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Non-Functional Requirements Research: Survey

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Abstract— NFRs are important since the system architecture greatly depends on the NFRs [20]. Mostly NFR Literature has considered only for key challenges and issues related to NFR. In context of such a need a roadmap for important issues is required. In this paper survey has been presented on interesting ongoing work in the field of non functional requirements and tried to figure out the approaches and methods that are suggested in literature to deal with these issues.

Index Terms— Non Functional Requirements, Modeling, Identification, Formalization, Quantification, Automation

1. INTRODUCTION

IEEE Definition: "non functional requirement (NFR) – in software system engineering, a software requirement that describes not what the software will do, but how the software will do it, for example, software performance requirements, software external interface requirements, design constraints, and software quality attributes. Nonfunctional requirements are difficult to test; therefore, they are usually evaluated subjectively" [50]. In the past relatively little attention has been paid to the process of systematically dealing with NFR's and developers have relied mostly on their own intuitions, in an ad hoc way. In the years, the topic has attracted increasing interest from researchers, as testified by the many specialized events and workshops, as well as by the growing percentage of NFR papers in software engineering conferences.
There has been a considerable increase in the quantity of NFR research over the past few years (see Figure 1(b)). Despite the excellent work in the surveys listed earlier, there remains, to date, no comprehensive survey of the whole field of study concerning trends in research. This paper provides a range of options (Road map) for future research in area of non functional requirements.

The paper is organized as follows: Section 2 describes the result summary of the literature survey. Section 3 discusses the eight categories of research, and reviews the contributions from various research groups and the growing trend. Section 4 presents the conclusion and Future Work.

I. CLASSIFICATION SCHEME

The goal of our paper is to categorize the issues of NFR. We used the five digital libraries to search: ACM Digital Library, SpringerLink, ScienceDirect, Google Scholar, IEEE Xplore, ACM Digital Library, We classify these papers into eight categories.

1. Identification and Specification: Studies on notion(facet), classification and types of NFR.

2. Elicitation: Studies on requirements elicitation methods to empower requirement centered on NFRs.

3. Modeling (Informal): Studies on an approach to record and model non-functional requirements using UML and Relational Diagrams.

4. Modeling (formal): Studies on semantic concepts for the specification of non functional properties.

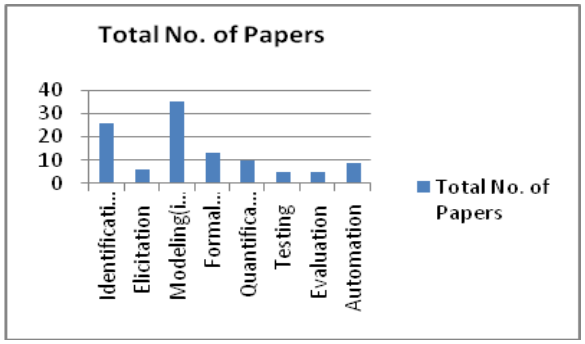

Fig 1(a) Paper in each category

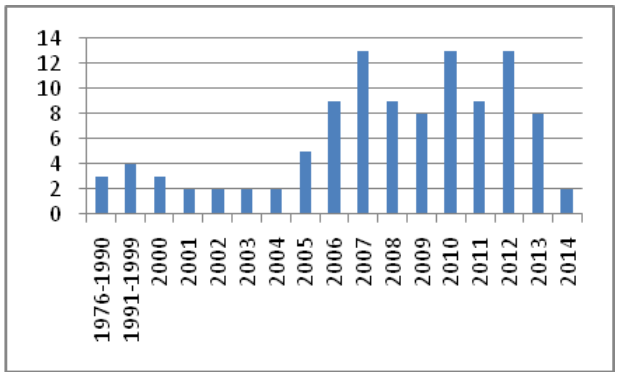

Fig 1(b) NFR Publication growth overtime

Quantification: Studies which explore number of avenues related to specification, design which deals and effect quantification of NFR.

5. Testing: Studies on issues, challenges while consider NFR, resulting from quality concern of stakeholders.

6. Automation: Studies on tools that assist the requirement Analyst while dealing with NFRs.

7. Evaluation: Studies on the degree to which NFR contributes to the improvement of software quality.

Assignment of category to each paper has been based on the main objective of the paper. Thus, in our classification some papers may be into another category by other researchers. For example many of the papers related to elicitation are presented by using any modeling language so we put them in the category of Modelling. Similarly identification and elicitation can be done by a single approach but we put them in different categories on the basis of focused concept used in the paper are Figure 1(a) shows the proportion of papers that fall into each of the different NFR area subject categories while Figure 1(b) shows the histogram charting NFR publication growth over time,

2. LITERATURE REVIEW

A. Identification and Specification

We surveyed different definitions and classification schemes proposed by different researchers. Critical Evaluation has been done as shown in Table 1. No Formal definition for NFR is found in literature except this: f: I → O (e.g., sum: int x int → int) which is defined by Chung etal [23]. NFR Framework is one of the prominent works that has been done in this field. For the specification of NFR there are three categories of approaches available in literature as shown in table 2. NFR Framework is the one of the important work which later on extended by number of researchers in order to solve the problem in their application domain [70]. Beside NFR Framework KAOS [103] and work with the help of UML has been found in literature which we are going to discussed in modelling. Formal language for NFR becomes a necessity but a familiar problem with formal methods in specifying such requirements is the high cost and difficulty of using them. Some of the work on formalization is shown in Table 2. There are few papers on the formal specification languages. Methods of supervised learning have been proposed in the literature to address the problem of identification and classification of NFR. Within the ECSS, ISO, and IEEE standards, a number of views and concepts are provided to describe various types of candidate portability requirements at the system, software, and hardware level [2].

B. Elicitation

There are only very few approaches and tools to elicit NFR. Many of the techniques and tools available are for functional requirements. Classification for the approaches used in elicitation of NFR as shown in Table 3 is based on different categories of approaches [108][116]. Ullah etal. has identified several key issues like conflicts of requirements, integration of NFR with FR and ambiguous specification of system features. They have found some of the solutions of these stated problems based on the available literature.

C. Modelling (informal)

A survey of the different works shows that most of them use UML with some extensions to add NFRs with the functional requirements models as shown in Table 4. UML proven to be successful modelling language to bring the revolution in NFR specification and modelling. Number of tools like Rational Rose, Smart Draw and Enterprise architect are available for UML.There are other approaches like Relational Model, Petrinets, Multimodel, NFR Framework, NFR Framework + that can be used to specify NFRs as mentioned in Table 4.

D. Formal Modelling

Formal methods offer a mathematical way to specify and analyze the behavior of NFR in a system together with a related tool support. Some relevant work done in this field by different researchers is discussed below. UML-B has been used for a real-time control system security concerns using an action systems approach [98]. There is requirement of tool support for UML-B. RoZ tool is used for modelling the airport security. It uses Z notation [63]. Another approach called KAMI is implemented as a distributed framework with a plugin architecture, which allows new tools to be incorporated to support other modeling notations and analysis procedures [34]. The approach is based on formal (probabilistic) models that are used at design time to reason about dependability of the application in quantitative terms. Another approach based on semantic concepts which form the basis of a semantic framework for the specification non-functional properties of component-based software [126][127]. Probabilistic way of characterizing the implementation of software non-functional requirements is proposed in [114]. SysML has been adopted as the modeling language by [107], since it enables requirement definition and can be formally extended. [90] has presented a semiformal approach for reasoning and refining functional requirements. Non Functional properties has expressed as NF-actions, NF-statements and NF-attribute. An another approach [83] aimed at lessen the risk of such misuses of quality models. It is centered on the definition of a language called *NoFun* which is to be used as a formal language for the exhaustive description of software quality. Borges and Mota [16] integrate UML class diagrams and *OhCircus* by written UML elements in terms of *OhCircus* constructs. *OhCircus* is a formal specification language which uses Z, CSP, calculus of Morgan and object-oriented theories. Casamayor [19, 20] propose a semi-supervised text categorization approach for the automatic identification and classification of non-functional requirements. Detection and classification of NFRs is performed using semi-supervised learning techniques. One more interesting work is shown in [26] which discuss an algebraic formalization of model based on graph theory which they use to prove safe termination in systems compliant with Ravenscar Computation Model (RCM), and show how to use the MAST+ static analyzer to verify the timing aspects. But till lot of work need to be done in this direction as mentioned in [19][21][23].

Table 1. Different Classification Schemes Proposed in Literature

Source	Research proposal	Critical Evaluation
Boehm(1976)[14]	Paper provides for the first time a clear, well-defined framework for assessing the often slippery issues associated with software quality, via the consistent and mutually supportive sets of definitions, distinctions and guidelines [14].	No emphasis has been found attributes of those NFRs.
McCall(1980)[72]	A Software Quality Measurement Manual was produced which contained procedures and guidelines for assisting software system developers in setting quality goals, applying metrics and making quality assessments.	It was assumed to be efficient model. Later it modified in 2000 where requirements are classified on the basis of product revision and transition.
Roman IEEE Computer (1985) [88]	It classifies requirements into interface, performance, operating, lifecycle, economic and political requirements.	It is complex classification.
Sommerville (1992) [100]	It considers organization, product and external aspects of requirement.	This model is accepted by many organizations but it could not sort the Non Functional Requirement specification issues.
Grady(1992)[42]	FURPS and FURPS+ is an acronym that represents the model. It introduces dimensions of quality.	Architectural integrity is not covered in the model
ISO/IEC 9126 (2001) [52]	Distinguishes four types of quality levels Quality in use, external quality, internal quality and process quality which helps to provide process oriented classification.	It sets standard for software practitioner to make the meaning of NFR and important NFR like performance clear to developers and users. But it is only limited to few NFRs.
Martin Glinz (2005) [39]	Presents New Classification of Requirements • Kind • Representation • Satisfaction • Role	Provides new notion to the NFRs but classification has no practical usefulness in daily life. It can be simplified further.
Jureta etal.(2006) [57]	This classification provides four categories: functional hardgoal, non functional hardgoal, functional softgoal and nonfunctional softgoal.	It is driven by nonfunctional perspective.
Martin Glinz (2007) [40]	Proposed New Definition to requirements and Specify classification rules based on Aspect-Oriented Representation.	Definition and Classification is less ambiguous than traditional definitions. Its Practical aspect needs to be find out.
Dewi Mairiza etal.(2010) [70]	It offers a novel classification of NFRs types based on types of systems and application domains.	It presents comprehensive lists of NFR types which helps developer to identify NFR for their particular system. But the Terminology present does not improve the notion of NFRs.
Chi-Lun Liu (2010) [66]	Proposes top level NFR ontology helpful in conflict detection between NFRs which is extended from Glinz's study.	Nothing has been done for improving NFR facet in it.

Table 2: Categorization of Approaches used in Identification

	[2]	[18]	[19]	[20]	[22]	[23]	[25]	[28]	[29]	[34]	[35]	[37]	[39]	[40]	[42]	[48]	[65]	[66]	[70]	[80]	[125]	[126]
Informal Approach(I)	I				I	I	I	I	I				I	I	I	I			I	I		
Semi-Formal Approach(S)			S	S													S	S				
Formal Approach(F)		F								F	F	F									F	F

Table 3: Classification of approaches used in elicitation of NFRs

Approaches	References	Description
NFR Framework Based	[4][27][48][84][101]	Process-oriented and qualitative method for handling NFRs
Quality Model Based	[6][9][52][58][104]	NFR method consists of quality attributes, based on quality model
NFR Framework with Quality Model Based	[52][56][58][121]	i* framework and meta-model are presented in these approach.
Guideline Based (Without NFR Framework and Quality Model Based	[51][111]	Approaches set the and focused on gathering only the minimum set of information on quality goals.

Table 4: Informal Modelling of NFR

Approach(Model)	Purposed
Use Case and Goal Driven (2005)[103]	Integrates FR with NFR at design level by using use case elements.
Extended Use Case (2006)[11]	To separate(cross-cut) the concerns at the requirements level(on tha basis of application domain) that can be achieved by checking concerns that produce spread and tangled representation that are difficult to understand and maintain. Extended elements helps to express and integrate NFR and challenges to requirement analyst with the FR.
OONFR(2001) [26][27]	UML Class Diagram is proposed which use LEL of UofD as input and class diagram has signals of what elements (classes, attributes, operations and relationship) are responsible for NFR.
Extended UML(2007)[123]	Dependency notation is introduced in UML to model design decisions.
Extending UML with NFR Framework(2005)[22][23]	Meta-Model to represent concepts in NFR Framework and made extension in UML and NFR Framework to integrate the notations of two modeling languages.
Novel Framework with UML(2005)[106]	UML design is integrated to NFRs for the purpose of reengineering process of legacy systems.
Layered Model(Conceptual ArchitecturalModel)(2005)[117]	Additional layer is added to traditional architectural model for satisfying NFR Role.
UMLsec (2002) [53]	UML extension mechanism based on formal semantics to evaluate security aspects of system design
SecureUML (2002) [68]	UMl extension mechanism to specify information for access control in the design of application.
Abuse Case Model(2002)[68]	Extended Use Case Model to capture and analyze security requirements by specifying check on interaction between system and actors.
Architectural pattern(2005) [61]	Improving system dependability and trustworthiness by improving the modeling of NFR(operationalizable NFRs, and checkable NFRs)
NFR Framework with Role Activity Model (2007)[3]	Remodelling business process to better representation and realization of NFR aspects of processes by linking RAD with NFR graphic facility.
Use Case extended to Control Case(2006)[114][124]	Focus is made on operating conditions by adding control cases to 4+2 view of architecture(UML Process view)
DERAF(2007) [69]	Combines the use of aspects with RT-UML, aiming to separate the handling of non-functional from functional requirements in the Model Driven Design of DERTS.
Integrated Model(2007) [113]	Approach is based on building a base quality model that relies on an explicit meta-model. Purpose models are also needed to support the planning and realization of quality assurance are derived from the base model by quantifying the relations modeled in the base model.
XML-NFR(2007) [117]	It is also step to integrate with functional requirements design model based on

	simple language XML but not solved many issues of NFR.
Pluggable Framework (Wireless Sensor networks)(2008) [15]	It allows WSN applications in TinyDDS(Data Distributed Services) to have fine-grained control over non-functional properties and specialize in their own requirements.
RASF(2008) [45]	A Multi-Agent Systems (MAS) approach in Reactive Autonomic Systems (RAS) whose specifications are mentioned in single formal framework.
XML with Petri-Nets(2008)[31]	The intermediate model is based on XML and indicates the relationship between the entities of design models and analysis models by minimizing the gaps
Extended PLUS (UML Based Model) (2009) [79]	It provide a unified and systematic framework for analysis modeling of NFRs in Software Product Lines by integrating it with Lines PLUS.
SysML(2009)[107]	It represents NFR as how non-functional requirements are related between them and to system components forming the overall system architecture.
KAMI(2009) [38][103]	Approach relies on run-time monitoring and uses the data collected by the probes to detect if the behavior of the open environment in which the application is situated can lead to a failure of the application
NFR with AORE(2010)[114]	It map non-functional requirements into function and architectures through non-functional scenario template which improves traceability from requirement analysis level to implement level.
Configuration Models(2012) [33]	Mapping nonfunctional aspects to given commercial-off-the-shelf modules which makes possible the integration of commercial software modules into product families
Relational Model (2011) [59]	It introduce change management mechanism that trace the the impact of NFRs on the other constructs in the ontology such as FR or NFR operationalization and vice versa.
Multimodel Approach(2012) [41]	Besides the refinement of NFR it allows the validation of its fulfillment through the application of metrics that are associated to each NFR.
Design Patterns Approach(2001) [44]	It provides guidance and reasoning support when applying patterns during the design of a software system.
UML with OCL [83]	Non functionality is described by means of a notation called NoFun, which allows us to introduce non-functional attributes of software
UML Based on EAST-ADL (2011) [91]	Provides solution for telecommunication systems for modeling product families, targeting cost sensitivity non-functional requirements and performing cost analysis.
Domain Specific Modelling Approach(NFR+ Framework) [119]	The solution enables a full bi-directional traceability from the requirements to models to the implementation.
UML for intrusion specification(2006) [49]	UML notations extended to suit the context of intrusion scenarios that allows developers to specify intrusions

E. Quanitification

There are very few languages to state non-functionality in form so that it can be quantified. One of the language [35][83] is NoFun which provides a common framework in which people can formulate, analyse and compare their proposals about non-functionality. A measure for reusability is refined by this language.The combination of both NoFun and the implementation selection algorithm can be an aid to software specification, design, reusability and maintenance. Stephan Jacobs [54] of Ericsson presented a case study on improving requirement engineering. From the concepts offered in Planguage Jacobs proposed that Gist, Scale, Meter, Past, Record, Must, Plan and Wish should be made visible in our requirements specifications by using keywords in bold letters. GIST is a rough summary of the requirement. According to Jacobs SCALE defines the unit in which the requirements has to be measured. METER defines the way how the measurement will be performed. PAST and RECORD are benchmarks. Past is a value which is typical for (own) products developed in the past. MUST, PLAN and WISH envisage the future. Must, Plan and Wish characterize the system that is to be built. Affleck [5] extends the previous quantitative reasoning extension into a single objective optimization model that aims to selectively choose operationalizations in order to increase the overall satisfaction of non-functional requirements. One metric is proposed in [1]

that can be used in the early stages of software development projects to estimate effort of new projects. Affleck [4] presents a process-orientated, lightweight, quantitative extension to the NFR Framework; focusing on providing quantitative support to the decision process and how decisions affect the system. Some key issues related to NFR quantification are discussed in [85][90].They discussed issues related to sharing of information between customer and supplier as it is must for optimal quantification. Requirements Convergence Plan can be used to create better NFR quantification circumstances for customers and suppliers. Another evaluation model of NFR is proposed in [94] which mainly focusing on the user maintenance and operation issues. This model consists of NFR categories, NFR metrics, description level grading and weight to each NFR. Another contribution to quantification of NFR is made by Bin [119] by proposing three methods for calculating non-functional properties. The cumulative method is applied to calculation of energy cost, memory cost, and number of defects and so on. The multiplicative method is applied to calculation of non-functional properties which can be described by probability, such as reliability, confidentiality. The graphic method is applied to calculation of consumed time. Paper also proposes a 0-1 programming method for selecting the best non-functional requirement implementation strategies. Bhatti etal.[13] tries to quality metrics on the basis of UML diagrams.

F. *Testing*

[97] has mentioned prevalent testing issues in the light of NFR. There is a great need to work on specification for testability, design for testability and code for testability as mentioned in previous sections of paper. They also mention certain research direction for future exploration in their paper. One of the solutions is to have aspect-oriented techniques. It offers a promising approach for capturing such issues under verification. In the Literature we found very few testing techniques (NFR) proposed that too are application based as mentioned in Table [5].

G. *Automation*

Automation of process is necessary for speed up the development process. Not only requirements have to be carefully considered but they also have to be implemented. But there need to validate the implementation which can be easily done with the help of tool. Tool can potentially help agile software development teams in reasoning about and visually modeling NFRs as first-class artifacts early on during requirements gathering and analysis phases. It is better to create a simple and open toolkit that in turn can be adapted to a variety of projects and architectures [30]. Since there is need to handle NFRs automatically various tools have been proposed by researchers as enlisted in Table 6.

H. *Evaluation*

Evaluation means NFR importance degree assessment given by the expert's team on the basis of certain variables. Some important evaluation has been done in [12][81][105] [123]

3. CONCLUSION AND FUTURE SCOPE

NFR needs to look after starting from the early stages of software development. There is a need to chance the facet of NFRs while specifying it in SRS. Most of the literature is based on NFR elicitation and NFR Framework (informal approach). Some formal approach needs to be work out. According to Singh et al. number of models are available for Functional Requirements like Four Variable Model, COCOMO. Model and Reference Model etc. but no standardized model has been found opted for NFR [21][97]. It is due to informal presentation, NFR still a challenge in the field of requirement engineering.

To complete the specification for NFRs besides the four variables (NAT, REQ, IN, OUT) of four variable model new variable can be introduced or new model can be introduced from scratch for dealing with NFRs. Extensions to this model is also suggested in [77]. Similarly Reference Model can be extended for NFR as mentioned by Chung.[21].

As proposed in [97] NFR can be handled more concretely by MBT, some approach needs to be work out for handling real life situations.

Aspects help to achieve modularity in software development process. The use of AO to deal with NFR has already been proposed in [69].

In this paper we surveyed different aspects of NFR. We are likely to focus on formal modeling of NFR in future work. As it is the foremost challenge that need to be overcome if we want NFR to be quantified. Some of the issues related to NFR are mentioned in Table 7 found from the literature survey.

Table 5. Testing issues based on application

Application	Issues	Solution Proposed
Web Based application[89]	Verification during testing	• Metrics for the navigability • Load and Performance Testing
Quality verification of mobile phones [76]	Lack of Tool Support Classify types of NFR	Aspect-oriented techniques

TABLE 6: TOOLS

Source	Tool or Approach Name	Purpose
Jan Ladiges etal.(2013) [62]	Presented a set of non-functional requirements on automated production facilities.	Approach used detects unintentional changes in its behavior after performing modifications.
Farid and Mitropoulos(2012)[33]	NORMATIC	Modeling for Agile Processes (NORMAP) Methodology.
Cesare etal.(2012) [84]	Q4BPMN	Non-Functional requirements can be directly expressed within the BPMN model.
Janne Merilinna etal.(2012)[75]	Supported by a tool enables to do that in the context of Domain-Specific Modeling (DSM).	Bi-directional traceability link between requirements and implementation is maintained by NFR+ Framework.
Kristoffer Dyrkorn(2008)[30]	Present an open-source toolkit that enables automated testing of non-functional requirements.	Provides developers and project managers with reports about the system under development.
Jane Cleland etal.(2007)[24]	Technique for automating the detection and classification of non-functional Requirements.	Approach is used to detect and classify stakeholders' quality concerns across requirements specifications containing scattered and non-categorized requirements
Lawrence Chung etal.(1996) [22]	Address tool support for the change process	Approach is based on existing NFR Framework
Al Balushi etal.(2007)[6]	ELICITO	Quality ontology-guided NFR elicitation tool

TABLE 7: NFR ISSUES

S.No	Categories	Issues
1	Identification and Specification	• Need to change the notion while specifying NFR in RFP [39][40] • Formal Techniques [20][21]
2	Elicitation	• Aspect oriented documentation of attributes and constraints [69][108]
3	Formal Modeling	Need to develop formal models like • Four Variable Model[21][77] • Reference model[21]
4	Quantification	• Formal models helps in quantification of NFR [77][81][93]
5	Testing	• Clear Identification and Specification(Formal techniques) • AOP[69][97] • MBT[41][97]
6.	Automated Tool	• Tool for empowering analyst by providing knowledge repository, detecting NFR conflict and to assess impact of NFRs in early stages [5][30].

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