Genetic Algorithm Approach in Optimizing the Energy Intake for Health Purpose

Lili Ayu Wulandhari and Aditya Kurniawan

Abstract Energy intake of individual have an important role to support daily activity and it must fulfill the energy requirement in appropriate amounts. Energy requirement is determined based on Basal Metabolic Rate (BMR)—which is affected by weights, heights, age and gender—and physical activity level (PAL). While energy intake is calculated based on calorie from each portion of food consumed. This food consists of five principal elements, namely main dish, vegetable side dish, meat, vegetable and fruit. In the daily life, the difference between energy requirement and energy intake must be set as minimum as possible in order to avoid overweight or underweight condition. However, an individual is still having difficulty in determining the ideal portion of every kind of food that will be consumed in everyday. Therefore it is important to develop a system which gives the information regarding an optimal portion of each kind of food for an individual consumption. Genetic Algorithm (GA) is used to find the best portion and composition of food so that it will provide a proportional energy intake according to individual requirement. In the analysis we compare the results from GA and linear programming approach, the experiment shows that GA is succeed in giving proportional portion and composition as well as providing the diversity of food based on individual requirement.

Keywords Nutrition · Food suggestion · Energy requirement · Energy intake · Genetic algorithm

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1 Introduction

Productivity level of an individual is influenced by the health condition, good health will affect to high productivity otherwise the productivity will decrease. Good health condition can be achieved by maintaining the nutrient consumption. Sufficiency of nutrient can be reached by arranging the dietary habit which is including the quality and quantity of the food. The Ministry of Health as an institution which handles nutritional matter in Republic of Indonesia, issued a guidance that recommend people to consume balanced nutrition. Balanced nutrition means consumption of daily food must contain nutrition in appropriate types and portion according to the individual needs. It also must fulfill the four pillars of balanced nutrition, namely food diversity, hygienic behavior, physical activity and maintaining a normal weight [4]. Recently, inappropriate types and portion of nutrition can induce disease associated with overweight, obesity and underweight condition.

Overweight and obesity is the effect of overnutrition as consequence of consuming energy rich drinks, rich in saturated fat, additional sugar and salt, but having deficiencies of consuming vegetables, fruit and cereals and lacking of physical activity. Overweight, obesity and underweight become serious issue since these conditions lead to high risk disease such as heart and vascular disease, hypertension, stroke and diabetes. Therefore, it is important to arrange the composition and serving suggestion of our nutrition to avoid the overweight, obesity and underweight condition. Balanced nutrition composition and serving in our food means it has sufficient quantity, quality and contains various nutrient such as energy, carbohydrate, protein, fat and minerals. And this composition and serving can be arranged based on the individual energy requirement [2]. Energy requirement must be estimated accurately, since error estimation can lead to significant weight loss or gain [10]. Individual energy requirement takes account of individual energy intake, energy expenditure, gender, age, height, weight and level activity. According to nutrient experts, energy expenditure through physical activity plays an important role to determine body weight where decreasing in energy expenditure through decreased physical activity to be one of the major factor in contributing to the overweight and obesity [1]. Description of energy requirement can be the references to food suggestion for person, which kind of food will fulfill their energy needs, so that food diversity and maintaining the normal weight as the part of 4 pillar balanced nutrition can be achieved [5].

Previous researchers and developers of health application had been developed a guidance and tools to estimate the energy requirement of individual to achieve ideal condition. Judges et al. [3] conducted an survey to the hospitalized underweight and obese patient in United Kingdom to estimate the energy requirement to avoid over or underfeeding. According to their survey, they found that the energy requirement for underweight patient is commonly predicted using the adjustment to metabolic stress and physical activity (90 %) while for obese patient commonly using basal metabolic rate (15 %). In computer science approach, Pouladzadeh et al. [7] proposed energy measurement based on the food image and Peddi et al. [6] accomplished the previous work by developing health mobile application to measure energy content in a food.

They capture the image of the food and proceed the image processing to identify the type and the energy of the food then using cloud based visualization to handle big data requirement to obtain accurate result of this application. The development of energy measurement approach, either in health or computer science field give us the information of the energy needs. However in daily life, people do not only need the calculation of energy requirement, they also need the suggestion what kind of food which fulfill this requirement.

The calculation of energy requirement and food suggestion will be conducted in an equation, so that the equation must contains five variables as the serving suggestion and five variables as the types of food. This equation needs an approach which can handle multivariables and find the optimal values. Therefore we proposed an approach to optimize the food consumption which fulfill the energy requirement and food diversity according to the guidance of health ministry especially in Indonesia.

In this paper, Genetic Algorithms (GA) is used as one of the common approach in optimization. The data input is obtained from the health ministry of Indonesia in the form of the energy value from each dishes consumed. In each food consumption consists of main dish, meat, vegetable side dish, vegetable and fruit. GA approach find the optimum food composition and serving of individual based on the gender, age, weight, height and physical activity which contains food diversity according to health ministry guidance. This paper is arranged in 5 sections, where Sect. 1 explains the background problem in food serving regarding to obtain balance energy. Section 2 describe the modeling of energy intake and requirement which will become the fitness function of GA, followed by Sect. 3 which presents the implementation of GA in optimizing the energy intake. Sections 4 and 5 presents the experimental result and conclusion respectively.

2 Energy Requirement and Intake Modeling

The Health Ministry of Indonesia have given a guidance that the daily food must fulfill four pillars of balanced nutrition which one of them is food diversity. Therefore, each food consumed ideally should contain main dishes, meat, vegetable side dishes, vegetables and fruits. These foods have a role in contributing the energy intake, or in other words, total energy intake is the accumulation of energy contributed by main dishes, meat, vegetable side dishes, vegetables and fruits as shown in Table 1. Therefore total energy intake (*TE*) is written as the following equation:

$$TE = x_1 MD + x_2 VD + x_3 AD + x_4 VE + x_5 FR \tag{1}$$

Table 1 The example of dishes energy value

Food type	Weight (g)	Household size	Energy (Calorie)
Main dishes			
Rice	100	3/4 glass	175
Noodle	200	2 glasses	175
Potato	210	2 pieces of middle size	175
Corn	125	3 pieces of middle size	175
Cassava	120	1.5 pieces	175
Meat			
Beef	35	1 piece of middle size	50
Chicken	40	1 piece of middle size	50
Egg	55	1 pieces	50
Shrimp	35	5 pieces of middle size	50
Fish	35	1 piece of middle size	50
Vegetable side dishes			
Tofu	100	2 pieces of middle size	80
Tempe	50	2 pieces of middle size	80
Green beans	25	2.5 tablespoons	80
Red Bean	25	2.5 tablespoons	80
Bean curd	20	1 sheet	50
Vegetable			
Spinach	–	1 bowl	25
Broccoli	–	1 bowl	25
Kangkung	–	1 bowl	25
Bean sprouts	–	1 bowl	25
Cassava leaves	–	1 bowl	50
Fruit			
Ambon banana	50	1 piece of middle size	50
Malang apple	75	1 piece of middle size	50
Sweet orange	100	2 pieces of middle size	50
Mango	90	3/4 pieces of large size	50
Papaya	190	1 pieces of large size	50

where,

x_1, x_2, x_3, x_4, x_5 : the numbers of serving
MD : Energy value of main dishes
VD : Energy value of vegetable side dishes
AD : Energy value of meat
VE : Energy value of vegetables
FR : Energy value of main fruits

Table 1 shows the example of the energy value of the dishes which is calculated based on the weight in kilogram and household size. Household size is used here, since it is more familiar to be used in Indonesia as the units to determine the energy intake in a day. The energy intake must follow the energy requirement for each individual based on the Basal Metabolic Rate (BMR) and physical activity level. The value of BMR is determined using Revised Harris Benedict Equation [9]:

Men

$$BMR = 88{,}362 + 13{,}397(Weight) + 4{,}799(Height) - 5{,}677(Age) \quad (2)$$

Women

$$BMR = 447{,}593 + 9{,}247(Weight) + 3{,}098(Height) - 4{,}33(Age) \quad (3)$$

where weight in Kilogram, Height in Centimeter and Age in years.

Based on the BMR value the energy requirement is calculated according to the physical activity level. The activity level is divided into five class namely low, mild, moderate, heavy and extreme level [11]. The definition and physical activity level (PAL) factor of each class is described in Table 2.

By knowing the PAL factor of individual, so the energy requirement is [11]:

$$ER = BMR * PAL \quad (4)$$

where *ER* is energy requirement and PAL is PAL factor based on the physical activity of each individual.

Table 2 The physical activity level

Activity level	Definition	PAL factor
Low level	Sedentary, do not have exercise at all in a week	1.2
Mild level	Having exercise at least about one to three times in a week	1.375
Moderate level	Having exercise at least about three to five times in a week	1.55
Heavy level	Having exercise at least about five to six times in a week	1.725
Extreme level	Having hard exercise about 2 times in a day such as an athlete or having a job which need extreme physical activities	1.9

3 Genetic Algorithm in Optimizing the Energy Intake

Genetic Algorithm (GA) is part of Evolutionary Algorithm, which is adapted from natural evolution. The concept of this algorithm is evaluating the individuals such that the excellent individuals will survive while weak individuals will be extinct. This GA principle is used to evaluate the portion and composition of food consumption from each individuals, so that this serving is appropriate to the energy requirement. The process of GA is described in the Fig. 1.

Based on Fig. 1, GA in optimizing the energy intake can be explained as follows:

1. Initialize the chromosomes
   The chromosomes here are composed by five variables which contributes energy intake for individuals, namely main dishes, meat, vegetable side dishes, vegetables and fruits, with total lengths is forty-five each chromosome. Each chromosome gives information regarding the portion and varieties. The portion is represented by three digit of binary numbers , which is the representation of random number between 1 and 5. While the varieties of the food is generated by six digit of binary number which the representation of the name of food in the linked database. The example of the chromosome arrangement is shown in Table 3, where the chromosomes have length of 45, since each variable is represented by 9 bit of binary value.
2. Evaluate Fitness Value
   The initial chromosomes above are evaluated by using the fitness function. Fitness function is formulated based on Eqs. 1 and 4 which give us the information regarding the energy requirement and energy intake of individual. We try to

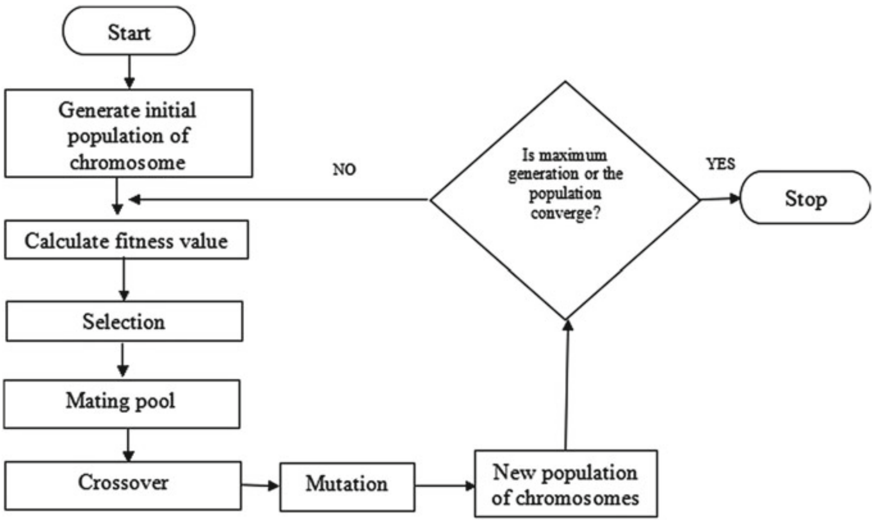

Fig. 1 Genetic algorithm process

Table 3 The example of chromosome arrangement

Type of food	Main Dish		Vegetable side dish		Meat		Vegetable		Fruit	
Columns of chromosomes	1–3	4–9	10–12	13–18	19–21	22–27	28–30	31–36	37–39	41–45
Variables	x_1	*MD*	x_2	*VD*	x_3	*AD*	x_4	*VE*	x_5	*FR*
The example of binary chromosomes	001	000001	011	000011	010	000111	010	000101	001	000110

obtain the composition and portion of food which gives the energy according to the requirement. Thus the fitness function (FV) for optimizing the energy intake is the minimum difference between the energy requirement and energy intake, as shown in the following equation:

$$Min(FV = abs(TE - ER)) \tag{5}$$

s.t $0 < x_1, x_2, x_3, x_4, x_5 \leq 7$

3. Selection
   Selection is executed to the chromosome to find the mating pool which contains the best chromosome by using roulette selection [8]
4. Crossover
   Crossover is an operation to maintain the diversity of the population. It is executed by choosing the pair of parents in mating pool and doing the crossover based on the probability of crossover (p_c).
5. Mutation
   Mutation has purpose to maintain the diversity as well. It will involves bit flipping, changing 0 to 1 and vice versa based on the mutation probability (p_m). The result of this mutation is new population and will be evaluated in the next step.
6. Evaluate the fitness value of new population. If the generation achieves maximum generation or the population has converged, stop, and return the best solution in current population. Otherwise, go to step 2 for the new population.

The best chromosome from GA produce the best composition and portion of food and fulfill the individual energy requirement requirements.

4 Experiment Results and Analysis

The experiments of this algorithm are conducted using gender, age, height, weight and level of activity as the input. We use 100 chromosomes for the population, 0.5 and 0.01 for probability of crossover and probability of mutation respectively. The results of the experiments shows that the average of error between the energy requirement and energy intake is 0.043 from thirty times experiments and 100 generations. The experiments are varied based on the three groups of ages, namely twenty two, thirty two and sixty five years old from male and female respectively. These group of ages are considered representing three classes that is young, middle and old classes. The weight and height of each age are taken from the ideal weight and height of that age, while the physical activity level is medium. The results of the experiments is shown in Table 4.

Table 4 shows the portion of food in a day for individual with ideal weight and height in each age classes. We can obtain the information that each individual consumes two servings in average for each component of food. Male has higher servings of food than female, where it is around 8.1, 15,8, 6.5,15.6 and 26.5 % for main dish,

Table 4 The result of GA in optimizing the energy intake

Gender	Age	Weight	Height	PAL	Error	x_1	x_2	x_3	x_4	x_5
Male	22	60	168	Medium	0.05	6.5	6	6	5	5
	32	65	160		0.04	7	6.5	4.5	5	6
	65	62	168		0.04	5	6.5	5	6	6
Female	22	60	157	Medium	0.04	6	5.5	4.5	5.5	4
	32	54	159		0.05	6	6	5	3	4.5
	55	62	159		0.04	5	4.5	5	4	4

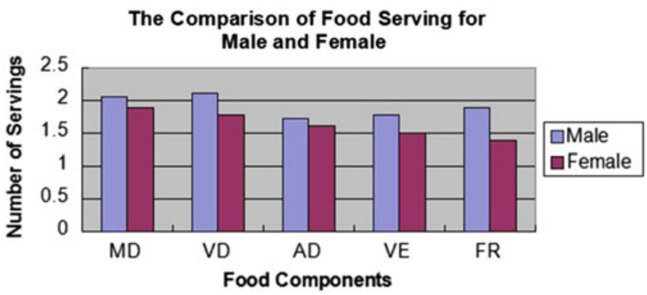

Fig. 2 The comparison of food servings for male and female

vegetable side dish, meat, vegetable and fruit respectively (Fig. 2). For the composition, we can take as the example of the food variation as shown in Table 5 where the number of serving follow Table 4.

In this research we also use linear programming approach to be a comparison of GA to check the energy fulfillment of each individual. The result of linear programming and GA approach is given in Table 6.

Table 6 shows that the percentage of energy fulfillment provided by GA is slightly smaller than Linear programming, however linear programming cannot provide the

Table 5 The composition of food servings

Gender	Age	Weight	Height	*MD*	*VD*	*AD*	*VE*	*FR*
Male	22	60	168	Macaroni	Cashew	Shrimp	Long beans	Papaya
	32	65	160	Brown rice	Bean curd	Corned beef	Carrot	Grape
	65	62	168	Noodle	Green bean	Chicken	Mushroom	Red apple
Female	22	54	159	Potato	Bean Curd	Meatball	beans	Melon
	32	60	157	Brown rice	Soybean	Fish	Long beans	Banana
	65	55	159	Rice	Bean curd	Fish	Cabbage	Star fruit

Table 6 The comparison of GA and linear programming in energy fulfilment of individual

Gender	Age	Weight	Height	PAL	Energy Fulfillment (%)	
					GA	Linear programming
Male	22	60	168	Medium	96.51	99.95
	32	65	160		99.87	99.64
	65	62	168		98.26	99.54
Female	22	60	157	Medium	98.94	99.73
	32	54	159		96.51	99.95
	55	62	159		97.07	99.82

diversity of food suggestion in its result. It just provide the best value of portion to meet the individual requirement.

5 Conclusion

This paper presents the Genetic Algorithm (GA) to find an optimum composition and portion for energy intake based on the energy requirement for each individual. Based on the experimental results, GA can provide acceptable composition and portion of each component with the tolerance of error is $80\,\% * ER \leq TE \leq 110\,\% * ER$. These results show that GA can be an approach which gives ideal composition and portion of food in order to achieve balanced energy for health purpose especially in Indonesia.

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