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Converting intervals into triangular fuzzy numbers for information security risk assessment systems

Presented method of transformation intervals in triangular fuzzy numbers for risk analysis and assessment systems, that will allow to automatize the intervals transformation process without involvement of subject field expert's.

In the course of solving problems of analysis and evaluation of information security risks in poorly formalized environments, it is often necessary to perform data processing in fuzzy conditions. Often, in practice, situations arise where such a transformation in the future may lead to inaccuracies in the calculation of final results due to inconsistencies in thoughts or expert mistakes.

To implement such a process, systems are used in which evaluation is based on linguistic variables based on reference parametric triangular fuzzy numbers (FN) with a given number of terms. Standards are determined by experts at the initialization stage of the basic values in the process of setting up such systems. As a basis, the expert takes intervals of values, which, based on their findings, transforms into a FN.

The effectiveness of using such rating systems will increase if the possibility of automated transformation of intervals is provided without the involvement of experts. To solve this problem, an appropriate conversion method is proposed. It will simplify the procedure for the formation of standards, due to the implementation of the process of transforming the intervals into triangular fuzzy numbers and minimizes the influence of the human factor.

The purpose of this work is to develop a method for transforming the intervals into triangular fuzzy numbers to further automate the corresponding construction process.

The work of the method for the transformation of intervals is presented in the form of a sequence of the following steps:

Stage 1 – Defining Corrective Parameters:

$$h_j = \frac{k_{j+1} - k_j}{m-1},$$

where k_j – numerical values of intervals for risk assessment $(j = \overline{1,m})$.

Stage 2 - Calculating Abscis values for triangular FN:

$$a'_j = k_j - h_j;$$

$$c'_j = k_{j+1} + h_j\,;$$
$$b'_j = k_j + 2h_j\,.$$

Stage 3 – Determination of the base shift value and the correction of terms:

$$sf = b'_1 - k_1\,,$$

$$a''_j = a'_j - sf\,;$$
$$c''_j = c'_j - sf\,;$$
$$b''_j = b'_j - sf\,,$$

where sf – is the shift parameter.

Stage 4 – The normalization of the resultant triangular FN:

$$a_j = (a''_j \times k_{m+1}) / b''_m\,;$$
$$c_j = (c''_j \times k_{m+1}) / b''_m\,;$$
$$b_j = (b''_j \times k_{m+1}) / b''_m\,;$$

where $j = \overline{1,m}$.

In this case, for

$$\overset{m}{\underset{j=1}{\forall}} (a_j\,,\ b_j\,,\ c_j) < 0$$

$a_j = b_j = c_j = 0$, and for

$$\overset{m}{\underset{j=1}{\forall}} (a_j\,,\ b_j\,,\ c_j) > k_{m+1}$$

in accordance $a_j = b_j = c_j = k_{m+1}$.

To illustrate the work of the method as an example, the source data used to represent the intervals with an even, uneven, growing and regressive type of distribution was used. The linguistic variable (LV) "EVALUATION PARAMETER LEVEL" (***EP**$_i$*) is used to represent the overall evaluation result.

For example, LV $\boldsymbol{EP_i}$ is determined by the intervals from the table. To determine the numerical values $\underset{\sim}{T}_{EP_{ij}}$, $j = \overline{1,5}$ we use the data from Table. with an even type of distribution of FN, that is, for which the condition of uniformity is true (see (6) in [5]): $\Omega_p =$ $(EP_2\ -EP_1 =\ EP_3\ -EP_2) \wedge (EP_3 - EP_2 = EP_4 - EP_3) = (2-0=4-2) \wedge (4-2=6-4) = 1 \wedge 1 = 1$.

Proceeding from the fact that $\Omega_p = 1$, the intervals $\boldsymbol{EP_i}$ [3] correspond to an even type of distribution.

Next, we use the expressions (1) – (5) to implement the procedure for transforming the specified intervals.

Stage 1. On the basis of the expression (1) we define the correcting parameters at m=5, $h_1 = \dfrac{k_2 - k_1}{4} = \dfrac{20-0}{4}$ =0,5; $h_2 = 0{,}5$; $h_3 = 0{,}5$; $h_4 = 0{,}5$; $h_5 = 0{,}5$.

Stage 2. Define the abscissas of expression (2): $a'_1 = k_1 - h_1$ =0–0,5=–0,5; $a'_2 = k_2 - h_2$ =1,5; $a'_3 = k_3 - h_3$ =3,5; $a'_4 = 5{,}5$; $a'_5 = 7{,}5$;
$c'_1 = k_2 + h_1$ =2,5; $c'_2 = 4{,}5$; $c'_3 = 6{,}5$; $c'_4 = 8{,}5$; $c'_5 = 10{,}5$;
$b'_1 = k_1 + 2h_1$ =1; $b'_2 = k_2 + 2h_2$ =3; $b'_3 = 5$; $b'_4 = 7$; $b'_5 = 9$.

Step 3. Calculate the values of the shift in expression (3): $sf = b'_1 - k_1$ = 1 – 0 = 1 and carry out a correction sf , based on the basis of (4):
$a''_1 = a'_1 - sf$ = –0,5–1 = –1,5; $a''_2 = 0{,}5$; $a''_3 = 2{,}5$; $a''_4 = 4{,}5$; $a''_5 = 6{,}5$;
$c''_1 = c'_1 - sf$ =1,5; $c''_2 = 3{,}5$; $c''_3 = 5{,}5$; $c''_4 = 7{,}5$; $c''_5 = 9{,}5$;
$b''_1 = b'_1 - sf$ =0; $b''_2 = 2$; $b''_3 = 4$; $b''_4 = 6$; $b''_5 = 8$.

Step 4. Perform the normalization values obtained by the formula (5): $a_1 = (a''_1 \times k_6)/b''_5$ =–1,88; $a_2 = 0{,}63$; $a_3 = 3{,}13$; $a_4 = 5{,}63$; $a_5 = 8{,}13$; $c_1 = (c''_1 \times k_6)/b''_5$ =1,88; $c_2 =$ 4,38; $c_3 = 6{,}88$; $c_4 = 9{,}38$; $c_5 = 11{,}88$; $b_1 = (b''_1 \times k_6)/b''_5 = 0$ etc.

Based on (5), $a_1 = 0$ and $c_5 = 10$, and all values displayed in the table.

Thus, for the first time, the method of converting intervals into triangular fuzzy numbers for systems of analysis and evaluation of information security risks, which, due to the implementation of parameters adjusting procedures, the formation of new abscissa values for the corresponding parametric numbers, the determination of the baseline value of the shift, the correction of the terms and the normalization of the result, allows us to formalize the process of developing standards without the participation of experts in the relevant subject area.

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