INVESTIGATING THE PERFORMANCE OF METAHEURISTICS TO OPTIMIZE THE REVENUE OF SEMICONDUCTOR SUPPLY CHAIN

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MUHAMMAD SHARIFUDDIN BIN ROSLEE

UNIVERSITI SAINS MALAYSIA

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LIST OF ABBREVIATIONS

IC – Integrated Circuits

SC – Supply Chain

OEM – Original Equipment Manufacturer

EV – Electric Vehicle

FMS – Flexible Manufacturing System

AT – Assembly Test

FAB – Semiconductor Production Plant

CRM – Customer Relationship Management

ODP – Order Demand Planning

OLT – Order Lead Time

ASSP – Application-Specific Standard Items

CSP – Customer Specific Products

EOL – End of Life

RPM – Resale Price Maintenance

VMI – Vendor Managed Inventory

TPS – Toyota Production System

DNA – Deoxyribonucleic acid

RNA – Ribonucleic acid

SCM – Supply chain management

BSO – Brainstorming Algorithm

SCA – Society and Civilization Algorithm

EO – Electromagnetism-like Optimization

BA – Bat Algorithm Optimization

BEA – Bees Algorithm

FA – Firefly Algorithm

SSA – Squirrel Search Algorithm

WOA – Whale Optimization Algorithm

SMA – Slime Mould Algorithm

MENGENALPASTI KEMAMPUAN METAHEURISTIK DALAM MENGOPTIMUMKAN RANTAIAN PENGHASILAN SEMIKONDUKTOR

ABSTRAK

Menyiasat prestasi metaheuristik untuk mengoptimumkan hasil rantaian bekalan semikonduktor ialah projek tahun akhir yang memberi tumpuan kepada mengenal pasti masalah kekurangan rantaian bekalan yang berkaitan dengan semikonduktor dan membandingkan antara 20 program pengoptimuman algoritma metaheuristik yang mampu mengoptimumkan rantaian bekalan semikonduktor. Perancangan yang teliti diperlukan pada banyak peringkat, daripada reka bentuk susun atur awal sehinggalah pembinaan kemudahan itu sendiri. Adalah penting bahawa keputusan perancangan yang betul dibuat dari awal dan bahawa dasar operasi di kilang sedia ada dan yang dicadangkan memaksimumkan pengeluaran produk tanpa mengorbankan kualiti produk atau kebolehpercayaan kilang jika permintaan pengguna yang semakin meningkat untuk kerumitan dan kepelbagaian produk yang lebih besar pada kos yang lebih rendah adalah untuk dipenuhi dengan menguntungkan.

Pada wafer biasa, terdapat antara 300 dan 500 langkah pembuatan, dan masa kitaran produk selalunya melebihi sebulan. Selain itu, mesin dibahagikan kepada jenis bersiri dan kelompok berdasarkan kuantiti item yang diproses pada masa yang sama. Lot wafer perlu menunggu lebih lama untuk operasi kelompok disebabkan oleh perubahan saiz kelompok. Adalah sukar untuk menganalisis perancangan pengeluaran dengan mengambil kira semua aspek ini. Apabila saingan berkembang, pengeluar semikonduktor mesti lincah dan fleksibel untuk kekal dalam perniagaan. Perubahan dalam campuran produk menjadikan sistem lebih rumit. Sebilangan besar produk berbeza mesti diproses oleh mesin di kemudahan pembuatan semikonduktor (fab), yang membawa kepada isu perkongsian sumber dan potensi untuk talian yang panjang.

Disebabkan oleh kesederhanaan, fleksibiliti, banyak kaedah yang boleh diakses, dan keupayaan untuk mengelakkan optimum tempatan sepanjang proses pengkomputeran,

metaeuristik menjadi semakin popular untuk menangani isu pengoptimuman. Algoritma yang digunakan untuk menangani isu pengoptimuman dalam beberapa sektor saintifik dan teknologi tidak memerlukan pengubahsuaian besar untuk berjaya. Pengoptimuman adalah mungkin untuk setiap fungsi objektif, tidak kira sama ada ia berterusan atau boleh dibezakan. Disebabkan sifat rawak pendekatan metaheuristik, terdapat kebarangkalian tinggi bahawa penyelesaian optimum global akan ditemui.

Matlamat pengoptimuman yang telah ditetapkan boleh dicapai dengan mengukur ukuran kualiti, juga dikenali sebagai fungsi kecergasan, fungsi objektif atau tahap kebaikan. Pengukuran ini bertujuan untuk memaksimumkan kualiti yang diingini sambil mengurangkan yang tidak diingini. Nilai kecergasan yang kecil selalunya menunjukkan nilai pembolehubah kawalan yang hampir kepada optimum, seperti yang ditunjukkan dalam kes ini. Di bawah ialah perbandingan nilai kecergasan antara 20 algoritma metaheuristik yang dijalankan melalui pengaturcaraan Python.

INVESTIGATING THE PERFORMANCE OF METAHEURISTICS TO OPTIMIZE THE REVENUE OF SEMICONDUCTOR SUPPLY CHAIN

ABSTRACT

Investigating the performance of metaheuristics to optimise the revenue of the semiconductor supply chain is the final year project that focuses on to identify the supply chain shortage problem related to semiconductors and to compare among the 20 metaheuristics algorithm optimization programmes capable of optimising the semiconductor supply chain. Thorough planning is required at many levels, from the initial layout design through the building of the facility itself. It is imperative that the correct planning decisions are made from the beginning and that the operating policies in existing and proposed factories maximise the product output without sacrificing product quality or factory reliability if the increasing consumer demands for greater product complexity and diversity at lower cost are to be met profitably.

On a typical wafer, there are between 300 and 500 manufacturing steps, and the product cycle time is frequently more than a month. In addition, machines are divided into serial and batch types based on the quantity of items being processed at the same time. Wafer lots would have to wait longer for batch operations due to batch size transformations. It is difficult to analyse the production planning with all of these aspects in consideration. As the rivalry expands, semiconductor manufacturers must be nimble and flexible in order to stay in business. Changes in the product mix make the system even more complicated. An enormous number of distinct products must be processed by machines in a semiconductor manufacturing facility (fab), leading to resource sharing issues and the potential for a lengthy line.

Due to their simplicity, flexibility, vast number of accessible methods, and ability to avoid local optimums throughout the computing process, metaheuristics are becoming increasingly popular for addressing optimization issues. The algorithms used to tackle optimization issues in several scientific and technological sectors do not require major modifications to be successful. Optimisation is possible for every objective function, regardless of whether or not it is continuous or differentiable. Due to the random

nature of metaheuristic approaches, there is a high probability that global optimal solutions will be discovered.

A predetermined optimization goal can be achieved by quantifying the quality measures, also known as fitness functions, objective functions, or goodness levels. These measurements aim to maximise desired qualities while decreasing undesirable ones. Small fitness values are often indicative of close-to-optimal control-variable values, as shown in this case. Below is the comparison of the fitness value among 20 metaheuristics algorithms run through Python programming.

CHAPTER 1:

INTRODUCTION

1.1 Overview of optimization

The quest for novel computational intelligence approaches has boosted the efficacy of resolving computer jobs and issues that are exceptionally challenging and uncommon, and for which existing methods may fail. Metaheuristics are becoming increasingly popular for addressing optimization issues due to their simplicity, flexibility, vast number of accessible methods, and ability to avoid local optimum throughout the computing process. The algorithms used to tackle optimization issues in several scientific and technological sectors do not require major modification to be successful. Optimisation is possible for every objective function, regardless of whether or not it is continuous or differentiable. Due to the random nature of metaheuristic approaches, there is a high probability that global optimal solutions will be discovered. Consequently, it is desirable to research novel approaches for addressing real-world optimization issues that are more effective than existing algorithms for the problem class under discussion (Pijarski & Kacejko, 2019).

Natural computing algorithms that take their design inspiration from the foraging activities of various organisms constitute an important subdomain of the field (Brabazon & An Mcgarraghy, 2020). The goal of optimising a design could be to reduce production costs or to increase production efficiency. Until an optimal or satisfactory solution is found, an optimization algorithm compares various solutions in order to be carried out iteratively. The use of computers in computer-aided design has brought optimization into the fold. Modern optimization algorithms fall into two broad categories. Deterministic algorithms are a set of rules when moving from one solution to another. These algorithms have been successfully applied to a variety of engineering design problems and are currently in use to suit some situations. Stochastic algorithms are based on probabilistic translation rules. These are gaining popularity because they have properties that deterministic algorithms do not.

Electronic products, such as remote controls for television and supercomputer models that simulate weather patterns, contain semiconductors, also known as microchips and integrated circuits (ICs). The global semiconductor supply chain is relatively fragile and susceptible to disruptions from natural and man-made shocks, whereas chips themselves are resilient and made to handle extreme temperatures, vibrations and other external shocks. Following factory shutdowns due to the pandemic, the car industry rebounded faster than expected, sending semiconductor supply into a downward spiral, which resulted in a shortfall in the tiny electronic components across numerous industries. As people all over the world scrambled to find new ways to work and play due to the outbreak, it put enormous strain on supply chains, especially for consumer electronics like laptops, video game consoles, and smartphones. The chip shortage spread to consumer electronics products at the end of last year, where strong demand for laptops, next-generation gaming consoles, and other devices had already tightened inventory.

This has increased the effectiveness of resolving complex and uncommon computational issues that conventional approaches may have trouble resolving. Due to its simplicity, adaptability, and capacity to avoid local optima, metaheuristics are becoming more and more popular for addressing optimization issues. Without significant modifications, the methods used to handle optimization issues in a variety of scientific and technological disciplines can be employed successfully. Any objective function, whether continuous or not, can be optimised. Global optimal solutions are feasible due to the intrinsic randomness of metaheuristic approaches. As a result, it is important to investigate novel approaches that outperform current algorithms for resolving practical optimization issues.

In connection, a semiconductor is a tiny electronic component used in items like TV remote controls and weather simulation supercomputers (ICs). Chips are strong and engineered to survive harsh temperatures, vibrations, and other external shocks, in contrast to the global semiconductor supply chain, which is subject to both natural and man-made shocks. As individuals rushed to find new ways to work and play as a result of the epidemic, supply chains were severely stretched, particularly for consumer devices like laptops, gaming consoles, and cell phones. Consumer electronics, where increased demand for laptops, gaming consoles, and other products had already reduced inventories, was affected by the chip shortage of the previous year.

Unified optimization framework used to regulate a problem-specific heuristic so that the approach may be applied to a range of problems. A metaheuristic, also known as a broad optimization framework. Using metaheuristics, a variety of difficult optimization problems have been effectively solved, or have at least produced good results, over the past two decades. Despite their shared historical and theoretical foundations, these strategies are highly different and challenging for novices to learn. Many of these challenges come organically in domains like operations research and logistics, which is the key point. Highly desired would be the potential of a less-than-ideal but still satisfying resolution for these (Chopard & Tomassini, n.d.).

To determine an algorithm's efficiency, we need to know how long it takes to solve one of a set of problems. However, as we will see later, this does not affect the main conclusions, only the actual computing times. That is, the time it takes an algorithm to return an answer is simply the sum of elementary operations performed until the programme stops (Chopard & Tomassini, n.d.).

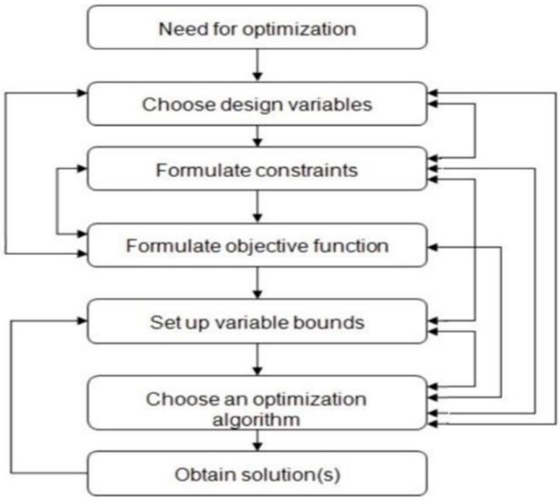

Figure 1.1 General algorithm approach. (Assistant Professor & Associate Professor, n.d.)

1.2 Problem statement

In contrast to chips, the global semiconductor supply chain is vulnerable to natural and man-made shocks. Automobile sales grew faster than expected, leading to a shortage of semiconductors across industries. Due to the outbreak, people were scrambling to find new ways to work and play, particularly for consumer electronics like laptops, gaming consoles, and smartphones. High demand for laptops, gaming consoles, and other devices had already tightened inventory last year. As a result, it is necessary to optimise the semiconductor supply chain. However, it appears as though the methodology that will be used is quite broad. The research is defined by adhering to the metaheuristic optimization method. On the other hand, metaheuristics is composed of numerous components, including genetic or evolutionary algorithms, tabu search, simulated annealing, variable neighbourhood search, (adaptive) large neighbourhood search, and ant colony optimization. and the slime mould algorithms are the area of interest to be selected.

As a network, the supply chain (SC) is supposed to deliver the correct items and services on time, according to specified standards, at the right location, and to the right client. Nowadays, supply chains (SCs) are undergoing several changes that contribute to their complexity, including corporate globalisation and the adoption of certain business philosophies such as lean manufacturing, efficient consumer responsiveness, and rapid response programmes. Implementing these attitudes or practises may introduce further complications, since SCs may become more susceptible to perturbations (Christopher & Towill, 2000).

Organizations and their SCs must be resilient in order to survive they must learn to respond fast to unanticipated disturbances and to swiftly recover to their original condition or shift to a new, more beneficial state after experiencing the disruption (Wang et al., 2016).

It is essential for the SC to be structured in such a way that it is prepared for events, can respond efficiently and effectively when they occur and can return to their original or even better condition after a disruptive event in order to decrease its susceptibility and increase its resilience. The methodologies highlighted by a large body of research support the necessity to include resilience research as a significant consideration in the development of SC design strategies. The primary goal of this work is to demonstrate how simulation may be used to assist in the decision-making process during SC design in order to produce a more robust SC. Simulation enables for the observation of SC behaviour under various SC design techniques, which may then be used to increase SC resilience (Ponis & Koronis, 2012).

As a result of the observation of natural, physical, and even sociological phenomena, excessive abstraction may obliterate critical aspects, not only for appreciating nature's rich diversity, but also for comprehending context and seeking alternative explanations for an observation. While similarities may be obvious, correlation does not imply causation. Myopic perspectives should be avoided. Thus, both biology and physics assist us in comprehending fundamental concepts. As with art, expression can be abstract or concrete, though ultimately our interpretation abstracts. The fundamental flaw in biomimicry, at least in its popularised manifestation, is that it is none of these. It is not based on science and thus lacks a firm foundation (Coppens, 2021).

1.3 Overview of the overall structure

The new terms in this kind of final thesis paper is agility. Agility is a business-wide competency that encompasses organisational structures, information technology systems, logistics processes, and in particular, philosophies. One of the most important characteristics of an agile organisation is its adaptability. In reality, the origins of agility as a business concept may be traced back to the development of adaptable manufacturing systems (FMS). It was formerly believed that the path to greater manufacturing flexibility would be through automation, which would allow for faster changeover example is reduced set-up times and consequently, greater responsiveness to changes in product mix or volume production. Contrary to popular belief, many businesses that have implemented lean manufacturing as a business approach are anything from nimble in their supply chain operations. The automobile business for example, in many ways, exemplifies this problem. The Toyota Production System (TPS) can be credited with establishing the foundations of lean manufacturing with its emphasis on the reduction and elimination of waste (Christopher & Towill, 2000).

The situation of lean manufacturing as it relates to car production and automakers can be applied towards the supply chain of semiconductors as well. As these labels imply, it is critical for every organisation to grasp the minimum requirements for joining a competitive arena, these are known as order qualifiers. To truly win the order, special qualities are required, which the author termed as the order winners. After defining order qualifications and order winners, it is natural to provide the suitable production plan. High levels of product quality are required for both agility and leanness. This includes a minimal total lead time, which is the amount of time it takes from a customer's initial request to delivery of their product or service. There must be a reduction in total lead time since demand is variable and hence difficult to estimate. In order to take advantage of market demand, a supply chain must be able to adapt rapidly (Christopher & Towill, 2000).

Another term is postponement. Postponement, also known as delayed configuration, is based on the notion of attempting to develop goods using common platforms, components, or modules, but deferring final assembly or customization until the ultimate market destination and either client demand is known. Process integration is the only way to maximise the value of information exchanged between supply chain parties. Collaboration between buyers and suppliers, cooperative product creation, common systems, and shared information are all examples of what is meant by "process integration". As corporations focus on their core capabilities and outsource all other tasks, this type of cooperation in the supply chain is becoming more and more common. This new environment necessitates a new kind of interaction with suppliers and alliance partners, and so a new kind of partnership is required (Christopher & Towill, 2000).

There are various advantages to the postponing technique. To begin, inventory can be stored at a generic level, resulting in fewer stock-keeping varieties and, as a result, less overall inventory. Second, because the inventory is generic, it has higher flexibility, which means that the same components, modules, or platforms may be embodied in a wide range of end products. Third, predicting is simpler at the general level than at the finished item level. It is critical to recognise that there are two decoupling points in real-world supply chains. The first is the material decoupling point, where strategic inventory is kept in the most general form conceivable. This point should preferably be as far downstream in the supply chain as practicable and as near to the ultimate marketplace as possible. The information decoupling point is the second decoupling point. The notion is that this should be as far upstream in the supply chain as feasible, it is, after all, the point at which information about actual ultimate demand may penetrate (Christopher & Towill, 2000).

1.4 Objectives of the project

1. To identify the problem of the shortage of supply chain related to semiconductor.
2. To compare among the 20 metaheuristics algorithm optimization programmes that can optimize the supply chain of the semiconductor.

CHAPTER 2:

LITERATURE REVIEW

2.0 Study of nine types of metaheuristics algorithms

The metaheuristics algorithms involved with this project contains of their respective types that might be difference in terms of group, name, short, year, version, batch size and difficulty.

<table>
<tr><th>Group</th><th>Name</th><th>Short</th><th>Year</th><th>Version</th><th>Batch Size</th><th>Difficulty</th></tr>
<tr><td rowspan="2">Evolutionary</td><td rowspan="2">Bees Algorithm</td><td rowspan="2">BEA</td><td rowspan="2">2004</td><td>base 1</td><td rowspan="2">yes</td><td rowspan="2">easy</td></tr>
<tr><td>base 2</td></tr>
<tr><td rowspan="14">Swarm</td><td rowspan="3">Bat Algorithm</td><td rowspan="3">BA</td><td rowspan="3">2010</td><td>original</td><td rowspan="3">yes</td><td rowspan="3">easy</td></tr>
<tr><td>base</td></tr>
<tr><td>modified</td></tr>
<tr><td rowspan="2">Whale Optimization Algorithm</td><td rowspan="2">WOA</td><td rowspan="2">2016</td><td>original</td><td rowspan="2">yes</td><td rowspan="2">easy</td></tr>
<tr><td>base</td></tr>
<tr><td>Firefly Algorithm</td><td>FA</td><td>2008</td><td>base</td><td>yes</td><td>easy</td></tr>
<tr><td rowspan="2">Squirrel Search Algorithm</td><td rowspan="2">SSA</td><td rowspan="2">2019</td><td>original</td><td rowspan="2">yes</td><td rowspan="2">medium</td></tr>
<tr><td>base</td></tr>
<tr><td>Society and Civilization Optimization</td><td>SCA</td><td>2003</td><td>base</td><td>yes</td><td>medium</td></tr>
<tr><td rowspan="2">Electromagnetism-Like Optimization</td><td rowspan="2">EO</td><td rowspan="2">2003</td><td>modified</td><td rowspan="2">no</td><td rowspan="2">medium</td></tr>
<tr><td>base</td></tr>
<tr><td>Human</td><td>Brainstorm Optimization</td><td>BSO</td><td>2011</td><td>original</td><td>no</td><td>medium</td></tr>
<tr><td>Bio</td><td>Slime Mould Algorithm</td><td>SMA</td><td>2020</td><td>changed</td><td>yes</td><td>easy</td></tr>
</table>

Table 2.1: Metaheuristic types and classification

2.1.1 Brainstorming Optimization

Swarm intelligence techniques like the Brain Storm Optimization (BSO) algorithm are based on the human propensity to solve optimization issues via brainstorming. Multiple Sequence Alignment is critical in bioinformatics. Even though a wide variety of methods have been developed to align sequences, it is still difficult to determine the ideal number of multiple alignments (Pujari et al., 2020).

Optimization is concerned with identifying the "finest" candidate solution to a given problem. Each solution in the exploration space is typified by a person in the swarm when it comes to swarm intelligence algorithms. Individuals are led towards better areas of search based on competition and collaboration until certain limits are met. Because the issue and its environment are intrinsically linked, an ideal optimization algorithm should be capable of developing its own capacity to learn and solve the problem at hand. This means it should be able to learn and solve the problem in its own environment (Shi, 2014).

It's possible that this algorithm will evolve in terms of capacity, which would mean that the search method would be altered. Divergent clusters are homogeneous to natural selection in the BSO solutions. One or two ideas are altered or combined with random information to generate the present concepts. Convergence and divergence in the solution space can lead to the best possible conclusion. Ideas are grouped and new ideas are generated by adding or altering information from the current ideas in solution space in this process. These algorithms have been used to tackle a wide variety of real-world situations. Several variations of BSO have been presented to efficiently address a variety of issue domains (Cheng et al., 2016).

The Multiple Sequence Alignment is a key construction element of molecular sequence analysis that is frequently used to detect and evaluate the similarities between DNA, RNA, and protein samples. Alignment is the arrangement of two or more sequences of residues (amino acids or nucleotides) to improve their compatibility. It can be critical for reconstructing phylogenetic trees or inferring homology. It can be used to predict the function and structure of an unknown protein by aligning its sequence with others of known function and structure (Pujari et al., 2020).

The BSO algorithm is a type of space search reduction technique in which all the produced concepts are eventually grouped into a large number of clusters. From cluster to cluster, the specifics of the search region consisting of solutions with ideal fitness values are developed. In BSO, the findings are separated into a variety of clusters. New persons are joined if an idea provides the highest value relative to other ideas within the same index; the quantity of concepts analysed in clusters is also a factor. When a new concept is close to the greatest idea, the utilising capability is enhanced, and when a new thought is generated randomly, the analysing capability is enhanced. This method consists of three main steps: concept clustering, new individual generation, and idea selection (Cheng et al., 2013).

This method of clustering has been replaced by a more straightforward grouping strategy. A new thought can be generated from one or two clusters, and this is the next phase. In the native BSO method, a probability value is employed to decide if one or two old ideas will yield a new idea. It is possible to refine a search area by constructing a new concept from the clusters of ideas, which improves the ability to use it. When all ideas have been considered, the best ones are selected for further consideration. After each new thought is created, the best idea is kept through the selection scheme, while the generation and grouping techniques are important for adding the new results to the group to maintain the general population's diversity (Zhan et al., 2012).

2.1.2 Society and Civilization Optimization

The capacity of a person to socialize with others is a fundamental social characteristic seen in all human and insect societies. Individuals can adapt and improve more rapidly via social interactions than through genetic inheritance alone. This is the main idea behind the optimization algorithm, which uses intra and intersociety interactions inside a formal society and the civilization model to address single objective confined optimization problems. On the other hand, leaders of a society can only improve through an intersociety information exchange that culminates in the migration of a leader from one society to another that is led by higher performing leaders. This process of leader mobility aids the expansion and growth of high-performing societies, which corresponds to a search for globally attractive locations in the parametric space (Ray & Liew, 2003).

On the other hand, leaders of a society can only improve through an intersociety information exchange that culminates in the migration of a leader from one society to another that is led by higher performing leaders. This process of leader mobility aids the expansion and growth of high-performing societies, which corresponds to a search for globally attractive locations in the parametric space. A society in this sense refers to a group of persons who interact with one another, whereas a civilisation is the collection of all of these societies at any particular period. Individuals are the fundamental social entities that interact in an effort to advance. This enhancement in an individual's performance is the result of obtaining useful information from a higher-performing individual of the same community (leaders). The aforementioned intrasociety contact between an average individual and its leader improves an individual's performance, which, over time, results in societies with greater performance (Ray & Liew, 2003).

A cultural algorithm model with two degrees of evolution is introduced. At the macroevolutionary level, a belief space recorded generalisations of individuals' experiences that were periodically updated, but at the microevolutionary level, individual solutions were formed under the influence of existing beliefs. All of the possible techniques may be considered as methods to harvest information from an existing population and then utilise it to direct the development of individuals. From the perspective of sharing or obtaining knowledge amongst people, ties may be formed with existing machine learning ideas where the goal is to extract data from others in order to avoid unappealing parts of the search space or exploit promising ones (Lee & Loia, 2007).

In this approach, the search space is traversed by candidate solutions initially dispersed in clusters resembling societies. In any civilization, the best solutions bias the search in their direction, i.e., the leaders urge their peers to follow them. Some leaders may travel to different places, bringing with them their equivalents from prior cultures. Civilization is the collection of all societies in which all individuals (solutions) may interact through their respective leaders. It is essential to understand that the stated algorithms aim to enhance the performance of persons in optimization issues. This is accomplished via gaining knowledge from good persons. These algorithms supplement existing convergence-oriented models that attempt to avoid infeasible search space areas. In this way, the excellent individuals or leaders serve as a guidance for the rest of the population (L. C. Jain & Nguyen, 2009).

It is essential to understand that the stated algorithms aim to enhance the performance of persons in optimization issues. This is accomplished via gaining knowledge from good persons. These algorithms supplement existing convergence-oriented models that attempt to avoid infeasible search space areas. In this way, the excellent individuals or leaders serve as a guidance for the majority of the people (L. C. Jain & Nguyen, 2009).

2.1.3 Electromagnetism—Like Optimization Algorithm

Electromagnetism-like (EML) algorithm is a novel evolutionary algorithm based on electromagnetic force of attraction between particles. Initially, it was intended to tackle optimization issues with constrained variables. The EML algorithm models the induced electric interaction between electrically charged particles. Due to its efficiency, the EML algorithm has been utilised for a variety of optimization issues (J.-L. Lin et al., 2012).

Influenced by the recent achievements made in the field of metaheuristics research. The process incorporates aspects of scatter search (SS), a population-based evolutionary search method, and a recently developed heuristic method for the optimization of unconstrained continuous functions that simulates the electromagnetism-like theory of physics; authors will refer to this method as the electromagnetism-like (EML) meta-heuristic from this point forward. Scatter search (SS) is an evolutionary or population-based strategy for combining answers to get superior results utilising convex or non-convex linear combinations. Diversification and intensification strategies are frequently used to improve the search. SS differs from other evolutionary processes such as genetic algorithms (GA) in that it provides unifying principles for connecting solutions based on generalised path constructions in Euclidean space and employs strategic designs where other techniques rely on randomisation (Debels et al., 2006).

The solution's objective function value provides the basis for this charge. Each solution point will exert attraction or repulsion on other solution points in an amount proportional to the product of the charges and inversely proportional to the distance between the points, as in evolutionary search algorithms (Coulombs Law). The method is based on the premise that less desirable solution points deter others in the population from moving in their direction, while more desirable solution points encourage others to travel in their direction. In a population-based perspective, this may be viewed as a sort of local search in Euclidian space. What sets this approach