Analytical Network Process based Model to Estimate the Quality of Software Components

Adesh Kumar Pandey
Department of Information Technology
KIET Group of Institutions
Ghaziabad, India
ak.pandey@kiet.edu

C. P Agrawal
Department of Computer Application
M.C.N.U.J.C.
Bhopal, India
agrawalcp@yahoo.com

***Abstract*— Software components are software units designed to interact with other independently developed software components. These components are assembled by third parties into software applications. The success of final software applications largely depends upon the selection of appropriate and easy to fit components in software application according to the need of customer. It is primary requirement to evaluate the quality of components before using them in the final software application system. All the quality characteristics may not be of same significance for a particular software application of a specific domain. Therefore, it is necessary to identify only those characteristics/ sub-characteristics, which may have higher importance over the others.**

Analytical Network Process (ANP) is used to solve the decision problem, where attributes of decision parameters form dependency networks. The objective of this paper is to propose ANP based model to prioritize the characteristics /sub-characteristics of quality and to o estimate the numeric value of software quality.

Keywords*— *Software component, ANP, quality, prioritization and software application.

I. INTRODUCTION

Component based software development (CBSD) is very popular technique of software development. It has become an important alternative for developing complex and distributed software applications. CBSD can ensure delivery of low cost and efforts, faster delivery, and quality software application to customer. In CBD development quality of components becomes more important as developers have to rely on the vendors, from whom they are taking the component/s to integrate it in their software applications. The components which they are going to assembled with their software application may not meet the quality requirements set by the developers and may produce catastrophic results for final product. Therefore, quality of the components must be considered with top priority to increase the reliability of the end product. In component-based systems, it is extremely important that we have to relate the system properties to component properties but it is very difficult task [17].

There is no general consensus on the traditional quality models which can fit for component based systems. There are several quality assessment models proposed exclusively for CBS. But most of these models are based or derived from ISO 9126. Several quality models are proposed by researchers for software systems which include McCall, Boehm, FURPS, Dromey, Sehra, ISO 9126 and others. Most of these models are generic models and are proposed for general application systems. Out of these models, ISO 9126 is a prominent model which includes the findings of almost all other models. This is widely recognized in industry and research community. Several researchers made efforts to implement this model for component based systems with minor modifications. Present paper also considers this model as base model and proposes a new ANP bases model to prioritise the characteristics /sub-characteristics of software quality defined in ISO 9126.

The first quality model was proposed by McCall [15]. The major advantage of this model is the relationship created between its quality characteristics; however the main drawback is that it does not include the functionality aspect of the software product.

McCall model is not applicable as per criteria outlined in the IEEE Standard for a Software Quality Metrics Methodology for a top-down approach to quality engineering. So we can say that it is not suited as a foundation for Software Quality Engineering. [10].

The Boehm presented a model, which is similar to the McCall model in which he proposed a hierarchical structure of characteristics, each of which contributes to total quality. Boehm's notion includes users' needs, as McCall's does; however, the hardware yield characteristics were also considered in the McCall model [16]. Various other dimensions were also considered in Boehm's model like the types of user expected to work with the system once it is deployed. General utility of the delivered system is broken down into Portability, Utility and Maintainability. Utility is further broken down into Reliability, Efficiency and Human Engineering. Maintainability is in turn broken down into Testability, Understandability and Modifiability. However, Boehm's model does not elaborate the methodology to measure these characteristics.

ISO 9126 quality model is proposed by ISO (International Standard Organization)[11], which provide a generic definition of software quality in terms of six main characteristics for software evaluation. These characteristics include: Functionality, Reliability, Usability, Efficiency,

978-1-4799-2900-9/14/$31.00 ©2014 IEEE

Maintainability and Portability. These characteristics cover some sub-characteristics, as shown in table 1.

TABLE 1: ISO 9126 Quality Characteristics

ISO 9126 QUALITY MODEL					
Functionality	**Reliability**	**Usability**	**Efficiency**	**Maintainability**	**Portability**
Suitability (SU)	Maturity (Ma)	Understandability (Un)	Time behavior (Tb)	Analyzability (An)	Adaptability (Ad)
Accurateness (AC)	Fault tolerance (Ft)	Learnability (Le)	Resource behavior (Rb)	Changeability (Ch)	Installability (In)
Interoperability (Int)	Recoverability (Re)	Operability (Op)		Stability (St)	Conformance (Co)
Compliance (Co)				Testability (Te)	Replaceability (Re)
Security (Se)					

One of the advantages of this model is that, it identifies the internal and external quality characteristics of a software product. On the other hand, it does not show very clearly how these aspects can be measured [12].

A. Analytical Hierarchy Process (AHP)

Studies in the literature identify the multi-criteria decision technique, known as Analytical Hierarchy Process (AHP) to be the most appropriate for solving complicated problems. AHP was proposed by Saaty [14] as a method of solving socioeconomic decision-making problems. AHP is a comprehensive framework that is designed to make multi-objective, multi-criteria and multi-factor decisions with or without certainty. In AHP we arrange the factors of decision making in a hierarchical structure descending from an overall goal to criteria, and sub-criteria in successive levels. The basic assumptions of AHP are that it can be used independently of an upper part or cluster of the hierarchy.

AHP is a decision analysis technique that reduces dimensionality of problems. Decisions are determined by a single number for the best outcome or by a vector of priorities that gives an ordering of the different possible outcomes.

B. Analytical Network Process (ANP)

Analytic Network Process (ANP) is a generalization of AHP by considering the dependence between the elements of the hierarchy [13]. Many decision making problems cannot be structured hierarchically. Therefore, ANP is represented by a network rather than a hierarchy. ANP is a comprehensive decision-making technique that captures the outcome of the dependence and feedback within and among clusters of elements [13]. ANP is a coupling of two parts: the first consists of a control hierarchy or network of criteria and sub-criteria that control the interactions while the second is a network of influences among the elements and clusters. Unlike a hierarchy, ANP uses a network without a need to specify levels. Some of the fundamental ideas in support of ANP are as follows [13]:

- ANP is built on the widely used AHP.
- ANP allows for interdependency between decision parameters; therefore, ANP goes beyond AHP.
- ANP deals with dependence within a set of elements (inner dependence) and among different sets of elements (outer dependence).
- In the loose network structure of the ANP, problems from any field are represented without concern of criteria since AHP can resolve hierarchically structured problems.
- ANP is a non-linear structure that deals with sources, cycles and sinks having a hierarchy of linear forms, with goals in the top level and the alternatives in the bottom level.
- ANP is a suitable technique to portray a real-world representation of the problem under consideration by prioritizing not only the elements but also the groups or clusters of elements.
- ANP utilizes a control hierarchy or a control network to deal with different criteria and eventually provide an opportunity to analyze the benefits, costs and risks.

C. AHP Versus ANP

AHP represents a framework with a unidirectional hierarchical

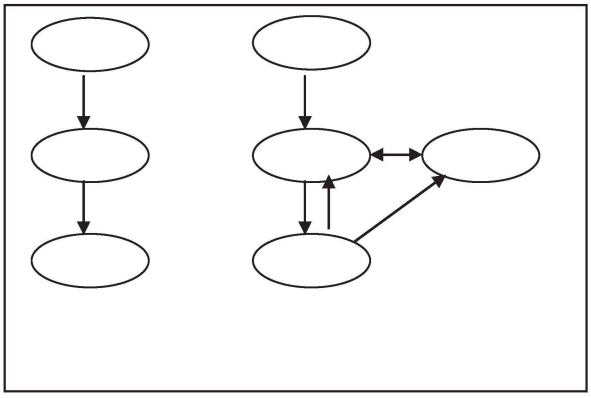

Figure1. (a) Structure of AHP (b) Structure of ANP

relationship, ANP allows for more complex interrelationships among decision making levels and attributes. The ANP replaces hierarchies with networks in which the relationships among the levels are not easily represented as upper or lower, dominated or being criteria determines the importance of the alternatives, as it would in a hierarchy, but the importance of the alternatives may, in turn, have an impact on the importance of the decision making criteria [13].

Therefore a hierarchical structure with a linear, top-to-bottom form is not applicable in a complex system. A system with feedback can be represented by a network where nodes correspond to the levels or components [13]. The structural difference between a hierarchy and a network is depicted in figure1. The elements in a node may influence some or all of the elements of any other node. In a network there can be source nodes, intermediate nodes and sink nodes. Relationships in a network are represented by arcs and the directions of these arcs signify dependence.

Interdependency between two nodes, termed outer dependence, is represented by a two-way arrow and inner

dependence between elements in a node is represented by a looped arc

II. QUALITY CHARACTERISTICS/SUB-CHARACTERISTICS PERIORTIZATION USING ANP

On the basis of our literature survey, we conclude that empirical approaches like AHP and ANP and are widely used to solve the problems that have various dependent parameters, which are related to each other either in hierarchical or network structures. The present paper will use ANP to prioritize characteristics and sub characteristics of ISO 9126 quality model by assigning weights to them as all quality characteristics and sub characteristics are not of equal importance. The proposed ANP based model will consider that there is inter relation between characteristics of ISO 9126 software quality model. It is also assumed that sub characteristics are also interrelated.

We have decided to take into account our institute biometric system, which is designed and developed in the institute and used for employee attendance management. Basically it is the component used in the employee management system of our institute. The goal of proposed model is to prioritize the quality characteristics while designing the biometric system. The complete process of ANP based model can defined in following steps:

Step1: Conducted survey on software professional working in biometric based projects. The professional vary in their experience and responsibilities in their respective organisation. They have asked to assign the weights as per standard table 2 defined by satty[14].The sample size is 20.

TABLE 2. Satty's standard table to assign the weights

Importance	Definition	Explanation
1	Equal Importance	2 activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one over another.
5	Strong Importance	Experience and judgment strongly favor one over another
7	Very Strong Importance	Activity is strongly favored and its dominance is demonstrated in practice.
9	Absolute Importance	Importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate Values	Used to represent compromise between the priorities listed above.

Step2: Analyze responses received from the survey to establish the importance of characteristics of ISO 9126 quality model by assigning the weights through ANP.

Step3: Analyse the inter relation between sub characteristics of top 3 characteristics having highest priority by applying the ANP on the responses received during the survey.

Step4: Calculate the weights of all sub characteristics and related characteristics.

Step-5 Evaluate the quality as single variable by following formula [9]

Quality value (Q) = SUM (weight value of corresponding sub-characteristics (w_i) x related metric (m_i))

III. QULAITY EVALUATION OF SOFTWARE COMPONENT

To evaluate the quality as a whole we have applied ANP to calculate the priority vector to establish the importance of different characteristics of ISO 9126 quality model for biometric application software. The result of the same is shown in table 3.

TABLE 3. Priority vector

ISO 9126 Quality Model	
Characteristics	**Priority Vector**
Functionality	0.205
Reliability	0.202
Usability	0.15
Efficiency	0.184
Maintainability	0.139
Portability	0.12

Here we consider 3 main attributes Functionality, efficiency and Reliability. There will be 10 pair wise matrices for determining the interdependencies of sub-characteristics of theses 3 main characteristics of ISO9126 Quality model. One of the pair wise matrix in which suitability is control attribute is shown in table 4.

TABLE 4. Pair wise matrix when suitability is control attribute

Suitability	Ac	Se	Co	Int	Ma	Ft	Re	TB	RB
Accuracy	0								
Security		0							
Compliance			0						
Interoperability				0					
Maturity					0				
Fault Tolerance						0			
Recoverability							0		
Time Behavior								0	
Resource Behavior									0

Professionals will fill the comparison matrices on the basis of a table proposed by Saaty[24]. They only have to fill the upper half of the matrix and the lower half will just be the reciprocal of the previous entry.

The network diagram in the figure 2 depicts the possible relationship and interdependency between functionality, reliability and efficiency and their sub-characteristics. Now we

apply ANP on theses 10 pair wise matrix to analyse the interrelation between sub-characteristics of functionality, Reliability and efficiency.

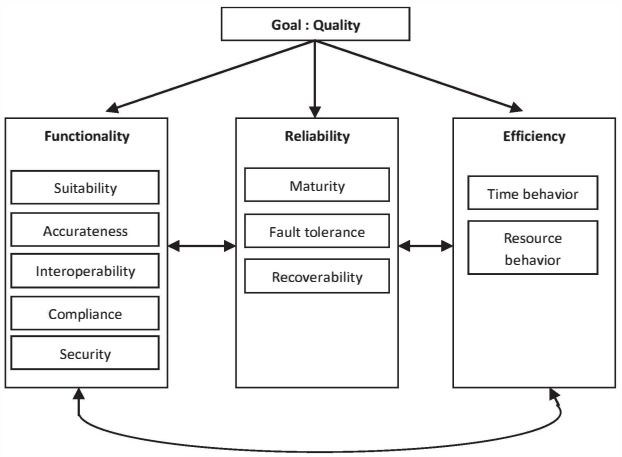

Figure 2. Network diagram to implement ANP

The obtained weight values by applying ANP are shown in table 5.

TABLE 5. Weight values of characteristics and their sub-characteristics

Characteristics	Sub-Characteristics	Weight Value of Sub-Characteristics	Weight Value of Characteristics
Functionality	Suitability	0.0818	0.5598
	Accuracy	0.1188	
	Security	0.1142	
	Compliance	0.1098	
	Interoperability	0.1352	
Reliability	Maturity	0.1012	0.2837
	Fault Tolerance	0.094	
	Recoverability	0.0885	
Efficiency	Time Behavior	0.0778	0.1565
	Resource Behavior	0.0787	
Grand Total			1.0

The set of 10 metrics collected to measure sub-characteristics are shown in table 6. For maturity, it has been assumed that a component having its first version has maturity 0, second released version 0.2, third released versions 0.4, forth version 0.6, fifth version 0.8 and six or more versions means the mature enough component and it may have maturity value 1.0. Finally numeric value of quality has been calculated as shown in table7.

IV. RESULT DISCUSSION

The table 1 gives us prioritization of characteristics of ISO 9126 quality model. This prioritization may help component developers to focus on those characteristics which are of greater importance. Further the proposed model consider the interrelationship and effectiveness between sub-characteristics by applying ANP to calculate their weight values as shown in figure2 and table 5.

TABLE 6. Metrics of 10 sub-characteristics

Parametric	Description	Metric	Value
Suitability	Refers to the appropriateness (to specification) of the functions of the software.	1-(No. of operations not suitable /Total number of operations provided)	1-1/4=0.75
Accurateness	This refers to the correctness of the functions.	Number of function in which error is reported / Total number function	1/4=0.25
Interoperability	Concerns the ability of a software component to interact with other components or systems.	Number of customizable properties /total number of properties	2/4=0.5
Compliance	This sub-characteristic addresses the compliant capability of software.	No of deployment in which organizational laws and guidelines are followed/Total no of deployment	3/3=1
Security	Relates to unauthorized access to the software functions.	No. of access controllability provided / Total no. of access controllability required	2/3=0.67
Maturity	This sub-characteristic concerns frequency of failure of the software.	No. of versions released so far for the same component	0.2
Fault tolerance	The ability of software to withstand (and recover) from component, or environmental, failure.	Total reported failure/number of times it has been recovered	2/2=1
Recoverability	Ability to bring back a failed system to full operation.	Number of Times system is recovered / Total reported failure	2/2=1
Time behavior	Characterizes response times for a given thru-put.	Time taken in one transaction /Number of biometric machines installed	3/10=0.3
Resource behavior	Characterizes resources used, i.e. memory, cpu, disk and network usage.	1- (%CPU usage for the execution of the component/100)	0.80

The proposed ANP based model can be used to estimate the quality of component before integrating it with software application since we are able to calculate the numeric value of quality as shown in table 7. However the proposed model has

been implementing in the particular domain only and result may vary if the domain is changed. The result of the quality value may also vary if all the characteristics of ISO 9126 quality model have been considered and the interdependence between their sub-characteristics have been studied by applying ANP.

TABLE7. Quality value of component

Characteristics	**Sub-Characteristics**	W_v	M_i	$M_i * W_v$	**Quality**
Functionality	Suitability	0.0818	0.75	0.06135	0.348534
	Accuracy	0.1188	0.25	0.0297	
	Security	0.1142	0.5	0.0571	
	Compliance	0.1098	1	0.1098	
	Interoperability	0.1352	0.67	0.090584	
Reliability	Maturity	0.1012	0.2	0.02024	0.20274
	Fault Tolerance	0.094	1	0.094	
	Recoverability	0.0885	1	0.0885	
Efficiency	Time Behavior	0.0778	0.3	0.02334	0.0863
	Resource Behavior	0.0787	0.80	0.06296	
Total Quality Value					0.637574

V. CONCLUSION

All characteristics and sub characteristics in ISO 9126 quality model are not of equal importance. We proposed a model based on ANP to prioritise the characteristics/sub-characteristics. Software developers may concentrate on the selected characteristics/sub-characteristics during development process of software component in the biometric domain. The proposed model is used to calculate the numeric value of the quality of software component in biometric domain. The proposed model may open the future research direction in other domain of software development as well. Further fuzzy ANP may also be applied to take care of human intervention in the proposed model since it may lead some fuzziness in the collected data.

REFERENCES

[1] Raghuraj Singh, Vibhash Yadav, "Predicting design quality of object-oriented software using UML diagrams", 3rd IEEE International Advance Computing Conference (IACC), pp:1662-67,2013

[2] Yi-Shan Chen, Chin-Tsai Lin and Jung-Ho Lu, "The analytic network process for the banking sector: An approach to evaluate the creditability of emerging industries", African Journal of Business Management, vol. 5, pp: 1343-1352, 2011.

[3] Arijit De , "A Fuzzy Ordered Weighted Average (OWA) Approach to Result Merging for Metasearch using the Analytical Network Process", Second International Conference on Emerging Applications of Information Technology, Kolkata, pp: 17-20, 2011.

[4] M. Dagdeviren, İhsan Yüksel et.al, "A fuzzy analytical network process (ANP) model for measurement of the sectoral competition level(SCL)", Expert system with application, vol. 37, pp: 1005-' 1014, 2010.

[5] Alen Jakupovic, Mile Pavlic, Sanja Candrlic, "Application of Analytic Hierarchy Process (AHP) to Measure the Complexity of the Business Sector and Business Software", in Conference on Computer Science and Software Engineering, New York, pp: 35-42, 2010.

[6] Hung-Tso Lin, "Personnel selection using analytic network process and fuzzy data envelopment analysis approaches", Computers and Industrial Engineering, voll.59, pp: 937-944, 2010.

[7] Erika Neira, Diana Lesmes, "Analytic Network Process (ANP): An Approach to Estimate the Colombian Baby Diapers Market Share", in proceedings of the international symposium on the analytical hierarchical process/network process multi criteria Decision Making, Pittsburgh, Pennsylvania, 2009.

[8] Arun Sharma, Rajesh Kumar, P S Grover, "Estimation of quality for software components: an empirical approach", ACM SIGSOFT Software Engineering Notes, Volume 33 Issue 6, November 2008

[9] Grover P S, R Kumar, A Sharma, "Few Useful Considerations for Maintaining Software Components and Component-Based Systems", ACM SIGSOFT Software Engineering Notes, 2007, Vol. 32, Iss. (5), 1-5.

[10] Cote, M., A. Suryn, W. Georgiadou, E,"Software Quality Model Requirements for Software Quality Engineering", 14th International Conference on Software Quality Management, 2006, 31-50.

[11] ISO 9126, "Information Technology – Product Quality - Part1: Quality Model", International Standard ISO/IEC 9126, International Standard Organization, June, 2001.

[12] Maryoly, O., M.A. Perez and T. Rojas, "A Systemic Quality Model For Evaluating Software Products" 2002, available at http://www.lisi.usb.ve/publicaciones.

[13] Saaty T.L. Decision Making with Dependence and Feedback: The Analytical Network Process. Pittsburgh: RWS Publications, 1996.

[14] Saaty T.L. The Analytical Hierarchical Process. New York: McGraw-Hill, 1980.

[15] McCall, J. A., Richards, P. K., & Walters, G. F., "Factors in Software Quality", Griffiths Air Force Base, N.Y. Rome Air Development Center Air Force Systems Command, 1977.

[16] Boehm, B. W., Brown, J. R., Lipow, M. L., Quantitative Evaluation of Software Quality. Proceedings of the 2nd International Conference on Software Engineering, San Francisco, California, United States, 1976, 592-605, IEEE Computer Society Press.

[17] I. Crnkovic, M. Larsson, and O. Preiss, "Concerning Predictability in Dependable Component-Based Systems", Classification of Quality Attributes, Architecting.