UNIVERSITI PUTRA MALAYSIA

NUMERICAL SIMULATION AND ANIMATION OF A DOLPHIN SWARM OPTIMIZATION FOR THE DETECTION AND HUNTING OF INTRUDERS IN A 3D ENVIRONMENT

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By

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DEDICATION

This thesis is wholeheartedly dedicated to my beloved family and friends, especially to my mother who always give unconditional love and my father who I miss. I also dedicated this thesis to my siblings, and my dearest best friend

ABSTRACT

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By
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The analysis of swarm intelligence algorithms has been successfully implemented to several optimization algorithms as a problem-solving strategy for problems that are difficult to solve using standard methods. There are many well-implemented algorithms available now, including particle swarm optimization, genetic algorithms, artificial bee colony algorithms, and ant colony optimization. Those algorithms have already proven promising results. However, as objects become more complicated, it becomes extremely difficult for algorithms to match human demands and expectations of prediction accuracy. Furthermore, there is an urgent need for a security system to detect various malicious threats, as humans have already entered a technological period in which information and data interchange is distributed all around community, including personal data. This intrusion detection-based system can be combined with various numerical solution techniques to improve their performance, and Dolphin Swarm Optimization is one such approach because dolphins have many notable biological traits and living habits including echolocation, information exchanges, cooperation, and division of labour, which can then be combined with swarm intelligence and brought into optimization problems. There are also numerous descriptions of the algorithm's four pivotal phases, which are the searching phase, the call phase, the receiving phase, and the predation phase. Dolphin swarm optimization can be used to enable efficient and accuracy for identifying and hunting intruders by combining biological traits of marine mammals known as dolphins with swarm intelligence. Security frameworks are evaluated with different optimization algorithms in terms of parameters such as false positive, detection rate, detection time, and

so on, and it is determined which optimization technique performs better. Furthermore, the dolphin swarm method, particle swarm optimization, genetic algorithm, and artificial bee colony algorithm are used to test ten benchmark functions with diverse features. To demonstrate the influence of the dolphin swarm algorithm, the convergence rates and benchmark function outputs of these four methods are compared. The results reveal that the dolphin swarm method outperforms the other algorithms in most circumstances. The dolphin swarm algorithm has some excellent characteristics, including first-slow-then-fast convergence, periodic convergence, local-optimum-freeness, and no specific need on benchmark functions. Furthermore, the dolphin swarm technique is well suited to optimization problems involving more fitness function calls and fewer people.

ABSTRAK

SIMULASI DAN ANIMASI BERANGKA PENGOPTIMUNAN KUMPULAN IKAN LUMBA-LUMBA UNTUK MENGESAN DAN MEMBURU PENCEROBOH DALAM PERSEKITARAN 3D

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Analisis algoritma kelompok kecerdasan telah berjaya dilaksanakan kepada beberapa algoritma pengoptimuman sebagai strategi penyelesaian masalah bagi masalah yang sukar diselesaikan menggunakan kaedah biasa. Sekarang, terdapat banyak algoritma yang dilaksanakan dengan baik, termasuklah pengoptimuman kumpulan zarah, algoritma genetik, algoritma populasi lebah tiruan dan pengoptimuman kumpulan semut. Algoritma tersebut telah membuktikan hasil yang memuaskan. Walau bagaimanapun, apabila objek menjadi lebih rumit, ia menjadi sangat sukar bagi algoritma untuk memuaskan permintaan manusia dan ramalan jangkaan dan ketepatan. Tambahan pula, terdapat keperluan mendesak untuk sistem keselamatan bagi mengesan pelbagai ancaman berbahaya, kerana manusia telah memasuki zaman teknologi di mana pertukaran maklumat dan data dapat diedarkan ke seluruh komuniti, termasuk data peribadi. Sistem berasaskan pengesanan penceroboh ini boleh digabungkan dengan pelbagai teknik penyelesaian berangka untuk meningkatkan prestasinya, dan pengoptimuman kawanan ikan lumba-lumba adalah salah satu pendekatan yang terbaik kerana ikan lumba-lumba mempunyai banyak ciri-ciri biologi dan habitat hidup yang ketara termasuk ekolokasi, pertukaran maklumat, untuk kerjasama, dan pembahagian kerja, yang kemudiannya boleh digabungkan dengan kelompok kecerdasan dan dapat dibawa dalam masalah pengoptimuman. Terdapat juga banyak penerangan tentang empat fasa penting algoritma, iaitu fasa pencarian, fasa panggilan, fasa penerimaan dan fasa pemangsa. Pengoptimuman kawanan lumba-lumba boleh digunakan untuk membolehkan kecekapan dan ketepatan untuk mengenal pasti dan memburu penceroboh dengan menggabungkan ciri

biologi mamalia laut yang dikenali sebagai ikan lumba-lumba dengan kelopmpok kecerdasan. Rangka kerja keselamatan dinilai dengan algoritma pengoptimuman yang berbeza dari segi parameter seperti positif yang palsu, kadar pengesanan, masa pengesanan, dan lain-lain, kemudian teknik pengoptimuman ditentukan berdasarkan prestasi yang lebih baik. Tambahan pula, kaedah kawanan ikan lumba-lumba, pengoptimuman kawanan zarah, algoritma genetik, dan algoritma populasi lebah tiruan digunakan untuk menguji sepuluh fungsi penanda aras dengan pelbagai ciri. Bagi menunjukkan pengaruh algoritma kawanan ikan lumba-lumba, kadar penumpuan dan hasil fungsi penanda aras bagi keempat-empat kaedah ini dibandingkan. Hasilnya mendedahkan bahawa kaedah kawanan ikan lumba-lumba mengatasi algoritma lain dalam kebanyakan keadaan. Algoritma kawanan ikan lumba-lumba mempunyai beberapa ciri yang sangat baik, termasuk penumpuan pertama-perlahan-kemudian-cepat, penumpuan berkala, kebebasan-optimum tempatan dan tiada keperluan khusus pada fungsi penanda aras. Tambahan pula, teknik kawanan ikan lumba-lumba sangat sesuai untuk masalah pengoptimuman yang melibatkan lebih sedikit orang dan lebih banyak panggilan fungsi kecergasan.

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I would like to devote my thesis to my dearest best friend, Nazatul Syahirah Binti Mohd Fazeli, who always be there through thick and thin, cheering me on and console me when I have a hard time. Thank you so much for everything.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREAVATIONS

ABC	Artificial Bee Colony Algorithm
ACO	Ant Colony Optimization
AI	Artificial Intelligence
BA	Bat Algorithm
DR	Detection Rate
DSA	Dolphin Swarm Algorithm
DSO	Dolphin Swarm Optimization
FAR	False Alarm Rate
FPR	False Positive Rate
HIDS	Host-based Intrusion Detection System
IDS	Intrusion Detection System
IoT	Internet of Thing
KDD	Knowledge Discovery Database
MANET	Mobile Ad-hoc Network
MIDS	Misuse Intrusion Detection System
NIDS	Network-based Intrusion Detection System
NSL	Network Security Laboratory
PSO	Particle Swarm Optimization
RNN	Random Neural Network
SI	Swarm Intelligence
SSO	Social Spider Optimization
VANET	Vehicular Ad-hoc Network

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Artificial intelligences (AI) are currently being developed all over the world to help in a variety of fields. Swarm intelligences (SI) were introduced in the 1980s as a mobile robotic system that distributes collective behaviour and self-organized technique using modern technology, science, and engineering. SI can also refer to the endeavour to create algorithms or issued problem-solving systems that are inspired by the collective nature of the social insect communities and other animal groups (Bonabeau et al., 1999).

The concept is derived from the term of swarm behaviour or swarming, which is defined as the movement of a large variety of insects or microscopic organisms. These can be defined as similar insect species or animals working with one another in collective behaviour, such as moving in the same direction or guarding one another.

Therefore, various research and studies are being undertaken to concentrate on the SI structure through conscience and collective behaviour in nature, which including communities of insects, flocks of birds, swarms of bees, and so on. Various algorithms based on SI algorithms are used to address difficult optimization problems with natural influences. Several studies have already been conducted by copying nature and then assimilating the nature behaviour into swarm intelligences studies. Some well-known swarm intelligence research, for example, particle swarm optimization (PSO), artificial bee colony (ABC), and bat algorithms (BA), have already been studied and practised for the improvement of better systems. One of its systems is one for detecting and tracking intruders.

Intruder detection and hunting are crucial in today's environment, because almost everyone owns a smart gadget as being one of the necessities. Security protection against risks and vulnerabilities is a fundamental component in network-space. Intrusion Detection Systems are the first detection systems to recognise and appear.

Furthermore, Dolphin Swarm Optimization (DSO) is a study using swarm intelligence that takes control of a marine species known as a dolphin. Dolphins are currently attracting the attention from numerous experts who want to learn further about dolphins due to their unique biological characteristics and surroundings. DSO also benefits from dolphin characteristics such as echolocations and their capacity to devise techniques for detecting and hunting predators, making them the greatest options for intruder detection.

1.2 Introduction

Mammalia that called "Dolphin" is acknowledge as one of the smartest, unique, and interesting among aquatic mammalians. There are more than 36 species of marine dolphins left that habitually live-in oceans and some of them live in rivers. They categorized as oceanic dolphins and river dolphins in which part of toothed whales but mostly smaller than whales. In addition, dolphin hearing is sharp so that they can adapt to both in air and water. A group of dolphins are also known as pod. Dolphins are social creatures that socialise, move together, defend one another, and search of food as a group. Pod life is critical in defending dolphins from threats such as sharks. Most pods comprise between 2 to 30 dolphins, based on the variety and the situation, although there are times when pods join forces with the other pods to create superpods of 100 or even thousands of dolphins. Superpods normally only remain for a brief time and may appear during mating season and whenever prey is abundant in a region. When the dolphins have finished engaging in the activity, they will back to their own pods alongside their family and/or friends until they contact some other dolphins for the next gathering.

Numerical optimization is the process of selecting the optimal element from a set of accessible alternatives based on some criterion. Optimization issues of various types appear in all quantitative disciplines, ranging from computer science and engineering to machine learning and finance, and the discovery of solution methods has long been a topic of study in mathematics. In its most basic form, an optimization issue consists of maximising or minimising a functional purpose by systematically selecting input values from a permitted set and determining the function's value. The application of optimization ideas and methods to new formulations is a significant topic in applied mathematics. In a wider sense, optimization involves obtaining the ideal suitable solution of some optimization issue given a specific context (or input), that may also include a variety of different types of objective functions and domains.

1.3 Problem Statement

Since several years, technology, research, and engineering have moved in the direction of AI and machine learning. People today depend more on technologies and modern intelligence, which has become a must for everybody because all data or information can be retrieved through the Internet of Things (IoT). As a result, attackers are improving their methods for breaching safety and confidentiality via networking, and in the worst-case situation, they may acquire people's information. Even though many security systems have been designed by experts, some problems still exist, and one of the key challenges is that new sets of rules evolve over time, making it difficult to keep up with the most recent regulations.

This research study may be useful in strengthening safety and defense solutions through simulating natural behaviour through swarm intelligence. For example, this study makes use of Dolphin Swarm Optimization (DSO), which is based on the behaviour of a swarm of dolphins when they discover the target, then search, hunt, and finally attack their prey using their own strategies (Yong *et al.*, 2016; Wu *et al.*, 2016; Li & Wang, 2019).

1.4 Objectives of the Study

In this research work, there are three main purposes that need to explore, such as:

- To investigate the detection and hunting of intruders using dolphin swarm optimization
- To analyze the performance of swarm intelligences in creating intrusion detection system.
- To compare the efficacy of dolphin swarm optimization against different swarm optimizations.

1.5 Significant of Study

In this research, swarm intelligence inspired from nature can help further development in many ranges of research fields such as science, engineering, computer science, medicine, and financial study. This is because of their natural habitat, traits, and behavior that looks complex to learn, but their characteristics can help people today to overcome variety of possible complex problems that require different solutions. Furthermore, the research helps to improve detection and hunting system of intruders using Dolphin Swarm Optimization (DSO).

1.6 Chapter Organization

This thesis consists of five main chapters where the first chapter is discussing the outline and the introduction of the research study. In the second chapter, the literature review based on earlier researcher and study that related with this research has discussed. Moreover, the third chapter is a methodology and an explanation of the elements and processes that have been implemented during this project. In addition, the detection and hunting of intruders using DSO was analysed in Chapter Four. In Chapter Five, the conclusion of the entire project and future studies related to this project have been suggested.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter offer an overview of earlier study and relevant literature related to progression and part of study in this research. The detection and hunting of intruders also would further review as it is our main purpose for the study.

2.2 Swarm Intelligence

Beni came up with the term "Swarm Intelligence" (SI) in the concept of cellular robotics systems (Beni and Wang, 1989). This research field's methodology, methods, and techniques are influenced by the activity of insects, animals, and fishes, and their amazing capacity to execute difficult tasks in the form of groups, which appears unreachable at the individual level. Individual ants, bees, birds, and fish have seemed to have very limited intelligence, but when they socially interact with one another and with their environment, they appear to be capable of performing difficult things such as finding the shortest route to a food supply, preparing their nest, synchronizing their movement, and travelling as a single coherent entity at high speed, and so on. This achievement is even more when one considers that they carry out such activities without the involvement of a central power, for instance the queen of the hive that commanding any of this behaviour. There are variety of optimization method based on biological traits of animals and nature that are being studied and researched. For instance, particle swarm optimization (PSO), genetic algorithm (GA), artificial bee colony algorithm

(ABC), ant colony optimization (ACO), and social spider optimization (SSO) are currently gain much attention from researcher as their performance is favourable and well implemented.

2.2.1. Particle Swarm Optimization

The concept of particle swarm optimization (PSO) has been applied in a variety of situations to solve a variety of problems. PSO's algorithm mimics the behaviour of animal groups that lack a ruler among the group or colony, such as flock of birds and schools of fish. The PSO algorithm's approach for determining optimal values is inspired by the activities of this animal community. Particle swarm optimization is composed of a swarm of particles, which each pose a potential solution. Generally, a community of animals without leaders would seek food at random, following another of the groups who is in the closest position to a food supply (potential solution). These groups accomplish their satisfactory at the same time by conversing among members who are already in a better situation. The animal in better situation will alert the groups, and others will migrate to that location at the same time. This would continue until the best conditions, or a source of food are being secured (Rini, Shamsuddin & Yuhaniz, 2019).

2.2.2. Genetic Algorithm

A genetic algorithm (GA) is a method for solving limited and unlimited optimization problems inspired by the natural selection phase that replicates biological development. Genetic algorithms are often conducted to achieve high-quality methods for solving problems by utilising biologically inspired operators including mutation, crossover, and selection. Besides, the algorithm develops a network of feasible solutions where Throughout time, the community evolves toward an ideal outcome. At every phase, the genetic algorithm randomly picks members from the selected population and uses them as ‘parents’ to develop the ‘children’ for the further phase.

2.2.3. Artificial Bee Colony

The artificial bee colony (ABC) method is an optimization technique that simulates honeybee food source and has been successfully applied to a wide range of practical issues. It was influenced by honeybees' clever foraging behaviour. The method is especially based on the model presented by Tereshko and Loengarov (2005) for honeybee colony foraging behaviour. The model is made up of three key components: employed and unemployed foraging bees, as well as food sources.

2.3 Dolphin Swarm Optimization

Dolphins usually interact and communicate with each other by echolocation ways which by vocalization or whistling. The principle of echolocation of dolphins is similar with the communication among bats; they produce bio sonar by emitting high frequency clicks and receiving echo for communication and orientation, enabling dolphins to hunt deep in the sea. Au and Whitlow (1993) claim that dolphins echolocation clicks are the loudest echo made among other marine animals. Furthermore, amplitude of sonar wave produces by dolphin is vary depending on their species.

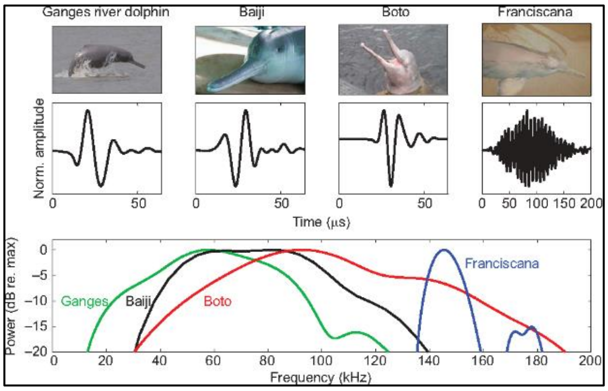

Figure 2.3. 1 - Overview of river dolphin echolocation signals which shows waveforms and power spectra of representative echolocation clicks from the Ganges River Dolphin, Baiji, Boto, and Franciscana

Dolphin's biological traits and living habitat such as echolocation, cooperation and division of labor, and exchange information are giving them advantages to hunt their prey. The unique and interesting about dolphin is they have good eyesight but, they do not use that ability to hunt for prey. They use their special ability to emit bio-sonar instead as their good eyesight is useless when they meet environment with poor light conditions. The echolocations not only help them to communicate with each other, but also use to evaluate the positioning, distance, and size of target based on the echo wave. Moreover, mostly dolphin is mammalian that live in community and move together. This trait is helpful for them when facing their target especially larger target compared to them. They will emit their echo to call other dolphins for assistance to attack the prey, as well as protecting them if they meet predators. Beside cooperate to prey on food or guarding each other, they also have division of system. The dolphins that meet nearby prey will start hunting down the prey before calling other dolphins in the group to surround and attack the target. Furthermore, various research explained that each dolphin can exchange information with each other. They able to express themselves using variety of sound at different frequencies. The exchanging information's trait is the important key for them to achieved successful predation.

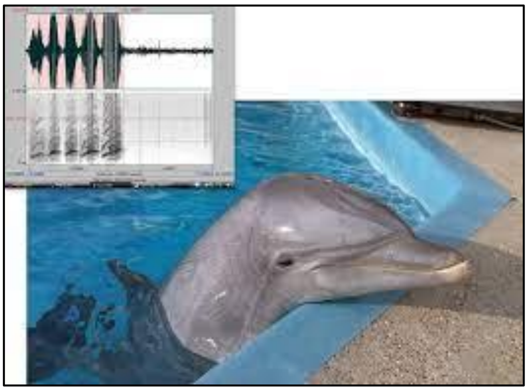

Figure 2.3. 2 - Dolphin Echolocation with amplitude of wave

Dolphins usually live-in group because it is easier for them to protect themselves from predators and hunters. Besides, they can easily hunt for food in group especially hunting large school of fish. For this reason, dolphin swarm optimization (DSO) inspired from dolphin's behavior in detecting, chasing and hunt on school of sardines to perform optimization (Yong et al., 2016). He analyses those dolphins will swim in both flip and rotational swimming technique when hunting and attacking the school of sardines.

Figure 2.3.3 – Swarm of dolphins hunting the school of fish (Yong et al., 2016)

Wu, Yao, and Yang (2016) suggest dolphin swarm algorithm based on dolphin's predatory process from their biological behavior and habitat such as search phase, call phase, reception phase, and predation phase for their goals. The process can implement in pivotal stages that similar as predatory process of dolphin which involving initializing stage, search stage, call stage, reception stage, predation stage and termination stage (Wu et al., 2016).

Starting with initializing stage, the dolphins will use bio-sonar to sense target like a group of small fish such as school of sardines. Then, they will search, hunt, and attack the sardines in their hunt place. The school of small fish usually will form bait-ball formation as the last defensive technique when they exposed to danger of predator, but the formation will attract more predators especially dolphins. When dolphins found their target, they will drive the target into shallow water or stranded the target on the mud banks and completely attack them. These shown that if the dolphins continue to chase after the target until reached the place the benefit them, they surely will achieve their goals of feeding the large group of small fish.

Additionally, when researcher compare the performance of DSO with another acknowledge optimization algorithms such as particle swarm optimization (PSO), artificial bee colony (ABC) and bat algorithms (BA) also found that DSO algorithm exceeds the other algorithms because the qualities of the DSO which is firm and sturdy (Yong et al., 2016). However, the other swarm intelligence optimization is undeniable about the facts that they were discovered earlier than DSO and already solving various types of optimization problem. For example, the global optimization algorithms that providing better solution when dealing complex problem in n-dimensional space like PSO, still improving as well as studied by several researcher to solve optimization solution in better techniques.

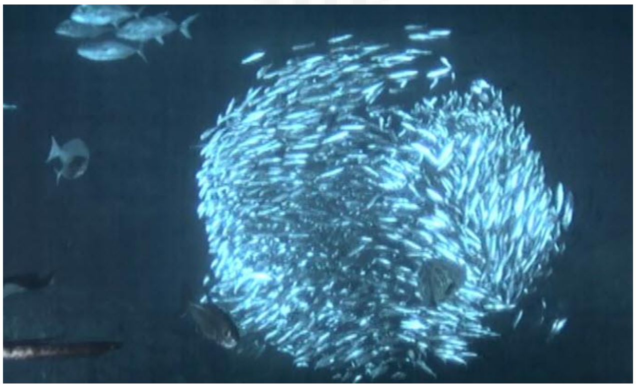

Figure 2.3.4 – Bait-ball of sardines

2.4 Intruder Detection System (IDS)

In this era where all data and information are obtainable as well as accessible through cyberspace, human mostly rely on the smart devices in their daily life such as computer, smartphone, and internet. However, this convenience can lead to serious risk of privacy, data, and information attack. Although there is improvement in security management today, but the cyber-attack also happened as the attack is progressing alongside with the advancement of the security management protection.

Intrusion detection is the process in computer system or networks involving observation of any strange occasion that can detected, and then inspecting them for possible risks and threats which can be sign of defying the imminent threats of violation of computer security policies, acceptable use policies, or standard security practices (Scarfone & Mell, 2007).

Intrusion detection system (IDS) is among the development of security protection from any form of harmful risks and threats. This security system is proficient but appears to be tough in the making of the system as IDS requires attack Detection Rate (DR), including low False Alarm Rate (FAR) (Kolias et al., 2011). Aljanabi, Arfian and Hussein (2020) explained that IDS can inspect and detect networks attack, including monitor range of network systems, cloud computing system, and an information system for better advancement security features system. In addition, IDS can be in two types of systems such as host-based IDS (HIDS) and network-based IDS (NIDS) which HIDS can detect intruders in specific hosts whereas NIDS inspecting specific networks actions to detect threats and risks.

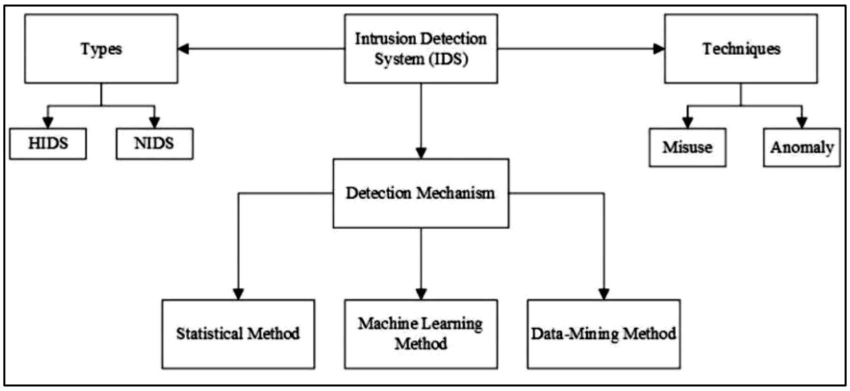

Figure 2.4 – Overview of Intrusion Detection System (Aljanabi et al., 2020)

IDS classified as anomaly and misuse intrusion detection system. Anomaly-based intrusion systems (AIDS) can detect hidden and unusual attacks on real-time networks after discovering the threats from normal behavior of input data whilst misuse intrusion detection system (MIDS) is non-robust and incapable to detect unknown attacks because MIDS only detect intrusion based on pre-built set rules or known as signatures (Qureshi *et al.*, 2019).

2.5 Vehicular Ad-hoc Network

Vehicular Ad-hoc Network (VANET) is a special subtype of Mobile Ad-hoc Network (MANET) that attract many researchers to further study about this network. VANET include critical data which connected with daily life but, VANET is oppressed with the development of latest technology nowadays. Moreover, VANET also faces several security attacks as lack of centralized controlling authority, and high mobility (Engoulou et al, 2014).

Sharma and Kaul (2018) explained that applications of VANET have not been applied at present even though the concept for this network already bring up since 2000. However, it is understandable as VANET lack of security from harmful nodes and threats, so people still doubting the ability of VANET to keep their data and information safely through network-space. Even though solutions already brought upon to solve the security attacks that are dealed by VANET, but mostly the intruder detection components had similar problems involving low detection rate, high false positives and negatives and the development of IDS in VANET requires loads of training and data set.

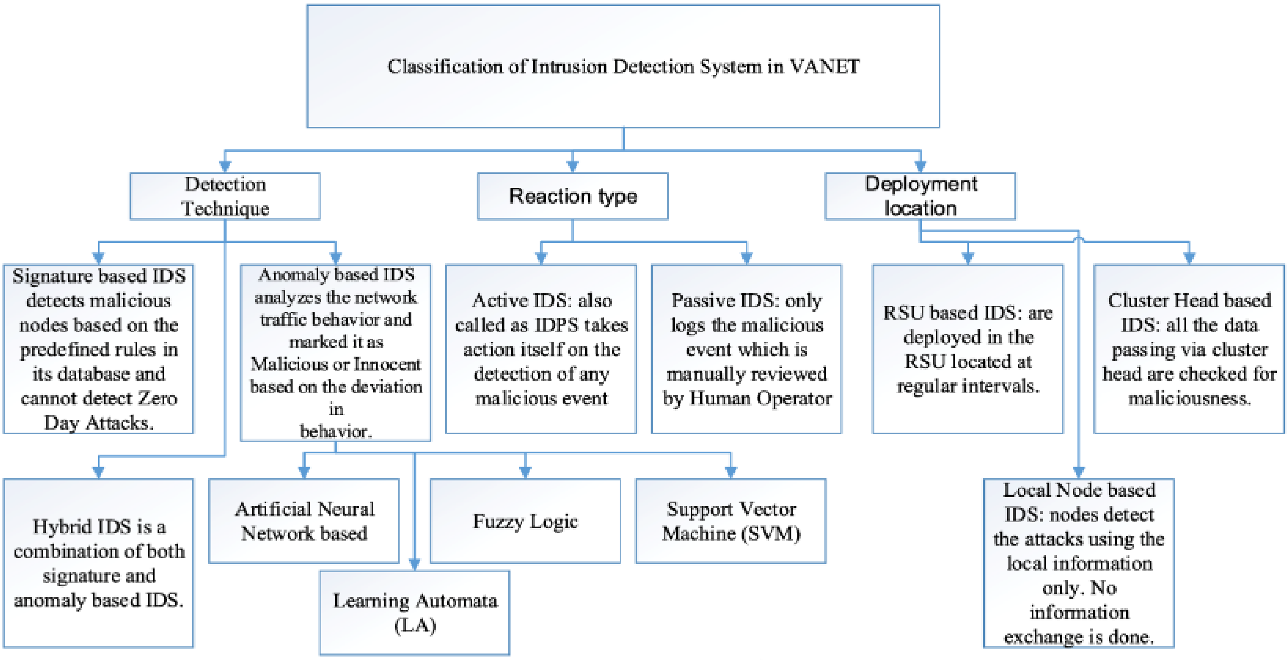

Figure 2.5 – Classification of IDS in VANET (Sharma & Kaul, 2018)

CHAPTER 3

METHODOLOGY

3.1 Introduction

The process of detecting and hunting intruders utilizing dolphin swarm optimization is observed and analyzed in this chapter. The study area is within range of 15km x 15km. Since swarm intelligence is the main concept of DSO, it requires dolphins with a threshold number which will assist in simulating the natural characteristics and living habits of dolphin as shown in dolphin's predatory process.

3.2 Initializing Phase

Dolphins in a specific amount are required to replicate the biological traits and living behaviors portrayed in the dolphin's hunting process, as per the theory in swarm intelligence. Since there are numerous optimization situations, the dolphins represent a potential solution and can also be termed as a plausible D-dimensional approach in the optimization process. The dolphin is categorized as:

$$Dol_i = [x_1, x_2, \dots, x_D]^T (i = 1, 2, \dots, N) \qquad (3.1)$$

Where N is the number of dolphins and x_D denotes an element of each dimension. The individual optimal solution, *L* represents the individual optimum solution of what Dol_i obtains in a single time unit and surrounding optimum solution, *K* indicates the optimum solution that Dol_i identifies or obtains from others. Moreover, fitness, *E* is the process that determines that whether solution is preferrable. The algorithm of DSO calculates *E* through fitness function which the preferable operation being determined by the value that is closest approaching zero, because different fitness functions correlate to different optimization problems. Furthermore, DSO employs three methods of distance which impact information exchange between dolphins and consequently influence dolphins' movement throughout the hunting process (Li & Wang, 2019).

3.3 Pivotal Phase

In this study, a swarm of dolphins was observed, and recorded once they began to hunt on a target as their food, then the data is applied to the detector. The DSO method is divided into six key phases: activation, search, call, reception, predation, and termination. This study, on the other hand, is primarily concerned with four major phases: the search phase, the call phase, the receiving phase, and the hunting stage (Wu *et al*., 2016).

3.3.1 Searching phase

In the search phase, each dolphin searches their surrounding using sound wave or known as echolocation toward random directions. To prevent the dolphins from getting stuck in the search phase, the maximum search time is set and within that time, the other sound produces by dolphin after maximum search time, will search for a new solution, which can be formulated as:

$$X_{ijt} = Dol_i + V_j t \qquad (3.2)$$

Where X_{ijt} represents the new solution, Dol_i is initial dolphin, V_j is the sound after maximum search time and t is time except maximum search time, T_1. For the new solution, X_{ijt} that Dol_i gets, its fitness E_{ijt} is calculated as:

$$E_{ijt} = Fitness\ (X_{ijt}) \qquad (3.3)$$

Next, if the fitness of surrounding optimum solution is more than fitness of individual optimum solution, then the individual optimum solution, L_i of Dol_i is determined as

$$L_i = X_{iab} \qquad (3.4)$$

3.3.2 Calling phase

Li and Wang (2019) stated that each dolphin will sends out a sound to notify the other dolphins of its result in the search phase, including finding a better solution and the location. After that, DSO will enter reception phase.

3.3.3 Reception phase

When the information received by other dolphins with their own optimum solution, the dolphins will compare the optimum solution and choosing the best solution

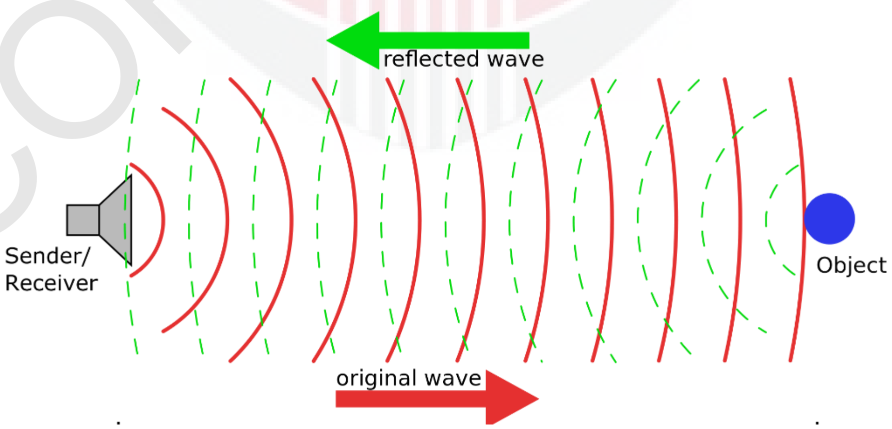

Figure 3.3.1 - Dolphins emit a high-pitched sound and listen to how the sound echoes to gain information about the area around them.

3.3.4 Predation phase

Each dolphin will calculate the encircling radius based on the information exchanged, then analyze the distances between the other dolphin's ideal solutions as well as the position after the predatory phase and obtains a new position.

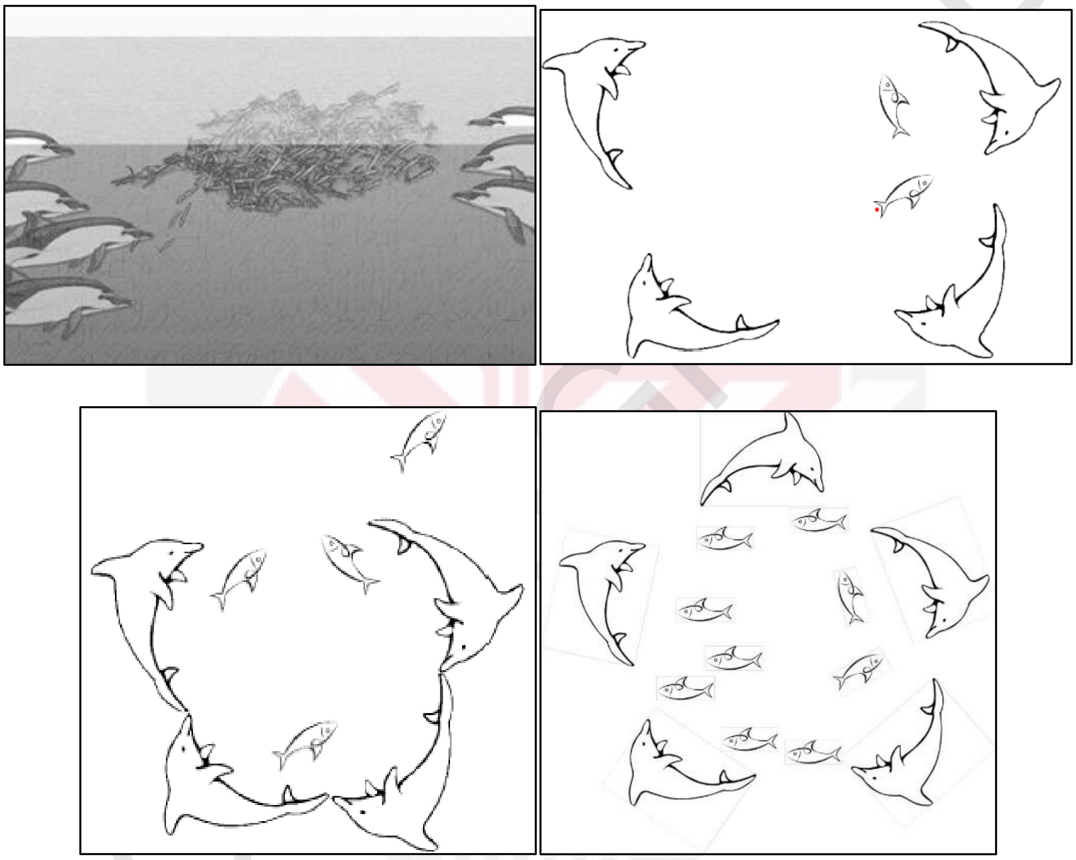

Figure 3.3.2 - Pivotal Phase of Dolphin Swarm Optimization; search, call, reception, and predation phase

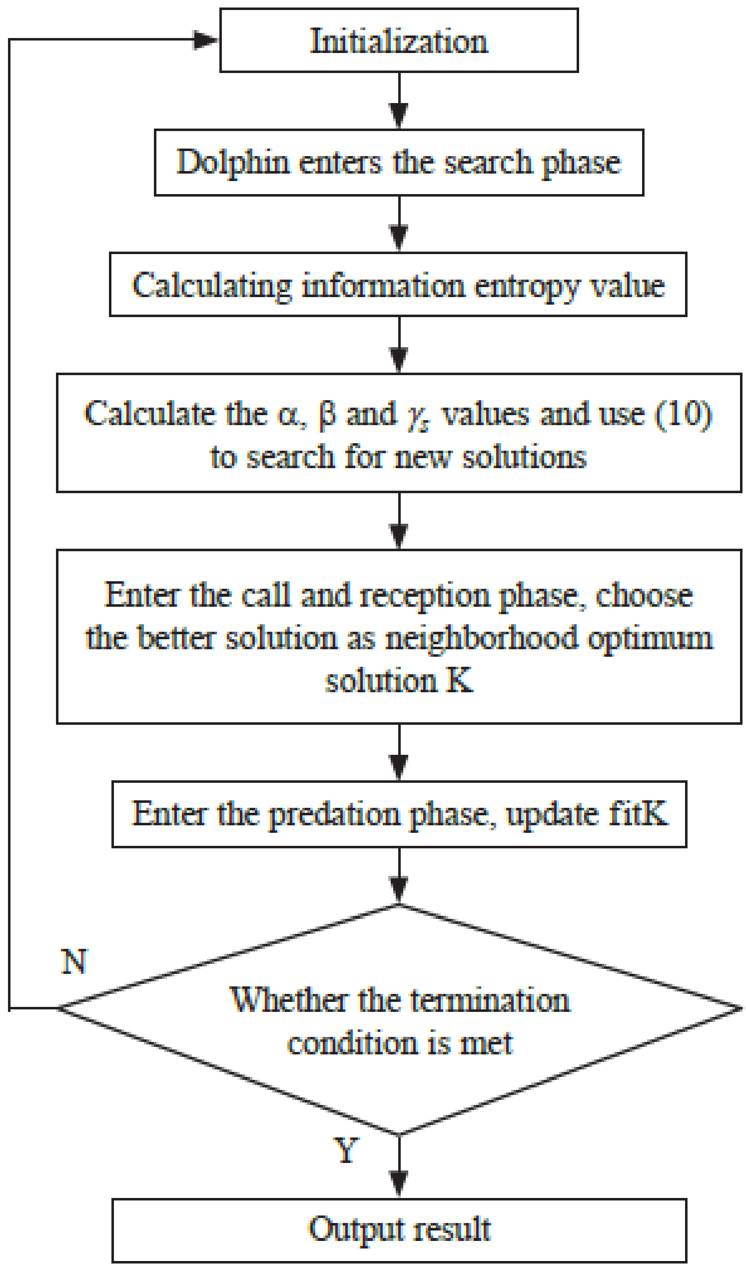

Figure 3.3.3 - Flowchart of Improved Dolphin Swarm Optimization Algorithm (Li & Wang, 2019)

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Intrusion Detection using Dolphin Swarm Optimization

Intruder and hunting detection by using dolphin swarm optimization (DSO) is based on the process of dolphin's predation. The predatory process of dolphins is divided into three parts. The first stage occurs when each dolphin actively uses echoes to hunt nearby preys and examines the surrounding environment. The second stage, in which dolphins share information with one another. When a dolphin comes upon larger prey, it calls for assistance. The receiving dolphins' approach and encircle the prey. The final phase, once the predation is complete and or the dolphins have devoured their prey. For this study, the dolphin behaviour, particularly when identifying prey using echolocation including using large amounts of dolphins to pursue prey, has been utilized to detect and hunt intruders in the range of 15km x 15km under specific area. The process was analyzed for four main phases where the phase includes the search phase, the call phase, the receiving phase, and the predation phase.

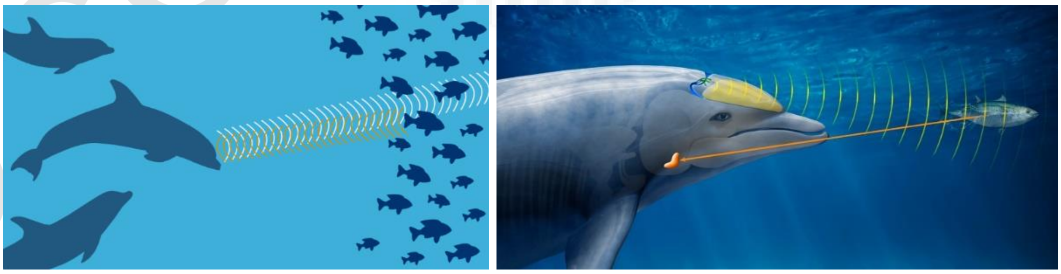

Figure 4.1. 1 - Dolphin Echolocation is used for hunting nearby prey and exchange information with other dolphins

Figure 4.1. 2 – Predatory stage of Dolphin after finding their prey such as bait-ball of sardines and exchange information with one another

Figure 4.1.1 shows the detection rate of intruders affected by number of detectors that using dolphin behaviour. According to the graph, the detection rate (DR) gradually decreased and then stabilised as the number of detectors increases. It is described as the ratio of total harmful events reported to total harmful events happened. When the parameter is increased, the detecting system's accuracy improves (Sharma & Kaul, 2018). Furthermore, as shown in Figure 4.1.2, boosting the false positive rate (FPR) might lead to improved detection accuracy because DSO is being used to identify the best solution. The false positive rate is expressed as the ratio of false intrusion detected to the total number of actual nodes. According to Sharma and Kaul (2018), false positive happen when an intruder detection triggers a warning for an activity that never occurred. Moreover, detection time is a crucial determinant in detection systems. It is described as the total time required by the intrusion detection system to identify harmful intruders carry out an action, with the lesser detection time being more efficient. Furthermore, while approaching with DSO method, the shortest time can be identified because DSO employs the minimum and best training data, which can lead to a reduction in the time required to find unidentified visitors (Sharma & Kaul, 2018).

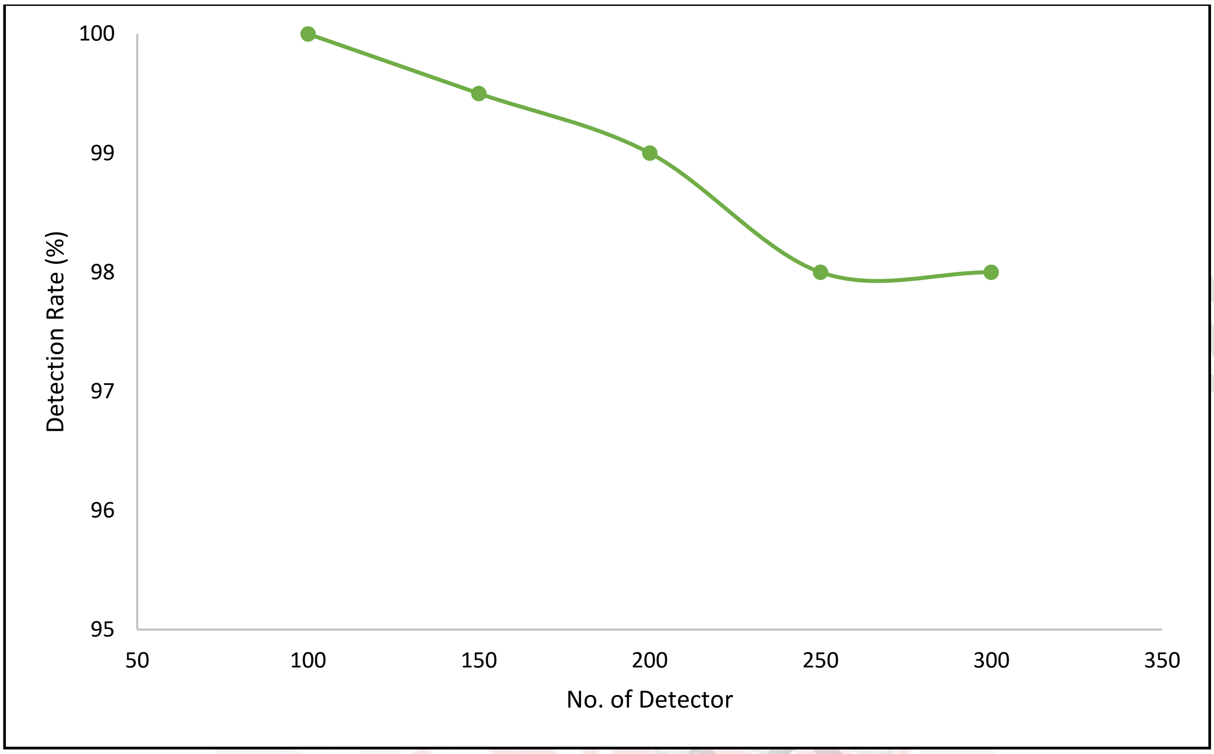

Figure 4.1. 3 - Detection rate decrease when the number of detector increase

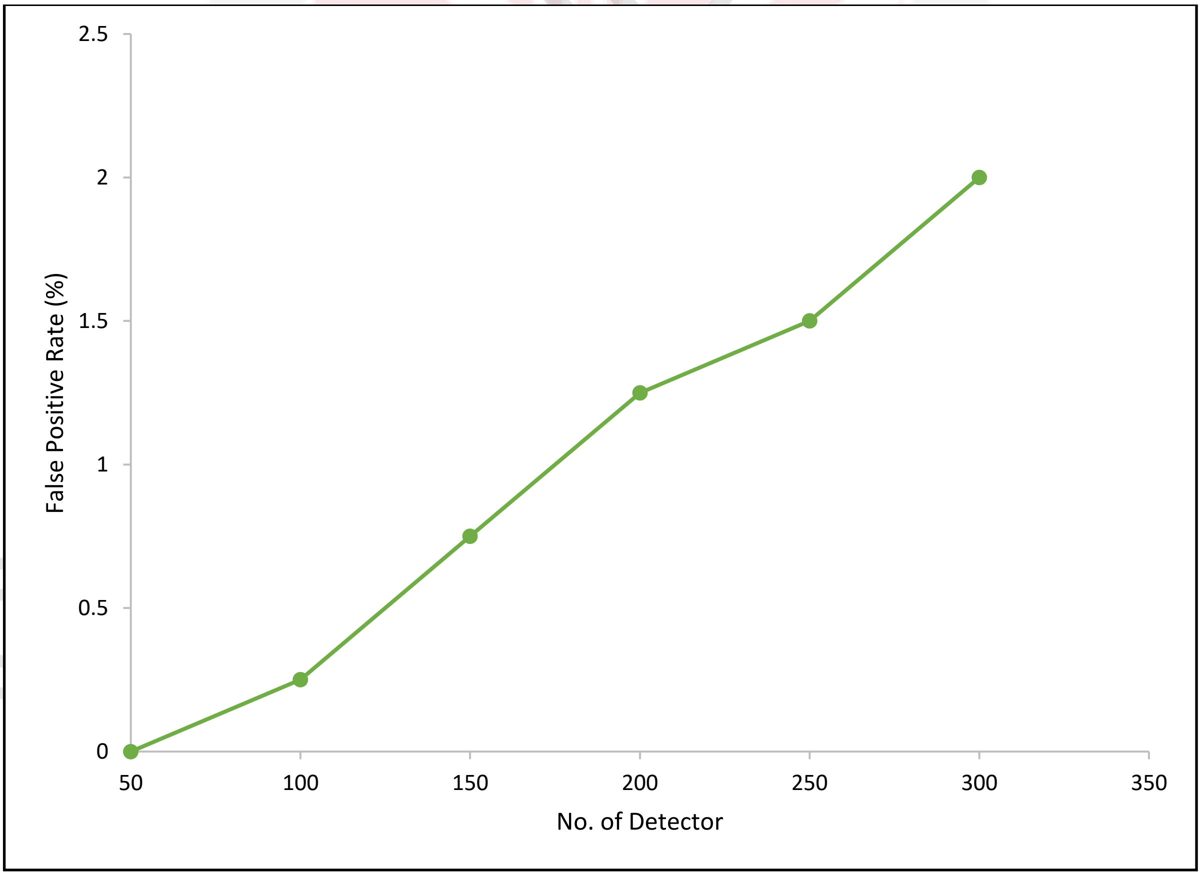

Figure 4.1. 4 - False Positive Rate will increase when the number of detectors is increasing

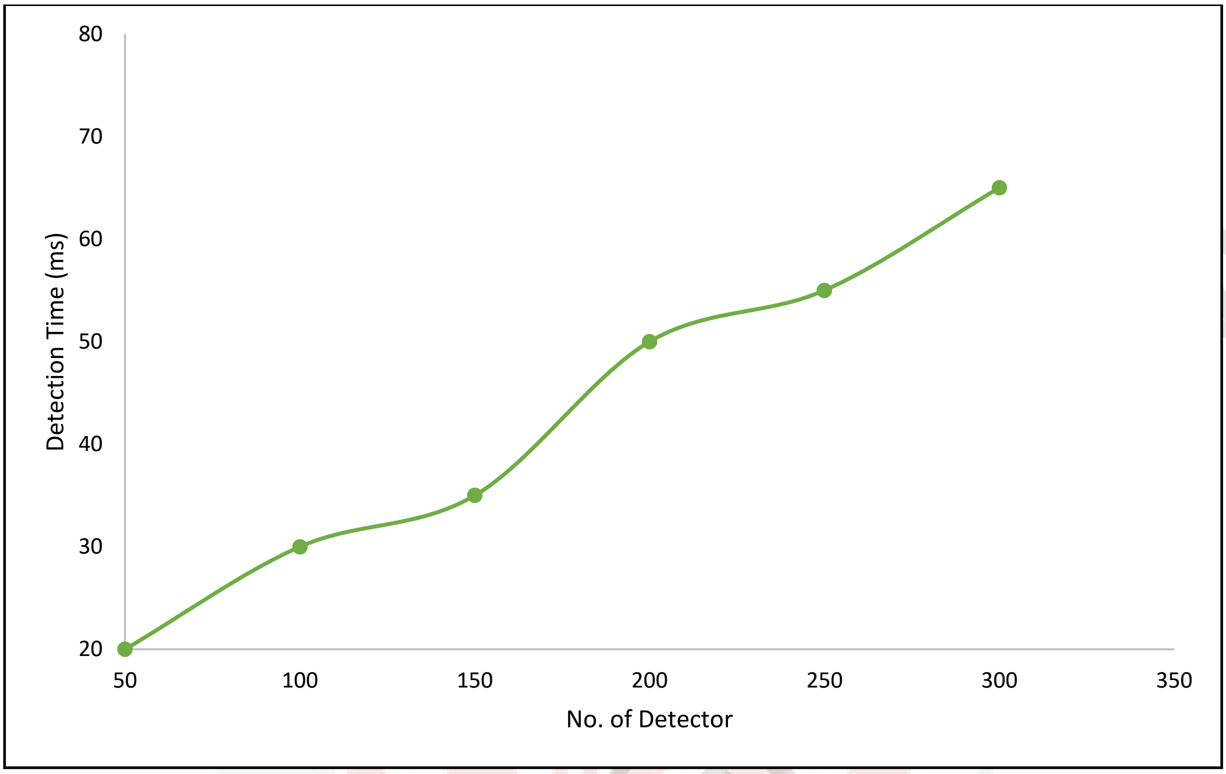

Figure 4.1. 5 - Detection Time for Intruders' Attack is gradually increase

4.2 Swarm Intelligence Relation with Intruder Detection System

Intrusion detection has been researched by using swarm intelligence. Swarm intelligence is an artificially intelligent approach in which different agents in a similar environment engage with each other to achieve a mutual objective. Utilizing optimization algorithms such as particle swarm optimization (PSO), ant colony optimization (ACO), and artificial bee colony optimization (ABC) resulted in an optimal intrusion prevention system. One of the studies is using ABC method for intrusion detection system that also been used to train neurons, which have been subsequently tested against unidentified data points. Qureshi *et al.* (2019) introduced a novel swarm intelligence-based Artificial Bee Colony Algorithm (ABC) based Random Neural Network intrusion detection system (RNN-ABC). Different methods were utilized to investigate the RNN-ABC's efficiency, and empirical research demonstrated that when the colony size is greater and more employed bees engage in finding an effective solution within the phase space of the dataset, the accuracy is reasonably high. The analysis also indicates when inputs are randomized in response to variability in the data, overall mean square error is kept to a minimum, lowering the possibility of biased threat prediction. Because the suggested technique has a higher overall accuracy of 92.65%, it is sensitive to network evasion. In terms of abnormality detection, the results reveal that RNN-ABC surpasses typical neural networks. In the future, RNN-ABC could be used to build a hybrid version for multi-class detection and prevention in NSL-KDD. The NSL-KDD dataset is used, and binary class recognition is achieved by adaptive optimization.

Table 4.2 - Accuracy RNN-ABC (Qureshi *et al.,* 2019)

Metrics	Method-I (%)	Method-II (%)
Sensitivity	90.01	92.20
Specificity	76.58	84.62
False Negative Rate (FNR)	9.99	7.80
False Positive Rate (FPR)	23.42	15.38
Positive Predictive Value (PPV)	97.42	98.27
Accuracy	88.79	91.65

Based on the results from one of the studies conducted using swarm intelligence to provide a better system of intrusion detection, there has been demonstrated the outcomes and impressive results with using swarm intelligence that is built on the basis and motivation of nature's biological evolution for the prediction of novel attacks. ABC, which is inspired by honeybees' food search behaviour in a hive, applies a population-based method for finding better alternatives. Common control parameters, including maximum iterations, colony size, etc., are evenly divided among all groups of bees to discover the ideal solution, allowing the proposed intruder detection system to interrupt malicious actions with more precision and fewer false positives.

4.3 Performance Results Comparison between Swarm Algorithms

Swarm intelligence optimization techniques such as particle swarm optimization (PSO), the artificial bee colony algorithm (ABC), and the genetic algorithm (GA) are commonly used in solving optimization problems. These bio-inspired evolutionary algorithms can provide minimal, quick, and secure solutions to complex optimization complex and harder to calculate. In most situations, the Dolphin Swarm Algorithm (DSA) outperforms in several measures of comparable optimization, such as with PSO, ABC, and GA in terms of intensity, including convergence rate. As stated by Wu *et al.* 2017, DSA performance is better with low-dimensional performance and in smaller group. Besides, DSA is prone to dimensional development, which may cause DSA to converge slowly in the early stages because of lack of looping number.

Table 4.3. 1 - 10 dimensions, 10 individuals, and 10 000 calls of benchmark functions

f	DSA		PSO		GA		ABC	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	**4.0952E-02**	**1.9310E-02**	1.0381E-01	6.7210E-02	2.5144E+00	1.4113E+00	8.7918E+00	5.8950E+00
2	3.6584E+02	3.7017E+01	5.2116E+01	4.8908E+01	**3.3395E+00**	7.5360E+00	3.1984E+01	**6.3306E+00**
3	**1.8570E-01**	**8.8500E-02**	1.6225E+00	6.2251E-01	3.0973E+02	5.7932E+02	2.9351E+01	1.1479E+01
4	**2.2849E-01**	**5.5701E-02**	1.1778E+00	3.1622E-01	3.4555E+00	1.1239E+00	2.3269E+00	8.5382E-01
5	**5.5000E-01**	**5.0133E+02**	9.5000E-01	7.5239E+02	3.1000E+00	1.9903E+03	2.6550E+01	4.8312E+03
6	**1.2387E-01**	**4.2163E-01**	2.9170E-01	1.6633E+00	4.8454E+00	1.3540E+00	1.0538E+01	2.0277E+01
7	**1.2126E+01**	**4.3159E-02**	1.4582E+02	1.4755E-01	2.3748E+02	1.0488E+01	4.2692E+02	1.1533E+02
8	4.5203E+01	1.5839E+01	3.9601E+01	1.2466E+01	**3.1065E+01**	**1.0484E+01**	1.1078E+02	1.5082E+01
9	3.0474E-01	**2.8693E-02**	1.8998E-01	7.7729E-02	**1.5882E-01**	4.3140E-02	3.6338E-01	1.7930E-01
10	**1.9193E-02**	**1.2286E-02**	1.1459E+00	2.2834E-01	6.4376E-01	2.1027E-01	5.9111E+00	2.8407E+00

Table 4.3. 2 - 30 dimensions, 10 individuals, and 10 000 calls of benchmark functions

f	DSA		PSO		GA		ABC	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	**1.5366E+00**	**4.1730E-01**	2.4810E+01	8.4769E+00	1.1025E+02	1.9096E+01	2.3064E+02	1.1955E+02
2	3.5572E+07	1.8406E+08	3.0532E+02	6.3785E+06	**2.8050E+01**	**4.7533E+00**	1.1133E+06	4.4385E+11
3	4.8027E+03	3.0112E+03	1.8541E+03	2.2175E+03	8.3556E+03	5.5925E+03	**8.9346E+02**	**2.7768E+02**
4	4.7295E+01	3.2349E+00	1.6671E+01	5.6519E+00	1.7271E+01	2.5167E+00	**8.9888E+00**	**1.6007E+00**
5	**1.6650E+01**	**1.6492E+04**	6.9450E+01	4.3500E+04	1.0045E+02	1.1690E+05	4.6680E+02	8.9046E+05
6	**7.7853E+01**	**7.6855E+00**	7.2054E+02	3.1462E+01	1.0932E+04	2.4360E+01	1.3858E+05	1.6839E+02
7	**2.6139E+03**	**2.8632E+02**	6.5296E+04	3.8438E+03	2.0330E+05	1.9170E+04	8.2267E+05	7.1539E+04
8	5.7357E+02	**1.2665E+01**	4.6590E+02	8.5866E+01	**3.2698E+02**	5.5421E+01	7.6486E+02	1.3112E+02
9	**1.3722E-01**	**5.4700E-02**	7.1891E-01	1.8520E-01	1.0199E+00	2.7714E-02	1.0621E+00	2.4348E-02
10	**3.6159E+01**	**1.3720E+01**	6.8454E+02	3.0980E+03	2.4708E+03	1.7005E+02	3.2510E+04	6.5621E+04

Table 4.3. 3 - 30 dimensions, 10 individuals, and 20 000 calls of benchmark functions

f	DSA		PSO		GA		ABC	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	**4.5687E-01**	**1.3113E-01**	6.0207E+00	2.6094E+00	2.4860E+01	4.3055E+00	1.4821E+02	7.3404E+01
2	1.4030E+06	1.9511E+07	9.6458E+01	1.4728E+03	**1.3919E+01**	**1.7036E+00**	1.7950E+04	8.8785E+08
3	**7.2629E+02**	**1.3672E+02**	9.8590E+02	1.7856E+02	8.1918E+03	1.2433E+03	7.4988E+02	1.9090E+024
4	3.2425E+01	5.1714E+00	1.3214E+01	3.6323E+00	1.1264E+01	1.3484E+00	**7.5195E+00**	**1.0374E+00**
5	**9.6500E+00**	**4.7348E+03**	4.8950E+01	5.3335E+03	2.3900E+01	1.3369E+04	4.3845E+02	1.7307E+05
6	**1.0345E+00**	**3.5901E+00**	3.5383E+02	2.4369E+01	1.1233E+03	8.2030E+00	8.2524E+04	1.0039E+02
7	**5.7867E+02**	**2.8560E-01**	5.7293E+03	1.2105E+02	1.5000E+04	1.0281E+03	2.8673E+05	3.7745E+04
8	3.8178E+02	1.9239E+02	4.0938E+02	1.2907E+02	**1.4909E+02**	**2.8508E+01**	6.6761E+02	1.5228E+02
9	**4.9872E-02**	**9.0204E-03**	3.2722E-01	9.9407E-02	6.0646E-01	1.0127E-01	1.0172E+00	3.5509E-02
10	**2.5223E-01**	2.6650E+02	4.7023E+01	3.6029E+02	4.1694E+00	**1.2468E+02**	4.3353E+03	8.4872E+03

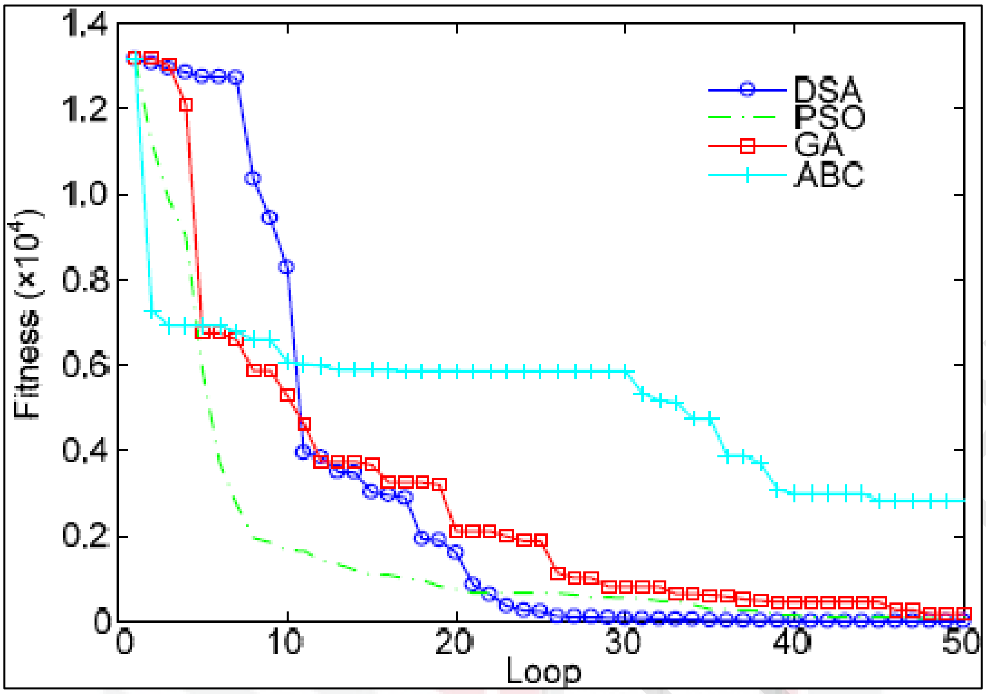

Figure 4.3. 1 - The former 50 loops' convergence curves under a unimodal function $f_1(x)$

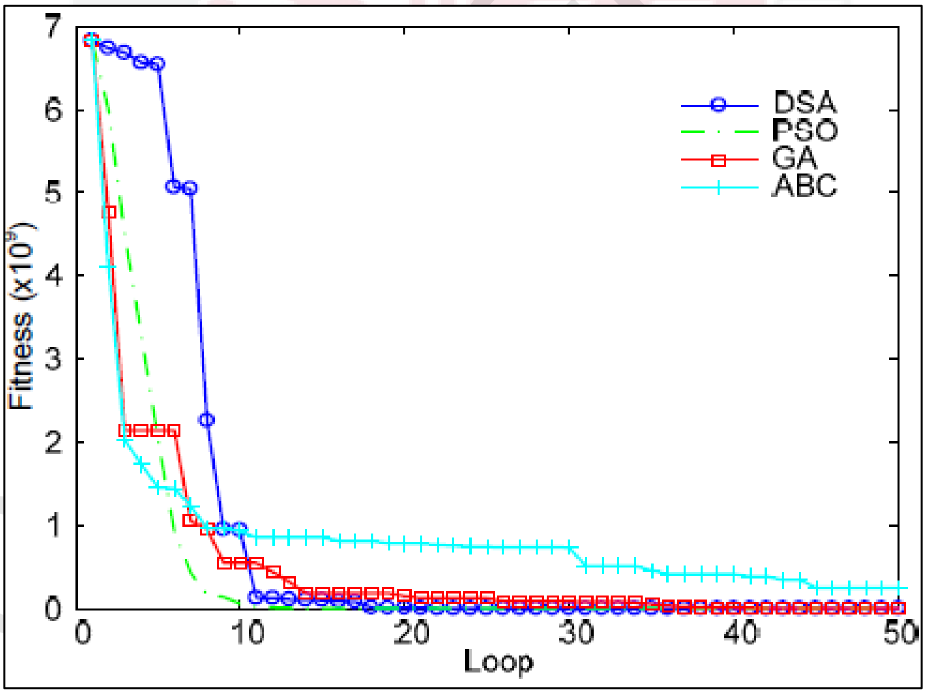

Figure 4.3. 2 - The former 50 loops' convergence curves under a step function $f_5(x)$unimodal function $f_1(x)$

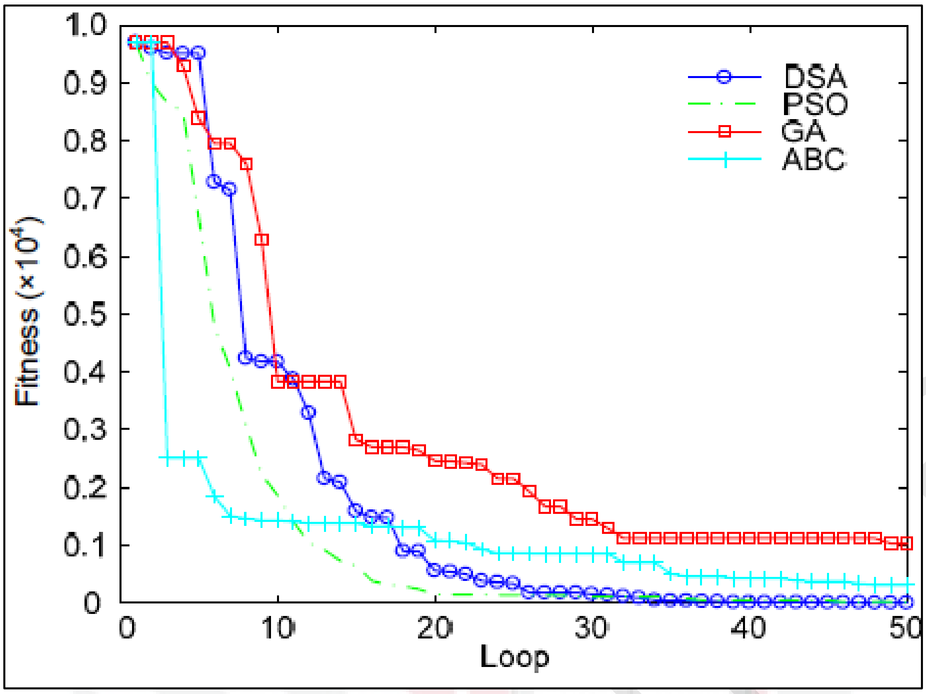

Figure 4.3. 3 - The former 50 loops' convergence curves under a random number function $f_6(x)$

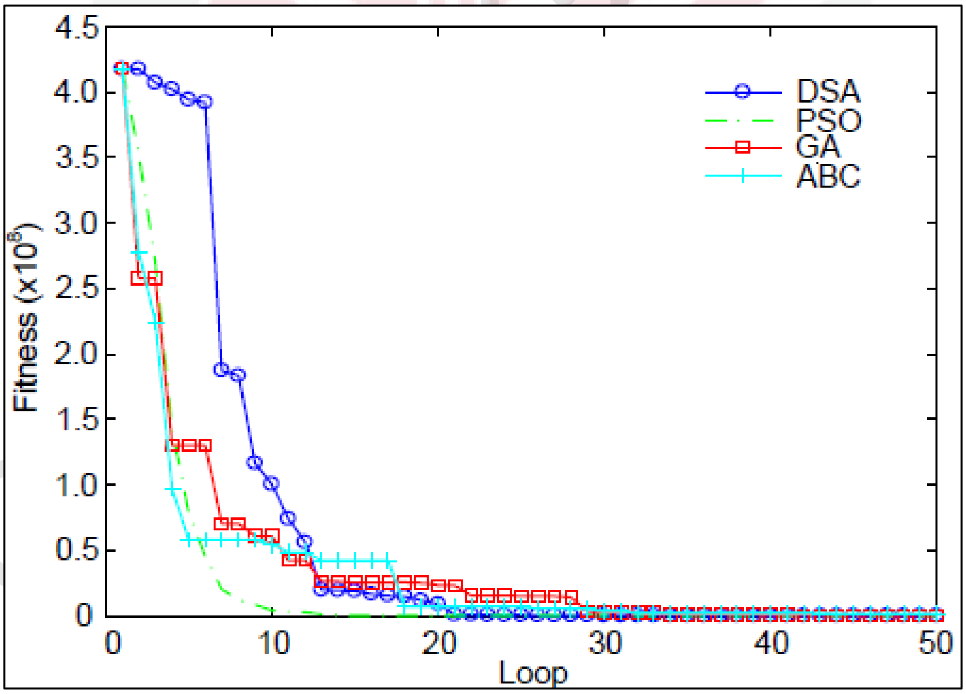

Figure 4.3. 4 - The former 50 loops' convergence curves under a multimodal function $f_7(x)$

CHAPTER 5

CONCLUSIONS

5.1 Conclusion

Dolphin swarm optimization (DSO) is one of the swarm intelligent algorithms that inspired from natural characteristics of dolphin, then assimilate these characteristics and living habits. DSO involves four different phases such as searching, calling, reception, and predation which applied to find the optimal solution to detect and hunt intruders. DSO is observed to use behaviour of dolphin which include emitting echolocation in searching phase whenever they encounter unidentified threats or nearby prey, then each dolphin will exchange information after obtaining optimal solution from the searching phase. After that, other dolphins that receive the signals of echolocation will try to compare the optimum information received from dolphins, then they will choose the best solution. In the last phase of pivotal stage which is predation phase, surrounding area, radius, distance, and position between the dolphin that give the optimum solution will be calculated. After the location is obtained, the hunting of unidentified threats begins. DSO performs better in detecting and hunting intruder by observing detection rate, false positive and detection time. The average of the observed study for detection rate is 98.9% with the average of false positive is approximately 0.96%, and 42.5ms for the average of detection time. Besides, DSO is compared with PSO, ABC, and GA in terms of convergence rate and the benchmark functions. From the results obtained from research of comparison between swarm intelligent, DSO shows great features such as first-slow-then-fast convergence and periodic convergence. Moreover, DSO shows compatibility as it is more suitable for the optimization problems where fitness functions are called more often. After comparing the outcomes of these four methods for 10 different benchmark functions, we conclude that DSO outperforms in far more than half of the cases, especially for low-dimensional unimodal functions, high-dimensional multimodal functions, step functions, and functions of different numbers. The experimental results reveal that DSO performs better with smaller organizations, that it is sensitive to increasing dimension, and that the results in low-dimensional multimodal functions and high-dimensional unimodal functions may be unsatisfactory and should be improved.

5.2 Recommendation for Future Research

For further review and studies of this unique marine mammal known as dolphin, numerical simulation, and animation of dolphin swarm optimization for detecting and hunting intruders in a 3D environment is strongly recommended. This is owing to the belief that more significant natural characteristics and living habits of marine mammals can contribute to the development of artificial intelligence and machine learning. Since there seems to be an increase in the analysis of marine creatures, their functions can also be explored in full depth because underwater creatures possess restrictions in exploring thoroughly, so the records can also be used for even farther advancement and may inspire the advancement of advanced technologies through using the marine mammal capabilities. This study can potentially be improved by using a system such as a neural data network that focusing on different marine species that can be utilised as bio-inspired optimization algorithm and assessed with different parameters.

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