A PROTOTYPE TOOL TO ASSESS THE FUNCTIONAL QUALITY OF E-COMMERCE WEBSITES

Ruhaila Maskat *
*Universiti Teknologi MARA **
Faculty of Information Technology & Quantitative Sciences,
*Shah Alam, Selangor, Malaysia **
*ruhaila@tmsk.uitm.edu.my **

Hazura Zulzalil *
*Universiti Putra Malaysia **
Faculty of Computer Science and Information Technology,
*Serdang, Selangor, Malaysia **
*hazura@fsktm.upm.edu.my **

Wan Faezah Abbas *
*Universiti Teknologi MARA **
Faculty of Information Technology & Quantitative Sciences,
*Shah Alam, Selangor, Malaysia **
*wfaezah@tmsk.uitm.edu.my **

ABSTRACT

E-Commerce website is the new marketing and sales method to reach new customers. By overcoming the geographical constraint, e-commerce website allows users to perform purchasing activities without being physically present. Though many e-commerce websites have achieved great success, many have also failed. Their failures are mainly due to the absence of quality. This study presents a prototype software tool that could assist in assessing the functional quality of e-commerce websites in an automatic manner. Unlike the currently available methods of evaluation, this tool does not necessitate the assessment of e-commerce websites by a human expert. On the other hand, the tool performs a scanning activity to allocate the existence of e-commerce characteristics. Adopting the quality model by Stefani and Xenos (2001), six different e-commerce characteristics were selected from the functional factor of the model. Three other factors identified by the model are usability, reliability and efficiency, which are not within the scope of this project. Three major script languages have been sited to be regularly used in e-commerce website development. They are JavaServer Pages (JSP) from Sun Microsystems, ASP from Microsoft and PHP an open source language. Though they share the same functionalities, they differ considerably in syntax. Therefore, this project has focused on evaluating e-commerce websites, which were built using JavaServer Pages (JSP). The objective of this paper is to develop a prototype tool capable of evaluating JSP-based e-commerce website based on the characteristics chosen. The tool is competent to perform the data collection through fully automatic means and finally generates result of evaluation into XML format.

KEYWORDS

Web metrics, Quality, E-Commerce.

1. INTRODUCTION

With the advent of the Internet, a new method of business activity has come into existence. This activity involves purchasing merchandises or services through the Internet or also known as online purchasing. Not only does this allows users to avoid the hassle of being physically present during a business transaction, it also increases the amount of purchasing time to twenty-four hours a day, seven days a week. This increases the likelihood of a company to double its revenue. In addition, online purchasing allows companies to reach new groups of users from all around the globe. A survey made by Coppel (2000) showed that in 1999, approximately one quarter of the estimated 250 million Internet users worldwide shops online through e-commerce websites. Their total spending is 110 billion US Dollars. In addition, Jupiter Research stated that

by 2005, e-commerce transactions would exceed 7 trillion US Dollars annually (Grover and Teng, 2001). This promised great opportunities for many industries. Unfortunately, a majority of these websites do not entirely meet customers' expectations as discovered by Schubert and Dettling (2002) in a survey of two types of e-commerce business sectors; banking and consumer goods. Therefore, the quality of e-commerce websites needs to be measured in order to meet the requirements of consumers. Hodge (2000) stated that the area of measuring the quality of e-commerce websites has attracted interests from many areas such as the government, commercial, academic and nonprofit user and ISP providers.

At present, the activites of collecting data to measure the quality of e-commerce were mostly through questionnaires, either in electronic form or paper form. This type of data collection, which is categorized as manual, requires human experts and users to provide the input. The collected data will then be stored in a knowledge database. Albuquerque and Belchior (2002), Sartzetaki et al. (2003) and Olsina et al. (2001) are some evaluations performed via questionnaires. However, there are also a number of quality measurement efforts where the data collection was performed through semi-automatic means. This could be witnessed in Hodge (2000), Schubert and Dettling (2002) and Olsina et al. (2001). In addition, Brajnik (2000) have categorized automatic tools for usability evaluation by *a) location b) type of service c) information source* and *d) scope*. A-Prompt, Bobby, Doctor HTML and LIFT are some of the automatic usability tools listed by Brajnik (2000).

In this paper we present a prototype tool developed using Java programming language. The primary function of this prototype is to assist companies in assessing the functional quality of their e-commerce systems without requiring human experts' evaluation. So far, three major script languages have been sited to be regularly used in e-commerce website development. They are JavaServer Pages (JSP) from Sun Microsystems, ASP from Microsoft and PHP an open source language. Though they share the same functionalities, they differ considerably in syntax. Therefore, this project has focused on evaluating e-commerce websites which were built using JavaServer Pages (JSP). This tool carries out a scanning activity to detect the availability of six functional characteristics of e-commerce applications. The six characteristics were selected from a quality model proposed by Stefani and Xenos (2001) for e-commerce systems. Listed by the model are four quality factors, following the ISO/IEC 9126 quality framework (ISO/IEC 9126, 1999). They are usability, functionality, reliability and efficiency. Each factor consists of relevant e-commerce characteristics. The characteristics were further categorized based on their levels of importance. The levels are *a) high b) middle* and *c) low*. We have chosen six e-commerce characteristics related to the functional factor as listed in Table 1.

Table 2. Selected characteristics of e-commerce websites relating to functional quality factors

Characteristics of e-commerce systems	**Level**
Adaptation to user profile.	High
Search engine service.	High
Electronic shopping cart.	High
Multilinguality	Middle
Alternative presentation of the products, using images, multimedia etc.	Middle
Frequently Asked Questions (FAQ)	Middle

The main objective of this study is to develop a prototype tool capable of evaluating JavaServer Pages e-commerce website based on the functional quality factors proposed by Stefani and Xenos (2001). The means of data collection for this software is fully automatic. No human experts are required to provide any inputs. This study assumes that all necessary files are available in their source code form and the ones applicable have been decompiled. The results of the evaluation are generated into XML format.

The following section defines the six quality factors selected, describes the e-commerce characteristics investigated to be of relevance to each quality factors and determines the metrics that are suitable to perform the evaluation on the selected characteristics. The third section exhibits the resulting output of the prototype. An XML viewer was built within the tool for the purpose of displaying the results which are in the form of XML format. The underlying reason for generating the results in XML format was to be as a feeder input to another on-going effort. The final section states the advantages and limitations of this tool and suggests several possible future work.

2. THE PROTOTYPE TOOL

This study has produced a prototype, which assesses the quality of six e-commerce characteristics related to the functional quality factor. The characteristics which were adopted from the e-commerce system quality model by Stefani and Xenos (2001) are as listed below:

1. Adaptation to user profile
2. Search engine service
3. Multilinguality
4. Electronic shopping cart
5. Product alternatives such as images and multimedia
6. Frequently Asked Questions (FAQ)

This study anticipates that the user executing this tool holds the authority to access all the source code used by the website that is intended for evaluation. Although it is possible to point to a running website the evaluation would be shortfall due to the limitation in accessing certain programmed engines such as Java beans and servlets. Due to security measures, these engines are stored in a compiled form and are placed within a directory on the webserver, which are inaccessible by any external users. In the environment that maintains JavaServer Pages websites, the architecture is designed in such a form that the workings/engine is separated from the data display. Therefore, due to this, we believe that the best way to fully evaluate the quality of an e-commerce website would require all source code used by the website to be uncompiled and to be fully accessible.

A ratio scale was used to represent the relationship of *'greater functionality than'* within the six characteristics selected. The scale starts with the digit zero to show non-existence of the characteristic, continued with an increasing series of numbers showing the existence of the characteristics as well as an improvement of quality. Within this section, we will explain further about each characteristic.

2.1 Adaptation to User Profile

Based on Stefani and Xenos (2001), the "adaptation to user profile" characteristic is concerned with the extent to which a user is able to alter the e-commerce website to suit his personal profile. The application should be able to detect the differences in users' profiles and perform necessary interactions to fulfill the user's needs and preferences. Until today, personalization technology has evolved substantially to meet the increasing demands of Internet users. Five personalization technologies have been identified to be in existence (Wu et al., 2002). They are cookies, profile based personalization, personal tools, opportunistic links and recommender systems. This study adopts the personalization framework proposed by Wu et al. (2002). The framework describes personalization from the perspective of customers and users. According to Wu et al. (2002), two areas of concern, which depicts the interaction between the user and the website were used to construct this framework. They are:

1. How much active vs. passive input has to be provided by the user?
2. What types of personalized changes does the user experience?

From the framework, five types of personalization were identified. They are Control Personalization, Content Personalization, Link Personalization, Customized Screen Design Personalization and Anthropomorphic Personalization. Wu et al. (2002) stated, control personalization is concerned with the degree of control that a user can have to independently perform personalization. Control personalization is basically a higher-level personalization that is able to overwrite others applied before them. An example of control personalization is despite the fact that a website could have initially personalized its appearance through implicit manner, the user with control personalization will have the choice to either accept the personalization or reject it.

Another kind of control personalization is the Context Personalization. Context personalization is related with "navigation context", which is basically a series of sequentially ordered screens or information alerting users for viewing and action (Wu et al., 2002). This navigation would only commence upon users' choice to proceed with a transaction with the website. For example, when a user decides to purchase a product, a series of screens requesting for user's shipping address and credit information would be displayed by the website. Context personalization provides users with the awareness of the stage and the nature of the activity that they are currently in.

Next, is content personalization. This personalization is concerned with providing users with information that is of relevant to them (Wu et al., 2002). It is without a doubt that it is essential for content to

be personalized among other items on a website. This is due to the voluminous information available on the Internet, which could easily lead to information overload. In content personalization, filtering is a mechanism commonly used to provide optimized information to users. An example of content personalization is a list of recommended books to users based on their previous purchases. The next type of personalization is Link Personalization. According to Rossi et al. (2001), link personalization "attempts to select additional relevant links for the user, modifying the original navigation space by reducing or improving the paths to related web-pages". There are two types of link personalization, implicit and explicit. An example of an explicit link personalization is the bookmark featured in web browsers. Bookmarks allow users to select links of their choice and store them within the browser's navigation space. An example of implicit link personalization would be automatic link generation tools such as Dynamic Hyper Link Engine (Bieber, 1998). "Personal tools" provided by Yahoo! is an example of explicit link generation while "opportunistic links" would be an example of implicit link generation.

Customized Screen Design Personalization is also another type of personalization that allows users to perform alterations that affects the display of the website. This personalization allows users to customize the look and feel of the website according to their fancy. The final type of personalization identified in the framework proposed by Wu et al. (2002) is the Anthropomorphic Personalization. Human like behavior is the objective of anthropomorphic personalization. A greeting such as "Hello Ruhaila, how are you?" whenever a user logs into a website is an example of this type of personalization. Wu et al. (2002) have created a coding scheme for website personalization from the five types of personalization previously discussed. The scheme could be seen in Figure 1. A score has been given to each personalization to represent the relationship of "higher personalization than". The interval scale given portrays a series of numbers with increasing value in accordance with the increasing degree of personalization.

Implicit Personalization

	Item	Score
3	**[CTNi]** Content personalization using implicit data (e.g. recommendation)	3
4	**[CTRi]** Implicit control personalization (e.g. automatic navigation customization)	3
5	**[ALK]** Automatic link personalization (e.g. Opportunistic links)	2
6	**[ANT]** Anthropomorphic personalization	1
Total		9

Explicit Personalization

	Item	Score
7	**[CTNe]** Content personalization using user's evaluations (e.g. customized news)	3
8	**[CTRe]** Explicit control personalization (e.g. user configured "one-click" payment)	3
9	**[ULK]** User configured link personalization (e.g. personal tools)	2
10	**[SCR]** Customized screen design	1
Total		9

[ ] – Abbreviation

Figure 1. The coding scheme for website personalization (Wu et.al, 2002)

Based on a survey on 27 different websites by Wu et al. (2002), control and content personalization are given the highest score, which is 3. This is due to the fact that the two personalization schemes provide the most percentage of customization to users, that is 50%. Control and content personalization also assists users in performing tasks that allow them to achieve their goals. A score of 2 is given to link personalization. Wu et al. (2002) explained that due to the greatest number of link personalization is customarily opportunistic links, therefore the degree of customization is lesser as opportunistic links perform customization based on a large number of users that satisfies the opportunistic criteria instead of on individual users. The final two schemes, which are customized screen design and anthropomorphic personalization are given 1 as the score due to its minimal assistance in users' activities. Wu et al. (2002) also stated that these two schemes are simply feature add-ons that do little in user navigation. A total of the score provided to the schemes would produce a maximum sum of 18 points. 9 points for implicit personalization and 9 for explicit personalization. Wu et al. (2002) later used the summed score to categorize the 27 websites into levels of personalization. Points that are 7 or higher is given a level of HIGH personalization, points 3 to 6 is given MEDIUM level of personalization and points 2 and below are considered to have LOW personalization.

2.2 Search Engine Service

Search engine is a program that searches documents for specified keywords and returns a list of the documents where the keywords were found (PcWebopaedia, 2003). Stefani and Xenos (2001) stated that search engine is considered to be an important facility for website users. With the use of search engines, users are able to locate the information required. An efficient and operable search engine would help users in finding correct information within the smallest amount of time.

In this study, we have attempted to strictly follow the metric proposed by Olsina (1999) for search engine service. In the paper, Olsina (1999) carried out a case study on the websites of four museums to evaluate their quality. According to Olsina (1999) the evaluation criterion on search engine service is "multi-level discrete absolute". The scale used are from 0 to 2 where 0 shows the unavailability of any search mechanism, 1 shows a basic function search engine and 2 shows an expanded search engine inclusive of the basic function. Here, Olsina (1999) has specifically stated searching by Author and/or Keyword Title is considered to be the characteristics for basic search engine while searching by School and/or Style and/or Century (or Date) and/or Painting and/or Medium is the characteristic of expanded search. This scale is then mapped to a percentage of 0% for the scale of 0, 70% for the scale of 1 and 100% for the scale of 2. Figure 2 displays the metric proposed by Olsina (1999).

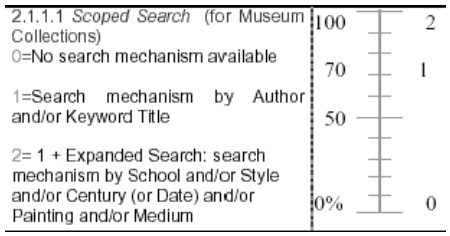

Figure 2: Measurement for Search Engine

As we can see the characteristics of the search engine proposed in Olsina (1999) is customized for museum websites and thus not relevant to e-commerce websites. Thus, we had made alterations concerning this. Initially, we had planned that the characteristics of a basic search engine should only be able to make a singular keyword search. For example, a search on "computers". While for expanded search engine, a more functional characteristic should be portrayed such as the inclusion of logical operators to combine words or exclude any particular word. For example, "monitor AND flat" and "car NOT porsche". Unfortunately, we had found that due to the lack of uniqueness in the source code for basic search engine, therefore we had to limit our scale to only two. They are 0 for unavailability and 1 for availability of search engine service with the use of logical operators as its characteristics. We see this to be a potential area for further study.

2.3 Multilinguality

Multilinguality could be seen as being an extension of user personalization. It is a product of customization with the purpose of catering for the users needs in terms of information presentation. Lindenberg (2002) is an article published by Sun Microsystems, which provides guidelines and recommendations by Java experts in what is the standard way to handle multilinguality in JavaServer Pages applications. The scale for this "multilinguality" characteristic was constructed based on this article. According to Lindenberg (2002), there are two areas that need to be taken into consideration when we intend to support for multilinguality. They are user's preferred language and locale. Locale here would include user's country and time zone. For example, users in Great Britain and America both use English as their language but they do not share the same locale-sensitive information such as date and currency.

In our study, we have constructed a metric of a ratio scale from 0 to 2, which represents a "greater functionality than" relationship. The scale 0 represents the unavailability of any localization function, 1 shows the availability of locale-sensitive localization while 2 shows the availability of locale-sensitive localization with the addition of dynamic content localization. Dynamic content localization, which involves the use of ResourceBundles is considered to be a higher level functionality compared to locale-sensitive localization due to the fact that it provides deeper customization dynamically.

2.4 Electronic Shopping Cart

Electronic shopping cart is a primary and inseparable component of an e-commerce website. Some of the functions of an electronic shopping cart listed by Stefani and Xenos (2001) are; allowing users to drop and store products while performing navigation and providing users with the freedom to create a list of future shopping items. We have selected to cater for the former function and have left out the latter as we have noticed a high degree of ambiguity in its implementation which we will explain later in this section. Our metric is from 0 to 1, where 0 shows the unavailability of any electronic shopping cart functions and 1 shows its availability.

2.5 Product Alternatives

According to Stefani and Xenos (2001), an alternative to the text representation of the product and services being offered by an e-commerce website would include thumbnails, photographs and videos. In this study, we have included this quality characteristic as part of the evaluation tool. We have divided the quality characteristic into two subparts where the first would be for images while the second for multimedia components. Multimedia components here would include videos, audios and Flash movies. In this study, images can be of any file type, which are viewable by an Internet browser, such as gif or jpeg.

The measurement for images would be a ratio scale of 0 to 2. 0 represents unavailability of any images, 1 represents basic image files of any type while 2 represents an image file with added functionality. In this case, we have selected a zooming function. The zooming function is very useful in the case of Amazon.com where books are its primary product. Users are provided the zooming function to get a better view of the book's cover. This assists in speedier decision making during purchasing activities. The zooming function is considered to be providing a better functionality compared to still images. Therefore, the scale represents the relationship of "greater functionality than". The scale used for multimedia component is 0 to 1. Similarly, 0 shows unavailability of any multimedia components while 1 shows its existence.

One might suggest that a multimedia component should be considered a higher functional form of images. We do not agree on this due to the fact that not all websites are suitable to offer multimedia components as an alternative to their products. An example is viewing a book cover in Amazon.com does not require a digital movie of the book. A zooming function would suffice. On the other hand, for cdnow.com, which offers movie CDs it is very suitable to allow viewing of trailer of the movies on sale.

2.6 Frequently Asked Questions (FAQ)

Stefani and Xenos (2001) stated in their paper that apart from having search engines, in order for an e-commerce website to be considered functional is to provide a FAQ or also known as Frequently Asked Questions. We have found that the words "Frequently Asked Questions" and its abbreviation are greatly used interchangeably by almost all websites. Therefore, we deduce that the best way to identify the adoption of the FAQ function is by performing a search on both. We had also came across the word "frequently asked question" to be used inside the content of a website commonly to explain the purpose of the function or inform of its existence. This could not be used to imply that the function is actually offered. Therefore, we came to the conclusion that for the purpose of identifying the adoption of FAQ, we would need to scan for the hypertext link pointing to the FAQ page. A majority of the websites presents its FAQ page in very much the same way where the question commonly asked is followed by its answer. The scale used for the FAQ quality characteristic is a ratio scale of 0 to 1 where 0 shows the unavailability of the FAQ function while 1 shows its availability.

2.7 Result

The product of this study is an evaluation tool for e-commerce websites. The screenshot of the prototype can be seen in Figure 3. The tool has been tested with collections of web pages, which are primarily gathered from sample codes provided freely on the Internet. Figure 4 shows a screen displaying the output result generated in XML format. The resulting output was intended to be used as an input for another ongoing effort.

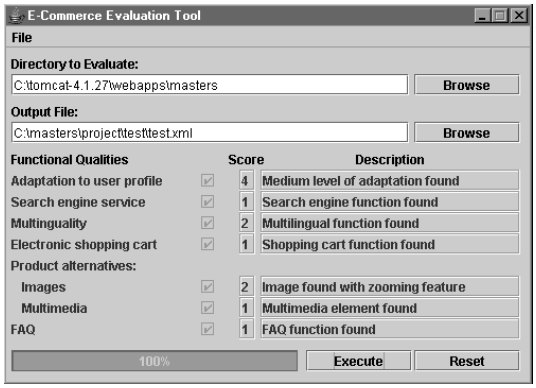

Figure 3: Prototype tool

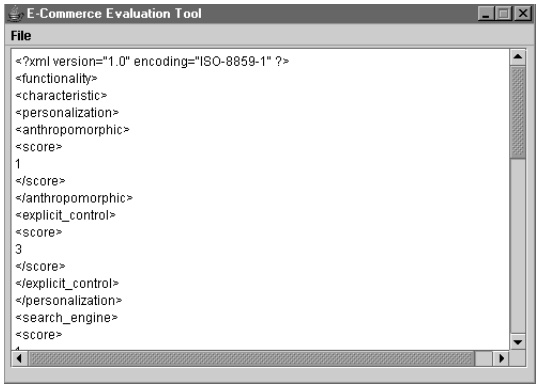

Figure 4: Generated XML output

The test environment for this tool includes as below:

1. Microsoft Windows 98
2. Sun Microsystem Java Runtime Environment
3. Microsoft DOS prompt

The measurements that we have constructed and implemented within the prototype evaluation tool have either followed an existing scale from a framework or adapted based on available measurements. Most of the constructed measurements use ratio scale to show the unavailability and availability of the functional quality characteristics of relevance. The measurements are further detailed to display the relationship of "greater functionality than" for available characteristics. The use of ratio scale is influenced by the fact that not all functional quality characteristics are suitable for all e-commerce websites. The nature of business of the organization plays an important role in determining the suitable characteristics for their e-commerce websites. Although we do not deny that a majority of the characteristics do apply to all e-commerce websites, but because of the existence of the small number of unsuitable characteristics we believe that it should be reflected within the measurements.

3. CONCLUSION

This study has successfully developed a prototype tool capable of assessing e-commerce websites based on the quality framework by Stefani and Xenos (2001). Six functional quality characteristics were selected and quality measurements for each have been incorporated within the tool. The tool is capable to perform data collection by fully automatic means. Components of the e-commerce application are required to be placed within a single directory and must be in their uncompiled form for the tool to retrieve in order to begin evaluation process. Results of the evaluation have been successfully generated in an XML format. In addition, a viewer feature has been developed as part of the software tool to allow viewing of the resulting output file.

The tool developed is not without limitations. The limitations are firstly; the tool supports only a single e-commerce application at one time. Multiple selection of e-commerce is not handled in this tool. Secondly, the software tool caters for a limited number of programming styles. Due to the various approaches programmers can implement in achieving a task, this software tool is not able to cater for all of these styles. Finally, this tool does not support tracing of value. This includes value passing from one variable to another and from function to function.

In spite of the problems encountered during the construction of the prototype tool, the tool yields qualified features. Firstly, the tool supports for directory drill-downs. Since the components of web applications are heterogeneous, therefore, it is natural that they are grouped based on their types and within different directories. The tool is able to search through all sub-directories within the primary directory for relevant files. Secondly, relevant variables within the source codes to be evaluated can be identified. This is applied in the situation where a series of processes need to be identified for their presence. Thirdly, the most attractive feature of this tool is the capability of collecting data automatically. Instead of having human assessors to identify the availability of quality characteristics within the e-commerce applications, this tool

will perform this process and generate results based on the measurement rules suggested. Fourthly, an XML viewer has been constructed as part of the tool. This viewer allows users to view the generated XML file. Finally, this tool supports good programming practice standards

The idea of automatic data collection displays great potential in the area of e-commerce quality measurement thus this study suggests several enhancements. With automatic data collection, the evaluation exercise is not dependant on the technical know-how of the assessors. The rules and logic of the evaluation could be incorporated within the evaluation tool. This also suggests the possibility of selecting different evaluation rules if seen necessary.

Our suggestions for future enhancements of this study are as below:

1. Incorporates variable tracing.
2. Supports evaluation of multiple e-commerce applications simultaneously.
3. Includes evaluation of more programming styles.
4. Tested on other platforms such as Unix and Linux.

REFERENCES

Journal

Grover, V. and Teng, J.T.C. 2001. E-Commerce and the Information Market. *Communications of the ACM*. Vol. 44. No. 4. pp.79-86.

Mendes, E., Mosley, N. and Counsell, S. 2001. Web Metrics- Estimating Design and Authoring Effort. *IEEE Computer Society*. pp 50-57.

Conference paper or contributed volume

Albuquerque, A.B. and Belchior, A.D. 2002. E-Commerce Website Quality Evaluation. *Proceedings of the 28th Euromicro Conference IEEE.*

Brajnik, G. 2000. Automatic web usability evaluation: what needs to be done?. *6th Conference on Human Factors & the Web*. Austin, Texas.

Coppel, J. 2000. E-commerce: Impacts and policy challenges. OECD – Economics Department Working papers no. 252. http://oecd.org/eco/eco.

Hodge, G. 2000. Web Metrics and Evaluation: Current State of Implementation Among the CENDI Agencies PHASE 1.

ISO/IEC 9126. 1991. Information technology- Software evaluation -Quality characteristics and guide-lines for their use.

Lindenberg, N. 2002. Developing Multilingual Web Applications Using JavaServer Pages Technology. http://developer.java.sun.com/developer/technicalArticles/Intl/MultilingualJSP/. Accessed on 4 August 2003.

Mendes, E. 2000. Investigating Metrics for a Development Effort Prediction Model of Web Application. *2000 Australian Software Engineering Conference*. IEEE Computer Society. pp.31.

Offutt, J. 2002. Web Software Applications Quality Attributes. *Quality Engineering in Software Technology (CONQUEST 2002)*. Nuremberg Germany. pp.187-198.

Olsina, L. 1999. Web-site Quality Evaluation Method: A Case Study on Museums. *ICSE99 – 2nd Workshop on Software Engineering over the Internet*.

PcWebopaedia. http://www.pcwebopaedia.com.

Sartzetaki, M., Psaromiligkos, Y., Retalis, S. and Avgeriou, P. 2003. An Approach for usability evaluation of e-commerce sites based on design patterns and heuristics criteria. *The 10th International Conference on Human-Computer Interaction*. Hraklion Crete. June 22-27.

Schubert, P. and Dettling, W. 2002. Extended Web Assessment Method (EWAM) – Evaluation of E-Commerce Applications From The Customer's Viewpoint. *Proceedings of the 35th Annual Hawaii International Conference on System Sciences (HICSS-35'02)*. IEEE Computer Society.

Stefani, A. and Xenos, M. 2001. A Model for Assessing the Quality of E-Commerce Systems. *Proceedings of the PC-HCI 2001 Conference on Human Computer Interaction Patras*. pp.105-109.

Wu, D., Im, I., Tremaine, M., Instone, K. and Turoff, M. 2002. A Framework for Classifying Personalization Scheme Used on e-Commerce Websites. *Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS'03)*. IEEE Computer Society.

Wu, Y. and Offutt, J. 2002. Modeling and Testing Web-based Applications. ISE-TR-02-08.