Fuzzy Multi-Objective Linear Programming Method

Applied in Decision Support System
to Control Chronic Disease

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Abstract

Diet and nutrition plays a key role to maintain good health. Based on the statistics results, it shows that bad eating habits and dietary changes, the tendency to promote people to get chronic disease is high. Fuzzy Multi-Objective Linear Programming approach has been employed to obtain a complete food plan for human body. This plan will help people to obtain nutritional requirements in daily routine and to control chronic disease such as diabetes and heart attack. Decision Support System for Health was created to identify chronic and suggest food plan

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Keywords: diet, nutrition, chronic disease, Fuzzy Multi-Objective Linear Programming, decision support system
1. Introduction

Nowadays, diet of western society has become increasingly energy-rich but nutrient-poor [1]. This situation has been expressed concern for over thirty years. People consider that they are able to choose what they eat and how much they want to eat. Thus, they do not concern about a balanced diet and nutrient requirement for their body. A healthy diet relationship with food and human body will leads to develop physical and mental [2]. Only a small percentage of people meet dietary requirements for vitamin E, potassium, calcium, magnesium, and fiber or consume sufficient vegetables and fruit. Many researchers prove that the diet and nutrition plays a key role as a risk factor for chronic diseases for many years [3]. It has been calculated that, in 2001, chronic diseases contributed approximately 60% of the 56.5 million total reported deaths in the world [4].

The main factors that contribute to this problem are bad eating habits and dietary changes. From the statistics, most health experts believe as much as 50-60% of cancers are due to bad eating habits [5]. In addition, the risk of being obese or overweight is directly related to bad eating habits such as skipping meals, eating away from home, high consumption of fast and processed foods, as well as low consumption of fruit and vegetables. For dietary adjustments, it may not only influence present health, but may determine whether or not an individual will develop such diseases as cancer, cardiovascular disease, and diabetes much later in life [6].

However, diet and nutrition play a fundamental role in the promotion and maintenance of good health throughout the entire life course. Nutrition specifically identified the need to prevent and control chronic diseases by promoting appropriate diets and healthy lifestyle. Nutrient-rich diets high in whole grains, low-fat dairy products, lean meats, fish, and vegetables and fruit are typically recommended for good health. In addition, it also can help prevention and control of chronic disease. Increasing consumption of fruits, vegetables, and other foods high in fiber, and reducing consumption of total fat to less than 30% of average daily caloric intake may be protective and reduce cancer risk among the United States population [7].

Mamat et al. [8], [9] discussed about optimizing human diet problem with price using fuzzy linear programming. In this research, fuzzy theory approach was employed, where the prices of food were assumed as fuzzy numbers. The study identifies that a minimizing cost human diet problem with fuzzy price could be a minimum cost diet problem of human. It also shows that the most expensive diet is low-carbohydrate. By minimizing the cost, human still can fulfill their nutrient requirement every day.
2. Method

This study focused on Fuzzy Multi-Objective Linear Programming (FMOLP) method. This method is one of Fuzzy Linear Programming (FLP) method. Therefore, the FMOLP method has been implemented in Decision Support System for Health. The method is shown as follows:

The FLP model may be expressed as:

\[
\text{Minimize } \sum_{j=1}^{n} \overline{c}_j x_j \\
\text{Subject to } \sum_{j=1}^{n} a_{ij} x_j \geq b_i, \sum_{j=1}^{n} a_{ij} x_j \leq d_i, \quad i = 1, 2, ..., m; \quad x_j \geq 0
\] (2.1)

where:
- \( x_j \) : 100 g of food \( j \) eaten per day
- \( a_{ij} \) : the amount of nutrient \( i \) in 100 g of food \( j \)
- \( b_i \) : the required daily amount of nutrient \( i \)
- \( c_j \) : the nutrients in food \( j \) per 100 g
- \( d_i \) : the maximum daily amount of nutrient \( i \)
- \( m \) : the number of nutrients
- \( n \) : the number of food.

\( c_j \) is the uncertain value of nutrients in food \( j \) per 100 g. \( \overline{c}_j = (c_j^- / c_j / c_j^+) \) are triangular fuzzy numbers that assign the uncertain value of nutrients in food. Since the uncertain nutrients in formula (2.1) are assigned by triangular fuzzy number \( \overline{c}_j = (c_j^- / c_j / c_j^+) \), the objective will become multi-objective. The multi-objective problems can be represented by FMOLP method. Definition 1 shows the membership function of triangular fuzzy number.

**Definition 1.** The membership function of triangular fuzzy number \( \overline{c}_j = (c_j^- / c_j / c_j^+) \) is:
\[ \mu_{c_j}(x) = \begin{cases} 
\frac{(x - c_j^-)}{(c_j^+ - c_j^-)}, & c_j^- < x < c_j \\
\frac{(c_j^+ - x)}{(c_j^+ - c_j^-)}, & c_j \leq x < c_j^+ \\
0, & x \geq c_j^+ \text{ or } x \leq c_j^- 
\end{cases} \quad (2.2) \]

where \( \mu_{c_j}(x) \) is the membership function for uncertain value of nutrients in food \( j \) per 100 g.

Equation (2.3) shows the formula of multi-objective:
\[
\min \sum_{j=1}^{n} c_j^- x_j, \ \min \sum_{j=1}^{n} c_j x_j \ \text{and,} \ \min \sum_{j=1}^{n} c_j^+ x_j \quad (2.3)
\]

The objectives also can be written as:
\[
\max z_1 = \sum_{j=1}^{n} (c_j - c_j^-) x_j, \ \min z_2 = \sum_{j=1}^{n} c_j x_j \ \text{and,} \ \min z_3 = \sum_{j=1}^{n} (c_j^+ - c_j) x_j \quad (2.4)
\]

The maximum and minimum value for each objective can be determined based on the specified constraints. It is show as follows:

\[
\begin{align*}
z_i^{\max} &= \max z_i \text{ and} \\
 z_i^{\min} &= \min z_i, \ i = 1, 2, 3 \\
\text{subject to} &\quad \sum_{j=1}^{n} a_{ij} x_j \geq b_i, \ \sum_{j=1}^{n} a_{gj} x_j \leq d_i, \\
&\quad i = 1, 2, \ldots, m, \ x_j \geq 0.
\end{align*} \quad (2.5)
\]

Based on equation (2.5), the membership function of each objective for FMOLP is defined as:
\[
\begin{align*}
\mu_{z_1}(x) &= \begin{cases} 
1, & z_1 > z_1^{\max} \\
(z_1 - z_1^{\min})/(z_1^{\max} - z_1^{\min}), & z_1^{\min} < z_1 \leq z_1^{\max} \\
0, & z_1 \leq z_1^{\min} 
\end{cases} \quad (2.6) \\
\mu_{z_2}(x) &= \begin{cases} 
1, & z_2 < z_2^{\min} \\
(z_2^{\max} - z_2)/ (z_2^{\max} - z_2^{\min}), & z_2^{\min} \leq z_2 < z_2^{\max} \\
0, & z_2 \geq z_2^{\max} 
\end{cases} \quad (2.7)
\end{align*}
\]
Fuzzy multi-objective linear programming method

\[
\mu_{z_3}(x) = \begin{cases} 
1 & , z_3 < z_3^\text{min} \\
(z_3^\text{max} - z_3)/(z_3^\text{max} - z_3^\text{min}) , & z_3^\text{min} \leq z_3 < z_3^\text{max} \\
0 & , z_3 \geq z_3^\text{max}
\end{cases} 
\quad (2.8)
\]

Based on fuzzy decision making proposed by (Bellman and Zadeh [10]; Fang et al. [11]), let
\[
\beta = \min_{x} \{ \mu_{z_1}(x), \mu_{z_2}(x), \mu_{z_3}(x) \}
\]

From equation (2.6), (2.7), and (2.8), the model in problem 2.1 becomes the following optimization problem:

maximize \( \beta \)

subject to 
\[
\sum_{j=1}^{n} (c_j^0 - c_j^-)x_j \geq \beta(z_1^\text{max} - z_1^\text{min}) \leq z_1^\text{max}
\]
\[
\sum_{j=1}^{n} c_j^0 x_j - \beta(z_2^\text{max} - z_2^\text{min}) \geq z_2^\text{min}
\]
\[
\sum_{j=1}^{n} (c_j^+ - c_j^0) x_j - \beta(z_3^\text{max} - z_3^\text{min}) \leq z_3^\text{min}
\]

where \( x_j \geq 0 \), \( 0 \leq \beta \leq 1 \).

3. Decision Support System For Health

Decision Support System for health is developed in order to meet the specific objectives. One of the objectives is to suggest a complete food plan for disease controlling. The food plan contains a balanced diet and nutritional requirements for people. However, people are required to recognize the type of disease based on the symptoms that have been experienced. It is another objective of DSS for health. The recognition process needs people to identify their symptoms based on the list of questions as certified by the doctor. Another objective is to suggest treatments and medications to control disease.

The symptoms of disease are divided into forty four main groups. This study shows only one of the examples of forty four main groups. Figure 3.1 shows forty four main groups of disease symptoms page. Figure 3.2 shows list of question for ankle problem symptom page. Figure 3.3 shows the result of disease recognition.
Figure 3.4 shows the nutrients requirements for human body. This figure contains the list amount of nutrients that user have, amount of suggested nutrients and amount of nutrients that should have for normal person. Figure 3.5 shows complete food plan for user.
Figure 3.3. Result of disease recognition page.

Figure 3.4. Nutrients requirements for human body.

Figure 3.5. Food plan for user page.
4. Testing And Evaluation

Testing and evaluation process for Decision Support System for health is carried out by 12 respondents within a range of 10 to 60 years old. The questionnaire consists of three sections: demography, overall system and evaluation of system function. Section A contains three parts in demographic including gender, age and occupations. Table 4.1 shows the demography of the respondents.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (Male)</td>
<td>11</td>
<td>45.8</td>
</tr>
<tr>
<td>Gender (Female)</td>
<td>13</td>
<td>54.2</td>
</tr>
<tr>
<td>Age (10-18 years)</td>
<td>4</td>
<td>16.7</td>
</tr>
<tr>
<td>Age (19-29 years)</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td>Age (30-50 years)</td>
<td>9</td>
<td>37.5</td>
</tr>
<tr>
<td>Age (51 years and above)</td>
<td>5</td>
<td>20.8</td>
</tr>
<tr>
<td>Occupation (Student)</td>
<td>4</td>
<td>16.7</td>
</tr>
<tr>
<td>Occupation (Government employees)</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td>Occupation (Private employees)</td>
<td>8</td>
<td>33.3</td>
</tr>
<tr>
<td>Occupation (Self-employed)</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>Occupation (Not Working)</td>
<td>1</td>
<td>4.2</td>
</tr>
<tr>
<td>Occupation (Retire)</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>Occupation (Others)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The findings show that the majority of the respondents are female and aged between 30 to 50 years old. Most of the respondents work as private employees and government employees and the remaining are student, self-employed, retire and not working.

Section B requires the respondents to give a scale on each question for the general performance of the system. This section contains six questions and the respondents need to state the scale from a range that starts with 1 until 5. Scale 1 denotes strongly disagree and Scale 5 denotes strongly agree. Table 4.2 shows the findings of general performance of the system.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Scale</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In general, the system is useful to be applied in daily live.</td>
<td>Neutral</td>
<td>7</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>12</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>5</td>
<td>20.8</td>
</tr>
<tr>
<td>The system is user-friendly.</td>
<td>Neutral</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>14</td>
<td>58.3</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>4</td>
<td>16.7</td>
</tr>
<tr>
<td>The design in the system looks attractive.</td>
<td>Neutral</td>
<td>5</td>
<td>20.8</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>16</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>The features in the system are very helpful to complete the task.</td>
<td>Neutral</td>
<td>8</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>16</td>
<td>66.7</td>
</tr>
<tr>
<td>The language used in this system is easy to understand.</td>
<td>Disagree</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>7</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>15</td>
<td>62.5</td>
</tr>
<tr>
<td>The instructions given by the system are clear.</td>
<td>Disagree</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>15</td>
<td>62.5</td>
</tr>
</tbody>
</table>

Based on the result of the findings, most of the respondents agree that the system is useful to be applied in daily live. Then, 75.0% of the respondents agree that the system is user-friendly. Majority of the respondents agree that the design in the system looks attractive. 66.7% of the respondents agree that the features in the system are very helpful to complete their task. Eight of the respondents state neutral scale on this question. Next, 8.3% of the respondents disagree about the language used in the system easy to understand. However, 62.5% of the respondents agree and 29.2% state
neutral scale. The findings also show that 15 respondents agree that the instructions given by the system are clear and the remaining give disagree and neutral scale. Therefore, the system does not have any critical problem and can be applied in daily live. The user-friendly system will help people to be more understand about the instructions and easy to use. The features in the system will help people to complete the process of disease recognition.

The next section is Section C. It is contains seven questions to evaluate function of the system. Each question represents a function applied in the system. The respondents required to give the scale 1 to 5 on each question in this section. Table 4.3 shows the evaluation of the system function.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Scale</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The system provides enough information about disease symptoms.</td>
<td>Disagree</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>7</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>14</td>
<td>58.3</td>
</tr>
<tr>
<td>All the questions displayed in the system are clear and easy to understand.</td>
<td>Disagree</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>16</td>
<td>66.7</td>
</tr>
<tr>
<td>The provided question meets the criteria for each symptom that experienced by me.</td>
<td>Neutral</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>14</td>
<td>58.3</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>4</td>
<td>16.7</td>
</tr>
<tr>
<td>The system provides a clear disease result.</td>
<td>Agree</td>
<td>17</td>
<td>70.8</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>7</td>
<td>29.2</td>
</tr>
<tr>
<td>The system suggests healthy foods to be taken in order to help me in getting a balance diet every day.</td>
<td>Neutral</td>
<td>7</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>12</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>5</td>
<td>20.8</td>
</tr>
<tr>
<td>The system suggests the type of treatments and medications that need to be taken based on the type disease.</td>
<td>Neutral</td>
<td>10</td>
<td>41.7</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>14</td>
<td>58.3</td>
</tr>
<tr>
<td>The suggested exercises are suitable with the type of disease faced by me.</td>
<td>Disagree</td>
<td>4</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>8</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>9</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>3</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Based on the findings in Table 4.3, 12.5% of the respondents disagree that the system provides enough information about disease symptoms. Meanwhile, 29.2% give
neutral scale and 58.3% of the respondents agree that the system provides enough information. Then, most of the respondents agree that all the questions displayed in the system are clear and easy to understand. Majority (75.0%) of the respondents agree that the provided question meets the criteria for each symptom that experienced by them. Seven one respondents state the neutral scale on this question. These findings also indicate that all the respondents fully agree about the system provides a clear result. Furthermore, a total of 70.8% of the respondents agree that the system suggests healthy foods to be taken in order to help them in getting a balance diet every day. 58.3% of the respondents agree that the system suggests the type of treatments and medications that need to be taken based on the type disease. The other respondents give neutral scale. Lastly, four respondents disagree about the suggested exercises are suitable with the type of disease faced by them. Twelve of the respondents agree and the remaining is neutral.

As a conclusion, the respondents give positive feedback on the evaluation of system function. Several respondents give neutral scale for certain questions. It can be considered as the doubts in decision making. However, most of the respondents agree on all the provided questions. They also give good comments in order to improve the system in the future.

5. Conclusion

Fuzzy Multi-Objective Linear Programming method is used to create food plans that best resemble current eating habits while meeting nutritional requirements. Meanwhile, Decision Support System for health is developed to give an easy way to recognize disease and get a complete food plan. It can give benefits for people that have chronic disease to control the way of eating habits by taking nutrient-rich foods.

References


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