SOLVING SINGLE-OBJECTIVE QUADRATIC ASSIGNMENT PROBLEMS USING SIMULATED ANNEALING ALGORITHM FOR HOSPITAL FACILITY LAYOUT OPTIMIZATION

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ABSTRACT

This research aims to study how to solve quadratic assignment problems using a simulated annealing algorithm for the internal arrangement of hospital facilities. This is done by reviewing the literature related to the algorithm, determining the variables and criteria necessary to evaluate its performance, designing the study and applying the algorithm to hospitals, and the collected data is analyzed. To provide results and recommendations, which contributes to improving squared allocation processes within the hospital and achieving the desired goal of the research.

The research concluded that the simulation annealing algorithm plays a prominent role in solving single allocation issues to reduce the distances traveled within hospitals, and thanks to its ability to simulate the development and adaptation processes carried out by living systems, this algorithm helps in improving the distribution of facilities and resources within the hospital in a way that reduces the distances needed Staff and patients need to cut it. Thus, the annealing simulation algorithm contributes to improving work efficiency and saving time and effort, which enhances the overall quality of health services provided in hospitals and contributes to enhancing patient experience and improving the work environment for medical and administrative staff.

Keywords: Single-objective quadratic assignment problems, simulation of annealing algorithm, hospital.

INTRODUCTION

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 maximum use of available resources, improve operations, and efficiently provide solutions to complex problems, 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. As technology has evolved, 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).

The simulation annealing algorithm is one of the modern and effective tools in the field of solving difficult and complex problems facing many fields, including engineering, computer science, economics, natural sciences, urban planning, etc. This algorithm is based on the concept of natural evolution and imitating the behavior of biological models of evolution. Adaptation: Simply put, the annealing algorithm simulates the behavior of living organisms, such as fish and birds, in a specific environment. These organisms interact based on simple rules and evolve over time.

For the purpose of generating a practical solution to the QAP problem, Q= (Q(1) Q(2),......,Q(n)) is imposed, which represents the

The simulation annealing algorithm is distinguished by its ability to generate effective solutions to complex problems, achieving a balance between exploring hypotheses and exploiting existing solutions, and its effectiveness depends on repeating the development cycle and gradually improving solutions over time. The simulated annealing algorithm also allows for handling large data sets and high-dimensional research problems, making it an ideal choice for wide and diverse applications.

Thanks to its continuous development and ability to automatically improve solutions, the simulated annealing algorithm attracts the attention of researchers and engineers in various fields, as it can be used to solve a wide range of problems, including optimizing logistics systems, designing wireless networks, improving the performance of drones, and designing medical systems. Smart, and many more.

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

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.

Single quadratic assignment problems also constitute an important category of optimization problems in the field of mathematical, engineering, economic, and administrative sciences. These problems aim to determine the optimal values for a group of variables, taking into account a set of restrictions and limitations. Single quadratic assignment problems are characterized by having one objective function that improves or minimizes Among them, they are considered improvement issues aimed at finding the optimal solution that achieves the maximum value or the lowest cost.

Examples of one-sided quadratic allocation problems include the optimal distribution of resources, where the quantity of each resource that must be allocated to each activity or project must be determined in order to achieve the maximum possible return or achieve the lowest possible cost. Applications of one-sided quadratic allocation problems include production planning, resource distribution, project scheduling, and project design. Grids, energy distribution, transportation planning, strategic planning, pricing, marketing, and many other areas that require making customized decisions that achieve specific goals.

On this basis, in this research we will solve unary quadratic assignment problems using a simulated annealing algorithm by applying it to the internal arrangement of hospital facilities.

1. Previous Studies:

Several previous studies related to the research topic are presented here. Dalanezi et al. (2007) applied the simulated annealing algorithm to enhance redundant system reliability, comparing its performance with genetic algorithm, Lagrange multipliers, and evolution strategy. Shan et al. (2009) introduced the Genetic Simulation Annealing Algorithm (GSAA) and Ant Colony Optimization (ACO) for assembly sequence planning, demonstrating improved efficiency by combining genetic algorithm with simulated annealing. Yew et al. (2010) developed a hybrid ant colony optimization algorithm for facility planning problems, showcasing enhanced performance through synergy between maximum ant system and genetic algorithm. Zaidoun & Al-Sabaawi (2014) proposed a hybrid algorithm linking genetic algorithm with simulated annealing to solve quadratic assignment problems, exhibiting superiority over individual algorithms. Li et al. (2018) addressed robotic assembly line balancing using simulated annealing algorithms, achieving significant improvements in cycle time reduction. Amer et al. (2019) presented a simulated annealing-based approach to alleviate vehicle congestion in smart cities, demonstrating enhanced traffic efficiency. Kumar et al. (2020) explored simulation-based optimization methods for improving decisions related to system design, comparing various algorithms including simulated annealing. Du et al. (2023) developed a dual-objective optimization framework for prefabricated construction service configuration, showing improved fitness value and synergistic effect using an improved genetic simulation annealing algorithm. Jamal & Benjamin (2023) proposed a modified acceptance criteria to solve discrete optimization problems, showing effectiveness in solving quadratic assignment problems. Lastly, Zainab & Faez (2023) proposed local search methods including tabu search and bee algorithm for solving quadratic assignment problems, comparing results with complete enumeration method and robust heuristics. Al-Hussein &

Besher (2024) discussed iterated local search for quadratic assignment problems, suggesting potential improvements based on studies on other combinatorial problems.

– **Comment on Previous Studies:**

The previous studies reviewed align with the current study's focus on hybrid algorithms. For instance, Dalanezi et al. (2007) developed a hybrid algorithm combining simulated annealing and genetic algorithm to enhance redundant system reliability, akin to the current study's approach in utilizing hybrid techniques. Similarly, Zaidoun and Al-Sabaawi (2014) proposed a hybrid algorithm linking genetic and simulated annealing algorithms for quadratic assignment problems, echoing the current study's exploration of hybrid methods. Additionally, Duan et al. (2016) aimed to improve the convergence rate and accuracy of synthetic fish swarm algorithm through hybridization with the PSO algorithm, akin to the current study's emphasis on enhancing algorithmic performance. Moreover, Yew et al. (2010) and Jamal & Benjamin (2023) tackled quadratic assignment problems, demonstrating consistency with the current study's problem domain. Furthermore, Amer et al. (2019) and Zainab & Faez (2023) focused on optimization problems related to traffic efficiency and facility allocation, respectively, aligning with the practical applications addressed in the current study. Lastly, Al-Hussein & Besher (2024) sought to enhance the efficiency of iterative local search in solving quadratic assignment problems, which resonates with the current study's interest in improving algorithmic effectiveness. These findings collectively underscore the relevance and applicability of hybrid algorithms in addressing optimization challenges across various domains.

– **Research Gap:**

From the above, it is clear that the research gap is that previous studies have not dealt with solving unary quadratic assignment problems through the use of a simulation annealing 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 the mathematical models, through the effect of solving unary quadratic assignment problems using a simulation annealing algorithm for the internal arrangement of hospital facilities.

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

- How can the performance of unary quadratic assignment problems be improved using a simulated annealing algorithm such that it reduces the number of distances traveled within a hospital?

- What are effective ways to integrate simulated annealing algorithm with unary quadratic assignment problems so as to minimize the number of distances traveled within a hospital?
- How can the ability of the simulation annealing algorithm be improved to deal with the increasing and complex stresses in one-sided quadratic assignment problems?
- Is it possible to use the mathematical model for hospital planning to rearrange a hospital's facilities?

Research Objective:

The research aims to use unified 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 a simulation annealing algorithm to find the best possible solution to the model. The objectives of this research can be summarized as follows:

- Analysis of the efficiency of the simulation annealing algorithm in solving unary quadratic assignment problems.
- Improving performance and accuracy in allocating resources within the hospital using the annealing simulation algorithm.
- Reducing the number of distances traveled within the hospital, thus saving time and effort and improving the efficiency of operations.
- Providing innovative and effective solutions to improve resource management and improve patient experience within the hospital.
- Rearranging some hospitals using the proposed mathematical model.

Search Hypothesis:

Main hypothesis: There is a statistically significant effect of the simulated annealing algorithm in solving unary quadratic assignment problems.

Research Importance:

Solving unary quadratic allocation problems using a simulated annealing algorithm for the internal arrangement of hospital facilities is research of great importance due to its direct impact on the efficiency and quality of health services provided to patients. In a hospital environment, an optimal organization of facilities and resources must be achieved to ensure that medical care is provided with the greatest possible efficiency and effectiveness. Using the annealing simulation algorithm, the distribution of resources within the hospital and the arrangement of facilities can be optimized in a way that improves patient experience, reduces distances traveled between departments, and increases the efficiency of internal operations. This research also contributes significantly to improving the quality of health care and achieving the hospital's goals in general, which enhances patients' experience and contributes to achieving satisfaction and confidence in the health system.

Research Methodology:

The method used in this research includes several steps as follows:

- **Literature review:** Previous studies and research related to the simulation annealing algorithm and its applications in the field of solving unary quadratic assignment problems are evaluated.
- **Determine the variables and criteria:** The variables and criteria that will be used in the process of evaluating the performance of the simulation annealing algorithm in solving unary quadratic assignment problems are determined.
- **Study design:** The study is designed in a way that suits the research objectives, and determines the information and data necessary for its implementation.
- **Application of the algorithm:** The simulation annealing algorithm is applied to the available data and information to solve unary quadratic assignment problems in a hospital environment.
- **Data analysis:** The data generated by applying the algorithm is analyzed to evaluate its performance and effectiveness in achieving the research objectives.
- **Presentation of results:** Conclusions and recommendations are presented based on data analysis and conclusions from the study, with an emphasis on how to improve within-hospital unitary quadratic allocations using a simulated annealing algorithm.

3. Theoretical Framework of the Research:

Concept of Algorithms:

Algorithms are the backbone of computational science. They are the building blocks for efficiently solving computational problems. Algorithms are step-by-step procedures designed to perform specific tasks or solve specific problems. They take input data, process it according to pre-defined instructions, and produce output data in a specified amount of 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).

An algorithm is a set of sequential and ordered instructions that are used to solve a specific problem. The algorithm must be sequential and properly organized to achieve the desired goal. It differs from a program that can contain several diverse algorithms to achieve a specific function. An algorithm differs from a program, as:

A program is a text that is written in machine language and executed by a computer to perform a specific task. The programming process is carried out by converting algorithms into a specific programming language. Writing the program is considered an essential step to achieve the desired purpose. The programming process includes following the appropriate algorithms and necessary code to achieve the required purpose correctly and clearly. Once the program is written, it can be implemented to solve the problem at hand.

The programming process takes place through the use of a specific programming language, which is considered the main tool that programmers deal with to build various programs. Programming languages vary greatly in the level of experimentalism, performance, and ease of use, and allow programmers to use a variety of tools and features to develop multiple applications. These include popular languages such as C, C++, Java, Python, and many others.

The programming process is also considered crucial for developing programs and solving various problems, and provides programmers with the ability to transform ideas into executable applications, which contributes to improving operations and increasing effectiveness in various fields.

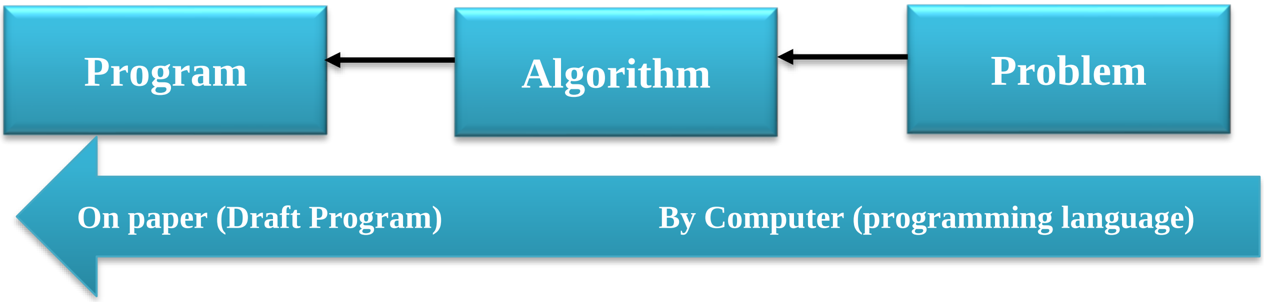

Figure No (1): Solve the problem with algorithm and program.

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.

Simulated Annealing Algorithm (SA):

Researchers Burkard and Rendl were among the pioneers in utilizing an optimization technique known as the Simulated Annealing (SA) algorithm to address the quadratic assignment problem (QAP) in 1984. This algorithm proved to be effective in providing favourable solutions compared to other methods proposed during that period.

The Simulated Annealing algorithm, characterized by its probabilistic approach, is widely employed in optimization problems due to its ability to explore large search spaces and avoid being trapped in local minima or maxima. It is particularly suited for discrete search spaces, such as those encountered in the Traveling Salesman Problem (TSP), Quadratic Assignment Problem (QAP), Knapsack Problem, and similar scenarios (Kumar et al., 2020).

Simulated Annealing Algorithm is an algorithm inspired by the annealing process in physics. It is used to solve problems searching for optimal solutions in a wide range of fields. The algorithm imitates the annealing process of materials, where the material is heated slowly and then cooled evenly. This allows improving its quality and reducing internal tensions (Amer, et al, 2016).

The potential solution to the problem is represented by a point in the complex space, and then the process of improving this solution is done by gradually changing it, as it accepts positive changes continuously, but sometimes it also accepts negative changes at a low rate, and this process is imitated by manipulating the cooling and heating rates in the algorithm, and an algorithm is used Simulated annealing in solving problems searching for optimal solutions in a wide range of fields, such as engineering, computer science, data science, industrial design, and others, and its applications include improving electrical circuit design, logistics planning, engineering design, and others (Amer, et al, 2019).

- **Step 1:** Start with an initial design point X_i, and set the iteration counter 1=i, with a high temperature value.
- **Step 2:** Create a new design point X_{i+1} randomly in the vicinity of the current design point.
- **Step 3:** Calculate the value of the objective function at the design points X_i and X_{i+1}
- **Step 4:** Calculate the difference in the value of the function through the following relationship:

$$\Delta E = E_{i+1} - E_i = \Delta f = f_{i+1} - f_i$$

- **Step 5:** Test the value of **ΔE**. If the value of **ΔE** is negative, this means accepting the point X_{i+1} as a new design point and then returning to the second step. Conversely, if the value of **ΔE** is positive, the use of the Metropolis criterion will be used, which is a criterion through which the point is accepted. Generated or rejected, which takes the form $e^{-\Delta E/KT}$, as the calculated value of $e^{-\Delta E/KT}$ is compared with a randomly generated value. If the calculated value is less than the randomly generated value, point X_{i+1} will be accepted as a new point, otherwise point 1 will be rejected. X_{i+1}.

The calculated value of $e^{-\Delta E/KT}$ is compared with a randomly generated value ($1 > c > 0$). If the calculated value is less than the randomly generated value, the point X_{i+1} will be accepted as a new point, otherwise the point X_{i+1} will be rejected.

The following figure shows the general flow chart of the steps of the Simulated Annealing (SA) algorithm as follows:

So, the simulation annealing (SA) method is based on simulating thermal annealing systems in solid materials, as when the metal is transformed into a molten state by heating it to a high temperature, the atoms inside the molten metal will move. Completely freely without one being exposed to the other, however, the movement of atoms is restricted by lowering the temperature, as lowering the temperature makes the atoms tend to organize and then crystals are formed, which represent the minimum possible internal energy.

- **Steps to Make an Annealing Simulation Algorithm (Zaidoun & Al-Sabaawi, 2014):**

The steps of the simulation annealing algorithm can be summarized as follows:

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Figure No (2):
General flow chart of the steps of the Simulated Annealing (SA) algorithm.

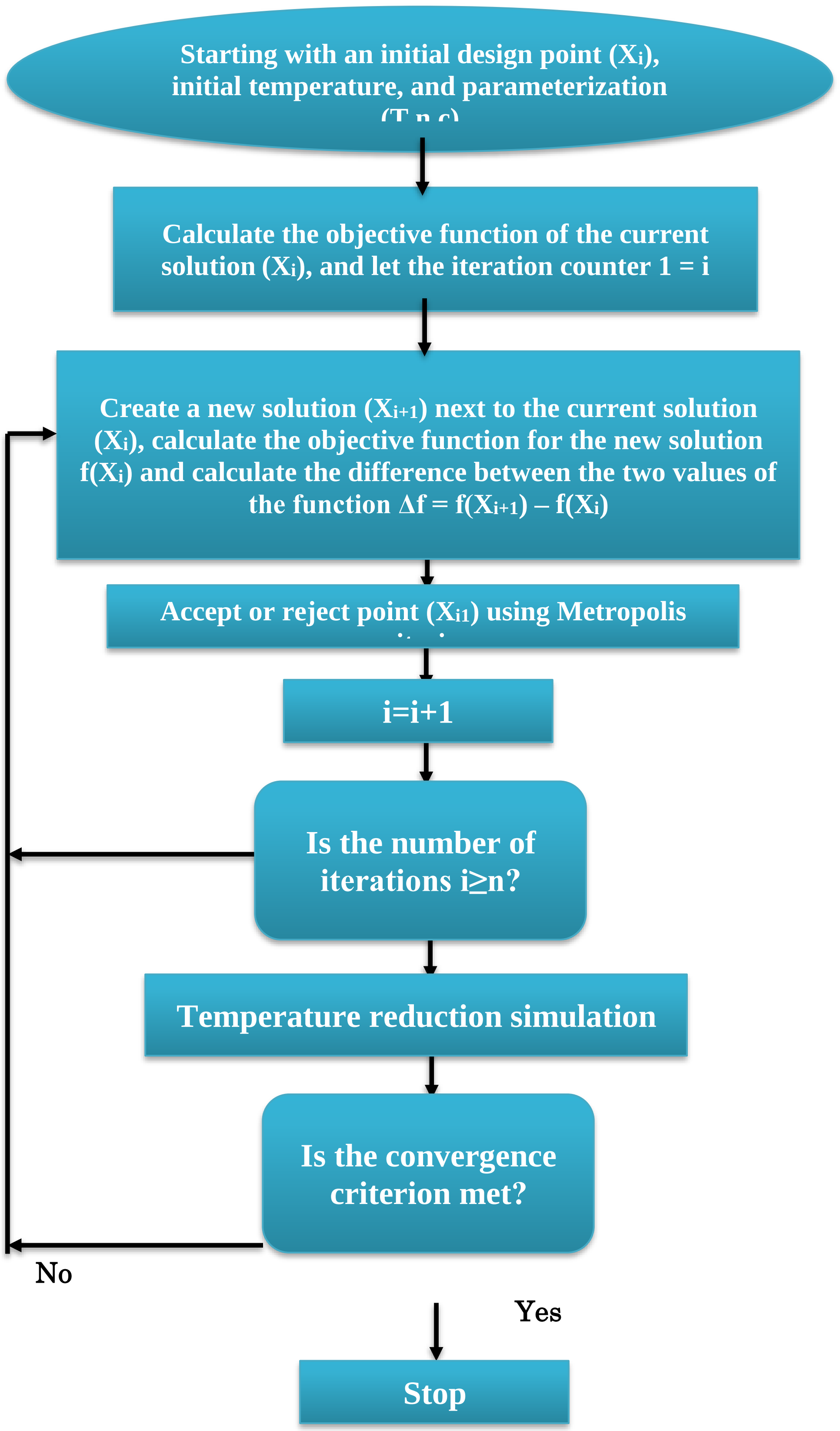

Figure No (2):
General flow chart of the steps of the Simulated Annealing (SA) algorithm.

4. 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 are divided into several main types, including unary quadratic, binary quadratic, and multiple quadratic (Al -Hussein & Besher, 2024).

In a unitary quadratic allocation problem, the decision maker must make one decision from among a set of options, while specifying a set of constraints and conditions that must be considered. For example, the goal may be to determine the optimal location for a new factory based on several factors such as cost and access. Raw materials and target market (Zainab & Faez, 2023).

As for the binary quadratic allocation problem, the decision maker must make two decisions related to the allocation of resources or elements, such as distributing goods between two warehouses or allocating work between several projects. The main challenge in this issue is to make balanced and effective decisions that achieve the organization's goals at the lowest possible cost (Kumar & Mitra, 2023).

As for the multiple quadratic allocation problem, it is seen as an expansion of the binary quadratic allocation problem, where the decision maker must make multiple decisions related to the allocation of resources or elements in several projects or sites. This issue is more complex, as interactions between multiple decisions must be taken into account and controlled. In a way that achieves a balance between various goals and trials (Mohamed & Geetanjali, 2020).

Quadratic allocation problems are a type of operations research problem that involves determining the allocation of limited resources over a variety of activities or locations in a way that achieves certain objectives. The importance of these problems comes from the growing need to improve the use of resources, increase efficiency in operations, and make effective strategic decisions.

One of the most important reasons for the importance of quadratic allocation problems is to improve the use of resources, as quadratic allocation problems help determine how to distribute limited resources in an effective way to achieve the maximum benefit from them, and these problems can be used to determine the distribution of employees, production planning, transportation planning, and other operational decisions. Journaling (Jamal, & Benjamin, 2023).

They also help in making strategic decisions, as quadratic allocation problems help in making important strategic decisions about business expansion, selecting new locations, improving product design, supply chain management, production planning, and other decisions that affect the long-term success of the organization.

The quadratic allocation problem is a problem that aims to distribute resources in a way that achieves the best possible fit between suppliers and customers. The goal is to determine the amount of specific products that should be allocated to each customer, taking into account constraints related to the capabilities available from suppliers and the unique needs of each customer. This problem involves the search for customization Optimization of 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). Quadratic allocation problems are important for many applications in various fields, such as logistics, space planning, network design, resource distribution, and task ordering. For example, they can be used to arrange rooms in a hotel so that they make the most of available space, or to determine shipping routes to minimize transportation costs. Or even in determining the distribution of seats in lecture halls to increase comfort.

4.1. 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:

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

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.

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:

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

And subject to restrictions:

If the facility is allocated i to the location j $X_{ij} = \{^1{}_0$

4.2. Methods for solving the Quadratic Assignment Problem:

The conventional approach to tackling 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 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.

5. The Concept of One-Sided Quadratic Problems:

Unary quadratic allocation problems are a type of mathematical problem that is concerned with determining the optimal allocation of a set of items or resources to specific locations, based on a set of constraints and conditions. In these problems, a set of items and a set of locations are given, and the algorithms must search for the optimal distribution. of items on the sites so that all items are processed according to the imposed restrictions (Al-Hussein & Besher, 2024).

There is usually a specific goal that must be achieved through these issues, such as reducing overall cost, increasing efficiency, or improving resource distribution. Constraints in these issues usually include capacity constraints, where more than one item cannot be placed in a particular location, in addition to constraints related to Costs, time, or any other conditions that may be relevant (Zainab & Faez, 2023).

Applications of unary quadratic allocation problems are wide-ranging and include areas such as space planning in buildings and facilities, arrangement of equipment on production lines, distribution of materials in supply chains, routing logistics operations and other areas that require efficient allocation of resources.

A variety of mathematical models are used to solve unary quadratic assignment problems, the most common being what is known as the integer linear programming (LP) model. In this model, each item and each location are a variable represented by a numerical value, and the objective function contains the relationship that links the optimization objective (such as production cost or time) to the controllable variables (Jamal, & Benjamin, 2023).

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

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

In addition, the mathematical models used in unary quadratic assignment problems include a set of constraints that impose conditions that optical solutions must satisfy. These include structural constraints (such as constraints on amplitude and distances) and functional constraints (such as constraints on efficiency and quality).

The integer linear programming (LP) model is a mathematical model used to solve a variety of problems that involve achieving a specific goal in compliance with a set of constraints. In this model, the variables and the relationships between them are represented in a linear form. The integer linear model consists of a set of variables that are defined and determine it, and the goal that must be achieved is expressed in the form of a goal function that is determined linearly. In addition, a set of constraints are defined that the available solutions must comply with (Al-Hussein & Besher, 2024).

For example, in a transportation problem, variables representing the quantities of goods sent from different sources to different destinations are specified, the goal is set at the total transportation cost, and the constraints are typically the maximum capacity of the sources and the minimum demand of the destinations. Advanced techniques are also used to solve integer linear programming models, such as linear programming solution algorithms such as Simplex, and mixed integer programming (MILP) solution algorithms for models that include integer variables and non-negative integer variables. The integer linear programming (LP) model can be represented mathematically as follows:

- **Objective:** A goal is defined as a linear function to be achieved or improved, such as a cost, profit, or return on investment.
- **Variables:** The variables used in the model represent quantities or decisions that must be made, and are represented by certain symbols or symbols.
- **Constraints:** A set of constraints are defined that possible solutions must conform to, and these constraints are usually represented by linear mathematical relationships between variables.

The LP model can be represented as follows:

Maximize (or minimize): $c1x1 + c2x2 + \ldots + c_n x_n$

Subject to:

$a11x1 + a12x2 + \ldots + a1nxn \le b1$

$a21x1 + a22x2 + \ldots + a2nxn \le b2$

.

.

$am1x1 + am2x2 + \ldots + amnxn \le bm$

where:

- x1,x2,...,xn are the controllable variables.
- c1, c2,..., cn are the target coefficients.
- aij are the coefficients of the variables in the constraints.
- b1,b2,...,bm are the specific values of the constraints.
- m is the number of constraints.

This model seeks to either achieve the maximum or the minimum of the objective function while achieving all the imposed restrictions, and determining the values of the variables x1, x2,..., xn is done according to this model to obtain the optimal solution that achieves the desired goal. The mathematical model is used to find solutions that satisfy all constraints and achieve the desired goal at the lowest cost or according to other specified criteria. These models are solved using a variety of mathematical techniques, such as integer linear programming (LP), nonlinear patch programming (NLP), and mixed integer programming. (MIP), and other advanced computational methods.

7. Solve Unary Quadratic Assignment Problems Using Simulated Annealing Algorithm:

The Simulated Annealing algorithm is a powerful tool for solving quadratic assignment problems. This algorithm is based on the concept of natural evolution and self-adaptation, as it mimics the behavior of biological models in the process of searching for the optimal solution.

The simulation annealing algorithm models the problem as a model of a physical system, manipulating artificial temperatures to optimize the solutions. Since quadratic allocation problems are often complex and contain multiple competing criteria and objectives, using a simulated annealing algorithm can help optimize resource allocation and achieve specified objectives.

The relationship between simulated annealing algorithm and quadratic allocation problems is that the algorithm is used to optimize the distribution of resources or elements in a given environment, so that a set of specified criteria or goals are achieved in the best possible way. This is done by simulating the annealing process in the system, where the solutions gradually adapt as the environment changes and is constantly improving to achieve optimal performance in the proposed solutions.

Unary quadratic allocation problems can be solved using a simulated annealing algorithm. This is done by applying the concept of natural evolution and imitating the behavior of biological models in the solution process, where the goal is to find an optimal distribution of resources or activities in a specific environment such that a set of specific criteria or goals are achieved.

When applying the simulated annealing algorithm to a one-sided quadratic allocation problem, the problem is represented by the concept of organisms (in this case fish) interacting in a simulated environment. The resources or elements that must be allocated to random locations in the environment are represented, and the organisms (fish) interact with these Resources and improving their distribution over time.

The process of improvement is also the development of the behavior of organisms over time so that they are better adapted to their environment. Using the concepts of exploration and exploitation, organisms can optimize the distribution of resources and achieve specific goals in an efficient manner.

The Simulated Annealing algorithm is based on the principles of statistical physics and does not have specific equations for solving unary quadratic assignment problems. Instead, the Simulated Annealing algorithm is applied to the problems by creating a representative model of the problem and optimizing the solutions based on the principle of gradual cooling.

It is possible to rely on the equations previously presented in the steps of running the simulation annealing algorithm to solve the unary quadratic assignment problem as follows:

1. **Start with an initial design point:** Set the point that represents an initial distribution of facilities within the hospital.
2. **Create a new design point:** Randomly generate a new design point in the vicinity of the existing point.
3. **Calculating the target value:** Use the previous two points to calculate the target value, which reflects the efficiency of the internal distribution of facilities.
4. **Calculating the difference in the target value:** Calculate the difference between the new target value and the old one to determine the amount of improvement in the distribution.

The solutions are also represented by different states within the system, and the performance resulting from each state is evaluated. Then, random movements are chosen to improve the solutions according to the laws of physics, taking into account the possibilities of accepting the worst solutions. Therefore, to solve unary quadratic assignment problems using a simulated annealing algorithm, the algorithm must be applied to a representative model of the problem, and the necessary steps performed to gradually improve the solutions over time.

5. **Test the value of ΔE:** Test the amount of improvement to determine whether or not to accept the new distribution using the Metropolis criterion.

6. **Repetition:** Repeat steps 2-5 until the optimal solution is reached or the specified stopping criterion is achieved.

These steps and equations can be modified based on the nature and requirements of the specific unary quadratic assignment problem.

6. Results and Recommendations:

A. Results:

The research results found that using a simulated annealing algorithm can significantly improve the distance traveled within hospitals. For example, medical departments and facilities within a hospital can be distributed more efficiently and organized using this algorithm, leading to reduced waiting times for patients and an improved patient experience, in addition to improving internal distribution processes and reducing costs resulting from long distances. These results highlight the practical value of using a simulation algorithm. Plasticization in improving hospital organization and improving the quality of health care.

The research results also found that unilateral allocation issues play a prominent role in reducing the distances traveled within hospitals. By determining the distribution of medical departments and facilities in an effective and organized manner, it is possible to achieve a reduction in the distances traveled by employees and patients within the hospital, which leads to improving the patient experience and saving time. And the effort of medical and administrative staff. Therefore, unilateral allocation issues are an important tool for improving the efficiency and quality of health services within hospitals and enhancing the overall organization of medical infrastructure.

The research results indicate that the simulation annealing algorithm plays a prominent role in solving single allocation problems to reduce the distances traveled within hospitals, and thanks to its ability to simulate the evolution and adaptation processes carried out by living systems, this algorithm helps in improving the distribution of facilities and resources within the hospital in a way that reduces the distances traveled. Staff and patients need them to cut them. Thus, the annealing simulation algorithm contributes to improving work efficiency and saving time and effort, which enhances the overall quality of health services provided in hospitals and contributes to enhancing patient experience and improving the work environment for medical and administrative staff.

B. Recommendations:

Based on the research results on the effect of simulation annealing algorithm in solving single allocation problems to reduce distances traveled within hospitals, the following recommendations can be made to the hospital:

- ***Adopting smart planning techniques:*** It is recommended that the hospital rely on smart planning techniques such as the simulation annealing algorithm to improve the allocation of resources within the hospital, which contributes to reducing distances traveled and improving the efficiency of resource use.
- ***Developing operations management systems:*** It is recommended to develop operations management systems within the hospital using modern technology and smart algorithms, which enables improving the organization of daily activities and operations and reducing the time spent moving between departments.
- ***Improving building design:*** It is recommended to make improvements to the design of hospital buildings based on the results of the research, which can reduce the distances traveled between different departments and improve the flow of operations.
- ***Training medical and administrative staff:*** It is recommended to train medical and administrative staff on the use of modern technology and the application of smart algorithms in the allocation and resource management processes, which contributes to achieving optimal hospital performance.
- ***Review policies and procedures:*** It is recommended to review policies and procedures for allocating resources within the hospital based on the results of the research, and improve them in accordance with the use of smart planning techniques and smart algorithms.

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