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MARKING A DOCUMENT USING AN EXPERT-FUZZY APPROACH TO ASSESSING THE CONFIDENTIALITY OF ITS CONSTITUENT INFORMATION

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Анотація. *Інтенсивний розвиток інформаційних технологій зумовив підвищений інтерес суспільства до проблем інформації та інформаційної безпеки і спричинив різке збільшення загальногалузевої наукової активності у цій сфері. Численні наукові праці в цій галузі стали фундаментом для розробки теоретичних основ регулювання суспільних відносин в інформаційній сфері. Разом із тим, ці праці мають виключно цивільно-правовий характер. Водночас питання регулювання відносин у тому, що стосується комерційної таємниці, у них або не розглядаються взагалі, або розглядаються лише фрагментарно. Комплексне дослідження багатокритеріального оцінювання рівнів конфіденційності відомостей, які підлягають включенню до документа, раніше не проводилося. У статті розглянуто підхід до оцінки рівня конфіденційності відомостей, які підлягають включенню до майбутнього документа. Цей підхід ґрунтується на застосуванні експертних висновків щодо ступенів впливу ознак конфіденційності на підсумковий рівень конфіденційності. Механізм нечіткого висновку, що становить аналітичну суть підходу, вирішує поставлене завдання, спираючись на прямий причинно-наслідковий зв'язок між ознаками конфіденційності відомостей та рівнями конфіденційності документів. Раніше внаслідок застосування системи нечіткого висновку вдалося сформувати обґрунтовану шкалу градації рівнів конфіденційності документів і досить легко отримати підсумкові оцінки рівнів конфіденційності відомостей, які підлягають включенню до майбутнього документа. У цій статті вирішується анологічне завдання, але вже з застосуванням іншого методу фазифікації ознак конфіденційності як якісних критеріїв оцінки.*

Ключові слова: *маркування документів, фактор конфіденційності, експертна оцінка, нечітка множина, нечіткий висновок.*

Abstract. *The intensive development of information technologies predetermined the increased interest of society in the problems of information and information security and led to a sharp increase in the industry-wide scientific activity in this area. Numerous scientific works in the subject area have become the basis for the development of theoretical foundations for the regulation of public relations in the information sphere. At the same time, the listed works are of an exclusively civil law nature. The issues of regulating relations regarding commercial secrets are either not considered at all or are considered fragmentarily. A comprehensive study on the multi-criteria assessment of the levels of information confidentiality to be included in the document has not previously been undertaken. The article discusses an approach to assessing the level of information confidentiality to be included in a future document. This approach is based on the application of expert judgments regarding the degree of influence of confidentiality features on the final level of confidentiality. The fuzzy inference mechanism, which constitutes the analytical essence of the approach, solves the task, relying on a direct cause-effect relation between the signs of the information confidentiality and the levels of the confidentiality of the documents. Earlier, because of the application of the fuzzy inference system, it was possible to form a reasonable scale of gradation of the levels of the confidentiality of the documents and it is quite easy to obtain final estimates of the levels of the information confidentiality to be included in a future document. In the current article, a similar problem is solved, but with the use of another method of fuzzification of confidentiality features as qualitative assessment criteria.*

Keywords: *document marking, confidentiality factor, expert judgment, fuzzy set, fuzzy inference.*

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1. Introduction

Existing approaches to the procedure for establishing the degree of information confidentiality to be included in future documents are based on the use of heuristic knowledge (in particular, the preference system) of the head responsible for assigning a confidentiality stamp (HCS) [1, 2]. At the same time, the process of establishing the level of confidentiality has several drawbacks, the main one of which is the low objectivity of the confidentiality assessment, due to the system of subjective preferences, which the HCS uses when analyzing contextual information for their confidentiality [3]. Therefore, to increase the objectivity of the process of assessment, synthesis, and selection of a consolidated solution with respect to the level of secrecy of information to be included in the document, it is necessary to attract independent expert knowledge and opinions regarding the presence of confidentiality factors and their influence on the level of secrecy. Based on these prerequisites, the importance and relevance of the study of methods for a balanced assessment of the level of confidentiality of documents become obvious.

In our previous works (see, for example, [4, 5]), to fuzzify confidentiality features as qualitative evaluation criteria, documents subject to confidentiality classification were considered as a universe. In this work, the description of confidentiality features in the form of fuzzy sets is carried out on a completely different basis.

The aim of the work is to create a mechanism for assessing the confidentiality of information to be included in a future document, which is the first step to protect documented information, allowing ensuring relatively reliable security of official secrets within a particular organization.

2. Problem definition

Assessment of the degree of confidentiality of information to be included in the document is a multi-criteria procedure that implies the application of the compositional rule for aggregating the assessment for each of the confidentiality signs: x_1 – economic significance; x_2 – scientific significance; x_3 – price significance; x_4 – official level; x_5 – interest in information from foreign countries; x_6 – attitude towards the publication of such information in foreign countries.

Suppose that 15 experts $(e_k(k=1\div15))$ are invited to identify the confidentiality features (CF) $x_i(i=1\div6)$ in the information to be included in the proposed (specific) document *D*. Corresponding estimates were obtained by independent questioning on a 100-point scale, so that for each k the condition $\sum_{i=1}^{6} e_{ki}=100$ is fulfilled. The obtained expert judgments are summarized in Table 1.

Table 1 – Expert judgments relative to the significance of the CF for specific document *D*

CF	Symbols of experts and their assessments on a 100-point scale														
	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}
x_1	30	25	20	30	20	30	20	28	27	30	25	30	20	30	25
x_2	25	18	25	20	25	20	25	25	10	20	15	25	25	18	15
x_3	15	20	10	10	30	15	13	12	20	25	18	20	17	20	20
x_4	20	12	15	27	15	18	15	20	13	15	20	8	15	15	10
x_5	7	15	18	5	8	7	17	5	25	3	12	15	13	10	25
x_6	3	10	12	8	2	10	10	10	5	7	10	2	10	7	5

Based on the data from Table 1, it is necessary to fuzzify the confidentiality features of information, to form an appropriate fuzzy inference system and establish the confidentiality stamp for the given document *D*.

3. Expert assessment of the level of confidentiality of a document using a fuzzy inference system

To aggregate the conclusions of experts regarding the presence of CF in the information from the point of view of their influence on the general level of secrecy of information to be included in the document, the following statements are taken as a basis:

d_1: "If in the assessed document the expert has identified CF x_1, x_2 and x_3, then the level of secrecy of information is significant";

d_2: "If the expert has identified four CFs (x_1, x_2, x_3 and x_6), then the level of secrecy of information is already more than significant";

d_3: "If in the process of analysis the expert has identified all types of CF, then the level of secrecy of information is too significant";

d_4: "If, in addition to the CFs specified in d_2, the expert additionally established the presence of FC x_5, then the level of secrecy of information is very significant";

d_5: "If among the CFs identified by the expert only x_1, x_2, x_3 and x_4 are significant, and the rest CFs x_5 and x_6 are insignificant, then the level of secrecy of information is still significant";

d_6: "If the expert does not identify the CFs x_1, x_2, x_4 and x_5, then the level of secrecy of information is insignificant".

The analysis of these considerations allows allocating six qualitative evaluation criteria, presented in the form of the term "VISIBLE" for each of the input linguistic variables $x_i (i = 1 \div 6)$, and the output characteristics, reflected in the form of the corresponding terms of the linguistic variable y – the level of secrecy of information to be included into the document. The output linguistic variable y is specified on a discrete set $J = \{0;\ 0{,}1;\ 0{,}2;\ ...;1\}$, and its terms are specified using the corresponding membership functions for all $j \in J$ as follows [6, 7]:

- Y_1 = SIGNIFICANT: $\mu_{Y1}(j) = j$;
- Y_2 = MORE THAN SIGNIFICANT: $\mu_{Y2}(j) = \sqrt{j}$;
- Y_3 = VERY SIGNIFICANT: $\mu_{Y3}(j) = j^2$;
- Y_4= TOO SIGNIFICANT: $\mu_{Y_4}(j) = \begin{cases} 1, & j = 1, \\ 0, & j < 1; \end{cases}$
- Y_0 = INSIGNIFICANT: $\mu_{Y0}(j) = 1 - j$.

Fuzzification of terms in the left-hand sides of the rules is carried out using the Gaussian membership function [8]:

$$\mu(u_i) = \exp\{-(u_i - 100)^2 / \sigma_{ki}^2\} \quad (k = 1 \div 15),$$

describing the corresponding fuzzy subset of the discrete universe $\{e_1, e_2, ..., e_{15}\}$, where $\sigma_{ki}^2 = 2500$ is the density assumed to be the same for all cases; e_{ki} is the *k*-th expert's estimate relative to the significance of the CF $x_i (i = 1 \div 6)$ (see Table 1).

In this case, the term "VISIBLE", as one of the values of the linguistic variables x_i, in each specific case can be described in the form of the following corresponding fuzzy sets:

X_1={0,1409/e_1; 0,1054/e_2; 0,0773/e_3; 0,1409/e_4; 0,0773/e_5; 0,1409/e_6; 0,0773/e_7; 0,1257/e_8; 0,1186/e_9; 0,1409/e_{10}; 0,1054/e_{11}; 0,1409/e_{12}; 0,0773/e_{13}; 0,1409/e_{14}; 0,1054/e_{15}};

X_2={0,1054/e_1; 0,0679/e_2; 0,1054/e_3; 0,0773/e_4; 0,1054/e_5; 0,0773/e_6; 0,1054/e_7; 0,1054/e_8; 0,0392/e_9; 0,0773/e_{10}; 0,0556/e_{11}; 0,1054/e_{12}; 0,1054/e_{13}; 0,0679/e_{14}; 0,0556/e_{15}};

X_3={0,0556/e_1; 0,0773/e_2; 0,0392/e_3; 0,0392/e_4; 0,1409/e_5; 0,0556/e_6; 0,0484/e_7; 0,0452/e_8; 0,0773/e_9; 0,1054/e_{10}; 0,0679/e_{11}; 0,0773/e_{12}; 0,0636/e_{13}; 0,0773/e_{14}; 0,0773/e_{15}};

X_4={0,0773/e_1; 0,0452/e_2; 0,0556/e_3; 0,1186/e_4; 0,0556/e_5; 0,0679/e_6; 0,0556/e_7; 0,0773/e_8; 0,0484/e_9; 0,0556/e_{10}; 0,0773/e_{11}; 0,0339/e_{12}; 0,0556/e_{13}; 0,0556/e_{14}; 0,0392/e_{15}};

X_5 = {0,0314/e_1; 0,0556/e_2; 0,0679/e_3; 0,0271/e_4; 0,0339/e_5; 0,0314/e_6; 0,0636/e_7; 0,0271/e_8; 0,1054/e_9; 0,0232/e_{10}; 0,0452/e_{11}; 0,0556/e_{12}; 0,0484/e_{13}; 0,0392/e_{14}; 0,1054/e_{15}};

X_6 = {0,0232/e_1; 0,0392/e_2; 0,0452/e_3; 0,0339/e_4; 0,0215/e_5; 0,0392/e_6; 0,0392/e_7; 0,0392/e_8; 0,0271/e_9; 0,0314/e_{10}; 0,0392/e_{11}; 0,0215/e_{12}; 0,0392/e_{13}; 0,0314/e_{14}; 0,0271/e_{15}}.

Taking into account the introduced formalisms, the rules $d_1 \div d_6$ are formulated as follows:

d_1: "If $x_1 = X_1$ and $x_2 = X_2$ and $x_3 = X_3$, then $y = Y_1$";

d_2: "If $x_1 = X_1$ and $x_2 = X_2$ and $x_3 = X_3$ and $x_6 = X_6$, then $y = Y_2$";

d_3: "If $x_1 = X_1$ and $x_2 = X_2$ and $x_3 = X_3$ and x_4=X_4 and x_5 =X_5 and x_6=X_6, then $y = Y_4$";

d_4: "If $x_1 = X_1$ and $x_2 = X_2$ and $x_3 = X_3$ and $x_5 = X_5$ and $x_6 = X_6$, then $y = Y_3$";

d_5: "If $x_1 = X_1$ and $x_2 = X_2$ and $x_3 = X_3$ and $x_4 = X_4$ and $x_5 = \neg X_5$ and $x_6 = \neg X_6$, then $y = Y_1$";

d_6: "If $x_1 = \neg X_1$ and $x_2 = \neg X_2$ and $x_4 = \neg X_4$ and $x_5 = \neg X_5$, then $y = Y_0$".

Applying the operation of intersection of fuzzy sets to the left-hand sides of the given above rules [7], the corresponding membership functions μ_{Mi}= (u) (i = 1 ÷ 6) are established as follows:

d_1: μ_{M1} = min{$\mu_{X1}(u)$; $\mu_{X2}(u)$; $\mu_{X3}(u)$}; M_1 = {0,0556/e_1; 0,0679/e_2; 0,0392/e_3; 0,0392/e_4; 0,0773/e_5; 0,0556/e_6; 0,0484/e_7; 0,0452/e_8; 0,0392/e_9; 0,0773/e_{10}; 0,0556/e_{11}; 0,0773/e_{12}; 0,0636/e_{13}; 0,0679/e_{14}; 0,0556/e_{15}};

d_2: μ_{M2} = min{$\mu_{X1}(u)$; $\mu_{X2}(u)$; $\mu_{X3}(u)$; $\mu_{X6}(u)$}; M_2 = {0,0232/e_1; 0,0392/e_2; 0,0392/e_3; 0,0339/e_4; 0,0215/e_5; 0,0392/e_6; 0,0392/e_7; 0,0392/e_8; 0,0271/e_9; 0,0314/e_{10}; 0,0392/e_{11}; 0,0215/e_{12}; 0,0392/e_{13}; 0,0314/e_{14}; 0,0271/e_{15}};

d_3: μ_{M3} = min{$\mu_{X1}(u)$; $\mu_{X2}(u)$; $\mu_{X3}(u)$; $\mu_{X4}(u)$; $\mu_{X5}(u)$; $\mu_{X6}(u)$}; M_3 = {0,0232/e_1; 0,0392/e_2; 0,0392/e_3; 0,0271/e_4; 0,0215/e_5; 0,0314/e_6; 0,0392/e_7; 0,0271/e_8; 0,0271/e_9; 0,0232/e_{10}; 0,0392/e_{11}; 0,0215/e_{12}; 0,0392/e_{13}; 0,0314/e_{14}; 0,0271/e_{15}};

d_4: μ_{M4} = min{$\mu_{X1}(u)$; $\mu_{X2}(u)$; $\mu_{X3}(u)$; $\mu_{X5}(u)$; $\mu_{X6}(u)$}; M_4 = {0,0232/e_1; 0,0392/e_2; 0,0392/e_3; 0,0271/e_4; 0,0215/e_5; 0,0314/e_6; 0,0392/e_7; 0,0271/e_8; 0,0271/e_9; 0,0232/e_{10}; 0,0392/e_{11}; 0,0215/e_{12}; 0,0392/e_{13}; 0,0314/e_{14}; 0,0271/e_{15}};

d_5: μ_{M5} = min{$\mu_{X1}(u)$; $\mu_{X2}(u)$; $\mu_{X3}(u)$; $\mu_{X4}(u)$; 1 – $\mu_{X5}(u)$; 1 – $\mu_{X6}(u)$}; M_5 = {0,0556/e_1; 0,0452/e_2; 0,0392/e_3; 0,0392/e_4; 0,0556/e_5; 0,0556/e_6; 0,0484/e_7; 0,0452/e_8; 0,0392/e_9; 0,0556/e_{10}; 0,0556/e_{11}; 0,0339/e_{12}; 0,0556/e_{13}; 0,0556/e_{14}; 0,0392/e_{15}};

d_6: μ_{M6} = min{1 – $\mu_{X1}(u)$; 1 – $\mu_{X2}(u)$; 1 – $\mu_{X4}(u)$; 1 – $\mu_{X5}(u)$}; M_6 = {0,8591/e_1; 0,8946/e_2; 0,8946/e_3; 0,8591/e_4; 0,8946/e_5; 0,8591/e_6; 0,8946/e_7; 0,8743/e_8; 0,8814/e_9; 0,8591/e_{10}; 0,8946/e_{11}; 0,8591/e_{12}; 0,8946/e_{13}; 0,8591/e_{14}; 0,8946/e_{15}}.

As a result, the rules can be rewritten in the more compact form:

d_1: "If $x = M_1$, then $y = Y_1$";

d_2: "If $x = M_2$, then $y = Y_2$";

d_3: "If $x = M_3$, then $y = Y_4$";

d_4: "If $x = M_4$, then $y = Y_3$";

d_5: "If $x = M_5$, then $y = Y_1$";

d_6: "If $x = M_6$, then $y = Y_0$".

Transformations of these rules using the Lukasiewicz implication [6, 7]

$$\mu(u, j) = \min\{1, 1 - \mu(u) + \mu(j)\}$$

made it possible to obtain the corresponding fuzzy relations in the form of the following matrices:

$R_1=$

	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0679	0,9321	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0773	0,9227	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0484	0,9516	1	1	1	1	1	1	1	1	1	1
0,0452	0,9548	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0773	0,9227	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0773	0,9227	1	1	1	1	1	1	1	1	1	1
0,0636	0,9364	1	1	1	1	1	1	1	1	1	1
0,0679	0,9321	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1

,

$R_2=$

	0	0,3162	0,4472	0,5477	0,6325	0,7071	0,7746	0,8367	0,8944	0,9487	1
0,0232	0,9768	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0339	0,9661	1	1	1	1	1	1	1	1	1	1
0,0215	0,9785	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0271	0,9729	1	1	1	1	1	1	1	1	1	1
0,0314	0,9686	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0215	0,9785	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0314	0,9686	1	1	1	1	1	1	1	1	1	1
0,0271	0,9729	1	1	1	1	1	1	1	1	1	1

,

$R_3=$

	0	0	0	0	0	0	0	0	0	0	1
0,0232	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	1
0,0392	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	1
0,0392	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	1
0,0271	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	1
0,0215	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	1
0,0314	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	1
0,0392	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	1
0,0271	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	1
0,0271	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	1
0,0232	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	0,9768	1
0,0392	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	1
0,0215	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	0,9785	1
0,0392	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	0,9608	1
0,0314	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	0,9686	1
0,0271	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	0,9729	1

,

R_4=

	0	0,01	0,04	0,09	0,16	0,25	0,36	0,49	0,64	0,81	1
0,0232	0,9768	0,9868	1	1	1	1	1	1	1	1	1
0,0392	0,9608	0,9708	1	1	1	1	1	1	1	1	1
0,0392	0,9608	0,9708	1	1	1	1	1	1	1	1	1
0,0271	0,9729	0,9829	1	1	1	1	1	1	1	1	1
0,0215	0,9785	0,9885	1	1	1	1	1	1	1	1	1
0,0314	0,9686	0,9786	1	1	1	1	1	1	1	1	1
0,0392	0,9608	0,9708	1	1	1	1	1	1	1	1	1
0,0271	0,9729	0,9829	1	1	1	1	1	1	1	1	1
0,0271	0,9729	0,9829	1	1	1	1	1	1	1	1	1
0,0232	0,9768	0,9868	1	1	1	1	1	1	1	1	1
0,0392	0,9608	0,9708	1	1	1	1	1	1	1	1	1
0,0215	0,9785	0,9885	1	1	1	1	1	1	1	1	1
0,0392	0,9608	0,9708	1	1	1	1	1	1	1	1	1
0,0314	0,9686	0,9786	1	1	1	1	1	1	1	1	1
0,0271	0,9729	0,9829	1	1	1	1	1	1	1	1	1

,

R_5=

	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0452	0,9548	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0484	0,9516	1	1	1	1	1	1	1	1	1	1
0,0452	0,9548	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0339	0,9661	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0556	0,9444	1	1	1	1	1	1	1	1	1	1
0,0392	0,9608	1	1	1	1	1	1	1	1	1	1

,

R_6=

	1	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1	0
0,8591	1	1	0,9409	0,8409	0,7409	0,6409	0,5409	0,4409	0,3409	0,2409	0,1409
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054
0,8591	1	1	0,9409	0,8409	0,7409	0,6409	0,5409	0,4409	0,3409	0,2409	0,1409
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054
0,8591	1	1	0,9409	0,8409	0,7409	0,6409	0,5409	0,4409	0,3409	0,2409	0,1409
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054
0,8743	1	1	0,9257	0,8257	0,7257	0,6257	0,5257	0,4257	0,3257	0,2257	0,1257
0,8814	1	1	0,9186	0,8186	0,7186	0,6186	0,5186	0,4186	0,3186	0,2186	0,1186
0,8591	1	1	0,9409	0,8409	0,7409	0,6409	0,5409	0,4409	0,3409	0,2409	0,1409
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054
0,8591	1	1	0,9409	0,8409	0,7409	0,6409	0,5409	0,4409	0,3409	0,2409	0,1409
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054
0,8591	1	1	0,9409	0,8409	0,7409	0,6409	0,5409	0,4409	0,3409	0,2409	0,1409
0,8946	1	1	0,9054	0,8054	0,7054	0,6054	0,5054	0,4054	0,3054	0,2054	0,1054

.

The intersection of these fuzzy relations forms a common functional solution in the form of the following matrix R:

$R =$

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
e_1	0.9444	0.9768	0.9409	0.8409	0.7409	0.6409	0.5409	0.4409	0.3409	0.2409	0.1409
e_2	0.9321	0.9608	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054
e_3	0.9608	0.9608	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054
e_4	0.9608	0.9729	0.9409	0.8409	0.7409	0.6409	0.5409	0.4409	0.3409	0.2409	0.1409
e_5	0.9227	0.9785	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054
e_6	0.9444	0.9686	0.9409	0.8409	0.7409	0.6409	0.5409	0.4409	0.3409	0.2409	0.1409
e_7	0.9516	0.9608	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054
e_8	0.9548	0.9729	0.9257	0.8257	0.7257	0.6257	0.5257	0.4257	0.3257	0.2257	0.1257
e_9	0.9608	0.9729	0.9186	0.8186	0.7186	0.6186	0.5186	0.4186	0.3186	0.2186	0.1186
e_{10}	0.9227	0.9768	0.9409	0.8409	0.7409	0.6409	0.5409	0.4409	0.3409	0.2409	0.1409
e_{11}	0.9444	0.9608	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054
e_{12}	0.9227	0.9785	0.9409	0.8409	0.7409	0.6409	0.5409	0.4409	0.3409	0.2409	0.1409
e_{13}	0.9364	0.9608	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054
e_{14}	0.9321	0.9686	0.9409	0.8409	0.7409	0.6409	0.5409	0.4409	0.3409	0.2409	0.1409
e_{15}	0.9444	0.9729	0.9054	0.8054	0.7054	0.6054	0.5054	0.4054	0.3054	0.2054	0.1054

.

It reflects on a finite discrete set $J = \{0;\ 0,1;\ 0,2;\ ...;\ 0,9;\ 1\}$ internal cause-effect relation between expert assessments regarding the presence of CF $x_i (i = 1 \div 6)$, on the one hand, and their influence on the confidentiality levels of the given document *D*, on the other.

According to [6, 8], the *k*-th row of the matrix *R* is the fuzzy subset of the universe *J* which formally reflects the conclusion of the *k*-th expert regarding the level of confidentiality of document *D*. To numerically interpret each of the expert conclusions the defuzzification procedure is applied. In particular, the conclusion of the first expert regarding the level of confidentiality of the document *D* (the 1st row of the matrix *R*) is interpreted by the following fuzzy set:

$$E_1=\{0,9444/0;\ 0,9768/0,1;\ 0,9409/0,2;\ 0,8409/0,3;\ 0,7409/0,4;\ 0,6409/0,5;\ 0,5409/0,6;\ 0,4409/0,7;\ 0,3409/0,8;\ 0,2409/0,9;\ 0,1409/1\}.$$

Then, establishing the α-level sets $E_{1\alpha}$ and calculating the corresponding cardinalities $M(E_{1\alpha})$ by formula $M(C_\alpha) = \frac{1}{n}\sum_{k=1}^{n} i_k$, $i_k \in C_\alpha$ [6], we have:

- for $0 < \alpha < 0,1409$: $\Delta\alpha = 0,1409$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; \dots; 0,8; 0,9; 1\}$, $M(E_{1\alpha}) = 0,50$;
- for $0,1409 < \alpha < 0,2409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; \dots; 0,8; 0,9\}$, $M(E_{1\alpha}) = 0,45$;
- for $0,2409 < \alpha < 0,3409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; \dots; 0,7; 0,8\}$, $M(E_{1\alpha}) = 0,40$;
- for $0,3409 < \alpha < 0,4409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7\}$, $M(E_{1\alpha}) = 0,35$;
- for $0,4409 < \alpha < 0,5409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; 0,4; 0,5; 0,6\}$, $M(E_{1\alpha}) = 0,30$;
- for $0,5409 < \alpha < 0,6409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; 0,4; 0,5\}$, $M(E_{1\alpha}) = 0,25$;
- for $0,6409 < \alpha < 0,7409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3; 0,4\}$, $M(E_{1\alpha}) = 0,20$;
- for $0,7409 < \alpha < 0,8409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2; 0,3\}$, $M(E_{1\alpha}) = 0,15$;
- for $0,8409 < \alpha < 0,9409$: $\Delta\alpha = 0,1$; $E_{1\alpha} = \{0; 0,1; 0,2\}$, $M(E_{1\alpha}) = 0,10$;
- for $0,9409 < \alpha < 0,9444$: $\Delta\alpha = 0,0036$; $E_{1\alpha} = \{0; 0,1\}$, $M(E_{1\alpha}) = 0,05$;
- for $0,9444 < \alpha < 0,9768$: $\Delta\alpha = 0,0324$; $E_{1\alpha} = \{0,1\}$, $M(E_{1\alpha}) = 0,10$.

The numerical assessment of the expert's conclusion E_1 relative to the level of confidentiality of document *D* is established as follows [6]:

$$F(E_1)=\frac{1}{\alpha_{\max}}\int_0^{\alpha_{\max}} M(E_1)d\alpha=\frac{1}{0,9768}\int_0^{0,9768} M(E_{1\alpha})d\alpha=\frac{1}{0,9768}[0.1409\cdot 0,5+0,1\cdot 0,45+0,1\cdot 0,40+$$
$$+0,1\cdot 0,35+0,1\cdot 0,30+0,1\cdot 0.25+0.1\cdot 0.20+0,1\cdot 0,15+0,1\cdot 0,10+0,0036\cdot 0,05+0,0324\cdot 0,1]=0,3008.$$

Similar actions are used to establish numerical estimates of the conclusions of the remaining experts relative to the levels of confidentiality of document *D*: for expert conclusion e_2 – $F(E_2)$ = 0,2882; for e_3 – $F(E_3)$ = 0,2886; for e_4 – $F(E_4)$ = 0,2990; for e_5 – $F(E_5)$ = 0,2853; for e_6 – $F(E_6)$ = 0,3025; for e_7 – $F(E_7)$ = 0,2872; for e_8 – $F(E_8)$ = 0,2941; for e_9 – $F(E_9)$ = 0,2905; for e_{10} – $F(E_{10})$ = 0,3019; for e_{11} – $F(E_{11})$ = 0,2876; for e_{12} – $F(E_{12})$ = 0,3016; for e_{13} – $F(E_{13})$ = 0,2880; for e_{14} – $F(E_{14})$ = 0,3032; for e_{15} – $F(E_{15})$ = 0,2852.

As can be seen from the presented above results, the integral assessments of experts regarding the level of confidentiality of document *D* are quite close. Nevertheless, to obtain a consolidated assessment of all experts e_k (k = 1 ÷ 15) relative to the influence of CF $x_i (i=1\div 6)$ on the level of secrecy of information to be included in document *D*, that is, for the final marking of document *D*, the following rather trivial rules are applied:

p_1: "If the aggregate assessment of each expert regarding the CF for their influence on the level of secrecy of information in document *D* is interpreted as having an insignificant effect, then the consolidated assessment of the experts regarding the cumulative influence of these CF on the level of secrecy of information in document *D* is characterized as insignificant";

p_2: "If the aggregate assessment of each expert regarding the CF for their influence on the level of secrecy of information in document *D* is interpreted as having a significant effect, then the consolidated assessment of the experts regarding the cumulative influence of these CF on the level of secrecy of information in document *D* is characterized as visible";

p_3: "If the aggregate assessment of each expert regarding the CF for their influence on the level of secrecy of information in document *D* is interpreted as having a more than significant effect, then the consolidated assessment of the experts regarding the cumulative influence of these CF on the level of secrecy of information in document *D* is characterized as weighable";

p_4: "If the aggregate assessment of each expert regarding the CF for their influence on the level of secrecy of information in document *D* is interpreted as having a very significant effect, then the consolidated assessment of the experts regarding the cumulative influence of these CF on the level of secrecy of information in document *D* is characterized as strong";

p_5: "If the aggregate assessment of each expert regarding the CF for their influence on the level of secrecy of information in document *D* is interpreted as having a too significant effect, then the consolidated assessment of the experts regarding the cumulative influence of these CF on the level of secrecy of information in document *D* is characterized as too strong";

These rules represent a cause-effect relation where the input characteristics are the aggregated estimates of experts $e_k (k=1\div 15)$, and the output is the linguistic variable *y* – the consolidated assessment of the influence of the FC $x_1 \div x_6$ on the level of secrecy of information to be included in document *D*. These judgments make it possible to form a list of the corresponding terms of input and output linguistic variables (see Table 2) and a minimum set of fuzzy rules for obtaining a consolidated conclusion of the expert community about the degree of secrecy of the analyzed document.

In a symbolic form, the given rules $p_1 \div p_6$ are as follows:

r_1: $(e_1 = A)$ & $(e_2 = A)$ & … & $(e_{15} = A) \Rightarrow (y = Y_1)$;
r_2: $(e_1 = B)$ & $(e_2 = B)$ & … & $(e_{15} = B) \Rightarrow (y = Y_2)$;
r_3: $(e_1 = C)$ & $(e_2 = C)$ & … & $(e_{15} = C) \Rightarrow (y = Y_3)$;
r_4: $(e_1 = D)$ & $(e_2 = D)$ & … & $(e_{15} = D) \Rightarrow (y = Y_4)$;

r_5: $(e_1 = E)$ & $(e_2 = E)$ & … & $(e_{15} = E) \Rightarrow (y = Y_5)$.

Table 2 – The list of linguistic variables and their terms

Inputs: e_k ($k = 1 \div 15$)	Variable name	Aggregated expert assessments
	Term-set	{A = INSIGNIFICANT, B = SIGNIFICANT, C = MORE THAN SIGNIFICANT, D = VERY SIGNIFICANT, E = TOO SIGNIFICANT}
	Universe	[0, 1]
Output (y)	Variable name	Consolidated assessment of the expert community
	Term-set	{Y_1 = INSIGNIFICANT, Y_2 = VISIBLE, Y_3 = WEIGHABLE, Y_4 = STRONG, Y_5 = TOO STRONG}
	Universe	[0, 1]

These rules are implemented in MATLAB notation by Mamdani-type Fuzzy Inference System editor. The graphical interface of this editor (see Fig. 1) shows that the consolidated assessment of the expert community regarding the influence of CF on the level of secrecy of information to be included in document *D* is the number 0.295. According to the gradation obtained in [6] on a scale of [0, 100], this means that document *D* can be marked with the stamp “For official use”.

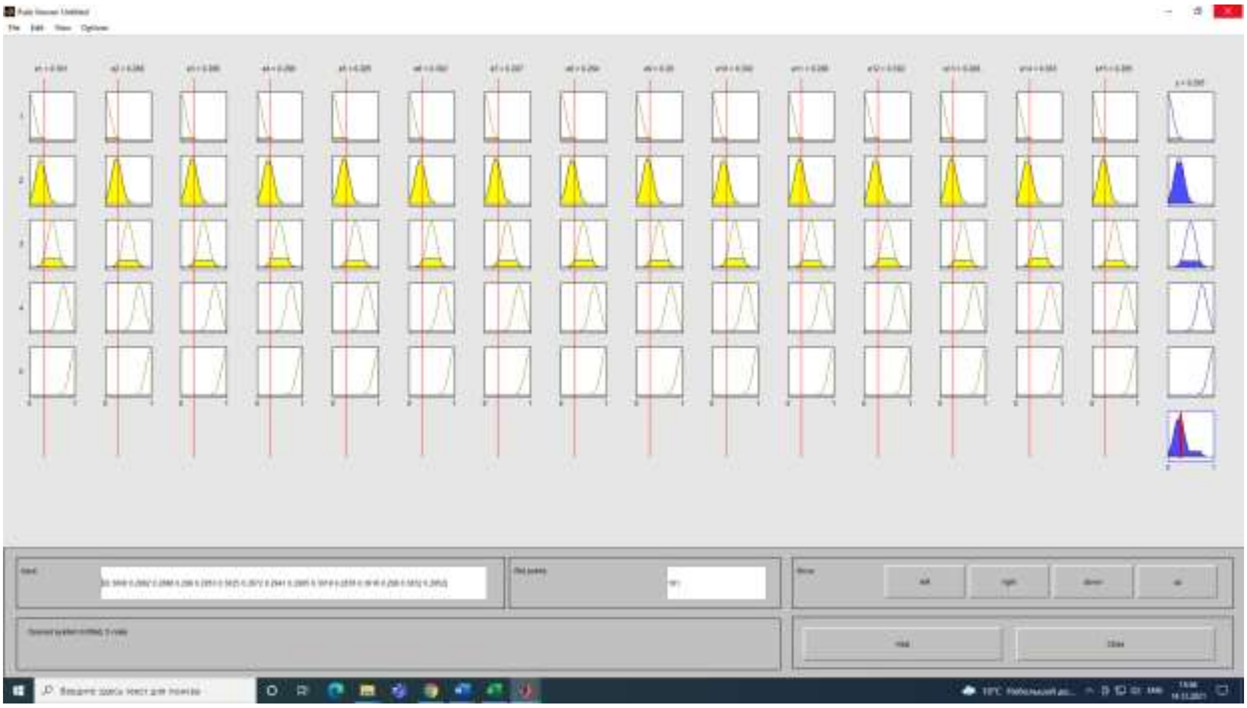

Figure 1 – View interface of the fuzzy inference system

6. Conclusion

In [4, 5], to fuzzify fuzzy sets reflecting the confidentiality features of information, there have been used discrete universes in the form of sets of documents to be marked for their confidentiality. In this article, a universe in the form of a set of 15 experts was applied to fuzzify confidentiality features. This is the fundamental difference between this approach and the ones previously proposed by us. As can be seen from the article, the starting points are the expert assessments presented in Table 1, which quantitatively reflect the presence of confidentiality features in the document under consideration. According to these expert estimates, this document is assigned a certain confidentiality status (stamp). Obviously, in other situations regarding the presence of confidentiality features, the final status of the document will change accordingly. This is the main essence of the proposed in the article method of marking documents.

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