Knowledge Management in Website Quality Evaluation Domain

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Abstract. This paper deals with the problem of building a repository of knowledge about the methods and models of assessing the quality of Internet services. The repository has been constructed in the form of ontologies representing the various methods of quality assessment. For this purpose, the algorithm was developed based on ontologies with conceptualization of knowledge contained in the individual methods, and each completed ontology was evaluated. As a result of the research, domain ontologies were implemented reflecting the website quality assessment methods.

Keywords: Ontology evaluation · Knowledge conceptualization · Website quality

1 Introduction

In the sectors related to e-commerce and online advertising, revenue is directly determined by the number of users visiting corporate websites, blogs, portals and social platforms. More users increase the potential of advertising and this has a direct impact on the number of transactions and the amount of revenue, as well as attraction of new customers [3]. In the United States, recent revenues online advertising amounted to 42.78 billion dollars [1], while in Europe this figure was 27.3 billion euros [2]. It is worth noting that for businesses using a website to generate transactions, the website's quality can have a major impact on sales [4]. Poor quality of service and user experience can cause existing Internet customers [4], potential sales and repeat visits to be lost [5]. Therefore, in order to maximize profits from electronic commerce or online advertising, website owners should take care to offer only the highest quality.

The quality of a website can be understood as the attribute that specifies how well it meets the needs of users [6] [35]. It should be noted that quality is defined by a model composed of characteristics and features/criteria describing its various components [14]. In the literature, there are many methods used to assess the quality of Internet services, with the most formalized including: eQual [7], Ahn [8] SiteQual [9],

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Web Portal Site Quality [10] and Website Evaluation Questionnaire [11]. They have been widely used in both academic work [12] and business practice [13]. Analysis of the literature and areas of practical use of methods and models for the assessment of website quality indicates a gap in the area of a research repository of knowledge. The possible construction of such a repository in the form of ontologies allows formal specification and analysis of the various methods of assessment and specific influencing factors on the quality of a website [18], and consequently the sharing and reuse of the resulting area of domain knowledge [15]. The ontological form provides access to the knowledge and important is the ability to use the built ontology, e.g. in service quality assessment systems and their integration into the larger domain ontologies.

This paper presents an algorithm for constructing ontologies for different methods of assessing the quality of Internet services. In accordance with the developed algorithm, ontologies were constructed and evaluated based on the inference models and questions of competence. The article concludes with a presentation of research findings and possible future directions of work.

2 Literature Review

The term "ontology" in computer science is defined as "the specification of conceptualization" [16] and it allows concepts and domain knowledge to be captured. A similar definition says that an ontology is treated as a data structure and a tool for data representation, allowing knowledge to be shared and reused in artificial intelligence systems that use a common vocabulary [17]. Therefore ontology seems to be a natural form of representation of the repository of knowledge about the methods of quality assessment. This is due to the fact that the use of ontologies will create conceptual models explaining the structure of the different methods of evaluation criteria. The use of ontologies will also be shared and repeated use of such structures is possible to facilitate management. The possibility of using ontologies as a repository of knowledge is confirmed by work [26] where a biomedical knowledge base was created using ontologies. Ontologies are also implemented in the knowledge bases of systems, e.g. an expert system for the study of company financial ratios [19] or a decision support system for the construction of railway infrastructure [20]. In [21] ontologies, in addition to rule-based expert systems, other modules are present within the agent system. The role of ontologies in this system is to enter user queries, return results to users, and provide a system of knowledge from experts and knowledge engineers. Analysis of the literature shows that ontologies are also used in the systems and methods of quality assessment. For example, the work [18] presents an ontology quality that formalizes the knowledge necessary to evaluate the quality of e-government. This ontology is then used in a self-adaptive quality monitoring system, used to test the quality of services provided within e-government platforms [22]. In this system, in addition to ontology quality, ontologies also use characteristics of portals, user behavior and the problems encountered by users while using the portal [23]. In contrast, [24] consider the use of ontologies in the assessment of the quality of tourism services websites. In this case, the ontology would be part of the provision of

a description of issues related to the field of tourism and it could assist in identifying the requirements for this type of website. Its application is presented by the authors in comparison to other possible methods to determine the requirements for tourism services [25]. However, analysis of the literature showed that there is a repository of knowledge covering a few important methods for assessing the quality of services. Meanwhile, the reasons discussed above and the use of ontologies show that the construction of a repository of knowledge about the methods of assessing the quality of web services based on ontologies is justified.

3 Ontology Building Framework

The ontology construction methodology is frequently used, differing in the degree of formalization, destination and detail [29]. The most formal and detailed methodology includes Methontology [27] and NeOn [28]. Methontology defines in detail the process of conceptualization, while NeOn largely formalizes the problem of ontology specification. Therefore, the author's quality assessment methods are based on these two methodologies. This algorithm is shown in Fig. 1.

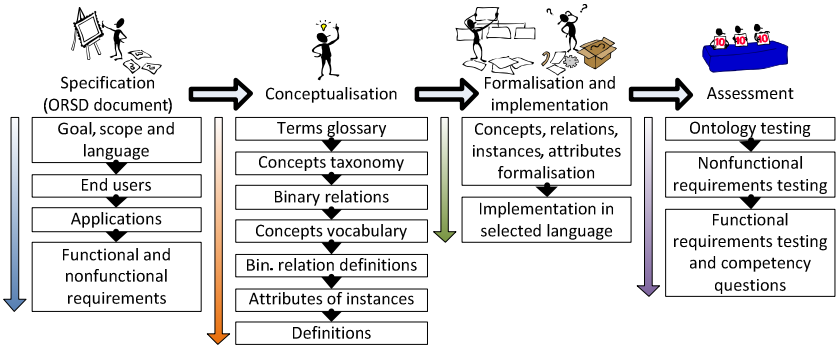

Fig. 1. Algorithm for ontology implementation

The first stage of the algorithm is a specification involving the preparation of the document ORSD (Ontology Requirements Specification Document) [31], which has the goal of building an ontology, the language of its implementation, and questions of competence used to verify the correctness of the ontology after its construction. The second phase includes the tasks leading to the conceptualization of knowledge, which is to include the ontology. The next step is to formalize the ontology based on a previously made conceptualization and implement it in the selected language and use the appropriate ontology editor. The last step in the construction of the ontology is its assessment, checking the consistency of ontology reasoners by using and verifying answers to the questions of competence defined in the specification phase. Fig. 1 shows the algorithm used to build an ontology of conceptual methods for assessing the quality of websites, i.e.: eQual, Ahn, SiteQual, Website Evaluation Questionnaire and Web Portal Site Quality.

4 Building Ontologies of Websites' Quality Evaluation Methods

The first built ontology was eQual. According to the developed algorithm implemented at the beginning stage of the specification, the effect was the document ORSD which characterized the requirements of the ontology'. Part of this document is presented in Table 1.

Table 1. Partial requirements of the ORSD eQual ontology

1.	Purpose - Reflected in the ontology quality assessment method eQual	
2.	Scope - The ontology includes characteristics, criteria and the evaluation scale model eQual	
3.	Implementation language - OWL 2 DL	
4.	Users - Experts evaluating the quality of websites	
5.	Applications - Evaluation of quality websites	
6a	Non-functional requirements - NFR1. The names of classes and instances begin with a capital letter (excluding proper names and names of criteria). NFR2. The names of the attributes and relationships consist of a verb written with an initial lower case letter and a noun written with an initial capital letter, e.g. "hasValue".	
6b	Functional requirements	
	CQG1. Belonging and weight	CQ1. What criteria do the quality characteristics of "Empathy" have?
		CQ2. What criteria have a weight factor of > = 5?
	CQG2. The value of services ratings	CQ3. What services are rated > = 5 with respect to the criterion "reputation"?
		CQ4. What criteria weighing > = 5.0 are rated < 4 for service "website2"?
		CQ5. What services are rated > = 6 in terms of criteria weighing > = 5.5?
	CQG3. Completeness of ratings	CQ6. In terms of what criteria is service "website2" evaluated?
		CQ7. Which services are assessed for at least 8 criteria?

The next step was the conceptualization of eQual methods. During the implementation of the first tasks in this stage, a glossary of terms used in the table of eQual method criteria was built [7]. These criteria are represented by the concepts in the ontology. In addition, the glossary contains terms that operate in the ontology in the form of attributes and relationships. This was adopted with the assumption that the assessment of individual services with respect to the following criteria will be included in the instances of concepts representing the evaluation criteria. Part of the glossary of terms in the eQual ontology is presented in Table 2, where C is the concept, R is the relationship, A_I is the attribute instance, and A_C is the attribute class/concept.

Table 2. Partial glossary of terms for the eQual ontology

Term	Description	Type
Personalization	Feature describing the degree of personalization service	C
Information quality	Characteristics of grouping attributes relating to the quality of information	C
eQual	The name of the quality assessment method	C
isCriterion(C,Ch)	Feature C is the criterion associated with characteristics Ch	R
hasCriterion(Ch,C)	Characteristics Ch criterion is assigned to C	R
hasEvaluation(I_W,I_C)	I_W has a rating service for the instance and features of C	R
isEvaluation(I_C,I_W)	An instance of I features of C contains an assessment of the I_W service	R
hasEvaluationValue (I_C,Integer)	An instance of I features of C is an integer value assessment	A_I
hasWeightValue (C,Double)	Feature C is the criterion of having a floating-point value of the weight	A_C

Another task carried out in the conceptualization phase was the construction of a taxonomy of concepts. Fig. 2 shows the hierarchy of the separate attributes (criteria) of the quality of the individual characteristics of the grouping criteria.

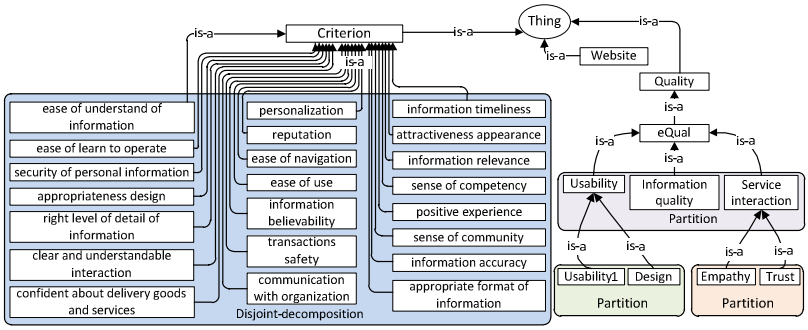

Fig. 2. Taxonomy of concepts in the eQual ontology

This approach allowed more transparent applications of the ontology. This is also consistent with the representation of open and closed worlds in the ontology [32]. Namely, the quality of each model contained in the various assessment methods is a closed model. This means that it is complete and a new one cannot be added to it. The quality evaluation criteria are the open portion of the world, which means that there may be additional criteria not included in the ontology to date.

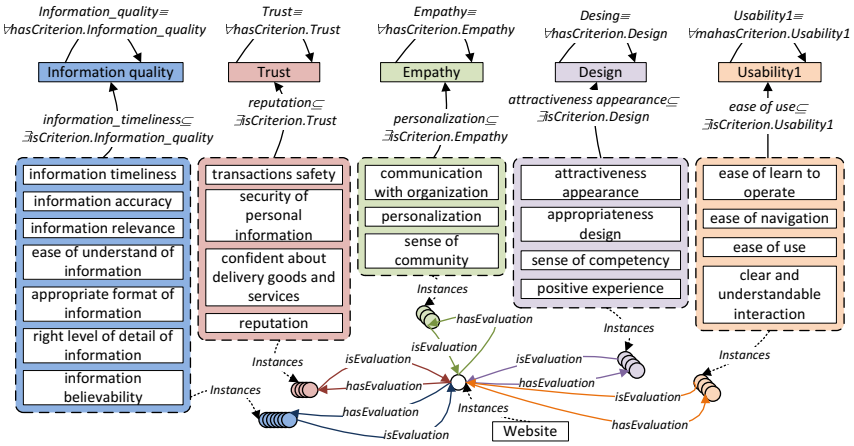

Fig. 3. Diagram of the ad hoc binary relations of the eQual ontology

For these reasons, the part reflecting the ontology of the eQual quality model was used to partition taxonomic relationships between concepts occurring at the same level of the hierarchy. In contrast, separability of the taxonomic relationship was among the criteria used, since these criteria describe the different parts' quality, but there may be other criteria describing the quality.

The next task was to build an ad hoc diagram of binary relations. It was decided to provide all the relationships here on one diagram, because it allows us to more clearly demonstrate the concept articulated in the ontology. The diagram is shown in Figure 3, and it takes into account the relationships between concepts relating to the criteria and characteristics (isCriterion, hasCriterion) and the relationship existing between instances of concepts (hasEvaluation, isEvaluation). In order to improve the readability of Fig. 3, the different concepts of evaluation criteria are grouped under the performance characteristics. Specific relationships are illustrated in the diagram; each relationship refers to each concept contained in the group.

The fourth task was to build a dictionary of concepts. The concepts included in the constructed ontologies are shown in Fig. 2. The fifth task required detailed definitions of ad hoc binary relations. These definitions are presented in Table 3, which takes into account the relationships between concepts and between instances of concepts. The concepts in square brackets are recorded ancestors (i.e. specifying the type) or instances involved in the relationship. The relations "isCriterion" and "hasCriterion" exist between concepts. When the relationship is "isCriterion", the source concepts are different quality criteria and the concepts are the specific characteristics of the target, which, according to the model eQual, include criteria. In the other work relationship, "hasCriterion", the concept of both the source and the destination is the same relating to the characteristics of the quality of the model eQual. This solution, in a situation where C1 represents the characteristics of the concept and the concept C2 means the criteria, can be understood as follows: (a) there are certain criteria in the C2 group that belong to the characteristics of the C1 group ("C2 isCriterion some C1"), (b) the characteristics of the C1 are only those criteria that belong to the characteristic ("C1 hasCriterion only C1"). This configuration relationship "isCriterion" and "hasCriterion" allows exploration of membership criteria and describes the characteristics of the membership as a conclusion to the specific criteria in the relevant characteristics. As for the relationships "isEvaluation" and "hasEvaluation", they overlap between instances of concepts. The ratio of "isEvaluation" has a jurisdiction function, which means that if one instance of source refers to a number of destinations, then the reasoner will interpret these instances as the same. The relation of "hasEvaluation" is an inverse relationship to "isEvaluation", and therefore it is inverse functional.

Table 3. Definitions of the ad hoc binary relations of the eQual ontology

Relation	Source concept	Cardinality	Target concept	Property	Inverse
isCriterion (condition necessary)	[Criterion] *undefined area* in example personalization	N - existential quantification	[eQual] *undefined range* in example Empathy	-	has Criterion
hasCriterion (condition necessary and sufficient)	[eQual] *undefined area* in example Empathy	1 - universal quantification	[eQual] *undefined range* in example Empathy	-	is Criterion
isEvaluation	[criterion] Website1_reputation	-	[Website] Website1	Functional	has Evaluation
hasEvaluation	[Website] Website1	-	[Criterion] Website1_reputation	Inverse functional	is Evaluation

The sixth task was to define attributes of specific instances and classes. For instance, in the ontology the eQual attribute ("hasEvaluationValue") determines the value of the evaluation of a given service award criterion. Specific values for this attribute are assigned to individual instances of concepts corresponding to the evaluation criteria. According to the eQual method, evaluation value is an integer in the range 1-7. This step also defines two classes of attributes, i.e. "hasEvaluationValue" and "hasWeightValue", the task of which is to limit the range of possible values for the attributes and classes, for instance from 1 to 7. They provide a mechanism to control the accuracy of the applicant weights and grades. In addition, the attribute "hasWeightValue" is also an attribute of the concepts contained in the class "Criterion", and it is to be stored in the weights of the criteria. The seventh task in the conceptualization stage was to create detailed definitions of constants that will be used in the ontology. There are two constants that relate to the scope of the assessment (assessment scale) and weights. The constant "Evaluation" is an integer and has a value point in the range of 1-7. The second constant, "Weight", is a double, and its possible values are well within the range of <1.0, 7.0>. In this step, the applied ontology editor Protege [33] was formalized and implemented. With its help, we formalized concepts, relationships, instances and attributes and implemented the eQual ontology language OWL 2 DL [34] on the basis of the conceptualization presented earlier.

The last step was the construction of an ontology evaluation involving, among others, the classification of concepts using a reasoner and checking the answers to the questions of competence ontology [28]. The eQual ontology is available in [36] and the effect of the reasoner is given in [37]. By analyzing the form of the ontology reasoner, it can be seen that different criteria are correctly assigned to the relevant performance characteristics. The hierarchy of concepts is generated by the reasoner, so it is consistent with the model of quality contained in the eQual method. The individual quality criteria are also included in the concept of "Criterion" so that the ontology is clear. As for the question of competence contained in Table 1, it checks the response of the ontology, and it was necessary to introduce the sample data presented in Table 4. The criteria that are not included in Table 4 were assigned a weight of 1.0. In addition, the ontology did not include their instances, and therefore none of the sites had assessments against the criteria listed in Table 4.

Table 4. Sample weighting of the criteria and evaluation in the eQual ontology

Characteristics	Criterion	Weight	Rate1	Rate2
Empathy	Communication with organization	4.1	5	1
	Personalization	2.5	4	6
	Sense of community	3.7	7	7
Trust	Transaction safety	1.4	5	3
	Security of personal information	5.1	2	4
	Confident about delivery of goods and services	4.3	3	-
	Reputation	6.2	5	2
Information quality	Information timeliness	6.7	6	2

The answers to the questions of competence ontology included in Table 1 are shown in Fig. 4. A comparison of Table 4 and Fig. 4 shows that all the answers are

correct ontologies. Consequently, it is clear that the ontology is built correctly and fully reflects the quality assessment method of the eQual websites. According to the presented algorithm, there is another ontology structure that also reflects the evaluation of the quality of websites, which in turn presents the ontology in the basic form and is deduced by the reasoner: Ahn [38] SiteQual [39] Website Evaluation Questionnaire [40] and Web Portal Site Quality [41].

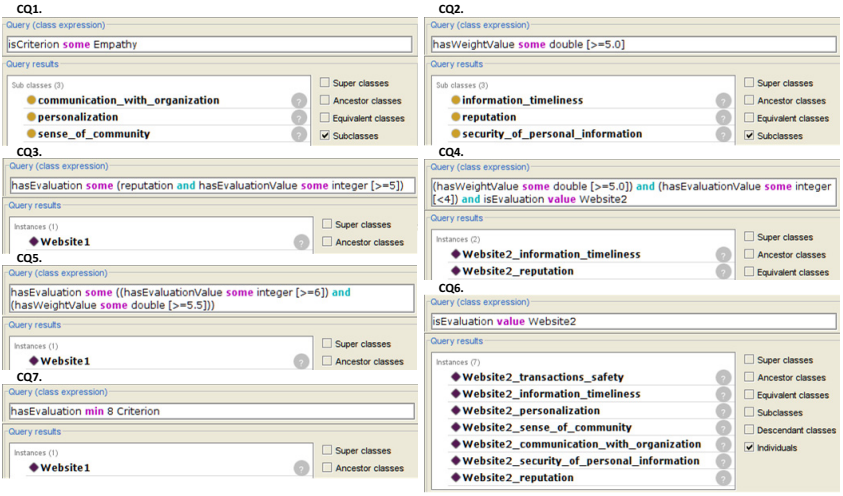

Fig. 4. Answers to the competence questions of the eQual ontology

5 Summary

This article discusses the problem of using conceptualization methods to evaluate the quality of websites. Five methods were used and the conceptualization of domain ontologies was then evaluated. In the evaluation process, the mechanism requesting competency questions was used, addressed to the built ontology. Recognition of the different methods in the form of an ontology allows the reuse and sharing of knowledge contained in the individual methods. Therefore, the natural direction of further research seems to be to build a combination of ontologies to enable integration of data from a variety of assessment methods. This would also allow for the evaluation of services through a variety of methods contained in the integrated ontology and for a comparison of the results of the assessment in a terminology and a reference plane. Such an ontology, along with the assessment criteria in the selection process presented in [30] could serve as the core of the expert system of assessment of website quality. An additional direction of future work should include the development of an ontology about the possibility of environmental data records and to build and maintain a repository of detailed use cases of a developed ontology.

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