Modification of Symbiotic Organisms Search Algorithm for Blood Distribution Problems in Pekanbaru City Blood Bank Unit

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Abstract

The hospital is a health service unit that is responsible for public health problems. Hospitals certainly need blood to carry out service activities to the community which include the interests of organ transplant operations, cancer treatment, and other diseases to heal patients. Because the more levels of blood needed, of course, the need for an optimal blood distribution system to maximize blood quality. One of the most recent optimization techniques is the Symbiotic Organisms Search algorithm, also known as the SOS method. but the obstacles encountered in previous research this algorithm is not optimal in solving cases on a large scale. This paper aims to modify the Symbiotic Organisms Search algorithm to solve combinatorial problems on a large scale. Modifications were made by replacing the parasitism phase with the mutation phase and adding a local search as a guide for the initial solution. SOS modification algorithm will be compared with the original SOS algorithm and Particle Swarm Optimization (PSO) algorithm. The results of the experiment found that the SOS Modification Algorithm was able to find the smallest distance compared to its two competing algorithms. So it can be said that the modification of the algorithm is successful for solving large-scale combinatorial problems as for the case used is the data set of the number of blood banks in Pekanbaru City, Indonesia.

Keywords
Blood Supply Chain, Healthcare Industry, Optimization, Symbiotic Organisms Search

Introduction

The hospital is a health service unit that is responsible for public health problems. Hospitals certainly need blood to carry out service activities to the community which include the interests of organ transplant operations, cancer treatment, and other diseases in order to heal patients. Blood was a rare and perishable substance, and a lack of supply would result in loss of life. However, excessive donation or improper management will lead to the wastage of blood and increase costs. (Abdolazimi et al. 2023).

Because the more levels of blood needed, of course, the need for an optimal blood distribution system to maximize blood quality. Blood distribution is usually carried out through the Hospital Blood Bank, which is one of the hospital service units responsible for the availability of blood for transfusion that is safe, of good quality, and in sufficient quantity to support the health services of the hospital itself. To maintain blood quality, blood distribution activities from the Blood Transfusion Unit (BTU) to hospitals through the Hospital Blood Bank until patients are accepted are carried out using a closed distribution system, which is a distribution system that must be carried out by BTU officers and hospital staff without involving the patient's family. In addition, the distribution system is also carried out with a cold chain distribution system, namely a system for storing and distributing blood products at the right temperature and conditions from the place where the donor's blood is collected until the blood is transfused to the patient.

Temperature, storage, and transportation distribution of blood greatly affect the viability of blood cells contained in blood bags. If storage at a temperature that is not optimal will cause blood cells to die, increase in various unwanted chemical substances, and can increase the risk of microorganism breeding. These things will raise the potential for transfusion reactions such as fever, infection, and even sepsis. The treatment of blood and its components during transportation from storage and treatment areas also needs special attention, both storage facilities in the form of cool boxes or ice boxes with due regard to optimal temperatures, and the personnel carrying out the transportation must be trained. The maximum transport time is 24 hours, and it is not recommended that blood or its components be in transit for more than 30 minutes before being transfused to the patient. Therefore, an optimal distribution management system and distribution route is needed to maximize the survival of blood cells. Take the impact of COVID-19 as an example the world has become a disaster resulting in an increase in the number of hospital patients and depleting the blood that collects in blood centers. In such cases, even though more people should donate blood, the smooth distribution of blood will play a very important role in controlling the pandemic outbreak. (Aghsami et al. 2023). Therefore, optimizing a route and managing the distribution process is necessary to produce effective performance and reduce traversing costs. The problems discussed are included in the Vehicle Routing Problem (VRP), which is a type of non-polynomial-hard problem.

Meneses et al. (2023) states that, the existing optimization models for blood supply chain management issues must be adapted to the level of planning. This decomposition in the decision level is necessary since a large-scale integrated optimization model that considers the entire network and planning decisions simultaneously would not be practical for a supply chain this complex and it is difficult to obtain useful insights due to stubbornness. However, it is necessary to consider the interactions among the different decision levels appropriately to arrive at the optimal solution because all levels of planning are interrelated. Thus, a framework for the integration of supply chain issues within the same planning level and across different planning levels was developed.

One of the new optimization techniques is the Symbiotic Organisms Search method, also known as the SOS method. This method was first introduced by Cheng and Prayogo in 2014 which was inspired by the biological relationship between each organism in the ecological system. The obstacle faced in implementing the SOS algorithm to solve combinatorial problems is that in the parasitic phase, the SOS algorithm requires to creation a parasitic organism using the dimensions of the objective function to be searched (only intended for the benchmark function), while the VRP does not have the dimensions of the objective function for that. there needs to be another suitable mechanism to replace the mechanism in the parasitic phase. Ruskartina et al. (2015) also suggested that it is necessary to modify the parasitic phase by adding a more specific search algorithm to overcome combinatorial problems. The mechanism proposed to change the phase of this parasite is by using a mutation mechanism. The mutation mechanism makes it possible to bring up new individuals who are not from the previous population by referring to changes or replacement of elements from the solution vector (Santosa and Willy, 2011). This refinement of the SOS algorithm will be studied in this study, namely by modifying the SOS algorithm by adapting the mutation mechanism to replace the mechanism in the parasitic phase to be able to find the best route.

Literature Review

Combinatorial optimization is rooted in combinatorial science, operations research, and computer science (Korte and Vygen, 2008). Combinatorial optimization has become popular because many combinatorial problems cannot be modeled as continuous functions or have limited search space. On the other hand, these problems can be easily formulated in a combinatorial form. Some of the problems that are easier to state in the combinatorial model include the "Traveling Salesman Problem, Vehicle Routing Problem, Assembly lines, job scheduling and network routing" (Purnomo 2014).

The SOS algorithm was first introduced by Chen and Prayogo in 2014. At the beginning of its formation, this algorithm was tested on a benchmark function of 26 functions. the result is that the SOS algorithm is able to excel from the comparison algorithm in terms of convergence and speed of finding the optimal solution. so according to Ezugwu and Prayogo (2018) many researchers have developed this algorithm by adapting it to various cases. As research conducted by Cheng et al. (2015) who developed SOS for discrete problems. Discrete SOS was used first for multiple project scheduling problems. Then Tejani et al. (2016) developed adaptive SOS to increase the effectiveness of search space exploitation capabilities. Namaa et al. (2016) improved SOS by introducing a random weighted reflective parameter and predation phase.

Some researchers have also carried out a hybrid between the SOS algorithm and other algorithms such as Abdullahi and Ngadi (2016) proposed a hybrid SA based symbiotic organisms search or known as SOSSA. the purpose of doing this hybrid is to increase the optimization of the scheduling process in cloud computing. In addition, the authors considered the improvement of the classical SOS algorithm based on convergence rate and quality of solutions produced by SOS. Vincent et al. (2017) conducted a study by combining local search strategies with SOS and adding two new phases, namely competition and amensalism. then Umam et al. (2018) conducted a hybrid between SOS and variable neighborhood search for TSP problems. then replace the parasitism phase with the mutation phase in the Genetic algorithm. In this study, local search will be applied to SOS to lead to a better initial solution so that it can shorten computation time.

Methodology

Cormen et al. (2022) state that an algorithm is a sequence of logical and structured steps to solve a problem, the problem will systematically achieve certain goals. Algorithms are usually written in the form of a sequence of instructions that must be followed to complete a task or problem. The algorithm can also be defined as a procedure or method to solve a problem or task. An algorithm can also be interpreted as a sequence of instructions or logical rules that are used to solve a particular problem or task. Algorithms are often used in computer programming to design effective and efficient programs or applications.

According to Medhi and Ramasamy (2017) programming algorithms in route scheduling (routing) are a series of systematic steps to determine the best route in a transportation network. Winston (2022) stated that there is a simple example of a programming algorithm in route scheduling. The algorithm is as follows:

1. Start the program
2. Determine the starting point of the journey
3. Determine the purpose of the trip
4. List all possible routes between the starting point and travel destination
5. Calculate the distance and travel time for each route
6. Choose the route with the shortest distance and travel time
7. Show the shortest route to the screen

8. Finish the program

The SOS method simulates an ecological system in which there is a reciprocal relationship between organisms and other organisms where both will benefit from this relationship (mutualism), the relationship between organisms and other organisms but one does not benefit directly (commensalism) and the relationship between organisms and parasites (parasitism).

Pseudocode Algorithm SOS (Cheng and Prayogo, 2014)

```
Input    : Ecosize, Function
Output : Best Organism, Best Fitness, FE
Begin
Generate ecosystem, calculation fitness, set FE=1
Repeat

while FE < Femax
   for i = 1: ecosize; update best fitness and best organism
      Mutualism Phase
         If fitness better than before
            eco(i; j) ← x (new1;new2)
         end
      FE=FE+2
      Commensalism Phase
         If fitness better than before
            eco(i) ← x (new1)
         end
      FE=FE+1
      Parasitism Phase
         If fitness better than before
            eco(j) ← parasite
         end
      FE=FE+1
   end
   If best fitness < globalmin
      break
   end
end
```

Figure 1. Pseudocode for SOS Algorithm.

Mutation is possible to bring up new individuals who are not derived from the results of interbreeding. Mutation refers to changing the order or replacing elements of the solution vector (in VRP problems) by generating new values (function optimization). The elements are also chosen randomly. Suppose for a solution vector X, for k selected elements. An important parameter in mutation is the probability of mutation. This probability will determine which chromosome will undergo the gene change. The greater the value of the probability of mutation, the more chromosomes in the population that will experience mutations. Suppose the mutation probability value is 0.01, then there will be around 1% of all chromosomes in the population that will experience mutations. Purnomo (2014) stated that in designing mutation operators, several things must be considered:

Ergodicity: The mutation process must allow to exploration of the entire search space.

Validity: The mutation process must produce a valid settlement. In optimization problems with constraints, validity is sometimes difficult to achieve.

Locality: the mutation process should result in only slight changes in the structure of the individual chromosomes.

Several mutation processes can be carried out such as the 2-opt, 3-opt, and 4-opt operators. Mutation with the 2-opt operator randomly selects two sides (a,b) and (c,d) of the tour, replacing destinations (a,b) and (c,d) with (c,a) and (d,b) and check if being able to connect four nodes in different ways will give lower cost.

$$Cab + Ccd > Cac + Cdb$$

Another process can be carried out by selecting which individual will be mutated using random numbers and then compared with the mutation probability. The selected individual will then be mutated by selecting the order of the individual's route. Santosa dan Willy (2011) explained that exchanging route sequences can be done in several ways, namely swap, slide, and flip. For example, suppose there is a route 4 - 6 -|2–3–5–1| - 7. Here are the differences between the three ways of mutation:

Swap: Carrying out the process of swapping at points 3 and 6 it becomes 4 – 6 - |1 – 3 – 5 – 2| - 7.

Slide: Shifting the route to 4 – 6 - |3 – 3 – 2 – 1| - 7.

Flip: Reversing the segment between the 2 vertical lines of the route will be 4 – 6 - |1 – 5 – 3 – 2| - 7.

Alba (2005), states that VND starts from a descent method to reach a local minimum, then investigates systematically or randomly, causing the environment to be further away from this solution. Each time, one or more points in the current environment are used as the initial solution for local descent. One point jumps from the current solution to a new reference point if and only if a better solution is found. Although simplicity is more specific. The following is a systematic observation of VND:

a. A local minimum relates to one environmental structure that is not necessarily better than another.

b. A global minimum which is a local minimum corresponds to all possible environmental structures.

c. Most of the minimum local problems relate to one or several neighborhoods that are relatively close to each other.

Variable Neighborhood Descent (VND) is a deterministic type of VNS. This is based on the systematic observation of VNS (a), that a local optimum for the first solution moving x + z' (or heuristic, or in environment N1(x)) is not necessarily good for the next solution moving x ϵ 2 (in environment N2 (x)). It might be better to incorporate decent heuristics. The VND scheme can be seen in Figure 2.

	VND Method
1.	Looking for the initial solution x
2.	Repeat the sequence until the best solution is reached
	(i) Set l ←1; (ii) Repeat the following steps until l = lmax : (a) Find the best neighborhood x' of x (x' ϵ Nl (x)); (b) If the solution x' obtained is better than x, set x ← x' and l ← 1; otherwise, l ← l + 1

Figure 2. Pseudocode for VND Algorithm.

All information or data relevant to the research is gathered as part of data collection. The following information was gathered at the time of data collection. Table 1 shows the data matrix for the distance from and the destination for distributing blood bags to each hospital, measured using Google Maps in kilometers.

Table 1. Data set from the distance Matrix Between Nodes (KM)

from\to	RS-1	RS-2	RS-3	RS-4	RS-5	RS-6	RS-7	RS-8	RS-9	RS-10	RS-11	RS-12	RS-13	RS-14	RS-15	RS-16	RS-17	RS-18	RS-19	RS-20
RS-1	0	5,73	2,28	0,67	1,8	9,58	2,48	2,28	8,78	2,19	10,04	6,69	1,31	1,13	0,81	0,64	1,36	2,14	2,56	8,19
RS-2	5,73	0	5,16	5,78	5,58	3,9	4,37	4,29	5,96	6,56	4,41	2,69	5,59	6,61	5,33	5,19	4,44	3,88	6,44	3,99
RS-3	2,28	5,16	0	1,71	0,64	8,64	3,89	3,63	9,67	1,47	9,01	5,18	3,41	2,25	1,49	2,42	2,43	1,52	1,28	8,04
RS-4	0,67	5,78	1,71	0	4,17	9,56	3	2,77	9,25	1,53	9,99	6,46	1,98	0,84	0,45	1,41	1,67	1,97	1,88	8,38
RS-5	1,8	5,58	0,64	4,17	0	9,17	3,73	3,48	9,76	0,99	9,55	5,78	3,02	1,61	1,06	2,07	2,28	1,75	1,01	8,39
RS-6	9,58	3,9	8,64	9,56	9,17	0	8,26	8,17	7,37	10,11	0,58	3,88	9,49	10,38	9,1	9,06	8,32	7,59	9,89	3,27
RS-7	2,48	4,37	3,89	3	3,73	8,26	0	0,26	6,31	4,48	8,76	6,24	1,52	3,6	2,76	1,86	1,47	2,65	4,72	6,45
RS-8	2,28	4,29	3,63	2,77	3,48	8,17	0,26	0	6,5	4,24	8,69	6,08	1,44	3,41	2,52	1,66	1,22	2,39	4,47	6,24
RS-9	8,78	5,96	9,67	9,25	9,76	7,37	6,31	6,5	0	10,66	7,95	8,6	7,75	9,93	8,97	8,17	7,62	8,18	10,79	4,16
RS-10	2,19	6,56	1,47	1,53	0,99	10,11	4,48	4,24	10,66	0	10,48	6,63	3,49	1,43	1,72	2,66	3,06	2,73	0,51	9,38
RS-11	10,04	4,41	9,01	9,99	9,55	0,58	8,76	8,69	7,95	10,48	0	4,1	9,99	10,81	9,53	9,53	8,8	8,02	10,24	3,84
RS-12	6,69	2,69	5,18	6,46	5,78	3,38	6,24	6,08	8,6	6,63	4,1	0	7,04	7,23	6,04	6,34	5,69	4,55	6,32	5,02
RS-13	1,31	5,59	3,41	1,98	3,02	9,49	1,52	1,44	7,75	3,49	9,99	7,04	0	2,33	1,97	0,99	1,38	2,72	3,86	7,67
RS-14	1,13	6,61	2,25	0,84	1,61	10,38	3,6	3,41	9,93	1,43	10,81	7,23	2,33	0	1,29	1,77	2,43	2,8	1,91	9,21
RS-15	0,81	5,33	1,49	0,45	1,06	9,1	2,76	2,52	8,97	1,72	9,53	6,04	1,97	1,29	0	1,01	1,35	1,53	1,97	7,96
RS-16	0,64	5,19	2,42	1,41	2,07	9,06	1,86	1,66	8,17	2,66	9,53	6,34	0,99	1,77	1,01	0	0,79	1,84	2,96	7,58
RS-17	1,36	4,44	2,43	1,67	2,28	8,32	1,47	1,22	7,62	3,06	8,8	5,69	1,38	2,43	1,35	0,79	0	1,39	3,24	6,85
RS-18	2,14	3,88	1,52	1,97	1,75	7,59	2,65	2,39	8,18	2,73	8,02	4,55	2,72	2,8	1,53	1,84	1,39	0	2,74	6,65
RS-19	2,56	6,44	1,28	1,88	1,01	9,89	4,72	4,47	10,79	0,51	10,24	6,32	3,86	1,91	1,97	2,96	3,24	2,74	0	9,36
RS-20	8,19	3,99	8,04	8,38	8,39	3,27	6,45	6,24	4,16	9,38	3,84	5,02	7,67	9,21	7,96	7,58	6,85	6,65	9,36	0

Results and Discussions

The data used for processing this data is the last data that the data cleaning process has carried out. In this stage, problem-solving will be carried out on consumer purchase patterns with the Association Rule method using the FP-Growth Algorithm. Data preparation must be done because not all attributes are used in data mining. This process is carried out so that the needs will use the data.

Pseudocode Modified SOS Algorithm

```
Input   : Number of population, maximum iteration
Output : Best Route, Total distance
Begin
Generate ecosystem, calculation initial distance,
Generate neighbourhood set
        Local search.
        Improve or not. if x" better than x*, set (x ← x").
calculation distance
set IT=1
Repeat
    while it < itmax
        for i = 1: ecosize; update best distance and best route
            Mutualism Phase
                If distance better than before
                    eco(i; j) ← x (new1;new2)
                end
            Commensalism Phase
                If distance better than before
                    eco(i) ← x (new1)
                end
            Parasitism Phase
            Rand
                If rand < 0,33
                    Flip
                    Elseif rand > 0,67
                        Swap
                    Else
                        Slide
                end
            If distance better than before
                eco(i) ← x (new1)
            end
        End
        It=it+1
        If it == itmax
            break
        end
    end
```

Figure 3. Pseudocode Algorithm of Modified SOS.

Table 2. The Total distance from the running results of the PSO, SOS, and SOS Modification

Rep.	PSO	SOS	Modified SOS
1	62,3	64,4	40,43
2	60,5	61,9	42,1
3	53,2	55,03	39,04
4	55,6	57,29	38,97
5	59,14	54,3	43,51
6	52,8	58,55	39,91
7	**51,7**	55,22	43,46
8	54,8	57,3	43,44
9	62,5	53,36	40,95
10	61,3	**51,52**	**37,51**

Table 2. compares the running results of Particle Swarm Optimization (PSO), original Symbiotic organisms Search (SOS), and modified Symbiotic organisms Search on a set of case Blood Transfusion Unit (BTU). 10 runs are carried out for each algorithm. All of the algorithms are written in MATLAB code and the limit of iteration of each is 1000000 on an Intel(R) Core(TM) i3 processor 2.27GHz. the parameter that is applied is the maximum number of iterations which is set the same for the entire algorithm. The modified SOS algorithm is capable of producing the smallest total distance search compared to the original PSO and SOS algorithms. Computation time (comp time) is used to evaluate the efficientcy of the optimization algorithm. The computational time required for each algorithm can be seen in **Table 3**.

Table 3. Computation Time of the PSO, SOS and SOS Modification

Rep.	PSO	SOS	Modified SOS
1	4,51	7,38	1,06
2	2,46	4,45	1,17
3	4,63	5,04	**1,03**
4	2,63	5,13	1,14
5	4,62	5,67	1,76
6	3,62	5,78	1,06
7	3,48	7,19	1,25
8	3,67	6,24	1,17
9	**2,38**	4,67	1,35
10	4,42	**4,35**	1,19

Conclusion

From the study that has been carried out, it can be concluded that the modification of the SOS algorithm is able to produce better distance output for blood bag distribution routes, for the Pekanbaru city area, compared to the original SOS algorithm and PSO algorithm. this can be seen in terms of the minimum distance that can be produced. The modified algorithm is able to provide the smallest distance for the distribution of blood bags with a total of. 37,51 while the original SOS algorithm is only able to produce the smallest distance in the number of 51,52 and the PSO algorithm 51,7. The fastest computing time that can be achieved by each algorithm with a very large maximum iteration parameter (1000000 iterations), the modified SOS algorithm is 1,03 seconds, the original SOS algorithm is 4,35 seconds and the PSO algorithm is 2,38 seconds.

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