An Investigation on Quality Models and Quality Attributes for Embedded Systems

Lucas Bueno R. Oliveira
University of São Paulo - USP,
São Carlos, SP, Brazil
IRISA - Université de Bretagne-Sud,
Vannes, France
buenolro@icmc.usp.br

Milena Guessi
Dept. of Computer Systems,
University of São Paulo - USP,
São Carlos, SP, Brazil
guessi@icmc.usp.br

Daniel Feitosa and Christian Manteuffel
University of Groningen - RUG,
Groningen, The Netherlands
{d.feitosa, c.manteuffel}@rug.nl

Matthias Galster
University of Canterbury,
Christchurch, New Zealand
matthias.galster@canterbury.ac.nz

Flavio Oquendo
IRISA - Université de Bretagne-Sud,
Vannes, France
flavio.oquendo@univ-ubs.fr

Elisa Yumi Nakagawa
Dept. of Computer Systems,
University of São Paulo - USP,
São Carlos, SP, Brazil
elisa@icmc.usp.br

***Abstract*—Embedded systems have gained more and more importance in recent years, being adopted in a diversity of application areas. Due to the increasing variety and complexity of these systems, a rising demand for software quality can be observed. Initiatives proposing quality models and quality attributes (QM&QA) for embedded systems can already be found. Nevertheless, there is a lack of a complete, detailed panorama about the research that proposes QM&QA dedicated specifically to this domain. In this paper, we apply the systematic review technique to investigate how QM&QA for embedded systems have been defined, evaluated, and used. In addition, we identify which quality attributes are considered as the most important ones in the embedded systems domain. As a result, this work provides a detailed state-of-the-art about the QM&QA for embedded systems and identifies new, important research topics for the future, contributing to improve the quality of these systems.**

Keywords-Embedded System; Quality Model; Quality Attribute; Systematic Review.

I. INTRODUCTION

Recently, a large number of products containing embedded software has been developed and used, bringing an effective impact to the society. Embedded systems have been widely adopted in different application areas, such as telecommunication, transportation, entertainment, and medicine [1]. According to Liggesmeyer and Trapp [2], over the last 20 years, software's impact on the embedded system functionalities, as well as on the innovation and differentiation potential of new products, has rapidly grown. Besides that, the complexity and diversity of these products are creating a considerable challenge for embedded software development, which usually has to meet stringent requirements, such as real-time or performance [1]. The development process of embedded systems has to ensure the compliance with various quality attributes, such as maintainability, safety, security, and dependability. In this context, the quality assessment activity must be considered a key concern during the development of such systems. This statement is especially true considering the fact that many embedded systems are considered critical, i.e, systems whose failures may cause serious damage to the environment or to human lives, damage to expensive equipment, or nonrecoverable financial losses [3].

In another perspective, software quality models have become well-accepted means to describe, manage, and predict software quality. Over the years, a variety of quality models have been proposed to support the development of general software systems. McCall's Quality Model [4], considered as the precursor of the actual models, establishes three major perspectives for defining and identifying the quality of a software product: product revision, product transition, and product operations. Each of these perspectives describes a set of quality attributes that refers to the ability of a software system to undergo changes, to adapt to new environments, and to adequately performs its functionalities. Similarly, Boehm's Quality Model [5] attempts to define software quality by a given set of attributes and metrics. Another important quality model is ISO/IEC 25010 standard [6], which incorporates quality goals that encompass a large number of quality attributes. Given its relevance, quality models and sets of quality attributes (QM&QA) that intent to specifically address the needs of embedded systems can also be found [7], [8]. These studies can be considered important initiatives, as embedded systems have particular characteristics, such as the use of dedicated hardware and real-time constraints, that differentiate them from general information systems. Nevertheless, as far as we are concerned, there is no complete, detailed view of how QM&QA have been defined, evaluated, and used in the embedded systems domain. Therefore, a study involving a broad, fair analysis of this research topic seems to be quite relevant, considering the impact that it could have on the quality of the embedded systems being developed.

The main objective of this paper is to present a detailed state of the art of QM&QA for embedded systems, the application areas that they are intended for, and how QM&QA have been evaluated. In addition, this work also aims at identifying which quality attributes are considered as the most relevant ones in the embedded systems context. For this, we have adopted and applied the systematic review

 ISBN: 978-1-61208-304-9

technique [9], which allows for a complete, fair evaluation of a topic of interest. Results have shown that most studies are recent, indicating a growing interest and concern of the community on the proposition of QM&QA for embedded systems. Besides that, we have observed that there is a lack of quality models that are widely adopted and used by developers of embedded systems. Based on our findings, we intend that this state of the art makes it possible to identify interesting, important research topics for further investigations.

The remainder of this paper is organized as follows. Section II presents the conducted systematic review and describes its results. Section III presents the quality assessment of these results. Section IV summarizes the main, important findings of the systematic review and identifies perspectives of future research. Finally, Section V presents our conclusion and future work.

II. Systematic Review Application

Our systematic review was conducted from November/2012 to April/2013 by six persons: four software engineering researchers, an embedded system expert, and a systematic review specialist. To conduct our systematic review, we followed the process proposed by Kitchenham [9]. In short, this process is composed of three main phases: planning, conduction, and reporting. These phases are explained in more details during the presentation of our systematic review.

A. Phase 1 - Planning

In this phase, the objectives and the systematic review protocol are defined. The protocol consists of a predetermined plan that describes the research questions and how the systematic review will be conducted, i.e., the search strategy. It also establishes the selection criteria, the data extraction and synthesis method.

1) Research Questions: Aiming at finding possibly all primary studies to understand and summarize evidences about QM&QA for embedded systems, the following research questions (RQ) were established:

- **RQ1:** How are QM&QA for embedded systems defined?
  - **RQ1.1:** What are the information sources used to define QM&QA for embedded systems?
  - **RQ1.2:** Are the QM&QA developed in a prescriptive or descriptive manner?
- **RQ2:** What are the application areas where QM&QA for embedded systems have been used?
  - **RQ2.1:** Are the QM&QA designed for critical embedded systems?
  - **RQ2.2:** Which design approaches, such as service-orientation or component-orientation, have been adopted to develop these embedded systems?
- **RQ3:** How have QM&QA for embedded systems been evaluated?
  - **RQ3.1:** What is the level of evidence used to evaluate the QM&QA?
  - **RQ3.2:** In how many embedded systems the QM&QA have been applied?
  - **RQ3.3:** Have the QM&QA been used in actual projects?
- **RQ4:** What are the main quality attributes for embedded systems?

2) Search Strategy: In order to establish the search strategy and considering the research questions, we initially identified two main keywords “Embedded System” and “Quality Model”. We also identified related terms for these keywords: “Embedded Software”, “Quality Attribute”, “Non-functional Requirement”, “Non-functional property”, and “Quality Requirement”. We considered the plural form of all keywords and related terms. Besides that, only papers written in English were considered in our systematic review, since it is the most common language in scientific papers. We used the Boolean operator OR to link the main terms and their synonyms; furthermore, all these terms were combined using the Boolean operator AND. The final search string was: *(“Embedded System” OR “Embedded Systems” OR “Embedded Software”) AND (“Quality Model” OR “Quality Models” OR “Quality Attribute” OR “Quality Attributes” OR “Non-functional Requirement” OR “Non-functional Requirements” OR “Non-functional Property” OR “Non-functional Properties” OR “Quality Requirement” OR “Quality Requirements”).*

In addition to the search string, we also defined a control for our systematic review. For this, we considered two previously known studies [7], [8]. They were our baseline to check whether our search string was properly defined, i.e., if our string was able to find these studies in the publication databases. Moreover, in order to select the most adequate databases for our search, we considered the following criteria discussed in [10]: *content update* (publications are regularly updated); *availability* (full text of the primary study is available); *quality of results* (accuracy of the results obtained by the search); and *versatility export* (since much information is obtained through the search, a mechanism to export the results is required). The selected databases to our systematic review were: ACM [11], IEEE Xplore [12], ScienceDirect [13], Scopus [14], Springer [15], and Web of Science [16]. According to Dybå et al. [17] and Kitchenham et al. [18], these publication databases are the most relevant sources. Aiming at not missing any important primary study, we also considered the related works presented in the reference list of the primary studies selected by our systematic review.

3) Inclusion and Exclusion Criteria: The selection criteria are used to evaluate each primary study obtained from the publication databases. These criteria make it possible to include primary studies that are relevant to answer the research questions and exclude studies that do not answer them. Our inclusion criteria (IC) were:

- **IC1**: The primary study presents a quality model for embedded systems;

 ISBN: 978-1-61208-304-9

- **IC2**: The primary study reports the use of a quality model for embedded systems;
- **IC3**: The primary study proposes a set of quality attributes; and
- **IC4**: The primary study is an empirical study that has as outcome a set of quality attributes.

The established exclusion criteria (EC) were:

- **EC1**: The study does not propose or report QM&QA for embedded systems;
- **EC2**: The study is a previous version of a more complete paper about the same research; and
- **EC3**: The primary study is a table of contents, short course description, copyright form or conference proceedings.

4) Data Extraction and Synthesis Method: In order to extract data, we planned to build data extraction tables related to each research question. These tables will synthesize the results to facilitate drawing conclusions. During the extraction process, the data of each primary study will be independently extracted by two reviewers. In case of disagreements, discussions will be conducted. To summarize and describe the set of data, statistical synthesis method and meta-analysis will be applied.

B. Phase 2 - Conduction

In this phase, we adapted the generic search string defined in the Phase 1 according to the specificity of each publication database. The search of primary studies was then performed by searching for all primary studies that matched the adapted search string. After removing primary studies indexed by two or more publication databases, 308 primary studies remained for analysis. Initially, the title and abstract of each study were read and the selection criteria were applied. A total of 15 studies were selected for further reading. These studies were read in full by two reviewers and the selection criteria were again applied. As a result, nine primary studies were selected for the data extraction. Besides, we looked for the related work (i.e., the main references) of each primary study read in full. Among all related works evaluated, we selected two relevant primary studies that had not been previously identified [19], [20]. Finally, a set of 11 studies was selected as the most relevant to our systematic review.

Table I shows all primary studies included, their publication year, and references (Ref.). It is important to notice that only three primary studies found propose quality models for embedded systems (i.e., they were included by IC1). Therefore, most of studies are dedicated to provide sets of quality attributes for embedded systems. Moreover, it is possible to observe that 73% (i.e., 8/11) of the studies were published in the last five years, which might indicate an increasing interest for this topic of research.

C. Phase 3 - Reporting

This phase presents the analytical results of our systematic review. Data extraction and synthesis of knowledge considering each research question are discussed below.

TABLE I. QM&QA FOR EMBEDDED SYSTEMS

ID	Author	Year	Criteria	Ref.
S1	Wijnstra, J.G.	2001	IC3	[19]
S2	Purhonen, A.	2002	IC3	[21]
S3	Åkerholm, M. et al.	2004	IC4	[20]
S4	Choi, Y. et al.	2008	IC1	[22]
S5	Sherman, T.	2008	IC4	[8]
S6	Carvalho, F. and Meira, S.R.L.	2009	IC2	[23]
S7	Paulitsch, M. et al.	2009	IC3	[24]
S8	Peper, C. and Schneider, D.	2009	IC3	[25]
S9	Jeong, H.Y. and Kim, Y.H.	2011	IC1	[26]
S10	Guessi, M. et al.	2012	IC4	[7]
S11	Ahrens, D. et al.	2013	IC1	[27]

1) RQ1 - Research Question 1: This research question aims at understanding how QM&QA for embedded systems have been defined. For this, we have investigated which sources of information are most used to develop the QM&QA and whether they are defined in a descriptive or prescriptive way. Descriptive primary studies depict how quality has been addressed in systems of this domain. On the other hand, prescriptive primary studies introduce guidelines of how quality should be addressed in embedded systems. Table II summarizes the sources of information and methods of development used in each primary study.

We noticed that most of QM&QA for embedded systems (54.5%) were developed from documental analysis, i.e., using information collected in documents associated to existing systems, such as system requirement documents. Moreover, personal experience and literature reviews were considered in 36.4% and 27.3% of the primary studies, respectively. Developed systems, standards and regulations, interviews, questionnaires, existing software architectures, and on-going projects were also considered in at least one primary study. Furthermore, it is possible to observe that there is no predominance of prescriptive or descriptive studies. We also identified that there is no correlation between the information source and prescriptive/descriptive QM&QA. Thus, the choice of information sources may be more related to the context in which the model was defined than the purpose for what it was intended.

2) RQ2 - Research Question 2: This research question investigates for which application areas QM&QA for embedded systems have been developed. To answer this question, we collected data regarding the application areas of the embedded systems, as well as the approaches used to design these systems. We also collected data to discover whether QM&QA were designed to critical embedded systems. Table III summarizes the obtained results.

Regarding this research question, it is possible to point out that several studies (S5, S6, S9, and S10) are concerned about quality of embedded systems in general, i.e, without a specific application area. QM&QA for embedded systems for the transportation area can also be highlighted (S3, S7, and S11). With respect to the design approaches, we found out that they are often related to component-based embedded systems, as presented in studies S3, S4, S6, S9, and S11. It

TABLE II. INFORMATION SOURCES AND METHODS OF DEVELOPMENT USED TO DEFINE QM&QA

Source of information	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	(#)	(%)
Documental analysis		X		X	X	X			X		X	6	54.5
Personal experience	X							X	X		X	4	36.4
Literature review		X					X			X		3	27.3
Developed systems		X			X							2	18.2
Standards and regulations		X					X					2	18.2
Interviews		X									X	2	18.2
Questionnaires			X								X	2	18.2
Existing architectures							X					1	9.1
On-going project								X				1	9.1
Method of development	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**(#)**	**(%)**
Prescriptive study		X	X	X		X		X				5	45.5
Descriptive study	X				X		X		X	X	X	6	55.5

TABLE III. APPLICATION AREAS AND DESIGN APPROACHES OF THE QM&QA

ID	Application Area	Design Approaches	Critical System
S1	Medical imaging	Product Lines	Yes
S2	Digital signal processing	Generic	No
S3	Automotive	Components	Yes
S4	Digital TV	Components	No
S5	Generic	Generic	Both
S6	Generic	Components	Both
S7	Aviation	Integrated Modular Architecture	Yes
S8	Ambient intelligence	Service Oriented Architecture	Yes
S9	Generic	Components	Yes
S10	Generic	Generic	Both
S11	Automotive	Components	Yes

TABLE IV. OVERVIEW OF THE EVALUATION OF QM&QA FOR EMBEDDED SYSTEMS

ID	Level of Evidence	Number of Systems	In use
S1	No evidence	NR	Yes
S2	Academic studies	0	NR
S3	Expert opinions or observations	NR	NR
S4	Industrial evidence	2	Yes
S5	No evidence	NR	NR
S6	Expert opinion or observations	0	NR
S7	Expert opinion or observations	NR	NR
S8	Demonstration or toy programs	1	NR
S9	No evidence	NR	NR
S10	Academic studies	NR	NR
S11	Industrial studies	1	NR

is also possible to identify QM&QA that are not limited to a specific type design approach, such as presented in studies S2, S5, and S10. Furthermore, we found out that most of primary studies (nine out of 11) are dedicated to critical embedded systems. This result was expected and reinforces the importance and interest in the quality of this type of systems.

3) RQ3 - Research Question 3: This research question investigates on the evaluation of the QM&QA for embedded systems available in the literature. For answering this question, we collected data about the level of evidence used in the evaluation, the number of systems in which these QM&QA have been applied, and whether they are in actual use or not. The following levels of evidence were considered: industrial evidence (i.e., actual use of QM&QA in industry), industrial studies (i.e., QM&QA developed in the industry); academic studies (e.g., controlled lab experiments or evidence based results); expert opinions or observations; demonstration or working out toy examples; and no evidence. Table IV presents the information about the evaluation of the QM&QA for embedded systems. Studies that do not report whether the proposal is in actual use or not are represented as Not Reported (NR).

It is possible to observe that only three studies (S4, S8, and S11) present QM&QA that were evaluated through their application in embedded systems. Five studies were evaluated using expert opinion (S3, S6, and S7) or academic studies (S2 and S10). Three studies do no present information about their evaluation (S1, S5, and S9). However, it is worth highlighting that QM&QA proposed in S1 and S9 are descriptive studies that emerged from personal experience (see Table II) and may not need an explicit evaluation. Besides that, it can be noticed that, among the QM&QA evaluated using embedded systems, only primary study S4 reports its application at least twice. Regarding the adoption of QM&QA, only S1 and S4 studies indicate that their proposals are currently supporting the evaluation of embedded systems. The other included studies do not present evidences about their current adoption. Despite these QM&QA may be in actual use, no publication reporting this information was found in our systematic review.

4) RQ4 - Research Question 4: This research question investigates the main quality attributes for embedded systems. Table V presents the main quality attributes identified in this review and the primary studies that address these attributes.

We identified 18 major quality attributes related to embedded systems. These attributes are those addressed by at least 25% of the primary studies, i.e., three or more studies. It is observed that the main quality attributes are related to maintainability and reliability. This result seems coherent, since an embedded system involves the coordinated project of software and hardware. Besides that, the maintainability is a challenging issue of the development of this type of

TABLE V. QUALITY ATTRIBUTES OF EMBEDDED SYSTEMS

Attributes	(#)	(%)	Primary studies
Maintainability	10	91	S1, S2, S3, S4, S5, S6, S7, S9, S10, S11
Reliability	10	91	S1, S3, S4, S5, S6, S7, S8, S9, S10, S11
Security	7	64	S3, S4, S5, S6, S7, S8, S9
Safety	7	64	S1, S3, S5, S6, S7, S10, S11
Functionality	7	64	S1, S4, S5, S6, S8, S9, S10, S11
Efficiency	7	64	S2, S3, S4, S5, S6, S10, S11
Portability	7	64	S1, S2, S4, S6, S9, S10, S11
Testability	7	64	S1, S3, S5, S6, S7, S9, S11
Performance	5	45	S2, S5, S7, S10, S11
Usability	5	45	S3, S4, S5, S6, S9
Availability	4	36	S1, S5, S9, S11
Extensibility	4	36	S1, S2, S3, S11
Reusability	4	36	S2, S4, S6, S11
Cost	4	36	S1, S2, S5, S6
Fault tolerance	3	27	S2, S9, S10
Recoverability/ Repairability	3	27	S6, S9, S11
Interoperability	3	27	S1, S9, S10
Flexibility	3	27	S3, S5, S6

systems. Embedded systems are also often used in safe-critical context and, therefore, they must be reliable. Most of studies also address security, safety, functionality, efficiency (i.e., efficient consumption of hardware resources, such as processor, memory, and battery), portability (i.e., ability of being transferred and used in a different environment), and testability as important quality attributes. Other quality attributes addressed by less the half of the studies were: performance, usability (i.e., ability of being understood, learned, configured, and used), availability, extensibility, reusability, fault tolerance, recoverability (repairability), interoperability, and flexibility.

III. Quality Assessment

In order to analyze the quality of the included primary studies, we developed a checklist containing seven questions based on the quality assessment created by Kitchenham et al. [28]. Table VI presents the quality assessment criteria and the scores obtained by the primary studies. For each question in the checklist, the following scale-point was applied: the study fully meets a given quality criterion (1 point), the study meets the quality criterion in some extent (0.5 point), and the study does not meet this quality criterion (0 point). Thus, the total quality score fell into the range between: 0 - 1.0 (very poor); 1.1 - 2.0 (poor); 2.1 - 3.0 (fair); 3.1 - 4.0 (average), 4.1 - 5.0 (good), 5.1 - 6.0 (very good), and 6.1 - 7.0 (excellent). It can be noticed that eight out of 11 studies were considered as having good quality. On the other hand, two studies were considered as having poor quality. Despite of that, these two studies were not excluded from this review because we were interested in covering all publications available in the research area. It is also important to highlight that studies considered as having poor quality did not present information about evaluation, limitation of their results, and perspectives of future research.

IV. Brief Discussion

After carrying out the systematic review, a first finding was that QM&QA are often defined using two or more different sources of information. This fact may evidence that the establishment of QM&QA is a complex task and requires broad knowledge about the domain. This review also points out that, among the studies that propose generic QM&QA (i.e., QM&QA that can be applied to any type of embedded system), only study S9 is described in the format of a quality model (i.e., included by IC1), but it is considered to have a poor quality. Therefore, contributions that provide widely accepted quality models for embedded systems are still necessary.

In parallel, QM&QA could be used as means to conduct quality evaluation of embedded systems. This review also pointed out that few QM&QA were evaluated using evidences obtained in the industry or in real embedded systems. Thus, more studies reporting experiences of evaluating embedded systems might increase the reliability of the QM&QA and also provide important feedback to improve them. In this scenario, this topic of research can be considered as a promising one and results of this review can be used as a starting point. Notice that the set of attributes can also be different, including a different distribution, if we considered specific application areas, such as automotive and robotics. Finally, we identified that only study S11 proposes a set of metrics related to its QM&QA. Therefore, we believe that the identification of metrics associated to QM&QA is also an important topic of research, and it can contribute to provide some measurement to the development of embedded systems.

V. Conclusion and Future Work

The adoption of quality models and the identification of most important quality attributes can contribute to improve the quality, which is so needed in embedded systems. In this perspective, the main contribution of this work is to present a detailed state of the art on the QM&QA available in literature, the way they were defined and evaluated, and the main quality attributes addressed by them. For this, we conducted the steps of a systematic review. As future work, we intend to make a more specific investigation of this research area, for instance, to identify metrics associated to each quality attribute. Furthermore, we intend to consolidate the results of this systematic review in a general quality model for embedded systems, aiming at contributing to a more effective development of such systems.

VI. Acknowledgments

This work is supported by Brazilian funding agencies São Paulo Research Foundation - FAPESP (Grant N.: 2011/06022-0 and 2011/23316-8), Capes/Nuffic (Grant N.: 034/12), and CNPq (Grant N.: 142099/2011-2, 474720/2011-0, and 239981/2012-0), as well as the INCT-SEC (Grant N.: 573963/2008-8 and 2008/57870-9).

TABLE VI. QUALITY ASSESSMENT OF THE INCLUDED PRIMARY STUDIES

Source of information	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Q1: There is a rationale for why the study was undertaken	1	1	1	1	1	1	1	1	1	1	1
Q2: It presents an overview about the state of the art of the area in which the study is developed	0.5	1	1	1	0.5	1	1	0.5	0.5	1	1
Q3: There is an adequate description of the context in which the work was carried out	0.5	0.5	1	1	1	0.5	1	1	0	1	1
Q4: It provides a clear justification about the methods used during the study.	0	0.5	0.5	0.5	0.5	0.5	1	1	0	1	0.5
Q5: There is a clear statement of contributions and has sufficient data been presented to support them	0	1	0.5	1	0.5	0.5	0.5	1	0.5	1	1
Q6: It discusses the credibility and limitations of their findings explicitly	0	0.5	0	1	0	0.5	1	1	0	1	1
Q7: It discusses perspectives of future works based on the study contributions	0	0.5	1	1	0	0.5	1	1	0	0	1
Study overall score	2	5	5	6.5	3.5	4.5	6.5	6.5	2	6	6.5
Study overall score (%)	29	71	71	93	50	64	93	93	29	86	93

References

[1] W. Wolf, Computers as Components – Principle of Embedded Computing System Design, 2nd ed. Morgan Kaufman, 2008.

[2] P. Liggesmeyer and M. Trapp, "Trends in embedded software engineering," in IEEE Software, vol. 26, no. 3, 2009, pp. 19–25.

[3] A. Aguiar, S. Filho, F. Magalhaes, T. Casagrande, and F. Hessel, "Hellfire: A design framework for critical embedded systems' applications," in ISQED'10, San Jose, USA, 2010, pp. 730 –737.

[4] J. McCall, P. Richards, and G. Walters, Factors in Software Quality. Nat'l Tech. Information Service, 1977.

[5] B. W. Boehm, J. R. Brown, and M. Lipow, "Quantitative evaluation of software quality," in ICSE'76, San Francisco, USA, 1976, pp. 592–605.

[6] ISO/IEC, "Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) – System and software quality models," ISO/IEC, Tech. Rep. 25010/2011, 2011.

[7] M. Guessi, E. Y. Nakagawa, F. Oquendo, and J. C. Maldonado, "Architectural description of embedded systems: a systematic review," in ISARCS'12, Bertinoro, Italy, 2012, pp. 31–40.

[8] T. Sherman, "Quality attributes for embedded systems," in Advances in Computer and Information Sciences and Engineering, T. Sobh, Ed. Springer, 2008, pp. 536–539.

[9] B. Kitchenham, T. Dybå, and M. Jørgensen, "Evidence-based software engineering," in ICSE'04, Edinburgh, Scotland, UK, 2004, pp. 273–281.

[10] O. Dieste, A. Grimán, and N. Juristo, "Developing search strategies for detecting relevant experiments," in Empirical Software Engineering, vol. 14, no. 5. Hingham, MA, USA: Kluwer Academic Publishers, 2009, pp. 513–539.

[11] ACM Digital Library, [Online]. Available: http://dl.acm.org/ - Accessed in 08/18/2013.

[12] IEEE Xplore, [Online]. Available: http://ieeexplore.ieee.org/ - Accessed in 08/18/2013.

[13] ScienceDirect, [Online]. Available: http://www.sciencedirect.com/ - Accessed in 08/18/2013.

[14] Scopus, [Online]. Available: http://www.scopus.com/ - Accessed in 08/18/2013.

[15] Springer, [Online]. Available: http://www.springerlink.com - Accessed in 08/18/2013.

[16] Web of Science, [Online]. Available: http://www.isiknowledge.com/ - Accessed in 08/18/2013.

[17] T. Dybå, T. Dingsoyr, and G. K. Hanssen, "Applying systematic reviews to diverse study types: An experience report," in ESEM'07, Madrid, Spain, 2007, pp. 225–234.

[18] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering," Keele University and Durham University Joint Report, Tech. Rep. EBSE 2007-001, 2007.

[19] J. Wijnstra, "Quality attributes and aspects of a medical product family," in HICSS'01, Maui, Hawaii, 2001, pp. 1–10.

[20] M. Åkerholm, J. Fredriksson, K. Sandström, and I. Crnkovic, "Quality attribute support in a component technology for vehicular software," in SERPS'04, Linkoping, Sweden, 2004, pp. 1–9.

[21] A. Purhonen, "Quality attribute taxonomies for DSP software architecture design," in PFE'01, Bilbao, Spain, 2002, pp. 238–247.

[22] Y. Choi, S. Lee, H. Song, J. Park, and S. Kim, "Practical S/W component quality evaluation model," in ICACT'08, Phoenix Park, South Korea, 2008, pp. 259–264.

[23] F. Carvalho and S. Meira, "Towards an embedded software component quality verification framework," in ICECCS'09, Potsdam, Germany, 2009, pp. 248–257.

[24] M. Paulitsch, H. Ruess, and M. Sorea, "Non-functional avionics requirements," in Leveraging Applications of Formal Methods, Verification and Validation, 2009, vol. 17, pp. 369–384.

[25] C. Peper and D. Schneider, "On runtime service quality models in adaptive ad-hoc systems," in SINTER'09, Amsterdam, The Netherlands, 2009, pp. 11–18.

[26] H. Y. Jeong and Y. H. Kim, "A quality model of lightweight component for embedded system," in Applied Mechanics and Materials, vol. 121-126, 2011, pp. 4907–4911.

[27] D. Ahrens, A. Frey, A. Pfeiffer, and T. Bertram, "Objective evaluation of software architectures in driver assistance systems," in Computer Science - Research and Development, vol. 28. Springer-Verlag, 2013, pp. 23–43.

[28] B. Kitchenham, O. Pearl Brereton, D. Budgen, M. Turner, J. Bailey, and S. Linkman, "Systematic literature reviews in software engineering - a systematic literature review," in Information and Software Technology, vol. 51, no. 1, Newton, MA, USA, 2009, pp. 7–15.