QUANTITATIVE ANALYSIS IN HEURISTIC EVALUATION EXPERIMENTS OF E-COMMERCE WEBSITES

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ABSTRACT

This paper reports a pilot study on developing an instrument to predict the quality of e-commerce websites. The 8C model was adopted as the reference model of the heuristic evaluation. Each dimension of the 8C was mapped into a set of quantitative website elements, the websites were scraped to get the quantitative website elements, and the score of the dimension was calculated. A software was developed in PHP for the experiments. In the training process, 10 experiments were conducted and quantitative analysis was regressively conducted between the experiments. The conversion rate was used to verify the heuristic evaluation of an e-commerce website. The results showed that the mapping revisions between the experiments improved the performance of the evaluation instrument, therefore the experiment process and the quantitative mapping revision guideline proposed was on the right track. The experiment results and the future work have been discussed.

KEYWORDS

E-commerce Website, Heuristic Evaluation, Regression Experiments, 8C framework, Quantitative Analysis

1. INTRODUCTION

E-commerce websites have increased greatly in the new era; they face many competitors. Research revealed that efforts put into usability design and modification improved the performance of usability on websites greatly [1]. To help website developers and other stakeholders understand how to develop e-commerce websites properly and maximize profit, many evaluation methods have been developed [1, 2]. One approach is called user based testing [1], which takes into account subjective perception, both in terms of website content and design. This perception varies with the expertise, the cognitive skills and the end goal of each user [1]. If an automatic approach is used to evaluate website content and design from the user's perspective, that should standardize the evaluation process and make the evaluation consistent and objective.

7C framework was introduced to evaluate the quality of e-commerce website content and user interface design [3], which is considered as a useful reference model for developers, analysts, managers, and executives, when designing and/or evaluating the interface channels between the customer and the web based application. However, it is insufficient to completely address the new generation of web applications [4]. Collaboration and user-generated content are important features in the new generation websites. The 7C framework was extended into the 8C framework by adding collaboration as the 8th element in the model and the meaning of each of the eight

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design elements was updated as well, so that they are effective in representing the interface design elements of new generation websites [4].

Usually when a website is evaluated against the 7C framework, subjective perception is used. For example, in [5], a checklist consisting of 63 checkpoints was developed based on research literature and expert opinions to evaluate a group of 4 and 5-star luxury hotel websites against the 7C framework. This approach again could be inconsistent and subjective. An automatic approach could improve this.

The heuristic evaluation method is a technique for evaluating the usability, with the inspection being carried out mainly by evaluators from principles established by the discipline [6]. In most applications the results tend to be qualitative, however, these qualitative results do not allow us to determine how usable it is or how it becomes an interactive system. Hence, the need for quantitative results may also be very necessary in order to determine the effort that would be needed to get a sufficiently usable system [6].

The accurate prediction of a numerical target variable is an important task in machine learning. Quantitative heuristic analysis has been used in machine learning to predict various values in the data mining and inductive rule learning communities, where a strong focus lies on the comprehensibility of the learned models [7]. In [7], a heuristic rule learning algorithm that learns regression models is used where a region around the target value predicted by the rule is dynamically defined. In [8], a unified measure of web usability was used based on a multiple regression model, and then the estimated index is used to measure its impact on community bank performance. Results showed that banks with higher usability score perform significantly better than those with lower score.

Conversion rate (CR) is the percentage of users who take a desired action. The typical example of conversion rate is the percentage of website visitors who buy something on the site, For the purpose of managing user interface design and tracking the effectiveness of user experience efforts, the conversion rate is usually very important [9]. The conversion rate measures what happens once people are at your website, which is greatly influenced by the design and is a key parameter to track for assessing whether a user experience strategy is working. Lower conversion rates? You must be doing something wrong with the design. Higher conversion rates? You can praise your designers [9]. This suggests that there is a proportional relationship between the conversion rate of an e-commerce website and its user interface design. It is reasonable to use the conversion rate to measure the quality of the user interface of an e-commerce website.

This paper presents a pilot study on developing an instrument to predict the quality of e-commerce websites. The objective of the resulting instrument is to provide a meaningful estimation on the quality of a given e-commerce website. The 8C model was adopted as the reference model of the heuristic evaluation. Each dimension of the 8C model was mapped into a formula consisting of a set of quantitative website elements, the websites were scraped to get the quantitative website elements, and the score of the dimension was calculated based on the formula. Another formula was defined to calculate the total score for the website based on the scores from each dimension.

A software was developed in PHP for both training and testing experiments. An experimental process and its quantitative mapping revision guideline were proposed and used. In the training process, 10 experiments were conducted and quantitative analysis was regressively conducted between the experiments. The conversion rate was used in this study to test and verify the heuristic evaluation of an e-commerce website. 100 websites from five different categories were selected as the training data. 7 websites ordered by the conversion rate were used as testing data to test the results at the end of each experiment in the training process and 15 websites ordered by the CR were used as the testing data.

In the rest of this paper, the design of the experiment is described first, then the experiments and the results are presented and discussed, after that a summary and future work are given lastly.

2. THE EXPERIMENT ENVIRONMENT AND DESIGN

This study considered the seven dimensions defined in the 7C framework and the additional dimension "collaboration" introduced in the 8C framework. For the web 2.0 features, only those features easy to be obtained via web scraping were considered such as website forum, blog and Ajax. Table 1 presents the key meaning of each dimension in 8C [4].

Table 1. The key meaning of each dimension in 8C.

Dimensions	**Meanings**
1: Context	How the site is organized, and how the content is presented to the users?
2: Content	What are offered by the site?
3: Community	Non-interactive communication; Interactive communication.
4: Customization	Refers to the site's ability to tailor itself (tailoring) or to be tailored.
5: Communication	Site-to-user communications.
6: Connection	Refers to the extent of formal linkage from one site to others.
7: Commerce	Deals with the interface that supports the various aspects of e-commerce.
8: Collaboration	Generally in the form of feedback forms, forums, and bulletin boards.

Quantitative usability estimation is typically associated with the calculation of metrics that assess dimensions of software quality [6]. Measuring the user experience offers so much more than just simple observation. Metrics add structure to the design and evaluation process, give insight into the findings and provide information to the decision makers [10].

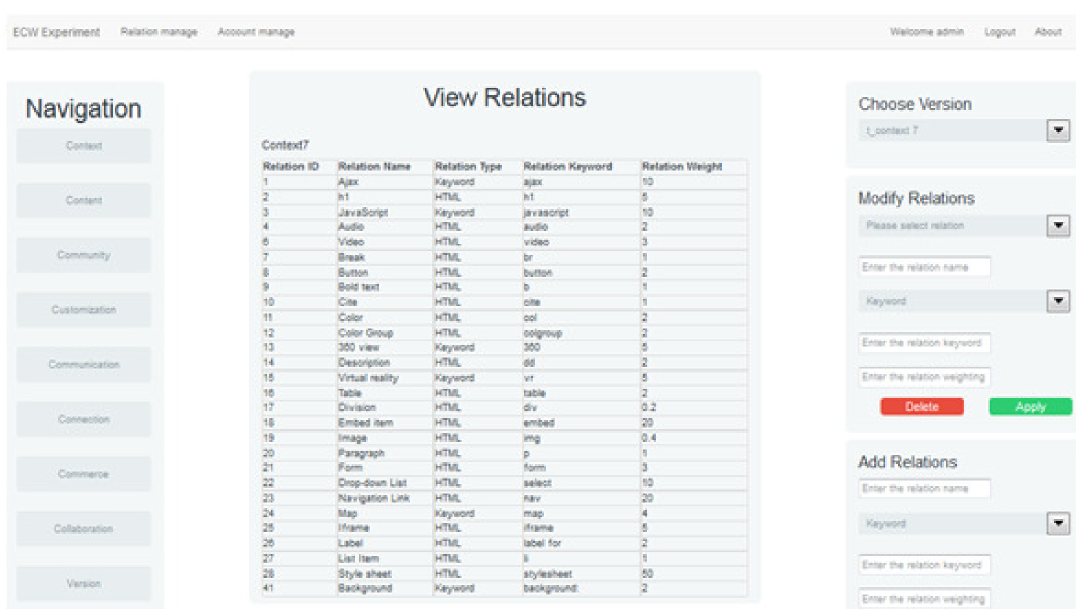

Figure 1. The mapping management UI and the relations in a mapping

A software written in PHP was developed for both training and testing experiments. Figure 1 shows the software mapping management user interface with the mapping relations between the ***Context*** dimension and the selected HTML tags/keywords in ***Experiment 7***. For an e-commerce website to be experimented, only the home page was considered in this study.

Two major approaches were used to identify the website quantitative elements and calculate the metrics for each dimension: finding keywords and scraping HTML tags, where a keyword could be an important text or a JavaScript/CSS keyword. Each keyword or HTML tag is associated with a numeric weight, which determines the importance of the relation, higher weight means more important. The mapping relations between each dimension and the selected keyword or HTML tag are defined before each experiment, which can be adjusted in the subsequent experiments based on the experiment results.

Let *NR* be the total number of the relations in a mapping between a dimension and the selected HTML tags/keywords; *RSi* be the score of relation *i*; *Wi* be the associated weight of relation *i*; if the relation *i* is a keyword, *RSi* will be *Wi*; if relation *i* is an HTML tag, *RSi* will be calculated by the following formula:

$$RSi = \frac{STagNi}{TTagNi} * Scalar * Wi \qquad (1)$$

Where *STagNi* is the number of the occurrence of the selected HTML tag for relation *i*; *TTagNi* is the total number of HTML tag on the selected page; Scalar is set as 100 to make the score a meaningful magnitude. The total score *TS* is the sum of the scores for all 8 dimensions in 8C framework.

$$TS = \sum_{i=1}^{8}(RSi) \qquad (2)$$

An experimental process and its revision guideline were proposed and used. Initially, in ***Experiment 1***, only the keywords/HTML tags that can intuitively reflect the meaning of a dimension as defined in the 8C framework were selected as the relations for the mapping of that dimension heuristically. The weights for the relations also were selected in the similar way heuristically.

Then the scores for all the training websites were calculated respectively according to formula (2). The training websites were ordered based on their CRs (CR) first, and then the training websites were ordered again based on their scores. If the score order is different from the CR order, the mappings for all the 8 dimensions were reviewed and revised in the following three aspects:

1. Check if any relation score is dominating the dimension score based on the overall performance of the training websites, if yes, adjust the weight of that relation to make the relation score of a meaningful magnitude.
2. Check if the score of any dimension is dominating the total score based on the overall performance of the training websites, if yes, scale all the scores in that dimension to make the dimension score of a meaningful magnitude.
3. Recheck all the mappings against the 8C model and make adjustment accordingly. This may involve adding or deleting relations.

The above would result in the new mappings for the next experiment. This process went through regressively for 10 experiments. As an example, Table 2 shows the mappings for ***Collaboration*** dimension in ***Experiment 1***, ***Experiment 6*** and ***Experiment 8***.

Table 2. The mapping for Collaboration in three experiments.

Experiment 1		**Experiment 6**		**Experiment 8**	
Relation Name	Relation Weight	Relation Name	Relation Weight	Relation Name	Relation Weight
Forums	3	Forums	3	Forums	3
Bulletin boards	3	Bulletin boards	3	Bulletin boards	3
FAQ	3	FAQ	3	FAQ	3
		Feedback	5	Feedback	5
				Review	5
				Suggestion	5
				Comment	5

3. THE EXPERIMENT ENVIRONMENT AND DESIGN

100 websites from five different categories (Electronics, Publishing & entertainment, Home and garden, Books, Industrial equipment), 20 from each category were selected as the training data. The five categories were selected from [11], where the CRs for 25 retail categories were listed. ***Electronics*** and ***Publishing & entertainment*** were associated with high level CR; ***Home & garden*** and ***Books*** were associated with middle level CR; and ***Industrial equipment*** were associated with low level CR

Table 3. The categories of training data.

Categories	**Conversion Rates**
Electronics	Around 23%
Publishing & entertainment	Around 20%
Home & garden	Around 14%
Books	Around 13%
Industrial equipment	Around 7%

The top 10 e-commerce websites based on CR for 2010 were listed in [12], only 7 of them were valid for the experiments, and they all were used to test the results at the end of each experiment for all the 10 experiments. Table 4 shows the 7 testing websites.

Table 4. The testing data.

Website Names	**Conversion Rates**
Woman Within	25.3%
Blair	20.4%
1800petmeds	17.7%
qvc	16%
ProFlowers	15.8%
Oriental Trading Company	14.9%
Roamans	14.4%

After each experiment, the training websites were ordered again based on their scores. If the score order is different from the CR order, the mappings for all the 8 dimensions in 8C model were reviewed and then revised if needed, this resulted in the new mapping for the next experiment. Figure 2 shows the absolute score differences between the expected order and the actual order. [9]

suggests that there is a proportional relationship between the CR of an e-commerce website and its user interface design. It is reasonable to assume that the less the difference, the more accurate the evaluation. The differences in each experiment for all the 7 training websites were averaged and Figure 3 shows the average for all the experiments except ***Experiment 9***. As the scores of ***Experiment 10*** were obtained by scaling the scores in ***Experiment 9*** by 10%. It was observed that the trends of the curve going down along the experiments. This suggested that the mapping revisions between the experiments improved the performance of the evaluation instrument and it is positive.

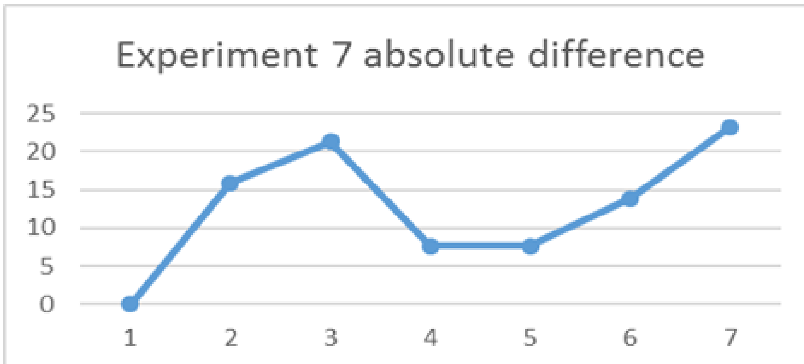

Figure 2. The absolute score differences between the expected order and the actual order for one experiment

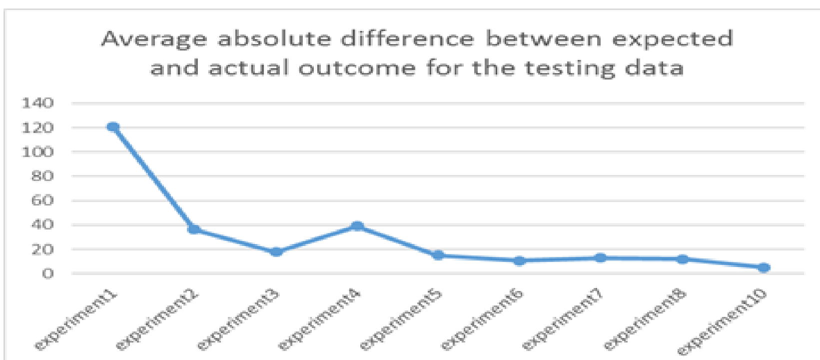

Figure 3. The average absolute difference between expected and actual outcomes for nine experiments

Table 5. The dimension contribution analysis of Experiment 8 & 10.

	Experiment 8			**Experiment 10**		
Attribute Category	Attribute Number	Contribution to the total score	Standard deviation	Attribute Number	Contribution to the total score	Standard deviation
Context	28	40.94%	15.43	28	14.71%	1.55
Content	11	5.93%	7.08	11	8.21%	2.62
Community	18	9.04%	7.77	18	12.60%	3.13
Customization	5	7.85%	6.00	5	11.22%	2.43
Communication	13	12.47%	6.55	13	17.79%	2.65
Connection	2	5.15%	4.81	2	7.44%	1.97
Commerce	10	14.68%	8.30	10	15.80%	2.55
Collaboration	7	3.93%	3.94	7	12.22%	3.48

In ***Experiment 8***, it was observed that some of the dimensions' scores dominated the total score of the website. Table 5 shows the dimension contribution analysis of ***Experiment 8 & 10***, where the number of attributes number is the number of relations in the mapping for each dimension (Attribute Category) of the 8C; contribution to the total score is the sum of the scores in a dimension for all the training websites divided by the total score of all the training websites in an experiment. ***Context*** made much more contribution (40.94%) than the others did. On the other hand, some were too small to influence the total score, such as Content (5.93%) ***Connection*** (5.93%) and ***Collaboration*** (5.93%). The standard deviation can provide some ideas on whether the attributes in a dimension is informative. For example, standard deviation for ***Collaboration*** was the smallest one in ***Experiment 8***, however, there were 7 attributes in this dimension. This suggested that the meaning of the attributes might be overlapping. So standard deviation for each dimension over all the training websites should be considered in the review process after each experiment in the future study.

In this study, scaling the scores for the dimensions were attempted to balance the influences of all the dimensions. For a website, let TS be its total score, and let score codes and scale parameter codes be defined in Table 6.

Table 6. Codes used in the scale formula.

Score Code	**Meaning of the code**	**Scale Parameter**	**Scale Number**
SC1	Score of Context	P1	1
SC2	Score of Content	P2	4
SC3	Score of Community	P3	4
SC4	Score of Customization	P4	4
SC5	Score of Communication	P5	4
SC6	Score of Connection	P6	4
SC7	Score of Commerce	P7	3
SC8	Score of Collaboration	P8	9

Formula (3) was used to calculate *TS* in ***Experiment 9***, the resulting scores were much larger than the other experiments, so the results were divided by 10 for further scaling, which were recorded as ***Experiment 10***.

$$TS = \sum_{i=1}^{8} (SCi * Pi) \qquad (3)$$

The right column of Table 5 shows the contribution of each dimension after the scaling in ***Experiment 10***. This time the contributions of the dimensions are much balanced.

The verifying data was obtained from [13], which listed top 15 e-commerce websites based on CR for 2014. All of them were valid for the experiments and were used to check the mappings used in all the experiments except ***Experiment 9*** as ***Experiment 10*** can represent ***Experiment 9***. Table 7 shows the order of the 15 verifying websites. Figure 4 shows the average absolute difference between expected and actual outcomes for the 15 verifying websites. It was observed that the trend of the curve was going down along the experiments, which was consistent with the testing results of Figure 3. This suggested that the experiments were on the right track and the results were positive. The resulting instrument from ***Experiment 10*** could be used to evaluate a given e-commence website and provide meaningful estimation on the quality of the website.

Table 7. The 2014 data.

Website Names	Conversion Rates
Play.Google	30.00%
MovieMars	22.95%
DollarShaveClub	20.00%
1800Contacts	18.40%
1800Flowers	16.90%
Coastal	14.50%
Keurig	13.00%
FTD	11.70%
ProFlowers	11.70%
PureFormulas	10.74%
FreshDirect	10.50%
TheGreatCourses	10.04%
1800PetMeds	10.00%
AmeriMark	10.00%
OvernightPrints	9.95%

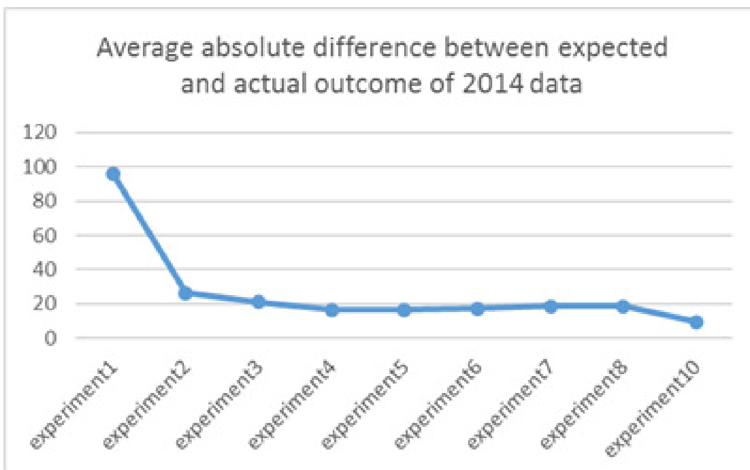

Figure 4. The average absolute difference between expected and actual outcomes for 2014 data.

Table 8. The average score of each category in each experiment.

No	Electronics	Entertainment	Home	Books	Industrial
1	165.27	142.92	157.36	152.41	148.19
2	144.16	124.11	124.71	129.84	124.40
3	108.77	83.19	85.73	93.20	88.15
4	98.73	85.15	90.07	91.09	94.00
5	90.08	77.28	82.28	87.61	83.50
6	91.27	81.50	84.73	86.80	89.00
7	163.41	141.10	145.65	136.69	148.75
8	159.83	138.54	142.54	134.37	145.52
9	467.53	395.98	380.85	358.28	403.04
10	46.77	39.89	40.21	36.00	40.34

Table 8 shows the average score of each category in each experiment. According to Table 3, websites in ***Electronics*** category should have the highest scores; websites in ***Industrial***

Equipment category should have the lowest scores; and ***Books*** are in the middle. In Table 8, the ***Electronics*** websites always have the highest score in all the experiments, ***Books*** websites are in the middle sometimes, particularly in ***Experiment 10***. These are consistent between the two tables (Table 3 and Table 8). However, ***Industrial Equipment*** websites usually do not have the lowest scores. This suggests that the website design and usability could have an impact on an e-commerce website's CR, however, there are other factors as well, such as the product nature, those relevant factors should be taken into consideration as well in an e-commerce website evaluation. In addition, the experiment results are dynamic; they are impacted by the network environment. The quantitative mappings might not be available temporarily for those popular websites due to heavy network traffic sometimes, and those popular websites are likely the websites with high scores. ***Industrial Equipment*** websites are not as popular as book websites or entertainment websites, so they are less impacted by network traffic; on the other hand, book websites or entertainment websites might get lower scores than their real scores due to network traffic, this issue should be addressed in the future experiment.

4. SUMMARY AND FUTURE WORK

This paper presented a pilot study on developing an instrument to predict the quality of e-commerce websites. The objective is to provide a meaningful estimation of a given e-commerce website. The 8C model was adopted as the reference model of the heuristic evaluation. Each dimension of the 8C was mapped into quantitative elements by means of web scraping. A software was developed in PHP for both training and testing experiments. 10 experiments were conducted and quantitative analysis was regressively conducted between the experiments. The conversion rate was used to test and verify the heuristic evaluation. It was observed that the trends of the curve for the differences between the expected and actual outcomes was going down along the experiments for both of the testing data and verifying data. This suggested that the mapping revisions between the experiments improved the performance of the evaluation instrument, therefore the experiment process and the revision guideline proposed in Section 2 was on the right track.

However, there are limitations in this study. The experiments only had been done on the home page of each website, although home page is very important for a website and it can provide rich information about the website, it is not sufficient for an e-commerce website, in some cases, the shopping cart or product list are not on the home page. Due to technique incapacity, not all the website features can be mapped into quantitative elements. The experiment results could be impacted by the network environment although that impact is not significant.

The above should be considered in the future work. In addition to that, the mapping revision process could be more robotic by improving the revision guideline (algorithm), for example, the standard deviation for each dimension over all the training websites could be considered in the review process after each experiment in the future work. The evaluation framework should not be limited to the 8C model; it could be extended to include other factors. [13] proposed a number of ways to improve the CR of an e-commerce website, which should be considered in the future study.

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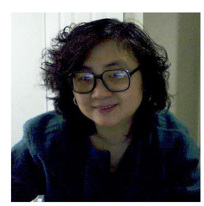

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