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# SOFTWARE SELECTION ON BASE OF SUGENO INTEGRAL

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## ABSTRACT

The article is devoted to the problem of software selection. As a rule, this tasks are formalized as models of multi-criteria decision making (MCDM). The peculiarity of this problem is in the fact that the evaluation criteria, is generally defined by linguistic expert. This requires the use of special methods, in particular, the theory of fuzzy sets. To solve the problem, an approach based on the a fuzzy measure was used. In general, a fuzzy measure allows one to take into account the effect of the mutual influence of criteria. The main difficulty lies in identifying this measure. The fuzzy Sugeno measure and Sugeno integral were used. An example of solving the indicated problem is given.

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## 1. Introduction.

Software selection problem based on the formal methods is very actual [1-3]. As a rule, this tasks are formalized as models of multi-criteria decision making (MCDM). The peculiarity of this problem lies in the fact that the evaluation criteria, is generally defined by linguistic expert. This requires the use of special methods, in particular, the theory of fuzzy sets.

One of the problems MCDM – this is a problem taken as interrelation between criteria, i.e. the problem is non-additivity. Using these criteria such as the simple arithmetic mean, a weighted arithmetic mean, the geometric mean and a weighted geometric mean, median, mode, and others can lead to incorrect result. One of the approaches to solving this problem is the use of non-additive criteria, in particular, a fuzzy measure. The concept of fuzzy measure, based on the work of Choquet [4] in 1974 introduced by M. Sugeno [5]. In 1989, M. Sugeno [6] proposed the concept of  $\lambda$  fuzzy measure and a new method of aggregation is the Sugeno integral.

In general, a fuzzy measure allows one to take into account the effect of the mutual influence of criteria. The main difficulty lies in identifying this measure. There are several approaches to solving this problem [7 -9]. One of the approaches to solving this problem is the formalization of the expert's preferences based on the use of Shapley coefficients and maximization of entropy. Another approach to identifying a fuzzy measure [10] is an approach based on minimizing the squared differences between the Choquet integral and global estimates of alternatives.

In this paper, we will use the Sugeno aggregation function based on the fuzzy  $\lambda$  Sugeno measure.

## 2. Preliminaries.

Let's consider the basic concepts of the theory of fuzzy measure.

**Fuzzy measure.** Consider a variety of criteria  $X = \{x_1, x_2, x_3 \dots\}$ .  $P(X)$ . is a collection of all potential subsets that can be built on base of  $X$

A **fuzzy measure** is a mapping  $\mu(X): \rightarrow [0,1]$  that satisfies the following two conditions:

- (i)  $\mu(\emptyset) = 0$  and  $\mu(X) = 1$
- (ii) if  $A \subseteq B$  then  $\mu(A) \leq \mu(B)$

In general, a fuzzy measure is non-additive

A fuzzy measure  $\mu(A)$  of a subset of criteria  $A$  has the meaning of a weighting coefficients and indicates the degree of importance of a given subset of criteria.

If  $\mu(A \cup B) = \mu(A) + \mu(B)$  then the measure is additive

If  $\mu(A \cup B) \geq \mu(A) + \mu(B)$  then the measure is super - additive

If  $\mu(A \cup B) \leq \mu(A) + \mu(B)$  then the measure is sub - additive

**Fuzzy  $\lambda$ - Sugeno measure:** A set of criteria  $X = \{x_1, x_2, x_3, \dots, x_n\}$  is given and consist of  $n$  criteria and a real number  $\lambda \in (-1, \infty)$ . A **fuzzy  $\lambda$ - Sugeno measure** is a function  $g_\lambda(X): \rightarrow [0,1]$  that satisfies the following two conditions:

$$g_\lambda(X) = 1$$

$$\text{If } A, B \subseteq T \text{ then } g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A)g_\lambda(B)$$

$$\text{and } A \cap B = \emptyset$$

The parameter  $\lambda$  can be determined from the equation

$$\lambda + 1 = \prod_{i=1}^n (\lambda g_i + 1)$$

If  $-1 < \lambda < 0$  then  $\sum_{i=1}^n g_i > g(X)$  - super-additive measure

If  $\lambda = 0$  then  $\sum_{i=1}^n g_i = g(X)$  - additive measure

If  $\lambda > 0$  then  $\sum_{i=1}^n g_i < g(X)$  - sub- additive measure

**Sugeno Integral:**

Suppose a  $g$  fuzzy measure is defined on a set  $X$ , then the Sugeno integral for the function  $f: X \rightarrow [0, \infty]$  will have the form

$$\int f dg = \max_{1 \leq i \leq n} (\min(f(x_i), g(x_i)))$$

subject to the condition

$$f(x_1) \leq f(x_2) \leq f(x_3) \dots \dots f(x_n) f(x_0) = 0$$

Consider software selection problem by 4 criteria  $X = (x_1, x_2, x_3, x_4)$ , which  $x_1$ - functionality,  $x_2$ - cost,  $x_3$ - reliability,  $x_4$  - convenience

To set the linguistic expert assessments, define following linguistic terms:

**Very low** -0.2, **Low** -0.4, **Medium** - 0.5, **High** -0.7, **Very high** -0.9

**3. Problem solving.**

Software alternatives and criterion values obtained from experts are presented in a matrix

Table 1. Criteria values for various software alternatives

	$x_1$	$x_2$	$x_3$	$x_4$
$A_1$	0.7	0.5	0.4	0.9
$A_2$	0.2	0.4	0.7	0.5
$A_3$	0.7	0.5	0.9	0.4
$A_4$	0.5	0.4	0.7	0.9
$A_5$	0.2	0.5	0.9	0.7

Given expert evaluation of fuzzy measures for the individual criteria

$$g_\lambda(x_1) = 0.7, g_\lambda(x_2) = 0.5, g_\lambda(x_3) = 0.5, g_\lambda(x_4) = 0.7$$

Sugeno equation for 4 criteria is

$$\lambda + 1 = \prod_{i=1}^4 (\lambda g_i + 1)$$

We have:

$$\lambda + 1 = (0.7\lambda + 1)(0.5\lambda + 1)(0.5\lambda + 1)(0.7\lambda + 1)$$

After simplification, we obtain an algebraic equation

$$0.122\lambda^4 + 0.84\lambda^3 + 2.14\lambda^2 + 1.4\lambda = 0$$

After solving the equation in Matlab, we get the following roots:

$$\lambda_1 = 0$$

$$\lambda_2 = -2.49 + 1.75i$$

$$\lambda_3 = -2.49 - 1.75i$$

$$\lambda_4 = -0.97$$

We choose the root  $\lambda \in (-1, \infty)$ , we have  $\lambda = -0.97$

The result shows the presence of a generally negative relationship between the criteria, i.e. sub-additivity takes place.

Let's calculate fuzzy measures for all subsets of criteria

$$g_\lambda(\emptyset) = 0.$$

$$g_\lambda(x_1, x_2) = g_\lambda(x_1) + g_\lambda(x_2) + \lambda g_\lambda(x_1)g_\lambda(x_2) = 0.8605$$

$$g_\lambda(x_1, x_3) = g_\lambda(x_1) + g_\lambda(x_3) + \lambda g_\lambda(x_1)g_\lambda(x_3) = 0.8605$$

$$g_\lambda(x_1, x_4) = g_\lambda(x_1) + g_\lambda(x_4) + \lambda g_\lambda(x_1)g_\lambda(x_4) = 0.9247$$

$$g_\lambda(x_2, x_3) = g_\lambda(x_2) + g_\lambda(x_3) + \lambda g_\lambda(x_2)g_\lambda(x_3) = 0.7575$$

$$g_\lambda(x_2, x_4) = g_\lambda(x_2) + g_\lambda(x_4) + \lambda g_\lambda(x_2)g_\lambda(x_4) = 0.8605$$

$$g_\lambda(x_3, x_4) = g_\lambda(x_3) + g_\lambda(x_4) + \lambda g_\lambda(x_3)g_\lambda(x_4) = 0.8605$$

$$g_\lambda(x_1, x_2, x_3) = g_\lambda(x_1, x_2) + g_\lambda(x_3) + \lambda g_\lambda(x_1, x_2)g_\lambda(x_3) = 0.9432$$

$$g_\lambda(x_1, x_2, x_4) = g_\lambda(x_1, x_2) + g_\lambda(x_4) + \lambda g_\lambda(x_1, x_2)g_\lambda(x_4) = 0.9762$$

$$g_\lambda(x_1, x_3, x_4) = g_\lambda(x_1, x_3) + g_\lambda(x_4) + \lambda g_\lambda(x_1, x_3)g_\lambda(x_4) = 0.9762$$

$$g_\lambda(x_2, x_3, x_4) = g_\lambda(x_2, x_3) + g_\lambda(x_4) + \lambda g_\lambda(x_2, x_3)g_\lambda(x_4) = 0.9432$$

$$g_\lambda(x_1, x_2, x_3, x_4) = 1$$

The results of calculation showed fuzzy measure of paired relationships among the greatest strength has relationship between  $x_1$  and  $x_4$  and the weakest among  $x_2$  and  $x_3$  the sets consisting of 3 criteria are the most interference criteria  $x_1, x_3, x_4$  and the smallest  $x_2, x_3, x_4$

Calculate values of Sugeno integral for all alternatives:

$$C_1 = \int f dg = \max(\min(x_3, g_\lambda(x_1, x_2, x_3, x_4)), \min(x_2, g_\lambda(x_1, x_2, x_4)), \min(x_1, g_\lambda(x_1, x_4)), \min(x_4, g_\lambda(x_4))) = 0,7$$

$$C_2 = \int f dg = \max(\min(x_1, g_\lambda(x_1, x_2, x_3, x_4)), \min(x_2, g_\lambda(x_2, x_3, x_4)), \min(x_4, g_\lambda(x_3, x_4)), \min(x_3, g_\lambda(x_3))) = 0,6$$

$$C_3 = \int f dg = \max(\min(x_4, g_\lambda(x_1, x_2, x_3, x_4)), \min(x_2, g_\lambda(x_1, x_2, x_3)), \min(x_1, g_\lambda(x_1, x_3)), \min(x_3, g_\lambda(x_3))) = 0,4$$

$$C_4 = \int f dg = \max(\min(x_1, g_\lambda(x_1, x_2, x_3, x_4)), \min(x_2, g_\lambda(x_2, x_3, x_4)), \min(x_4, g_\lambda(x_3, x_4)), \min(x_3, g_\lambda(x_3))) = 0,7$$

$$C_5 = \int f dg = \max(\min(x_1, g_\lambda(x_1, x_2, x_3, x_4)), \min(x_2, g_\lambda(x_2, x_3, x_4)), \min(x_4, g_\lambda(x_3, x_4)), \min(x_3, g_\lambda(x_3))) = 0,6$$

We have:

$$C_1=0,7 \quad C_2=0,6 \quad C_3=0,4 \quad C_4=0,7 \quad C_5=0,6$$

Thus are best alternatives  $A_1$  and  $A_4$

#### 4. Conclusions.

The article is devoted to the problem of modeling the software selection process. The main attention is paid to the problem of mutual influence of selection criteria. To solve this problem, was proposed an approach based on the use of Sugeno fuzzy measure and Sugeno integral. The problem of software selection with the 4 criteria was solved.

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