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ARTICLE

SOFTWARE QUALITY ASSESSMENT USING FUZZY PARAMETRIC CHARACTERISTICS

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ABSTRACT

The article is devoted to the problem of software quality assessment during the trial operation stage. The developed approach is based on the hierarchy of quality assessment parameters according to GOST 28195-89. The approach is proposed to evaluate the quality of software during the trial operation stage with the breakdown of work into several stages and the subsequent aggregation of the resulting assessment. They formalized the set-theoretical description of the software quality assessment system. To evaluate some aspects of software quality that are evaluated by an expert method, the mathematical apparatus of fuzzy logic is used. The division of this process into separate stages is justified by the nature and specificity of quality indicator collection. At the same time, it is proposed to include usability indicator in the comprehensive assessment of software quality, obtained on the basis of user survey results.

KEY WORDS
software quality, fuzzy logic, GOST 28195-89, quality metric, quality factor.

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INTRODUCTION

In the process of software development life cycle management, individual stages of work are distinguished, distributed over time depending on the chosen life cycle model. Quality assessment can be iterative, for example, in a spiral life-cycle management model, when the quality of each software version (PT) is tested taking into account the revised functionality. Testing staff (PT), in most cases, should have skills related to functional testing, performance testing, reporting on progress, planning, test conducting and automation [1].

Software Quality (SQ) - PT ability to meet specified or anticipated needs under specified conditions [2]. Research in the field of SQ assessment is carried out in the following areas: PT metrics, estimation methods, aggregation methods, model context depending on application type and instrumental support [3, 4]. Regardless of the selected life-cycle management model or other methods for PT development, comprehensive tests of PT are carried out at the final stage of work to assess its quality. To evaluate SQ, a pilot operation program is being developed which allows to evaluate all aspects of the system functioning. Some studies are focused on the development of PT quality prediction models. So in [5] a quality forecasting approach is proposed based on the basic components that are the part of any PT. The SQ assessment process is systematic and regulated by standards.

SQ is formed from a variety of indicators evaluated by various methods [6]: measuring, registration, organoleptic, calculated. Moreover, these methods cannot evaluate the whole range of quality indicators, for example, usability assessment or the availability and completeness of program documentation. An expert method is used for this. So in [7], the approach is proposed for the analysis and measurement of usability indicators at the implementation stage. The authors developed the platform with code annotations that are interpreted by the annotation processor to obtain valuable information and automatically calculate usability indicators during compilation.

Regardless of the approach to SQ estimation, there are PT failures that are difficult to detect by code pre-testing. Such failures can be caused by the factors of configuration parameter changes, depending on suppliers and business goal [8].

Thus, the SQ assessment process is a time-consuming task and requires the development of approaches to improve the efficiency of this process.

METHODS

Application of fuzzy logic to the SQ assessment process is not a new approach. In [9], a quality model is proposed that supports five concepts of quality and uses the theory of fuzzy logic to measure quality. A feature of the work is the use of Choquet Integral with fuzzy measures, which allow to take into account the relationship between the criteria. In [10], the assessment of software module quality is considered based on the frequency of checks and the density of errors using fuzzy logic for quantitative evaluation. Fuzzy logic is used as a quantitative assessment mechanism, allowing an expert to conduct a quality assessment in a natural language. So, in [11], they proposed a comprehensive approach to assess the quality of software based on qualitative factors from ISO/IEC 9126. Some researchers propose at the first stage the choice of a target model to assess SQ to determine the composition of the estimated functional goals, which are then formally presented and evaluated using fuzzy logic [12]. There are the works in which researchers create a fuzzy SQ estimation model by integrating several existing models. Thus, a unique set of factors, criteria and sub criteria is formed [13].

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The analysis of the approaches shows that in most works, the authors take the existing standard to assess SQ as the basis. The mathematical apparatus of fuzzy logic is mainly applied to the assessment of all quality indicators. In this paper, we propose the approach that allows SQ to be assessed at the trial operation stage, with the work divided into several stages and the subsequent aggregation of the resulting assessment. In this case, to evaluate some aspects of SQ, evaluated by an expert method, the mathematical apparatus of fuzzy logic will be used. The division of this process into separate stages is justified by the nature and specificity of quality indicator collection.

The work is based on GOST 28195-89 [14]. This standard describes SQ indicators and the ways of their evaluation. Integral quality assessment is formed by the convolution of all indicators. However, in addition to calculation methods that allow, for example, to evaluate the probability of failure-free operation indicator, the expert method is used when an expert must evaluate the indicator in the range [0..1].

In this paper, it is proposed to translate the process of indicator evaluation evaluated by the expert method into a language that is natural for a man using fuzzy logic. This will allow an expert to evaluate the quality in the usual terms (satisfactory, good, excellent) and, in the same turn, to formulate the result of the indicator evaluation in the range [0..1] through the stage of inference defuzzification.

It is also proposed to include the indicator of usability in the comprehensive assessment of SQ, obtained on the basis of user survey results, by the sociological method [15].

IMPLEMENTATION

According to GOST 28195-89 [14], SQ is evaluated by a set of 6 factors, each of which is evaluated by its own set of criteria [Fig. 1]. Moreover, each criterion is evaluated by a metric or a set of metrics. The metric is formed by evaluative elements. Thus, 4 levels of SQ score are formed. At all levels of the hierarchy (evaluation elements, metrics, criteria and factors), a single rating scale is adopted in the range [0..1].

The analysis of SQ assessment standards allows us to describe this process from the point of view of system analysis. The SQ (Sq) estimation system is a tuple (1):

$$Sq = < LQ;\ R_{F\times QC};\ R_{QC\times M};\ R_{M\times EE};\ Op > \qquad (1)$$

Tuple (1) is described by the following set of elements:

LQ – many available quality indicators that evaluate all aspects of PT quality (2);

$$LQ = \{EE, M, QC, F\} \qquad (2)$$

EE – the subset of the evaluation elements;

M – the subset of metrics;

QC – the subset of quality criteria;

F – the subset of factors.

$R_{F\times QC}$ – the binary relation between the elements of a multitude of factors and quality criteria;

$R_{QC\times M}$ – the binary relation between the elements of quality criterion and metric sets;

$R_{M\times EE}$ – the binary relation between the elements of metrics and evaluation elements;

Op – the set of operations to determine the value elements or metrics (provided that the metric is evaluated in a unique way). Moreover, this set includes operations for hierarchy indicator evaluation [Fig. 1], which are evaluated by several values.

The binary relations ($R_{F\times QC}, R_{QC\times M}, R_{M\times EE}$) are filled with the coefficients w_{ij}, that establish the relationship between the elements of two sets. Moreover, the values w_{ij} are weight coefficients reflecting the influence of the quality indicator j on i.

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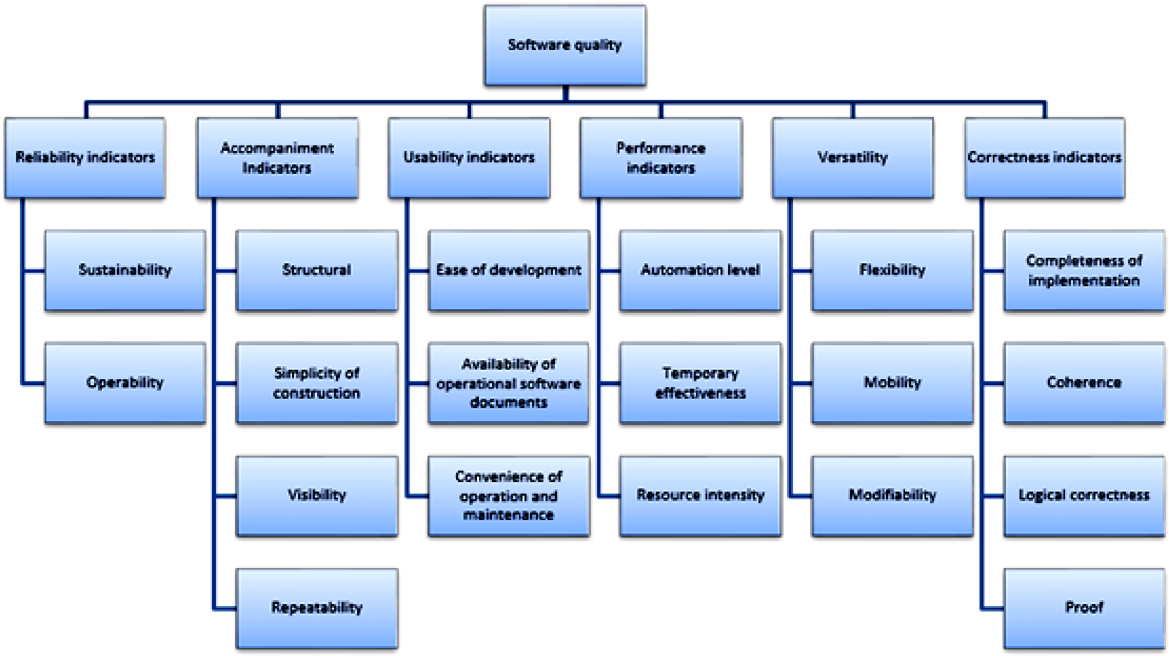

Fig. 1: Software quality assessment hierarchy.

According to GOST 28195-89 [14], the integral estimate of SQ is determined by the expression, which is the arithmetic mean weighted sum of factors, criteria, metrics and evaluation elements. The average assessment of the evaluation element, taking into account several of its values is carried out according to the formula (3).

$$ee_{kq} = \frac{\sum_{t=1}^{n} ee_t}{n} \qquad (3)$$

where ee_{kq} – the average estimate of the evaluation element q for the metric k;

n– the number of values q of the evaluation element ee_{kq} .

Based on the evaluation elements, an estimate of the metric (4) is formed.

$$m_{jk} = \frac{\sum_{i=1}^{Q} ee_{kq}}{Q} \qquad (4)$$

where m_{jk} – the average estimate of the metric for the criterion;

Q– the number of evaluation elements in the metric.

The calculated metrics are the basis for the quality criterion determination (5).

$$C_{ij} = \frac{\sum_{k=1}^{S}(m_{jk} * v_{jk})}{C_{ij}^{base}} \qquad (5)$$

where C_{ij} is the relative indicator of the criterion j for the factor i ;

S– the number of metrics that evaluate the criterion j ;

C_{ij}^{base} - The basic value of the criterion corresponding to the world level;

v_{jk} – the metric k weight coefficients for the criterion j . At that $\sum_{k=1}^{S} v_{jk} = 1$

Thus, each factor is evaluated (6).

$$F_i = \sum_{i=1}^{J}(C_{ij} * w_{ij}) \qquad (6)$$

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where F_i – the factor i, where $i = \overline{1,6}$;

J – the number of criteria that evaluate the factor i;

w_{ij} – the weighting factors of the criterion j for the factor i. At that $\sum_{j=1}^{J} w_{ij} = 1$.

Thus, each factor is evaluated and compared with the value of the base indicator, which is determined at the design stage. Evaluation elements are calculated by various methods, depending on the availability of analytical information processing. [Fig. 1] shows the hierarchy of SQ indicators, which reflects the relationships between factors and quality criteria, which are further decomposed into metrics and evaluation elements.

However, from the position of direct assessment of each element, it is necessary to group the evaluation elements and metrics by the method of evaluation. In this regard, it is proposed to group according to the method of calculation into analytical methods and expert ones using fuzzy logic, which in turn are decomposed into an expert assessment and user assessment. In particular, end-to-end tests can be developed for users to simulate real user scenarios.

Formalization of expert assessments using fuzzy logic is necessary. It is proposed to evaluate the elements and metrics in the form of linguistic variables LV_{name}. The variable name corresponds to the name of the evaluation element. Each linguistic variable will be evaluated by a variety of terms $\{low, average, high\}$, that characterize the level of evaluation elements for the metric. The semantics of terms is defined on the interval [0, 1] and formalized by membership functions of the type $z, s, gauss$.

For example, according to [14], to evaluate the metric of PT work mastering (LV_{SD}) it is recommended to use assessment elements: the possibility of mastering PT according to the documentation (LV_{PDSTD}), the possibility of mastering PT using a test example (LV_{PMSTE}) and the possibility of phased mastering of PT (LV_{PPDS}). A fuzzy assessment of the metric mastering the work of PT is formed by the assessment of three linguistic variables through the logical conclusion of Mamdani [Fig. 2]. After the stage of defuzzification, the assessment of the variable LV_{SD} takes a numerical value, which is used in the assessment of the quality criterion according to the formula (5).

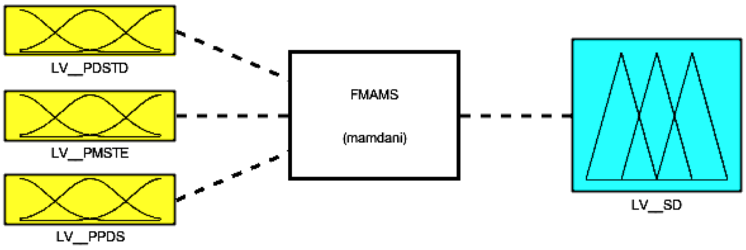

Fig. 2: Fuzzy metric assessment mastering software.

Each input linguistic variable for the inference system [Fig. 2] is evaluated on the basis of three terms. [Fig. 3] shows the semantics of the of the linguistic variable terms LV_{PDSTD}.

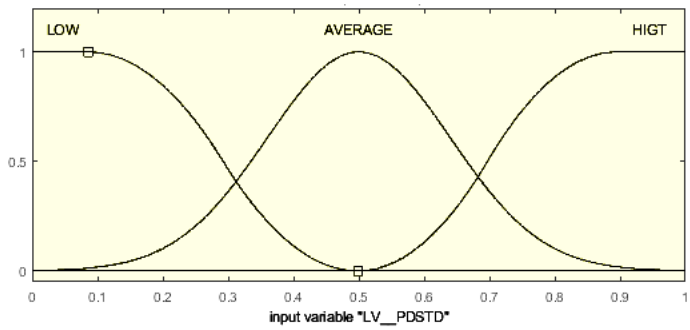

Fig. 3: The semantics of the terms {low, average, high} for the linguistic variable LV_{PDSTD}.

Thus, the proposed SQ estimation approach is reduced to the following sequence of actions:

1. The structuring of quality indicators according to (1) based on recommendations of regulatory documents and taking into account the specifics of PT development.
2. Determination of baseline indicators for each SQ factor.
3. Separation of the set of evaluation elements and metrics according to the evaluation method into subsets of analytical estimates and expert estimates using fuzzy logic, which in its turn are decomposed into an expert assessment and user assessment.
4. The implementation of a fuzzy inference to assess quality metrics based on linguistic variables that reflect the semantics of the evaluation elements, and obtaining the numerical value of the estimates based on defuzzification results.
5. Calculation of quality criteria based on metric estimates by the formula (5).
6. Calculation of factors based on the assessments of quality criteria by the formula (6).
7. The analysis of the obtained factor estimates for comparison with the values of the basic indicators and the development of a decision about the integral assessment of SQ.

SUMMARY

The developed approach allows us to estimate SQ based on the indicators decomposed into 4 levels of the hierarchy. A set-theoretic description of the SQ assessment process allows you to structure the hierarchy of indicators and the relationships between them, taking into account the degree of the lower level component hierarchy influence on the upper ones. The lower two levels (metrics and evaluation elements) are evaluated by analytical and expert methods using the mathematical apparatus of fuzzy logic. The semantics of linguistic variable terms are described by three terms. Quality criteria are evaluated as the weighted average of the metrics. Factors are estimated as a weighted sum of quality criteria.

CONCLUSION

The advisory nature of SQ standards allows developers to take them as a basis and modify them taking into account the specifics and needs of the developed PT. The proposed approach to the assessment of SQ using fuzzy parametric characteristics allows us to systematize the SQ process taking into account individual aspects of the project. The proposed set-theoretic description of the SQ system structures the elements of the system and establishes the relationships between them. This allows you to modify the standard SQ easily taken as the basis and formalize the required representation of the process.

The introduction of fuzzy parametric characteristics simplifies an expert's work during evaluation of a multitude of parameters evaluated by qualitative features. Linguistic variables are described by three terms corresponding to a high, low and average value of the indicator. Defuzzification of fuzzy estimates allows you to use them in the future for the numerical evaluation of quality indicators of a higher hierarchy level.

In SQ approach, they proposed to take into account the expert assessments of the developed system users. This will make it possible to form the estimates of real consumers of the system and evaluate the effectiveness of some aspects of the system practical use. The vision of users, as a rule, differs from the vision of developers, which may cause difficulties in the process of the system mastering.

Successful implementation of the proposed approach requires laborious work of experts on the formation of weighting factors for metrics and quality criteria. Weighting factors individually reflect the significance of the parameter when they develop the parameter estimate of the highest hierarchy level.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None.

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