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THE VARIABILITY OF FUZZY AGGREGATION METHODS FOR PARTIAL INDICATORS OF QUALITY AND THE OPTIMAL METHOD CHOICE

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ABSTRACT

This article examines the process of evaluating the integral index of the software quality using the method of fuzzy aggregation of multiple private indicators. The aim of the study is to determine the applicability of this approach in practice and research of its formalization and algorithmization approaches. A set of aggregation algorithms in the fuzzy inference model was used and their comparison in the application to the given problem is provided. Various modifications of the standard algorithm of fuzzy inference using fuzzy set operators, as well as different kinds of norms and conforms are considered. The study has revealed a wide variation of aggregation methods and provided the method of selecting the optimal one based on the comparison with standard numerical grades. The applicability of the methods of fuzzy logic was shown in the mathematical explanation of the decision making process, opening up the possibility of fuzzy-linguistic description of the subject area, private alternatives indicators and target vector formalizing.

Keywords: fuzzy logic, indicators tree, decision-making, mathematical methods in economics, quality, algorithmization.
JEL- codes: C610, C630

INTRODUCTION

While determining the price of a software system in terms of economic theory, we are faced with a number of fundamental difficulties. The process of developing software allows you easily and clearly identify the total costs, however, the definition of average or marginal costs is very difficult (almost impossible at the production stage and even in the early stages of marketing. Therefore, the cost of software production is permanent, regardless of its nature. Depending on the pricing method, the following problems may occur:

- when using other than the cost methods - difficulty of revenue forecasting;
- for the method of expert evaluations - subjectivity;
- inaccessibility of accurate baseline information about competitors and the effect of the product use;

Due to the easy copying, and wide variability in production volume, traditional cost-based pricing methods can be applied very limitedly. At the buyer's market, the most expedient is to use methods of calculation based on the quality price.

The purely analytical approach to the software evaluation is usually associated with the definition of multiple coefficients in computational formulas that will cause some difficulties. With regard to the empirical approach to the assessment (as the alternative to the analytical one), it requires more data on analogues with known parameters. In addition, the task is valid processing of this data based on certain information technologies (which is not always an easy task).

The purpose of this study is to offer a more complete method, compared to the existing ones, of quality software assessment based on poorly formalized factors, such as factors of consumer choice, with the assistance of the fuzzy logic apparatus (Rutkovskaya, 2004; Sugeno, 1993). Obviously, this can be achieved by formalizing and quantifying indicators of software quality and user expectations as a fuzzy object (Zadeh, 1965).

METHODOLOGY

The first step in this modeling process is to build an integrated system of indicators of software systems quality. This is a hierarchical structure, which includes all possible properties that are important in the evaluation of the software system.

It is advisable to build a common integrative system of indicators of quality, flexibility towards individualization, or at least a common building methodology, formal to the extent of algorithmization. Indicators are the quantitative expression of a particular property of the system. Software properties criteria system has weighted characteristics, indicating the importance degree of the properties of a specific set of objectives, respectively. Let U be a universal set of quality properties, which is a discrete set or an n-dimensional vector; variable u, taking values on this set is interpreted as a "Quality Score." A fuzzy subset A on U, corresponding to a particular software product, is determined by the characteristic function $\mu_A(u \in U_i) = x_i$, where x_i -

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value of i-th metric of vector U. In a comparative study of a number of similar products there emerges an array A_j, where j - identification number of a particular product.

User expectations can be formalized as the fuzzy subset B, defined similarly to the subset A. The estimation of quantitative component of the vector B can serve an expression of $B_i = \sum_{i=1}^{n} A_i$ - identification of consumer needs through the 'perfect' product.

$A_i \times X_j \leq B_k \times X_j$ - condition for full needs satisfaction;

$A_i \times X_j \subseteq A_k \times X_j$ -preference for the product k to a product i;

The above model has been tested on the example of the process of selecting a software implementation of Fuzzy Logic. By this stage, numerical integral estimates were known, obtained using the analytic hierarchy process.

In this regard, a review and evaluation of the twelve implementations of fuzzy logic in different programming languages (6 in compiled and 6 - in interpreted).

FuzzyLogic.pm - amateur module that implements basic operations of fuzzy logic. Differs with non-standard terminology and logic of the program. It has tools for organizing fuzzy inference, basic operations and relations between fuzzy subsets. In spite of small volume, has sufficiently extensive documentation. Subsets are determined using discrete numerical sets. It has developed tools for fuzzy qualifications. It is characterized by clear method; therefore, only linear membership functions (MF) are supported. The program logic separates input and output variables. The module features detailed documentation and clear, structured code of the resulting program.

Fuzzy.pm - a simple module to Perl supports only a triangular membership functions. It features small volume, low functionality; membership functions defining not in fractions of a unit, as a percentage. Is of no special interest. Fuzzy inference is not supported, operation on the fuzzy subsets are not implemented.

FuzzyAdvisor.fs - implementation of an expert system based on fuzzy logic. It focuses on the use of fuzzy inference rules.

FuzzyLogic.Net.cs - characterized by extremely low functionality, confusing and incomprehensible code.

Tagaki-Sugeno.cs - implementation of Tagaki-Sugeno Fuzzy System under the .NET platform. Supports linear, triangular and trapezoidal membership functions. It allows you to define your own membership functions. Full support for linguistic variables, a set of fuzzy inference rules, fuzzy logic operations. It has scant documentation, but rather clear and understandable code.

Fuzzy.rb - the only implementation of fuzzy logic in Ruby. Supports trapezoidal membership functions. It implements a system of Tagaki-Sugeno fuzzy inference. It has the implementation of fuzzy logic operations. Characterized by a lack of any documentation.

Free Fuzzy Logic Library - probably the most complete implementation of fuzzy logic in the form of a C++ library. Trapezoidal, triangular, linear, point membership functions, membership functions in the form of s-curves. A very large amount of code is well documented. There is a support for a set of fuzzy inference rules, fuzzy sets, operations and relations of fuzzy logic. However, the code using this library turns out to look a bit confusing and less structured.

In addition to choosing alternatives themselves, it was necessary to build a system of indicators that are relevant for evaluation process. Based on ISO 1926, 8 properties model parameters were selected, combined into two groups:

a) Functionality- a set of properties that characterize the completeness of the implementation of Fuzzy Logic;
a. MF not on R - the ability to set the membership functions of fuzzy subsets on the sets other than the subsets of real numbers - lists, hierarchical structures, trees, etc.;
b. Fuzzy inference - the implementation of fuzzy inference rules in the form of "IF … THEN… ";
c. Operations on subsets - implementation of basic algebraic and logic operations on fuzzy subsets, as well as comparisons of the relationships between them;
b) Applicability - a set of properties that characterize the degree of comfort with which particular alternative will be used;
d. Documentation - the completeness and quality of the documentation, references, code commenting;
e. Code clarity - clarity of the structure of classes and methods that allow you to write a clear and intuitive code using this library;
f. Reliability - degree to which this module is tested;
g. Extensibility - subjective (expressed in the ability of the author) and objective (expressed in licensing conditions) ability to make adjustments in the module source code;
h. Readiness -version of the module with respect to the release version - 1,0

To determine the weights of all indicators of hierarchy analysis method was used, the results of which are shown in Table-1:

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Table-1. The weights of indicators for choosing a fuzzy logic implementation.

Indicator	Weight
MF not on R	0,2823
Fuzzy inference	0,2374
Operations	0,061
Documentation	0,0729
Code clarity	0,1023
Reliability	0,0665
Extensibility	0,1447
Readiness	0,0327

Further, all of the above alternatives have been evaluated by an expert method. A score ranging from 0 to 1 was assigned to each alternative for each indicator. Alternatives' scores are shown in Table-2:

Table-2. Scores estimations of fuzzy logic implementation for every indicator.

Alternative	MF not on R	Fuzzy inference	Operations	Documentation	Code clarity	Reliability	Extensibility	Readiness	Интегральная
Fuzzy Logic	0	1	1	0,75	0,25	0	0,75	0,06	0,489
Fuzzy Inference	0	1	1	0,75	1	0,5	0,75	0,05	0,669
Fuzzy	0	0	0	0,75	0,75	0,5	0,75	0,01	0,274
fuzzy	0	1	0	0	0,5	0	1	0,01	0,434
Py fuzzy	0	0	0	0	0,25	0,5	1	0,1	0,207
FFLL (C++)	0	1	1	0,25	0,25	0,75	0,5	1	0,497
fuzzy.cpp	0	0	1	0	0	0,5	0,5	0,5	0,183
Fuzzy Advisor	0	1	0	0,5	0,25	0,5	0	0,5	0,349
fuzzy.Rb	0	1	0	0	0	0,5	0,25	1	0,34
DotFuzzy	0	1	0	0,5	0,25	0,75	0,25	1	0,418
FL.NET	0	0	0	0,5	0,25	0,75	0,25	1	0,181
TSFL	0	1	0	0,5	0,75	0,75	0,25	1	0,469

As we can see, the highest integrated score was assigned to the Fuzzy Inference (Perl) Module - 0.669. However, none of the above modules have received scores above 0.75, indicating incomplete compliance of functional and other capabilities to the needs imposed by this study.

These estimates served as a benchmark for comparison with those obtained using fuzzy approach and linguistic estimates of the output of the program. Graphically these referential scores are shown in Figure-1.

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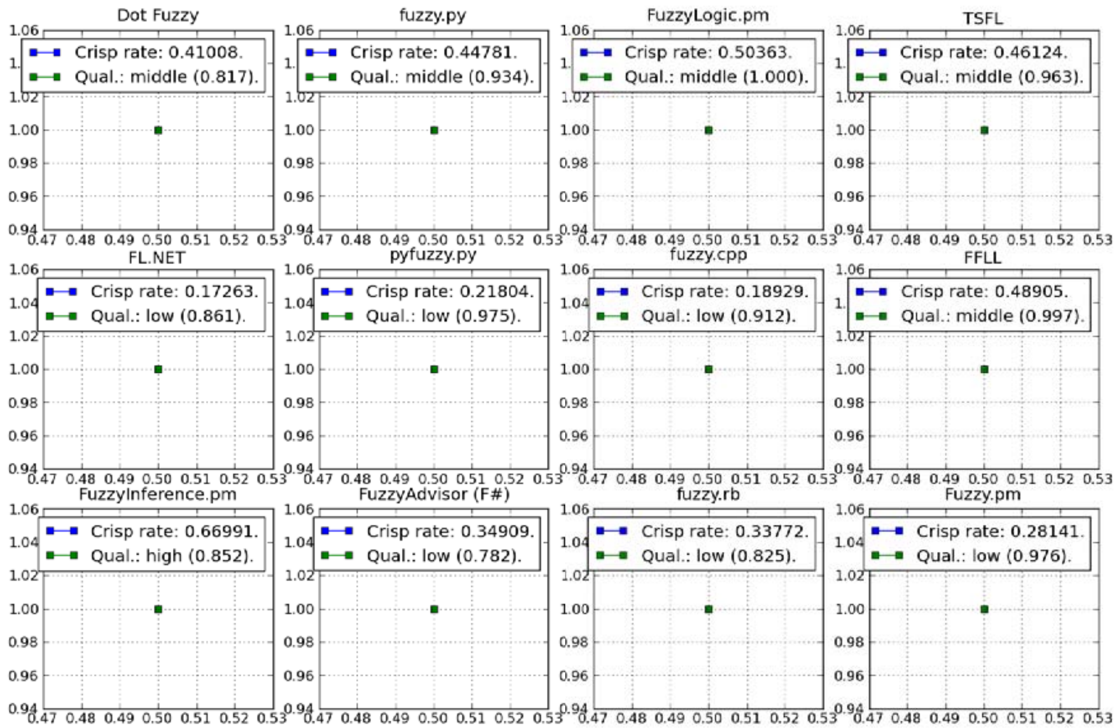

Figure-1. Referential point-like scores.

For obtaining the fuzzy integrated scores of each alternative the algorithm was drawn up, which calculates the fuzzy score of alternatives according to the selected qualification formula (Koroteev, 2011, 2012). Qualification process is proved to be a highly variable, which has created the problem of choosing the best option qualifications fuzzy estimates.

Variability of qualification is determined by four factors (Bamadio, 2013; Dubois, 1987; Mitaim, 2001, Zadeh, 1965):

- Classification of fuzzy (rating in the legend) or linguistic (rating2) estimates;
- A criteria convolution by adding up (plus) or union (or) of the fuzzy subsets;
- Finding the nearest fuzzy subset procedure - by finding the nearest centroid (centr), the largest intersection capacity (card), the Euclidean distance (Euclid) or the Hamming distance (Hamming);
- Using (COM) or not (-) the fuzzy concentration operation to reduce the fuzziness of a fuzzy subsets.

Totally these options give 2 * 2 * 4 * 2 = 32 qualification options.

RESULTS

To implement a choice of the qualification method program performed the evaluation process for all 32 identified qualification options. The results of the comparison of each of these 32 results with the reference scores serve to select data qualification method. Some of the options of the program outputs are shown in Figures 2-5.

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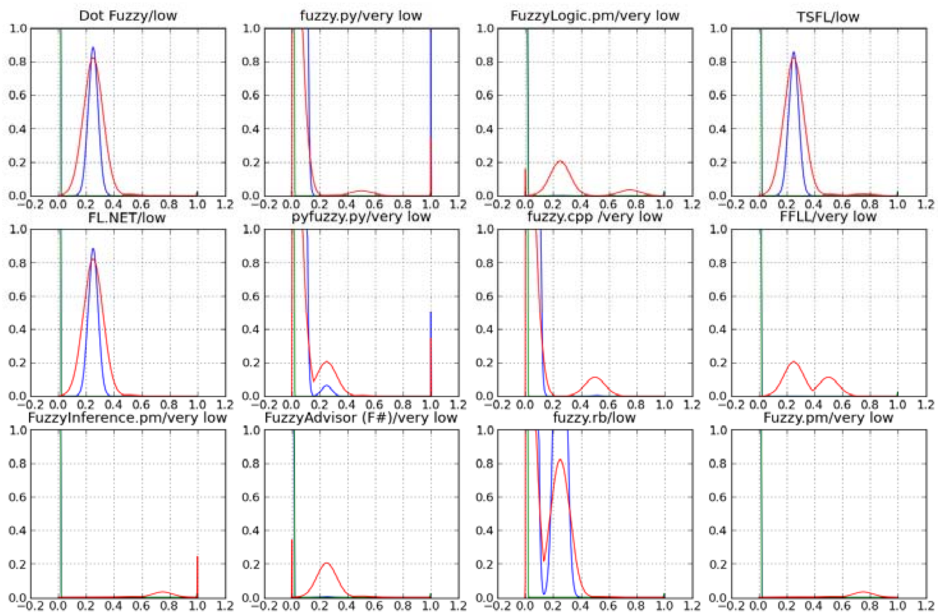

Figure-2. Qualification method «Rating 2 or centr CON».

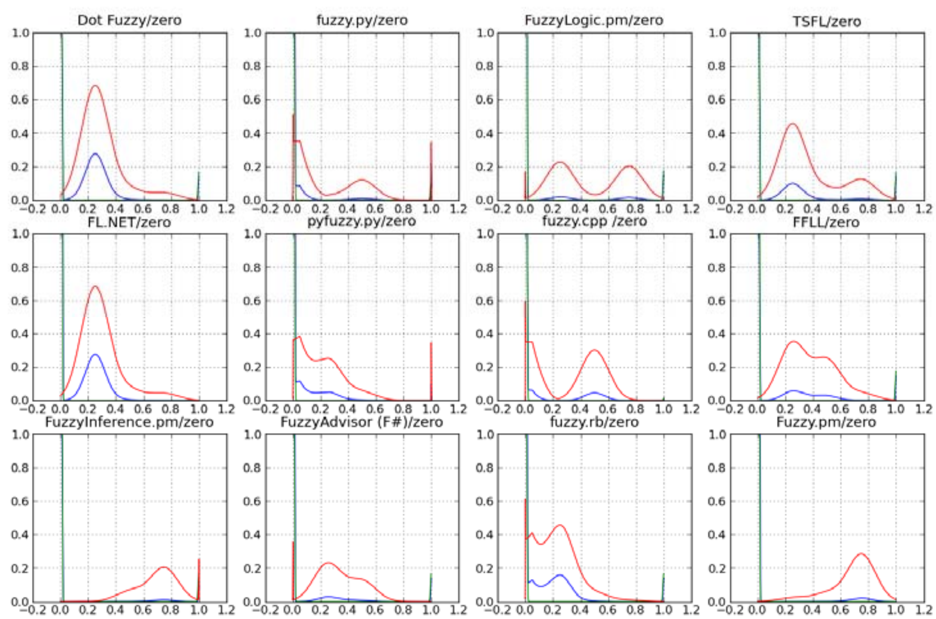

Figure-3. Qualification method «rating 2 plus card CON».

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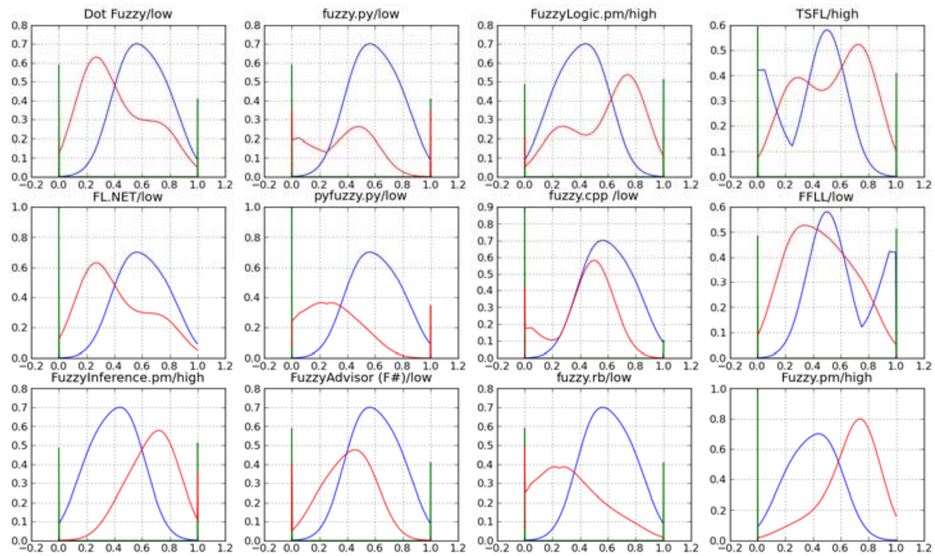

Figure-4. Qualification method «rating plus Hamming».

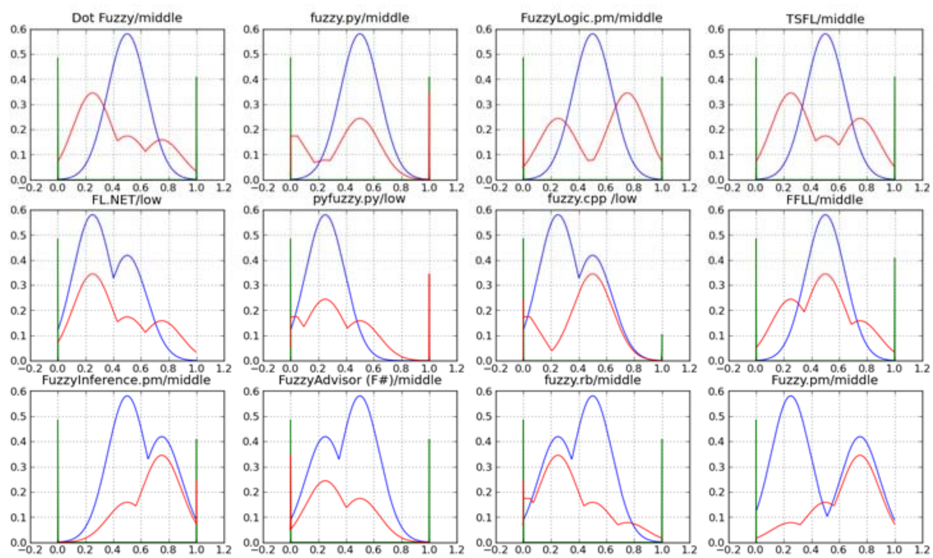

Figure-5. Qualification method «rating or centr».

For each of these options correlation coefficients and standard deviation with numerical estimates adopted as the standard have been calculated. The calculation results are shown in Table-3.

According to the results of the analysis of three version of qualification were selected:

$$Q(F) = min\left[centr(Q_i) - centr\left(\sum_j Q'_j \times X_j\right)\right] \text{(centr plus1)}$$

$$Q(F) = \min\left[centr(Q_i) - centr\left(\sum_j F_j \times X_j\right)\right] \text{(centr plus2)}$$

$$Q(F) = min\left[centr(Q_i) - centr\left(\prod_j Q'_j \times X_j\right)\right] \text{(centr or 1)}$$

where F_j - fuzzy score of the individual indicator,
Q'_j - linguistic score of the individual indicator,

$$\prod_j X_j = X_1 \vee X_2 \vee ... \vee X_j$$

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Table-3. The results of correlation analysis of qualification options.

Метод	Корр. с лингв. оценкой	ср.отклон ение	Корр. с неч. оценкой	ср.отклон ение
card plus 1	0,541046	0,202562	0,573023	0,175847
centr plus1	0,749819	0,111392	0,869735	0,110357
Euclid plus 1	0,661144	0,256771	-0,765146	0,303507
Hamming plus 1	0,506384	0,208203	-0,507435	0,256409
card plus 2	0,587505	0,196460	0,804989	0,096925
centr plus2	0,749819	0,111392	0,804989	0,096925
Euclid plus 2	-0,496757	0,385090	0,804989	0,096925
Hamming plus 2	-0,408207	0,363616	0,804989	0,096925
card plus 2con	0,000000	0,403249	0,110880	0,308648
centr plus 2con	0,227292	0,299168	0,110880	0,308648
Euclid plus 2con	-0,437623	0,375992	0,110880	0,308648
Hamming plus 2con	-0,207070	0,323011	0,110880	0,308648
card plus 1con	0,401567	0,187247	0,401777	0,184776
centr plus 1con	0,000000	0,190693	0,518236	0,163282
Euclid plus 1con	0,547351	0,186415	-0,808169	0,315174
Hamming plus 1con	-0,204295	0,233624	-0,008842	0,225012
card or1	0,000000	0,190693	0,530777	0,124935
centr or1	0,749819	0,111392	0,894836	0,102178
Euclid or1	0,309582	0,201049	-0,401522	0,249999
Hamming or1	0,437623	0,200297	-0,437623	0,251403
card or2	0,047381	0,232976	0,748388	0,115598
centr or2	0,574445	0,141937	0,748388	0,115598
Euclid or2	-0,284719	0,361451	0,748388	0,115598
Hamming or2	-0,244259	0,344371	0,748388	0,115598
card or1con	0,485001	0,174096	0,485365	0,171504
centr or1con	0,000000	0,190693	0,502063	0,165367
Euclid or1con	0,482614	0,161569	-0,812936	0,313245
Hamming or1con	-0,204295	0,233624	0,009266	0,218743
card or2con	0,000000	0,403249	0,385485	0,317286
centr or2con	0,000000	0,323798	0,385485	0,317286

The final version of fuzzy classification has been selected with the greatest correlation fuzzy evaluation with numerical reference data. A graphical representation of the fuzzy evaluation of the final qualification method for this is shown in Figure-6.

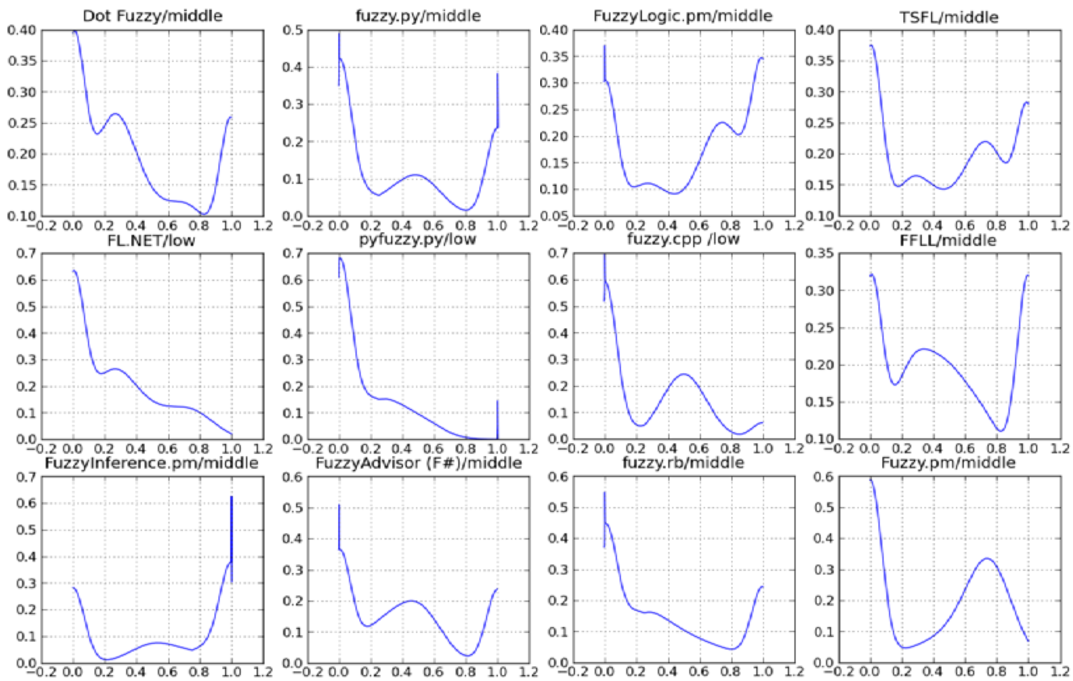

Figure-6. The final version of the classification.

CONCLUSIONS

Experimental verification of the created algorithm showed operability of the constructed linguistic evaluation process (Zadeh, 1975) of the software quality. In the course of this work it was found that most are directly measurable characteristics of the product quality. Methods of their evaluation depend on the nature of the indicator and can be both expert method and more accurately - observation, direct measurement.

The most subjective method is through defining user needs and it will require analytical methods based on the market analysis of the distribution of consumption. However, the most difficult of all parameters are weights of the indicators that are their priority in the implementation of the user's selection.

This problem is directly related to the question of software market segmentation. It is supposed to use the analytical tools that are part of the model described above and can make it possible to identify, though unclear and assess your options on the basis of numerical data.

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