Quality Assessment Technique for Enterprise Information-management System Software

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Keywords: Software Quality, Enterprise Information System, Quality Requirement, Quality Evaluation, Quality Model, Quality Characteristic, Quality Measure.

Abstract: The paper represents an overview of existing methods and standards used for the quality assessment of computer software. Quality model, quality requirements and recommendations for the evaluation of software product quality are defined in standards, but there is no unified definition for the algorithm that describes the process of software quality assessment completely and contains particular methods of measurement, ranking and estimation of quality characteristics. So the paper describes the technique that allows obtaining software quality quantitative assessment, defining whether the considered software meets the required quality level, and, in case it is needed to select between equivalent software tools, allows comparing them one with each other.

1 INTRODUCTION

Enterprises implementing R&D need in complex information-management system covering various activity aspects and related to different classes. In order to reasonably select certain computer-based system from a series of similar ones or evaluate adequacy of the automated system to the required quality level it is needed to obtain quantitative estimates of its performance indices.

2 WORLD PRACTICE

World practice knows a number of approaches that allow assessing computer-based system efficiency (Scripkin, 2002). Among them there can be marked out approaches based on evaluation of the direct financial return resulted from the system installation, as well as approaches proposed by Norton D. and Kaplan R. (1996) that are oriented also to nonfinancial component of automation effect, i.e. growth of client loyalty, rate of putting on the market of new products and services, managerial decision quality and so on. Entropy-based methods (Prangishvilly, 2003) can be related to another group. Zelenkov Yu.A. (2013), for instance, suggests entropy-based approach for assessing efficiency of computer-aided system that is oriented to estimation of the degree of unpredictability of the investigated business process results before, during and after the system installation. However the above-listed methods allow judging the system efficiency either based on the results of its implementation, which does not allow comparison of similar systems without their installation, or do not touch such issues as maintainability, reliability, usability and etc., i.e. consider not all aspects of the system functioning.


So quality model, quality requirements and recommendations for the evaluation of software product quality are defined in standards, but there is no unified definition for the algorithm which describes the process of software quality estimation completely. Quality characteristics as well as basic stages of assessment process (measurement, ranking and estimation) are defined in the standard, however there are no particular methods of measurement, ranking and estimation defined in it.

3 PROBLEM FORMULATION

So it is necessary to develop quality metering technique within the framework of which solving of the stated problem can be divided into the stages shown in Figure 1:

- Fulfillment of the stage named **System Description Based on Quality Indices** requires the following:
  1. Determine list of characteristics based on which the software must be assessed (this list may differ for different enterprises or computer-based systems);
  2. Determine list of basic aspects that must be described in order to evaluate the software based on the specified characteristics;

- Fulfillment of the stage named **Measurement Using Quality Indices** requires the following:
  3. Define quality indices measuring procedures;

- Fulfillment of the stage named **Ranking of Measurement Results** requires the following:
  4. Determine the appropriate ranking level for each index;

- Fulfillment of the stage named **Obtaining Overall Assessment** requires the following:
  5. Suggest a method that allows obtaining of the software quality overall assessment.

Fulfillment of the stage named **System Description Based on Quality Indices** requires the following:

So the problems are stated that must be solved for obtaining quantitative assessment of the software quality.

4 PROBLEM SOLVING

As one of the variants for forming the list of characteristics there was considered a variant of the list compilation based on the analysis of environment in which the software of one of the Russian industrial enterprises is operated. However in this case there is risk of considering not all the indices and it is needed to substantiate comprehensiveness of the list obtained. Therefore another alternative is selected to take as a basis complete list provided in ISO 9126 International Standard specifying major characteristics and corresponding to them software quality indices. In this case there appears a problem of irrelevance of a number of indices, but it is solved by use of relevance coefficients when obtaining overall assessment. Figure 2 provides list of quality characteristics and indices specified in the standard.

Figure 1: Solving stages of the stated problem.

Figure 2: Characteristics and indices.

For each of the above mentioned indices the authors developed a list of objects the requirements (ISO/IEC, 2007) to which must be formulated, and according to which the considered software must be described for assessing its quality; measuring procedures are also suggested (see Table 1).
Table 1: Requirements and measuring procedures.

<table>
<thead>
<tr>
<th>Quality Index</th>
<th>Program Description</th>
<th>Requirements to Program</th>
<th>Measuring Procedure</th>
<th>Measuring Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Suitability</td>
<td>Appropriateness of a set of functions to specified tasks</td>
<td>List of tasks that are solved by the system</td>
<td>List of tasks that the system must solve</td>
<td>Calculation (% of fulfilled tasks relative to the required ones)</td>
</tr>
<tr>
<td>2 Accuracy</td>
<td>Consistency of the results obtained and the expected ones</td>
<td>Results of functions execution</td>
<td>Requirements to the results of function execution</td>
<td>Calculation (% of the results obtained relative to the expected ones)</td>
</tr>
<tr>
<td>3 Interoperability</td>
<td>Ability to interact with specified systems</td>
<td>List of computerized systems with which the considered system is able to interact</td>
<td>List of computerized systems with which the considered system must interact</td>
<td>Calculation (% of available systems relative to the required ones)</td>
</tr>
<tr>
<td>4 Compliance</td>
<td>Compliance with standards, conventions, laws</td>
<td>List of standards and conventions the system is compliant with</td>
<td>List of standards and conventions the system must be compliant with</td>
<td>Calculation (% of satisfied standards relative to the required ones)</td>
</tr>
<tr>
<td>5 Security</td>
<td>Software ability to prevent unauthorized access to functions and data</td>
<td>Test set for unauthorized access to be passed by the system</td>
<td></td>
<td>Calculation (% of successful tests)</td>
</tr>
<tr>
<td>6 Maturity</td>
<td>Frequency of failures due to software errors</td>
<td>Frequency of failures due to software errors</td>
<td>Statistics (% of system failures due to software errors)</td>
<td>%</td>
</tr>
<tr>
<td>7 Fault Tolerance</td>
<td>Ability to provide specified performance quality level in case of program errors</td>
<td>Number of functions in operable state in case of system hole</td>
<td>Statistics (% of functions in operable state)</td>
<td>%</td>
</tr>
<tr>
<td>8 Recoverability</td>
<td>Ability to recover data and performance quality level</td>
<td>Sequence of data recovering operations</td>
<td>Statistics (% of recovered data)</td>
<td>%</td>
</tr>
<tr>
<td>9 Understandability</td>
<td>User efforts to understand general logical concept</td>
<td>User time spent for understanding general logical concept</td>
<td>Statistics (average spent time)</td>
<td>hour</td>
</tr>
<tr>
<td>10 Learnability</td>
<td>User learning efforts to train in software applying</td>
<td>Time spent by user for learning</td>
<td>Statistics (average spent time)</td>
<td>hour</td>
</tr>
<tr>
<td>11 Operability</td>
<td>User efforts to operate and control</td>
<td>User time spent for operation and operating control</td>
<td>Statistics (average spent time)</td>
<td>hour</td>
</tr>
<tr>
<td>12 Time Behavior</td>
<td>Rate of functions execution</td>
<td>Rate of functions execution</td>
<td>Statistics (average execution time)</td>
<td>min</td>
</tr>
<tr>
<td>13 Resource Behavior</td>
<td>Volume of used resources</td>
<td>Volume of used resources</td>
<td>Measurement</td>
<td>Kb</td>
</tr>
<tr>
<td>14 Analyzability</td>
<td>Efforts needed for diagnostics of imperfections, potential failures, determination of components to be upgraded</td>
<td>Code metrics (metrics of program stylistics and understandability)</td>
<td>Calculation</td>
<td></td>
</tr>
</tbody>
</table>

ICEIS 2014 - 16th International Conference on Enterprise Information Systems
Table 1: Requirements and measuring procedures (cont.).

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Code metrics (code cyclomatic complexity)</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Changeability: Efforts needed for modification, failure recovery or change of external environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Stability: Risk of unforeseen effects caused by system changes</td>
<td>Number of faults revealed while changes</td>
<td>Statistics (average number of faults per one modification)</td>
</tr>
<tr>
<td>17</td>
<td>Adaptability: Ease of adaptation to various operating environments</td>
<td>Specification of conditions (requirements to PC, necessary additional software) at which program operation is possible</td>
<td>Peer review</td>
</tr>
<tr>
<td>18</td>
<td>Installability: Efforts needed for the software installation</td>
<td>Software installation instructions</td>
<td>Calculation (time period needed for the system installation) hour</td>
</tr>
<tr>
<td>19</td>
<td>Conformance: Software capability of being compliant with standards and conventions accepted in the sphere of installation</td>
<td>List of standards and conventions the software complies with</td>
<td>Calculation (% of satisfied standards relative to the required ones) %</td>
</tr>
<tr>
<td>20</td>
<td>Replaceability: Possibility to use another similar software tool instead</td>
<td>Description of software tool to be applied instead</td>
<td>Peer review</td>
</tr>
</tbody>
</table>

Values of indices 1 – 4, 19 (% of executed functions, laws and etc. relative to the required ones) \( P_i \) are calculated according to an expression given in the following form:

\[
P_i = \left( \frac{\sum s_i}{\text{length}(TF)} \right) \times 100 \tag{1}
\]

where

\[
s_i = \begin{cases} 
1 & \text{if } f_i \in F, i=1..\text{length}(TF) \\
0, & \text{otherwise}
\end{cases} \tag{2}
\]

\( F = \{f_1, f_2, ..., f_n\} \) is a set of functions (laws, systems and etc.) that the system can execute (satisfy, interact with),

\( TF = \{t_1, t_2, ..., t_m\} \) is a set of functions (laws, systems and etc.) that the system must execute (satisfy, interact with).

Values of indices 5 – 8 (% of tests passed, data recovered and etc.) are calculated according to the following expression:

\[
P_i = \left( \frac{\sum B_i}{n} \right) \times 100 \tag{3}
\]

where

\( n \) is a number of measured parameters,

\( B_i \) is a value of the parameter measured \( (0 \text{ means that the test has not been passed, data is not recovered and so on, } 1 \text{ means otherwise, } i=1..n) \).

Average value (indices 9 – 12, 16) is calculated using formula:

\[
P_i = \frac{\sum Z_i}{n} \tag{4}
\]

where

\( n \) is a number of measured parameters,

\( Z_i \) is a value of the parameter measured, \( i=1..n \).

The simplest metrics of the program stylistics and understandability (index 14) is the estimate of the program saturation with comments \( F \):

\[
F = N_{\text{com}} / N_{\text{line}} \tag{5}
\]

where

\( N_{\text{com}} \) is a number of lines having comments in the program,

\( N_{\text{line}} \) is a total number of program lines.

Based on practical experience it is considered that \( F \geq 0.1 \), i.e. minimum one comment must be per every ten lines of the program. The study shows that comments are distributed through the program text nonuniformly: they are in excess in the beginning of the program, while the program middle or end lacks
of them. This can be explained by the fact that as a rule in the beginning of the program there are identifier specification statements requiring denser comment. In addition, in the program beginning there are also located “headlines” including general information on the developer, nature, functionality of the program and so on. Such saturation compensates lack of comments in the program body, and therefore formula (5) does not quite accurately reflect the level of the program saturation with comments in the functional part of the text. Hence more informative is a variant in which all the program is divided into \( n \) equal segments for each of which \( F_i \) is defined:

\[
F_i = \text{sign} \left( \frac{N_{\text{com}}}{N_{\text{line}}} - 0.1 \right)
\]  

(6)

and here

\[
F = \sum_{i=1}^{n} F_i
\]  

(7)

The level of the program saturation with comments is considered to be normal if \( F = n \) condition is true.

Halstead M. (1981) suggested the method of calculating a characteristic allowing estimation of the quality level of programming \( L \):

\[
L = \frac{V'}{V}
\]  

(8)

where \( V = N \times \log_2 n \) is a program volume, \( V' = N' \times \log_2 n' \) is theoretical volume of the program, \( n_1 \) is a number of unique program statements (dictionary of statements), \( n_2 \) is a number of unique program operands (dictionary of operands), \( N_1 \) is a total number of statements in the program, \( N_2 \) is a total number of operands in the program, \( n_1' \) is a theoretical number of unique statements, \( n_2' \) is a theoretical number of unique operands, \( n = n_1 + n_2 \) is the program dictionary, \( N = N_1 + N_2 \) is the program size, \( n^* = n_1 + n_2^* \) is theoretical program dictionary, \( N^* = n_1^* \times \log_2 (n_1) + n_2^* \times \log_2 (n_2) \) is theoretical program size (for stylistically correct programs deviation of \( N \) from \( N' \) does not exceed 10%).

For estimation of cyclomatic complexity (index 15) it is proposed to use the method suggested by McCabe T.J. (1976). In calculations program management flow graph is used: graph junctions correspond to indivisible blocks of program instructions and directed edges every of that connects two junctions and corresponds to two instructions, the second of which can be executed immediately after the first one. Then complexity \( M \) is defined as follows:

\[
M = E - N + 2P
\]  

(9)

where:

- \( E \) is a number of edges in graph,
- \( N \) is a number of junctions in graph,
- \( P \) is a number of connectivity components (set of graph nodes such that for any two nodes of this set there exists route from one node to another, and there is no route from the set node to a node not of this set).

According to McCabe it is recommended to calculate the complexity of the developed modules, and divide the latter into smaller ones every time when their cyclomatic complexity exceeds ten.

Currently the market offers a number of finished products allowing automatic calculation of code metrics. For instance, Microsoft Visual Studio, Embarcadero RAD Studio XE, NDepend, IBM Rational ClearCase, and Source Monitor.

Measuring procedures for quality indices are defined above. In order to determine ranking level corresponding to the value measured let us introduce the following symbols:

- \( r \) is a number of ranking levels (1st ranking level corresponds to the worst values of indices, \( r \)-th level – to the best ones);
- \( R_i \) is \( i \)-th ranking level;
- \( P_{\min} \) is the value of index that is critical for selection of ranking level better than the 1st one;
- \( P_{\max} \) is the value of index that is critical for selection of ranking level worse than the \( r \)-th one, then correspondence between values and ranking levels can be defined in the following way:

<table>
<thead>
<tr>
<th>Level</th>
<th>Index value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( \leq P_{\min} )</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( R_i )</td>
<td>( \left[ P_{\max} - P_{\min}, (R_i - 1) \right] )</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>( R_r )</td>
<td>( &gt; P_{\max} )</td>
</tr>
</tbody>
</table>
Below an example is given of determining correspondence between value and ranking level for percentagewise measured indices.
Let us consider 5 possible ranking levels \( r = 5 \), and specify \( P_{\text{min}} = 20\% \); \( P_{\text{max}} = 80\% \), then applying formulas given in Table 2 we will obtain:

<table>
<thead>
<tr>
<th>Level</th>
<th>Index value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( \leq 20% )</td>
</tr>
<tr>
<td>2</td>
<td>( (20 + \frac{80 - 20}{5 - 2} \cdot (1 - 1)); (20 + \frac{80 - 20}{5 - 2} \cdot (2 - 1)) % )</td>
</tr>
<tr>
<td>3</td>
<td>( 40;60% )</td>
</tr>
<tr>
<td>4</td>
<td>( 60;80% )</td>
</tr>
<tr>
<td>5</td>
<td>( &gt;80% )</td>
</tr>
</tbody>
</table>

Let us introduce the following symbols in order to solve the problem of obtaining overall quality assessment:
\( P \) is a set of indices based on which the software is assessed,
\( k \) is a number of assessed indices,
\( P_i \) is measured value of index, \( i = 1..k \),
\( \phi_i(P_i) \) is corresponding ranking level, \( i = 1..k \),
\( \alpha_i \) is \( i \)th index relevance, \( \alpha \) (is determined individually for each software by method of paired comparisons (Hvastynov, 2002)), \( i = 1..k \),
\( r \) is a number of ranking levels,
then overall software quality assessment \( K \) can be represented in the form of:

\[
K = \sum_{i=1}^{k} \alpha_i \cdot \phi_i(P_i) \tag{10}
\]

and maximum value of quality assessment criterion in the form of:

\[
K_{\max} = \sum_{i=1}^{k} \alpha_i \cdot r \tag{11}
\]

So for software quality assessment it is necessary to do the following:
1. Describe the requirements to the program (see Table 1, column \textit{Requirements to Program});
2. Describe the program in accordance with quality indices (see Table 1, column \textit{Program Description});
3. Define relevance of quality indices (\( \alpha_i \));
4. Obtain quantitative assessment based on quality indices \( P_i \) (formulas 1 – 9);
5. Determine the number of ranking levels and correspondence between quality index \( \phi_i(P_i) \) values and ranking levels;
6. Obtain overall software quality assessment \( K \) according to formula 10.

In order to solve the task of the software quality conformance to the specified criterion it is needed to determine the value of the criterion \( K_g \) by expertise so that

\[
0 \leq K_g \leq K_{\max} \tag{12}
\]

in this case if assessment value is \( K \geq K_g \), then the software under consideration meets the required quality level.

Developed technique was used by the authors for the quality assessment of the enterprise information-management system software which was established in the institute and for the comparison of this system with similar computer programs and for demonstrating of its effectiveness.

5 CONCLUSIONS

So the paper describes the method that allows obtaining software quality quantitative assessment, defining whether the considered software meets the required quality level, and, in case it is needed to select between equivalent software tools, allows comparing them one with each other.

REFERENCES