Classification and Application of Nature Inspired Algorithms

Major Project Report

Submitted in fulfillment of the requirements

for the degree of

Master of Technology

in

Computer Science & Engineering

(Networking Technologies)

By

Palak Sukharamwala

(18MCEN16)

Computer Science & Engineering Department

Institute of Technology

Nirma University

Ahmedabad-382 481

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Under the guidance of

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Declaration

This is to certify that

a. The report comprises my original work towards the degree of Master of Technology in Computer Science & Engineering (Networking Technologies) at Nirma University and has not been submitted elsewhere for a degree.

b. Due acknowledgment has been made in the text to all other material used.

- Palak Sukharamwala

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Statement of Originality

I, **Palak Sukharamwala**, Roll.No. **18MCEN16**, give undertaking that the Major Project entitled **Classification and Application of Nature Inspired Algorithms** submitted by me, towards the partial fulfillment of the requirements for the degree of **Master of Technology in Computer Science and Engineering (Networking Technologies)** of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made.It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Internship Certificate

Dear Ms. Palak Sukharamwala,

This to certify that Ms. Palak Sukharamwala (18MCEN16), a student of M.Tech in Computer Science Engineering – Networking Technologies from Institute of Technology, Nirma University worked in Robert Bosch Engineering and Business Private Limited, as an intern during 15th July, 2019 to 30th June, 2020. During this period she was found regular and had done her project on “Classification and Application of Nature Inspired Algorithm (NIA)”, under supervision of me.

She has worked with utmost dedication and high level of engineering and analytical competence.

We wish her all the best for her future endeavours.

Yours sincerely

Robert Bosch Engineering and Business Solutions Private Limited - (CIN: U72400KA1997PTC023164)
Manojkumar Parmar

Acknowledgements

It is my pleasure in expressing thanks and profound gratitude to **Dr. Vijay Ukani**, Associate Professor, Computer Engineering Department, Institute of Technology, Nirma University, Ahmedabad for his valuable guidance and continual encouragement throughout this work. The appreciation and continual support he has imparted has been a great motivation to me in reaching a higher goal. I would like to thank **Prof. Gaurang Rawal** also, His guidance has triggered and nourished my intellectual maturity that I will benefit from, for along time to come.

I would like to express my gratitude and sincere thanks to **Dr. Madhuri Bhavsar**, Honble Head of Computer Engineering Department, Institute of Technology, Nirma University, Ahmedabad for her kind support and providing basic infrastructure and healthy research environment. A special thank you is expressed whole heartedly to **Dr. R. N. Patel**, Honble I/C Director, Institute of Technology, Nirma University, Ahmedabad for the unmentionable motivation she has extended throughout course of this work. I would also thank the Institution, all faculty members of Computer Engineering Department, Nirma University, Ahmedabad for their special attention and suggestions towards the project work.

It gives me immense pleasure to thank **Mr. Manojkumar Parmar**, external guide of my internship project, from **Robert Bosch Engineering and Business Solution Pvt. Ltd.**, for guidance, monitoring and encouragement regarding the project. I would also like to thank **Mr Mohan B V** Chief Expert and General Manager, for giving me opportunity to work with Innovation team.

I am truly grateful to my parents for their blessings and constant motivation which helped me to complete this project successfully. Last but not the least, I would like to thank God for always being there for me.

- Palak Sukharamwala

18MCEN16

Company Profile

Robert Bosch Engineering and Business Solutions Private Limited (RBEI), is one of the world's leading global supplier of technology and services, offering end to end engineering, IT and Business solutions.

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Abstract

Nowadays technology is so advanced that once an impossible tasks are reality. Technologies and algorithms are strong enough to solve many technically challenging and complex problems. The technologies supported by algorithms are growing at an exponential rate. However, the current methods and approaches are facing multiple challenges on various fronts of data, algorithms, software, computational complexities, and energy efficiencies.

Nature also faces above mentioned challenges, and it has found solutions. Formulation of solutions is available as Nature Inspired Algorithms(NIA) based on the study of nature. The set these algorithms can guide in many blind spots of technology. Identification of those blind spots, study of algorithms and how to use them in betterment of current techniques, is the purpose of this major project.

Abbreviations

NIA	Nature-inspired Algorithm
NIC	Nature-inspired Computing
TRIZ	Russian : Teoriya Resheniya Izobretatelskikh Zadatch English : Theory of inventive problem solving
AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
SI	Swarm Intelligence
EA	Evolutionary Algorithm
FOA	Fruit Fly Optimization
FOA-MHW	Fruit Fly Optimisation Algorithm-Multiplicative Holt-Winters
BA	Bat Algorithm
LSSVM	Least Square Support Vector Regression Model
MARS	Multivariate Adaptive Regression Splines
SA	Strawberry Algorithm
BFOA	Becteria Foraging Optimization Algorithm
DP	Dynamic Programming
GA	Genetic Algorithm
TSP	Traveling Salesman Problem
ACO	Ant Colony Optimization

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Chapter 1

Introduction

Nature gets things done in an unbelievable manner. Behind the noticeable marvels, now and then there are concealed endless undetectable causes. Researchers have been watching nature for hundred of years and attempting to comprehend, clarify, adjust and duplicate counterfeit frameworks. There are endless living and non-living operators, act in equal and some of the time against one another, to characterize nature and control the amicability, the excellence. This is viewed as the argument of nature that dwells in the idea of development of the regular world. The development of unpredictability in nature follows a particular request. There is likewise an appropriated, self-sorted out and ideal preparing of data in nature with no focal control. This entire arrangement of structures, mechanical, physical, compound, organic and social, is conveyed by the unpredictability of the most reduced to the most noteworthy. This grouping communicates its common reliance and its connection regarding structure and history. Exercises change because of evolving conditions. These wonders known or incompletely referred to so far rise as new zones of science and innovation and software engineering that review nature-based critical thinking strategies just as endeavors to comprehend the standards and systems hidden regular, physical, synthetic and organic living beings that perform complex errands properly with restricted assets and abilities.

Science is a bridge between researchers and nature which has advanced throughout the hundreds of years by improving itself with new ideas, strategies and devices and has

formed into very much characterized orders of logical action. From that point forward, mankind has been attempting to comprehend nature by growing new devices and strategies. The field of nature-based software engineering (NIC) is interdisciplinary in nature, joining software engineering with information from various parts of science, arithmetic and building, which permits the advancement of new computational devices, for example, calculations, equipment or programming to take care of issue. This report gives a diagram of existing arrangement on Nature Inspired Algorithm (NIA), new methodology called End Goal based grouping, guides to help new order and Future work is portrayed.

1.1 My Publications

While doing research we find this novel approach to deal with the selection process of NIA, to share this knowledge with the rest of the research community, we wrote research paper titled "Mapping of real world problems to NIA using goal based classification and TRIZ" and wrote a book chapter on the same concept for Wiley Publication.

Chapter 2

NIA Next Disruption

Nowadays Computing tools are advanced enough to solve the complex problems, which seems to be impossible few years back. Each technology has its exploitation limitation. Inventing and using it for all application comes under exploitation, but no tool can solve all kind of problems. There will always some problems and issues which current technology and tools can not solve, such problems are listed below.

2.1 Limitation of Current Technologies

2.1.1 High Data Dependencies

Data is the essence of AI/ML algorithm to achieve reasonable accuracy. Today's algorithms are highly data dependent. However, Issues like cost of acquisition of data, processing it, maintaining it and storing it in compliant way, makes it difficult to have sufficient amount of data many a times. The cost of data is one the biggest investment for any organization who want to leverage AI/ML. In absence of data, the accuracy of AI/ML algorithm suffers and renders them unfit for use [1]. The key question is can we develop algorithms and alternatives which are not highly dependant on data, which can achieve "less data approach"?

We need to be aware of the limitations of AI and where humans still need to take the lead. Data and algorithms cannot solve all type of problems. For a specific set

of problems, the available set of algorithms fails to perform adequately despite of huge amount of available data [2].

For quite a while, Facebook accepted that issues like the spread of deception and despise discourse could be algorithmically recognized and halted. However, under ongoing tension from administrators, the organization immediately swore to supplant its calculations with a multitude of more than 10,000 human analysts. The clinical calling has likewise perceived that AI can't be viewed as an answer for all issues. The IBM Watson for Oncology program was a bit of AI that was intended to assist specialists with treating disease. Despite the fact that it was created to convey the best proposals, human specialists thought that it was hard to confide in the machine. Thus, the AI program was relinquished in many emergency clinics where it was trialed.

These models exhibit that there is no AI answer for everything. Only one out of every odd issue is best tended to by applying machine knowledge to it. [3]

2.1.2 Demand for Higher Software Complexity

The increasing software demands also lead to increase in complexity. The complexity is increasing at repaid rate as demand for intuitive and complex solutions is growing. The traditional methods of software programming and solutions are already proven inadequate to manage complexity [4]. The question is can we develop software with reduced complexity yet rich in features?

2.1.3 NP-Hard Problems

There are sets of intractable problems (NP-hard) which are not solvable due to computational complexity involved arising from known set of algorithms for example Traveling Salesman Problem. TSP is discussed in detail in following sections. The question is can we solve NP-Hard problems with available compute power today? [5] [6]

2.1.4 Disproportionate Energy Consumption

Though DL algorithms are claimed to mimic human brains, still they lack in terms of efficiency and energy consumption. There is a long way to go to mimic human brains

perfectly.

Despite the availability of data, algorithm and computational power, it is not possible to solve set of problems due to sheer amount of energy usage. The cost-benefit analysis produces unfavorable results due to impact of energy usage on environment [7]. The key question is can we solve the problem in energy efficient way to match human brains energy efficiency frontier?

The discussed problems are considered small today; however, they are growing drastically. These problems indicate that growth of AI/ML based algorithms and applications are not sustainable from technical, business, and environmental point of view. Therefore to tackle the stated problem, there is a need to explore alternative solutions. Scientists believe NIA is the best suitable alternative.

2.2 How Can NIA Help?

Nature faces varied problems, and it has found the best way to solve them using constrained optimization over a time. The species on earth are doing various forms of optimization for rest of their life in their respective environment. Their survival is proof that the evolved optimizations are the best possible solutions. Nature has its way of transferring minimum intelligence from one generation to another using genes. Later on, life forms acquire higher amount of intelligence based on their experiences interacting with environment. In the entire process of acquiring intelligence, the usage of data is very minimum. At the same time, the decisions derived from the intelligence is good enough at the least. The life forms are capable of managing the complexity of real-world, and their decisions are achieved in the most energy-efficient way as their survival depends on it.

Similarly to nature, today's digitally powered world is facing significant complex problems due to temporal and spatial complexity, variability, and constrained environments. The similarity between problems faced is striking, and hence the proposition is to take over solutions of nature and implement it to solve our problems. The solution formalized by studying nature is referred as Nature Inspired Algorithm (NIA) [8]. The NIAs are

designed to optimize numerical benchmark functions and solve NP-hard problems for a large number of variables, and dimensions.

The growth of current technologies is bound to diminish and will pave the way for new technologies to emerge.Authors believe that NIA is going to be the next disruptive technology to address the problems faced by current technologies [9].

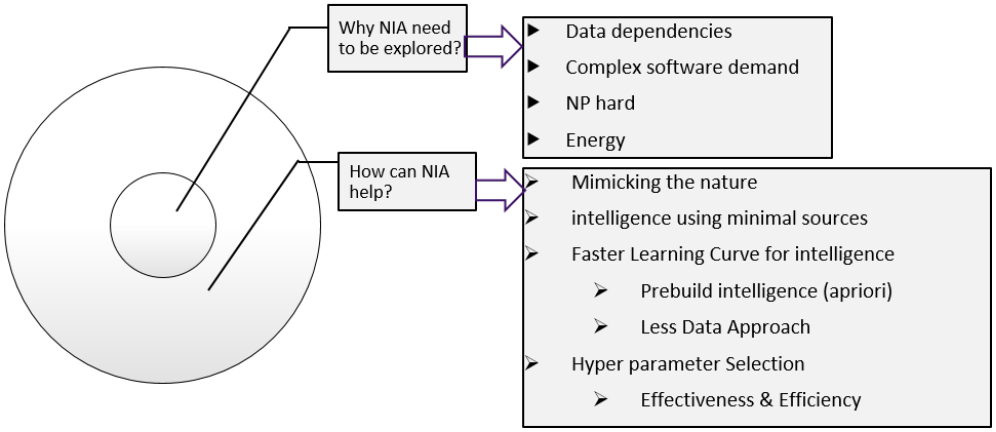


Figure 2.1: Need of exploring NIA and how NIA can help

Chapter 3

Traditional Classification and Limitations

There exist a classification for NIAs, which is solution based. It focuses on the techniques used by algorithms. Figure 3.1 shows the classification. Algorithms are classified into following classes [10][11][12][13].

- Swarm Intelligence
- Evolutionary Algorithms
- Bio-inspired Algorithms
- Physics-based Algorithm
- Other Nature Inspired Algorithms

3.1 Traditional Classification

3.1.1 Swarm Intelligence

Swarm Intelligence (SI) is basically the total lead of decentralized, self-sorted out structure. The comparable thought is used for Artificial Intelligence. Right off the bat it

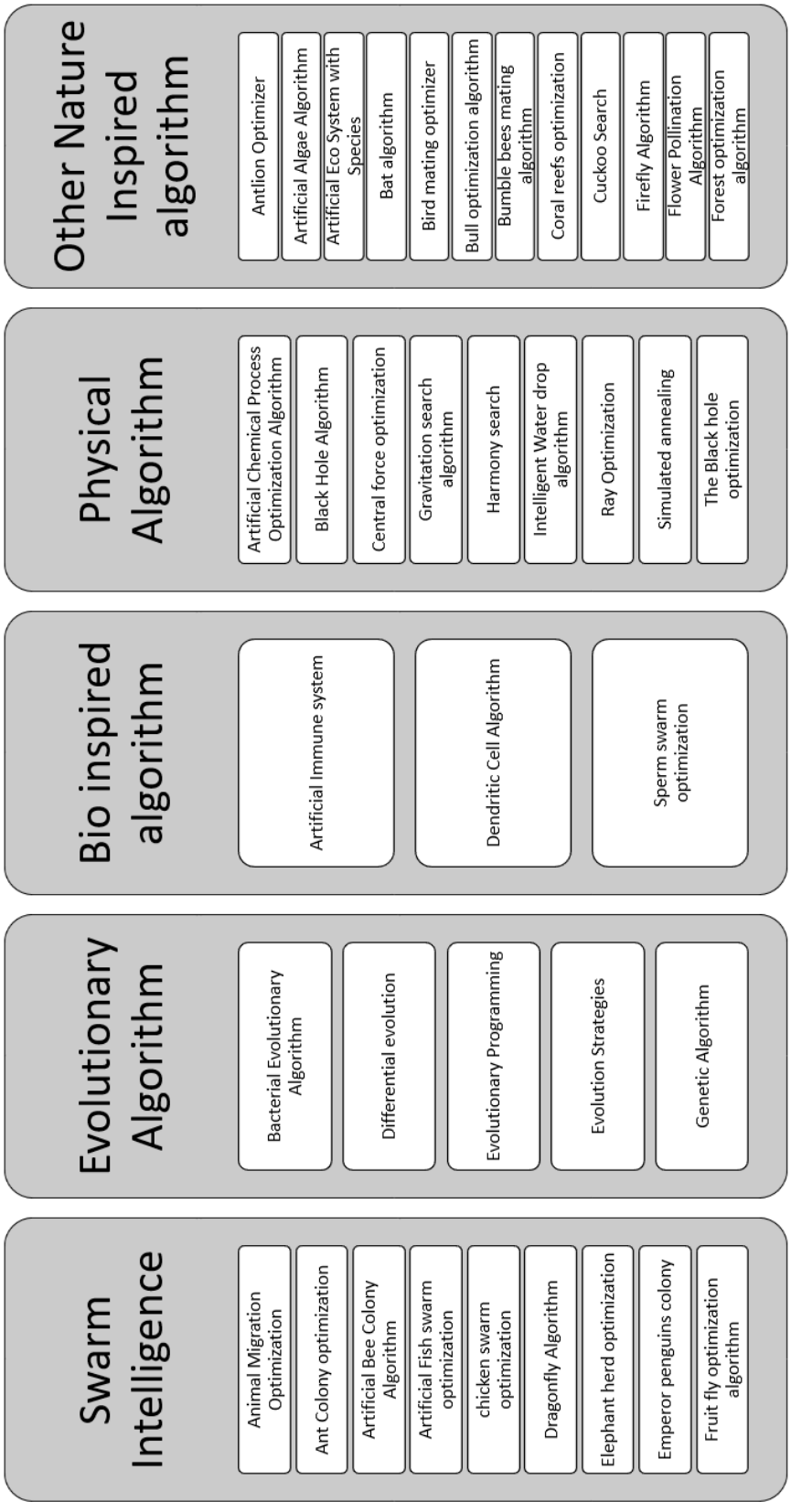


Figure 3.1: Categories of traditional classification of NIAs

was introduced by Gerardo Beni and Jing Wang in 1989, concerning cell automated frameworks[14].

Generally SI frameworks comprise of a populace of basic specialists or boids associating locally with each other and with few predefined conditions. The motivation frequently originates from nature, particularly organic frameworks. The operators adhere to straightforward guidelines, and despite the fact that there is no unified control structure directing how singular specialists ought to carry on, nearby, and in a specific way arbitrary, collaborations between such operators lead to the rise of "insightful" worldwide conduct, obscure to the individual operators. Instances of multitude knowledge in regular frameworks incorporate subterranean insect provinces, winged creature rushing, birds of prey chasing, creature crowding, bacterial development, fish tutoring and microbial insight.

The utilization of multitude standards to robots is called swarm apply autonomy, while 'swarm knowledge' alludes to the more broad arrangement of calculations. 'Multitude expectation' has been utilized with regards to determining issues. Comparable ways to deal with those proposed for swarm apply autonomy are considered for hereditarily altered living beings in engineered aggregate knowledge[15].

3.1.2 Evolution Algorithm

In artificial intelligence, an evolutionary algorithm (EA) is a subset of evolutionary computation [16], a nonexclusive populace based meta heuristic enhancement calculation. An EA utilizes components enlivened by natural development, for example, propagation, transformation, recombination, and determination. Up-and-comer answers for the improvement issue assume the job of people in a populace, and the wellness work decides the nature of the arrangements (see additionally misfortune work). Development of the populace at that point happens after the rehashed use of the above administrators.

Developmental calculations frequently perform well approximating answers for a wide range of issues since they in a perfect world don't make any suspicion about the fundamental wellness scene. Procedures from transformative calculations applied to the demon-

strating of organic development are commonly restricted to investigations of smaller scale developmental procedures and arranging models dependent on cell forms. In most real applications of EAs, computational complexity is a prohibiting factor [17]. Actually, this computational complexity is because of fitness function evaluation. Fitness approximation is one of the possible solutions to overcome this issue. However,simple EA can solve often complex problems [17]; therefore, there may be no direct co-relation between complexity of algorithm and complexity of problem.

3.1.3 Bio-inspired Algorithms

Bio-inspired computing, short for naturally roused figuring, is a field of study which tries to take care of software engineering issues utilizing models of science. It identifies with social conduct, and rise. Inside software engineering, bio-motivated figuring identifies with man-made reasoning and AI. Bio-propelled registering is a significant subset of characteristic calculation.

Bio-inspired computing can be recognized from customary man-made brainpower by its way to deal with PC learning. Bio-motivated figuring utilizes a developmental methodology, while customary A.I. utilizes a 'creationist' approach. Bio-roused registering starts with a lot of basic standards and basic living beings which cling to those guidelines. After some time, these living beings advance inside basic limitations. This strategy could be viewed as base up or decentralized. In conventional man-made consciousness, knowledge is frequently customized from over: the developer is the maker, and makes something and instills it with its insight.

3.1.4 Physics-based Algorithm

Physics-inspired algorithms uses basic principles of physics, for example, laws of motion, Newton's laws of gravitation and Coulomb's force law of electrical charge. They are all based on deterministic physical principles. Broad categorisation of these algorithms are as follows:

- Colliding Bodies Optimisation is inspired byNewton's laws

- Gravitational Search Algorithm, Central Force Optimisation (CFO), Space Gravitation Optimisation and Gravitational Interaction Optimisation are inspired by Newton's gravitational force.
- Big Bang–Big Crunch search, Black Hole Search, Galaxy-based Search Algorithm, Artificial Physics-based Optimisation and Integrated Radiation Search are inspired by celestial mechanics and astronomy
- Electromagnetism-like Optimisation, Charged System Search and Hysteretic Optimisation are inspired by electromagnetism
- Ray Optimisation, Harmony Search Algorithm, Simulated Annealing, Water Drop Algorithm, River Formation Dynamics Algorithm and Water Cycle Algorithm are inspired by optics, acoustics, thermodynamics, hydrology and hydrodynamics respectively
- Simulated Annealing algorithm is based on the principle of thermodynamics. The algorithm mimics the cooling process by gradually lowering the temperature until it reaches to a steady state

3.1.5 Other Nature Inspired Algorithms

As per named their origin of inspiration is away from nature but can be social, emotional, etc. That's why they have been classified into different category.

3.2 Limitation of Traditional Classification

Drawback of the traditional classification is that it is not helpful for mapping of real life problem to conceptual problem. For an application, selection of algorithm is achieved using brute force. This classification does not make it easy to select algorithm.Hence the solution based approach is not ideal for mapping problem.

Drawback of tradition classifications are following :

- It is solution based approach. The classification focuses on, how nature is solving an issue, not on what nature actually want to achieve.
- It is not helpful for mapping of real life problem to conceptual problem as it does not factor nature's problem.

Chapter 4

End Goal Based Classification

4.1 Literature Survey for End Goal Classification

However in traditional classification, there is a lack of understanding of underlying problem for NIA, which limits capability of NIA.

A six-step approach is used to produce classification, which consist of deep literature survey of NIAs. Algorithms were been studied to keep focus on ontology. What problem algorithms is trying to solve was the main focus of studying them. Output of the literature survey was knowledge about algorithms, their properties, pros and cons and which problem they try to solve using these approaches.

a. Literature survey to collect a list of 75 algorithm

b. Study the NIA to understand problems, its mathematical formulations, corresponding algorithms, its applications, benefits, limitation

c. Mapping of core goals using Ethology [18]

d. Clustering NIA on core goals and sub-goals

e. Taxonomy structure

f. Mapping of Algorithm on Taxonomy

4.2 TRIZ

TRIZ is the Russian acronym, in English it means "Theory of Inventive Problem Solving [19]." TRIZ helps to understand and define complex problems systematically. It is used in roles such as product development, design engineering, and process management. practical methodology, a knowledge base,tool sets and model-based technology for generating innovative solutions for problem solving are included in TRIZ.

It is applicable for problem formulation, failure analysis, system analysis and patterns of system evolution. There is a quite similarity of goals and methods to achieve them with the field of pattern language, a cross domain practice for specifically describing and sharing patterns of design. Three primary findings of research are:

a. Problems and solutions are repetitive in nature across sciences and industries

b. Patterns of technical evolution are also repetitive across sciences and industries

c. Scientific effects outside the field in which they were developed are used as the innovations

Prism of TRIZ, as depicted in Figure 4.1 [20]. represents the 4 step approach for problem-solving. The real-world problem is mapped to conceptual problem using abstraction. The conceptual problem and corresponding solutions (40 TRIZ Principle) database is then used to find analogous solution to conceptual problem. The conceptual solution then is converted to a real-world solution. Authors envisioned that the TRIZ prism is the most suitable methodology to map real-world problems to nature problems and then provide corresponding solutions from NIA. In simple words, prizm TRIZ suggests to take help from solved problem to solve newer problems. Here, NIAs are used as solved solutions of nature's problems.

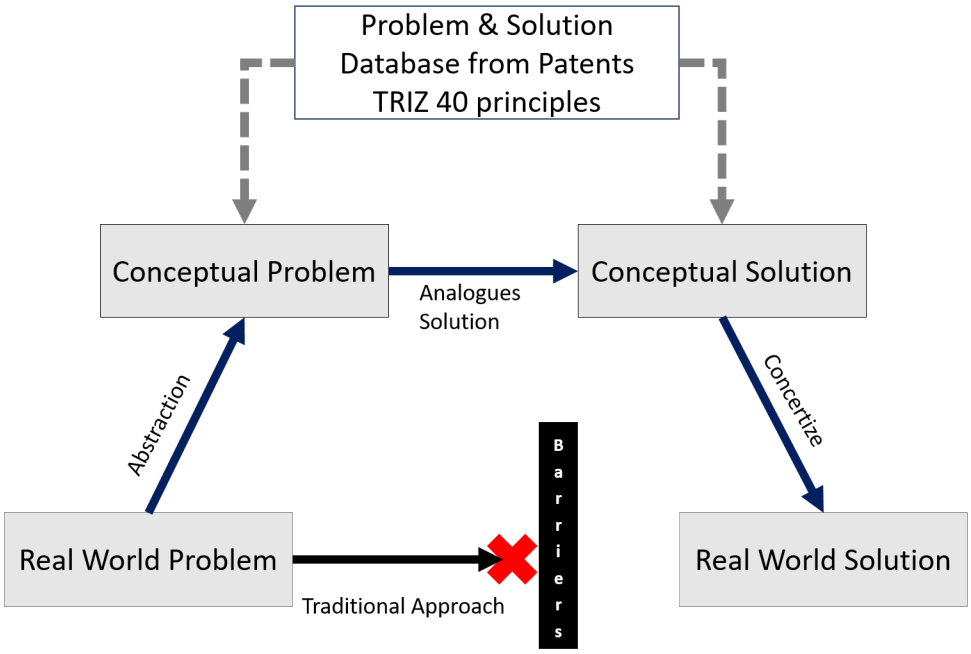


Figure 4.1: TRIZ problem-solution approach

4.3 Combined Methodology

A novel methodology as depicted in Figure 4.2, which combines TRIZ with our new classification. Which also in favor of the primary findings of TRIZ. If problems and solutions are repetitive in nature across sciences and industries, then existing pairs of problems and solutions can be used. For us that pair of problems and solutions are inspired from nature. It is again 4 step process with modification in an intermediate steps [9].

a. The real-world problem is mapped to conceptual problem using abstraction.

b. The conceptual problem is then mapped to end goal of NIA.

c. From an available database of NIA problem and solution; analogous NIA is derived into conceptual solution.

d. The conceptual solution then is converted to a real-world solution.

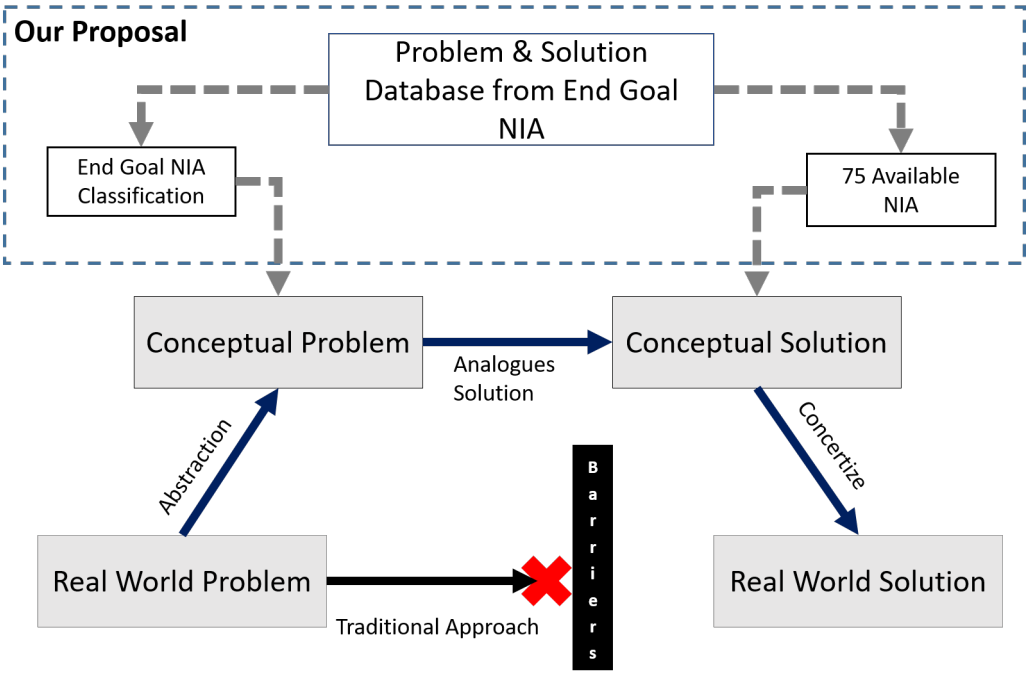


Figure 4.2: Combine methodology NIA + TRIZ

4.4 End Goal Based Classification

Our classification is 4 levels deep and varies based on goals and sub-goals, as depicted in figure 4.3. All 75 NIA are classified using this and are present at one of the leaf nodes. Figure 4.3 represents classification diagram and following are explanation for respective levels of proposed classification.

a. Biology and non biology based to distinguish living from non living

b. Based on the primary goal

c. Based on the sub goal

d. Based on the behavior

The detailed mapping of leaf nodes for NIA is available in Table 4.1 for biology based algorithms and Table 4.2 for non-biology based algorithms. For non-biology based, the classification is available based on primary goals only as sub goals and behavior has no real meaning.

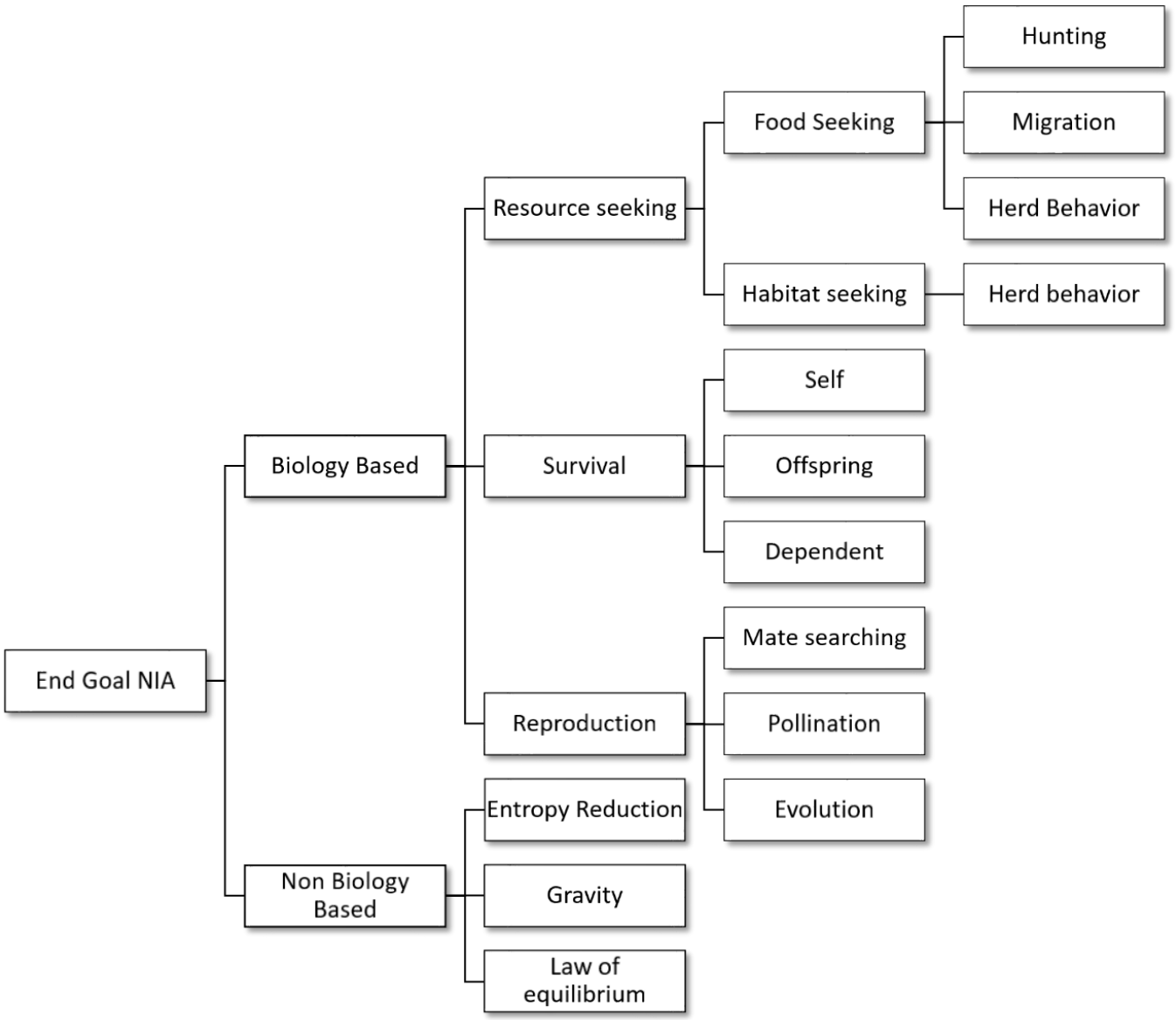


Figure 4.3: End goal based classification of NIA

Table 4.1: Biology based algorithms

Level:2 Primary Goal	**Level:3 Sub Goal**	**Level:4 Behavior**	**NIA**
Resource Seeking	Food Seeking	Hunting	Ant lion Optimizer
			Bat algorithm
			Grey wolf optimizer
			Lion Optimization Algorithm
			Salp swarm algorithm
			Whale optimization algorithm
		Migration	Animal Migration Optimization
			Artificial Algea Algorithm (AAA)
		Herd Behavior	Ant Colony optimization
			Artificial Bee Colony Algorithm
			Artificial Fish swarm optimization
			chicken swarm optimization
			Dragonfly Algorithm
			Fruit fly optimization algorithm
			Gross hoper optimization
			krill herd algorithm
			Locust search algorithm
			Particle swarm optimization algorithm
			Strawberry algorithm
	Habitat Seeking	Herd Behavior	Monarch butterfly optimization
			Moth flame optimization algorithm
			Sperm swarm optimization
Survival	Self		Artificial Immune system
			Dendritic Cell Algorithm
			Gross hoper optimization
	Offspring		Cuckoo Search
			Emperor penguins colony
	Dependant		Tree physiology optimization
Reproduction	Mating Searching		Elephant herd optimization
			Firefly Algorithm
			Honey bee mating optimization
			Social spider optimization
	Evolution		Artificial Eco System with Species
			Bacterial Evolutionary Algorithm
			Bird mating optimizer
			Bull optimization algorithm
			Bumble bees mating algorithm
			Coral reefs optimization
			Differencial evolution
			Evolutionary Programming
			Evolution Strategies
			Genetic Algorithm
			Memetic algorithm
	Pollinstion		Flower Pollination Algorithm
			Forest optimization algorithm

Table 4.2: Non-biology based algorithms

Level:2 Primary Goal	**NIA**
Gravity	Black Hole Algorithm
	Central force optimization
	Gravitation search algorithm
Entropy Reduction	Artificial Chemical Process Optimization Algorithm
	Intelligent Water drop algorithm
Law of Equilibrium	Harmony search
	Water wave optimization
	wind driven optimation

4.5 Application of End Goal Based Classification

Following are the example to explain, how to co relate this new approach with application. It shows mapping of problem definition to naturally solved issue.

4.5.1 Fruit Optimization Algorithm to Predict Monthly Electricity Consumption

In a paper, Jiang et al. [21] demonstrated use of fruit fly optimization algorithm to improve prediction of monthly electricity consumption with limited amount of training data. The proposed solution uses a hybrid forecasting model named FOA-MHW (Fruit Fly Optimisation Algorithm - Multiplicative Holt-Winters). The Holt-Winters algorithm is exponential smoothing algorithm for forecasting for time series data. The parameters of exponential smoothing are generated using FOA.

The real-world problem of MHW is to find optimal parameters for smoothing with minimum amount of data. The parameter finding is converted into conceptual problem of Food-seeking problem which is under Resource seeking ($Resourceseeking- > Food-seekingproblem- > HerdBehaviour$) as referred in Figure 4.3. For food-seeking in herd, the fruit fly is one of the superior species as it uses acute smell sensing in swarm with intelligent communication. Hence corresponding solution of fruit fly optimization is suitable for the identified problem. Therefore for the stated problem, FOA is found most suitable and outperformed traditional algorithms.

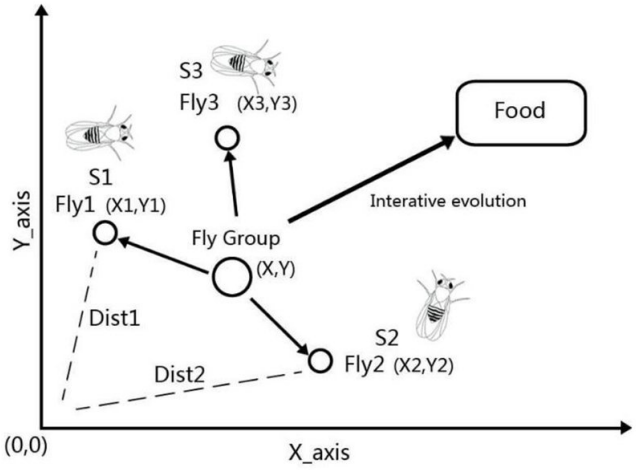


Figure 4.4: Diagram for fruit fly optimization algorithm FOA

4.5.2 Bat Algorithm to Model River Dissolved Oxygen Concentration

Yaseen et al. [22] uses Bat Algorithm (BA) in Modeling River Dissolved Oxygen Concentration. Here NIA is integrated with Least Square Support Vector Regression Model. Compare to M5 tree and MARS models, LSSVM-BA model's accuracy is increased by 20% and 42%, respectively, in terms of root-mean-square error.

It is been studied that the efficiency of LSSVM models depends on the values of regularization parameters and the kernel. The hyper-parameters of LSSVM are decision variables, so that they should be determined accurately by optimization algorithms for performance betterment. In this paper, the hyper-parameters of LSSVM were tuned using the BA. In BA, Bat's hunting behaviour is mimicked. Bat hunting comes under resource seeking followed by food seeking category($Resourceseeking- > Food - seekingproblem- > Hunting$) as referred in Figure 4.3, So it can be concluded that parameter optimization problem can be mapped with food seeking problem.

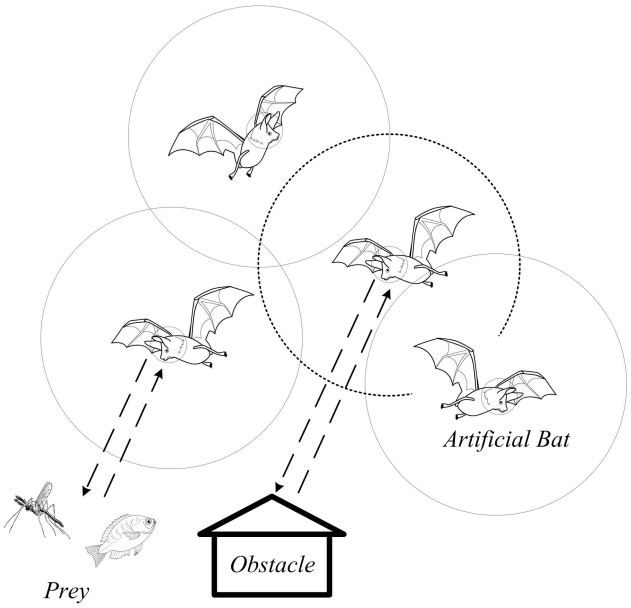


Figure 4.5: Diagram for bat algorithm

4.5.3 Genetic Algorithm to Tune The Structure and Parameters of a Neural Network

Frank et al.[23] discuss tuning of Neural Network parameters using Genetic Algorithm. This is the very first paper from 2003 where it was proposed to use NIA to train network.

Neural network is proved to be the best approximator. Any nonlinear continuous function to an arbitrary accuracy can be solved by a three-layer feed forward neural network. It is possible the a fixed structure may not be able to provide the optimal performance within a certain training period. A small network may not be able to give good performance due to limited power of information processing. On the other hand, A large network, may have some connections redundancy. Above all, cost of implementation for a large network is high very high. It could be the best if algorithm suggests the best structure for a neural network. In terms of hardware and processing time, it may lead to low cost for implementation of the neural network,

Here parameters like number of neurons, number of level, dense layer activation function and network optimizer are presented in one array form. Array is also used to present output solution. Choosing the correct representation of an output solution is very im-

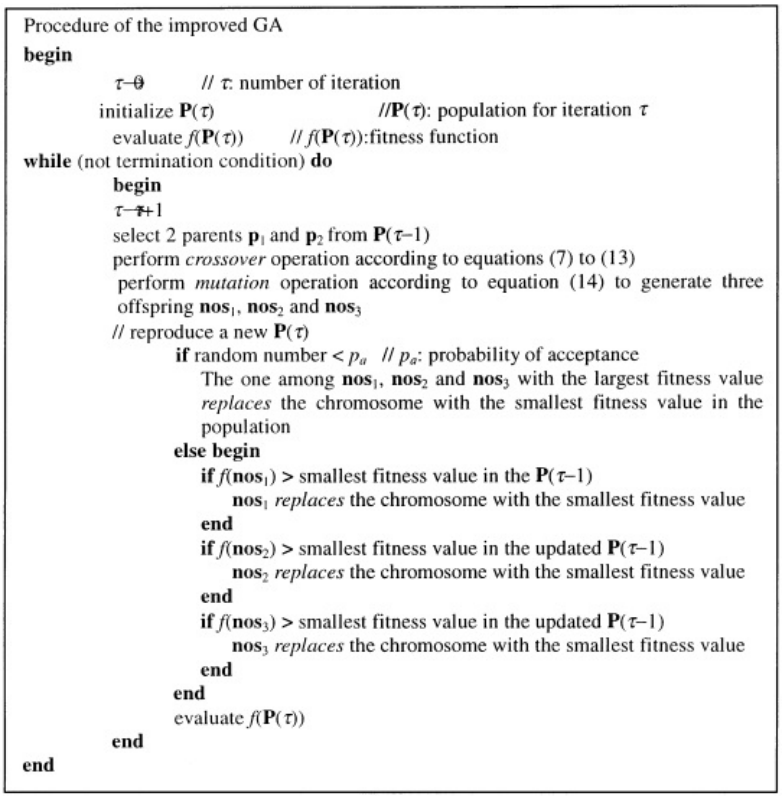


Figure 4.6: Procedure of improved Genetic Algorithm

portant in Nature Inspired Algorithms. In initialization, any random value for these parameter is taken. Priory can also be used instead of random values. Networks are trained using these parameter. The difference between predicted and actual value is fitness function. The change values of parameter is according to improved Genetic Algorithm. Figure 4.6 depicts pseudo algorithm along with procedure.

If we talk about abstraction from real world problem to Nature issues, then we can say the best structure is the result of survival among rest. self survival can be mapped with survival of the best structure. That is the reason GA algorithm from $Biologybased- > survival- > selfcategory$ as referred in figure 4.3 is chosen.

Chapter 5

Application of NIA

5.1 Solution of NP-H Using NIA

5.1.1 0-1 Knapsack Problem

Combinatorial optimization problems' family is the parent class for knapsack problem. Here, 0-1 knapsack problem is one of the variant of knapsack problem. Knapsack problem appears decision-making processes of a huge variety of fields in real world. Few traditional applications are to cut raw objects is least wasteful way, in the site of construction, passing tests with maximised score,etc.[24] The knapsack problem has been the research topic for hundred years. Computer scientists always has fascination for knapsack problem because the decision problem form is NP-complete. Hence, there is no known algorithm for both correctness and speed (polynomial-time).

The knapsack problem is defined as a set of items(xi) is given, each with a weight(wi) and a value(vi). Determine the number of each item to include in a collection so that the total weight is less than or equal to a given capacity(W) and the total value is as large as possible. in 0-1 knapsack the condition is that each and every chosen items must be whole, fraction of an item cannot be selected in solution.[24]

DP solution for the 0-1 knapsack problem performs in pseudo-polynomial time. Solution runs in $O(nW)$ time and $O(nW)$ space. In 1974, another algorithm for 0-1 knapsack

was discovered named "meet-in-the-middle". Name matches with the algorithm in cryptography due to parallels to a similarly of concept. However it is preferable to the DP algorithm when capacity(W) is large compared to number of total itmes (n). It takes O($2^{n/2}$) space and O($n2^{n/2}$) time. A greedy approximation algorithm was proposed to solve the knapsack problem, but where the supply of each item is restrained, algorithm is not capable to give optimal solution.[24] These results concludes that Dynamic Programming is the best approach among the traditional algorithms to treat the knapsack problem.

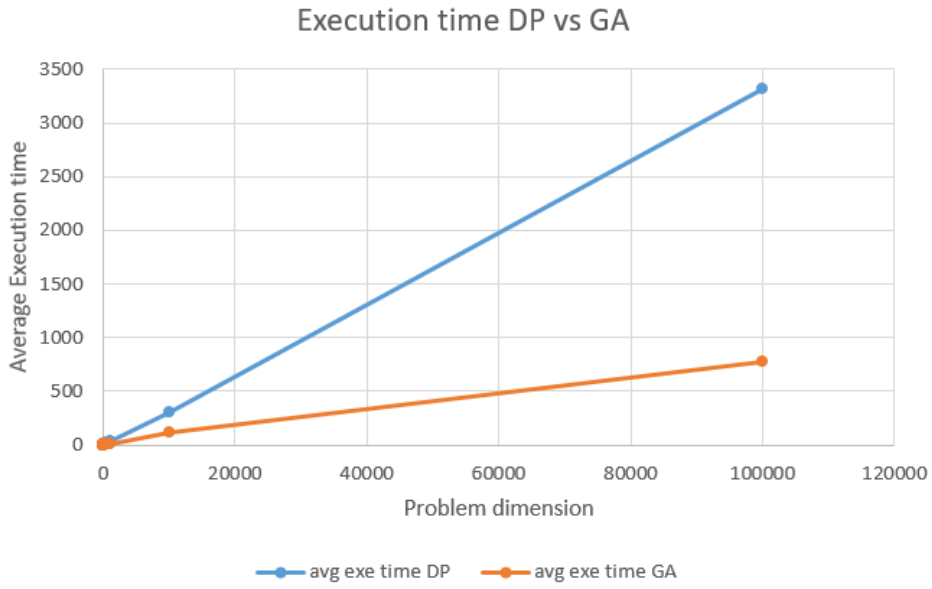


Figure 5.1: Execution time comparison between dynamic programming and genetic algorithm

Generally knapsack is an packing kind of problem. As we all know some operations gets better over time. Experience makes those task to perform better and to take better decisions. Experience comes with the the generations and generations are part of evolution. So here we can take help of ($Biologybasedalgorithms- > Reproduction- > Evolutionaryalgorithms$) for knapsack problem. In which genetic algorithm is one of the best choice. Figure 5.2 shows flow diagram to use Genetic Algorithm to solve 0-1 knapsack problem.

When this flow diagram is implemented. It shows better results then Dynamic pro-

gramming. Figure 5.1 shows the execution time compression. Here, problem size is the total number item, so it is observable that slope of execution time for GA is is lesser than slope of execution time for DP. In terms of execution time GA performs much better than DP.

5.1.2 Travelling Salesman Problem

Travelling Salesman Problem is also an NP-hard problem in combinatorial optimization group. It is important in operations of research and theoretical computer science. The decision version of the TSP belongs to the class of NP-complete problems, in the theory of computational complexity. It is expected that running time for any algorithm for the TSP increases superpolynomially with the number of cities in the worst cases. The TSP has several applications in planning and logistics.

TSP is defined as a list of cities and the distances between each pair of cities is given and the question is to find the shortest possible route that visits each city and returns to the origin city.

The most obvious solution would be to try brute force approach. Testing all permutations takes a polynomial factor of $O(n!)$ running time, the factorial of the number of cities, hence this solution becomes impractical even for only 20 cities. Branch-and-bound algorithms can be used to process 40–60 cities.

A method of heuristically generating "good solutions" to the TSP was proposed by an Artificial intelligence researcher Marco Dorigo in 1993. As we all know NIAs are the best meta-heuristic algorithms. Route finding task is matter of team work, simultaneous searching helps to achieve the best solution. Herd behaviour can be helpful for this type of problem. Scientists' concerned problem is already solved by nature. Ants are the best solver of route optimization problem. Hence ($Biology - basedalgorithms- > Resourceseeking- > HerdBehaviour- > AntColonyOptimization$) leads to the end of our algorithm search.

A large number of virtual ant agents to explore many possible routes on the map are sent by ACO. Based on a heuristic combining the distance to the city and the amount

of virtual pheromone deposited on the edge to the city each ant chooses the next city based on probability. Depositing pheromone on each edge is explored by ant, until all ants completes a tour. At the end the ant which completes the shortest tour deposits more virtual pheromone. The amount of pheromone deposited is inversely proportional to the tour length: the shorter the tour, the more it deposits.

5.2 Optimization

All the living and non-living world, the planetary, galactic, heavenly framework and the glorious bodies known to mankind have a place with nature. One normal viewpoint can be seen in nature, be it physical, substance or organic, that the nature keeps up its harmony using any and all means known or obscure to us. A rearranged clarification of the condition of balance is the possibility of ideal looking for in nature. There is ideal looking for in all circles of life and nature [25][26][27]. In all kind of optimization, there are goals or objectives which is suppose to be achieved and constraints which are supposed to be satisfied [28] [29] [30] [31]. This optimizing behaviour can be defined as an optimisation problem [32][33][34][35]. Which means, finding the best solution is measured by a performance index, which is known as objective function. It differs from problem to problem [36] [37] [38] [39]. Following are the topics, I have already worked upon.

- Implementation of Strawberry Algorithm and Bacteria Foraging Optimization Algorithm
- Comparison BFOA with gradient Descent for mathematical function optimization (No significant results)

5.3 Optimal Feature Selection in Neural Networks

Many Machine Learning and Deep Learning algorithms depend upon which kind of feature is been offered. It is data scientist's job to select feature optimally to achieve the best accuracy in minimal amount of time. To automate this process NIAs can be used.

Illustrations mentioned in section 4.5 are example of feature selection using NIA. Instead of using human intelligence, which may lead to non optimal solution, Nature's intelligence is used. Exploitation of NIA for this use is still under process.

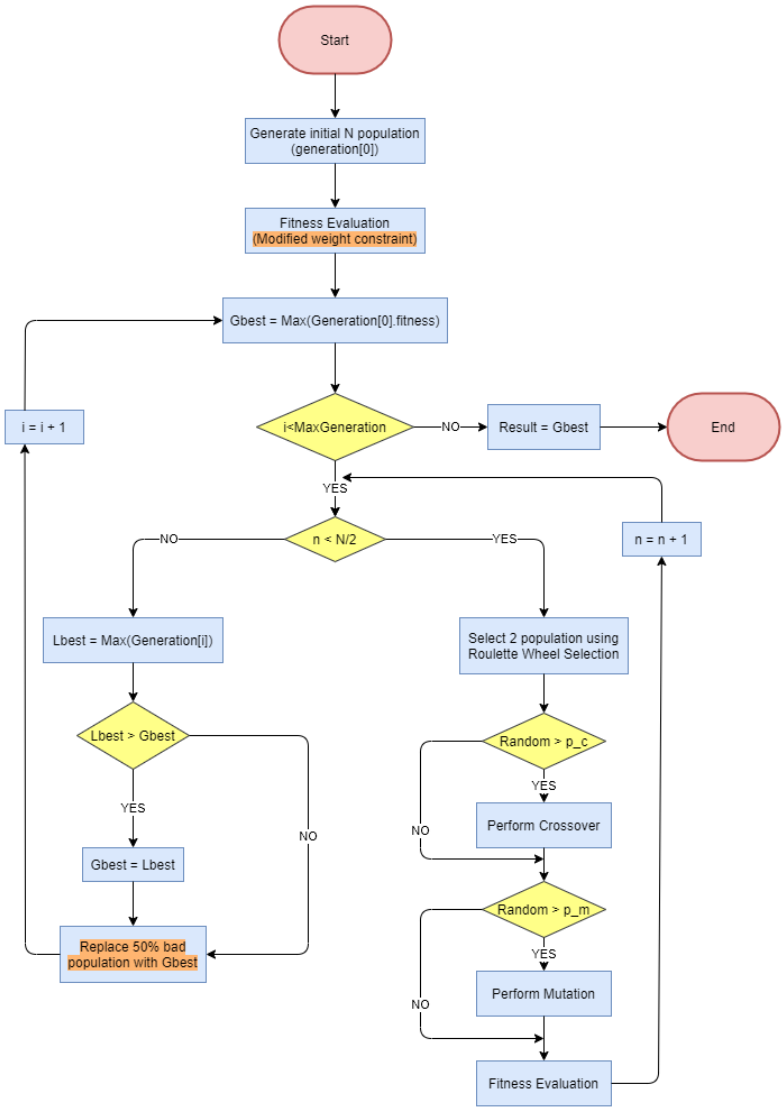


Figure 5.2: Flow chart of genetic algorithm to solve 0-1 knapsack problem

Chapter 6

NIA as Meta-heuristic in Industrial Application

6.1 Logistic Problem Solver

Logistic problems are one of those problem that are highly in demand. Each organizations puts their requirements for business, as new problem statement of logistics. Deciding route for new transport network is such a trick question. Analysing traffic flow, people flow, managing busiest hours on busy roads, etc. pre-research is needed to solve routing problem. Even after efforts bus managing company have to bare issues like higher maintenance cost than income because of less occupied buses. In the era of shared cabs, shared buses could be the one the solutions. The most interesting feature of shared bush is undefined bus routes, re-route on demand. Lack of predefined route gives liberty to customer to take any buses near by them. In detail problem statement is defined below.

6.1.1 Problem Statement

- Customer is supposed to provide number of tickets they want
- If nearest bus has that many empty seats then
- RE-route of bus route as new request arrives

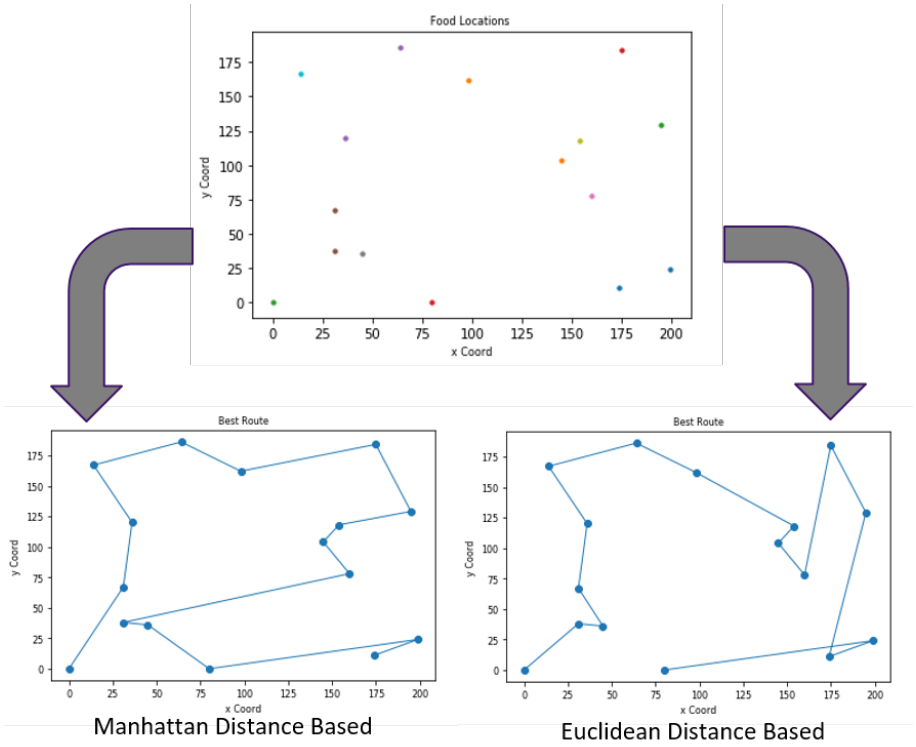


Figure 6.1: Two different distance equation as optimal function

- Else check the same with other buses.

6.1.2 Solution

Here to solve this problem Ant colony optimization is used. It is kind of Evolutionary ACO. ACO is used to optimize path after arrival of new request. Re-routing procedure is handles by Ant Colony Optimization. The motto behind choosing ACO as meta heuristic is, it can handle huge number of stations. No other routing algorithm is capable enough to locate optimal route among higher number of stations.

More over here total path distance is an optimization function. In this solution Manhattan distance is used for rectangular planned cities to follow roads, but for drone delivery Euclidean can be used, as that is eye-sight distance as shown in Figure 6.1.

6.1.3 GUI

Customer end GUI is consist of text box asking for number of passengers that want to travel.One button to check availability. One button to confirm reservation and a label to show status. Currently GUI is under development.

6.1.4 Console Outputs

Algorithm was run for 50 requests generated at certain time intervals. Here attached snapshots are represents first, second, third, forth, tenth and fiftieth request respectively.

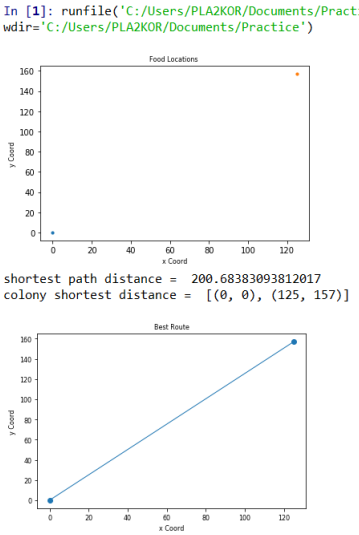


Figure 6.2: Bus route after first request

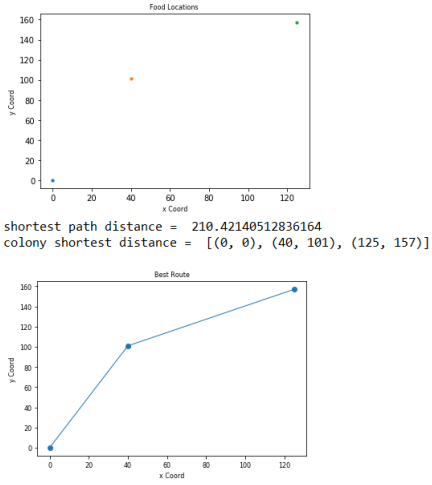
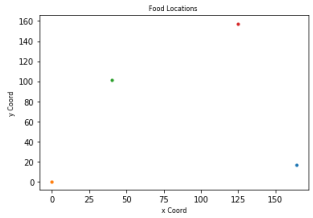


Figure 6.3: Bus route after second request




```
shortest path distance =  355.7520625960825
colony shortest distance =  [(0, 0), (40, 101), (125, 157), (164,
17)]
```

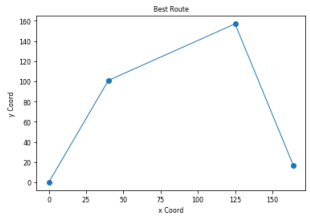
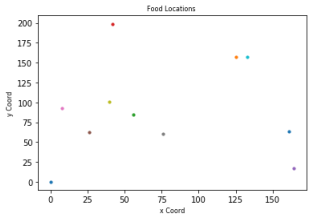


Figure 6.4: Bus route after third request




```
shortest path distance =  533.403202032238
colony shortest distance =  [(0, 0), (26, 62), (8, 93), (40, 101),
(56, 85), (76, 60), (164, 17), (161, 63), (133, 157), (125, 157),
(42, 198)]
```

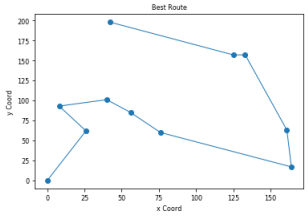


Figure 6.5: Bus route after tenth request

Chapter 7

Work done and Future Work

7.1 Work Done

- Literature Study of NIA (75 Algorithms)
- Studied Existing Classification Technique
- New Classification Technique (End Goal based)
- Evidence Gathering with Examples
- Implemented Strawberry Algorithm and Bacteria Foraging Algorithm
- Experimented to replace Gradient Descent with Bacteria Foraging Algorithm
- Solved NP-H Problems with NIA
  - 0-1 Knapsack Problem using Genetic Algorithm
  - Traveling Salesman Problem using Ant Colony Optimization
- Creating Dynamic Bus Routine Demo

7.2 Future Work

- Dynamic Bus Routine

  - To encode more Encoding rulesworld constraints to make it more efficient
  - To build final product to serve Bosch automotive mobility service

- To create NIA recommendation tool
- Use of NIA for feature selection in Neural Networks
- Use of NIA for Evolutionary Neural Networks
- To introduce coral reef inspired software architecture

Chapter 8

Conclusion

The sole purpose of introducing 'The End Goal based Classification' is to convey the missing pattern to link problem and solution. Author identified this issue and tried to carve path for the same. The identification of the problem and classification of problem helps to narrow down the range of suitable NIAs. A task like Parameter tuning, structure selection, parameter optimization which follows brute force approach can be solved with the help of NIA classification and mapping with conceptual problems. This approach is expected to benefit researchers and engineers working on computationally intensive and data starved problems to identify solutions in the most efficient way. Here NIA are not claimed to be revolutionary algorithms as they exist since decades, but using NIA as catalyst will definitely improve performance in terms of time of computational complexity or efficiency or energy consumption. To support this statement industry is working in the that direction. Dynamic bus Routing and solution of NP-Hard Problem using NIA are examples for that.

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