



Triangular Fuzzy Number Generator (TriGen)

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ABSTRACT

The Triangular Fuzzy Number Generator (TriGen) demonstrated in this paper is a software tool which is developed to generate symmetry Triangular Fuzzy Number (TFN). Preparing TFN manually for fuzzy system or analysis requires calculation effort. When the number of data increases, calculating TFN requires longer time to complete and may be exposed to calculation error. Hence TriGen is developed to diminish computational difficulties and reduce processing time of calculating TFN. This tool provides a function for capturing input data and calculates the spread of TFN based on Percentage Error and Standard Deviation approaches. The tool also embeds the formulas that allow it to calculate the actual result. Technical problem solving is described by numerical examples.

Key words: Triangular Fuzzy Number, Spread, Data Preparation Tool, Standard Deviation

1. INTRODUCTION

Data preparation involves the process of cleaning, transforming, consolidation or manipulation of raw data. It is an important process to transform a data source into a format, quality and structure suitable for further analytic [1][2]. Data preparation is crucial as it prepares data and its content to the next process. It also ensures data that is ready for analysis is accurate and consistent to produce valid analytics result. Though data preparation is said to be time-consuming and crucial process, however it is required to produce accurate, meaningful and clean data to leverage the analytics. Data preparation is needed as raw data may contain discrepancies, outliers or errors, and/or lack of attributes. Data preparation ensures data to be formatted sufficiently and adheres to specific set of rules [2]. In data mining and machine learning, various techniques of data pre-processing has been used [3] and yield the improvement in the analytic model's performance. A formal data preparation process allows less time to find and structure the data sufficiently. Additionally, it enhances the performance and accuracy of the analytic model.

Fuzzy systems application in industrial and scientific applications are widespread [3]–[10]. In a fuzzy system, data is presented in a fuzzy number form to exhibit the fuzziness or uncertainty of the domain case study [11], [12]. Fuzzy numbers are defined as a generalization of a real number (crisp and non-fuzzy) to a set of possible values, between 0 and 1 [13]. This weight is known as the membership function. Based on membership function, fuzzy number is built. Fuzzy data can be presented in a form of center value (crisp) with its spread. However, data that is collected from real-world application (non-fuzzy) is not literally in the fuzzy format. Organizing and preparing the non-fuzzy data to fuzzy data format should be done correctly to avoid mistakes. Thus, computational tool is neces-

sary to assist fuzzy data preparation efficiently while saving computation time and prevent mistakes.

Fuzzy numbers are used to represent fuzziness and play an important role in many applications [13]. Nevertheless, the main difficulty in the development of applications is the computational complexity [12], [14]. Apart from algorithm development, more attention should also be placed on computerizing data preparation and transformation for fuzzy numbers. As the volume of data grows, computational efficiency is a concern. The use of manual calculation for fuzzy data preparation is tedious due to the requirement of considerable time and effort from the programmer's expertise [15]. Hence, the Triangular Fuzzy Number Generator (TriGen) is developed to reduce the computation task of fuzzy data preparation and transformation. This tool allows the construction of symmetry triangular fuzzy numbers \tilde{y} in a form of center c and spread α , $\tilde{y} = [c, \alpha]$. Furthermore, TriGen provides a function to upload real number datasets as input and allow the user to download the generated spread of TFN in comma-separated values (CSV) format. Accompanying the tool is the function that generates spread based on Standard Deviation and Percentage Error approaches. Such approaches are optimized to determine symmetry triangular fuzzy numbers to obtain the interval parameters in fuzzy forms.

The remaining of the paper is organized as follows. Section 2 provides the concept and formulation of triangular fuzzy numbers. Section 3 explains the structure of the application tool with its input, process algorithm and output. Section 4 presents the result and discussion. Finally, Section 5 provides the overall conclusions.

2. TRIANGULAR FUZZY NUMBER GENERATOR (TRIGEN) PROCESS ALGORITHM

Section 2.1 describes the formulation and calculation of triangular fuzzy numbers [12], [16], [17]. While Section 2.2 explains the Triangular Fuzzy Number Generator (TriGen) algorithm.

2.1. Triangular Fuzzy Number

Let \tilde{y} be a triangular fuzzy number with membership function:

$$\tilde{y} = m(x) = \begin{cases} \frac{x-a}{b-a}, & x \in [a, b] \\ \frac{c-x}{c-b}, & x \in [b, c] \\ 0, & x < a \text{ and } x > c \end{cases} \quad (1)$$

From Eq. (1), a triangular fuzzy number is defined as

$$\tilde{y} = [\alpha_l, c, \alpha_r]. \quad (2)$$

From Eq. (2), a symmetry triangular fuzzy number has same spread, $\alpha_2 - \alpha_1 = \alpha_3 - \alpha_2$. \tilde{y} is denoted as

$$\tilde{y} = [c, \alpha], \tag{3}$$

where c is center value and α is spread of triangular fuzzy number. \tilde{y} is non-fuzzy number if $\alpha = 0$.

In this study, the spread of symmetry TFN is generate based on Standard Deviation (SD) and Percentage Error (PE) approaches. In various fuzzy system application, usually spread is determined by the human expert with experience to define the fuzziness or uncertainty in the data [18]. However, less effort has been made to determine the spread in building fuzzy number with absence of expert justification. Though, determination of spread is important and need to be defined before TFN is built. Thus, the two approaches of standard deviation and percentage error are proposed to define the spread in a systematic procedural step.

Standard deviation is defined as follows:

$$S = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n}} \tag{4}$$

where S , is standard deviation for population, x_i is each values of the data, \bar{x} is the mean of x_i and n is the number of data points.

Based on standard deviation approach, the standard deviation σ value in Equation (4) is used to determine the spread S . The symmetry TFN of \tilde{y}_t^S is as follows:

$$\tilde{y}_t^S = [y_t - s, y_t, y_t + s] \tag{5}$$

where \tilde{y}_t^S is a fuzzy time series data at time, t with TFN form with spread of standard deviation, S and y_t is a time series data at time, t ($t = 1, 2, \dots, n$).

Figure 1 shows the symmetry triangular fuzzy number based on Equation (5).

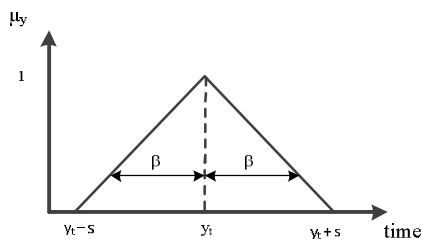


Figure 1: Symmetry TFN using standard deviation approach

While, in percentage error approach, the 95% confidence interval is optimized whereby the spread of TFN is adjusted from 5%, 3% and 1%. Only 5% spread and less are considered as the best spread to be used following the nature of confidence interval [19]. The symmetry TFN of \tilde{y}_t^p is written as:

$$\tilde{y}_t^p = [y_t - y_t \cdot p, y_t, y_t + y_t \cdot p] \tag{6}$$

where \tilde{y}_t^p is a fuzzy time series data at time, t with TFN form with spread, p ($p = 0.01, 0.03, 0.05$). y_t is a time series data at time, t ($t = 1, 2, \dots, n$).

Percent error refers to the difference between measured value and the accepted value. It is often used to report the difference between experimental values and accepted value.

$$\text{percent error} = \frac{|ev-av|}{av} \times 100\% \tag{7}$$

where ev is experimental value and av is accepted value.

In this paper, the TriGen tool is developed based on first order of autoregressive (AR1) model. The following process algorithm explains the steps taken by the TriGen.

1.2. Triangular Fuzzy Number Generator (TriGen) Algorithm

The algorithm process of TriGen is described as follows:

- Step 1.** Data input preparation.
Input format to generate TFN is $y_t = y_1, y_2, \dots, y_n$
- Step 2.** Calculate Standard Deviation
The Standard Deviation, σ is calculated according to the Equation (4).
- Step 3:** Calculate spread of Standard Deviation, S .
The spread of Standard Deviation, S of each data is calculated based on Equation (5).
- Step 4.** Calculate spread of Percentage Error, p .
The spread of Percentage Error, p of each data is calculated based on Equation (6).
- Step 5.** Generate symmetry triangular fuzzy number.
TFN are generated based on spread of Percentage Error, S and spread of Standard Deviation, p . Triangular fuzzy number will be computed by TriGen.

The existing TriGen is developed to provide computation for generating TFN. Practically, the tool is able to compute correctly, reduce computational difficulties and also reduce the computational time as compared to manual calculation by hand. User may opt for percentage error or standard deviation approach to define the spread for symmetry triangular fuzzy number. This tool is also capable to import AR(1) input through comma-separated values (CSV) format and transforming the input into TFN form.

3. THE SOFTWARE TOOL: TRIANGULAR FUZZY NUMBER GENERATOR (TRIGEN)

TriGen is built based on Javascript to generate the spread of TFN. While, HTML is used to design the interface of TriGen and with some element of CSS. The input, output and the main structure of the software is described in this section. The features provided by TriGen follows algorithm procedures which is defined in Section 2.2.

3.1. Input: Data Preparation

Time series datasets will be used as input to generate spread of TFN in this study. The dataset is sorted by the previous data to the most recent data. Dataset should be arranged in CSV file format. The input data format is as shown in Figure 2.

	A
1	6339.24
2	6251.48
3	6292.32
4	6353.74
5	6385.4
6	6373.14
7	6371.17
8	6386.34
9	6370.06
10	6382.19
11	6429.69
12	6444.52
13	6472.67
14	6490.9

Figure 2: Input datasets in CSV format.

The dataset which is uploaded to the TriGen is used to compute the TFN's spread. Figure 3 shows user interface for dataset file selection and upload function in TriGen.

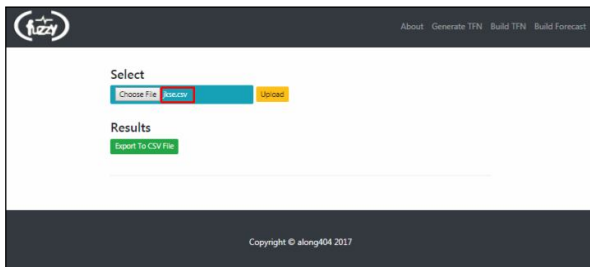


Figure 3: Dataset selection and upload function.

3.2. Output: The spread of TFN

The computation results are presented in the same view after the 'Upload' button is clicked. In this view we can see the generated spread of TFN. The calculation is computed based on the algorithm described in Section 2.2.

Functions is used to help the calculation and to provide an organized layout. Figure 4 describes the algorithm used to compile the entire process.

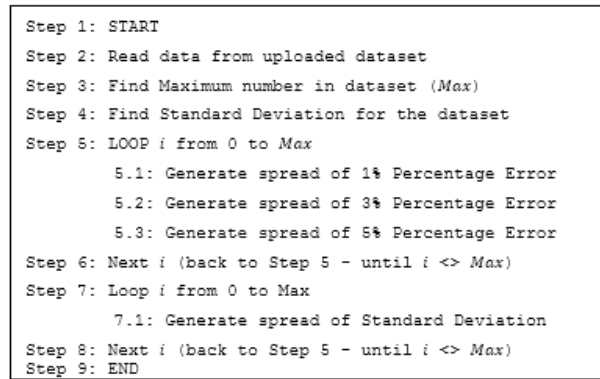


Figure 4: Algorithm on the Structure of Data Flow.

The spread of triangular fuzzy number is computed by TriGen based on Standard Deviation and Percentage Error approach. The algorithm in Figure 4 is transformed into program code. Declaration is the main part in code and is demonstrated in Figure 5.

```

7   var table = $("#resultTable");
8   var resulthtml2 = "";
9   resulthtml2 += ["<tr>"];
10  <th></th>"];
11  <th><font size="3"> y</font><font size="1">t</font></th>"];
12  <th width="10%"><font size="3"> TFN</font><font size="1"> C</font></th>"];
13  <th><font size="3"> TFN</font><font size="1"> 5% L</font></th>"];
14  <th><font size="3"> TFN</font><font size="1"> 5% R</font></th>"];
15  <th><font size="3"> TFN</font><font size="1"> 3% L</font></th>"];
16  <th><font size="3"> TFN</font><font size="1"> 3% R</font></th>"];
17  <th><font size="3"> TFN</font><font size="1"> 1% L</font></th>"];
18  <th><font size="3"> TFN</font><font size="1"> 1% R</font></th>"];
19  <th><font size="3"> TFN</font><font size="1"> Std Dev L</font></th>"];
20  <th><font size="3"> TFN</font><font size="1"> Std Dev R</font></th>"];
21  "</tr>"];
22
23  var y = 0;
24  var length_csv = 0;
25  var keep_all = new Array();
26  var keep_all_yt = new Array();
27
    
```

Figure 5: Variable declaration.

Another important part in coding is the process. It is the most critical part because how the programmer organizes the code will influence the performance of the developed tool. Figure 6 shows code segment to read the input and keep the data in the array.

```

27
28
29  var regex = /^[a-zA-Z0-9\s\.\-:;]+(\.csv|.txt)$/;
30  if (regex.test($("#fileUpload").val().toLowerCase())) {
31    if (typeof( FileReader ) != "undefined") {
32      var reader = new FileReader();
33      reader.onload = function (e) {
34        var rows = e.target.result.split("\n");
35        length_csv = rows.length;
36        for (var i = 0; i < length_csv - 1; i++) {
37
38          keep_all[i]=rows[i];
39
40          var yt = rows[i];
41
42          keep_all_yt[i]=yt;
43
    
```

Figure 6: Data arrangement.

The array of data is then used to generate the spread of TFN with related Equation from Section 2.1. Figure 7 shows the code segment to generate the spread of TFN.

```

54
55
56  for (var i = 0; i < length_csv-1; i++) {
57
58    yt = keep_all_yt[i];
59
60    var yt5 = yt * 0.05;
61    var yt3 = yt * 0.03;
62    var yt1 = yt * 0.01;
63
    
```

Figure 7: TFN spread generator.

```

95 function standardDeviation(arr){
96   var n = arr.length;
97   var sum = 0;
98
99   arr.map(function(data) {
100     sum+=Number(data);
101   });
102
103   var mean = Number(sum) / Number(n);
104
105   var variance = 0;
106   var v1 = 0;
107   var v2 = 0;
108
109   if (n != 1) {
110     for (var i = 0; i<n; i++) {
111       v1 = v1 + (arr[i] - mean) * (arr[i] - mean);
112       v2 = v2 + (arr[i] - mean);
113     }
114
115     v2 = v2 * v2 / n;
116     variance = (v1 - v2) / (n-1);
117     if (variance < 0) { variance = 0; }
118     stddev = Math.sqrt(variance);
119
120     return stddev;
121   }
122 }
    
```

Figure 8: Standard Deviation calculation.

There is also special function that have been set to calculate the value of the standard deviation which is based on Population Standard Deviation. Figure 8 shows the function to calculate the Standard Deviation. Figure 9 shows the program code to display the result, which is generated spread of TFN.

```

63 resultHtml2 += [
64   '<tr id="row">',
65   '<td>', 'yt' + (i+1), '</td>',
66   '<td>', 'yt', '</td>',
67   '<td>', 'yt', '</td>',
68   '<td>', (yt-yt5).toFixed(4), '</td>',
69   '<td>', (yt-yt3).toFixed(4), '</td>',
70   '<td>', (Number(yt)+Number(yt3)).toFixed(4), '</td>',
71   '<td>', (yt-yt1).toFixed(4), '</td>',
72   '<td>', (Number(yt)+Number(yt1)).toFixed(4), '</td>',
73   '<td>', (yt-stdDev).toFixed(4), '</td>',
74   '<td>', (Number(yt)+Number(stdDev)).toFixed(4), '</td>',
75   '</tr>'].join("\n");
76
77
    
```

Figure 9: Algorithm on the Structure of Data Flow.

The download function is provided for user to transfer the generated spread of TFN into CSV file format for further analysis. Figure 10 shows the code segment for data export.

```

194 function exportTableToCSV(filename) {
195   var csv = [];
196   var rows = document.querySelectorAll("table tr");
197
198   for (var i = 0; i < rows.length; i++) {
199     var row = [], cols = rows[i].querySelectorAll("td, th");
200
201     for (var j = 0; j < cols.length; j++)
202       row.push(cols[j].innerText);
203
204     csv.push(row.join(","));
205   }
206
207   // Download CSV file
208   downloadCSV(csv.join("\n"), filename);
    
```

Figure 10: Export and download function.

Figure 11 shows the code which is used for TriGen interface to display all the generated TFN's spread.

```

<section id="about" style=" padding-top: 50px; padding-bottom: 50px;"
<div class="container">
<div class="row">
<div class="col-lg-8 mx-auto">
<div>
<div>
<div class="table">
<table border="1">
<thead>
<tr>
<th>TFN C</th>
<th>TFN 5% L</th>
<th>TFN 5% R</th>
<th>TFN 3% L</th>
<th>TFN 3% R</th>
<th>TFN 1% L</th>
<th>TFN 1% R</th>
<th>TFN SD L</th>
<th>TFN SD R</th>
</tr>
</thead>
</table>
</div>
</div>
</div>
</div>
</div>
</div>
    
```

Figure 11: Result displays.

4.RESULT AND DISCUSSION

Based on the algorithm process in Section 2.2, TriGen produces the spread of TFN from single point data (input). The gener-

ated result computed by TriGen yield similar values with manual calculation by using Microsoft Excel. In contrast, user need to set each column with percentage error or standard deviation formula, as shown in Figure 12. However, in TriGen such calculation is automatically completed by the tool.

Figure 12: Construction of TFN in Microsoft Excel.

TriGen provide a file upload function. User need to prepare datasets such as illustrated in Figure 1, and upload into TriGen. The tool will automatically generate spread of TFN based on Standard Deviation and Percentage Error approach. Figure 13 shows the generated spread of TFN. In addition, TriGen provide function that allow user to download the spreads in CSV format for further analysis. Figure 14 show the generated spreads in CSV format.

Based on Figure 12 (manual) and Figure 14 (TriGen), both methods produce the same result. To validate the generated spread result with the manual calculation, we test the percent error for each spread based on Equation 7. This is to ensure that this tools produce the significant result with manual calculation.

Table 1: Percent error for generated spread.

5% PE		3% PE		1% PE		SD	
Left	Right	Left	Right	Left	Right	Left	Right
0	0	0	0	0	0	0	0

* The percent error is in percentage (%)

Table 1 shows the percent error for generated spread. From Table 1, we can see that the percent error for all spread is 0% which tell us that this tools have achieved the same result with the manual calculation. However, TriGen offer least computation effort in constructing TFN. Besides that, TriGen also reduce computational error compare to manual calculation because the formula is embedded inside the TriGen. This tool also provides a function to determine the spread.

5.CONCLUSION

This paper presents TriGen, a tool to build symmetry triangular fuzzy number. This tool accepts the single point input which will then be used to generate spreads of TFN. TriGen provides four variations spreads of TFN as a result from the standard deviation and percentage error approaches. From this result, extensive study and analysis can be conducted to select best spread to be used. Also, TriGen is able to compute the spread of TFN efficiently and uses less of computation time. This tool can also give users the option to download the generated spreads in CSV format. For enhancement, the function of TriGen will be embedded with first order autoregressive function. The tool should be able to predict using the generated spreads and produce the Means Square Error automatically.

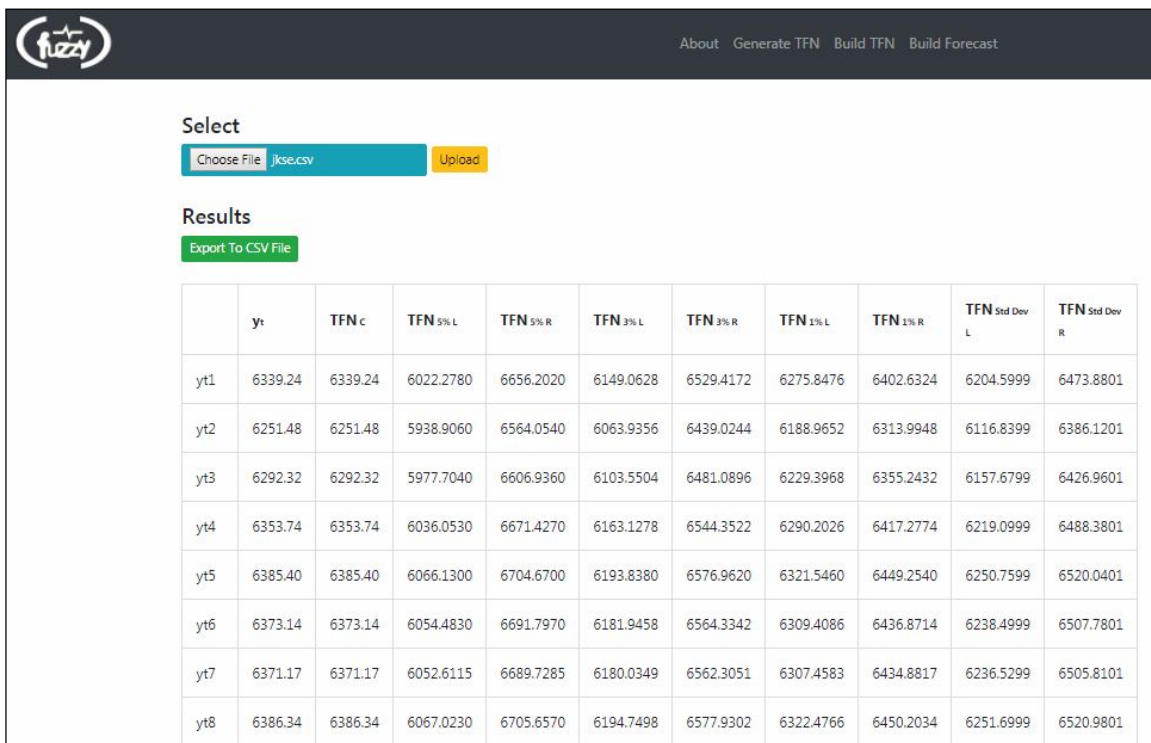


Figure 13: Generated spread of TFN using TriGen

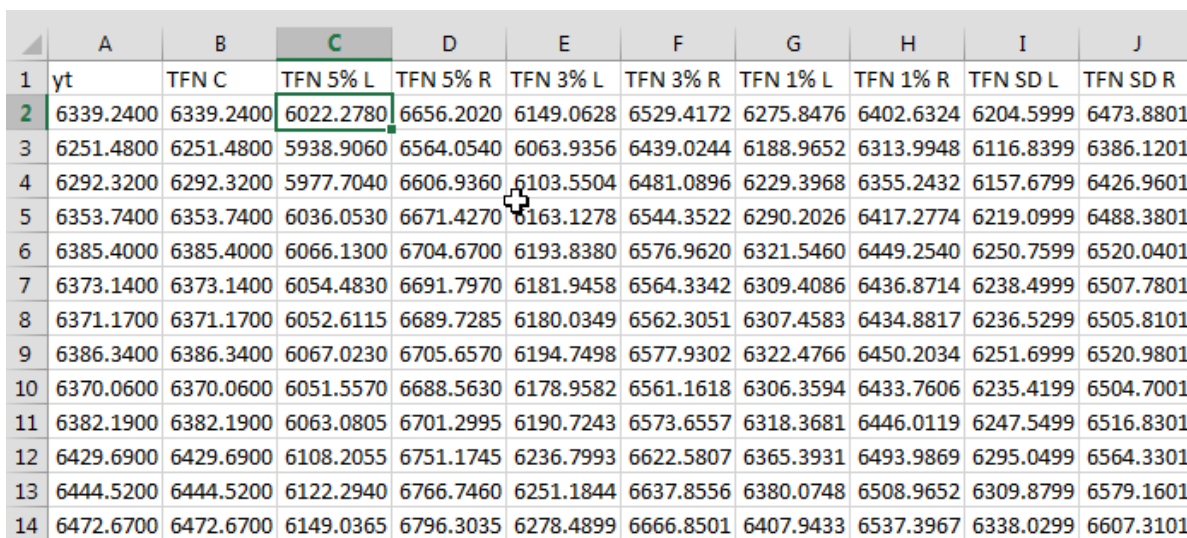


Figure 14: Generated spread of TFN in CSV using Microsoft Excel

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