A Weighted Quality Evaluation Framework by applying the Analytic Hierarchy Process

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Abstract

QuEF (Quality Evaluation Framework) is an approach to define an environment for the analysis and evaluation of MDWE (Model-Driven Web Engineering) methodologies under different criteria. These criteria are assessed in QuEF by means of some indicators, metrics and values that help to establish a numerical evaluation of each methodology. However, some designers consider their methodologies should not be assessed by QuEF as, in their view and experience, the relevance (weight) achieved by some criteria in the final evaluation is not suitable enough. This problem can be modelled through a process of multi-criteria group decision making (MCGDM). The present paper defines a method based on the essence of the previous analytic hierarchy process, in order to obtain in QuEF the criteria established by a methodology designers group. This tool can lay the bases of a framework for quality assessment, which gathers different points of view. An illustrative example is presented to verify the efficiency of the proposed method.

1.0 Introduction

Model-Driven Web Engineering (MDWE) is a specific domain of the Model-Driven Engineering (MDE) paradigm [1] which focuses on Web environment. The growing interest on the Internet has led to generate several MDWE approaches, which offer a frame of reference for the Web environment. In this line, there are lot of MDWE approaches without standard consensus [2][3][4], lack of standards and scarcity of both, practical experience and tool support. According to this situation, it is necessary to offer suitable mechanisms to value current methodologies, because, as it can be deduced from surveys and studies [5][6], there is an important lack in this sense. This context defines QuEF (Quality Evaluation Framework), an approach to establish an environment in order to analyze and evaluate MDWE (Model-Driven Web Engineering) methodologies under different criteria. Recently, in other papers and following this idea, the framework [7][8] has been structured and organized with regard to four different components: *Thesaurus & Glossary component*, *Quality Model component*, *Approach Features Template component* and *Quality Evaluation Process component*. The most important is the *Quality Model component*, which defines and describes the set of quality features, its weight and relations among them, with the aim of evaluating the methodology quality.

Although, QuEF is being accepted as a valid framework for the analysis and quality evaluation of MDWE, some methodology designers disagree with the *Quality Model* as, in their view and experience, they consider the relevance (weight) achieved by some concepts in the final evaluation not to be suitable enough. This refusal can be changed by group decision making (GDM). GDM is responsible for finding the best solutions to problems, taking the information provided by some decision makers as a starting point. In this context, a common approach is the *analytic hierarchy process* (AHP) introduced by Saaty [9][10], which is a widely accepted key multi-criteria decision-making methodology. It divides and structures the criteria into several level factors for prioritizing, ranking and evaluating different decision alternatives. In this regard, the essence of the AHP is used to define a method which builds the quality model. Thus, this method defines the hierarchy of elements, features and sub-features that identify a methodology and sets the relevance of the quality features in the hierarchy, according to the methodology designers' priorities. An illustrative example is shown to verify the effectiveness of the proposed method. In this way, this process definition can lay the bases of a framework for quality assessment taking into account the point of view of distinguished methodology designers' point of view.

The present paper is structured as follows: Section 2 describes Quality Evaluation Framework and introduces the proposal. Section 3 reviews the Analytic Hierarchy Process. Then, Section 4 analyzes this proposal, an AHP-based method to build a quality model. Section 5 provides an example of the suggested method and, finally, Section 6 states the conclusions and contributions and plans possible future work.

2.0 Quality Model of QuEF

The Quality Model metamodel is shown in Fig 1. On one hand, the information needs, which involve the description of the environment to be analyzed, evaluated and improved, are described by means of Features, Sub-Features and metrics. Simultaneously, a Feature contains a set of Sub-Features measured by a set of metrics. On the other hand, the Quality Aspects necessary are described by Quality Characteristics and Quality Sub-Characteristics which are taken and adapted from ISO or some other standards [11][12]. Quality Characteristics can be, for instance, Usability, Functionality or Maintainability.
Then, every Sub-Feature can be linked with Quality Sub-Characteristics which represent the influence of every Sub-Feature on every Quality Sub-Characteristic.
For instance, this could be the case of a defined Tool Support Feature that includes a Sub-Feature as an Analysis Tool Support. An association link can indicate that

the Analysis Tool Support (Sub-Feature) influences Maintainability (Quality Sub-Characteristic).

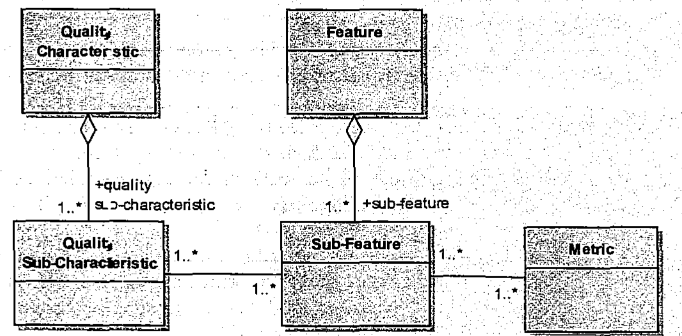

Fig. 1 Quality Model metamodel

There are two aspects to consider in the framework definition when applying an AHP-based method. First of all, this method can defined either the hierarchy design or the Quality Model of the environment to be analyzed and evaluated. In fact, this aspect is just a step in the application of AHP. Secondly, the method can be applied with the aim of defining the importance or relevance of each element in the hierarchy. Thus, this work is focused on the definition of weights for Features and Sub-Features, although it could also be used to define weights for Metrics, Quality Characteristics and Quality Sub-Characteristics. Furthermore, this process helps to reach a consensus on the definition of Sub-Features influence on Quality Sub-Characteristics. In QuEF, these relations are determined by a matrix called Matrix of Influences. In this matrix, Sub-Features are organized in rows and columns; features are listed in rows and Quality Sub-Characteristics appear in columns also organized by Characteristics. A weight can determine this influence from each relation modelled by a cell. Consequently, in this last case a weight represents the degree of influence (it is an association link between Sub-Features and Sub-Characteristics), apart from the degree of importance.

3.0 The Analytic Hierarchy Process

A group decision making (GDM) is responsible for finding the best solution(s) to a problem according to the information provided by some decision makers who normally approach the decision process from a different view, but with the aim of reaching an agreement.

The Analytic Hierarchy Process (AHP), proposed by Saaty[9][10], is a key multi-criteria decision making methodology that allows the problem solving with multiple decision makers and criteria, by means of creating a ratio scale corresponding to the main alternatives. Saaty suggested a four-step process for a conventional AHP:

1. *Hierarchy design*: The first step deals with structuring a complex problem into a hierarchy where the goal is at the top, criteria and sub-criteria are respectively placed at levels and sub-levels, and decision alternatives appear at the bottom of the hierarchy.
2. *Development of judgment matrices*: The second step incorporates the preferences of the decision makers involved in the problem by means of reciprocal pairwise comparison matrices that use a nominal scale.
3. *Priorization*: In this step, the process aggregates and computes the experts' preferences to obtain a final vector of weight coefficients for alternatives by means of any of the methods for deriving priorities from judgment matrices, such as the eigenvector method (EVM) or the logarithmic least squares method (LLSM).
4. *Synthesis.* Finally, the total or final priorities for the alternatives compared are obtained by comprising the global priorities for the alternatives as a result of an aggregation procedure (additive or multiplicative) result.

One of the main characteristics of AHP is the ability to assess the consistency of the decision maker when providing his judgments, defining the consistency as the cardinal transitivity in judgments.

4.0 A Weighted Quality Evaluation Framework

QuEF represents a valid framework for the analysis and quality evaluation of the MDWE. Some methodology designers disagree with the *Quality Model* as, in their view and experience, they consider the relevance (weight) achieved by some concepts in the final evaluation not to be suitable enough.

This Section introduces the essence of an AHP-based method in order to build a Quality Model according to different methodology designers' views. Then, a representative case of the proposed method, in which three designers have participated, is shown.

4.1 An AHP-based method to build a quality model

The proposed method to build a Quality Model according to different methodology designers' views involves 4 steps described in depth below:

Step 1: Quality Hierarchy design

In this step, a hierarchy for the elements describing a methodology in a quality environment is obtained, as observed in Table 1. This involves a systematic literature review process which focuses on a single question to identify, appraise, select and synthesize all high quality research evidence suitable to that question.

Quality of methodology	Features	Sub-Features
X_0	F_1	
		f_{11}
		...
		...
		f_{1j_1}
	F_i	
		f_{i1}
		...
		f_{ij_i}
	F_t	
		f_{t1}
		...
		f_{tj_t}

Table 1. The hierarchy design

The node that represents the methodology quality $\{X_0\}$ is located at the top of the hierarchy and splits up into a set of features $F = \{F_i, i = 1,2,\dots,t\}$, and each feature, F_i, includes a set of j_i sub-features, $F_i = \{f_{ij}, j = 1,2,\dots,j_i\}$.

Step 2: Development of judgment matrices

Next, the methodology designers group $E = \{e^k, k = 1,2,\dots,n\}$ involved in the development of the Quality Model states the priorities by means of reciprocal pairwise comparison matrices between features and sub-features. For this aim, each designer e^j provides $t+1$ matrix.

$$M_{Fi}^k = \begin{array}{c} \\ f_{i1} \\ \vdots \\ f_{iji} \end{array} \begin{array}{c} \begin{array}{ccc} f_{i1} & \dots & f_{iji} \end{array} \\ \begin{pmatrix} 1 & \dots & a_{i1-ij_i}^k \\ \vdots & 1 & \vdots \\ a_{ij_i-i1}^k & \dots & 1 \end{pmatrix} \end{array} \quad \text{and} \quad M_F^k = \begin{array}{c} \\ F_1 \\ \vdots \\ F_t \end{array} \begin{array}{c} \begin{array}{ccc} F_1 & \dots & F_t \end{array} \\ \begin{pmatrix} 1 & \dots & a_{1t}^k \\ \vdots & 1 & \vdots \\ a_{t1}^k & \dots & 1 \end{pmatrix} \end{array}$$

$$\{M_{F_i}^k, F_i = 1,2,\dots,t\} \; and \; M_F^k,$$

Where a $M_{F_i}^k$ is the comparison matrix between the sub-features, $\{f_{ij}, j = 1,2,\dots,j_i\}$, of the features, F_i, and M_F^k is the comparison matrix between the features, $F = \{F_i, i = 1,2,\dots,t\}$, provided by the expert, e^k.

The use of Saaty's nominal scale (shown in Table 2) is also suggested. The degree of the importance of feature Y over X, a_{xy}, and the reciprocal comparison, is deduced from $1/a_{xy}$.

Numerical rating	Linguistic judgment
1	X is equally preferred to Y
2	X is equally to moderately preferred over Y
3	X is moderately preferred over Y
4	X is moderately to strongly preferred over Y
5	X is strongly preferred over Y
6	X is strongly to very strongly preferred over Y
7	X is very strongly preferred over Y
8	X is very strongly to extremely preferred over Y
9	X is extremely preferred over Y

Table 2. The rate of importance of features Y over X

It is noteworthy that the consistency ratio for each judgment matrix should be checked. If inconsistent, the matrix should be reconstructed to be, at least, nearly consistent.

Step 3: Aggregation of judgment matrices

Once matrices designers have obtained consistent judgment matrices, collective judgment matrices result from adding all completed judgment matrices. This aggregation is carried out by applying some types of OWA operator. To use an OWA operator is recommended as it reorders arguments according to the magnitude of their respective values [9], before the aggregation takes place. Furthermore, they satisfy some interesting properties such as compensativeness, idempotency, symmetry and monotonicity.

Definition 1: An OWA operator of dimension n is a function $\varphi : Rn \rightarrow R$, which has a set of weights or weighting vectors associated with it, $W = (w1, \ldots, wn)$, with $w_i \in [0, 1]$, $\sum_{i=1}^{n} w_i = 1$ and it is defined to aggregate a list of values $\{p_1, \ldots, p_n\}$ according to the following expression:

$$\varphi_w(p_1, \ldots, p_n) = \sum_{i=1}^{n} w_i \cdot p_{\sigma(i)}$$

being $\sigma : \{1, \ldots, n\} \rightarrow \{1, \ldots, n\}$ a permutation such that $p_{\sigma(i)} \geq p_{\sigma(i+1)}$, $\forall i = 1, \ldots, n-1$, i.e., $p_{\sigma(i)}$ is the i highest value in the set $\{p_1, \ldots, p_n\}$.

A natural question to define the OWA operator is how to obtain the associated weighting vector, In [13] Yager's answer is found.

So, we compute the collective judgment matrices, $\overline{M}_{F_i}$ with $i = 1, \ldots, t$ and $\overline{M}_F$ by,

$$\overline{M}_{F_i} = \varphi_w(M_{Fi}^1, \ldots, M_{Fi}^n), \text{ with } \{k = 1,2,\ldots,n\} \text{ for } i=1,\ldots,t$$

$$\overline{M}_F = \varphi_w(M_F^1, \ldots, M_F^k) \text{ with } \{k = 1,2,\ldots,n\}$$

The collective judgment matrices summarize the priorities of the methodology designers involved in the quality model development.

Step 4: Calculate the relevance.

In this step, we compute the relevance of each feature, p_{F_i}, and each sub-feature, $p_{f_{ij}}$ to be used in the of Quality Model. This step implies 3 phases described as follows:

1. Calculate the sum of each row of the matrices. We compute the sum of each row to normalize the matrix later.

$$\overline{M}_F = \begin{matrix} & F_1 & \cdots & F_t \\ F_1 & 1 & \cdots & a_{1t} \\ \vdots & \vdots & 1 & \vdots \\ F_t & a_{t1} & \cdots & 1 \end{matrix} \qquad v_{F_i} = \sum_{j=1}^{j=t} a_{ij}$$

$$\overline{M}_{F_i} = \begin{matrix} & f_{i1} & \cdots & f_{ij_i} \\ f_{i1} & 1 & \cdots & a_{i1-ij_i} \\ \vdots & \vdots & 1 & \vdots \\ f_{ij_i} & a_{ij_i-i1} & \cdots & 1 \end{matrix} \qquad v_{f_{ij}} = \sum_{l=1}^{l=j_i} a_{ij-il}$$

2. Normalize each pairwise comparison matrix. The standardized pairwise comparison matrix between the sub- features, $\overline{M}_{F_i Norm}$, of the features, F_1 is calculated by

$$\overline{M}_{F_i Norm} = \begin{matrix} & f_{i1} & \cdots & f_{ij_i} \\ f_{i1} & 1/v_{f_{i1}} & \cdots & a_{i1-ij_i}/v_{f_{i1}} \\ \vdots & \vdots & 1 & \vdots \\ f_{ij_i} & a_{ij_i-i1}/v_{f_{ij_i}} & \cdots & 1/v_{f_{ij_i}} \end{matrix}$$

Where $v_{f_{ij}}$ was obtained in the previous phase.

A similar process should be carried out for the normalized pairwise comparison matrix between the features, $\overline{M}_{CNorm}$:

$$\overline{M}_{FNorm} = \begin{matrix} & F_1 & \cdots & F_t \\ F_1 & 1/v_{F_1} & \cdots & a_{1t}/v_{F_1} \\ \vdots & \vdots & 1 & \vdots \\ F_t & a_{t1}/v_{F_t} & \cdots & 1/v_{F_t} \end{matrix}$$

Where v_{F_i} was obtained in the previous phase.

3. Calculate the relevance (weight) for each feature and sub-features, $p_{f_{ij}}$. Now, the vector row that includes the averages row is calculated. Consequently, we obtain the priority vector among features, p_F, and the priority vector among sub-features, p_{F_i}, for every feature, F_i.

$$p_F = \begin{pmatrix} \frac{1}{t}\sum_{i=1}^{i=t} a_{1i} \\ \vdots \\ \vdots \\ \frac{1}{t}\sum_{i=1}^{i=t} a_{ti} \end{pmatrix};\ p = \begin{pmatrix} p_{F_1} \\ \vdots \\ \vdots \\ p_{F_t} \end{pmatrix} \qquad p_{F_i} = \begin{pmatrix} \frac{1}{j_i}\sum_{l=1}^{l=j_i} a_{il-i1} \\ \vdots \\ \vdots \\ \frac{1}{j_i}\sum_{l=1}^{l=j_i} a_{il-ij_i} \end{pmatrix};\ p_{F_i} = \begin{pmatrix} p_{f_{i1}} \\ \vdots \\ \vdots \\ p_{f_{ij_i}} \end{pmatrix}$$

4.2 An Illustrative Case

In this section, an illustrative case is analyzed in order to verify the effectiveness of the previously proposed method.

Step 1: Quality Hierarchy design

Once the literature has been studied, the hierarchy shown in Table 3 describing a methodology in a quality environment is obtained.

Quality of methodology	Features	Sub- features
X_0		
	F_1=MDE	
		f_{11} = Standard Definition
		f_{12} = Model–Based Testing
		f_{13} = Traces
		f_{14} = Level of Abstraction
		f_{15} = Transformations
	F_2=Web Modelling	
		f_{21} = Web Conceptual Levels
		f_{22} = Interfaces
		f_{23} = Content Modelling
		f_{24} = Presentation Modelling
		f_{25} = Navigation Modelling
		f_{26} = Business Modelling
		f_{27} = Development Process
	F_3=Tool Support	
		f_{31} = Analysis Tool Support
		f_{32} = Code Generation and Specific Tool Support
		f_{33} = Team Work Tool Support
		f_{34} = Creation, Edition and Composition Tool Support
		f_{35} = Transformation Tool Support
		f_{36} = Trace Tool Support
	F_4= Maturity	
		f_{41} = Modelling Examples
		f_{42} = Publications
		f_{43} = Topicality
		f_{44} = Application in Real-World Projects
		f_{45} = External Web References

Table 3. The Quality Model hierarchy

Step 2: Development of judgment matrices

Three designers have participated $E = \{e^1, e^2, e^3\}$ in this case to develop the Quality Model. In addition, 5 surveys have been carried out in order to obtain the five judgment matrices of each expert($\{M^k_{F_i}, F_i = 1,2,3,4\}$ *and* M^k_{F}.). The surveys can be consulted in the following URL:
http://features.articulos.iwt2.org
http://model-driven_engineering_feature.articulos.iwt2.org
http://web_modelling_feature.articulos.iwt2.org
http://tool_support_feature.articulos.iwt2.org
http://maturity_feature.articulos.iwt2.org

To illustrate this step, we show the judgment matrices provided by an expert e^1. Due to the limited space of the contribution, we do not offer the judgment matrices by the experts, e^2 and e^3.

For the sub-features:

$$M^1_{F_1} = \begin{array}{c} \\ f_{11} \\ f_{12} \\ f_{13} \\ f_{14} \\ f_{15} \end{array} \begin{array}{c} \begin{array}{ccccc} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} \end{array} \\ \begin{pmatrix} 1 & 1 & 3 & 1 & 3 \\ 1 & 1 & 3 & 1 & 3 \\ 1/3 & 1/3 & 1 & 1/3 & 1 \\ 1 & 1 & 3 & 1 & 1 \\ 1/3 & 1/3 & 1 & 1 & 1 \end{pmatrix} \end{array} \qquad M^1_{F_3} = \begin{array}{c} \\ f_{31} \\ f_{32} \\ f_{33} \\ f_{34} \\ f_{35} \\ f_{36} \end{array} \begin{array}{c} \begin{array}{cccccc} f_{31} & f_{32} & f_{33} & f_{34} & f_{35} & f_{36} \end{array} \\ \begin{pmatrix} 1 & 5 & 3 & 7 & 1 & 9 \\ 1/5 & 1 & 1/5 & 1/5 & 1 & 3 \\ 1/3 & 5 & 1 & 1 & 7 & 7 \\ 1/7 & 5 & 1 & 1 & 7 & 7 \\ 1/9 & 1 & 1/7 & 1/7 & 1 & 1 \\ 1/9 & 1/3 & 1/7 & 1/7 & 1 & 1 \end{pmatrix} \end{array}$$

$$M^1_{F_2} = \begin{array}{c} \\ f_{21} \\ f_{22} \\ f_{23} \\ f_{24} \\ f_{25} \\ f_{26} \\ f_{27} \end{array} \begin{array}{c} \begin{array}{ccccccc} f_{21} & f_{22} & f_{23} & f_{24} & f_{25} & f_{26} & f_{27} \end{array} \\ \begin{pmatrix} 1 & 9 & 7 & 1 & 1 & 1 & 1 \\ 1/9 & 1 & 1 & 1/5 & 1/5 & 1/5 & 1/5 \\ 1/7 & 1 & 1 & 1/5 & 1/5 & 1/5 & 1/5 \\ 1 & 5 & 5 & 1 & 1 & 1 & 1 \\ 1 & 5 & 5 & 1 & 1 & 1 & 1 \\ 1 & 5 & 5 & 1 & 1 & 1 & 1 \\ 1 & 5 & 5 & 1 & 1 & 1 & 1 \end{pmatrix} \end{array} \qquad M^1_{F_4} = \begin{array}{c} \\ f_{41} \\ f_{42} \\ f_{43} \\ f_{44} \\ f_{45} \end{array} \begin{array}{c} \begin{array}{ccccc} f_{41} & f_{42} & f_{43} & f_{44} & f_{45} \end{array} \\ \begin{pmatrix} 1 & 1/5 & 1/9 & 1/3 & 1/7 \\ 5 & 1 & 1/7 & 7 & 7 \\ 9 & 7 & 1 & 9 & 7 \\ 3 & 1/7 & 1/9 & 1 & 1/3 \\ 7 & 1/7 & 1/7 & 3 & 1 \end{pmatrix} \end{array}$$

And for the features:

$$M^1_F = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & F_3 & F_4 \end{array} \\ \begin{pmatrix} 1 & 1 & 5 & 5 \\ 1 & 1 & 5 & 5 \\ 1/5 & 1/5 & 1 & 5 \\ 1/5 & 1/5 & 1/5 & 1 \end{pmatrix} \end{array}$$

It must be pointed out that the overall consistent indexes seem to be normal; therefore it is not necessary to refine the experts' judgements.

Step 3: Aggregation of judgment matrices

Once the experts' judgments have been obtained by means of a pairwise comparison matrix, collective judgment matrices will be computed according to the matrix provided by 3 methodology designers.

The OWA operator is used with the following associated weighting vector $W = (0.3, 0.4, 0.3)$. It shows the same weight both in the lowest and highest comparison, although it gives a higher value in the intermediate comparison.

As a result, the collective judgment matrices among sub-features of each feature result as follows:

$$\overline{\mathrm{M}}_{\mathrm{F}_1} = \varphi_{\mathrm{w}}\left(\mathrm{M}^1_{\mathrm{F}_1}, \mathrm{M}^2_{\mathrm{F}_1}, \mathrm{M}^3_{\mathrm{F}_1}\right);\ \overline{\mathrm{M}}_{\mathrm{F}_2} = \varphi_{\mathrm{w}}\left(\mathrm{M}^1_{\mathrm{F}_2}, \mathrm{M}^2_{\mathrm{F}_2}, \mathrm{M}^3_{\mathrm{F}_2}\right);$$
$$\overline{\mathrm{M}}_{\mathrm{F}_3} = \varphi_{\mathrm{w}}\left(\mathrm{M}^1_{\mathrm{F}_3}, \mathrm{M}^2_{\mathrm{F}_3}, \mathrm{M}^3_{\mathrm{F}_3}\right);\ \overline{\mathrm{M}}_{\mathrm{F}_4} = \varphi_{\mathrm{w}}\left(\mathrm{M}^1_{\mathrm{F}_4}, \mathrm{M}^2_{\mathrm{F}_4}, \mathrm{M}^3_{\mathrm{F}_4}\right);$$

The collective judgment matrices are the followings:

$$\overline{M}_{F_1} = \begin{array}{c} \\ f_{11} \\ f_{12} \\ f_{13} \\ f_{14} \\ f_{15} \end{array} \begin{array}{c} \begin{array}{ccccc} f_{11} & f_{12} & f_{13} & f_{14} & f_{15} \end{array} \\ \begin{pmatrix} 1.00 & 1.00 & 3.40 & 1.40 & 3.40 \\ 1.00 & 1.00 & 3.00 & 1.80 & 3.40 \\ 0.29 & 0.33 & 1.00 & 0.28 & 1.40 \\ 0.71 & 0.56 & 3.57 & 1.00 & 1.00 \\ 0.29 & 0.29 & 0.71 & 1.00 & 1.00 \end{pmatrix} \end{array}$$

$$\overline{M}_{F_3} = \begin{array}{c} \\ f_{31} \\ f_{32} \\ f_{33} \\ f_{34} \\ f_{35} \\ f_{36} \end{array} \begin{array}{c} \begin{array}{cccccc} f_{31} & f_{32} & f_{33} & f_{34} & f_{35} & f_{36} \end{array} \\ \begin{pmatrix} 1.00 & 4.60 & 2.60 & 6.60 & 1.00 & 8.60 \\ 0.22 & 1.00 & 0.22 & 0.22 & 1.00 & 2.00 \\ 0.38 & 4.55 & 1.00 & 1.00 & 4.27 & 4.27 \\ 0.15 & 4.55 & 1.00 & 1.00 & 6.60 & 6.60 \\ 1.00 & 1.00 & 0.23 & 0.15 & 1.00 & 1.00 \\ 0.12 & 0.5 & 0.23 & 0.15 & 1.00 & 1.00 \end{pmatrix} \end{array}$$

$$\overline{M}_{F_2} = \begin{array}{c} \\ f_{21} \\ f_{22} \\ f_{23} \\ f_{24} \\ f_{25} \\ f_{26} \\ f_{27} \end{array} \begin{array}{c} \begin{array}{ccccccc} f_{21} & f_{22} & f_{23} & f_{24} & f_{25} & f_{26} & f_{27} \end{array} \\ \begin{pmatrix} 1.00 & 8.60 & 6.60 & 1.40 & 1.00 & 1.00 & 1.00 \\ 0.12 & 1.00 & 1.00 & 0.22 & 0.22 & 0.22 & 0.22 \\ 0.15 & 1.00 & 1.00 & 1.00 & 1.00 & 1.00 & 1.00 \\ 0.71 & 4.55 & 5.00 & 1.00 & 1.00 & 1.00 & 1.00 \\ 1.00 & 4.55 & 5.00 & 1.00 & 1.00 & 1.00 & 1.00 \\ 1.00 & 4.55 & 5.00 & 1.00 & 1.00 & 1.00 & 1.00 \\ 1.00 & 4.55 & 5.00 & 1.00 & 1.00 & 1.00 & 1.00 \end{pmatrix} \end{array}$$

$$\overline{M}_{F_4} = \begin{array}{c} \\ f_{41} \\ f_{42} \\ f_{43} \\ f_{44} \\ f_{45} \end{array} \begin{array}{c} \begin{array}{ccccc} f_{41} & f_{42} & f_{43} & f_{44} & f_{45} \end{array} \\ \begin{pmatrix} 1.00 & 0.22 & 0.11 & 0.33 & 0.14 \\ 4.55 & 1.00 & 1.00 & 0.15 & 0.15 \\ 9.00 & 1.00 & 1.00 & 8.60 & 6.60 \\ 3.00 & 6.56 & 0.12 & 1.00 & 0.33 \\ 7.00 & 6.56 & 0.15 & 3.00 & 1.00 \end{pmatrix} \end{array}$$

Likewise, the collective judgment matrix among features is obtained as:
$\overline{\mathrm{M}}_{\mathrm{F}} = \varphi_{\mathrm{w}}(\mathrm{M}^1_{\mathrm{F}}, \mathrm{M}^2_{\mathrm{F}}, \mathrm{M}^3_{\mathrm{F}})$ and it is:

$$\overline{M}_F = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & F_3 & F_4 \end{array} \\ \begin{pmatrix} 1 & 1 & 3.80 & 3.80 \\ 1 & 1 & 4.60 & 4.60 \\ 0.26 & 0.22 & 1 & 5.40 \\ 0.26 & 0.22 & 0.19 & 1 \end{pmatrix} \end{array}$$

Step 4: Calculate the relevance.

Finally, the relevance of every feature and sub-feature to be used in the Quality Model is calculated.

For the sake of simplicity, an example to estimate the relevance of the feature is offered:

1. Calculate the sum of each row of the matrices

$$\overline{M}_F = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & F_3 & F_4 \end{array} \\ \begin{pmatrix} 1.00 & 1.00 & 3.80 & 3.80 \\ 1.00 & 1.00 & 4.60 & 4.60 \\ 0.26 & 0.22 & 1.00 & 5.40 \\ 0.26 & 0.22 & 0.19 & 1.00 \end{pmatrix} \end{array} \quad \begin{array}{l} v_{F_1} = 9.6 \\ v_{F_2} = 11.2 \\ v_{F_3} = 6.88 \\ v_{F_4} = 1.66 \end{array}$$

2. Normalize every pairwise comparison matrix

$$\overline{M}_{FNorm} = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & F_3 & F_4 \end{array} \\ \begin{pmatrix} 0.10 & 0.10 & 0.40 & 0.40 \\ 0.09 & 0.09 & 0.41 & 0.41 \\ 0.04 & 0.03 & 0.15 & 0.78 \\ 0.16 & 0.13 & 0.11 & 0.60 \end{pmatrix} \end{array}$$

3. Calculate the average elements of every priority column.

$$\overline{M}_{FNorm} = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \\ \\ \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & F_3 & F_4 \end{array} \\ \begin{pmatrix} 0.10 & 0.10 & 0.40 & 0.40 \\ 0.09 & 0.09 & 0.41 & 0.41 \\ 0.04 & 0.03 & 0.15 & 0.78 \\ 0.16 & 0.13 & 0.11 & 0.60 \end{pmatrix} \\ \begin{array}{cccc} \mathbf{0.10} & \mathbf{0.09} & \mathbf{0.27} & \mathbf{0\ 55} \end{array} \end{array} \qquad p_F = \begin{pmatrix} 0.10_{F_1} \\ 0.09_{F_2} \\ 0.27_{F_3} \\ 0.55_{F_4} \end{pmatrix}$$

The sub-features behave similarly. The relevance obtained for each sub-feature is:

$$p_{F_1} = \begin{pmatrix} 0.10_{f_{11}} \\ 0.09_{f_{12}} \\ 0.033_{f_{13}} \\ 0.17_{f_{14}} \\ 0.31_{f_{15}} \end{pmatrix}; p_{F_2} = \begin{pmatrix} 0.07_{f_{21}} \\ 0.38_{f_{22}} \\ 0.17_{f_{23}} \\ 0.10_{f_{24}} \\ 0.10_{f_{25}} \\ 0.10_{f_{26}} \\ 0.10_{f_{27}} \end{pmatrix}; p_{F_3} = \begin{pmatrix} 0.06_{f_{31}} \\ 0.22_{f_{32}} \\ 0.07_{f_{33}} \\ 0.09_{f_{34}} \\ 0.24_{f_{35}} \\ 0.33_{f_{36}} \end{pmatrix}; p_{F_4} = \begin{pmatrix} 0.45_{f_{41}} \\ 0.25_{f_{42}} \\ 0.05_{f_{43}} \\ 0.16_{f_{44}} \\ 0.09_{f_{45}} \end{pmatrix}$$

5.0 Conclusions

The *Quality Model* of QuEF defines and describes a hierarchy of features and their relevance to assess methodology quality. Some methodology designers disagree with the *Quality Model* as, in their view and experience, they consider the relevance (weight) achieved by some concepts in the final evaluation not to be suitable enough. In this contribution, an AHP-based method has been proposed to build a Quality Model, which sets the relevance of each item in the hierarchy taking into account the views of a methodology designers group to resolve the current rejection. To exemplify this project, we have shown an illustrative example of the proposed method.

6.0 ACKNOWLEDGMENTS

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Software Quality Requires User Acceptance

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Abstract

The development of high-quality software is an important concern of the software industry. Software quality focuses principally on two areas, software engineering and software management. However, a Software Quality User-Acceptance Strategy (SQUAS) has been derived to have significant leverage on the aspect of user post-acceptance. This provides a clear, well-defined framework to inform the target users about software products and about the benefits of using the products via a variety of mutually supportive sets of approaches, distinctions, guidelines, and experiences so that the users' expectations can align with what is being provided. The users' experiences are, therefore, enhanced and the software becomes a quality product. This framework has been tested on users of e-government software, and is sufficiently developed to serve as a viable basis for choices concerning the quality of future software refinements and extensions.

1.0 Introduction

Users need quality of software in their working environment. Suppose you receive a software product which is hard to understand, difficult to use, and no features to integrate with other programs, does it follow that you will accept that product? Thus, according to Boehm *et al.* [1], users need software quality characteristics such as understandability, completeness, conciseness, portability, consistency, maintainability, testability, usability, reliability, structure and efficiency. However, it is no longer sufficient to just deliver software quality which has excellent technical and product characteristics – products also need to fit in with users' expectations for their work practices and activities. How can this be achieved? The study in this paper describes an attempt to establish a conceptual framework and some fundamental initial results in the analysis of the characteristics of SQUAS through users of e-government software.

Section 2 of the paper gives a brief overview of the definition of software quality and relates to software quality models. Section 3 describes the SQUAS philosophy and the SQUAS modeling. Section 4 discusses and analysis the characteristics of the SQUAS. Section 5 summarizes the problems we countered attempting to