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A Survey on Bio-inspired Algorithms of Cybersecurity

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ABSTRACT: Cyberspace has evolved into a vital resource and dynamic hub for modern living as a result of a rising reliance on information, technology, and communication. As a result, cyber security concerns are a worldwide phenomenon with disastrous effects. Because of its worldwide connectivity and data explosion, cyberspace is complicated and unpredictable, and as cyber infrastructures get more intricate and dynamic, so does the threat surface. Cyberspace management, or securing and assuring security, calls for the use of sophisticated complex systems. Natural tendencies that facilitate adaptability for survival have been generated by nature through evolution in complex systems, including animal and plant life. By using them in cyber security, predation-avoidance and anti-predation strategies used by non-extinct prey could be exploited or adopted as mechanisms for adaptability. An overview of the existing situation of is provided in this chapter. With the explosion of data generation, finding optimal solutions to data-driven issues is becoming increasingly difficult, if not impossible. It is becoming increasingly clear that the use of intelligent bio-inspired algorithms is required for addressing highly complex problems and providing working solutions in a timely manner, especially when dealing with dynamic problem definitions, fluctuating constraints, incomplete or imperfect information, and limited computation capacity. As a result, more and more intelligent algorithms are being investigated for solving various complex issues.

Keywords: Bio-inspired ,Feature Selection, Cybersecurity, Optimization Techniques

1. INTRODUCTION

Humans typically plan, create, administer, and oversee the present cyber security infrastructure, which has a significant impact on the decision-making process. For example, what characteristics should the system have? and what actions it ought to repeat? The main disadvantage of such systems' automation may be their reliance on human administration to be programmed and informed what to do (and how to execute it). Due to non-adaptive behavior, present designs are therefore neither robust nor resilient because they cannot adapt (i.e., optimize a specific goal in a dynamic environment) to a novel or unexpected circumstance in a constantly changing environment. As a result, there is an alternative to creating security architectures that require ongoing human monitoring and management. Every biological system in nature, if we examine closely, operates according to the principles that are missing from the security architectures in use today. For example (1) due to the development of the immune system and the biological systems are constantly undergoing alterations due to the centuries-long modifications that living things' physiology has undergone. Genuinely resilient and strong. The immune system in particular has been acting in a reactive and a flexible manner from the start, as a result of which Compared to the past, life expectancy has dramatically improved. older generations. (2) The details at the organism and Without the presence of any centralized control, processing at the cellular level is done in parallel and across different locations. At the same time, the management of the current cyber infrastructure is growing more difficult and complex. The management of hundreds or thousands of security devices in a company with thousands of employees presents significant technical hurdles. security measures alone and without assistance from humans, which could result in poor management. Even so In light of these difficulties, the security community is suggesting and creating amazing solutions that are motivated by self-organization biological processes that are inherent to nature[1] . (3) There are vast populations of social insects like ants and bees. Many relatively simple creatures can construct intricate nests or determine the quickest route from the nest to the food supply. Making adjustments to duties in order to attain such In these cultures, cooperative effort is used to complete the difficult aim,

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demonstrating the size of the overall job (under each individual response) in the direction of a global intelligence outcome target made up of modest but significant individual responses [2], Cyber Champions experience the fewest serious attacks and the fewest successful breaches (8 percentage points fewer than Business Blockers and 36 percentage points fewer than Cyber Risk Takers) (Figure 2).Cyber Champions respond to detection and remediation more quickly; an extra day of being fully functional can significantly affect the bottom line .Cyber Champions are better able to guard against data loss; only 4% of Cyber Champions lose more than 500,000 records, which is 6.5X fewer than Cyber Risk Takers, who account for 27% of data loss incidents . The fact that the Cyber Champions have a greater percentage of business unit leads who are in charge of cybersecurity — nearly twice (1.9X) that of the industry average — may contribute to some of their success in aligning with the business Cyber Risk Takers [3].

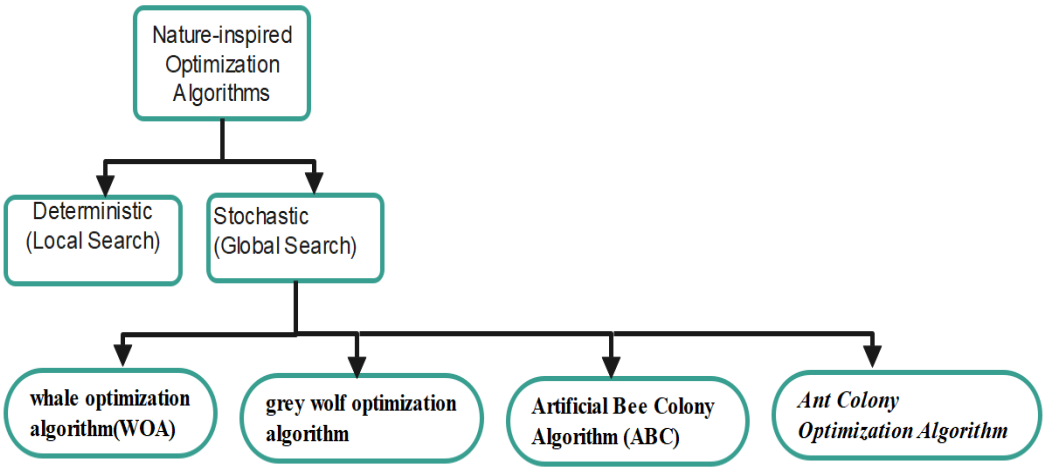

FIGURE 1. - Classification of bio-inspired research [3]

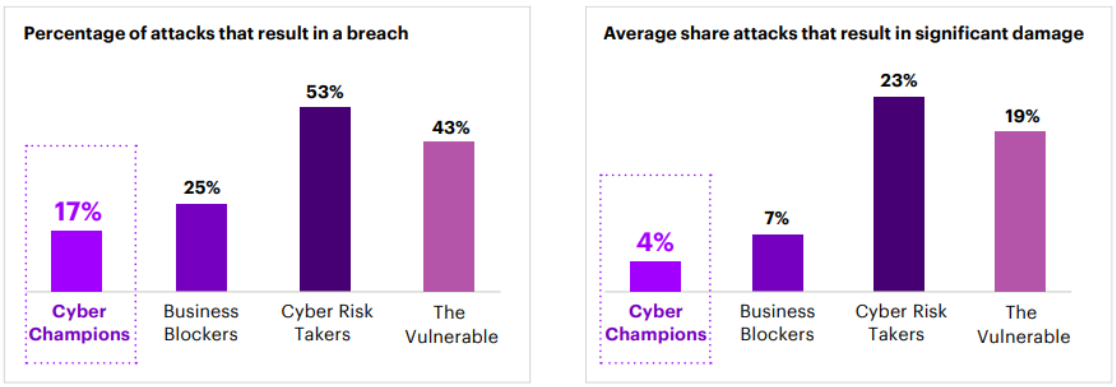

FIGURE 2. - Impact of breaches on Cyber Champions (Source: Accenture State of Cybersecurity Resilience 2021, security executives (N=3,455: Cyber Champions N=172, Business Blockers N=522, Cyber Risk Takers N=885, The Vulnerable N=1,876)

2. FEATURES SELECTION

The challenge with feature selection is how to select the fewest amount of features from the original dataset, which can occasionally have a lot of features. With the passage of time, the necessity of feature selection has grown in significance in order to advance, find answers, and illuminate several issues[4].

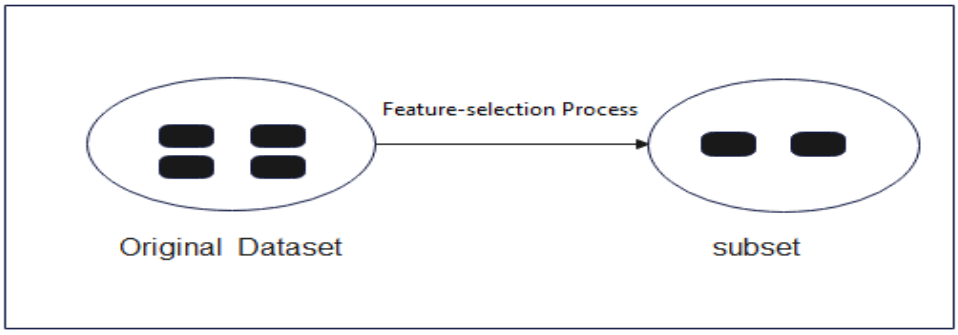

FIGURE 3. - A concept of feature selection

2.1 FEATURES -SELECTION PROCESS

One of the most crucial steps in data mining and artificial intelligence is feature selection, which aims to provide a set of training data for use in predictive modeling. A subset of the entire dataset is chosen for the process, and this subset has the bare minimum of attributes required to achieve the greatest amount of data variation feasible [5] [6].

Any feature is relevant if the decision depends on it; otherwise, it is irrelevant. The feature-selection method will eliminate redundant, irrelevant, and misguiding features to achieve the optimal subset representing the best answer. Additionally, if it has a strong correlation with other variables, it will be redundant. Accuracy of categorization will frequently improve as a result of all this [7] [8].

This process can be done in two ways:

• Forward selection: Here the features are chosen one by one, when at the beginning, the generation subset is empty.

• Backward elimination: Here all features are chosen and then they are eliminated one by one.

3. OPTIMIZATION TECHNIQUES

Optimization techniques determine the optimal solution for any given problem's feasible solution. Many of these methods solve functions with single and multiple variables, with or without constraints. Various methods are used to derive these techniques such as linear method, nonlinear simulated annealing [9], being inspired from metallurgical strengthening process, and genetic algorithms that find the best solution from a given population. Optimization techniques are classified as a traditional or heuristic-based approach. being inspired from metallurgical strengthening process, and genetic algorithms that find the best answer from a given population. Optimization methods are classified as either traditional or heuristic. To discover the best solution, traditional methods employ differential calculus techniques [10],[11]. The traditional technique is also referred to as direct or gradient methods [12] vemploys objective function values; however, in gradient methods [13], information from the derivative function is employed. We use heuristic-based methods to achieve improved outcomes for complex problems [14].As shown in Fig. 4, this method can be classified as evolution-based[15]. nature-based swarm intelligence[16] and logically based. Darwinian evolution inspires evolutionary methods.

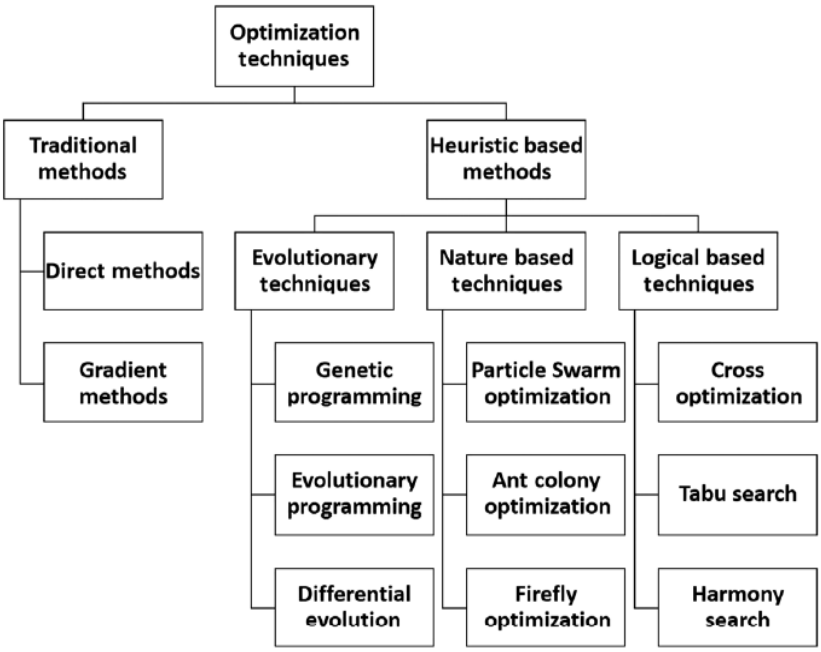

FIGURE 4. - Classification of bioinspired optimization techniques[17]

4. BIO-INSPIRED APPROACHES FOR CYBERSECURITY

4.1 ANT COLONY OPTIMIZATION ALGORITHIM (ACO)

created the ACO algorithm in 1999, basing it on ant social behavior [18][19]. Comparing ACO's methods to FA's, which use attraction, and ABC's, which employ route concentration (quality of solutions) [20].

The intrusion detection system is intended to detect intrusions. The assault comprises of either a signature-based or an anomaly-based detection approach. However, this identification technique is very reliant on the input quality features. discovers a strategy to detection using supervised learning the connection between a class and an attribute. In order to improve ant colonies, On the KDD99 dataset, a feature selection request was made [21].

4.2 ARTIFICIAL BEE COLONY ALGORITHIM (ABC)

proposed the Artificial Bee Colony Algorithm (ABC) in 2005 [22].There are two fundamental bee behaviors in the ABC algorithm. One is that if a bee discovers a plentiful food source, it directs other bees to the source of food. Bees are the other giving up on one food source and seeking for another [23].

Systems for intrusion detection and prevention are part of a full network architecture with protection needs for it as a result of work done at faster speeds. Where ABC operates, based on intelligent search bee swarm behavior and intrusion detection approach. Use of the CART and BNMB option selection algorithms, which boost discovery and decrease computational complexity, is another addition [20].

4.3 GREY WOLF OPTIMIZATION ALGORITHIM

The GWO is a suggested swarm-based algorithm.by (Mirjalili 2014). (Mirjalili 2014). To find the dataset's most pertinent features that contribute to high classification accuracy, the GWO method was used as a feature selection mechanism. Additionally, support vector machines were employed to determine the accuracy with which certain traits may anticipate attacks. To find the dataset's most pertinent features that contribute to high classification accuracy, the GWO method was used as a feature selection mechanism. Additionally, the performance of the suggested technique was tested using 20% of the NSL—KDD dataset. This study's analysis method is based on data separation. Through testing the IDS system against new kinds of network threats, this technique is essential for determining the effectiveness of the system and revealing its true performance [24].

4.4 WHALE OPTIMIZATION ALGORITHIM

The WOA is a revolutionary population-based stochastic optimization technique that was recently created and is inspired by nature. The WOA employs a group of search agents to determine which optimization problem has the greatest solution [24].

Energy systems heavily rely on cyber infrastructure , hence cyber security is a key concern. such as infrastructure that can distribute and process a substantial volume of real-time data produced during system operations F. Using data sets from MSU and ORNL, the WOA-ANN model has been used to categorize attacks and detect power system failures at various levels of difficulty (dual, triple, multi-category). Get the best weights and biases for classification tasks with the lowest MSE using ANN trained with WOA. Finding the attack information in the power system [25].

4.5 PARTICLE SWARM OPTIMIZATION ALGORITHIM (PSO):

Kennedy and Eberhart created SO in 1995, basing it on the natural schooling behaviors of fish and birds [26], [27]. Due to PSO's book "SZarm Intelligent detailed "s explanation of algorithm operation, it is frequently utilized [20].

Particle motion is affected by deterministic and random elements. These two important parameters were used to determine the current best location and the current best global location. Because IoT environments lack proper security and preventive monitoring technologies, DoS assaults happen there. identifies attacks like DoS, Probe, and U2R using hybrid particle swarm optimization. The most significant security flaw in IoT applications is that no encrypted user can provide full access control if assaults are handled over a wide region. Additionally, the implementation environment that assesses the degree of security breach in a particular data set can be quite difficult, as is the case for some Users who transfer data using deep-rooted software Forms that are encrypted with private keys [27].

4.6 CUCKOO SEARCH ALGORITHIM

For the purpose of resolving optimization issues, Xin Shen Yang devised a brand-new metaheuristic method called the cuckoo search algorithm (CSA. equations The data were classified as having High disparities between normal and suspicious data distributions, and the models were statistically classified as nonlinear and non-Gaussian. The cuckoo search strategy is applied to these distributions' nonlinear equations [28].

In order to limit the quantity of features, we have applied the Cuckoo Search algorithm to a variety of network intrusion data. We contrast CS's performance with that of the GA and PSO. The majority of the critical features were successfully chosen by the CS algorithm, and intrusion detection rates were kept high [28].

4.7 BAT ALGORITHIM

Yang proposed the Bat Method (BA), a swarm intelligence algorithm, in 2010 [29]. The echolocation of micro bats, which generate a loud sound pulse to identify an obstruction or a prey, served as the author's inspiration. Everyone in the group has the same personality type, and they all fly aimlessly while looking for their destination. In order to handle huge data volumes and fast network connections in real time, new security solutions are needed due to the never-ending stream of security threats. IDS for network anomalies that incorporate the Support Vector Machines classifier with An upgraded version of the BAT (BA) algorithm are a common feature of most security systems. In terms of attack detection rate and false alarms created with less repetitions, we employ binary and BA versions [30].

4.8 BEE ALGORITHIM

A brand-new population-based search algorithm called the Bees Algorithm (BA) was created in 2005 [31]. The program imitates how honey bee swarms forage for food. Biology and computing may be related. The primary strategy of the research to increase the efficacy of IDS was based on the detecting system in honeybees that protects the colony. The focus during UA phase was on the attack features. A neural network was trained to identify the attack features in order to categorize them as undesired qualities during the testing phase [32].

4.9 CAT SWARM OPTIMIZATION

is based on monitoring the behavior of cats. It consists of two stages—tracing mode and seeking mode—and the combination of these two phases provides this method considerable strength [33].

The original cat swarm optimization for feature selection issue, also known as ICSO, was improved by Lin et al. in 2016. The phrase "Frequency-Inverse Document Frequency" was used by the authors to provide two improvements to the current CSO (TFIDF). The proposed strategy outperformed the native CSO in terms of accuracy [34].

4.10 GRASSHOPPER OPTIMIZATION ALGORITHIM

The The Grasshopper Optimization Algorithm (GOA), which was proposed by Saremi et al. provides mathematical models that solve optimization challenges .that mimic the actions of insects and grasshoppers in the natural world [35]

Mafarja et al. (2017) found that combining Evolutionary Population Dynamics (EPD) with GOA increased the effectiveness of the basic GOA for feature selection challenges .Results and analysis from using the suggested strategy on 22 benchmark datasets show that Analysis demonstrated that the suggested technique enhanced the feature-selection procedure.in classification accuracy, the number of features chosen, the amount of CPU time used, and When compared, the convergence tendencies of all hybrid approaches [36] .

4.11MOTH FLAME OPTIMIZATION

Moth Flame Optimization (MFO), which Mirjalili (2015) introduced, was inspired by the way that moths migrate in nature, which is to fly at night in a straight line for very long distances while maintaining a fixed angle towards the moon. For solving optimization issues, this simulation technique has been successful [37].

such as the GA and PSO based on well-known datasets, were compared to the proposed technique. The suggested algorithm's superior performance over previous feature selection methods was demonstrated [38].

4.12FIREFLY ALGORITHIM

was developed by Yang (2009) and is presently utilized for a variety of optimization issues. It was inspired by the behavior of fireflies, which attract other fireflies by flashing signals. By suggesting a Return-Cost-based Binary Firefly Algorithm, Zhang et al. (2017)[39] .

enhanced the ability of FA in the feature-selection area (RC-BBFA). The results show that the RC-BBFA reduced th number of attributes with excellent classification accuracy after applying the suggested strategy to 10 datasets.

4.13FISH SWARM OPTIMIZATION ALGORITHIM

Fish swarm optimization (FSO) was introduced by Li (2002) as a way to express the intelligent behavior of fish over the course of their existence in terms of foraging, migration, and other forms of group behavior[39]

In order to improve the accuracy of the feature-selection procedure, Manikandan and Kalpana (2017) improved the native FSO technique in artificial fish swarm optimization (AFSO) and used it with the Classification and Regression Tree (CART). AFSO performs better, according to the results, in terms of measure, accuracy, precision, and recall [40].

4.14CROW SEARCH ALGORITHIM

Since it is well known that crows store leftover food in different storage capacities so they can return to these in case they become hungry, Askarzadeh (2016) presented the Crow Search Algorithm, which was inspired by the cunning behavior of the crow [41].

The Chaotic Crow Search Algorithm (CCSA), which Sayed et al. (2017) presented, is a new algorithm that improves upon the original Crow Search Algorithm (CSA) in the feature selection domain. The native CSO's random movement settings were swapped out for ten chaotic maps. The outcome shows that (CCSA) outperformed the native CSA and had a higher value in the best and mean fitness value test [42].

Table 1. - Summary of Bio-inspired Algorithm

Authors	Algorithm	Description	Application
Dorigo	1- Ant Colony Optimization (ACO)	Continuously running and able to adjust in real time to changes is the ant colony algorithm. Urban transportation systems and network routing are both interested in this.	On the KDD99 dataset
Karaboga	2- Artificial Bee Colony Algorithm (ABC)	Additional benefits of the ABC algorithm include excellent robustness, quick convergence, and high adaptability.	*Use of the CART and BNMB option selection algorithms*
Mirjalili	3- grey wolf optimization algorithm	simple in concept, quick to seek out, highly precise in their search, and simple to implement,	On the NSL—KDD dataset
Xin-She Yang and Suash Deb	6-Cuckoo Search Algorithm	fewer tuning factors and easier to apply.	network intrusion data
Xin-She Yang	7-Bat Algorithm	The purpose of the bat algorithm is to find solutions using algorithms based on local search and	NSL-KDD dataset

		population.	
Karaboga	8- Bee Algorithm	to enhance local search while preserving GA's capability for global search.	KDD'99 dataset
Chu and Tsai	9- Cat Swarm Optimization	simple idea, straightforward implementation, robustness to control parameters, and effective computation	(TFIDF)
Saremi et al	10-Grasshopper Optimization Algorithm	It offers the GOA versions, including hybrid and multi-objective variants. Additionally, it covers the key uses of GOA in a number of different contexts, including scheduling, economic dispatch, feature selection, load frequency management, distributed generation, wind energy systems, and other engineering issues.	22 benchmark datasets
S. Mirjalili	11-Moth Flame Optimization	having a small number of setting parameters, being simple to comprehend and use, and achieving quick convergence.	KDDCUP 99, NLS-KDD

5. Conclusions

In conclusion, this study survey offered a thorough examination of the most recent research methodologies and computational methods pertaining to biologically inspired algorithms. The material cited primarily addressed bio-inspired algorithms. The majority of the cited literature concentrated on Dynamically Inspired Algorithms: Where I Used PSO's Approach to Address Problems with Extreme Cloud Computing Security. Additionally, algorithms like Ant Colony have garnered interest for their ability to interpret certain problems between researchers. However, other research also used the GA approach to create a secure network system. Given the multi-objective optimization utilizing GA-based GA Approaching, a potential future application would be intriguing because the majority of the results were simulation-based and did not integrate with other models of matching, learning, and prediction.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest

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