A Multi-objective Genetic Algorithm for Optimizing the Nurse scheduling Problem

A. Wibowo, Y. Lianawati

Abstract: This paper explains the use of Genetic Algorithms in overcoming nurses scheduling problems in St. General Hospital Elisabeth. In this paper, Multi-Objective is used to solve problems with mathematical models and is applied to overcome nurse scheduling problems. Health is one of the essential things in human life. There are some departments in the hospital which serve the patients in the hospital, and one of them is the nursing department. The nurses in this department serve the patients every time, but they have limited time as the working hour must not be more than schedule 8 hours. So, there will be a problem in this aspect, especially the working for each nurse because the nurses must be stand by to serve the patients every time. The scheduled operation will be complicated, so we propose a solution by Genetic Algorithm method. The scheduling making by applying Genetic Algorithm method will give more optimal and faster output comparing with a current or manual process.

Index Terms: Multi-objective, Optimizing, Nurse, Nurse scheduling, scheduling problem, Genetic algorithm

I. INTRODUCTION

Health is one of the essential things in human life. Health allows everyone to undergo productive activities [1]. One of the goals of the state is to advance the welfare of the nation, including basic human needs, namely food, clothing, education, employment, peace of life, and health. The goal of health keeping is to obtain a healthy life [2]. Recently, the population has increased significantly in 2019 the population in Indonesia is about 266.91 million inhabitants. Data obtained from the Ministry of Health Information Center.

One aspect in the world of health in a hospital is medical personnel, especially nurse institution. The medical staff has a critical role in influencing performance in the service of a hospital [3]. Medical staff, especially the nurses, will serve a patient in a hospital. A nurse is someone who has been legalized by the government.

The types of nurse are professional and registered. Nursing is a form of medical treatment for the sick or healthy according to Nursing Law Number 38/2014. The standard job of the nurse is to fulfill the basic need of every individual. The issue that is happening nowadays is the nurse shifting, which exceeds the time limits. Every hospital ought to have an internal policy to distribute the workload of the nurse. The nurse who works at the hospital should also obey the distribution policy. The medical staff who work 24 hours on a schedule will divide into three parts, morning, evening and night.

The hospital may not urge the nurse or other medical staff to work outside the time limits based on the internal policy. Some hospitals experience many problems, such as the lack of medical personnel to handle patients who need medical care, the inability of nurses to care for patients and exceed the time due to excessive workload must do [4]. It causes the manager obligated to maximally handle the nurse without intending to decrease the performance and satisfaction. Unfortunately, the distribution of work may still arise.

Research on nurse scheduling has been widely carried out by previous researchers. For example in the study of Warner [5], determine the scheduling which enables the quest to be faster and more complete compared to the manual schedule. On the research involves mathematical approach in programming mixed integer square to calculate the minimum standard of employee affair for the nurse scheduling. Whereas in research conducted by Banet [6], using heuristic method for find an optimized solution in 19 of the 45 cases tested with the average difference from the optimal doctor satisfaction study in 26 other cases is 0.35%. The result mentioned can detect an optimized solution in 42.2% of the tested cases, by using Greedy Algorithm and Annealing meta-heuristic simulation. In the another study conducted by Knyazev [7], solved the problem of cycle scheduling using genetic algorithm methods to obtain optimal results. Tsai and Li [4], solved the problem of nurse scheduling in one hospital with nurse limitations. Genetic algorithm method is used to obtain the best solution. Dodaro and Maratea [8], examined the scheduling of nurses to be assigned to treat according to existing constraints. ASP method is used in completing nurse scheduling so that optimal results are obtained from the resulting schedule.

This research will explain about the nurse scheduling using the method of meta-heuristic, which is a Genetic Algorithm. The technique is more eminent and convenient in terms of implementation and finding more optimized solutions from many variables [9]. It also tends to run well. The Genetic Algorithm can overcome large and complicated problems. The result of nurse scheduling with Genetic Algorithm aims to be the expected and acceptable solution.

A. Wibowo∗, Computer Science Department, Bina Nusantara University, Jakarta, Indonesia. (a.wibowo2003@gmail.com)
Y. Lianawati, Computer Science Department, Bina Nusantara University, Jakarta, Indonesia.

Retrieval Number: C6204098319/2019©BEIESP
DOI:10.35940/ijrte.C6204.098319
Journal Website: www.ijrte.org

5409

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

II. RESEARCH METHODS

Scheduling is the process of distributing resources to select jobs in a certain period. It can be used for making a decision and is a theory of fundamental principle, model, technique, and logical conclusion in the process of decision making [10]. The scheduling algorithm allocates and schedules jobs to ensure that all the task instances in the task set meet their deadlines. If a task set meets its deadlines, then it is said to be schedulable [11].

Nurse scheduling is a complex task and requires a lot of time in the manufacturing process [12]. Scheduling is the determination of the timing and sequence of operations in the project and their assembly to give the overall completion time [13].

A. Meta-heuristic

A meta-heuristic method is a method used to find a solution for a problem which needs a proper better solution. In finding an efficient and comprehensive solution, the meta-heuristic process uses the mechanism that imitates behavior or social strategy in nature. There are several heuristic methods which can be used to solve the distribution issue. In this study, the Genetic Algorithm is used to overcome the nurse scheduling problem.

The characteristics of meta-heuristic [14]:
a) Metaheuristic are nature-inspired, use of random variables.
b) Metaheuristic do not require substantial gradient information.
c) Metaheuristic have several parameters that need to be fitted to the problem at hand.

B. Optimization

Optimization is the task of finding one or more solutions which correspond to minimizing or maximizing one or more specified objectives and which satisfy all constraints a single-objective optimization problem involves a single objective function and usually results in a single solution, called an optimal solution [15]. Optimization is the process of adjusting input or device characteristics, mathematical operations, or experiments to find the minimum or maximum output or results [16] [19].

Problems which may emerge in optimization are problems that possess many solutions and used to obtain many optimized solutions.

Figure 1 Optimization Function Diagram

In figure 1, it is explained about the flow of optimization to get output, starting from the input variable process that will be processed and become an output.

C. Genetic Algorithm

The Genetic Algorithm is a stochastic optimization technique that depends on a random-based searching mechanism. Genetic algorithms have been successfully adapted in many areas to solve a large number of optimization problems, including scheduling and transportation problems [17].

Here are essential structures of Genetic Algorithm:
a) Initial population
b) Evaluation
c) Selecting population detected by genetic operator
d) Crossover
e) Mutation of certain chromosome
f) Evaluating new population

There are three significant advantages of using Genetic Algorithm [18]:
a) Genetic Algorithm does not have many mathematical requirements about the optimization problems.
b) The use of evolution operators makes Genetic Algorithm very useful in performing a global search (in probability)
c) Genetic Algorithm provides us with great flexibility to hybridize with domain-dependent heuristics to create an efficient implementation for a specific problem.

Implementing Genetic Algorithm requires Soft Constraint and Hard Constrain. Soft Constraint is an obstacle which is not necessary to be solved, while Hard Constraint is otherwise.

D. Methodology

Figure 2 explains the flow of Genetic Algorithm that will do after collecting the data, constrain and fitness function. Hereafter the data will be utilized using Genetic Algorithm from randomizing the representation of chromosome, creating population, calculating fitness value, selection, crossover, mutation until obtaining the optimized output.
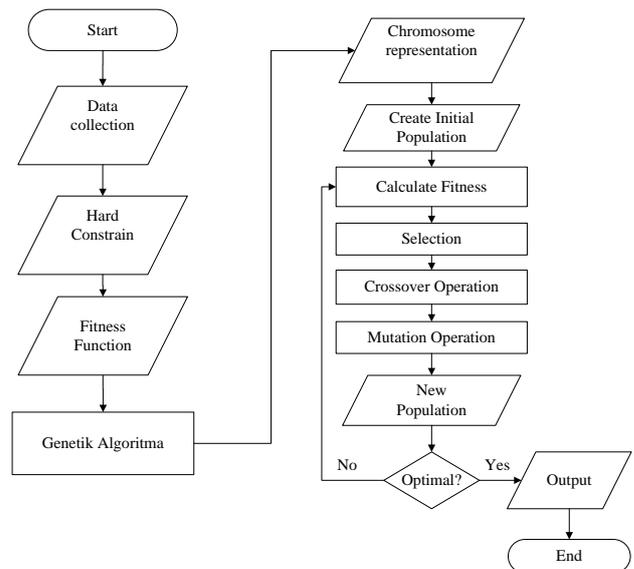
Figure 2 Purpose methods for Genetic Algorithm

E. Problem Analysis and Formulation

i = index nurse $\{1,2,3,....p\}$
    where   i = 1,2,3,..,4 is PK1
             i = 5,6,... 12 is PK2
j = index shift $\{1,2,3\}$
        1=morning, 2=evening, 3=night
k = index day $\{1,2,3,...31\}$

F. Decision Variable

Retrieval Number: C6204098319/2019©BEIESP
DOI:10.35940/ijrte.C6204.098319
Journal Website: www.ijrte.org

5410

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

$$X_{i,j,k} = \begin{cases} 1, & \text{if the nurse } i \text{ works on day shift } k \\ 0, & \text{others} \end{cases}$$

Fitness function to minimize variations in the number of workdays and variations in the number of shifts run by nurses. In the value of the coefficient of a hard constraint violation is given a greater value to get a violation of the hard constraint tends to value 0.

$$Z = F_1 + F_2 + F_3 + F_4 + 100 * F_5$$

G. Constrain

1. Every day the number of nurses working in 1 shift is one person

   a. The number of nurses who work in each morning shift is at least one nurse.
   $$A = \sum_{i=1}^{p} Xi,1,k \geq 1$$

   b. The number of nurses working in each day shift is at least one nurse.
   $$B = \sum_{i=1}^{p} Xi,2,k \geq 1$$

   c. The number of nurses who work in each night shift is at least one nurse.
   $$C = \sum_{i=1}^{p} Xi,3,k \geq 1$$

   d. Maximum number of morning shift nurses four people
   $$D = \sum_{i=1}^{p} x_{i1,k} \leq 4$$

   e. The maximum number of day shift nurses is four people
   $$E = \sum_{i=1}^{p} x_{i,2,k} \leq 4$$

   f. The maximum number of night shift nurses is four people
   $$F = \sum_{i=1}^{p} x_{i,3,k} \leq 4$$

2. Nurses who get the night shift, will be on holiday the next day
   $$G = x_{i,3,k} + x_{i,1,k+1} + x_{i,2,k+1} + x_{i,3,k+1} \leq 1$$

3. Nurses within 1 month maximum 24-day / shift work
   $$H = \sum_{j=1}^{3} \sum_{k=1}^{31} x_{i,j,k} \leq 24$$

4. Each shift in 1 day must consist of at least 1 PK1 and 2 PK2

   a. Each shift in 1 day must consist of at least 1 PK1
   $$I = \sum_{i=1}^{3} x_{i,1,k} + x_{i,2,k} + x_{i,3,k} \geq 1$$

   b. Each shift in 1 day must consist of at least 2 PK2
   $$J = \sum_{i=4}^{p} x_{i,1,k} + x_{i,2,k} + x_{i,3,k} \geq 2$$

5. Number of nurses working days
   $$y_i = \sum_{j=1}^{3} \sum_{k=1}^{31} x_{ij,k}$$

   a. Average number of nurses' work
   $$mean\ y = \sum_{i=1}^{p} y_i$$

6. Number of morning shifts for nurses i
   $$z_{p,i} = \sum_{i=1}^{31} x_{i,1,k}$$
   $$i = 1,2,..p$$

7. Number of day shifts for nurses i
   $$z_{s,i} = \sum_{i=1}^{31} x_{i,2,k}$$
   $$i = 1,2,..p$$

8. Number of night shifts for nurses i
   $$z_{m,i} = \sum_{i=1}^{31} x_{i,3,k}$$
   $$i = 1,2,..p$$

9. The average number of morning shifts
   $$mean\ Zp = \sum_{i=1}^{p} Z_{p,i}$$

10. The average number of afternoon shifts
    $$mean\ Zs = \sum_{i=1}^{p} Z_{s,i}$$

11. The average number of night shifts
    $$mean\ Zm = \sum_{i=1}^{p} Z_{m,i}$$

12. Variation in the number of working days
    $$F_1 = \sum_{i=1}^{p} \frac{(y_i - mean\ y)^2}{p}$$

13. Variation in the number of morning shifts for nurses i
    $$F_2 = \sum_{i=1}^{p} \frac{(z_{p,i} - mean\ z_p)^2}{p}$$

14. Variation in the number of day shifts for nurses i
    $$F_3 = \sum_{i=1}^{p} \frac{(z_{s,i} - mean\ z_s)^2}{p}$$

15. Variations in the number of night shifts for nurses i
    $$F_4 = \sum_{i=1}^{p} \frac{(z_{m,i} - mean\ z_m)^2}{p}$$

16. Total Violation Value

$$F_5 = A + B + C + D + E + F + G + H + I + J$$

III. RESULTS AND DISCUSSION

In this research, the test result aims to look for optimized value in nurse scheduling using Genetic Algorithm in which is presented in the form of table and graphic. The test is done through some parameters to maximize the intended output. The result of the fitness value is affected by those parameters.

The test is held on March 28th, 2019, at 16.00, with the parameters below:
a) Mutation rate = 0,5,
b) Tournament size = 4 in which 4 chromosome will compete on each other.
c) Maximum of generation= 200

The test obtains fitness value, which is 1, and there is no violation so that it can be stated as successful in getting the optimized output to minimize abuse in the schedule.

The explanation of the testing result uses a Genetic Algorithm is shown in Table 1 below:

Table 1 The generation test results that get the smallest fitness score

| Number	Testing	Generation
1	1	111
2	2	94
3	3	63
4	4	153
5	5	49
6	6	34
7	7	174
8	8	57
9	9	40
10	10	157
11	11	26
12	12	78
13	13	37
14	14	74
15	15	14
16	16	18
17	17	42
18	18	39
19	19	55
20	20	146
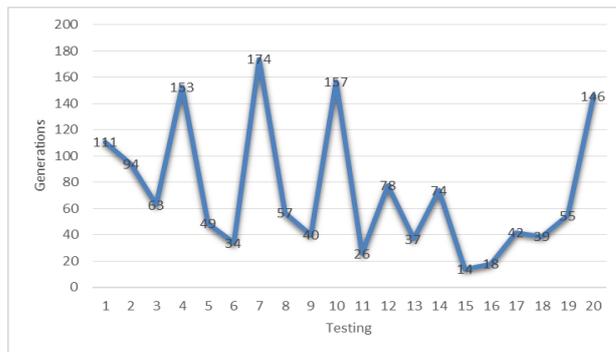
Figure 3 Graphic of testing for Generation

Table 1 shows the results of the Generation that obtained the smallest fitness value. The test was held 20 times and got the lowest Generation on the 15th test, namely the 14th Generation. The highest generation level is in the 7th test, with results in generation 174. Figure 3 is a graphical display of the testing program, which obtains the smallest fitness value.

Based on the lowest level of Generation on Table 1, Table 2 shows the iteration process of 15th test below:

Table 2 Search process of fitness value on 15th test

Number	Generation	f5/Fitness Value	MinZ	Time / Second
1	0	96	9985	00.00
2	1	75	7885	15.014
3	2	75	7885	20.989
4	3	75	7885	26.985
5	4	75	7885	32.994
6	5	75	7885	38.992
7	6	75	7885	45.027
8	7	75	7885	51.968
9	8	75	7885	57.965
10	9	75	7885	63.961
11	10	75	7885	69.958
12	11	75	7885	75.955
13	12	45	4623	82.971
14	13	45	4623	88.948
15	14	0	1	94.965
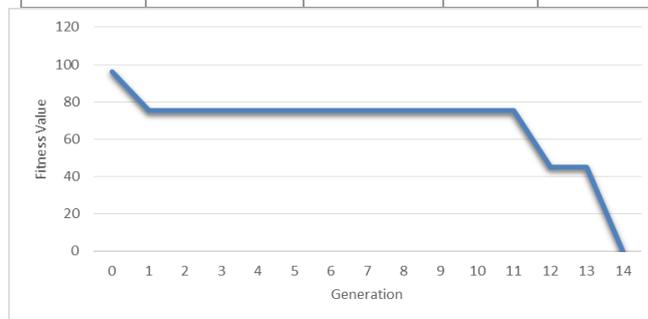
Figure 1 Fitness value graphic of every generation on 15th test

Looking at the testing result, Table 2 shows the testing result in which the best result of fitness value is on the 15th test of 14th generation. It is such an optimized solution to conduct nurse scheduling without any violation. Figure 4 trial results obtained the best fitness value results in the 15th experiment in the 14th generation, which is the optimal solution for scheduling nurses in the absence of violations that occur.

Testing : 28/03/2019 16:00:00	The result : Optimal
Max Gen : 200	Best generasi : 14
Mutation : 0,5	MinZ : 1
Tournament : 4	F5 : 0

Mar-19

Level	Nurse	Frid 1	Sat 2	Sun 3	Mo 4	Tue 5	We 6	Thu 7	Frid 8	Sat 9	Sun 10	Mo 11	Tue 12	We 13	Thu 14	Frid 15	Sat 16	Sun 17	Mo 18	Tue 19	We 20	Thu 21	Frid 22	Sat 23	Sun 24	Mo 25	Tue 26	We 27	Thu 28	Frid 29	Sat 30	Sun 31
Perawat Junior (PK 1)	Nurse 1	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N
	Nurse 2	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O
	Nurse 3	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M
	Nurse 4	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E
Perawat Senior (PK 2)	Nurse 5	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N
	Nurse 6	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N
	Nurse 7	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O
	Nurse 8	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O
	Nurse 9	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M
	Nurse 10	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M
	Nurse 11	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E
	Nurse 12	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E	N	O	M	E

Figure 4 Result of optimized scheduling

Figure 5 represents the result of nurse scheduling using the Genetic Algorithm method. In the schedule above has stated that every nurse in a day gets shifting based on the symbols below:

M = Morning (Shift 1)
E = Evening (Shift 2)
N = Night (Shift 3)
O = Day-off

The scheduling succeeded to obtain the optimized result with the Genetic Algorithm related to the issues happening at St. Elisabeth Hospital, Purwokerto. The schedule contains no violation within.

Table 3 Comparison of scheduling results before and after using the Genetic Algorithm method

Number	Variable	Before		After	
		Value	Information	Value	Information
1	Time	3 hour	Requires a lot of time	94.965 seconds	Does not require much time
2	Violation value	82	There are many violations	0	No violation occurred
3	Fitness value	8219	High fitness value	1	Low fitness value
4	Nurse Workload	19-24	Nurse workload is not balanced	23-24	Nurse workload is balanced

Table 3 explains the comparison results of the schedule created manually and the schedule created using the Genetic Algorithm method. In this comparison, the results of the fitness value in the manual process are higher while the fitness value in the Genetic Algorithm process is lower, and the time required in the manual process is longer, so it can be concluded that the nurse scheduling process using the Genetic Algorithm method can handle problems in hospitals

IV. CONCLUSION

Based on the issue discussed in this research and the testing result, the author can conclude:

a) The process of nurse scheduling is obligated to meet the requirement at every hospital. The schedule needs to relate to the terms and conditions applied.

b) Multi-objective nurse scheduling with Genetic Algorithm stated as capable of overcoming the optimization issue so it can minimize the infringement in the scheduling process. It also violation pace in setting the schedule at St. Elizabeth Hospital, Purwokerto.

c) The significant factors in affecting the process of nurse scheduling using Genetic Algorithm are mutation rate, tournament size, and generation size.

d) From the test results obtained fitness value 1 and violation 0, it is confident that this program can overcome the problem of scheduling nurses using Genetic Algorithm to detect certain violations in a short time of 94,965 seconds.

REFERENCES

1. G. McCartney, F. Popham, R. McMaster , and A. Cumbers, "Defining health and health inequalities", Public Health. 172 (2019) pp. 22-30
2. T. Yeung, "Local health department adoption of electronic health records and health information exchanges and its impact on population health", International Journal of Medical Informatics, 128 (2019) pp. 1–6
3. J. F.Bard, and H. W. Purnomo, "Cyclic preference scheduling of nurses using a lagrangian-based heuristic". Journal of Scheduling, 10(2007) pp. 5–23.
4. C.C. Tsai and S.H.A. Li, "A two-stage modeling with genetic algorithms for the nurse scheduling problem", Expert Systems with Applications, 36 (2009) pp. 9506–9512
5. M. Warner, "Scheduling Nursing Personnel According to Nursing Preference: A mathematical programming approach", Operations Research, 24(1976) pp. 842-856.
6. D. Banet, "Heuristic scheduling for clinical physicians", ThinkIR: The University of Louisville's Institutional Repository, 2009.
7. D. Knjazew, " A competent genetic algorithm for solving permutation and scheduling problems", Genetic algorithms and evolutionary computation (Vol.6). Boston: Kluwer Academic Publishers 2002. ISBN: 0792374606.

Retrieval Number: C6204098319/2019©BEIESP
DOI:10.35940/ijrte.C6204.098319
Journal Website: www.ijrte.org

5413

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

8. C. Dodaro, and M. Maratea, "Nurse Scheduling via Answer Set Programming", Springer International Publishing AG, 2017.
9. T. Chen, J. Li, P. Jin and G. Cai, "Reusable rocket engine preventive maintenance scheduling using genetic algorithm", Reliability Engineering & System Safety, 114(2013) pp. 52-60
10. K. R. Baker, " Introduction To Sequencing and Scheduling", New York, 1974.
11. J. Singh and N. Auluck, " Controlled Duplication Scheduling of Real-Time Precedence Tasks on Heterogeneous Multiprocessors", Spriger International Publishing, (2017) pp. 3-21.
12. W. Agyei, W. Obeng-Denteh, and E. Andaam, "Modeling Nurse Scheduling Problem Using 0-1 Goal Programming: A Case Study Of Tafo Government Hospital, Kumasi-Ghana", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 4, ISSUE 03, MARCH 2015.
13. S. Mubarak, "Construction Project Scheduling and Control", New Jersey: Sons Inc, 2015.
14. M.Y. Cheng and D. Prayogo, "Symbiotic Organisms Search: A new metaheuristic optimization algorithm ", Elsevier, 2014.
15. J. Branke, K. Deb, K. Miettinen, and R. Slowinski, "Multiobjective Optimization", Germany: Springer, 2014.
16. R. Haupt and Haupt, "Pratical Genetik Algorithms", New Yersy: John Wiley and Sons,Inc., 2004.
17. A. Hiassat, A. Diabat and I. Rahwanc, " A genetic algorithm approach for location-inventory-routing problem with perishable products", Elsevier, 2017.
18. M. Gen and Cheng, "Genetik Algorithm for Scheduling of Laboratory personnel", Clinical Chemistry, (1997) pp. 118-123
19. M. L. Pinedo, "Scheduling: Theory, Algorithms, and Systems", USA: Springer-Verlag New York, 2012.

AUTHORS PROFILE

A. Wibowo is a lecturer in the Master of Information Technology at Bina Nusantara University. Expertise in exploration of Learning Machines, Artificial Intelligence, Data Mining and Scheduling.

Y. lianawati is a graduate in the Department of master of information technology at Bina Nusantara University. He has now completed his education to get a master's degree at Bina Nusantara University by researching the scheduling of nurses using genetic algorithms.