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Method and tool for support of software requirements profile quality assessment

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***Abstract* – method for support of software requirements profile quality assessment was reviewed. External and internal quality of software requirements profile in the method was reviewed separately. Metrics and indexes as general taxonomy was used in the method for assessment. Radial-metrics diagrams was used For visualization of received results. Method in full volume was supported by developed tool. An example use of tool for assessment draft of new standard «Requirements to computer security of NPP Instrumentation and Control Systems (NPP I&C)» developed by Ukrainian state regulatory body was represented.**

Keywords – software requirements profile, software requirements profile quality assessment tool, ISO/IEEE 29148, ISO/IEC 25012

I. INTRODUCTION AND STATEMENT OF PROBLEM

Foundation of software developing is terms of references, which includes a set of software requirements. The requirements combined to single semantic taxonomic structure [1], which has stable name – requirements profile [2]. Software requirements profile – is a product of work of experts, which includes non-functional and functional requirements.

For making set of non-functional requirements experts use standardized software quality models [3-6], which describe software quality characteristics. Functional requirements are created according to the purpose of software, which is being developed. Because software requirements in profile are verbal, their representation, description and assessment weakly formalize and can not be done without an expert.

Metrical approach for non-functional requirements assessment is standardized, because it is described in international standards and such requirements correspond to software quality characteristics [7].

Assessment of non-functional requirements, that do not meet software quality models characteristics and functional requirements are not standardized in the form of formalized methods and techniques.

Existing approaches, methods and tools, which are applied to software requirements quality assessment have some limitations and disadvantages:

- approaches and methods for manual assessment of software requirements quality [8,9] are results driven of analytical work of experts;
- approaches and methods software requirements assessment at the level of models [10-12] propose theoretical result only, which can be realized as a tool in the future;
- approaches and methods, which, as a rule, are based on experience of experts only [13, 14];
- approaches, methods and tools for qualitative assessment for non-functional software requirements [15, 16].

The objective of the article is to develop method and tool of software requirements profile quality assessment. Structure of the paper is the following:

- a short description of method of software requirements profile quality assessment using standards ISO/IEEE 29148 и ISO/IEC 25012 (section II);
- a description of possibilities of the tool to support software requirements profile quality assessment, which is based on the proposed method (section III);
- an assessment of part of real profile of software requirements from draft of new standard «Requirements to computer security of NPP Instrumentation and Control Systems (NPP I&C)» developed by Ukrainian state regulatory body (section IV);
- discussion of the results and future plans.

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II. METHOD OF SOFTWARE REQUIREMENTS PROFILE QUALITY ASSESSMENT

First of all, let's specify the following terms:

– software requirement – is a statement which translates or expresses a need and its associated constraints and conditions;

– software requirements profile – is a set of requirements, which are combined in a single structure;

– requirement characteristic – is a set of features, that define distinctive particularities of a requirement;

– quality of requirements profile – is a complex notion, which combines in itself, on the one hand, quality of each requirement at profile, on the other hand – quality of all set of requirements at software requirements profile. It is constituent of software quality;

– requirement attribute – is a field of entity (software requirements, software requirements profile, classification features) that can be distinguished quantitatively or qualitatively by human or automated means.

The object of assessment for method (Fig. 1) is the software requirements profile. Quality of the software requirements profile consist of two parts: internal quality and external quality of the software requirements profile. Internal software requirements profile – is quality of each requirement, which is part in the software requirements profile. External quality – is quality of the full software requirements profile. In accordance with standards [17, 18] complex terms internal and external quality of software requirements profile detailed as: characteristics and attributes of software requirements and their classification features; semantics and syntax of software requirements; characteristics and attributes of software requirements profile and their classification features. Nomenclature of quantitative (qualitative) indexes and metrics, which combined to a single taxonomy for assessment of such elements of the software requirements profile was made (Fig. 2) (I – index, M – metric). Metric – is technique and scale of assessment.

Quantitative metrics on Fig. 2 were marked by background of gray color and qualitative metrics – white color. All metrics can be logically separated into 2 groups:

– external quality of software requirements profile (EQSRP) metrics: M1-M21;

– internal quality of software requirements profile (IQSRP) metrics: M22-M67.

Since there are a lot of metrics (67 items), for an example will be presented only some of them - one from each group:

– from external quality of software requirements profile (EQSRP) metrics (1):

$$\text{(M18)}\ SRPAQ = \frac{SRPPAQ}{SRPAAQ} \qquad (1)$$

SRPAQ – software requirements profile attributes quality, primitives: *SRPPAQ* – software requirements profile performed attributes quantity, *SRPAAQ* – software requirements profile all attributes quantity;

– from internal quality of software requirements profile (IQSRP) metrics (2):

$$\text{(M65)}\ SRPSRMSS = \frac{1}{MSSQ} \qquad (2)$$

SRPSRMSS – software requirements profile software requirement mandatory semantic structures, MSSQ – mandatory semantic structures quantity (primitive).

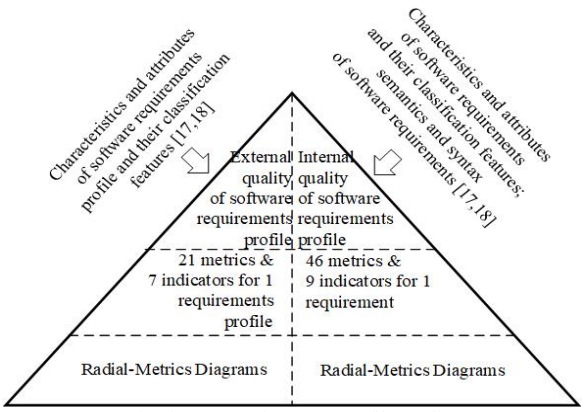

Fig. 1. Structure of software requirements profile quality assessment method.

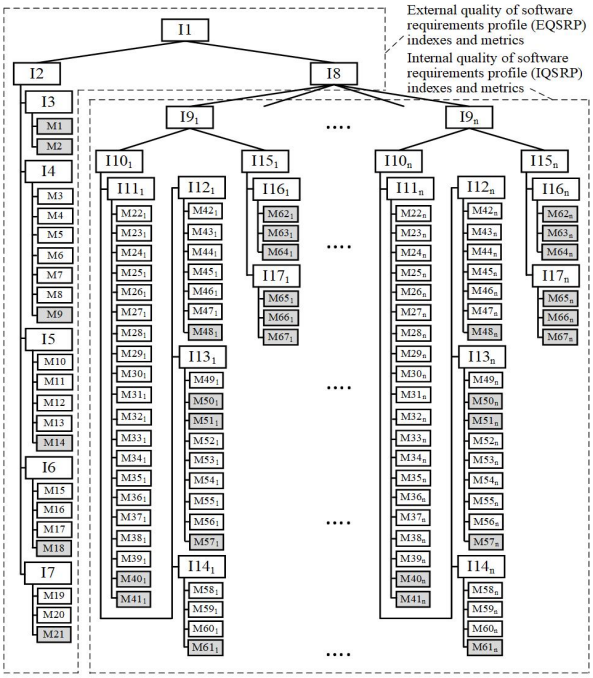

Fig. 2. Taxonomy of indexes and metrics of software requirements profile quality assessment.

The set of indexes in accordance with groups of internal and external quality of the software requirements profile is represented in table 1 following columns: ID, Abbreviation and Full name. To switch from multi-vector values of the set of connected indexes or metrics (Fig. 2) to single scalar value the additive convolution method is used to calculate all indexes.

TABLE I. INDEXES

ID	Abbreviation	Full name
1. External quality of software requirements profile (EQSRP) indexes		
I1	*SRPQGI*	Software requirements profile quality generalized index
I2	*SRPEQGI*	Software requirements profile external quality generalized index
I3	*SRPSQI*	Software requirements profile structure quality index
I4	*SRPCQI*	Software requirements profile characteristics quality index
I5	*SRPCFCQI*	Software requirements profile classification features characteristics quality index
I6	*SRPAQI*	Software requirements profile attributes quality index
I7	*SRPCFAQI*	Software requirements profile classification features attributes quality index
I8	*SRPIQGI*	Software requirements profile internal quality generalized index
2. Internal quality of software requirements profile (IQSRP) indexes		
$I9_1$	*SRPQIRGI*	Software requirements profile quality individual requirement generalized index
$I10_1$	*SRPEQIRGI*	Software requirements profile external quality individual requirement generalized index
$I11_1$	*SRPCQIRI*	Software requirements profile characteristics quality individual requirement index
$I12_1$	*SRPCFCQIRI*	Software requirements profile classification feature characteristics quality individual requirement index
$I13_1$	*SRPAQIRI*	Software requirements profile attributes quality individual requirement index
$I14_1$	*SRPCFAQIRI*	Software requirements profile classification feature attributes quality individual requirement index
$I15_1$	*SRPIQIRGI*	Software requirements profile internal quality individual requirement generalized index
$I16_1$	*SRPSQIRI*	Software requirements profile syntax quality individual requirement index
$I17_1$	*SRPSEQIRI*	Software requirements profile semantics quality individual requirement index

Number and nomenclature of indexes and metrics from the external quality of the software requirements profile (EQSRP) are always permanent for any software requirements profile. Nomenclature of indexes and metrics from internal quality of software requirements profile (IQSRP) is always permanent, but their number corresponds to the quantity of requirements in the software requirements profile.

For example, if the software requirements profile consists of 20 requirements, then the number of metrics M22-M67 will be 20 and the number of indexes I9-I17 will be 20 as wells. For each such index and metric there is an index, which corresponds to ordinal number of the requirements in the software requirements profile (Fig. 2).

III. TOOL FOR SUPPORT OF SOFTWARE REQUIREMENTS PROFILE QUALITY ASSESSMENT

Tool was developed in accordance with the software requirements profile quality assessment method. The tool supports the process of indexes and metrics calculation, visualization of received values in form of RMD, a system of hints for each index and metric. The tool supports calculation of the level of external quality of the software requirements profile using the relevant indexes (I1-I7) and metrics (M1-M21) (Fig. 3). The tool supports calculation of the level of internal quality of the software requirements profile using the relevant indexes (I9-I17) and metrics (M22-M67) (Fig. 4) as well.

User interface of the tool includes of following elements (Fig. 3): menu (Project, Settings, About) (1), search of project (2), software requirements profile (3), work area for input initial data (4), designation of index (5), button for index value calculation (6), button for values visualization as RMD (7), system of hints according to index (8), name of requirement (9), input boxes for input of weight coefficients values (10), designation of metric (11), system of hints according to metric (12), calculated value of quantitative metric (13), designation of primitives (14), system of hints according to primitives (15), input boxes for input of primitives values (16), button for save received results in database (17). Tool validates input boxes on empty values of metrics, primitives and weight coefficients, as well as the equality of the sum of the weights.

The tool supports the construction of radial-metrics diagrams (RMD) [19] (Fig. 5) for detail visualization of received values of indexes and metrics. In RMD each index (metric) is represented by a separate vector, on which the value of the index or metric is marked. Value of the index (metric) and value of its weight coefficient are indicated near the scale of vector. The value of the index is marked on the scale of vector directly and can fall into one of three sectors: not correspond (red sector), partial correspond (yellow sector) or correspond (green sector). The intervals of such sectors can be adjusted by an expert, with consideration of particularities of the evaluated software requirements profile.

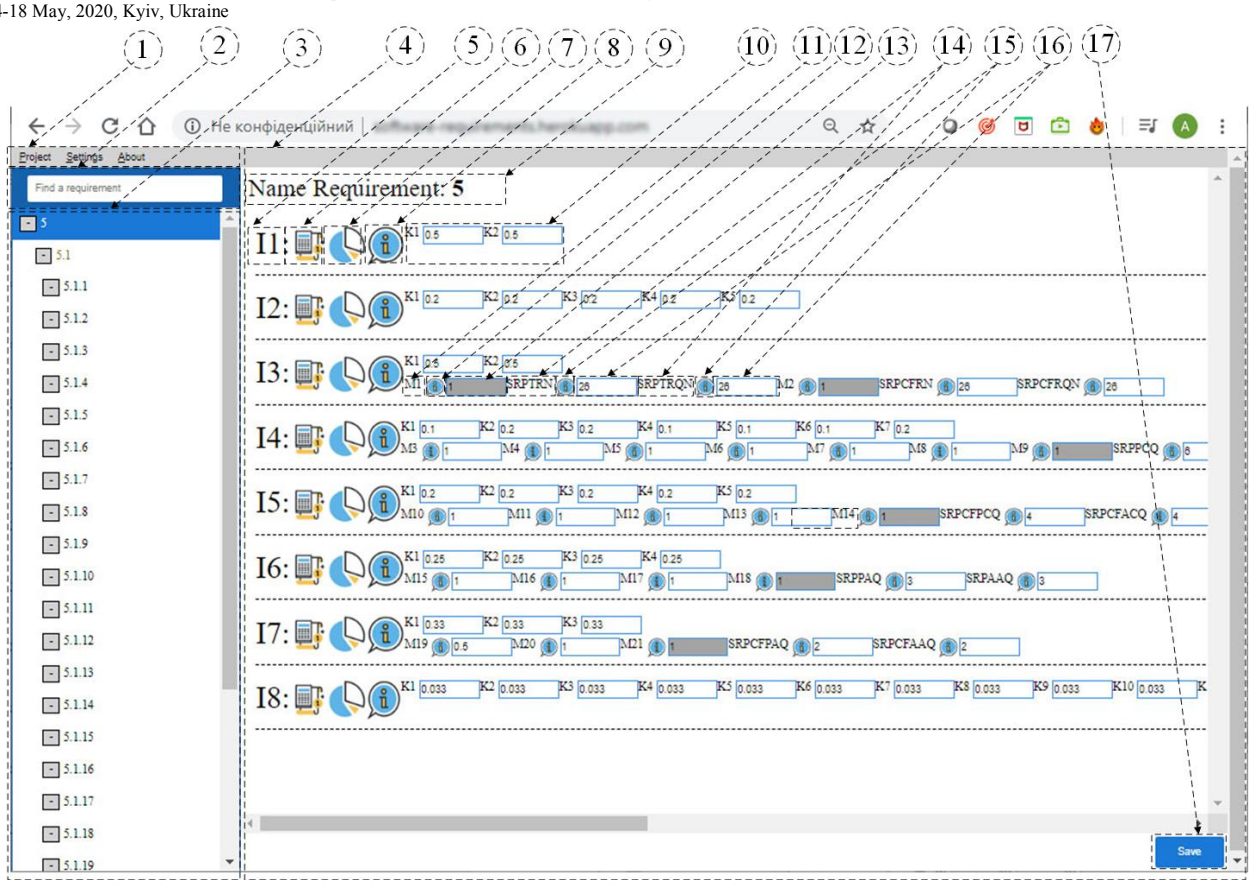

Fig. 3. Screenshot of tool (External quality of software requirements profile indexes and metrics).

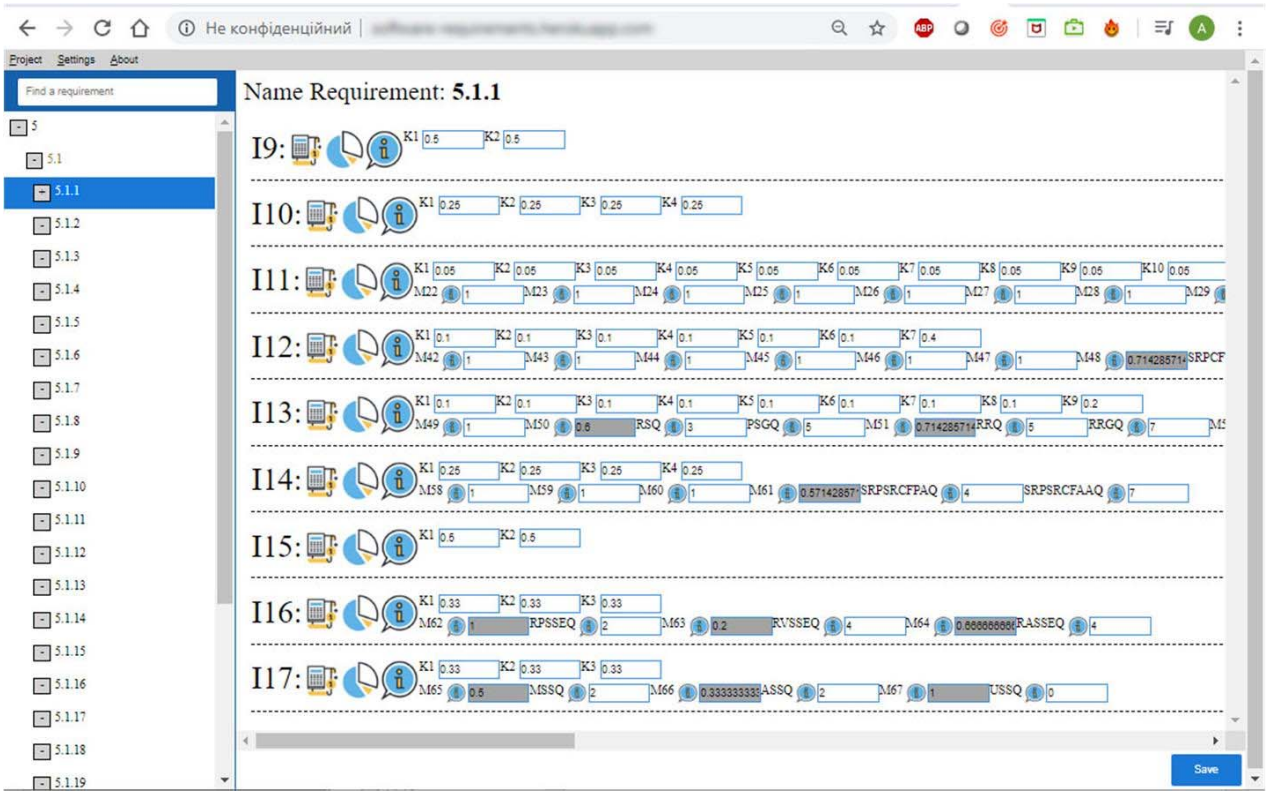

Fig. 4. Screenshot of tool (Internal quality of software requirements profile indexes and metrics).

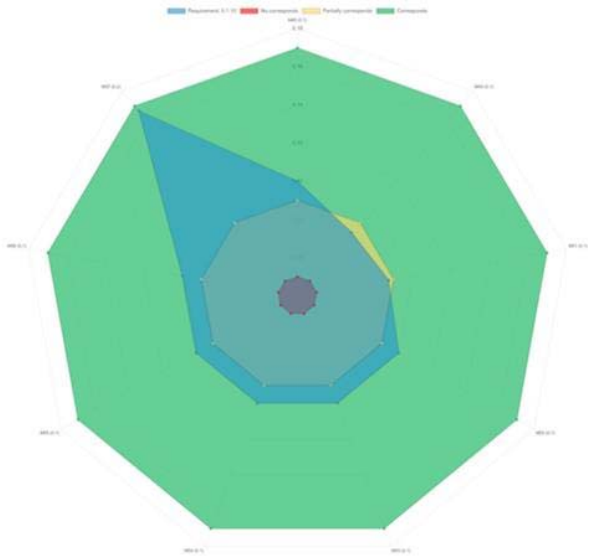

Fig. 5. Overall view of radial-metrics diagram.

An expert can view the calculated value (Fig. 6) for each index (metric). To do this, the expert have to press button 6 (Fig. 3). To make expert's work more comfortable and productive , appropriate hints are provided for each index (metric) (Fig. 7). Hint is enable when the computer mouse cursor directs at button 8 (Fig. 3).

Fig. 6. Screenshot of index volume.

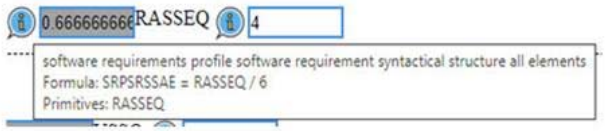

Fig. 7. Screenshot of hint for metric.

IV. CASE STUDY

Tool was approbated for the software requirements profile quality assessment. For assessment of the 5th chapter «Assurance of computer security on stage of development» of the draft of new standard «Requirements to computer security of NPP Instrumentation and Control Systems (NPP I&C)» developed by Ukrainian state regulatory body was selected. Such requirements profile (5th chapter of draft of new standard) includes 26 requirements. Since the limited size of the article does not allow to represent the software requirements profile in full value, the article includes separate requirements of full software requirements profile only in table. 2 (translation from Ukrainian language).

New separate new project for the software requirements profile quality assessment was created. All requirements in accordance with the software requirements profile were inputted in the project. Structure of software requirements profile in project fully corresponds to the initial software requirements profile. Following initial data for the calculation of quantitative metrics, indexes and visualization of received results were inputted on following step:

- values of qualitative metrics;
- values of primitives for quantitative metrics calculation;
- values of weight coefficients for indexes calculation.

TABLE II. SEPARATE REQUIREMENTS OF DRAFT OF NEW STANDARD «REQUIREMENTS TO COMPUTER SECURITY OF NPP INSTRUMENTATION AND CONTROL SYSTEMS (NPP I&C)»

№	Description
5	Assurance of computer security on development stage
5.1	General project events of computer security of information-communication systems (ICS)
5.1.1	ICS development imply minimization of vulnerabilities and realization in system of general and additional (dependence from level computer security of ICS) techniques of computer security
	…….
5.1.3	Software must be verified in accordance with requirements of nuclear and radiation security for information and control systems, important for security of nuclear power plants. Verification of realization of computer security technics in software of ICS and absence of their negative influence on functions of ICS, which is important for nuclear and radiation security. Verification of tools, which are used for software development release in accordance with requirements for software of ICS and their components
	…….
5.1.5	During the development of an ICS, it is taken into consideration, that connection between the ICS of different levels of computer security is initiated from the ICS of a higher level. In ICS project activities ensure that there is no negative impact from other ICS
	…….
5.1.7	Access to computer networks in ICS is minimized by the number of access points
	…….
5.1.11	ICS realizes testing techniques for any software modifications
	…….
5.1.13	Any previously developed component (especially including one provided by third parties) which was selected, configured and installed for minimization of vulnerabilities in ICS
5.1.14	During projection, configuration, and/or installation of parameters of programmed equipment realize effective events for protection for:

	- control of selective user access to software functions and to memory; - linear delivery data in ICS with lower levels of computer security; - monitoring software modifications and parameters
	…….
5.1.17	Any information relating to projection, development, integration and usage of ICS is identified and, where appropriate, designated as information with limited access. For such information, there is a need to use a protection against unauthorized disclosure, theft, distortion or destruction
5.1.18	Techniques of protection against unauthorized access to ICS components and computer networks equipment are ensuring
	…….
5.1.22	The project documentation defines the functions, which are critical to computer security and computer security elements applied in the software

All inputted data were saved in the project and on their basis values of metrics and indexes were calculated. Values of 46 metrics and 9 indexes were calculated for assessment of the internal quality of each requirement. In total 1192 metrics values (46 metrics * 26 requirements) and 234 indexes values (9 indexes * 26 requirements) were received. For assessment of external quality 21 metrics values and 7 indexes values were calculated. The article does not represent the calculated metrics values. Index values for internal (table 2) and external (table 3) quality were represented only. For a better presentation of information when visualizing the results obtained in the form of RMD, the tool provides the ability to set 3 ranges of boundary values. Color value was set for each such range in RMD. For example, for such case study for each ranges of boundary values were set following values and their color conformance:

– for range (sector) «not correspond» are set values (0-0.69) and red color;

– for range (sector) «partial correspond» are set values (0.7-0.79) and yellow color;

– for range (sector) «correspond» are set values (0.8-0.9) and green color.

Expert has one RMD for each index for visualization of received results. I.e. in the case study expert has access to watch visual data about internal quality of software requirements profile – 234 RMDs and data about external quality of software requirements profile – 7 RMDs. In the article all RMDs are not represented. For example, several following RMDs are represented only:

– for visualization of values of index I9 of the internal quality of software requirements profile for 26 requirements (Fig. 8);

– for visualization of values of indexes I3-I7 of the external quality of software requirements profile for software requirements profile (Fig. 9).

Multicolour RMD sectors enable the expert to operatively and visually determine the problematic values of indexes and metrics in accordance with developed taxonomy (Fig. 2).

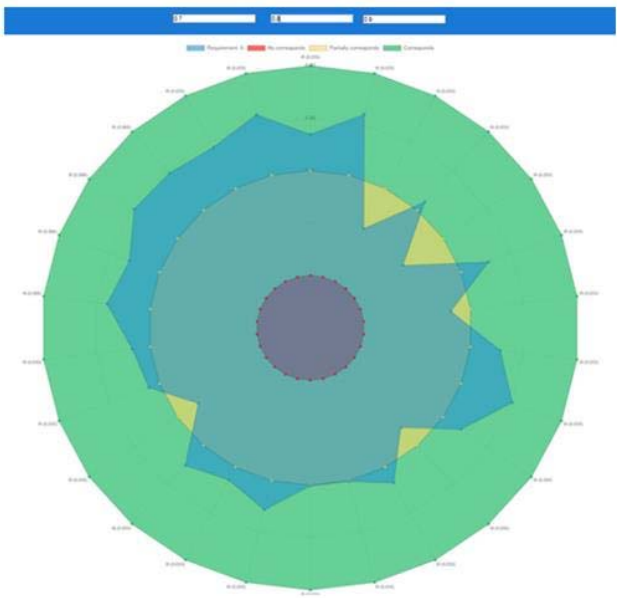

Fig. 8. RMD for I9.

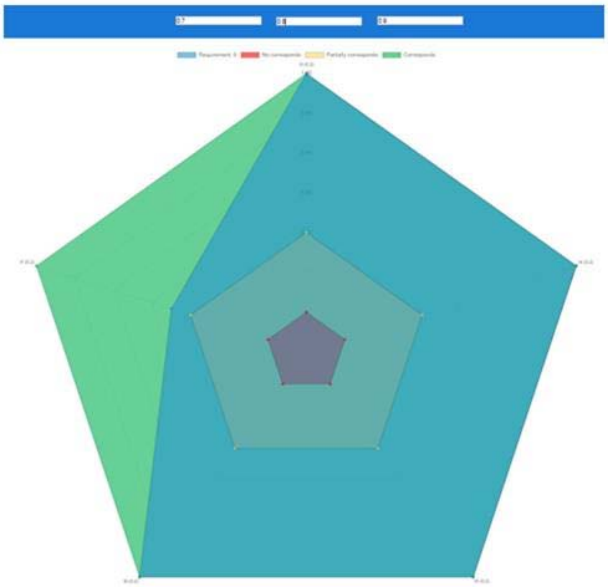

Fig. 9. RMD for I3-I7.

The values of all indexes were summarized in two tables: internal quality of software requirements profile indexes values (table 3) and external quality of software requirements profile indexes values (table 4). The values of indexes in the table will be reviewed in more detail. For simplicity of analysis of the values of indexes in table were marked by colors in accordance with previously established ranges of boundary values. Thus, all values in the table 3 and table 4 are marked in red, yellow and green colors. Visually it can be seen, that in table 3 green color is

dominant, and in table 4 there is green color only. This indicates that the prevailing indicator values are in the «correspond» sector. Based on the taxonomy of indexes and metrics of software requirements profile quality (Fig. 2) the most integral index for each software requirement in assessing the internal quality of requirements profile is I9. This index combines the values of all indexes of a lower level via mechanism of additive convolution. Thus, out of 26 values of index I9 (one index for one requirement) in sector «correspond» (green color) there are 21 values (81%), in sector «partial correspond» – 5 values (19%), in sector «not correspond » not a single value. Based on the taxonomy of indexes and metrics of software requirements profile quality assessment, values of I10 and I15 indexes were analyzed. All values of index I10 are in the sector «correspond». Values of index I15 by sector were spread as follows: in sector «correspond» – 2 values (7%), in sector «partial correspond» – 15 values (58%), in sector «not correspond» – 9 values (35%). All values of indexes I11 and I13 are in sector «correspond». Values of indexes I12 were included in two sectors: in sector «correspond» there are 25 values (96%) and in sector «not correspond » – 1 value (4%). Values of index I16 were spread as follows: in sector «correspond» – 1 value (4%), in sector «partial correspond» – 9 values (35%), in sector «not correspond » – 16 values (61%). And for the last index I17, its values were spread as follows: in sector «correspond» – 3 values (12%), in sector «partial correspond» – 20 values (76%), in sector «not correspond» – 3 values (12%).

Values of all indexes for external quality of software requirements profile (I1-I8) are in sector «correspond».

Summarizing the results of the case study, we can make following conclusions:

– 155 values of indexes (67%) are in sector «correspond», 50 values (21%) – in sector «partial correspond» and 29 values (12%) – in sector «not correspond»;

– the received results are very sensitive to ranges of boundary values for sectors «correspond», «partial correspond» and «not correspond»;

– also, the significant influence on values of indexes make weight coefficients;

– the proposed method and tool based on the calculated values of indexes and metrics define the requirements, which should be paid closer attention (particularly for requirements for which values of indexes are in sector «not correspond») in order to confirm its quality or increase its level.

Therefore, it is recommended that developers of the draft of new standard «Requirements to computer security of NPP Instrumentation and Control Systems (NPP I&C)» analyze the following requirements: 5.1.3, 5.1.5, 5.1.7, 5.1.18 (text of requirements in table 2, values of indexes in table 3). I.e. such requirements for which the values of the highest hierarchy (Fig. 2) of indicator I9 from the group of indicators internal quality of software requirements profile are in sector «partial correspond».

TABLE III. INTERNAL QUALITY OF SOFTWARE REQUIREMENTS PROFILE INDEX VALUES

# of requirement	I9	I10	I11	I12	I13	I14	I15	I16	I17	Number of index values		
										Corresp.	Partial corresp.	No corresp.
5.1.1	0.84	0.9	0.97	0.89	0.87	0.89	0.76	0.77	0.76	6	3	-
5.1.2	0.86	0.9	0.96	0.85	0.89	0.93	0.81	0.85	0.77	8	1	-
5.1.3	0.76	0.86	0.97	0.83	0.85	0.93	0.69	0.55	0.69	5	1	3
5.1.4	0.8	0.9	0.97	0.89	0.9	0.89	0.71	0.66	0.76	6	2	1
5.1.5	0.76	0.9	0.97	0.87	0.8	0.93	0.6	0.52	0.7	5	2	2
5.1.6	0.83	0.9	0.96	0.83	0.88	0.93	0.76	0.74	0.77	6	3	-
5.1.7	0.78	0.9	0.97	0.87	0.88	0.92	0.65	0.55	0.76	5	2	2
5.1.8	0.83	0.93	0.97	0.97	0.86	0.93	0.93	0.6	0.84	8	-	1
5.1.9	0.85	0.93	0.97	0.94	0.89	0.93	0.77	0.77	0.77	6	3	-
5.1.10	0.82	0.93	0.98	0.89	0.94	0.92	0.7	0.72	0.7	6	3	-
5.1.11	0.78	0.84	0.97	0.63	0.85	0.93	0.7	0.66	0.76	4	3	2
5.1.12	0.82	0.92	0.96	0.87	0.89	0.96	0.7	0.72	0.72	6	3	-
5.1.13	0.8	0.93	0.97	0.89	0.9	0.95	0.67	0.6	0.74	6	1	2
5.1.14	0.8	0.96	0.99	0.93	0.94	0.96	0.65	0.6	0.69	6	-	3
5.1.15	0.83	0.95	0.98	0.93	0.91	0.96	0.71	0.66	0.76	6	2	1
5.1.16	0.81	0.95	0.98	0.98	0.93	0.96	0.68	0.6	0.76	6	1	2
5.1.17	0.83	0.95	0.98	0.92	0.96	0.7	0.72	0.69	0.69	5	2	2
5.1.18	0.78	0.89	0.98	0.92	0.76	0.92	0.66	0.6	0.72	5	2	2
5.1.19	0.81	0.95	0.98	0.93	0.92	0.96	0.67	0.6	0.74	6	1	2
5.1.20	0.82	0.95	0.98	0.93	0.94	0.96	0.68	0.66	0.7	6	1	2
5.1.21	0.84	0.94	0.98	0.92	0.93	0.95	0.74	0.77	0.7	6	3	-
5.1.22	0.83	0.95	0.98	0.92	0.92	0.96	0.72	0.72	0.72	6	3	-
5.1.23	0.85	0.94	0.98	0.92	0.92	0.95	0.76	0.6	0.91	7	1	1
5.1.24	0.85	0.93	0.98	0.9	0.91	0.94	0.76	0.77	0.76	6	3	-
5.1.25	0.84	0.92	0.96	0.9	0.9	0.92	0.77	0.77	0.77	6	3	-
5.1.26	0.86	0.93	0.98	0.94	0.87	0.95	0.78	0.69	0.88	7	1	1
									Total:	155 (67%)	50 (21%)	29 (12%)

TABLE IV. EXTERNAL QUALITY OF SOFTWARE REQUIREMENTS PROFILE INDEXES VALUES

# of project	I1	I2	I3	I4	I5	I6	I7	I8
5	0.89	0.97	1	1	1	1	0.83	0.81

V. CONCLUSIONS

The proposed method and tool formalize the process of assessment of software requirements profile quality. The tool allows us to configure particularities of assessment of each software requirements profile by setting values of ranges of boundary values and values of weight coefficients. Visualization of the received results in the form of RMD simplifies the work of expert and defines requirements, the quality of which should either be confirmed or improved.

On the one hand, proposed method and tool both have flexible mechanisms of customization (ranges of boundary values and weight coefficients), and on the other hand are very sensitive to qualification of expert, who make the assessment of software requirements profile quality.

The paper represents a real example of assessment of part of the draft of new standard «Requirements to computer security of NPP Instrumentation and Control Systems (NPP I&C)» developed by Ukrainian state regulatory body.

In the future, it is planned to develop a methodology for assessing the quality of the software requirements profile and an interactive assistance module for the expert and integrate such additions into the existing.

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