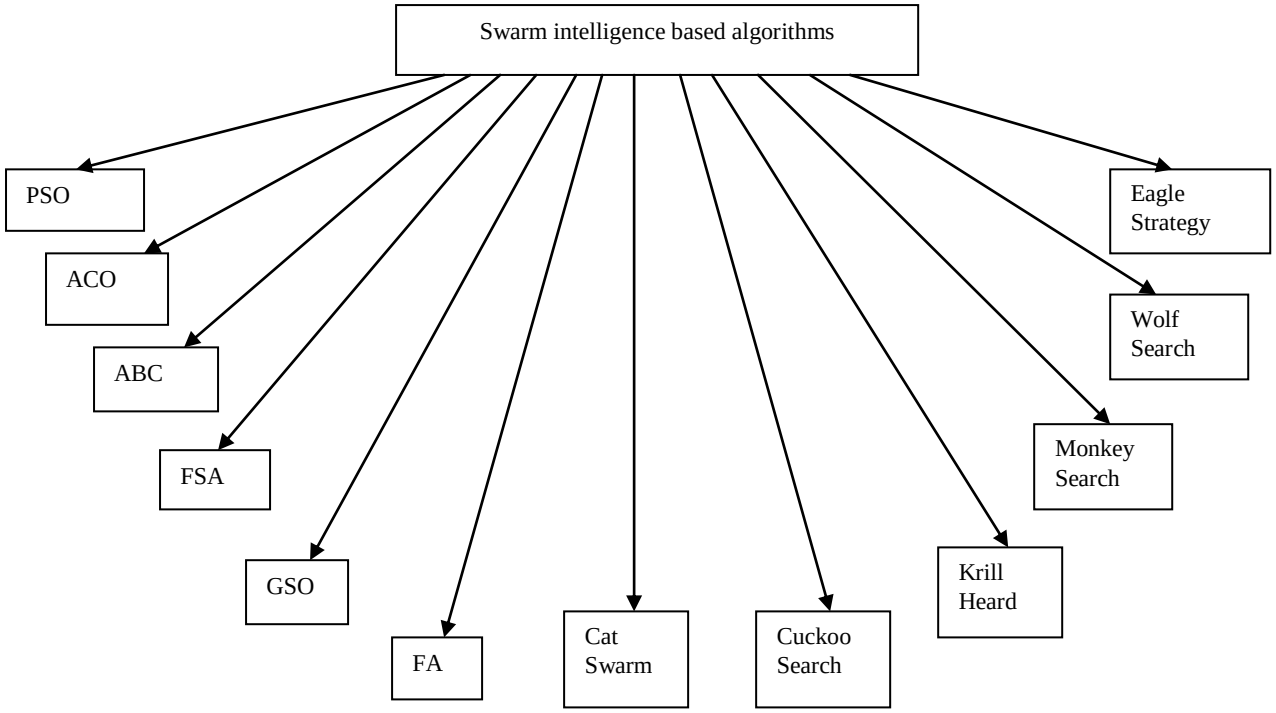

Fig.4 Different Swarm Intelligence Based Algorithms

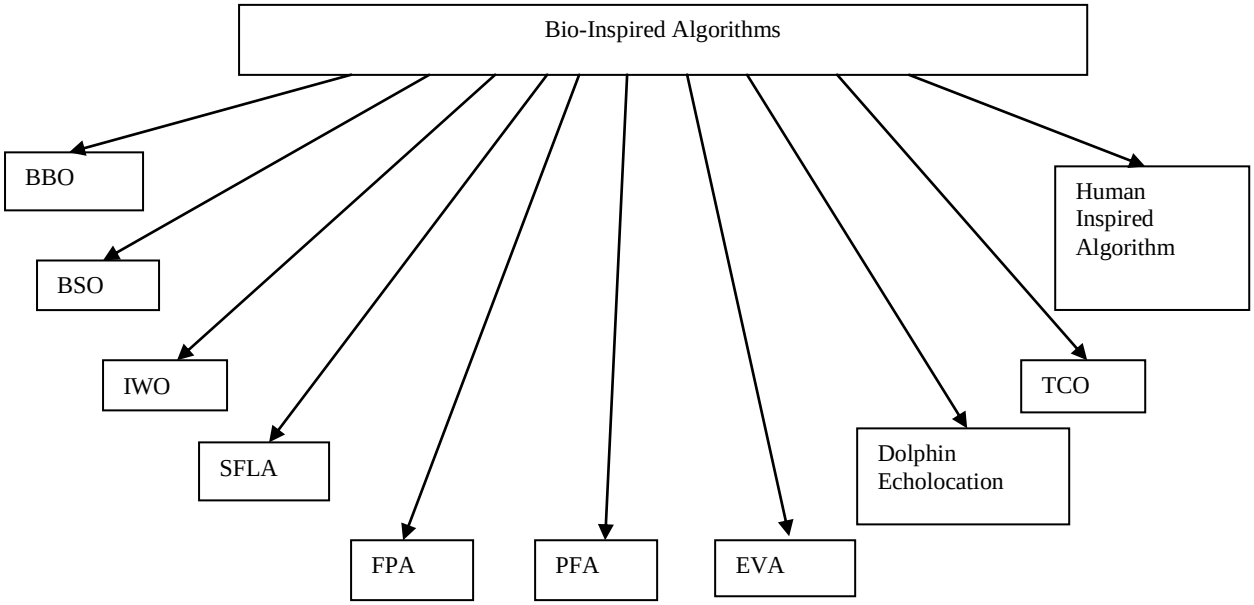

Fig.5 Different Bio-Inspired Algorithms which are not based on Swarm Intelligence

The meaning of the abbreviations used in fig.4 and fig.5 is described in table-I as shown below.

Table-I: Meaning of the Abbreviations used in fig.4 and fig.5

S.No.	Abbreviation	Full-Form of the Algorithm
1.	PSO	Particle Swarm Optimization
2.	ACO	Ant Colony Optimization
3.	ABC	Artificial Bee Colony
4.	FSA	Fish School Algorithm
5.	GSO	Glowworm Swarm Optimization
6.	FA	Firefly Algorithm
7.	BBO	Biogeography Based Optimization
8.	BSO	Brain Storm Optimization
9.	IWO	Invasive Weed Optimization
10.	SFLA	Shuffled Frog Leap Algorithm
11.	FPA	Flower Pollination Algorithm
12.	PFA	Paddy Field Algorithm
13.	EVA	Egyptian Vulture Algorithm
14.	TCO	Termite colony optimization

D. Physics and Chemistry Based Algorithms

There is a certain group of algorithms which are inspired by the natural phenomenon other than biology; this category of algorithms is generally inspired by the physical or chemical processes occurring in nature and is termed as 'Physics and Chemistry Based Algorithms'. Several algorithms belonging to this category are represented by fig.6.

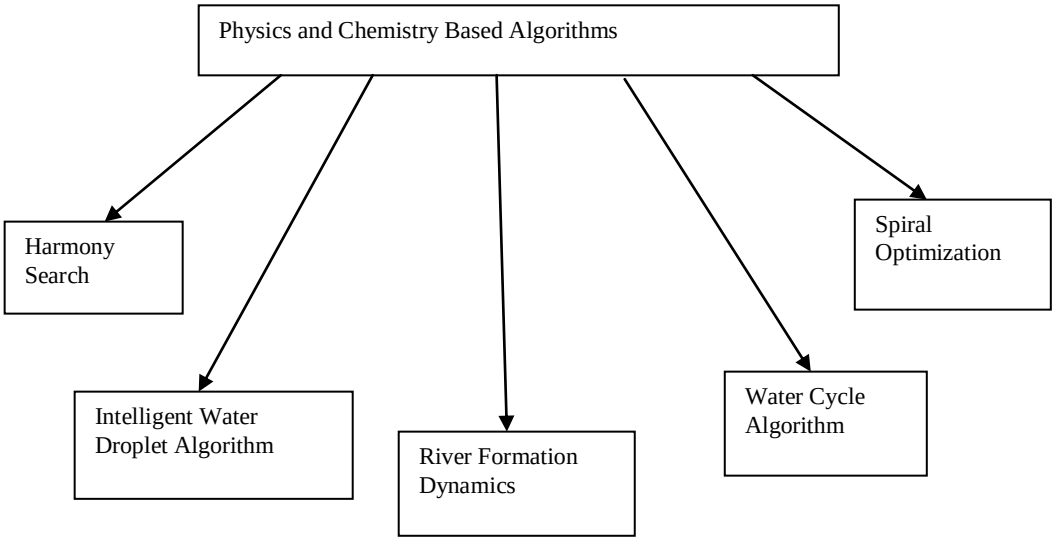

Fig.6 Algorithms Inspired by the Phenomenon Based on Physics and Chemistry

III. APPLICATIONS

NIAs are widely used for solving various real-world problems belonging to different domains that are very complex in nature. Some of the broad application areas of the NIAs are mentioned below.

a. Medical image segmentation and clustering for early diagnosis of diseases.

b. Patient monitoring in ICUs and their mortality prediction.

c. Path planning of robots.

d. Routing in networks.

e. Optimal design of engineering devices.

f. Intrusion detection

g. Prediction in Finance

h. Geological data analysis

i. Industrial optimization

j. Logistics

k. Autonomous vehicles.

l. Traffic control system.

m. Handwritten character recognition.

n. Natural language processing.

o. Operations Research

p. Anomaly detection etc-.

IV. CHALLENGES

Although many NIAs have been developed and are being used widely, there are some issues associated with them. Some of these are discussed below:

a. 'No Free Lunch theorem for optimization', proposed by Wolpert in 1997 [14], still proves to be true, i.e. there is no 'master' nature-inspired algorithm that will give best results for any kind of optimization problem.

b. Plethora of NIAs have been proposed recently. But for many of these algorithms only empirical analysis has been performed, and the mathematical analysis lags far behind.

c. NIAs are stochastic in nature i.e. they involve randomness in their functioning, and hence do not guarantee to return the optimal solution (although they do give near-optimal solution).

d. Most of the NIAs involve many parameters, fine-tuning all of them is quite challenging.

e. A proper balance between 'exploration' and 'exploitation' needs to be maintained, which requires a lot of effort in many of the NIAs.

V. Conclusion and Future Extension

In this paper, a preliminary survey of the NIAs has been presented. An endeavor has been made to cover as many NIAs as possible, while keeping the manuscript simple and easy to understand. NIAs have also been classified into major categories on the basis of their source of inspiration like: Evolutionary algorithms, Swarm intelligence based algorithms, Bio-inspired algorithms (but not swarm based), Physics/Chemistry based algorithms etc. Different application areas of the NIAs are mentioned, and limitations or challenges in the field of nature-inspired computing are also discussed. The survey could be remarkably extended by describing each one of the NIAs in detail, and by performing the suitability analysis of the various NIAs for different kinds of applications.

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