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Preface

Web engineering is a new discipline that addresses the pressing need for systematic and tool-supported approaches for the development, maintenance and testing of Web applications. Web engineering builds upon well-known and successful software engineering principles and practices, adapting them to the special characteristics of Web applications. Even more relevant is the enrichment with methods and techniques stemming from related areas like hypertext authoring, human-computer interaction, content management, and usability engineering. The goal of the 4th International Conference on Web Engineering (ICWE 2004), in line with the previous ICWE conferences, was to work towards a better understanding of the issues related to Web application development. Special attention was paid to emerging trends, technologies and future visions, to help the academic and industrial communities identify the most challenging tasks for their research and projects.

Following a number of successful workshops on Web engineering since 1997 at well-known conferences, such as ICSE and WWW, the first conference on Web engineering was held in Cáceres, Spain in 2001. It was followed by ICWE 2002 in Santa Fe, Argentina and ICWE 2003 in Oviedo, Spain. In 2004 ICWE moved to the center of Europe and was held in Munich, Germany from July 26 to 30. ICWE 2004 was organized by the Institute for Informatics of the Ludwig-Maximilians-Universität (LMU) Munich.

The ICWE 2004 edition received a total of 204 submissions, out of which 25 papers were selected by the Program Committee as full papers (12% acceptance). Additionally, 60 papers describing ongoing research results were included, as either short papers or posters. The selected papers cover a wide spectrum of topics, including Web development processes, design methods, Web usability, security and performance, Web metrics, personalized and adaptive Web applications, the Semantic Web, and more.

ICWE 2004 attracted people from five continents, with a wide and uniform geographical distribution of the papers' authors. ICWE 2004 also hosted for the first time a tool demonstration track, and featured a two-day tutorial and workshop program, consisting of five tutorials and four workshops. Workshops and tutorials gave to the conference attendees the opportunity to enjoy a more informal forum for discussing the newest Web engineering topics, from Web quality, to the development of secure Web applications, to MDA applied to the construction of Web applications. Links to the workshops and tutorials can be found at the conference Web site: www.icwe2004.org

We wish to express our gratitude to all the individuals and institutions who made this conference possible. We are very grateful to Lutz Heuser, Gerti Kappel and Roel Wieringa for presenting their keynotes at the conference. We would like to acknowledge all workshop organizers and tutorial presenters and the local organizing committee. Our thank goes also to the workshop and tutorial co-chairs

as well as to the demo and poster chair for their engagement. In particular, Maristella Matera did an excellent job managing the workshops organization. Our special thanks go to the program committee members and additional referees for the very professional work done during the review process. The Online Conference System (OCS) was used during the review process for bidding and gathering submitted papers and reviews. We would like to thank the technical support team (Martin Karusseit and Markus Bajohr) at the University of Dortmund, which provided invaluable assistance on the use of the Online Conference Service of METAFrame Technologies. We are also grateful to Springer-Verlag for their helpful collaboration and quick publication schedule. Our deep recognition is due to Florian Hacklinger for his contribution in setting up and updating the conference Web site.

Last but not least, we want to thank the more than 450 authors from over 35 countries who contributed to this book and the conference. We thank them for their submissions and presentations and for providing us with the material in time. We count on them for the next conference edition, ICWE 2005, to be held in Sydney, Australia.

Munich and Milan, May 2004

Nora Koch
Piero Fraternali
Martin Wirsing

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A Web Metrics Survey Using WQM

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Abstract. Quality is an essential characteristic for web success. Several authors have described different methodologies, guidelines, techniques and tools in order to assure the quality of web sites. Recently, a wide ranging set of metrics has been proposed for quantifying web quality attributes. However, there is little consensus among them. These metrics are sometimes not well defined, nor empirically or theoretically validated. Moreover, these metrics focus on different aspects of web sites or different quality characteristics, confusing, rather than helping, the practitioners interested in using them. With the aim of making their use easier, we have developed the WQM model (Web Quality Model), which distinguishes three dimensions related to web features, lifecycle processes and quality characteristics. In this paper we classify the most relevant web metrics using this framework. As a result of this classification we obtain that most of the metrics are classified into the "usability / exploitation / presentation" cell. Another conclusion obtained from our study is that, in general, metrics are automated but not validated formally nor empirically which is not a good way of doing things.

1 Introduction

Nowadays web technology is of paramount importance in Information Systems. In fact, the world economy's slowdown has not affected the web field because large firms stopped expanding, and began consolidating and moving to the web, to cut costs [45]. Over the next few years, the web is expected to increase by a factor of 20, growing to 200 million sites by 2005, and the number of actual web pages will increase even more [42].

The ever increasing presence of web technology and its importance for the survival of organizations make it essential to develop a complete Web Information Systems Engineering (WISE), meant as a collection of sound principles, methods, techniques and tools for developing web-based information systems, which differ from traditional information systems in their unique technological platform and design philosophy [37] and quality assurance is one of the challenging processes to the Web Engineering as a new discipline [11]. WISE aims improve and achieve quality web sites. Despite discussion of sticky web sites and development of mechanisms to encourage users to return, thus far the only mechanism that brings repeat users to web sites is quality [36].

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However, and perhaps because the quality of web sites is not universally definable and measurable [9] their quality is not always assured [2, 10].

In recent years several experts have worked on different proposals to improve web quality: methodologies [39], quality frameworks [13, 25], estimation models [28], criteria [50], usability guidelines [34], assessment methods [49] and metrics.

In fact, web metrics is a particularly valuable area of ongoing commercially relevant research [47]. Since the nineties, a wide ranging set of metrics has been proposed for quantifying web quality attributes [1, 3, 5-7, 12, 14, 17, 18, 22-24, 26-31, 33, 38-41, 44-46, 51].

However, these metrics are sometimes not well defined and neither empirically nor theoretically validated. All these metrics, focused on different aspects of web sites or different quality characteristics, can confuse, rather than help, the practitioners interested in using them.

With the aim of classifying these metrics and making their use easier, we have elaborated the WQM model (Web Quality Model), which distinguishes three dimensions related to web features, lifecycle processes and quality characteristics [48].

Recently, Dhyani et al. [12] proposed a web classification framework using different categories: web graph properties, web page significance, usage characterization, web page similarity, web page search and retrieval, and theoretical information. The authors try to determine how the classified metrics can be applied to improving web information access and use. However they discard other important dimensions such as lifecycle and web features which are included in our model. Moreover in this survey they do not consider some very interesting metrics such as [24, 28, 38].

In the following section we present the WQM model explaining each of its dimensions. In the third section we will summarize the result of the classification of the most relevant web metrics. Conclusions and future work will appear in the last section.

2 Dimensions in Web Quality

In Ramler et al. [43] the authors define a cube structure in which they consider three basic aspects when making a test of a web site. Following this idea, in Ruiz et al. [48] we proposed another "cube" in which the three dimensions represent those aspects that must be considered in the evaluation of the quality of a web site: features, life cycle processes and quality aspects, which can be considered orthogonal. We have used this model to classify different studies on web engineering and we have refined our dimensions. In this section we will summarize the last version of the WQM, which is represented in figure 1.

2.1 Web Features Dimension

In this dimension we include the three "classic" web aspects: *Content*, *Presentation* and *Navigation* [6, 15, 16]. Navigation is an important design element, allowing users

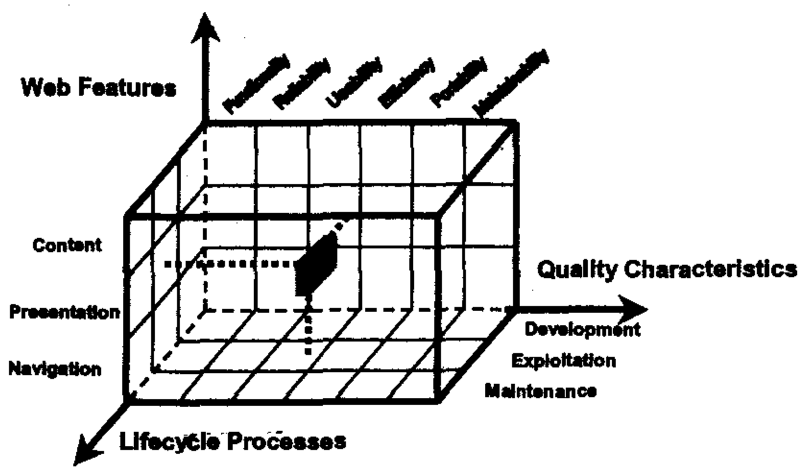

Fig. 1. Graphic representation of the model.

to acquire more of the information they are seeking and making that information easier to find. Presentation and content are prime components in making the page easier to use [42].

In *Content* we have included not only data such as text, figures, images, video clips, etc, but also programs and applications that provide functionalities like scripts, CGI programs, java programs, and others. *Content* also deals with structure and representation issues. Due to the close intertwining of functions and data the border between them is not clearly drawn, and we consider them the same feature.

Navigation concerns the facilities for accessing information and for moving around the web.

Presentation is related to the way in which content and navigation are presented to the user.

2.2 Quality Characteristics Dimension

For the description of this dimension we use as a basis the Quint2 model [35] based on the ISO 9126 standard [20]. We have decided to use Quint2 instead of the standard because this model extends the ISO standard with new characteristics very appropriate for web products. Quint2 is a hierarchical model that fixes six basic characteristics, each one of them with a set of subcharacteristics, to which a set of attributes is associated. These are the basic elements. Table 1 shows the characteristics of Quint2, indicating, if necessary, those subcharacteristics added or removed respect to ISO 9126.

There is also a *compliance* subcharacteristic for all characteristics (attributes of software that make it adhere to application related standards, conventions in laws and similar prescriptions).

Table 1. Model Quality Characteristics

Functionality. A set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs. • *Suitability*: Attribute of software that bears on the presence and appropriateness of a set of functions for specified tasks. • *Accuracy*: Attributes of software that bear on the provision of right or agreed results or effects. • *Interoperability*: Attributes of software that bear on its ability to interact with specified systems. • *Security*: Attributes of software that bear on its ability to prevent unauthorized access, whether accidental or deliberate, to programs or data. • *Traceability* (Quint2): Attributes of software that bear on the effort needed to verify correctness of data processing on required points.
Reliability. A set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time. • *Maturity*: Attributes of software that bear on the frequency of failure by faults in the software. • *Fault tolerance*: Attributes of software that bear on its ability to maintain a specified level of performance in cases of software faults or of infringements of its specified interface. • *Recoverability*: Attributes of software that bear on the capability to re-establish its level of performances and recover the data directly affected in case of a failure and on the time and effort needed for it. • *Availability* (Quint2): Attributes of software that bear on the amount of time the product is available to the user at the time it is needed. • *Degradability* (Quint2): Attributes of software that bear on the effort needed to re-establish the essential functionality after a breakdown.
Usability. A set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users. • *Understandability*: Attributes of software that bear on the users' effort for recognising the logical concept and its applicability. • *Learnability*: Attributes of software that bear on the users' effort for learning its application (for example, control, input, output). • *Operability*: Attributes of software that bear on the users' effort for operation and operation control. • *Explicitness* (Quint2): Attributes of software that bear on the software product with regard to its status (progression bars, etc.). • *Attractivity* (*Attractiveness* in Quint2): Attributes of software that bear on the satisfaction of latent user desires and preferences, through services, behaviour and presentation beyond actual demand. • *Customisability* (Quint2): Attributes of software that enable the software to be customized by the user to reduce the effort required for use and increase satisfaction with the software. • *Clarity* (Quint2): Attributes of software that bear on the clarity of making the user aware of the functions it can perform. • *Helpfulness* (Quint2): Attributes of software that bear on the availability of instructions for the user on how to interact with it. • *User-friendliness* (Quint2): Attributes of software that bear on the users' satisfaction.
Efficiency. A set of attributes that bear on the relationship between the level of performance of the software and the amount of resources used, under stated conditions. • *Time behaviour*: Attributes of software that bear on response and processing times and on throughput rates in performing its function. • *Resource behaviour*: Attributes of software that bear on the amount of resources used and the duration of such use in performing its function.
Portability. A set of attributes that bear on the ability of the software to be transformed from one environment to another. • *Adaptability*: Attributes of software that bear on the opportunity for its adaptation to different specified environments without applying other actions or means than those provided for this purpose for the software in question. • *Installability*: Attributes of software that bear on the effort needed to install the software in a specified environment. • *Replaceability*: Attributes of software that bear on the opportunity and effort of using it in the place of specified other software in the environment of that software. • *Co-existence* (not included in Quint2): The capability of the software to co-exist with other independent software in a common environment sharing common resources.
Maintainability. A set of attributes that bear on the effort needed to make specified modifications. • *Analysability*: Attributes of software that bear on the effort needed for diagnosis of deficiencies or causes of failures, or for identification of parts to be modified. • *Changeability*: Attributes of software that bear on the effort needed for modification, fault removal or for environmental change. • *Stability*: Attributes of software that bear on the risk of unexpected effect of modifications. • *Testability*: Attributes of software that bear on the effort needed for validating the (modified) software. • *Manageability* (Quint2): Attributes of software that bear on the effort needed to (re)establish its running status. • *Reusability* (Quint2): Attributes of software that bear on its potential for complete or partial reuse in another software product.

2.3 Life Cycle Processes Dimension

By introducing this dimension, we believe that we are also considering the people involved in the development who have different skills and therefore different priorities and attitudes [32] are included. For example, the developer's interests are considered in the development process.

So, in this dimension we include the diverse processes of the web site life cycle following the ISO 12207-1 standard [19]. In the current version of the model we only included three main processes: the development process, the exploitation process (which includes the operative support for users) and the maintenance process (which includes the evolution that the web site undergoes).

It is important to emphasize that the activities of these processes must not be developed sequentially, because, due to the characteristics of web development, it will be necessary to use more iterative models and even more flexible developments without following formal methodologies [4].

3 Analysis of Existing Metrics

3.1 Surveyed Metrics

For the present study, we have surveyed different studies of metrics related in some manner with web topics. We have reviewed about 60 papers, from 1992 to 2003. From all these we have selected the ones (about 40) where metric proposals (considered useful for classification purposes on WQM) were included, discarding some others where the proposed metrics were not really applicable in our context or did not provide any relevant information. Examples of the discarded metrics include all the process metrics, focusing our work only on product metrics. We also discarded repeated metrics, i.e., those metrics proposed by more than one author.

We included each metric only once. 326 metrics were selected, and are listed at the end of this paper. Finally, we wish to note that the process of classifying metrics is not a simple task and we are conscious that some of the assignments may be arguable.

3.2 Filling the Cells of the Cube

Although the model does not restrict the number of cells that can be assigned to a given metric m, for the sake of simplicity and practicality we tried to minimize this number by assigning the metrics to the cells where they could be most useful. To avoid unnecessary complexity, we decided to show in the WQM only the quality characteristic assigned, instead of the precise sub-characteristic.

Assigning metrics to life cycle processes was not easy. We have given some special consideration to exploitation and maintenance. In the web world, where typical timeline in web development is 3-6 months [44], it is difficult to distinguish when exploitation finishes and maintenance begins. In case of doubt we have classified metrics in both processes.

3.3 The Resulting Cube

Due to the extent of the detailed assignments of metrics to cells, this information is included at the end of this paper.

In this section we will summarize the main figures of our classification shown in table 2. The "% Absolute" row shows the percentage of metrics classified on each value dimension and the sum of these values is greater than 100% because, as we have already explained, a metric can be classified in more then one cell in the cube. Because of this we have extracted prorated values shown in the "% Prorated" row.

Table 2. Metrics Classification.

	[redacted]											
[redacted]	96	179	67	50	21	263	47	40	78	64	267	162
	30%	55%	21%	15%	6%	81%	14%	12%	24%	20%	82%	50%
[redacted]												

Figure 2 shows metric distribution over the three dimensions of the model: web features, quality characteristics, and lifecycle processes, using prorated figures. The next subsections present several conclusions that we can extract from it.

3.3.1 Web Features Dimension

About 52% of the metrics were "presentation" metrics. This value confirms the tendency in the web world to give it the greatest importance, making the sites as attractive as possible for the end user.

At this point it is convenient to remark that usually there is a confusion between presentation and navigation [6] so, perhaps the results of the navigation could vary depending on the person who makes the classification.

3.3.2 Quality Characteristics Dimension

Most of the metrics (53%) are usability metrics. We have to take into account that this data is prorated, because if we examine absolute data (table 2) we can see that 81% of metrics are related to usability. Again this value confirms the end-user focus trying to design usable web sites that attract users.

However, it is curious that only 4% of metrics focus on reliability, when this characteristic it is also extremely important for customer acceptance of web sites.

Finally, we think that the appearance of new devices (such as PDA, mobiles, ...) will encourage the definition of new portability metrics.

3.3.3 Life-Cycle Dimension

With respect to life cycle, the exploitation and maintenance processes are the ones with most metrics. These results can be justified by taking into account the evolutionary nature of the web. The fact that there are not too many metrics defined

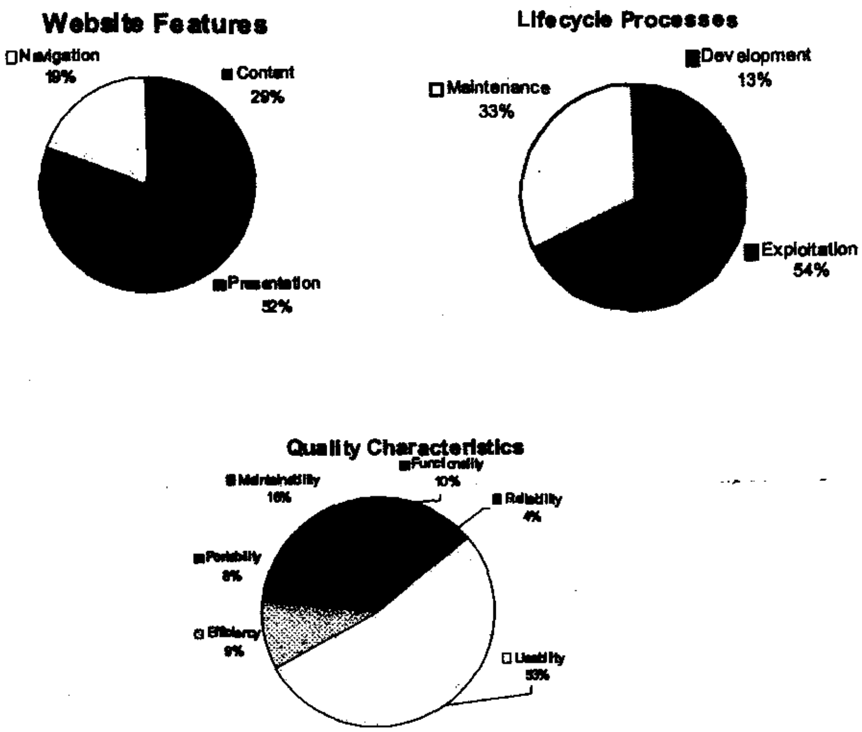

Fig. 2. Metric Distribution across the Model Dimensions

for the development process can be explained because getting their software to the market first is the top priority for firms doing business on the web and so, rather than develop software from requirements through the waterfall, web developments firms try to use rapid application development methods and continuous prototyping [44].

3.4 Metrics Properties

We have also evaluated the metrics considering the following properties [8]:

- *Granularity Level*, depending on whether the metric focuses on a single web page or on a web site.
- *Theoretical Validation* helps us to know when and how to apply metrics.
- *Empirical Validation*, with the objective of proving the practical utility of the proposed metrics.
- *Automated Support*, i.e., whether or not there is a support tool that facilitates the calculation of the metrics.

The results of this evaluation are shown at the end of this document.

As we can see there is a balanced distribution of metrics defined for web pages (47%) and web sites (53%).

The results of the validation confirm that, unfortunately, web metric validation is not considered as a major issue, especially theoretical validation (4%) but also, empirical validation (32%).

A large number of metrics are automated (79%). This is very important if we want to incorporate the metrics into web development and maintenance projects.

4 Conclusions and Future Work

There are many metric proposals for web quality, but no consensus has been reached for their classification. To advance in this area, it is essential to rely on a model that allows us to classify and systematize metric use. In this paper we have presented the WQM and we have surveyed the most relevant web metrics.

Nevertheless, this is only a first approach that needs to be reviewed until a definitive and complete version is reached that can be used with total reliability and guarantee of success.

Regarding the model, some modifications could be carried out in the life cycle dimension including a project process (following the standard ISO 15288, System Life Cycle Processes [21] in order to include in the WQM proposals related to web estimation effort like Mendes et al. [28-31]. We think this point is particularly interesting because as remarked in Reifer [44] web developments are hard to estimate and many professionals try to avoid this difficulty by using the more traditional processes, metrics and models for estimating web projects. However, these traditional approaches do not seem to address the challenges facing the field.

It could also be interesting to consider the metrics related to cost estimation because this is an essential element for providing competitive bids and remaining successful in the market [47].

Regarding the metrics classified in this study, we do not claim this survey to be complete. It would be necessary to make an even more exhaustive study of the state of the art. We also intend to define new metrics in those "cells" in which the nonexistence of metrics is detected.

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