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Optimization of Nursing Scheduling in Emergency by Using Genetic Algorithm

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Abstract: Scheduling nurse duty is one of the problems in health organizations that is quite complicated to solve. Starting from the uncertain number of patients, serious patient illnesses, characteristics of organizational groups, requests for nurses to take time off, and the qualifications and specialization of the nurses themselves are why scheduling in the ER is difficult to optimize. The same thing is being experienced by one of the health institutions, RSUD Dr. Pirngadi. Preparing schedules or determining the number of nurses on duty is still done manually, resulting in a lack of optimization in scheduling and the number of nurses who must be on duty, especially in the emergency department. In solving this problem, an appropriate method is needed so that the process of scheduling and optimizing the number of nurses can be formed properly. This research applies the Genetic Algorithm in optimal emergency department (IGD) nurse duty scheduling. Genetic algorithms, also called search algorithms, are based on the mechanisms of natural selection and genetics. Genetic algorithms are one of the appropriate methods for solving complex optimization problems. This method is good enough to optimize shift scheduling for the Emergency Room Nursing Service in a Hospital. This Genetic Algorithm can be a solution to multi-criteria and multi-objective problems modeled using biological and evolutionary processes. So, the concept of this method can be applied in optimizing the Nursing Service schedule. The results of calculations using the Genetic Algorithm show quite significant comparisons, including several nurses losing their positions and being eliminated by mutation because they could not compete with several other strong individuals.

Keywords: Attendance; Genetic Algorithms; Nurse; Optimization; Scheduling.

Introduction

The Emergency Department (IGD) is the front unit receiving patients during an emergency. In the ER, doctors must be available 24 hours a day to treat patients who come at any time when an emergency occurs. A shift schedule system maintains doctors' performance when working 24 hours in the ER [1]. To optimize and create the best combination in the doctor's shift schedule in the ER, a system for scheduling shifts for doctors in the ER that uses a genetic algorithm was created [1].

Scheduling nurse duty shifts is one of the problems in healthcare organizations that takes more work to solve. The unstable number of patients, patients with serious illnesses, organizational characteristics, absences and requests for nurse leave, and the qualifications and specialization of the nurses themselves are why optimizing the emergency room nurses' schedule is difficult [2-4]. The same thing is being experienced by one of the health institutions, RSUD Dr. Pirngadi. Preparing schedules or determining the number of nurses on duty is still carried out semi-manually, resulting in a need for more optimization in scheduling and the number of nurses who must be on duty, especially in the emergency department.

In scheduling, several ways or methods are used, including Tabu Search, TPB Algorithm (Tibrewalla, Phillipe and Brown), Monroe Algorithm, and Goal Programming. The Genetic Algorithm method is used in this research because several considerations and mechanisms are more precise and optimal in completing this research. The genetic algorithm aims to search based on natural system mechanisms, namely genetics and natural selection [5-7]. In contrast to conventional search techniques, genetic algorithms start from a set of randomly generated solutions. This set is called a population [8-10].

Meanwhile, each individual in the population is called a chromosome, representing the solution [11]. Chromosomes evolve in a continuous iterative process called generations [12]. At each generation, chromosomes are evaluated based on an evaluation function. After several generations, the genetic algorithm will converge on the best chromosome, which is expected to be the optimal solution [13-14].

There are several serious obstacles, such as the number of nurses needing to be more optimal and the number of shifts needing to be more stable. Therefore, it is very important to carry out this research to present a better and more optimal scheduling form. Researchers are interested in using Genetic Algorithms to optimize ER nurses' work scheduling. The reason is that the genetic algorithm can optimize a route to be shorter and does not require a long processing time. It is very suitable for scheduling optimal work shifts for nursing tasks.

Research Methods

Genetic Algorithms

A genetic algorithm is a search method based on natural selection and genetic mechanisms. Genetic

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algorithms are the right method to solve complex optimization problems [15]. In solving container optimization problems or, in this case, problems, heuristic methods can be used, namely a search method based on intuition or empirical rules, to obtain a better solution than the solution that has been achieved previously. In this era of increasingly advanced and rapidly developing technology, fast, precise, and efficient performance is also needed. So, the use of technology that has been developed is expected to improve the performance and quality of service providers. In solving the scheduling problem in this research, a genetic algorithm will be applied to find the best solution from the many possibilities generated. In the law of genetics, only quality individuals can produce new individuals or generations with the best qualities. Genetic Algorithms, as a powerful optimization method have become the most famous technique in evolutionary computing today [16]. In general, a genetic algorithm has five basic components, as reported by Michaelewicz (455) rewritten in the book "Genetic Algorithm and Engineering Optimization" by Mitsuo Gen and Runwei Cheng [16]: (1) Genetic representation for problem solutions (2) Method of creating initiation of solving the population, (3) Evaluation of fitness values based on possible solutions, (4) Genetic methods in generation replacement and reproduction, (5) Expected final results from processing this Genetic Algorithm [16].

Genetic Algorithm Mechanism

In general, the Genetic Algorithm can be described as a flow chart in the following image:

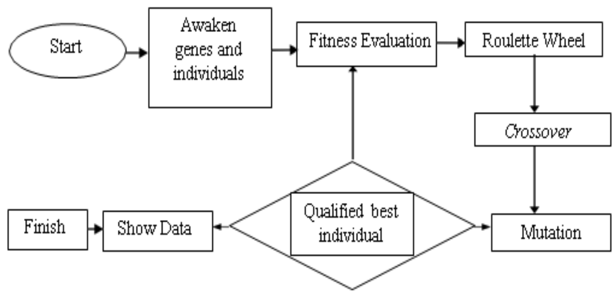

Figure 1. Genetic Algorithm Recurrence Chart [17].

Procedure Genetic Algorithm

1. Forming the Initial Population

The first step in this algorithm is to form an initial population to find the optimal solution. The initial population built in this final project uses random numbers with a predetermined number range [18].

(Chromosomes = [Population Variables, E.g. a, b, c, d]) (1)

2. Calculating the Objective Function

Calculating the objective function aims to evaluate the value of each chromosome to produce the fitness value of each chromosome.

F (x) = ((a + 2b + 3c +...+n) – number of chromosome (2)

In determining the variables, the objective function calculation is adjusted according to the variables you have, for example, P, Q, R, S, etc.

3. Fitness Function

The fitness function is used for the chromosome evaluation or selection process to obtain the desired chromosome. This function differentiates the quality of the chromosomes to find out how good the chromosomes that the fitness function produces are, as follows [19].

$$\text{Fitness i} = \left(\frac{1}{(\text{Objective Function}+1)} \right) \quad (3)$$

4. Determining the Value of the Probability Function

The next process is to determine the value of the probability function, which is carried out to get to the next stage, namely the selection process. The equation is:

$$\text{Pi} = \frac{(\text{Fitness i})}{(\text{Total Fitness})} \quad (4)$$

5. Selection Process Using Roulette Wheel

Roulette selection is a method of individual selection that still involves population diversity following its name, the working principle of the Roulette Wheel, where each individual occupies their circle on the Roulette wheel professionally according to their fitness value. The Roulette Wheel selection process determines the chromosome value according to the probability function value [18]. Then, for the 2nd chromosome, add the first probability function with the second probability function, and so on.

$$C1 = P1$$
$$C2 = P1 + P2$$
$$\dots$$
$$Cn = P1 + P2 + \dots + Pn \quad (5)$$

6. Crossovers

Crossover or interbreeding is a method of marrying two parent chromosomes to get better children. In a very small population of a chromosome with genes from other chromosomes, to overcome this, a rule is used that crossover only involves chromosomes that have a random value [0,1] whose value is smaller than the crossover probability (pc); in other words, chromosomes that have another random value < pc are chromosomes that need to be repaired by making these chromosomes as parents in crossover to get better chromosomes [17].

This method uses a one-cut point method, randomly selecting one position in the parent chromosome and exchanging genes using a crossover rate of 0.95. Crossbreeding occurs between two parents from top to bottom (odd-even pairs). Following what was put forward by [20], who designed a Meta-Genetic Algorithm that provided optimal parameter values for a simple Genetic Algorithm and showed that small population sizes ranging from 20 to 40 were associated with high crossover rates in line with low mutation rates. The findings generally reveal that mutation rates above 0.5 are not useful for optimal performance of Genetic Algorithms. Therefore, researchers suggest a series of other parameters with a population size value of 30 individuals, a Crossover Rate of 0.95, and a Mutation Rate of 0.01.

7. Mutations

A mutation changes the value of one or several genes in one chromosome. Gene change is done in various ways: changing gene 1 to 0 and vice versa, exchanging genes at one position with genes in another, changing genes with certain limits, and so on, depending on individual representation. The purpose of mutation is to speed up the differences between all chromosomes in a population so that searches can be mapped throughout space. In addition, mutation aims to restore important components lost during the crossover process [17].

The number of mutated chromosomes in a population is determined by a mutation rate parameter of 0.95. The mutation process replaces a randomly selected gene with a new value obtained randomly. The total length of genes is the total genes = (number of genes in chromosomes) * number of populations.

Induk	1	2	3	4	5	6	7	8
Anak	1	2	8	4	5	6	7	3

Figure 2. Example of mutation [17]

The total length of genes is the total genes = (number of genes in chromosomes) * number of populations.

Results and Discussion

Data Description

In this study, the data that will be analyzed is the attendance data for the nurses on duty at the Emergency Room (IGD) of the Regional Hospital. Dr. Pirngadi Medan is on duty in the morning, afternoon, and night shifts, off (night duty holiday), and on Sunday guard holidays. The number of nurses on duty for emergency room nurses on the attendance list is 31 people, including the Administration section and the Administration section. Data obtained in August 2023 can be seen in the following table:

Table 1. List of Regional Hospital Emergency Installation Services. Dr. Pirngadi Medan City, August 2023 :

No.	Nama	Pendidikan	Jabatan	NIP	Gol.	TANGGAL																														
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	Nasib Sitepu, S.Kep,Ns	S-1	Supervisor	19681209 199203 1 002		L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L	P	P	P	P	P	L	P	P
2	Marlina Silalahi, S.Kep,Ns	S-1	Ka. Ruangan	19870530 201101 2 025	III/b	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L	P	P	P	P	P	L	P	P
3	Sanusi Batubara, S.Kep,Ns	S-1	Ka. Tim Bedah	19670427 199103 1 006	IV/a	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L	S	S	S	S	P	L	P	P
4	Rosmery Natalia, S.Kep,Ns	S-1	Ka. Tim Medical	19801108 200701 2 002	III/d	L	L	P	P	P	T	P	P	P	P	P	L	T	T	L	P	P	P	P	P	T	P	L	P	P	P	T	T	L	P	P
5	Rina Maghfira	D-4	Pel. Kebidanan	19850708 201003 2 001	III/d	S	S	M	M	O	L	T	P	P	P	M	M	O	L	P	P	P	P	M	M	O	L	P	P	S	S	M	M	O	L	P
6	Tukiyati, S.Kep,Ns	S-1	Pel. Perawatan	19811104 200701 2 008	III/b	M	M	O	L	L	S	S	S	M	M	O	L	S	S	L	S	M	M	O	L	S	S	S	S	M	M	O	L	S	L	S
7	Andi Aguspel, S.Kep,Ns	S-1	Pel. Perawatan	19820813 200903 1 005	III/a	O	L	S	L	S	S	S	S	M	M	O	L	S	S	S	S	M	M	O	L	S	S	S	L	P	P	T	T	M	M	O
8	Hotnida Simamora	D-3	Pel. Perawatan	19810109 201001 2 021	III/a	L	P	P	P	M	M	O	L	M	M	O	L	L	L	P	P	M	M	O	L	T	P	P	P	P	P	T	L	M	M	O
9	Deswita, S.Kep,Ns	S-1	Pel. Perawatan	19841214 201001 2 021	III/d	L	L	S	S	M	M	O	L	S	S	S	S	S	S	M	M	O	L	S	S	M	M	O	L	S	S	S	S	M	M	O
10	Maya Irawan, A.Md.Kep	D-3	Pel. Perawatan	19871027 202203 2 001	II/c	P	P	M	M	O	L	T	P	S	L	M	M	O	L	P	P	S	S	M	M	O	L	P	P	M	M	O	L	P	P	S
11	Alex Sander Nainggolan, A.Md	D-3	Pel. Perawatan	19981224 202203 1 001	II/c	L	L	S	S	M	M	O	L	P	P	S	S	M	M	O	L	P	P	P	T	S	S	M	M	O	L	T	S	S	S	M
12	Surya Afriadi, AMK	D-3	Pel. Perawatan	19930428 202203 1 000		S	S	M	M	O	L	S	S	L	S	M	M	O	L	P	P	S	S	S	S	M	M	O	L	S	P	T	P	P	P	P
13	Ingot Maruli Tua	S-1	Pel. Perawatan	19850214 202221 1 007		L	L	P	P	S	S	S	S	M	M	O	L	T	T	S	S	M	M	O	L	T	P	S	S	M	M	O	L	P	P	P
14	Syafrina , AMK	D-3	Pel. Perawatan	Kontrak	Honor	O	L	P	P	S	S	M	M	O	L	P	P	M	M	O	L	S	S	S	S	S	S	M	M	O	L	S	S	L	S	P
15	Nuraini Dewi, AM.Kep	D-3	Pel. Kebidanan	Kontrak	Honor	P	S	M	M	O	L	T	L	L	P	M	M	O	L	S	S	S	S	S	S	M	M	O	L	S	S	M	M	O	L	P
16	Rina Adelina Sihombing	D-3	Pel. Kebidanan	Kontrak	Honor	L	L	S	S	S	S	M	M	O	L	P	P	T	T	M	M	O	L	P	P	S	S	M	M	O	L	S	S	S	S	P
17	Annisa Lubis, AM.Keb	D-3	Pel. Kebidanan	Kontrak	Honor	P	P	S	S	M	M	O	L	P	P	S	S	S	S	M	M	O	L	P	T	L	L	M	M	O	L	S	S	S	S	P
18	Titik Azizah, AM.Kep	D-3	Pel. Kebidanan	Kontrak	Honor	S	S	L	S	S	S	M	M	O	L	P	P	S	S	S	S	M	M	O	L	T	P	S	S	M	M	O	L	P	P	P
19	Aci Rahayu, STR,Kep	S-1	Pel. Kebidanan	Kontrak	Honor	O	L	P	P	S	L	S	S	M	M	O	L	T	T	S	S	M	M	O	L	T	P	S	S	M	M	O	L	P	P	P
20	Mahlaini Idawati Lubis	D-3	Pel. Kebidanan	Kontrak	Honor	O	L	P	P	P	L	S	S	M	M	O	L	T	T	P	P	S	S	M	M	O	L	P	P	P	P	T	L	M	M	P
21	Ira Mutia Monica	D-3	Pel. Kebidanan	Kontrak	Honor	S	P	M	M	O	L	P	P	S	S	L	P	M	M	O	L	P	P	S	S	M	M	O	L	S	S	M	M	O	L	P
22	Dwi Suci	D-3	Pel. Kebidanan	Kontrak	Honor	M	M	O	L	M	M	O	L	S	S	S	S	M	M	O	L	P	P	M	M	O	L	L	P	P	P	T	T	M	M	P
23	Sri Wahyuni	D-3	Pel. Kebidanan	Kontrak	Honor	M	M	O	L	P	T	M	M	O	L	P	P	P	T	M	M	O	L	P	T	M	M	O	L	P	P	T	T	M	M	P
24	Susilawati	D-3	Pel. Perawatan	Kontrak	Honor	M	M	O	L	L	T	T	P	S	S	M	M	O	L	S	S	S	S	M	M	O	L	S	S	L	S	M	M	O	L	P
25	Syarifuddin, AMK	D-3	Pel. Perawatan	Kontrak	Honor	O	L	P	P	M	M	O	L	P	P	P	P	M	M	O	L	P	P	P	T	T	P	M	M	O	L	S	T	P	P	P
26	George Bambang,AMK	D-3	Pel. Perawatan	Kontrak	Honor	L	S	S	S	L	L	M	M	O	L	S	S	S	S	M	M	O	L	S	S	S	S	L	S	M	M	O	L	S	S	P
27	Ahmad Ridwan	D-3	Pel. Perawatan	Kontrak	Honor	P/S	L	M	M	O	L	L	P	P	P	S	S	M	M	O	L	P	P	P	T	M	M	O	L	S	S	M	M	O	L	P
28	Riswandi	D-3	Pel. Perawatan	Kontrak	Honor	O	L	P	P	P	T	M	M	O	L	P	P	T	P	M	M	O	L	P	T	P	L	M	M	O	L	S	S	S	S	P
29	Bambang	S-1	Pel. Perawatan	Kontrak	Honor	M	M	O	L	P	T	P	L	S	S	M	M	O	L	P	P	P	P	M	M	O	L	P	P	P	P	M	M	O	L	P
30	Julia Khamarani	S-1	Adm	Kontrak	Honor	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L	P	P	P	P	P	L	P	P
31	Anggereni Siburian	S-1	Tata Usaha	Kontrak	Honor	L	P	L	L	L	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L	P	P	P	P	P	L	P	P

Based on the table for the list of ER nurse duty services above, the number of morning duty, afternoon duty, evening duty, and holidays, as well as night duty for each officer/nurse, can be determined as follows.

Table 2. Number of morning, evening shifts, holidays, and night shifts at RSUD. Dr. Pirngadi Medan City, August 2023 :

No.	Name	Variable				
		P	S	M	L	OFF
1	Nasib Sitepu, S.Kep,Ns	25	0	0	6	0
2	Marlina Silalahi, S.Kep,Ns	25	0	0	6	0
…	…	…	…	…	…	…
31	Anggereni Siburian	22	0	0	9	0

Information :	P: Morning S: Afternoon M: Night	OF: Night Watch Holiday L: Holiday

Application of Genetic Algorithms in Shift Scheduling

Determining the variables P, S, M, L, and OF to form chromosome-forming genes. If P is the morning shift code, S is the afternoon shift code, M is the night shift code, L is the holiday code, and Of is the night shift holiday code. To determine the values of several of these variables, use the table for the number of RSUD shifts. Dr. Pirng in the city of Medan.

The stages of the Genetic Algorithm in this research are as follows:

1. Form the Initial Population

Based on Table 3, the initial population of the Genetic Algorithm stages can be determined as follows:

Table 3. Initial population numbers

Nurse Code	Amount (variable value)				
	P	S	M	L	OF
A1	25	0	0	6	0
A2	25	0	0	6	0
…	…	…	…	…	…
A31	22	0	0	9	0

2. Based on the table above, the initial population size can be determined as follows:

(Chromosomes = [P; S; M; L; OF])
Kromosom 1 = [25, 0, 0, 6, 0]
Kromosom 2 = [25, 0, 0, 6, 0]
…
…
Chromosome 31 = [22, 0, 0, 9, 0]

Calculating Objective Function (Chromosomes = (P + 2S + 3M + 4L + 5 OFF)-31

Chromosome 1
= (25 + 2x0 + 3x0 + 4x6 + 5x0) -31
= (25+24)-31
= 18

Chromosome 2
= (25 + 2x0 + 3x0 + 4x6 +5x0) -31
= 25+24 -31
= 18
….
….

Chromosome 31
= (22 + 2x0 + 3x0 + 4x9 + 5x0)-31
= 27

Then, determine the average value of the objective function by adding up all the values of the objective function.

=(18+18+22+12+47+65+53+55+61+50+48+45+44+56+53 +49+50+52+48+44+63+57+47+58+ 40+65+52+46+51+18+27) / 31
= 1.357 / 31
= 43.774. So, the average value of the objective function is 43.774

3. Fitness Function

The fitness function is used to evaluate or select chromosomes to obtain the desired chromosome. This function differentiates the quality of the chromosomes to find out how good the chromosomes produced are by the fitness function [19], based on equation (3):

$$\text{Fitness } 1 = \frac{1}{\text{fo } 1 + 1}$$
$$= \frac{1}{19}$$
$$= 0.0526$$

$$\text{Fitness } 2 = \frac{1}{\text{fo } 2 + 1}$$
$$= \frac{1}{19}$$
$$= 0.0526$$

….

….

$$\text{Fitness } 31 = \frac{1}{\text{fo } 31+1}$$
$$= \frac{1}{27}$$
$$= 0.0370.$$

So, Total All Fitness = 1.2668

4. Determine the Value of the Probability Function

In determining the value of the probability function, calculations are carried out using equation (4):

$$P1 = \frac{0.0526}{1.2668}$$
$$= 0.0415$$

$$P2 = \frac{0.0526}{1.2668}$$
$$= 0.0415$$

….

….

$$P31 = \frac{0.0370}{1.2668}$$
$$= 0.0292$$

5. Selection Process Using Roulette Wheel:

The Roulette Wheel selection process determines the chromosome value according to the probability function value [18]. Then, for the 2nd chromosome, add the first probability function with the second probability function, and so on. The results of the selection process using equation (8) will be described below:

C[1] = 0.0415
C[2] = 0.0415 + 0.0415 = 0.083
…
…
C[31] = 0.0415 + 0.0415 + 0.0342 + 0.0327 + 0.0164 + 0.0119 + 0.0146 + 0.0140 + 0.0127 + 0.0154 + 0.0161 + 0.0217 + 0.0175 + 0.0138 + 0.0146 + 0.0157 + 0.0154 + 0.0148 + 0.0161 + 0.0175 + 0.0123 + 0.0135 + 0.0164 + 0.0133 + 0.0191 + 0.0119 + 0.0148 + 0.0167 + 0.0151 + 0.0415 + 0.0292 = 0.6019

After calculating the cumulative probability, the roulette wheel selection process can be carried out. The process is to generate a random number R in the range 0-1. If R[k] < C[4], then select the kth chromosome as the parent with the condition V [k-1] < R < C[k].

R[1] = 0.0315
R[2] = 0.0327
….
….

R[31] = 0.6012

The new chromosomes resulting from the selection process are:
Kromosom baru 1 = Kromosom 1 = [25, 0, 0, 6, 0]
Kromosom baru 2 = Kromosom 2 = [25, 0, 0, 6, 0]
Kromosom baru 3 = Kromosom 4 = [19, 0, 0, 6, 0]
….
Kromosom baru 31 = Kromosom 31 = [22, 0, 0, 9, 0]

6. Crossover

This method uses a one-cut point method, randomly selecting one position in the parent chromosome and exchanging genes using a crossover rate of 0.95. Crossbreeding occurs between two parents from top to bottom (odd-even pairs) [17].
New chromosome 1 = Chromosome 1 = [25, 0, 0, 6, 0]
New chromosome 2 = Chromosome 2 = [25, 0, 0, 6, 0]
Crossover Probability = 1.54

New chromosome 3 = Chromosome 4 = [19, 0, 0, 6, 0]
New chromosome 4 = Chromosome 3 = [21, 4, 0, 6, 0]
Crossover Probability = 0.25
Offspring 1 [21, 0, 0, 6, 0]
Offspring 2 [19, 4, 0, 6, 0]

New chromosome 5 = Chromosome 6 = [0, 12, 8, 7, 4]
New chromosome 6 = Chromosome 5 = [10, 4, 8, 4, 4]
Crossover Probability = 1.60

New chromosome 7 = Chromosome 8 = [10, 0, 8, 7, 4]
New chromosome 8 = Chromosome 7 = [2, 12, 6, 5, 4]
Crossover Probability = 0.30
Offspring 1 [10, 0, 8, 5, 4]
Offspring 2 [2, 12, 6, 7, 0]

New chromosome 9 = Chromosome 10 = [9, 4, 8, 5, 4]
New chromosome 10 = Chromosome 9 = [0, 14, 8, 5, 4]
Crossover Probability = 1.45

New chromosome 11 = Chromosome 12 = [7, 10, 6, 4, 3]
New chromosome 12 = Chromosome 11 = [5, 9, 7, 5, 3]
Crossover Probability = 0.26
Offspring 1 [5, 10, 6, 4, 3]
Offspring 2 [7, 9, 7, 5, 3]

New chromosome 13 = Chromosome 14 = [4, 11, 7, 5, 4]
New chromosome 14 = Chromosome 13 = [6, 8, 6, 5, 3]
Crossover Probability = 1.52

New chromosome 15 = Chromosome 16 = [1, 10, 7, 5, 3]
New chromosome 16 = Chromosome 15 = [3, 9, 8, 6, 4]
Crossover Probability = 0.34
Offspring 1 [3, 10, 7, 5, 3]
Offspring 2 [1, 9, 8, 6, 4]
New chromosome 17 = Chromosome 18 = [5, 12, 6, 4, 3]
New chromosome 18 = Chromosome 17 = [5, 10, 7, 5, 3]
Crossover Probability = 1.47

New chromosome 19 = Chromosome 20 = [9, 4, 6, 5, 4]
New chromosome 20 = Chromosome 19 = [5, 8, 6, 5, 4]
Crossover Probability = 0.69
Offspring 1 [5, 4, 6, 5, 4]
Offspring 2 [9, 8, 6, 5, 4]

New chromosome 21 = Chromosome 22 = [5, 4, 10, 5, 5]
New chromosome 22 = Chromosome 21 = [7, 7, 8, 5, 4]
Crossover Probability = 1.56

New chromosome 23 = Chromosome 24 = [1, 10, 8, 6, 4]
New chromosome 24 = Chromosome 23 = [7, 0, 10, 4, 5]
Crossover Probability = 0.77
Offspring 1 [7, 10, 8, 6, 4]
Offspring 2 [1, 0, 10, 4, 5]
New chromosome 25 = Chromosome 26 = [0, 15, 6, 7, 3]
New chromosome 26 = Chromosome 25 = [12, 1, 7, 4, 4]
Crossover Probability = 1.50

New chromosome 27 = Chromosome 28 = [8, 4, 7, 5, 4]
New chromosome 28 = Chromosome 27 = [7, 4, 8, 6, 4]
Crossover Probability = 0.88
Offspring 1 [7, 4, 7, 5, 4]
Offspring 2 [8, 4, 8, 6, 4]

New chromosome 29 = Chromosome 30 = [25, 0, 0, 6, 0]
New chromosome 30 = Chromosome 29 = [10, 2, 8, 6, 4]
Crossover Probability = 1.48

New chromosome 31 = Chromosome 31 = [22, 0, 0, 9, 0] (for those without a pair, continue to the next process without crossover). Likewise, chromosomes that are likely to exceed the crossover rate of 0.35 continue to the next process without crossover.

7. Mutations

The mutation rate parameter determines the number of chromosomes that experience mutations in a population. The mutation process replaces a randomly selected gene with a new value obtained randomly [17]. The total length of a gene is total genes = (number of genes in a chromosome) * population size
= 5x31
= 155
Then, the length of the gene is multiplied by the mutation rate of 0.1 so that:
155 x 0.1 = 15.5

Table 4. Mutation process in determining gene positions and gene values randomly.

Gene position (1-155)	Gene Value (1-31)
2	4
56	4
….	….
….	….
155	10

The table above shows the positions and values of genes obtained randomly with predetermined limits, namely gene positions obtained from numbers 1 to 155 randomly and gene values ranging from numbers 1 to 31 randomly.
Mutation Results:
Kromosom 1 = [25, 0, 0, 6, 0]
Kromosom 2 = [25, 0, 0, 6, 0]
….
….
Kromosom 31 = [22, 0, 0, 9, 0]

The mutation results above were obtained randomly from the table of gene positions and gene values above. Then, the results are entered into a new generation table 5.

The table above is the final result of implementing the stages based on the Genetic Algorithm procedure that has been implemented so that a new generation of ER staff/nurse scheduling system that is more optimal is formed

Table 5. New Generations after using the stages of the Genetic Algorithm

Nurse Code	Total				
	P	S	M	L	OF
A1	25	0	0	6	0
A2	25	0	0	6	0
….	…	…		…	…
A31	22	0	0	9	0

Nurse Code	Date 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
A1	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	L	L	P	P	P	P	P	P	L	P
A2	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	L	L	P	P	P	P	P	P	L
A3	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	L	L	P	P				
A4	P	P	P	S	L	P	P	P	P	P	S	L	P	P	P	P	P	S	L	P	P	P	P	S	L	L	P	P	L	0	0
A5	OF	S	S	M	M	L	S	OF	S	S	M	M	L	S	OF	S	S	M	M	L	L	S	OF	S	S	L	L	S	S	M	M
A6	P	P	OF	S	M	M	L	P	P	OF	S	M	M	L	P	P	OF	S	M	M	L	P	P	OF	S	M	M	L	P	P	
A7	L	P	P	P	OF	M	M	L	P	P	P	OF	M	M	L	P	P	P	OF	M	M	L	L	P	M	M	OF				
A8	P	L	S	S	S	M	M	L	L	S	S	S	M	M	L	L	S	S	S	M	M	L	L	S	S	S	P	0	0	0	0
A9	M	M	L	P	P	S	OF	M	M	L	P	P	S	OF	M	M	L	P	P	S	OF	M	M	L	L	P	P	S	OF	P	0
A10	S	S	S	L	M	M	S	S	OF	S	L	M	M	S	S	OF	S	L	M	M	S	S	OF	S	L	L	M	M	S	S	OF
A11	S	S	P	M	L	S	OF	S	S	P	M	L	S	OF	S	S	P	M	L	M	OF	S	S	P	M	L	M	P	0	0	0
A12	M	P	OF	S	S	L	M	M	P	P	S	S	L	M	OF	P	P	S	S	L	M	M	P	P	S	S	L	L	M	S	OF
A13	S	S	S	P	OF	M	L	S	S	S	P	OF	M	L	S	S	S	P	OF	M	L	L	S	S	P	OF	M	L	M	M	M
A14	L	S	S	P	P	OF	M	L	S	S	P	P	OF	M	L	S	S	P	P	OF	M	L	L	S	S	M	M	M	0	0	0
A15	S	L	P	M	M	OF	S	S	L	P	M	M	OF	S	S	L	P	M	M	OF	S	S	L	L	M	S	S	S	0	0	0
A16	M	M	L	S	S	S	OF	M	M	L	S	S	S	OF	M	M	L	S	S	S	OF	M	M	L	L	P	OF				
A17	OF	M	M	L	S	S	S	OF	P	M	L	S	S	S	OF	P	M	L	S	S	S	P	P	M	L	S	S	S	P	M	0
A18	S	OF	P	M	L	S	S	S	OF	P	M	L	S	S	S	OF	P	M	L	S	S	S	P	M	L	L	P	M	M	M	0
A19	M	M	S	OF	P	L	M	M	S	OF	P	L	L	M	M	S	OF	P	L	L	P	P	S	OF							
A20	P	P	S	S	OF	M	L	P	P	S	S	OF	M	L	P	P	S	S	OF	M	L	P	P	S	S	OF	M	L	L	P	M
A21	L	M	M	S	OF	P	P	L	M	M	S	OF	P	P	L	M	M	S	OF	P	M	L	M	M	S	OF	M	M	L		
A22	S	L	M	M	P	OF	S	S	L	M	M	P	OF	S	S	L	M	M	P	OF	S	S	L	M	M	P	OF	P	P	L	P
A23	S	S	L	M	M	OF	P	S	S	L	M	M	OF	P	S	S	L	M	M	OF	P	S	S	L	M	M	OF	P	S	S	L
A24	P	M	M	L	M	M	M	OF	M	M	L	M	M	OF	M	OF	L	L	OF	OF											
A25	OF	S	S	S	L	L	M	OF	S	S	S	L	L	M	OF	S	S	S	L	L	M	S	S	S	S	L	M	M	M	S	S
A26	P	P	P	OF	S	L	L	M	M	OF	P	P	L	L	M	M	OF	P	P	L	M	M	P	P	P	P	L	P	0	0	0
A27	M	M	OF	P	P	S	L	M	M	OF	P	P	S	L	L	M	M	OF	P	S	L	L	M	P	OF	P	S				
A28	L	P	P	S	OF	M	M	L	P	P	S	OF	M	M	L	P	P	S	OF	M	M	L	P	P	S	OF	M	M	L	L	0
A29	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L
A30	M	M	L	P	P	OF	S	M	M	L	P	P	OF	S	M	M	L	L	P	P	OF	M	M	L	L	P	P	OF	P	P	0
A31	P	P	P	L	L	P	P	P	P	P	L	L	P	P	P	P	P	L	L	P	P	P	P	P	L	L	P	P	P	P	L

Figure 3. Results of Genetic Algorithm Implementation

The figure 3 above shows the result of applying the genetic algorithm in scheduling optimal work shifts for emergency room nurses using a case study at RSUD. Dr. Pirngadi, Medan City. After applying the stages of the Genetic Algorithm, it can be seen that:

A1: Get in the morning shift for 25 days and have six days off.

A2: Obtain a morning shift schedule of 25 days with six days off.

A3: Obtain a morning shift schedule of 21 days, have six days off, and have four free working days.

…

A29: Obtain a schedule for 25 days of morning shift and six days off work days.

A30: Obtain a schedule for ten days of morning shift, two days of afternoon shift, eight days of night shift, six days off Work days, four days off night shift, and one day of empty schedule.

A31: Obtain a schedule for 22 days of morning shift and nine days off work days.

Thus, it can be obtained that:

1. The best individual will be assigned to a nurse code with a stable number of attendance and holidays, namely a minimum of 20 days of attendance in all shifts or a minimum of 160 hours in a month. Individuals who have the best status are: A1, A2, A4, A5, A6, A8, A9, A10, A11, A12, A13, A14, A15, A17, A18, A20, A22, A23, A25, A26, A28, A29 , A30, A31.
2. Individuals who will be transferred or eliminated from the schedule due to not meeting the minimum number of working days: A3, A7, A16, A19, A21, A24, and A27.

So, optimal scheduling can be done as in the following table:

No.	Nurse	Date																													
	Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	A1	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	L	L	P	P	P	P	P	P	L	P
2	A2	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	L	L	P	P	P	P	P	P	L
3	A4	P	P	P	S	L	P	P	P	P	P	S	L	P	P	P	P	P	S	L	P	P	P	P	S	L	L	P	P	L	0	0
4	A5	O	S	S	M	M	L	S	O	S	S	M	M	L	S	O	S	S	M	M	L	L	S	OF	S	S	L	L	S	S	M	M
5	A6	P	P	O	S	M	M	L	P	P	O	S	M	M	L	P	P	O	S	M	M	L	P	P	O	S	M	M	L	P	P	0
6	A8	P	L	S	S	S	M	M	L	L	S	S	S	M	M	L	L	S	S	S	M	M	L	L	S	S	S	P	0	0	0	0
7	A9	M	M	L	P	P	S	O	M	M	L	P	P	S	O	M	M	L	P	P	S	O	M	M	L	L	P	P	S	O	P	0
8	A10	S	S	S	L	M	M	S	S	O	S	L	M	M	S	S	O	S	L	M	M	S	S	OF	S	L	L	M	M	S	S	O
9	A11	S	S	P	M	L	S	O	S	S	P	M	L	S	O	S	S	P	M	L	M	O	S	S	P	M	L	M	P	0	0	0
10	A12	M	P	O	S	S	L	M	M	P	P	S	S	L	M	O	P	P	S	S	L	M	M	P	P	S	S	L	L	M	S	O
11	A13	S	S	S	P	O	M	L	S	S	S	P	O	M	L	S	S	S	P	O	M	L	L	S	S	P	O	M	L	M	M	M
12	A14	L	S	S	P	P	O	M	L	S	S	P	P	O	M	L	S	S	P	P	O	M	L	L	S	S	M	M	M	0	0	0
13	A15	S	L	P	M	M	O	S	S	L	P	M	M	O	S	S	L	P	M	M	O	S	S	L	L	M	S	S	S	0	0	0
14	A17	O	M	M	L	S	S	S	O	P	M	L	S	S	S	O	P	M	L	S	S	S	P	P	M	L	S	S	S	P	M	0
15	A18	S	O	P	M	L	S	S	S	O	P	M	L	S	S	S	O	P	M	L	S	S	S	P	M	L	L	P	M	M	M	0
16	A20	P	P	S	S	O	M	L	P	P	S	S	O	M	L	P	P	S	S	O	M	L	P	P	S	S	O	M	L	L	P	M
17	A22	S	L	M	M	P	O	S	S	L	M	M	P	O	S	S	L	M	M	P	O	S	S	L	M	M	P	O	P	P	L	P
18	A23	S	S	L	M	M	O	P	S	S	L	M	M	O	P	S	S	L	M	M	O	P	S	S	L	M	M	O	P	S	S	L
19	A25	O	S	S	S	L	L	M	O	S	S	S	L	L	M	O	S	S	S	L	L	M	S	S	S	S	L	M	M	M	S	S
20	A26	P	P	P	O	S	L	L	M	M	O	P	P	L	L	M	M	O	P	P	L	M	M	P	P	P	P	L	P	0	0	0
21	A28	L	P	P	S	O	M	M	L	P	P	S	O	M	M	L	P	P	S	O	M	M	L	P	P	S	O	M	M	L	L	0
22	A29	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	P	P	P	P	P	P	L	L
23	A30	M	M	L	P	P	O	S	M	M	L	P	P	O	S	M	M	L	L	P	P	O	M	M	L	L	P	P	O	P	P	0
24	A31	P	P	P	L	L	P	P	P	P	P	L	L	P	P	P	P	P	L	L	P	P	P	P	P	L	L	P	P	P	P	L

Figure 4. Optimal scheduling results

In figure 4, it can be seen that there has been quite a significant change from the previous table, especially in the number of nurses, which has increased to 24 people from 31 people previously. Applying the genetic algorithm is very suitable because it can optimize the number of nurses on duty in the regional hospital's emergency department. Dr. Pirngadi, Medan City. So that it can save space and system costs for the nurses on duty. Individuals or nurses who are eliminated from their positions will be transferred or placed in other hospitals according to their capacity. In Table 2.7 are the results obtained after going through all the Genetic Algorithm procedures with several symbols or punctuation, such as: a) P is the symbol for the morning shift, b) S is the symbol for the afternoon shift, c) M is the symbol for the night shift, d) L is the symbol for holidays, e) O changed to Off is to reduce the use of excessive punctuation in the attendance table. O is the symbol for the night watch holiday. The coloring of the table is intended to make it easier to read attendance, such as horizontal yellow for the date, vertical yellow for the sequence number, and green for the nurse code. The names of nurses originally written with the full name of each nurse were changed to codes A1, A2, A3, and so on to save space and use of excess words.

Thus, applying the Genetic Algorithm in the optimal scheduling of emergency room nurse duty was successful because it could optimize the number of nurses, optimize nurse coding, optimize the use of excessive punctuation, and so on.

Conclusion

The best individual will be assigned to a nurse code with a stable number of attendance and holidays, namely a minimum of 20 days of attendance in all shifts or a minimum of 160 hours in a month. Individuals who have the best status are: A1, A2, A4, A5, A6, A8, A9, A10, A11, A12, A13, A14, A15, A17, A18, A20, A22, A23, A25, A26, A28, A29 , A30, A31. Individuals who will be transferred or eliminated from the schedule due to not meeting the minimum number of working days: A3, A7, A16, A19, A21, A24, and A27. So, optimal scheduling can be done as in the following table: This research produces an optimal scheduling system because it uses the stages of a Genetic Algorithm to make it easier for the Emergency Department (IGD), especially the admin in charge of making nurse/officer schedules. Using this genetic algorithm stage, you can minimize the number of errors and maximize time efficiency in making schedules for emergency room officers/nurses.

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