PREDICTION OF VEGETARIAN FOOD PREFERENCES FOR THE AGING SOCIETY

Athakorn Kengpol
Advanced Industrial Engineering Management Systems Research Center,
Faculty of Engineering,
Department of Industrial Engineering,
King Mongkut's University of Technology North Bangkok, Bangkok, Thailand
athakorn@kmutnb.ac.th

Wilaitip Punyota
Faculty of Engineering,
Department of Industrial Engineering,
King Mongkut's University of Technology North Bangkok, Bangkok, Thailand
vilaitip.p@gmail.com

Abstract. The objective of this research is to predict vegetarian food preferences from chronic disease among the elderly by using a hybrid method that includes both an artificial neural network (ANN) and particle swarm optimization (PSO), called ANN-PSO. ANN is a mathematical model that mimics the human brain that is intelligent in learning, prediction, recognition, classification by practice, and solving complex problems. In this study, data collection of vegetarian food preferences, including gender (male and female), a chronic disease selected from the diseases that are common among the elderly, and a vegetarian menu suitable for the chronic disease. Data were collected by interviewing 100 elderly people. Then, the data were analysed using artificial neural networks and applied the particle swarm optimization method to determine the appropriate parameters (weights) for the neural network. The results indicate that the application of PSO along with ANN can accurately predict vegetarian preferences for the aging society. The accurate vegetarian prediction model resulted in increasing consumption of vegetarian food and allowed manufacturers to produce meals or present menus tailored to the individual preferences of the elderly.

1. Introduction
The number of elderly, destined to be 60 or older, is growing in almost all countries and this global trend is likely to increase [1]. An essential component of health in the aging population and influencing the aging process is nutrition. Nutrition for the elderly however has not been clearly
defined. Also, no food manufacturer has produced foods that are especially suitable for the elderly. Since the metabolic rate of the elderly decreases with age and the energy requirements of the elderly decreases as well [2]. Ninety-five percent of the elderly have chronic disease problems consisting of high blood pressure, osteoarthritis, cataract, high cholesterol, diabetes, dementia, cardiovascular, depression, stroke and emphysema. The main factor causing these diseases is dietary behavior. If older adults consume healthy foods, this can help to reduce the risk of chronic disease [3].

As the World Health Organization (WHO) mentioned, many diseases that occur in the elderly are a result of dietary factors. These factors are part of the natural transition in the aging process. There are, for example, dietary fat is likely to be related to colon pancreatic, and prostate cancer. Additionally, vascular disease is caused by blood pressure, increased blood lipids, and glucose intolerance, all of which are affected by dietary factors, leading to cardiovascular disease [4]. Changing diet affects the level of risk factors and may have a greater impact on the elderly. Reducing saturated fats and reducing salt intake, which can lower blood pressure, can have a significant effect on lowering the risk of cardiovascular disease (CVD). Additionally, vegetarian dietary patterns are known to reduce CVD mortality and the risk of coronary heart disease (CHD) by 40% [5]. The consumption of vegetarian diets, such as fruits and vegetables, legumes and whole grains, and beans have been consistently associated with a lower risk for many chronic degenerative diseases and increased longevity [6]. Therefore, plant-based vegetarian diets are better protected against chronic disease than meat-based diets [7].

In recent years, the elderly have become more attentive to their health issues and try to consume healthy and suitable vegetarian food for them, but no models have yet recommended a suitable vegetarian food for the elderly. If the elderly are advised to choose a suitable vegetarian food, they are more likely to consume vegetarian food and may keep them in good health. Therefore, the objective of this research is to predict vegetarian food among the elderly preferences using an artificial neural network (ANN) hybrid with particle swarm optimization (PSO) or called ANN-PSO. An artificial neural network (ANN) is effective in classification, prediction. PSO is one of the powerful algorithms for finding the optimal parameter. PSO can increase efficiency and speed in the neural network model when the PSO is hybridized with ANN. PSO was used to find the structure and to calculate the optimal initial weight of the neural network model to obtain a more accurate vegetarian prediction model. The experiments were performed to compare the performance between the ANN model and the ANN-PSO model. The accurate vegetarian prediction model resulted in increasing consumption of vegetarian food and allowed manufacturers to produce meals or present menus tailored to the individual preferences of the elderly.

The paper is as following, section 2 discusses related studies; section 3 is comprised of the details of methodology research; section 4 is an analysis of the experimental results; and finally, the conclusion can be found in section 5.

2. Related Studies
As mentioned in part 1, the objective of this research is to predict vegetarian food among the elderly preferences using an artificial neural networks (ANN) hybrid with particle swarm optimization (PSO) to find the optimal structural and initial weight calculation of the artificial neural network model. Therefore, the research related to this research is as following.

2.1. Vegetarian food
Vegetarian food is defined as a meal that does not contain meat. Most vegetarian diets are made up of plants, vegetables and fruits, as well as using vegetable seasonings. There are studies involving fruit and vegetable consumption as follows: Yuan-Ting (2016) studied of older people who consumed more fruits and vegetables and found that they used less medical services [8]. Kahleova et al. (2018) studied a vegetarian diet for a 40 percent reduction in cardiovascular risk and coronary heart disease risk. In addition, it reduces the risk of the cardiac muscle by more than 80 percent according to nutrition [5].

2.2. An artificial Neural Network

An artificial neural network is a machine learning model that is primarily used to classify or predict information. ANN is a model of the human brain. The human brain is able to adapt to changing situations and can learn very quickly in the right context. The model architecture is built with data and learning rules and is trained through algorithms to predict the later dataset [9]. ANN is organized into layers consisting of an input layer, hidden layer and output layer as shown in Figure 1. The hidden layer is the root of the actual computed ANN of the network. The network operates upon receiving the input dataset and the output layer produces the desired results. The weight of the neurons entering the network can be different. In the same way, the transfer function of different neurons may be different (usually the same). Therefore, ANN training is required to achieve proper networking [10].

![Figure 1. Architecture of a single hidden layer feedforward neural networks.](image)

The input data is transmitted from the input layer to the output layer and is carried out using a feedforward technique, that is, the data is fed from the first layer and then flows one-way through and through, all the way to the last layer without backward previous class. If the input data is transmitted from the input data layer to the output layer, and back-propagation (BP) techniques are used, a method that optimizes the connected weight of the nodes based upon the difference between the network results and the actual results [11]. This distributed processing system is mathematically defined by equation 1:

\[ y_i = \sum_{j=1}^{n} w_{ij} x_j + \beta_j \]  \hspace{1cm} (1)

where, \( x_j \) is the input training node, \( w_{ij} \) are the connection weights associated with the input, hidden and layer nodes, \( \beta_j \) is the bias of the hidden and the output layer nodes and \( n \) is the number of input signals, \( i \) is the source node (\( i = 1, \ldots, n \)) and \( j \) is the destination node (\( j = 1, \ldots, n \)) [12]. Learning the ANN process is typically using a back-propagation algorithm (BP). BP is a complex gradient algorithm used to optimize the ANN by changing the weight of each node and bias conditions until the output values at the output layer most closely predict the actual results, resulting in less error training [13]. In this work, PSO is applied as a training algorithm.

Flow chart of the ANN training process can be described as follow. First of all, the input and output parameters of the ANN model are specified. Second, define appropriate learning algorithms and input-output datasets. The most appropriate neural network architecture and training parameters are then selected. Finally, the trained networks can be tested and used for simulations and predictions after the neural network training as shown the figure 2 [14].
2.3. Particle Swarm Optimization

Particle swarm optimization (PSO), an algorithm using swarm intelligence proposed by Kennedy and Eberhart [15]. The approach was inspired by birds, fish, and other similar social behaviours found in nature [16], by regrouping, redirecting, and speed suddenly to simulate the movement of the group. The principle idea of this algorithm is that it tries to find an optimised area, where each space has a degree of possibility for a candidate solution [17]. PSO starts with a random particle population and the algorithm finds the optimal population by updating generations [18].

The flowchart of PSO technique is shown in Figure 3 [14]. The operation of the PSO is described as follows 1. initialisation: determination of the position and velocity of random particles 2. evaluate fitness function: the fitness value is calculated for each particle with its position and speed updated 3. update pbest and gbest: the fitness value of each particle compared to the best individual pbest and the current position of particle X. Among all the particles, the best fitness value is defined as pbest or the global best value 4. update velocity and position: as defined by equation 2 and 3. 5. Meet the convergence: steps 2-4 are repeated until the stopping threshold is successful in order to achieve the best fitness value or the maximum number of iterations. The convergence means that the results from the model are close to the actual values. The more convergence, the closer the results from the model to the actual values. In this experiment, it can be observed from the loss function, which convergence near zero [19].

Updated velocity of particle

\[
V_{id}^{j+1} = wV_{id}^j + c_{1}r_{1}(p_{best_{id}} - X_{id}^j) + c_{2}r_{2}(g_{best_{id}} - X_{id}^j)
\]  

(2)

Updated position of particle

\[
X_{id}^{j+1} = X_{id}^j + V_{id}^{j+1}
\]  

(3)

**Figure 2.** Flow chart of the ANN training process [18].

**Figure 3.** Flow chart of a Particle Swarm Optimization (PSO) [14].
Where \( V_{id}^{j+1} \) = updated velocity of particle \( i \) in dimension \( d \) search region
\( V_{id}^{j} \) = velocity of particle \( i \) at iteration \( j \)
\( X_{id}^{j+1} \) = updated position of particle \( i \) in dimension \( d \) search region
\( X_{id}^{j} \) = position of particle \( i \) at iteration \( j \)
\( c_1, c_2 \) = acceleration factors
\( r_1, r_2 \) = random constant between 0 and 1
\( w \) = inertia weight

The PSO algorithm is used to develop the weight of a multilayer back forward of artificial neural network. The position of the particles in the loop is described as the particle with the coordinates as the connecting weight. Throughout the training process, the above equations (Equations (2) and (3)) refine the network weights until meeting the criteria. PSO uses a randomization process in the search area of the problem to bring the particles in the population to the optimal position. The optimum values obtained from the PSO were then used to testing the ANN model. The steps of the PSO training algorithm for ANN are shown in figure 4. The PSO algorithm is applied to provide the ANN model to have better predictive results.

![Figure 4. PSO-based algorithm flowchart in optimization of the weights of ANN [13].](image)

The application of ANN and PSO are, for example, Kengpol (2006) assessing customer satisfaction in choosing the right fragrances for each customer group by using ANN [20]. Somchai et al. (2014) used to identify populations at high risk for hypertension and to correctly identify patients with cervical cancer. In classification, the data was 90.95 percent on average by using ANN [21]. Ozerdem et al. (2017) modelled the problem of predicting short-term burden using the particle swarm optimization loads for the feedforward neural network. The result shown that the neural network is optimized for the particle group and results in faster convergence in less time [22]. Bensingh (2019) applied a hybrid neural network (ANN) and particle swarm optimization (PSO) techniques to predict
the optimal process parameters of the biosphere lens injection molding process. In this experiment, the efficiency of the ANN-PSO and ANN-GA (Genetic algorithm) hybrid was compared. It was found that PSO converged faster than GA within 40 to 50 iterations for all the five test runs [23]. Al-Majidi (2020) predicted the peak power point of solar cell arrays using feedforward artificial neural network (ANN) and particle swarm optimization (PSO) techniques to improve the accuracy of the ANN model. The result shown that the PSO technique, used in conjunction with feedforward ANN, can accurately predict the maximum power point. In addition, the converging speed of the proposed method has been enhanced under a transient state [12]. Zhang et al. (2020) predicted the stability of roads in tunnels and underground areas using the PSO optimized ANN model, abbreviated to the ANN-PSO model. Additionally, five other methods were developed and compared, including multiple linear regression (MLR), hybrid neural fuzzy inference system (HYFIS), support vector machine (SVM), classification and regression tree (CART), and conditional inference tree (CIT) in conjunction with the proposed ANN-PSO model to provide a comprehensive assessment. All five method comparisons show that ANN-PSO is most effective when measured by Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and R² [24].

Prediction is the analysis of historical data to find patterns of relationships in a data set that can be used as models for predictions, predicting outcomes or things that may happen in the future. Predictive results help a person or organization to make more effective decisions. From a related study on the prediction of food, Giuliani et al. (2015) predict daily food intake as a model to measure and assess differences in reaction and food [25]. Hunt et al. (2018) predict food insecurity in communal areas. Food safety links are examined among multiple demographics, socioeconomic, social risk factors, and food access variables. The findings of this research can help provide information on appropriate interventions by recommending food assistance programs to those in need [26]. Giacalone et al. (2019) study the relationship between the suitability of the situation and the product selection for food and beverages. A simple way to hedonic data is that of item-by-use (IBU) "appropriateness" or "situational fitness". Consumers are given a list of possible consumption situations and are asked to specify how well the product fits each of them. This study shown that the perceived suitability of consumers in food and beverage choices significantly affects their response to consumption [27]. Ruby et al. (2019) predict an adult consumer's willingness to handle safe food in the home, where there was no previous research on safe food handling and preparation among adult consumers. Ruby, therefore, predicts the effectiveness of using the theory of planned behavior (TPB) model to describe the objectives of safe food handling and preparation and to analyze the effect of food safety knowledge on consumer attitudes. The findings suggest that food safety knowledge affects consumer attitudes and can also help develop effective intervention strategies for improving safe food handling at home [28]. In the food industry, food safety, suitability, and quality are key issues directly related to health and society. Predicting or recommending food consumption to consumers is one of the factors that make consumers decide to consume food. Most consumers look for food products that are more reliable and expect manufacturers to provide quality products that are suitable for themselves [29]. Increasing consumer awareness of food safety and quality issues has led to the development of new, more complex techniques for choosing the right food for the consumer. Prediction of food that is appropriate for the consumer is a promotion of the health of the consumer. From the perspective of the manufacturer, being able to produce food that meets the needs of consumers is also promotion.

From the research mentioned above, the artificial neural network is capable of learning, recognition, classification, prediction. PSO can increase efficiency and speed in artificial neural network models. When PSO is hybridized with ANN, the neural network model is optimized as the PSO determines the optimum weight to feed the ANN model, which can be used to predict it more efficiently and reduce processing time. Therefore, the objective of this research is to apply the artificial neural network to predict vegetarian food preferences among the elderly and apply ANN hybrid with PSO to calculate the optimal weight of the neural network by comparing the efficacy between the ANN model and hybrid ANN with PSO (ANN-PSO). PSO was used to optimize the
weights between neurons and each layer bias in the ANN model. The performance of the model can be considered by analyzing loss function (cross entropy loss) and accuracy.

3. Methodology
The method of operation is separated into three steps, data collection, data analysis, and validation, as shown in Figure 5. Each of the steps is detailed as following.

3.1. Data collection
In this study, all 10 of the most consumed vegetarian dishes, which have been chosen by vegetarian restaurants. These dishes have nutritional properties as determined by the Institute of Nutrition in Thailand [30]. Ten food menus are included: 1. chili sauce with tamarind 2. red curry chicken with chakram 3. spice vegan soup 4. spicy fruit salad 5. Thai rice and herb salad 6. deep fried spring roll 7. Thai spicy mixed mushroom salad 8. stir-fired tempeh with cashew nuts 9. spicy winged bean salad 10. fried ivy gourd leaf with spicy cream dressing [31]. Each menu is made from ingredients that offer preventive, mitigating and curing benefits. For example, ivy gourd is a gentle, nutritious green fruit and a good source of protein, calcium, fiber and beta-carotene, vitamin A. Ivy Gourd can preserve eyesight, and improve vision, and lowers blood sugar levels by 20 percent [32]. Consuming certain mushrooms or consuming specific ingredients from them may reduce the risk of certain diseases. Mushrooms have been proposed as a potential breast cancer risk reduction agent [33]. These vegetarian foods are suitable for all 5 medical including high blood pressure, osteoarthritis, cataracts, high cholesterol, and diabetes. These are the most common diseases among the elderly in Thailand [1].

Figure 5. A structure of prediction preference vegetarian food.

This research creates a questionnaire and gather data from a sample of the elderly, which is a pilot study. Data is gathered from 100 customers who bought vegetarian food in vegetarian restaurants. The data are collected in 2 parts as follows: part 1 is individual questionnaires for vegetarian food consumers consisted of gender and 11 chronic diseases, setting the nominal scale and part 2 is a vegetarian menu preference questionnaire, where all 10 vegetarian menus are defined.

3.2. Data Analysis
Design a data analysis using Python program version 3.7 to create model an artificial neural network. The experiment is performed by assigning the input layer to 13 nodes (gender 2 node, chronic disease 11 node included high blood pressure, osteoarthritis, cataract, high cholesterol, diabetes, dementia, cardiovascular, depression, stroke, emphysema and other) and the output layer 10 nodes (vegetarian food menu).
food menu 10 node). In this trial, PSO is used to determine the optimal weight of a backpropagation neural network. Define the activation function of the hidden layer and output layer as sigmoid function. The sigmoid function, which produces a result between 0 - 1, is suitable for using in this task where the probability result is 0 = no and 1 = yes, as shown in Equation 4. The training cycles are set equal to 1,000 epochs. The learning rate and momentum are in the range [0, 1] [34].

\[
\text{Sigmoid Function} = \frac{1}{1 + e^{-x}}
\]  

(4)

### 3.3. Validation
This step determines how close the simulation is to the real value. By considering the loss function value using cross entropy loss, which is used for multi-class problem classification. Cross entropy loss is a calculation of the error that the result of the model is different from the actual result. The lower the cross entropy loss value, the more accurate the classification of the data can be. The assessment of accuracy is the ratio of the total number of correct predictions calculated from Equation (5) by True Positive (TP) rate, True Negative (TN) rate, False Positive (FP) rate, False Negative (FN) rate for each type of dataset [35].

\[
\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN}
\]  

(5)

### 4. Experiments and results
In this experiment, a survey of vegetarian food preferences among 100 elderly people in Bangkok, Thailand was initiated by collecting data on gender, congenital disease, and vegetarian food that the elderly enjoyed. This research is a pilot study to survey the preferences of vegetarian food in a restaurant with a small number of elderly people. Therefore, the researcher collects data from only 100 elderly people, regardless of the proportion of the elderly by age, because if considering the proportion of the elderly according to the age, the data can be collected less and the data is insufficient for training. The majority of the sample was 78% female, 22% male, and had a chronic disease. The most common disease in the sample was high blood pressure 31.71%, osteoarthritis 20.72%, cataract 18.94%, diabetes 15.39%, and high cholesterol 6.18%, respectively. The results of a survey of vegetarian food menu for the elderly are shown in Table 1.

The experiment is conducted on an Intel (R) Core (TM) i7-10510U CPU@1.80Ghz 2.30 GHz RAM 8GB. This experiment is designed and conducted using a Python programming language to create an artificial neural network model based upon a vegetarian food preference survey database. In this section introducing experiments and results, these trials predict the elderly preferences for vegetarian food by analysing data comparison between an artificial neural network (ANN) and an artificial neural network hybrid with particle swarm optimization (ANN-PSO). In terms of ANN, it divides the 80% training dataset and 20% testing data of all data. The neural network has input layer 13 nodes and output layer 10 nodes output. The neural network is designed and tested for the number of hidden layers, which found that one hidden layer of 7 nodes yielded the best results as shown in Figure 6. In addition, adjusting the learning rate 0.5 and the momentum value 0.9, and set the training cycle equal to 1000 epochs, resulting in optimal results.

In terms of ANN-PSO, the experiments adjust \( r_1, r_2, w \) which are random within the range [0, 1] and the ratio of \( c_1, c_2 \), which determines the importance given to local best and global best to find the best way to predict vegetarian preferences [36]. Finally, the optimum parameter \( w = 0.5, c_1 = 0.4, c_2 = 0.5, r_1 = 0.1, r_2 = 0.1 \) provide the best prediction model results. The prediction results for vegetarian diets were obtained from the output layer of the neural network model. By comparison in terms of the Cross Entropy Loss. What confirms that the neural network model works correctly is that as training repetitions increase, the Cross Entropy Loss value decreases.
From the simulation, it is found that the ANN neural network alone has a loss function (cross entropy loss) of training data 0.15 and 0.19 of testing data and that the neural network analysis method hybrid with PSO had a loss function of training data 0.03 and test data 0.023 as shown in Table 2.

Table 1. The results of a survey of vegetarian food menu for the elderly.

| Chronic disease          | Favorite food menu                                           |
|--------------------------|--------------------------------------------------------------|
| High blood pressure      | (M) Chili sauce with tamarind (F) Red curry chicken with chakram |
| Osteoarthritis           | (M) Spice vegan soup (F) Spice vegan soup                    |
| Cataract                 | (M) Spicy fruit salad (F) Spice vegan soup                   |
| High cholesterol         | (M) Thai rice and herb salad, chili sauce with tamarind, spice vegan soup, spicy fruit salad |
| Diabtes                  | (M) Spicy fruit salad (F) Thai spicy mixed mushroom salad    |
| Dementia                 | (M) Chili sauce with tamarind (F) Red curry chicken with chakram |
| Depression               | (M) Spice vegan soup                                         |
| Stroke                   | (F) Stir-fired tempeh with cashew nuts                       |

Table 2. The results of the vegetarian diet prediction experiment

| Parameter                | ANN     | ANN-PSO |
|--------------------------|---------|---------|
|                          | train ANN | test ANN | train ANN-PSO | test ANN-PSO |
| Cross Entropy Loss       | 0.15     | 0.19     | 0.03          | 0.02          |

The simulation test show that the Cross Entropy Loss decreased with the increase in the number of training and testing cycles, and the accuracy of ANN training data 0.92 and testing data 0.90. As for the ANN-PSO method, training accuracy was 0.95 and for testing data 0.96. From the experiment, the Cross Entropy Loss and the accuracy are consistent, that is, when the number of training cycles increased, the lower the Cross Entropy Loss (less error), the greater the accuracy, meaning the ANN-PSO can actually be used to predict preferences as shown in Figure 7.

Figure 7. Relationship Cross Entropy Loss and Epochs
5. Conclusion

In this research, a prediction of vegetarian food preferences among the elderly is presented using a hybrid method that included an artificial neural network (ANN) and particle swarm optimization (PSO) or called ANN-PSO. Based upon a survey of elderly vegetarian food preferences from a vegetarian restaurant in Thailand, where the majority of Thai people consume streamed rice along with dishes or condiments. The survey found that most of the elderly liked the spice vegan soup the most followed by spicy fruit salad, chili sauce with tamarind. Most of the elderly male prefer chili sauce with tamarind and spicy fruit salad the most. The elderly female prefer red curry chicken with chakram, spice vegan soup, and spicy fruit salad respectively. In the survey, most of the elderly choose to consume food that they like, regardless of the benefits or properties of the ingredients on the menu and their health. In terms of the vegetarian food prediction experiment, the results show that the artificial neural network method, hybrid with particle swarm optimization, which was used to determine the optimum weight of the neural network, performed better than that of an artificial neural network alone. Besides, this model has high accuracy up to 0.95, which can be applied to the elderly. This research is a tool that can predict vegetarian food preferences for the elderly, but whether the elderly choose to consume it or not, depending upon themself. It also allows producers to recognize the elderly preferences for vegetarian food and can offer food menus or produce foods based upon the preferences of the elderly. This research has explored and predicted preferences for only vegetarian food and the elderly in Thailand. For future work, this model can be applied to survey and predict the preferences of foreigners who like vegetarian food in Thailand or to explore and predict vegetarian preferences in other countries where different preferences can be tested. Moreover, it can be surveyed in an application on a mobile phone or a website so that the elderly or vegetarian food producers can comfortably predict vegetarian food preferences from each elderly person.

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