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Hybrid Genetic Algorithm for Optimization of Food Composition on Hypertensive Patient

Aprilia Nur Fauziyah, Wayan Firdaus Mahmudy
Faculty of Computer Science, Brawijaya University, Indonesia

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ABSTRACT

The healthy food with attention of salt degree is one of the efforts for healthy living of hypertensive patient. The effort is important for reducing the probability of hypertension change to be dangerous disease. In this study, the food composition is build with attention nutrition amount, salt degree, and minimum cost. The proposed method is hybrid method of Genetic Algorithm (GA) and Variable Neighborhood Search (VNS). The three scenarios of hybrid GA-VNS types had been developed in this study. Although hybrid GA and VNS take more time than pure GA or pure VNS but the proposed method give better quality of solution. VNS successfully help GA avoids premature convergence and improves better solution. The shortcomings on GA in local exploitation and premature convergence is solved by VNS, whereas the shortcoming on VNS that less capability in global exploration can be solved by use GA that has advantage in global exploration.

Corresponding Author:

Wayan Firdaus Mahmudy,
Faculty of Computer Science, Brawijaya University,
Jalan Veteran 8, Malang, Indonesia.
Email: wayanfm@ub.ac.id

1. INTRODUCTION

The non-communicable disease on decade of this year become the leading of disease that cause death in Indonesia. As example one of the non-communicable disease that has many patients is hypertension. Not only as non-communicable disease but also hypertension is main factor of cronic disease appeared, such as cardiovascular, cancer, diabetes, and respiration disease [1]. This is closely related to the pattern of human life daily such as food consumed, nutritional status, diet and other factors such as blood pressure, obesity, and cholesterol and insulin resistance [2].

The food consumed as one of the factors that affect blood pressure on hypertensive patient if not attention can cause developing dangerouse disease. One of the blood pressure control on hypertensive patient can be done by consumed food with less of salt [3]. This is caused consumed of salt is main factor of increase blood pressure and appear cardiovascular disease [2]. Therefore, consume food with appropriate nutrition need and less of salt degree is needed by hypertensive patient for controlling blood pressure.

The calculation on food composition can be done manually or by software. Manually, it more difficult to calculate food composition because nutritient amount must be appropriate with nutritient need on patient. But with software, it can be done easier with optimize on search of food composition in order to closer with nutritient need on hypertensive patient [4].

Several techniques can be used for solving food composition problem. Iwuji, et al [5] implement linear programming for solving food composition problem on hypertensive patient. That research serves diet plan that fulfill tolerance limit in DASH diet nutrient and obatain cost minimum. However linear programming may requires high computational time [6, 7].

Beside linear programming method, the meta-heuristic method can be used for solving optimization problems. Meta-heuristic gives solution that closer optimal, high performance, and flexible in reasonable

time computation [8]. One of the meta-heuristic methods is Genetic Algorithm (GA). Hussein [9] use GA to determine important features that have influence on classifier of heart attack. GA successfully improved quality of the result classifier become 87%, after the previous method by K-Means only reach accuracy on 68%. Other research by Şahman, et al [10] implement Genetic algorithm in cost optimization for feed recommendation on poultry and cattle. Their approach give lower cost than using linear programming. Rahman, et al [11] built evolutionary algorithm for solving shrimp diet formulation problem. Their approach can give feasible solution and they also impement what-if scenario to prove that evolutionary model is robust.

Our previous research [4] implements VNS for solving food composition problem on hypertensive patient. Although obtain feasible solution and fulfill nutrient need on hypertensive patient and give cost minimum. However, the useness of VNS still give less performance on search the solution. That was caused VNS less of exploration capability.

Several researchs explain, local method's shortcoming can be solved by implement other method that have good exploration capability. Such the research by Wijayaningrum, et al [12] proposed Hybrid GA and Simulated Annealing (SA) for solving food composition problem on poultry. That research proposed SA to avoid local optimum solution on GA. The result of method proposed give better solution than the useness classic GA.

Other several researchs [13]-[15] use GA and VNS for improving performance of search solution. The useness hybrid GA and VNS had been give outperform result on several researchs. That because GA has advantages on global exploration, although the other side GA has shortcomings on local exploitation and premature convergence [16]. However, GA's shortcoming can be solved by implement local based algorithm so between global exploration and local exploitation can be balanced [12]. VNS is one of the local based algorithm that has advanatage on searching local solution [13]. VNS explore neighborhoods from current incumbent solution [8], [17]. Most of the solution with optimal value will be used to getting promising neighborhood solution [17].

In order to obtain local optima, VNS move from one solution to other solution with mplement local search improvement. When optimum local is detected, VNS can jump out from trap with change neighborhood structure and find better solution. Therefore VNS can prevent optimization proses fall into local optima [8]. Beside, not like single solution based method like SA, Tabu Search, VNS not need many parameter and very simple [4], [8], [19]. Neighborhood structure and move strategy become enough parameter for running VNS. The advantages on GA and VNS can give advantages hybridization GA and VNS [4, 13, 18].Therefore on this research will be done hybridization between GA and VNS. The method proposed with their advantages is hoped can give better solution than result our previous research [4].

2. RESEARCH METHOD

On this research any hybridization techniques are proposed between GA and VNS, there are GA which is improved by VNS, VNS which is added with GA and another scenario of hybridization of GA VNS is reproduction on GA is improved by VNS.

2.1. Solution Representation

The arrangement of food solution is representated with integer number on every their nutritient. Integer number refer to index of foodstuffs on food database. The solution representation is shown by Table 1.

Table 1. Soluiton Representation

Type of menu	Breakfast	Lunch	Dinner
PK	3	1	2
S	1	3	10
N	2	12	11
H	16	6	3
B	16	18	26

Information: PK=Staple food
S=Vegetable
N=Plant source
H=Meat source
B=Fruit

From Table 1, the solution contain five components of food, there are staple food, vegetables, plant source, meat source amd fruit. Initial gen on cromosom is generated randomly with fulfill amount each nutritient component. The integer on food that randomly generated must be no more than limitation each food amount that available on data. 103 data are used in this research that it same with data on our previous research [4].

2.2. Fitness Function

Quality of solution is measured by fitness function. The fitness function that will be used on this study is same with the fitness function on our previous research [4] so that the result of pure VNS and result of hybridization GA and VNS can be compared. The fitness function is shown on (1)

$$Fitness = \frac{10000}{(penalty\ total * criteria\ value) + cost} \quad (1)$$

The objective function on (1) explain that the calculation fitness value of a solution is done with calculate penalty each of nutritient component and cost. 1000 is consonant number, cost is amount of all cost from foodstuffs. So that fitness value is obtained by division from 10000 and total of penalty and cost in each solution.

2.3. Reproduction

Reproduction on GA consisting crossover and mutation. Reproduction fase aims to producting offspring. In this research use one cut point crossover that select cut point randomly and exchange right side and left side from two parent that had been selected randomly. The mutation that is used in this research is reciprocal exchange mutation which is exchange two index that had been selected in one parent.

2.4. Selection

Selection aims to select cromosom that will be used on population next generation depends on its fitness value. In this research, uses eletism selection. Elitism works with sorting their fitness value and then select depends on their highest fitness value as much as population size.

2.5. Scenario of hybridization GA and VNS

The hybridization scenario GA VNS which is implemented in this research will be explained on several sub chapters. Briefly, three scenario of hybridization proposed on this study, there are GA VNS which is the the final solution of GA will be improved by VNS, furthermore on this study will be written GA VNS I. The second scenario is GA VNS which is the reproduction on GA will be combined with VNS on multiples of 50th generation, furthermore will be written GA VNS II. And the last scenario is VNS GA which is Initial population of GA are obtained by VNS. VNS will be run as much as population size so that give able solutions as much as population size for initial population on GA.

2.5.1.GA-VNS I

GA VNS I method is started with initialize GA parameter corresponding with parameter value which had been previously tested. Then, GA fase is run repeatedly until termination condition is fulfilled. After final solution is formed from GA and then next step is running VNS that is applied for improving final solution GA. VNS uses final solution GA as its initial solution. GA VNS I procedure is shown by Figure 1.

```
PROCEDURE GA-VNS I
Input : pop_size  : population size
        generation: generation size
        Cr        : crossover rate value
        Mr        : mutation rate value
        Kmaks     : neighborhood
Proses:
//Generate initial solution randomly as much as pop_size
Generate initial population P(t)
t=0
WHILE (t<=generation)
  //Reproduction
       Crossover(P(t), Cr)
       Mutation (P(t), Mr)
     C(t) <- crossover offspring, mutatation offspring
     Evaluation()
     Selection (P(t+1)) from P(t) and C(t)
     t=t + 1
END WHILE
curr: GA final solution
//Apply VNS
Curr ← GA final solution
best←curr
k ← 1
WHILE k<=Kmaks DO
  // shaking
     curr←Change (best,k)
     bestLocal←Local search (curr)
     // move or not
     IF Fitness(bestLocal) > Fitness(best) THEN
       Best ← bestLocal
       k ←1
     ELSE
       k ←k+1
     END IF
END WHILE
Output: best: the best solution from GA VNS I
END PROCEDURE
```

Figure 1. Pseudocode of GA-VNS I

2.5.2.GA-VNS II

GA VNS II is started with initialize GA parameter like population size, generation size, crossover amd mutation rate that corresponding with parameter value from GA testing. Next step, GA is run with firstly generates solution randomly. However, on the reproduction proses, VNS is applied on every multiples of 50th generation. VNS is applied on subset of offspring for searching better solution around individu each population. Solution from offspring GA and solution from VNS in every offspring will be evaluated use objective function. If GA solution is better than solution from VNS then solution is not replaced. Otherwise, GA solution will be replaced by solution from VNS. GA VNS II procedure is shown by Figure 2.

```
PROCEDURE GA-VNS II
Input : pop_size  : population size
        generation: generation size
        Cr        : crossover rate value
        Mr        : mutation rate value
        N_cr      : child number on crossover
                    Cr * pop_size
        N_mr      : child number on mutation
                    Mr * pop_size
Proses:
//Generate initial solution randomly as much as pop_size
Generate initial population P(t)
t=0
WHILE (t<=generation)
  //Reproduction
       Crossover(P(t), cr)
         if (generation % 50)
            Child_itr=0
            While(Child_itr <= N_cr)
               VNS()
               if(fitness_cr > fitness_vns)
                  C(t) <- solution_cr
               else
                  C(t) <- solution_vns
            END While
       Mutation (P(t), mr)
         if (generation % 50)
            Child_itr=0
            While(Child_itr <= N_mr)
               VNS()
               if(fitness_mr > fitness_vns)
                  C(t) <- solution_mr
               else
                  C(t) <- solution_vns
            END While
      C(t) <- offspring from crossover, offspring from mutation
      Evaluation()
      Selection (P(t+1)) from P(t) dan C(t)
      t=t + 1
END WHILE
Output: best: the best solution from GA VNS II
END PROCEDURE
```

Figure 2. Pseudocode of GA-VNS II

2.5.3.VNS-GA

VNS GA method is started by VNS procedure that is applied for forming set of solution. The solution will be used on initial population of GA. Because VNS is single solution based then VNS procedure will be repeated until fulfill population size. After initial population on GA is built, GA procedure is repeatedly run until fulfill termination condition. VNS GA scenario is shown by pseudocode on Figure 3.

```
PROCEDURE VNS-GA
Input : pop_size  : population size
        generation: generation size
        Cr        : crossover rate value
        Mr        : mutation rate value
        Kmaks     : neighborhood
Proses:
pop=0
WHILE (pop<=pop_size)
    curr: Generate initial solution randomly
    //Apply VNS
    best←curr
    k ← 1
    WHILE k<=Kmaks DO
     // shaking
    curr←Change (best,k)
    bestLocal←Local search (curr)
    // move or not
    IF Fitness(bestLocal) > Fitness(best) THEN
      Best ← bestLocal
      k ←1
    ELSE
      k ←k+1
    END IF
    END WHILE
    best: VNS solution
END WHILE
All VNS solution : best
//initialize initial solution on GA=VNS solution
Initial population P(t)=All VNS solution
t=0
WHILE (t<=generation)
 //Reproduction
      Crossover(P(t), Cr)
      Mutaton  (P(t), Mr)
    C(t) <- offspring from crossover, offspring from mutation
    Evaluation()
    Selection (P(t+1)) from P(t) and C(t)
    t=t + 1
END WHILE
Output: best: the best solution from VNS GA
END PROCEDURE
```

Figure 3. Pseudocode of VNS-GA

3. RESULTS AND ANALYSIS

In this section, the result of this study will be explained on several several sub-chapters, there are sub 3.1 will explain about analysis on GA, sub 3.2 will explain about analysis on GA VNS I, sub 3.3 will explain about analysis on GA VNS II, and sub 3.4 will explain about analysis on VNS GA.

3.1. Genetic Algorithm (GA)

The parameter value will be use on GA testing and hybidization of GA is determined based on testing that previously had done. GA parameter value that will be used are population size=100, generation=125, and crossover rate=0.6, mutation rate=0.4. The implementation using GA on this research give premature convergence, the pattern of convergence is shown on Figure 4.

Figure 4 show GA can improve but after 53th generation, premature convergence is happened until last generation didn't give better fitness. Premature convergence on GA can be solved by addition other method for avoiding premature convergence. Futhermore, on this paper we propose hybridization on GA with another method which is will be applied on this study is VNS.

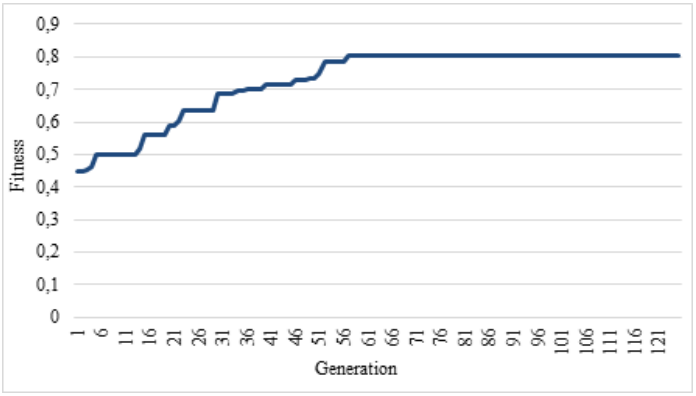

Figure 4. Graph of convergence pattern on GA

3.2. GA-VNS I

The first experiment on this research is combining hybrid GA with VNS. The procedure of GA-VNS I on this research has been described in section 2.5.1 which is firstly GA is run, and the final solution GA is used asinitial solution in VNS. The result from hybrid GA-VNS I is tested on 10 experiments and give greater fitness than pure GA. The graph of difference fitness hybrid GA-VNS I and pure GA is shown in Figure 5.

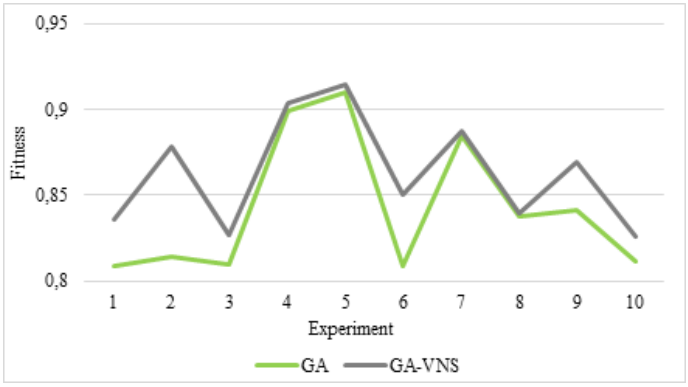

Figure 5. Graph of comparison between pure GA and hybrid GA VNS

Although when in the end of GA generation, GA has convergence, it can still achieve higher fitness with applying VNS. From the Figure 5 shows VNS can improve fitness of GA final solution, although it may difficult to achieve because globally GA have achieved higher fitness so if process on VNS can't give better solution then VNS can defend final solution of GA that have high fitness, the examples is on 7th experiment and 8th experiment.

3.3. GA-VNS II

The second experiment on this research combines VNS on GA's reproduction and its procedure is described in section 2.5.2. The aims of GA-VNS II is repair diversity on solution through reproduction, they are crossover and mutation. The pattern of hybrid GA-VNS II's fitness is shown in Figure 6.

Figure 6 shows convergence is happened on 40th generation and 61st generation. The convergence on 40th generation can be solved with use VNS. It can happen because VNS is run on GA reproduction on 50th generation therefore it can give a new solution, if new soluiton from VNS is better than previous solution from GA, VNS will be used as one of the solution on GA population then is hoped it can give more diverse solution on GA population. That is can give influence on next generation and then child from GA more variate therefore convergence can be avoided.

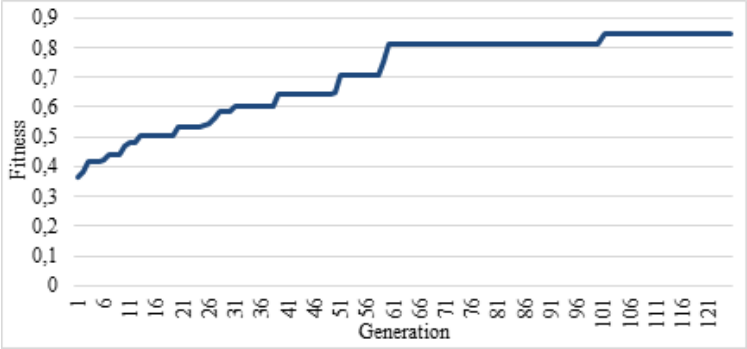

Figure 6. Graph of fitness pattern on GA VNS II

The second convergence is happened on 61st generation. The convergence was still unavoidable between 61st generation to 100th generation because there isn't other factor that can give more varied solution. The convergence can be overcome in the 100th generation due to factor of use VNS on GA reproduction.

Moreover, on every offspring on crossover and mutation is improved by VNS in order to achieve better fitness. Improvement with pure VNS is done on 50th generation and its multiple in order to does not take much longer computational time. Improvement on crossover and mutation is shown on Figure 7 and Figure 8.

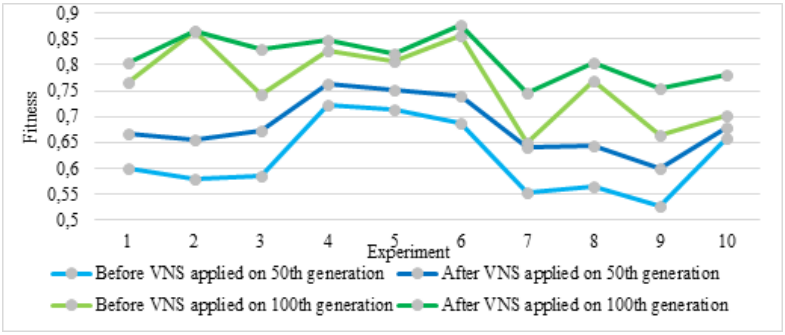

Figure 7. Graph of fitness pattern on Crossover

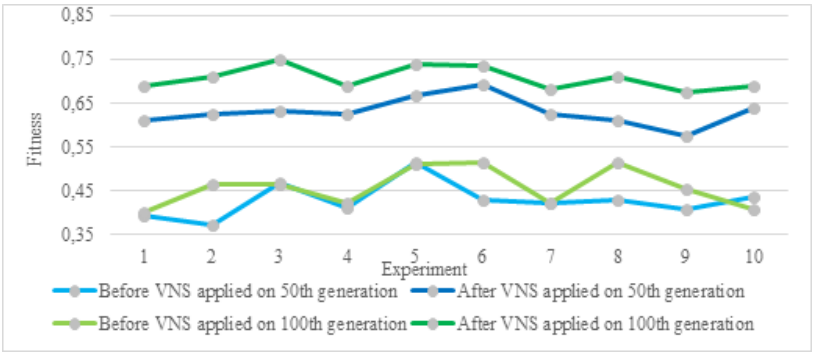

Figure 8. Graph of fitness pattern on Mutation

From Figure 7 and Figure 8 is shown 50th and 100th generation on crossover and mutation are happened improvement of fitness before and after VNS is combined. With new solution from VNS will be evaluated between solutions before VNS is combined (offspring of GA) and after VNS is combined. When solution from VNS is better than solution before VNS is combined, then VNS solution will replace solution

from offspring on GA. From the graph, VNS can give improvement of fitness and more variety solution. That is important to need when convergence is happened on process of GA.

3.4. VNS-GA

The last method proposed on this research is hybridization VNS-GA. This method proposed final solution of VNS is used as initial solution of GA. This method aim to improve quality of VNS final solution. Because GA is population based and VNS is single solution based then VNS will be run *n* times run (*n* is population size) for forming initial solution of GA. So that the idea of hybridization VNS GA on this session is forming initial solution from VNS with a number of population size and then its solutions will be used as GA initial solution. However this leads to longer computational time since VNS has to be processed as much as population size to provide the solution needed by GA as the initial solution. On the testing of VNS-GA is done with 10 times run to measure performance of VNS-GA. Figure 9 show the comparison before GA applied and after GA applied on VNS solution.

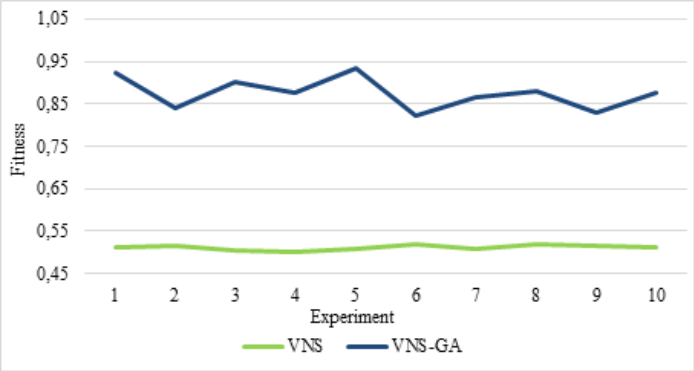

Figure 9. Graph of comparison between pure VNS and VNS-GA

From the Figure 9, with 10 times run VNS give average of fitness is 0,511592 and after improvement is done by GA, it can give solutions with average of fitness is 0,874828, that is proven VNS that give optimal solution in local area can be improved on searcing in global area using GA.

Hybrid GA-VNS method is proposed can give food composition recommendation is more optimal and appropriate with patient needed. The comparison of fitness and run time from any scenario of hybridization on GA and VNS is shown by Table 2.

Tabel 2. The Comparison of Hybridization GA VNS, pure GA and pure VNS

Method	Average of fitness	Average of run time (ms)
VNS	0,583206	1889,2
GA	0,817106	1890,3
GA-VNS I	0,863254	3306,2
GA-VNS II	0,889776	98494,3
VNS-GA	0,874828	98743,3

Generally, average fitness of GA is higher than average fitness of VNS on our previously research [4]. From Table 2 is shown hybridization between GA and VNS need more computational time than time required on pure VNS or pure GA however hybridization GA and VNS give better quality of solution and fitness. This is because hybridization use more than one algorithm those has advantages on local exploitation and global exploration so that in its search process need longer computational time but still in reasonable time.

Between the scenario hybridization GA and VNS, GA-VNS II give higher fitness value than other scenario. That is because GA-VNS II has advantage on repair solution and improve fitness when konvergence is happened on multiples of 50th generation. Whereas other scenario such as GA-VNS I, function of VNS is only improving again final solution of GA so that GA VNS I may less contribute when convergence is occured on process of GA. Generally, GA VNS I, VNS succesfully improve final solution of GA however when GA had have solution with high fitness, VNS often difficult achieve better solution.

Another scenario is VNS-GA. On this session, GA improves solution from final solution of VNS. The computational time required almost same with other hybridization scenario because VNS must be run as much as population size. That is because pure VNS give single solution so that in order to visible is used as initial solution of GA. In this scenario, VNS can help GA has initial population that not too bad than intial solution of GA that is generated randomly.

The result of proposed method is compared with our previous research [4] which implements pure VNS on composition food. The proposed method is tested with implement problem case to search composition food for hypertensive patient. The problem case used is same with problem case on our previous research [4] so that the result between our previous research and method proposed on this research can be compared. The result with using pure VNS on our previous research and proposed method on this research are shown on Table 3.

Tabel 3. The difference result between pure VNS and hybrid GA with VNS

Proposed method	Difference (%)				Sodium (max. 0,8 gram)
	Calori	Carbohidrat	Fat	Protein	
VNS (our previous research)	0,271251	6,27235	7,272371	6,007748	0,1762
GA VNS I	0,11413851	2,0735981	3,03661216	4,0465542	0,3391669
GA VNS II	0,54523847	0,95869758	1,459253	5,074644	0,3421669
VNS GA	0,0357567	1,1133	1,55991	6,33851	0,369764

Table 3 explains that the method of pure VNS in our previous research actually has given results that not bad because the difference between the results of optimization with total nutrients of the required patient does not exceed 10%. Although the amount of sodium from pure VNS is less than hybrid GA and VNS, it is not very influential because it is within reasonable limits which is for this case problem the maximum amount of sodium must be in food is 0,8 grams. The result of proposed method in this study gives more interesting result, that is difference of nutrient amount between result of hybrid optimization of GA and VNS with amount of nutrients needed by patient less (in percent). For better optimization results can use more food data for more solution variations and the amount of nutrients produced more closely to the needs of the patient's nutrition.

4. CONCLUSION

The proposed method in this study successfully solve optimization of food composition problem for hypertensive patient. Although need longer computational time however hybridization GA and VNS give better result than pure GA or pure VNS. VNS succesfully help GA avoids premature convergence and improves better solution. The shortcomings on GA in local exploitation and easy trapped in premature convergence is successfully solved by VNS, whereas the shortcoming on VNS that less capability in global exploration can be solved by use GA that has advantage in global exploration.

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BIOGRAPHIES OF AUTHORS

Aprilia Nur Fauziyah obtained bachelor degree in informatics from University of Brawijaya, Indonesia. Her research interest is optimization of combinatorial problems and software engineering.

Wayan F. Mahmudy obtained bachelor degree in mathematics from University of Brawijaya, and master degree in information technology from Institut Teknologi Sepuluh November, Indonesia. He also completed his Ph.D in Manufacturing Engineering at University of South Australia. He is a lecturer at Department of Computer Science, University of Brawijaya, Indonesia. His research area includes optimization of combinatorial problems and machine learning.