

AN AUTOMATIC QUALITY ASSESSMENT METHODOLOGY FOR ABSTRACT TEST SUITES

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Abstract – Testing is a major factor in the successful development of efficient and reliable telecommunication implementations. The need for a unified approach in conformance testing, led to the publication of the Conformance Testing Methodology and Framework (CTMF) standard ISO/IEC 9646 ([1], [2], [3], [4], [5], [6], [7]). The Tree and Tabular Combined Notation (TTCN), is the standard language used to specify Abstract Test Suites (ATSS) [3]. It is observed that quality of TTCN test suites published by international committees (ETSI, ITU-T) is often regarded as poor. This is an indication of weaknesses in current Quality Assessment (QA) practices. In this paper an automatic quality assessment method for Abstract Test Suites is defined, tested and evaluated.

Keywords: Conformance Testing; TTCN Abstract Test Suite; Software metrics; Automatic quality assessment.

1. INTRODUCTION

In order to provide effective support for the improvement of quality using an automated approach a specific model must be defined which could act as a template for an automated quality process. The set of the proposed sequential steps, which should be taken, in order to allow the automatic quality assessment of an ATS are listed below:

- The interpretation of a quality assessment model consisting of quality factors and quality criteria.
- The creation of a set of rules for the TTCN notation to assure that the previous quality factors and criteria are satisfied.
- The creation of a series of static measurement, called metrics, which implement the TTCN notation rules.
- The definition of specific quality limits for each metric based on the interpretation of the corresponding rule.

The generation of a quality assessment process, based on mathematical equations, extracted from metrics and relationships between the TTCN notation rules, quality factors and criteria.

The arrangement of these steps, in a form of a quality assessment tree, is depicted in Figure 1 [8]. Each of these

steps is described in detail within the following paragraphs. In order to test and evaluate the usefulness and effectiveness of the proposed method a software tool that automates the assessment process was developed. The tool provides automated support for assessment purposes based on the collection and calculation of the metrics.

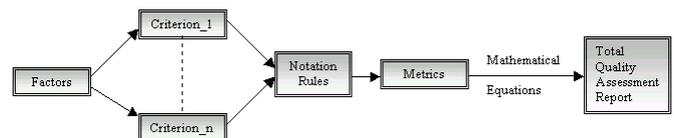


Fig. 1. Quality Assessment Tree

2. THE QUALITY ASSESSMENT MODEL

During the last decades several models for software quality assessment have been developed. Since the development of an ATS is similar to the standard software development a similar approach can be followed for the quality assessment of the ATSS. A well-known quality assessment model is the one developed by McCall, Richard and Walter [9]. This quality model is based on a number of quality factors. To make the evaluation process easier and more general the quality factors split into a number of corresponding criteria. Table I presents the McCall's quality factors while Table II presents the McCall's quality criteria. Finally, in the appendix, Table A presents the mapping between the factors and the above-mentioned criteria.

3. DEFINITION OF RULES FOR THE TTCN NOTATION

The following step to the evaluation process is the definition of quality rules for the TTCN notation. These rules influence the quality criteria of McCall's model. The defined rules can be grouped according to the elements that influence the quality of an Abstract Test Suite. These groups of rules will be referred from now on as GQR (Group of Quality Rules). The grouping of rules is very helpful to the assessment process, since each GQR affects one or more quality criteria and there is no need to map each rule

separately to the criteria. The only requirement is to specify the quality criteria, which are influenced by each GQR. An example of a GQR definition is illustrated in table III. The mapping between the GQRs and McCall's quality criteria is presented in the appendix through Table B. The symbol "✓" in the table indicates that the GQR influences the quality of the corresponding criterion.

TABLE I. Quality Factors

NO	FACTOR	DEFINITION
F0	Usability	effort required to learn and understand the TS document
F1	Correctness	Extent to which the TS document satisfies its specification and fulfils the user's mission objectives
F2	Maintainability	effort required to locate and fix an error in the TS document
F3	Testability	effort required to test a TS document to ensure it performs its intended function
F4	Flexibility	effort required to modify a TS document
F5	Portability	effort required to transfer a TS document from one system environment to another
F6	Reusability	Extent to which a TS document can be used within other applications (profiles or protocols, test methods)

TABLE II. Quality Criteria

No	CRITERION	DEFINITION
C0	Traceability	Those attributes of the TS document that provide a thread from the requirements to the realization with respect to the specific development and operational environment
C1	Completeness	Those attributes of the TS document that provide full realization of the required functionality
C2	Consistency	Those attributes of the TS document that provide uniform design techniques and notation
C3	Simplicity	Those attributes of the TS document that provide realization of functionality in the most understandable manner (usually avoidance of practices which increase complexity)
C4	Generality	Those attributes of the TS document that provide breadth to the defined functionality
C5	Instrumentation	Those attributes of the TS document that provide for the possibility to identify errors or unexpected situations
C6	Self-Descriptiveness	Those attributes of the TS document that provide explanation of the realization
C7	Operability	Those attributes of the TS document that determine operation and procedures concerned with the operation of the TS document
C8	Training	Those attributes of the TS document that provide transition from current operation or initial familiarization.
C9	System Independence	Those attributes of the TS document that determine its dependency on the system environment
C10	Modularity	Those attributes of the TS document that provide a structure of highly independent modules

TABLE III. Rules for the GQR TEST SUITE OPERATIONS

GQR: TEST SUITE OPERATIONS	
1.	The Notation used must be known and explained
2.	All alternative paths must be fully specified
3.	TSO must return a value in all circumstances. There must be a RETURN VALUE statement in every TSOs
4.	There must be no empty input variables
5.	There must be no side effects
6.	Examples must be given
7.	The THEN and ELSE parts of instructions must not be empty

4. TTCN METRICS DEFINITION

The TTCN quality rules, in text format, can not be used in an automatic quality assessment process. Only a manual quality assessment process can be based on text [10]. For the automatic process the computer can understand only numbers. Therefore, the next step to the automatic quality assessment process is the extraction of metrics for the TTCN quality rules. Metrics are static measurements obtained without executing the ATS.

For the quality assessment of ATSS, two types of metrics are proposed. The first kind of metric deals with rules that can be translated into metrics by measuring only one feature of the ATS. Based only on this measurement, an assessment for the quality of the ATS can be decided. Besides these rules, other type of rules cannot be translated into metrics, by measuring only one feature of the ATS. The metrics of these rules, is the products of the comparison of two or more features of the ATS. The outcome of these comparisons is usually an average number, which can lead to quality conclusions for the ATS. This is the second type of metric. For every GQR, a set of metrics is derived. The definition of a metric is explained in the following example.

Name: NUCT (Number of UNCANCELED Timers)

Description: The total number of uncanceled timers in the ATS.

Application: This metric belongs to the GQR_TIMERS and concerns the proper use of timers in the ATS. It must be used during the implementation phase, in order to make sure that all the timers used in the ATS are canceled after their usage.

Extraction procedure: The total number of uncanceled timer in the ATS is:

$$NUCT = (NOTM) - (NOTM_O) - (NOCT).$$

Where:

- NOTM is the number of timers used in the ATS metric.
- NOCT is the number of CANCEL timer statements in the ATS.
- NOTM_O is the number of timers used before a plane CANCEL.

Criteria: This metric influences the completeness and instrumentation of the ATS.

Interpretation & Action: All timers must be canceled. A timer, which is not canceled, indicates a serious error. The value of this metric must be equal to zero.

5. DEFINITION OF THE AUTOMATIC QUALITY ASSESSMENT PROCESS

The roadmap to the total quality assessment of an ATS goes through the quality assessment of the TTCN metrics, the GQRs, the quality criteria and the quality factors. As mentioned in section 2 of the paper the quality factors can be assessed by means of quality criteria. The quality of a criterion is influenced by one or more GQRs as it is shown in table V. Thus to evaluate the quality factors and criteria the quality evaluation of the GQRs is required. The evaluation of the GQRs is based on metrics. The relationship between the quality factors, the quality criteria, the GQRs and the metrics towards the quality assessment of the ATS is described in figure 2.

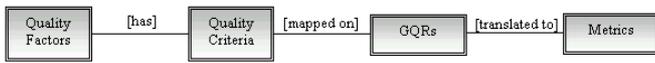


Fig. 2. Relationship between quality factors, quality criteria, GQRs and metrics

The automatic quality assessment process is based on the above relationship between TTCN quality factors, criteria, GQRs and metrics, which is expressed in the form of mathematical equations. The following example illustrates the form of those equations and the relationships between them.

Scenario of the example:

- The example model has three quality factors
- Each factor splits into a number of quality criteria
- The criteria are influenced by GQRs
- The GQRs are translated into metrics

The analysis of the first factor is illustrated in Figure 3, in a form of a quality assessment tree.

Extraction of quality equations:

$$\text{Factor}_1 = (F1_1 \times \text{Criterion}_1) + (F1_2 \times \text{Criterion}_2) \quad (1)$$

$$\text{Criterion}_1 = (C1_1 \times \text{GQR}_1) + (C1_2 \times \text{GQR}_2) \quad (2)$$

$$\text{Criterion}_2 = (C2_1 \times \text{GQR}_3) + (C2_2 \times \text{GQR}_4) \quad (3)$$

$$\text{GQR}_1 = (G1_1 \times \text{Metric}_1) + (G1_2 \times \text{Metric}_2) \quad (4)$$

$$\text{GQR}_2 = (G2_1 \times \text{Metric}_3) + (G2_2 \times \text{Metric}_4) \quad (5)$$

$$\text{GQR}_3 = (G3_1 \times \text{Metric}_5) + (G3_2 \times \text{Metric}_6) \quad (6)$$

$$\text{GQR}_4 = (G4_1 \times \text{Metric}_7) + (G4_2 \times \text{Metric}_8) \quad (7)$$

The extracted metric's values, described in the previous section, can not be used in the quality equations without first been formatted. The values must be formatted to fit into a specific range of values in order to allow a unified flow to

the structure of the equations. The extraction of these values is based on the actual values of the metrics.

A normalised procedure, which in fact is a mapping between the actual values of the metrics and values within the range [0,1] is required, (If the actual value is not already within this range). This can be accomplished by defining specific limits for each metric mapped on a value between 0 and 1. The comparison of the actual value with specific limits leads to the extraction of the value that the metric acquires in the quality equations.

The metric limits can also be used for the quality designation of each metric separately. The quality assessment is the outcome of the comparison of the actual value of the metric with its quality limits. The total quality evaluation of an ATS cannot provide detail information for the quality. The quality designation of each metric separately allows the detection of the strong and weak points of an ATS. Table IV is proposed in order to extract the formatted metric values, which will be used in the quality equations. The same table can also be used for the quality designation of each metric separately.

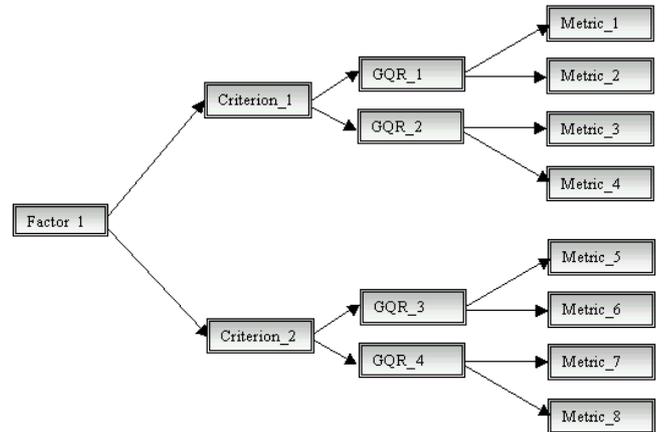


Fig. 3. Quality assessment tree of Factor_1

TABLE IV. The proposed quality designations relative to the equation values

Name of the metric		
Quality Designation	Limits	Value in Equations
ACCEPTED	MIN1 – MAX1	1
COMMENT	MIN2 – MAX2	0.8
INSPECT	MIN3 – MAX3	0.6
TEST	MIN4 – MAX4	0.4
REWRITE	MIN5 – MAX5	0.2

The equation components “Metric” are the formatted metric values within the range [0,1].

The total quality assessment should not be calculated as the mean value of all the quality assessment subcomponents (factors, criteria, GQRs and metrics), because they do not influence the total quality of an ATS equally. For this reason a number of quality weights were defined determining the degree of influence of every quality subcomponent towards the total quality assessment of an ATS. The weights (F,C,G)

used in the quality equations express these degrees of influence in the form of arithmetic values.

The values of all the weights are ranging between the values zero and one [0,1] and are defined in a way that the sum of all the weights in an equation equals one. Since the equation component “Metric”, the subcomponent from which all the other subcomponents derive, has values within the range [0,1] the outcome of all the equations is also within the range of values [0,1].

For the given example:

- G1_1, G1_2, G2_1, G2_2, G3_1, G3_2, G4_1, G4_2 are the quality weights determining the degree of influence of the metrics on the GQRs.
- C1_1, C1_2, C2_1, C2_2 are the quality weights determining the degree of influence of the GQRs on the criteria.
- F1_1, F1_2, F2_1, F2_2 are the quality weights determining the degree of influence of the criteria on the factors.

Following the same procedure for the other two factors, the equation for the total quality assessment is presented in equation (8).

$$TOTAL = (T1 \times Factor_1) + (T2 \times Factor_2) + (T3 \times Factor_3) \quad (8)$$

Where, T₁, T₂, T₃ are also quality weights determining the degree of influence of the factors on the total quality assessment, but in this case all within the range [0,100]. The sum of the quality weights for the total quality assessment is equal to 100. Thus, the range of values for total quality assessment equation is [0,100]. For the total quality assessment of the ATS, the outcome of equation (8) is compared with the values of the following table V.

TABLE V. Comparison values for the total quality assessment of an ATS

ATS Quality Designation	Minimum	Maximum
ACCEPTED	91	100
COMMENT	81	90
INSPECT	51	80
TEST	31	50
REWRITE	0	30

6. EXPERIMENTAL RESULTS

To evaluate the usefulness and effectiveness of the proposed methodology three kinds of ATSS at different state of implementation and with different level of complexity were assessed. For this purpose the software tool which automates the assessment procedure was used.

The three different kinds of ATSS are:

1. Draft ATSS, which have not been reviewed and verified in the laboratory environment (ETSI ATSS).
2. Mature ATSS that have been reviewed and verified in the laboratory environment (ETSI ATSS Improved).

3. Validated ATSS which have been extensively used and validated against real equipment (ATM switches UNI. 3.0 Signaling)

A screenshot of the software tool assessing an ATS is illustrated in figure 4. The left part of the figure is the ATS viewed with the help of an editing tool for ATSS. The front window displays the values of the calculated metrics. The results of the assessment for the three kinds of ATSS are presented in the following figures 5, 6 and 7 respectively

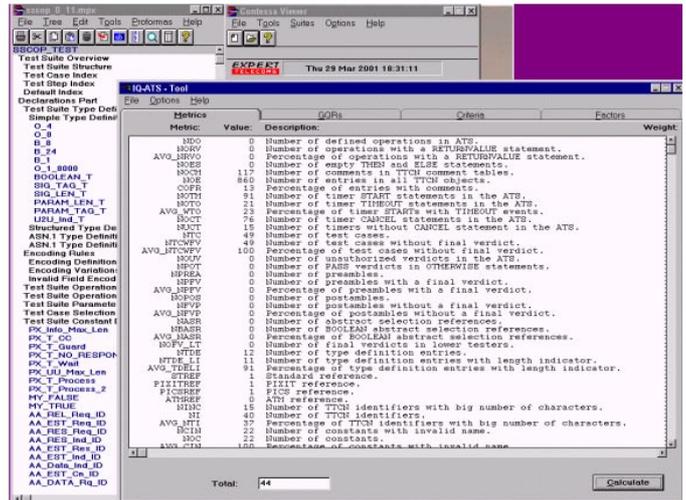


Fig. 4. A software tool assessing an ATS

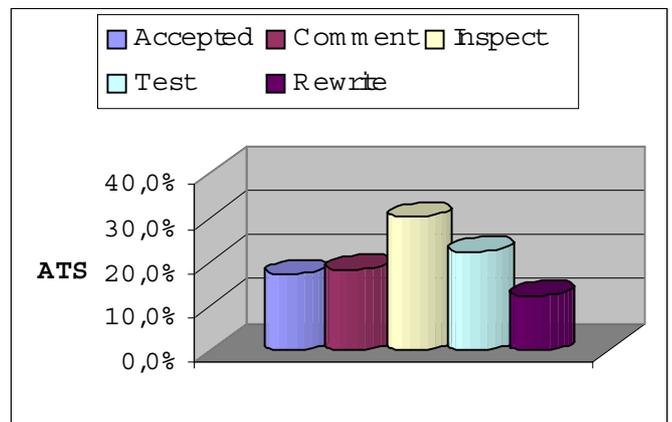


Fig. 5. Overall Quality distribution for draft ATSS

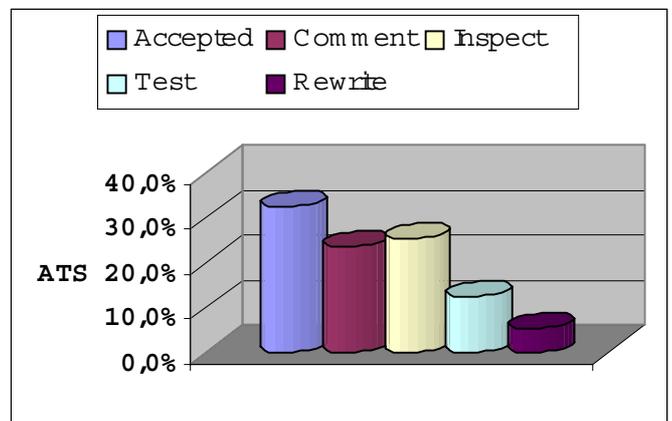


Fig. 6. Overall Quality distribution for mature ATSS

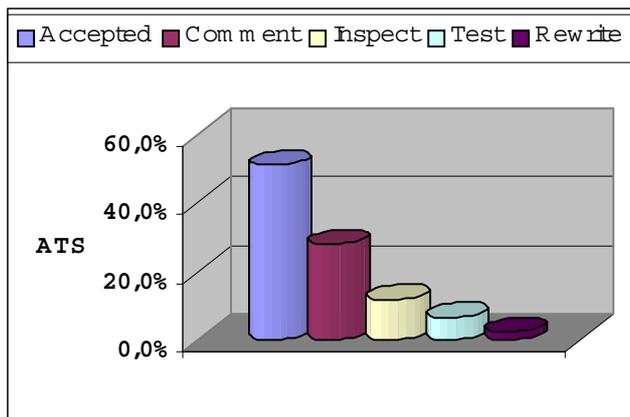


Fig. 7. Overall Quality distribution for validated ATSs

The assessment results depict that:

- A big percentage of draft ATSs is designated as “Inspect” and a considerable percentage of them as “Rewrite”. Also, less than 20% of them are designated as “Accept”
- The percentage of mature ATSs designated as “Inspect” is notably lower, the percentage of mature ATSs designated as “Accept” is double than that of the draft ATSs and the number of ATSs designated as “Rewrite” is now less than 6%.
- More than 60% of the validated ATSs is designated as “Accept” and less than 20% of them fills the last three categories “Inspect”, “Test” and Rewrite”.

From the above it is clear that the percentage of the ATSs designated as “Accept” is increased as we move from the draft ATSs, which are at the earliest state of implementation, to the mature ATSs, which are at the last state of implementation. On the other hand the percentage of the ATSs designated as “Inspect”, “Test” and Rewrite” is reduced as we move vice versa.

7. CONCLUSIONS

The assessed ATSs were not implemented based on the proposed methodology. But, taking into account the state of implementation of each kind and the analysis of results presented above one can conclude that the use of the methodology will offer an increase in the percentage of accepted ATSs in every level. Additionally, the decrease of the “Rewrite” and “Test” cases is quite important for the ATS development process, because it improves productivity by an equal factor at least. It also shows that the methodology has a direct and undisputed positive effect on ATS quality and productivity.

The application of this methodology during the development cycle of the TTCN ATSs is considered of high importance. As it has been already proven by the experimental results, the use of the IQ-ATS tool significantly assists to produce higher quality ATSs, by spotting development problems early in the development process. From a managerial point of view this has significant advantages in two main areas:

- Training. Training requirements are reduced, thus reducing the overall production costs.
- Quality reviews. These are also significantly reduced and are becoming much more automated, thus again reducing the overall development time and the associated costs.

The quantitative estimation of the impact of the methodology is not possible at this stage, as more complex experiments are required in order to deduct the overall reduction in the development phase. However, the usefulness of the methodology has been proven in the related experiments. The proposed methodology is today the unique methodology, which provides automated TTCN quality assessment. To our knowledge extend only EWOS ([10], [11], [12], [13]) had started defined a manual method for the quality assessment of ATSs based on checklists, which has been discontinued. Thus the proposed automatic methodology is also expected to solve the applicability problems met in existing manual methods such as the required time and effort as well as the possibility of human mistakes.

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APPENDIX TABLE A

Relations Between Quality Criteria And Factors

NO	FACTOR	CRITERIA										
		C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
F0	Usability								√	√		
F1	Correctness	√	√	√								
F2	Maintainability			√	√			√				√
F3	Testability				√		√	√				√
F4	Flexibility					√		√				√
F5	Portability							√			√	√
F6	Reusability					√		√			√	√

APPENDIX TABLE B

Mapping between Group of Quality Rules (GQR) and Quality Criteria

GQR ID	GQR DESCRIPTION	CRITERIA										
		C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
GQR_01	Test Suite operations		√							√		
GQR_02	Comments		√		√	√	√	√			√	
GQR_03	Timers		√				√					
GQR_04	Verdicts		√				√					
GQR_05	Uniqueness		√			√						
GQR_06	Abstract selection Rules (ASR)		√									
GQR_07	Test coordination procedures		√									
GQR_08	Test Suite coverage		√	√								
GQR_09	ISP/FS requirements		√	√						√		
GQR_10	Test Suite introduction and overview		√	√							√	
GQR_11	Detailed checks	√		√								
GQR_12	Naming conventions – Existence		√	√	√	√		√	√	√		
GQR_13	Naming conventions – Properties			√	√	√						
GQR_14	Test notation										√	
GQR_15	TTCN simplicity				√							
GQR_16	Proper functionality									√		
GQR_17	TTCN Modularity											√

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