SOLVE MULTI-OBJECTIVE QUADRATIC ASSIGNMENT PROBLEMS USING THE FISH SWARM ALGORITHM FOR THE INTERNAL ARRANGEMENT OF HOSPITAL FACILITIES

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Abstract
This study aims to study methods for solving multi-objective quadratic assignment problems using the fish swarm algorithm, by reviewing the literature related to the algorithm, identifying variables and criteria necessary to evaluate its performance, designing the study, and applying the algorithm to hospitals. The collected data is analyzed to provide results and recommendations, which contributes to improving quadratic allocation processes within the hospital and achieving the research goal.
The study concluded that the fish swarm algorithm shows a high level of efficiency in solving multi-objective quadratic mapping problems to reduce distances traveled within hospitals. The algorithm demonstrated the ability to improve planning and distribution of resources within hospitals. The algorithm also demonstrated the ability to improve the patient experience, which contributed to improving the efficiency of operations and reducing the time required to move between different places within the hospital.

Keywords: multi-objective quadratic assignment problems, fish swarm algorithm, hospital.

Introduction

Algorithms are the pillar of computational science. They are the basic blocks for solving computational problems efficiently. Algorithms are step-by-step procedures designed to perform specific tasks or solve specific problems. They take input data, process them according to pre-defined instructions, and produce output data in a specific time. Also, algorithms are not limited to a specific science; Rather, it can address a wide range of challenges across different fields, including mathematics, engineering, biology, finance, and more (Hill, 2016).
The importance of algorithms lies in their ability to determine the sequence or distribution of tasks or operations in an organized and appropriate manner to ensure the maximum benefit

from available resources, improve operations, and provide solutions to complex problems efficiently, whether it is a matter of sorting a list of numbers, searching for information on the Internet, or improving Resource Allocation In business, algorithms play a crucial role in modern computing (Tsamados, et al., 2022). Understanding algorithms involves not only knowing how to implement them, but also analyzing their performance characteristics, including time complexity (how long does the algorithm take to run) and spatial complexity (how much memory does it require). Effective algorithms balance these factors, ensuring they can handle large-scale calculations effectively (Tsamados, et al., 2022).

Algorithms also come in various shapes and sizes, each of which is designed to suit specific types of problems. Algorithms vary between simple and straightforward, complex and sophisticated, and can be classified based on their design strategies, such as brute force attack, divide and conquer algorithm, dynamic programming, and algorithms. Greedy. Concurrent with technological development, algorithms have also evolved. New types of algorithms have emerged, such as hybrid algorithms, which combine techniques from different algorithms to achieve better results. (Cormen et al., 2022).

One of the most famous algorithms is the fish swarm algorithm. It is a technology inspired by the behavior of groups of fish in nature, where a group of fish communicates, coordinates, and interacts with each other to achieve specific goals, such as survival, finding food, or moving effectively within the oceans...etc. The fish swarm algorithm is based on the concept of interaction between individual organisms in the group, as these groups continuously exchange information and trends to better achieve the goals of the group as a whole.

The main goal of the algorithm is to achieve a balance between exploring the surrounding environment and effectively exploiting the available resources. Individual fish communicate and interact with neighboring fish using simple signals such as movements, tones and colours, allowing the swarm to adapt to environmental changes quickly and effectively. The application of this algorithm to evolutionary computing and artificial intelligence is broad, as it can be used to solve a variety of computational, engineering, design, and planning operations.

The algorithm also has the ability to balance environmental exploration and resource exploitation, making it ideal for solving mapping and design problems in a variety of fields, including architecture, urban planning, wireless network design, and environmental optimization. The algorithm has evolved since it first appeared. It is constantly improved through the application of modern technologies such as machine learning and others, making it one of the essential tools in solving difficult problems that require a balance between navigation, exploration and exploitation in changing environments.

Quadratic assignment problems are also considered one of the combinatorial optimization problems that have gained wide fame and great interest from researchers due to the simplicity of their formulation and important applications. The goal of the Quadratic Assignment Problem (QAP) is to allocate n facilities to n locations. Each location takes only one facility, which is exactly the same as the linear assignment problem (LAP) except for the difference in the objective function. The quadratic term describes the objective function that represents the sum of the factors of the distances between sites and the flow quantities between the facilities allocated to those sites.

For the purpose of generating a practical solution to the QAP problem, Q= (Q(1) Q(2),……,Q(n)) is imposed, which represents the vector of correct permutations of the facility locations (1,2,..,n), since the goal of the problem is It consists in finding the optimal permutation vector that leads to finding the optimal cost (the lowest cost), and since reaching an optimal mathematical solution to the quadratic allocation problem, especially in cases where the size of the population is large, is close to impossible, therefore resorting to the use of intelligent techniques represented by algorithms Evolutionary and other methods for the purpose of solving the problem.

The relationship between the fish swarm algorithm and multi-objective quadratic allocation problems is to use the algorithm to solve these problems in an efficient and innovative way, as the algorithm can help determine the optimal distribution of resources based on the interaction of systems and adapt to changes in conditions and requirements. Thus, the artificial fish swarm algorithm can be used to solve multi-objective quadratic allocation problems to improve efficiency and better achieve the desired objectives for indoor application in hospital facilities.

On this basis, this research relied on employing the advantages of the fish swarm algorithm to solve the multi-objective quadratic assignment problem to find the optimal solution to the problem.

1. Previous Studies:

The following is a review of the most prominent previous studies related to the research topic:

The study (Hill, 2016) addressed the definition of the algorithm, where the algorithm, which is a basic building block in computer science, is defined from an intuitive and practical point of view, through the methodological lens of philosophy rather than formal computation, and the treatment extracts the characteristics of abstraction, control, structure, and limitedness, effective mechanism, determinism, intended aspects of the goal and preconditions. Analysis of the implications in computer science and philosophy has revealed unexpected results, new questions, and new perspectives on existing questions, including the relationship between our informally interpreted algorithms and Turing machines.

The study (Lin, et al, 2012) also addressed improving the parameters of the GM (1,1) model based on the artificial fish swarm algorithm. The aim of this study is to enhance the prediction accuracy of the GM (1,1) model using an improved artificial fish swarm algorithm. The results show that the proposed method enhances the accuracy of the GM (1,1) model and has better performance than particle swarm optimization.

Likewise, the study (Duan, et al, 2016) dealt with an improved artificial fish swarm algorithm that was improved by a particle swarm optimization algorithm with extended memory. Since the purpose of this study is to improve the convergence rate and accuracy of the basic artificial fish swarm algorithm (FSA), a new FSA algorithm improved by PSO algorithm with extended memory (PSOEM-FSA) is proposed. In PSOEM-FSA, the extended memory of PSO is introduced to store the historical information of each particle which consists of recent places, personal best positions, and global best positions, and a parameter called the effective factor of extended memory is used to describe the importance of the extended memory. Hence, the stability region in its deterministic version in a dynamic environment is analyzed by classical discrete control theory. The study proposes a new intelligent algorithm.

On the one hand, this algorithm makes the swimming fish have the characteristics of inertial speed; On the other hand, it expands the behavior patterns of fish for selection in the searching process, achieves higher accuracy and convergence rate than PSO-FSA, and possesses extended memory that is useful for orientation and purpose during searching. The simulation results verify that these improvements can reduce the blindness of the fish searching process and improve the optimal performance of the algorithm.

A study (Abdul Gafoor & Theagarajan 2022) addressed the intelligent approach of the results-based synthetic fish swarm algorithm (SAFSA) to diagnose Parkinson's disease. The goal of this study is to improve the accuracy of diagnosing Parkinson's disease by using machine learning techniques, such as the synthetic fish swarm algorithm, to classify signs. Researchers aim to leverage advancements in mobility, health control, and disease diagnosis to address the early detection of Parkinson's disease and differentiate it from similar conditions. By meticulously analyzing a diverse array of movement indicators and health parameters, they endeavor to develop a methodology capable of accurately and effectively discerning early signs of Parkinson's disease. This study endeavors to pioneer a novel approach utilizing the synthetic fish flock algorithm to identify crucial diagnostic features for Parkinson's disease. The proposed method promises to enhance diagnostic accuracy and efficacy, while also streamlining the diagnostic process by reducing the reliance on extraneous features. This, in turn, facilitates classification procedures and heightens diagnostic efficiency. Furthermore, the research contributes to an enriched understanding of the motor indicators associated with Parkinson's disease, fostering the development of contemporary diagnostic methods tailored for precise disease identification and diagnosis.

In a parallel study conducted by Celal and Alpaslan (2013), the synthetic fish flock algorithm was adapted and applied to address instances of the biological objective quadratic assignment problem (BiQAP), showcasing the algorithm's versatility and robustness in tackling complex biological objectives. Robust parameter sets were calculated for all 12 multi-objective ant colony optimization (MOACO) algorithms and BiQAP instances in the literature were solved within these parameter sets. The performance of the algorithms was evaluated by comparing the Pareto fronts obtained from these algorithms. In the evaluation step, a multiple significance test in a non-hierarchical structure is used, and the performance measure (P metric) necessary for this test is presented.

Study (Elbeltagi, et al, 2016), as the purpose of this study is to provide a comprehensive multi-objective optimization model for project scheduling taking into account time, cost, resources, and cash flow. Application of the developed model to scheduling a realistic case study project proves that the proposed model is valid in modeling realistic construction projects and gives important results for project schedulers and managers. The proposed model is expected to help construction managers and decision makers in successfully completing the project on time and reducing budget by utilizing available information and resources.

In the study of (Cubukcuoglu, et al, 2019), in this study, we propose a meme algorithm with efficient local search and mutation operators to solve bQAP. The local search is based on the swap neighborhood structure while the mutation operator is based on the destroy and rebuild procedure. Experimental results show that our bi-objective memetic algorithm (BOMA) significantly outperforms all island-based variants of the PASMOQAP algorithm recently proposed in the literature.

As well as a study (Mohamed & Geetanjali, 2020), where a globally convergent sequential quadratic programming (SQP) method was developed to solve multi-objective optimization problems with inequality type constraints. The direction of possible descent is obtained using a linear approximation of all objective functions as well as constraint functions. The subproblem in each iteration of the sequence has a possible solution. A non-differentiable penalty function is used to handle constraint violations. A descent sequence that converges to a critical point is generated under the Mangasarian-Fromovitz constraint qualifier as well as some other moderate assumptions. The method is compared with a selection of existing methods on a suitable set of test problems.

Also, the study (Ningtiyas, et al, 2021), where this study dealt with the simplest model for multi-objective quadratic assignment problems, the two-objective quadratic assignment problem, was discussed in this research. The weighted sum method was used to transform the multi-objective model into a single-objective model. An algorithm inspired by the foraging strategy, called the squirrel search algorithm, was proposed to solve this problem. The parameters of the squirrel search algorithm, such as the number of iterations, the number of flying squirrels, and the probability of predator presence, were observed by performing a computational experiment to solve a two-objective quadratic mapping problem.

The results showed that the general parameters, the number of iterations, and flying squirrels affect the performance of the algorithm in solving this problem. Also, the probability of predator presence, which is a control parameter, can achieve better results when using a smaller probability value.

There is a study (Cecen, 2021), where the purpose of this study is to provide feasible and rapid solutions to the problem of multi-objective airport gate allocation taking into account the goals directed at passengers and the goals directed at airlines, i.e. the total walking distance from the gate to the baggage carts and the total aircraft fuel consumption. During taxi operations. The results were compared with the baseline results, which were obtained from the algorithm using the fastest gate assignment and rotating baggage combinations without any conflicts in gate assignments.

The results found that the proposed model significantly reduced both TWD and TFC. The improvement of TWD and TFC changed from 22.8% to 46.9% and from 4.7% to 7.1%, respectively, according to the target priorities. In addition, the average number of non-dominant solutions was calculated as 6.94, which offers many possible solutions for air traffic controllers to manage ground traffic while taking into account the objectives of airlines and passengers.

As well as the study (Sandra, et al, 2022) where hyper heuristics (HH) have emerged as more general and powerful solutions to combinatorial optimization, and have been successfully addressed to solve many real-world problems. Implemented within the MOEA/DD and differential evolution nexus, four hyper selective heuristics (high-level heuristics) are studied in this work: Thompson sampling, probability matching, adaptive striving, and self-adaptive differential evolution. In the proposal, low-level inferences are based on the intersection performed by operators drawn from the set of candidates.

Statistical tests have indicated that the best version of the proposed approach, called HHMOEA/DD, outperforms those using the constant intercept operator and various literature methods. In addition, experiments indicate that results are improved by the combined combination of warm-up and operator ignore mechanisms.

- **Comment on Previous Studies:**

After reviewing previous studies that dealt with the topics of the study, we find that they agreed with the current study in dealing with multi-objective quadratic assignment problems. It dealt with a study (Sandra, et al, 2022), which was entitled Choosing hyper-inferences for the multi-objective quadratic assignment problem, and reached the best version of the proposed approach, called HHMOEA/DD, outperforms those using the fixed intersection operator and various literature methods. In addition, experiments indicate that results are improved by the combined combination of warm-up and operator ignore mechanisms. A study (Abdul Gafoor & Theagarajan 2022) discussed the intelligent approach of the SAFSA to diagnose Parkinson's disease. This study presents a feature selection method based on the SAFSA to overcome this problem.

The study (Lin, et al, 2012) also addressed improving the parameters of the GM (1,1) model based on the artificial fish swarm algorithm. The aim of this study is to enhance the prediction accuracy of the GM (1,1) model using the fish swarm algorithm. The results show that this method enhances the accuracy of the GM (1,1) model and has better performance than particle swarm optimization.

The current study agreed with the study of (Celal & Alpaslan, 2013) as it aimed to evaluate the performance of the multi-objective ant colony algorithm in quadratic assignment problems of the biological subject. The current study also agreed with the study (Ningtiyas, et al, 2021), which aimed to solve the problem of bi-objective quadratic mapping using the squirrel search algorithm. The results showed that the general parameters, the number of iterations, and flying squirrels affect the performance of the algorithm in solving this problem.

The current study also agreed with the study of (Cubukcuoglu, et al, 2019), as it aimed to propose a meme algorithm with effective local search and mutation operators to solve bQAP. The local search is based on the swap neighborhood structure while the mutation operator is based on the destruction and reconstruction procedure. Experimental results show that our two-objective memetic algorithm (BOMA) significantly outperforms all island-based variants of the PASMOQAP algorithm recently proposed in the literature.

- **Research gap:**

From the above, it is clear that the research gap is that previous studies have not dealt with solving multi-objective quadratic assignment problems by using the fish swarm algorithm, which is what we will do in the current research.

2. The General Framework of the Research:

Research Problem:

The problem of hospital planning lies in the total distances that patients, visitors, and medical staff travel inside the hospital, and because this has a direct impact on the lives of patients inside the hospital. Therefore, hospital planning models seek to reduce the distances between facilities with the highest common flow by bringing the distances between the units closer after they have been completed. Arranging them according to the objectives set in mathematical models, through the effect of the fish school algorithm on multi-objective quadratic assignment problems.

The most important research questions can be highlighted in the following points:

1. How can the performance of multi-objective quadratic assignment problems using the synthetic fish flock algorithm be improved so as to minimize the number of distances traveled within a hospital?

2. What are effective ways to integrate a synthetic fish swarm algorithm with multi-objective quadratic assignment problems such that it minimizes the number of distances traveled within a hospital?

3. How can the ability of the artificial fish swarm algorithm be improved to deal with the increasing and complex pressures in multi-objective quadratic assignment problems?

4. Is it possible to use the mathematical model for hospital planning to rearrange a hospital's facilities?

Research Objective:

The research aims to use multi-objective mathematical models in rearranging or designing hospitals to reduce the total distances traveled within hospitals by using the quadratic allocation model. This model will be solved using the fish swarm algorithm to find the best possible solution to the model. The objectives of this research can be summarized as follows:

1. Analysis of the efficiency of the artificial fish swarm algorithm in solving multi-objective quadratic assignment problems.

2. Improving the accuracy and performance of intra-hospital resource allocation using the artificial fish swarm algorithm.

3. Reducing the distances traveled within the hospital and saving time and effort.

4. Providing innovative and effective solutions to improve resource management and improve the patient experience within the hospital.

5. Rearranging and designing some hospitals using the proposed mathematical mode.

Research Hypotheses:

Main hypothesis: There is a statistically significant effect of the artificial fish swarm algorithm in solving multi-objective quadratic assignment problems.

Research Methodology:

The method used in this study includes several steps:

1. Literature Review: Previous studies and research that dealt with the artificial fish swarm algorithm and its applications, as well as multi-objective quadratic assignment problems, were reviewed.

2. Identifying Variables: The variables and criteria that will be used in the process of evaluating the algorithm's performance and its impact on solving multi-objective quadratic assignment problems have been identified.

3. Study Design: The current study was designed in a manner consistent with its objectives, and in a way that determines the information and data necessary for its implementation.

4. Application of the Algorithm: The artificial fish swarm algorithm was applied to the available data and information to solve multi-objective quadratic assignment problems in the hospital.

5. Data Analysis: The data resulting from the application of the algorithm was analyzed to evaluate its performance and level of effectiveness in achieving the research objectives.

6. Presentation of the Results: The results and recommendations were presented based on the analysis of the study data, with a focus on how to solve and improve quadratic allocations within the hospital using the algorithm.

3. Concept of Algorithms:

An algorithm can be defined as a set of sequential and organized instructions that are used to solve a problem. It differs from software, which can contain several diverse algorithms to achieve a specific function. The program is the text written in machine language and executed by the computer to perform a specific task. The software is written by the programmer who understands the existing problem and proposes and implements appropriate solutions to solve the problem. The program must also be correct and clear, as appropriate algorithms are followed. And the code necessary to achieve the desired purpose.

The programming process: It is the process of preparing and developing programs by translating algorithms into a specific programming language, where the programmer writes the program using the language he chooses, and each programming language is characterized by its unique characteristics that make it suitable to varying degrees for solving the problem at hand. Despite the diversity in programming languages, However, they all follow the same basic algorithm instructions, which means that they are based on the same basic programming principles and methods for translating ideas into instructions that a computer can understand and execute.

Programming language: It is the tool that programmers use to build various programs. Programming languages vary greatly, ranging from languages that deal directly with the physical components of the computer, such as assembly language, to languages that require converting them from the form in which programmers write to Another image that the computer can handle. These languages may differ in level of experimentalism (low-level) and high-level experimentalism (high-level), performance, ease of use, ability to express ideas, etc. Programming languages provide a variety of tools and features that can be used to develop different applications, ranging from desktop applications to web applications, mobile applications, and large systems. Programming languages can be divided into main categories such as plural languages and common programming languages such as C, C++, Java, Python, and others. Each language comes with a set of rules and instructions that must be followed to write a program that works correctly according to the specific language.

The following figure shows how to solve the problem through the algorithm and the program:

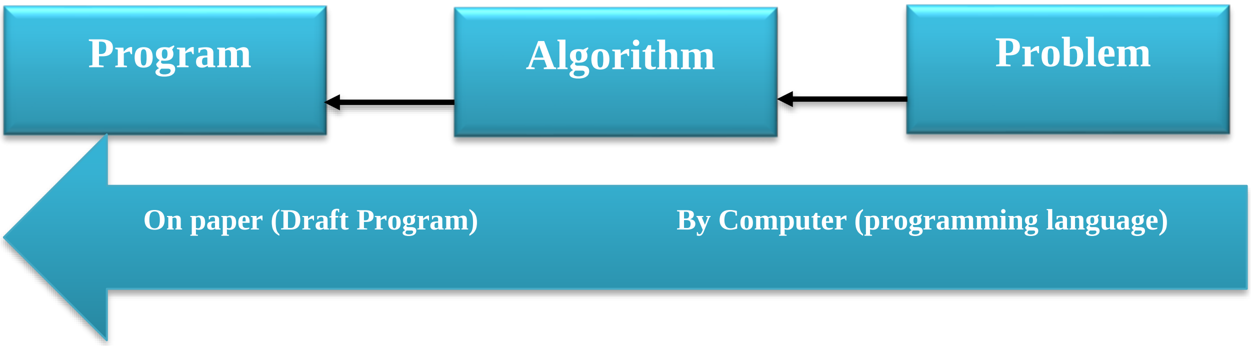

Figure No (1):
Solve the problem with algorithm and program.
Source: (Rohaut, 2009).

From this figure, it is clear that the algorithm expresses a series of formal instructions that allow the computer to achieve a specific goal. These instructions are often expressed in a language that humans understand, and describe what should be done based on the expected results. The structured algorithm can be translated into an advanced programming language such as C, Java, or PHP. But it is important to emphasize that programming often requires a human to adapt to the requirements of the computer. An algorithm also describes a way to solve common problems and is often reusable. Except in special cases, different algorithms can be used to achieve the same result, but some can be more effective than others depending on the nature and amount of data.

An algorithm, in its simplest form, is a set of well-defined and arranged instructions to solve a problem or perform a task. It is like a cooking recipe or a diagram that guides a computer (or even a human) through a series of steps to achieve a specific result. Algorithms are common in our daily lives, where it runs everything from simple calculations to difficult decision-making processes.

4. Types of Algorithms:

Algorithms form a fundamental part of computational science and are considered a powerful tool for solving a variety of problems in different fields. Algorithms are very diverse and can be classified based on several criteria, such as the type of problem they solve or the methods they use. There are traditional or classical algorithms, which include a wide range It is well-known and commonly used algorithms in fields such as sorting, searching, sorting, mathematical calculations, etc. Some examples of these algorithms include linear algorithm, binary search algorithm, quick sort algorithm, and others.

There are also evolutionary algorithms, which are algorithms that are inspired by biological evolution and that rely on concepts such as reproduction, mutation, and natural selection. Some examples of these algorithms include the neuron algorithm, the differential evolution algorithm, and the typical work algorithm.

4.1. Evolutionary Algorithms:

Examples of famous evolutionary algorithms:

A. Genetic Algorithm (GA):

In 1975, scientist John Holland and his colleagues introduced the genetic algorithm (GA) at Michigan State University, which is based on the natural concept of evolution and suggests that diversity helps ensure that populations remain alive despite changing conditions (Sabit, 2005). The idea of the GA lies in generating some solutions to the problem randomly, then examining these solutions and comparing them with some criteria designed by the algorithm designer, the best solutions are the ones that remain, while the less efficient solutions are neglected in accordance with the biological rule of survival of the fittest. The next step is to pair the remaining solutions with the most efficient solutions to produce new solutions similar to what happens. In living organisms, by mixing their genes, the resulting new organism's characteristics will be a combination of the characteristics of its parents. These solutions resulting from mating are also subject to examination and refinement to determine the extent of their efficiency and their closeness to the optimal solution.

Thus, the pairing and selection processes take place until the process reaches a certain number of iterations estimated by the algorithm designer, or the resulting solutions, or one of them, reaches a high efficiency rate. Thus, genetic algorithms successfully generate hypotheses by replicating mutations and recombining the best parts of existing hypotheses. The genetic algorithm can address any objective function with or without constraints, whether linear or nonlinear, and the solution space may be in one or more dimensions.

B. Particle Swarm Optimization PSO:

The bird swarm algorithm (particle swarm optimization (PSO)) is an evolutionary computational technique proposed by Kennedy and Eberhardt (1995). It mimics the behavior of flying birds and their communication mechanism to solve optimization problems, and is based on constructive cooperation between particles in contrast to the survival of the fittest approach used in other evolutionary methods. Typically, the PSO algorithm has many advantages. Therefore, the algorithm has recently gained popularity (Banks et al, (2008), (Song, et al, 2012), (Wang, et al, 2013),) and has found applications in many practical engineering problems. The idea of the algorithm is based on a group of elements called a "swarm"). ", and spread randomly in a limited area with the aim of searching for the optimal solution within this area.

C. Simulated Annealing Algorithm (SA):

Researchers Burkard and Rendl were the first to use the Simulated Annealing (SA) algorithm as one of the smart techniques to solve the quadratic assignment problem. This was in 1984, as this algorithm was able to give good solutions compared to the rest of the conjectures proposed at that time.

The Simulated Annealing (SA) algorithm is one of the intuitive algorithms with general probability used in optimization problems, through which a good approximation of the objective function for optimization problems is found in a large search space and tends not to change the value of the local minimum or maximum (local minimum or maximum), and is often used when the search space is discreet, as is the case in the Traveling Salesman Problem (TSP), the Quadratic Assignment Problem (QAP), the Knapsack Problem, and other problems (Kumar , et al, 2020).

D. Fish Swarm Algorithm (FSA):

Fish Swarm Algorithm (FSA) is a stochastic algorithm first proposed (Li, et al, 2002). and population-based driven by the intelligent collective behavior of fish populations in nature (Duan, et al, 2016). FSA has some advantages, such as the location of artificial fish Insensitive priming, resilience and fault tolerance (Reda, 2014). It has been applied in various problems including machine learning (Yazdani, et al, 2010) (Hu, et al, 2010), control, wireless sensor networks (Song, et al, 2010) and scheduling (Bing & Wen, 2010)). Both FSA and PSO are swarm intelligence algorithms, which are used to simulate natural or social behavior (Eberhart & Kennedy, 1995).

The theory consists of a group of agents (virtual fish) that interact with each other and move in space based on specific rules. The movement of the fish aims to improve the performance of the overall system and reach an equilibrium state or an optimal solution to the problem at hand. Examples of applications of the fish swarm algorithm include the design of smart systems. For traffic, improving electrical distribution systems, solving security problems in computer networks, and searching for the best ways to store data (Abdul Gafoor & Theagarajan, 2022).

Although these algorithms have different advantages respectively, some problems should be further improved and improved, such as the convergence speed and optimization accuracy of the algorithms, for example, (Song, et al, 2013) suggested. Improve the FSA by gradually expanding the visual field according to the iteration and apply the improved algorithm to the 2D piece stock problem. (Huang & Chen, 2013) established an improved synthetic FSA based on hybrid behavioral selection in order to deal with the problem of the lack of a general search theory for fish behavioral selection at present. (Zhang, et al, 2014) presented an improved artificial FSA by introducing the idea of interactive learning between individual historical optimization and global optimization as well as improving the update strategy for artificial fish placement.

The purpose of the algorithm is to imitate the behavior of predators, slaughter, pursue, move, etc. AFSA is based on the collective movement of fish towards a specific target and is inspired by nature, a parallel and random search algorithm. Unlike lions and monkeys, there is no leader in animal species like fish, and each member has a self-organizing behavior. Fish know nothing about their groups and their environment, and navigate the environment by exchanging data between neighboring members. This interaction further complicates the process of improving fish.

AFSA has the characteristics of fault tolerance and flexibility, and has a wide range of applications in resource balancing, fuzzy clustering, data mining, code diffusion estimation, DNA coding sequence optimization, signal processing, image processing, neural network optimization, task scheduling, etc... AFSA has advantages Fast convergence speed and high efficiency, but it also has the disadvantages of high time complexity, and the imbalance between global search and local search.

- **Basic Artificial Fish Algorithm:**

Artificial fish (AF) are imitations of real fish used in analysis and interpretation of a problem. Most fish live in areas with sufficient food, and move to areas with more food by following other fish or searching for food on their own, usually the areas with the largest number of fish. These are the ones that contain the most food. The subsequent behavior of each artificial fish depends on its current state and local environmental conditions. The AF affects the environment through its behavior and the behavior of its peers.

Suppose the search space is D (dimensions) and there are N fish in the swarm, the current state of the artificial fish (AF) is represented by a vector Xi = (xi1, xi2, xiD), i = 1,2, ..., N, where xd (d = 1,2, ..., D) is the variable that should be optimized. The food consistency of the AF at the current position is represented by Y = f(X), where Y is the value of the objective function. The distance between the ith and jth single AF can be expressed as dij=‖Xi−Xj‖. Visible represents the visible AF distance. Step represents the length of the AF step. δ represents the neighborhood crowding factor in the search space (Li, et al, 2002).

We can describe the five behaviors of a school of fish as follows (Li, et al, 2002):

1. Predation Behavior: Suppose the current AF state is Xi and we randomly choose a new state Xj in its current neighborhood (dij < Visual). In the extreme problem, ifYi<Yj: according to the following equation:

$$X_{i|next} = X_i + random() \times Step \times \frac{X_j - X_i}{\|X_j - X_i\|}.$$

If it cannot be fulfilled after pre-determined attempt times, it moves a step randomly: according to the following equation:

$$X_{i|next} = X_i + random() \times Step.$$

2. Swarming Behavior:

AF in the current state Xi searches for the guide number nf and its center position Xc in its current neighborhood (dij<Visual) if Yc/nf>δYi according to the following equation:

$$X_{i|next} = X_i + random() \times Step \times \frac{X_c - X_i}{\|X_c - X_i\|},$$

This means that it is in the middle of the area, there is enough food and it is not too crowded.

3. Following Behavior: Assume Xi is the current state of AF and search guide Xmax with Ymax in the vicinity, if Ymax/nf>δYi according to the following equation:

$$X_{i|next} = X_i + random() \times Step \times \frac{X_{\max} - X_i}{\|X_{\max} - X_i\|},$$

The current position of the guide means Xmax and it has a higher nutritional consistency and is not too crowded.

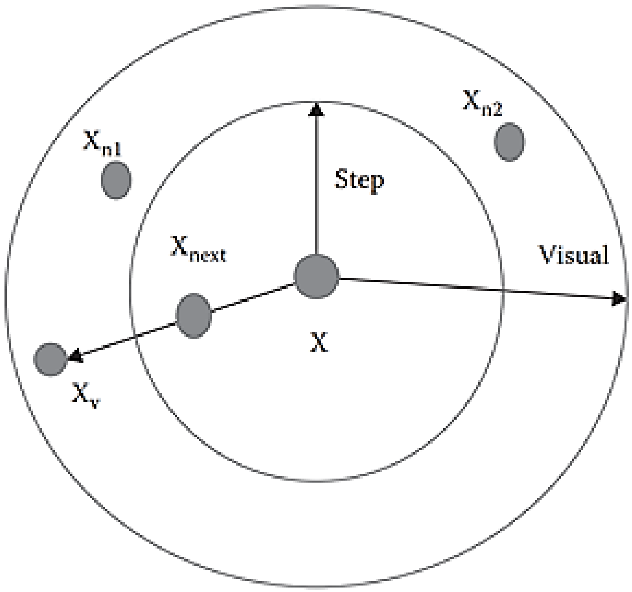

Figure No (4): Field of view of artificial fish

4. **Behavior Selection:** We evaluate the current environment for AF according to the problem to solve and then select a behavior to emulate. A simple way is to choose the best behavior according to the evaluation of the results of predation, swarming, and following behavior.

5. **Bulletin:** Bulletin is used to record the best AF condition and best value. Each AF compares and updates its own state with the bulletin after each iteration, so if its current AF state is better, the value in the bulletin is replaced.

5. **Multi-Objective Quadratic Assignment Problems:**

The beginning of the quadratic allocation problem (QAP) was in the 1950s, specifically in 1957, by researchers Koopmans and Beckmann. The problem was a mathematical model related to economic activity, which represented the allocation of a group of factories to a group of locations, taking into account the distances and transportation costs between those locations. (Sandra, et al, 2022).

Quadratic assignment problems constitute an important chapter in the field of practical and applied research, as they are considered among the most complex and important problems in several fields such as industry, logistics, transportation, communications, etc. Quadratic assignment problems have several primary categories, such as one-quadratic, two-quadratic, and multiple quadratic challenges (Al-Hussein and Bashir, 2024).

In the world of one-sided quadratic allocation problems, decision makers are faced with the task of choosing a single option from a set of alternatives while adhering to a predetermined set of constraints and considerations. For example, one may seek to determine the optimal location for a new manufacturing facility, weighing factors such as cost, proximity to raw materials, and accessibility to the target market (Zainab and Fayez, 2023).

In contrast, binary quadratic allocation problems entail allocating resources or entities across two distinct options, either dividing goods between two warehouses or distributing tasks between different projects. The primary obstacle in this scenario is to make fair and efficient decisions that align with organizational goals while minimizing costs (Kumar and Mitra, 2023).

Expanding on binary quadratic problems, multiple quadratic allocation problems require decision makers to make many allocations across many projects or regions. (Mohammed and Gitanjali, 2020). Quadratic allocation problems represent a subset of operations research puzzles that focus on optimizing the allocation of resources across diverse activities or locations to achieve specific goals. Its importance stems from the growing demand to enhance resource utilization, enhance operational efficiency, and drive informed strategic decision-making processes.

Quadratic allocation problems are among the most important reasons for optimizing resource utilization, as they help determine how to distribute limited resources in an efficient manner to achieve maximum benefit from them. These problems can be used to determine employee distribution, production planning, transportation planning, and other operational decisions (Jamal & Benjamin, 2023).

It also helps in strategic decision making, helping in making important decisions about business expansion, selecting new locations, improving product design, supply chain management, and production planning. Quadratic allocation problems are a problem that aims to distribute resources in a way that achieves the best possible consistency between suppliers and customers. The goal is to determine the number of specific products that should be allocated to each customer, taking into account the limitations related to the capabilities available from suppliers and the unique needs of each customer. This problem includes the search to optimize allocation resources to achieve maximum possible value or to achieve an optimal combination of objectives, such as reducing cost, increasing profitability, and improving service quality (Celal & Alpaslan, 2013).

As n represents the size of the problem, and Q represents the vector of possible permutations (1,2,….n), and $\varphi(i)$ indicates the location that will be allocated to facility (i), $f_{(ij)}$ represents the direct flow between the facilities (i): and ease (j), (d_{ij}) represents the distance between site i: and site j.

1. Mathematical Model of Quadratic Assignment Problem (QAP):

The mathematical model for a quadratic allocation problem usually consists of designing and solving mathematical equations that express the relationships between the different variables in the problem, and the variables are used to represent different quantities of resources and demands, while setting constraints and conditions that the proposed solutions must comply with (Yew, et al, 2010).

The mathematical model can be a set of linear or non-linear equations, and may include optimization processes such as reducing cost or achieving an optimal balance between multiple objectives. Linear programming, numerical programming, or non-linear programming techniques are used to solve these mathematical models and reach the optimal solutions. The QAP problem model can be designed by setting the F matrix, which represents the flow between the facilities, and the D matrix, which represents the distance between the facilities, so the mathematical model of the problem can be formulated as follows:

$$\min z = \sum_{i=1}^{n}\sum_{j=1}^{n} f_{ij} d_{\varphi(i)\varphi(j)} \qquad (1)$$

In general, the term Quadratic stems from formulating the problem as a true optimization with a second-order objective function, and assuming that X_{ij} represents a binary variable that takes the value 1 if the facility is allocated to the site I to location j, and takes the value 0 otherwise. Therefore, the problem can be written as follows:

And subject to restrictions:

If the facility is allocated i to the location j **$X_{ij} = \{^{1}_{0}$**

2. Methods for solving the Quadratic Assignment Problem:

The primitive way to solve the QAP problem is to generate all possible permutations, and then search among the permutations to find the optimal vector of permutations that gives the lowest cost, as the number of possible permutations represents the multiplier of the size of the problem. This method is considered very easy if the size of the problem is small, while

$$\min \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{l=1}^{n}\sum_{k=1}^{n} a_{ij} b_{kl} x_{ik} x_{jl} \qquad (2)$$

$$\sum_{i=1}^{n} x_{ik} = 1 \qquad (3)$$

$$\sum_{j=1}^{n} x_{jl} = 1 \qquad (4)$$

the difficulty increases with the size of the problem. For example, if n ≥ 10, the degree of search restriction will be (10) = 3,628,800 paths, and it is considered impossible if n > 30. Exact solutions to the QAP problem include the branch and bound algorithm. Despite the time it takes, this algorithm cannot find the optimal solution if the problem size is 7 > n. For this reason, evolutionary algorithms are used to obtain good solutions to the QAP problem. Multi-objective quadratic assignment problems (MOQAP) are a type of mathematical problem that aims to solve a set of decisions to achieve more than one objective at the same time, and achieving such objectives is considered challenging due to the complexity of the relationships between variables and the multiple objective (Cecen, 2021).

A multi-objective allocation problem requires achieving a variety of conflicting objectives at the same time, and usually involves balancing a set of variables such as cost, quality, and time. This issue usually involves searching for a set of solutions that meet multiple objectives in a balanced way. Final decisions are made based on the required balance between these goals according to the requirements of the project or organization in question. (Sandra, et al, 2022).

Also, in multi-objective quadratic assignment problems, several objective functions are defined, and the model seeks to find a set of values for the variables that achieve the best possible values for all the specified objectives. These objectives are usually contradictory, as they can be, for example, low cost and high quality, which It makes the process more challenging.

To solve multi-objective quadratic assignment problems, techniques such as Pareto Optimization can be used, which seeks to optimize all specific objectives based on the Pareto Principle. This is done by identifying a set of optimal solutions, one of which cannot be improved without negatively affecting the others. (Ningtiyas, et al, 2021).

The concept of multi-objective quadratic assignment problems is also used in many fields such as engineering, management, and economics, where multiple decisions require multiple objectives to achieve the best possible outcome.

Multi-objective quadratic assignment problems also represent a complex challenge in the field of scientific research and practical applications. These problems are characterized by multiple objectives that must be achieved at the same time, which requires a careful balance between these various objectives. For example, executives may want to achieve maximum financial profits. The company simultaneously reduces overall costs and increases customer satisfaction. Because of these variations, multi-objective quadratic assignment problems may require trade-offs between different objectives, where achieving one goal is sacrificed in favor of achieving another.

The model used in multi-objective quadratic assignment problems aims to achieve several goals at the same time, by identifying a set of decisions that lead to the best possible results for each goal. The mathematical model for multi-objective quadratic assignment problems is to identify decision variables and determine relationships. Among them, in addition to setting multiple objective functions (Mohamed & Geetanjali, 2020).

The mathematical model usually consists of a set of variables, and each variable symbolizes a specific decision that must be taken to achieve the goals. In addition, a set of goal functions is defined, where each function symbolizes a specific goal that must be achieved, such as reducing cost, increasing efficiency, and improving quality.

The mathematical model aims to determine the values of the variables that achieve the best possible values for each objective function, so that one value cannot be improved without negatively affecting the other. To solve this type of problem, techniques such as multi-objective linear programming and differential process analysis (Pareto Optimization) are used to determine a set It is one of the optimal solutions that achieves the best balance between multiple goals (Zaidoun & Al-Sabaawi, 2014). The model of multi-objective quadratic assignment problems is usually represented in general as a set of equations and constraints that aim to achieve a set of multiple goals. There are several ways to formulate these problems, including using multi-objective linear programming.

Consider an example of a simplified model for a multi-objective quadratic allocation problem, where we seek to achieve two goals: lowest cost and high quality. This model can be represented as follows:

1. **First Objective (Minimize Cost):**

Minimize=$C=\sum_{i=1}^{n} c_i x_i$

2. **Second Objective (Maximize Quality):**

Maximize=$Q=\sum_{i=1}^{n} q_i x_i$

whereas:

- C is the total allocation cost.
- Q is the overall quality index.
- ci is the cost of allocating item i
- qi is the quality index of item i
- xi is the decision variable that determines whether item i should be allocated or not.

6. Solving Multi-Objective Quadratic Assignment Problems Using the Fish Swarm Algorithm:

The fish swarm algorithm is based on a simulation model that mimics the behavior of fish in nature, where fish interact with each other and follow similar behaviors to achieve a common goal. When applying the fish swarm algorithm to multi-objective quadratic mapping problems, fish can interact with each other and exchange information and experiences to improve solutions. The challenge is how to properly direct the swarm to reach a set of balanced solutions that cover multiple sets of criteria and objectives.

Using the fish swarm algorithm, it is possible to create detailed and distinct solutions to multi-objective quadratic mapping problems, which can contribute to optimal decision making and achieving balance in many fields such as engineering, economics, medical sciences...etc.

The fish swarm algorithm can also be used to improve route planning within a hospital to reduce distances traveled. Fish can represent medical staff, medical vehicles, or even patients. Using the fish swarm algorithm, the movements of these organisms within the hospital can be optimized by guiding them intelligently and effectively.

For example, fish can cooperate with each other to determine the best ways to transport patients or medical materials between different rooms and departments in a hospital. Fish can also exchange information about the easiest and fastest ways to avoid crowded areas.

Using this approach, the organization of facilities and workflow within the hospital can be improved, which leads to reduced transportation time, increased efficiency of the medical services provided, improved patient experience, and reduced overhead costs for the medical institution as a whole.

Some equations can be used to show how the fish swarm algorithm can be applied to improve hospital facility planning:

1. The equation for determining target locations:

Target location = current location + (speed x time).

2. The equation for determining the direction of movement:

Direction of movement = target direction − current location.

3. Speed determination equation:

Speed = remaining distance / remaining time.

4. Self-updating speed equation:

New speed = current speed + (acceleration factor x time).

5. Self-direction equation:

Steering angle = angle of movement + (error x time).

6. Website update equation:

New position = current position + (speed x time).

These equations are used to effectively determine the movement of entities within the hospital, as they depend on a set of data such as current locations, speeds, angles, and update times. These equations are used in the algorithm to intelligently and effectively guide entities to achieve multi-purpose allocation goals within the hospital.

7. Results and Recommendations:

A. Results:

The results of the study showed that the artificial fish swarm algorithm shows effective results in reducing the distances traveled within hospitals, by improving the distribution of resources and planning routes and paths to hospitals. Using this algorithm, the order of operations can be improved and coordination between different departments and units in the hospital can be improved.

The results of the study also showed that multi-objective quadratic allocation problems showed effective results in reducing the distances traveled within hospitals by determining how to assign resources between various departments, and improving the planning of roads and paths within the hospital, which is reflected in the patient's experience and the provision of effective health care to him.

The results of the study also indicated that the fish swarm algorithm shows a high level of efficiency in solving multi-objective quadratic assignment problems. The algorithm has shown the ability to improve planning and improve the distribution of resources within hospital facilities, which contributes to reducing the time required to travel between hospital facilities and improving the quality and efficiency of work. Which reflects the ability to improve the patient experience and provide more effective quality health care.

Based on the research results, several recommendations can be made, including:

- **Implement Technology:** Hospitals should implement the Fish Swarm algorithm to improve resource allocation within the hospital, which may include distributing medical equipment and medical and nursing personnel in a way that reduces distances traveled and improves patient experience.
- **Improving Space Planning:** Hospitals can benefit from using the fish swarm algorithm to improve the design of buildings and the layout of internal spaces, which contributes to reducing the distances traveled between different departments and improving the flow of operations.
- **Improving Patient Experience:** By applying the fish swarm algorithm, hospitals can improve patient experience by reducing waiting time, reducing costs caused by excessive waiting and improving patient routing within the hospital, and can also improve the accuracy of the appointment schedule and distribute patients more effectively.
- **Improving the Efficiency of Operations:** Hospitals can use the fish swarm algorithm to improve the efficiency of internal operations, which helps reduce the waste of resources and transition time between different medical procedures, which reduces the distances traveled and improves the overall organization of the hospital.
- **Improving Strategic Planning:** Hospitals can use data and analyzes derived from applying the fish swarm algorithm to improve the strategic planning of resources and services, which helps in making more effective decisions and better directing future investments.

B. Recommendations:

- **Increased Satisfaction and Confidence:** By improving patients' experience and providing more efficient and effective health care, this will increase patients' satisfaction and confidence in the services provided by the hospital, which may lead to increased demand for benefiting from the medical services provided.

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