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ONTONAVSHOP: AN ONTOLOGY-BASED APPROACH FOR WEB-SHOP NAVIGATION

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Existing literature shows that navigation and visualization features play a significant role in successful Web shop design. Traditional Web shops, however, often lack a uniform, intuitive interface to navigate through products, while also providing an insightful overview of the product assortment. In this article, we employ ontologies for the presentation of product assortments in Web shops in order to ease the users' process of finding their desired products. OntoNavShop visualizes the product assortment ontology directly in a Web browser using a circular view algorithm that outputs SVG graphics. Consumers can navigate uniformly through the ontology and zoom into its categories. The visualisation is evaluated on efficiency, user satisfaction, and specific problems against a classical tree-based Web shop. Our evaluations under a representative group of users show that users maintain a better overview of the structure of the product assortment, while being able to find products more quickly (i.e., less time) and more efficiently (i.e., less clicks) than in our benchmark Web shop. The participants prefer the OntoNavShop over the classical approach, and the identified problems are rather minor.

Keywords: Ontology visualization, navigation, e-commerce, product assortment ontology, circular view algorithm

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1 Introduction

The design of a Web shop determines the identity of the Web shop and has the most influence on its success [31, 33]. The most successful Web shops have an easy-to-use, or intuitive, design: consumers can easily locate products in the Web shop and fast checkout [9]. However, every Web shop has a unique structural design, requires specific navigation, and uses different navigation controls. Faced with a new design, the users' cognitive load increases [21, 41]. As a result, the consumer has difficulties gaining an overview of the product assortment of a Web shop: consumers cannot determine which products are offered and which products are not included in the Web shop assortment [23]. Not every shop has a distinctive product assortment, i.e., it is obvious that the Apple Web shop does not sell the Microsoft Zune music player, but does the IKEA Web shop sell screws and nails? Closely related with the design and navigation of a Web shop, is gaining an overview of the structure of a Web shop. On the Web, consumers face multiple product assortment structures: are audio cables offered under the category 'audio products'?, is there a category 'cables'?, or are both categories presented in the Web shop?

Another important question to be asked is: once consumers have found or seen a product in a Web shop, can the consumer find the product again in another visit to the Web shop? In the dynamic Web environment, information changes continuously, thus yielding different results for the same query when allowing for some time to pass by. Moreover, Web shops update their assortment continuously, initiate sales, and highlight popular products. After a browsing session, consumers may face the challenge to relocate the product in the same Web store. In a physical store, the consumers have physical cues, e.g., the product was in the back of the store, or near the drug assortment. The cues in Web stores are less recognizable due to the dynamic nature of Web shops. As a result consumers are prevented from building a cognitive map, which would have been effective in another visit to the Web shop.

In our endeavours, we focus on cases where the user is unaware of the particular desired product. By improving the overview (visualization) of the product assortment, we aim to help these users in their final decision making. A generic search function would not be helpful here, as the user does not know which product to look for, thus being forced to go through a browsing process. Faceted-based navigation is very popular for browsing through the product assortment of a Web shop [40]. By allowing users to quickly find their desired products, we aim to bring a contribution to faceted-based navigation.

We identify four user-system interaction problems for Web shops. First, consumers face different interfaces and navigation features. Second, consumers have difficulties gaining an overview of the structure of the product assortment. Third, consumers cannot always distinguish which products belong to the product assortment. The fourth and last problem, consumers have difficulties relocating a product in a Web shop. In order to address these problems, we aim to define a product assortment visualization that allows users to get a quick overview of the available products and enable them to easily locate the products of their interest. In this research, we suggest an ontology-based approach for visualizing the product assortment of a Web shop. Ontologies [15] and their associated reasoning capabilities have been already shown useful in other e-commerce scenarios, e.g., e-marketplaces [2] or Web shops aggregators [29], which encouraged us to perform this research. More precisely, we investigate how ontologies can be used for e-commerce at user interface level in order to help potential customers easily find the desired products.

The article is structured as follows. Section 2 reviews the current body of literature on the navigation problem in Web shops and ontology visualization technologies. Subsequently, Section 3 describes our research methodology and research hypotheses. The OntoNavShop framework and its implementation are elaborated on in Sections 4 and 5, respectively, describing the product ontology, navigation visualization, and Web shop functionalities. Next, Sections 6 and 7 present and discus our results, respectively. Last, we draw our conclusions and make recommendations for further research.

2 Related Work

We have identified two major areas of related work. First, we present the navigation problem, with a focus on the state-of-the-art with respect to wayfinding. Next, we describe related studies on the application of (Semantic) Web technologies for visualizing data in e-commerce.

2.1 Navigation Problem

The features that are important to Web design can be different from domain to domain. Navigation features, however, are universally important in all domains [42]. Navigational hyperlinks and the product organization both contribute to the e-store design quality, affecting consumer purchases. Better-designed e-stores will attract more consumers who at the end of their session will purchase, intend to revisit, and possibly purchase again in the future [21]. Therefore, navigation design is of paramount importance for the success of Web shops.

Conforming to findings in the literature of usability, human-computer interaction, and design research, [31] measures Web site success by (1) frequency of use, (2) user satisfaction, and (3) intent to return. Five evaluation metrics are suggested, but only one metric is within the scope of this paper: navigation/organization. The hypothesis corresponding with the navigation metric is: "More navigable Web sites will be associated with greater perceived success by site users", where navigability is defined as "the sequencing of pages", "well organized layout", and "consistency of navigation protocols". The authors of [31] argue that the navigability of a Web site can be improved by an appropriate layout, sequencing, and arrangement of the Web site. Improving the browsing and navigation of Web shops is most likely to increase the traffic and sales [23]. Web sites with a difficult navigation generate less sales [33].

Consumers are most influenced by the content of a Business-to-Consumer (B2C) site, where they should easily locate and select the product(s) that satisfy their needs. From this point of view, the success of a B2C Web site does not solely depend on the information content, but also on the navigation characteristics [33]. Web shops with larger product assortments generate more traffic, but do not necessarily generate more sales. An explanation for this result is that consumers have a hard time finding the products they want [23]. The Web design helps attracting and retaining the interest of consumers, and is argued to be as important as the content. In [33], we are suggested with the top-3 important Web shop design principles: (1) ease of navigation, (2) time taken for navigation and page download, and (3) use of multimedia to improve the visual appeal. An intuitive navigation decreases the consumers search time in a Web shop. Previous work has shown that consumers are attracted to Web shops who have easy navigation [33]. The usage of distinctive navigation buttons (so called hot buttons), which support intuitive navigation and add to the unique character of the Web site, and the usage of a site map for large sites, which help the user understanding and navigation of the Web site, contribute to successful navigation [12].

The authors of [9] performed a heuristic evaluation on two successful Web shops, i.e., Amazon and the Apple store, to discover good practices and design problems for user interfaces. Five experts, academics and business experts, in marketing, usability, information systems, and new technologies, tested both Web sites on known usability principles. The experts firstly evaluated the attractiveness, secondly the navigation and usability aspects, and thirdly the transaction process of the Web site. The success of Amazon is dedicated to the easy structure and navigation features. Products are organized in an intuitive manner, where each category displays subcategories and specific items. The Apple store was also found easy navigable and logically structured. The authors argue that the design is the first impression of a Web site and thus influences the evaluation of the user on the Web site. [9] concludes that easy, simple navigation is a necessary condition for a successful Web site.

The buying process of consumers is a mixture of information search and information evaluation. B2C websites are assumed to have lower costs of information search than physical shops, therefore the expected sales of B2C Web shops with a sound and easy navigation are higher [33]. Some consumers prefer shopping online because of the convenience and time saving elements. Therefore, it is important that consumers spend little time searching information in B2C Web sites [33]. If a Web shop design attracts few consumers, one should not necessarily address the merchandising mix (the product assortment), as the relation between sales and the user interface design is important as well in Web shops [22]. A B2C Web site that does not meet consumer expectations will not be effective, despite having a sound technical architecture and formal e-commerce strategy [33]. Consumers choice is affected by the products position on the screen, although the position contains no information on the product [22]. Consumers should find the product of their interest quickly and easily, otherwise the risk that consumers leave the Web shop and continue their shopping in an alternative, competitor Web shop is high [33]. In other words, consumers on the Web aim for low costs for information search, thus they expect a sound navigation.

Navigation must be consistent, since not every consumer enters the Web shop using the front door (home page). The convenience of Web shops is determined by the layout, ease of use, and managing of the user's expectations. An increase in convenience results in a decrease of losing consumers. [22] suggests to use multiple levels of headings, informative headlines, and judicious use of white space.

Based on the literature review we notice the importance of navigation on (1) the traffic and sales of Web shops, (2) attracting consumers to the Web shop, (3) decreasing the costs of information search, and (4) increasing the convenience of Web shops. The next section elaborates on the concept of wayfinding, which helps consumers to re-find a product in a future visit [39].

2.1.1 Wayfinding

Wayfinding is defined as "the ability to find a way to a particular location in an expedient manner and to recognize the destination when reached" [39]. In wayfinding, the goal is to travel from start to a predetermined end point. Sensory cues (i.e., signs) from the external environment facilitate this process. The authors of [39] stress the flexibility in browsing and argue the higher importance of wayfinding for the Web compared to physical shops. Due to dynamic hyperlinks users can transport themselves through the Web site, which makes it difficult to recall the path they have traveled.

The aim in [39] is to analyze the variables that decrease cognitive overhead and facilitate wayfinding for the user. The process of wayfinding consists of: (1) cognitive mapping, (2) decision generation, and (3) decision execution. In cognitive mapping, the user employs previous experiences and the current Web site environment to construct a cognitive map. With decision generation, the user structures a series of decisions necessary to complete the task. A decision consists of planned behavior and expected image, respectively, the expected execution and the perceived outcome. In decision execution, the user compares the expected image of a decision with the perceived image of the current environment. If these images match, the planned behavior is executed, in all other cases the decision is transformed into a sub-task and the wayfinding process starts over with (1) cognitive mapping.

The results of [39] suggest that the initial cognitive map of a Web shop of the subjects should closely match the actual cognitive map. Web shops with a consistent navigation, who follow general Web conventions, and have a consistent presentation style increase the satisfaction of the consumers. The structure and navigation of a Web site can improve the wayfinding process. The user should have a clear overview of the structure of the Web site, be able to orientate, and recognize his position on the Web site in order to construct a cognitive map. In addition, the structure should be intuitive and meaningful so that it can be matched with the cognitive map [39]. In a physical store consumers have physical cues to aid them in relocating a product, while the dynamic pages of Web shops prevent the users from using cues. Links are often dynamic, which makes it difficult for consumers to build a cognitive map [22]. The literature suggests that Web shops can gain consumer satisfaction by improving wayfinding, especially because Web shops are becoming increasingly dynamic.

We have identified the importance of navigation on the success of Web shops and the opportunities of wayfinding on successful Web design. In our research we aim to devise a method to build a Web shop that allows for a convenient layout, with an easy-to-use navigation, in order to facilitate and attract consumers. Our approach aims for lower costs of information search and improve the wayfinding in a dynamic Web environment. Ontologies as a way to structure information and support navigation design [11] can help build a successful Web shop.

2.2 Semantic Web Technologies for Electronic Commerce

Semantic Web technologies have proven to be useful for the search and exploration of electronic commerce systems [8, 40]. For example, the authors of [5] propose an algorithm that uses non-monotonic inferences (concept contraction and concept abduction) in semantic matchmaking for the purpose of ranking resource descriptions. In the literature, we can find additional research that focuses on semantic matchmaking for the purpose of improving electronic commerce systems, e.g., [14, 20]. Another topic that is interesting for the domain of electronic commerce is taxonomy mapping [1, 30, 32], where the authors use advanced lexical and/or semantic approaches to improve the performance of their algorithms.

2.2.1 Ontology Visualization

Visualizing ontologies (i.e., formal descriptions of domains [15] using characterizing concepts, individuals, properties, and relations) remains a non-trivial task. According to the authors of an extensive survey of visualization techniques [17], it is difficult to visualize an ontology and allow the user to easily perform operations on the ontology. Sometimes, visualization techniques can be borrowed from other domains with different applications.

A common classification of visualization techniques is sixfold. Ontologies can be described using a basic and poor indented list. Alternatively, trees or graphs (in case of mutliple inheritance and role relations) with nodes form an intuitive representation of ontologies, where we can distinguish between a node-link tree that explicitly displays hierarchies, a zoomable node interface, space-filling algorithms for nodes, and distortion techniques that allow the user to focus on nodes. Last, there are also some multi-dimensional information landscape visualization techniques on the market. The effectiveness of each of these visualization techniques can be evaluated on the ability to gain an overview, to zoom in and out of concepts and individuals, to apply filtering, to retrieve product details on demand, to find related products, and to remember a browsing history.

Generally, 3D information landscapes – and in lesser extent node-link tree visualizations – provide the best opportunities to maintain oversight of an ontology. Space-filling visualizations can be useful for identifying nodes with many/few concepts or individuals, for gaining an overview of the source and target of a property, and for quick browsing.

Almost all visualizations are suited for zooming in on concepts without losing track of the content and individuals, except for the zoomable interfaces. This seems controversial. However, in zooming interfaces, it is difficult to keep track of the concept's or individual's context (i.e., path). Retrieving details on demand is mainly visualization specific, and all visualization techniques score high for viewing node siblings.

Filtering can best be done with the indented list, node-link tree, and distortion visualizations. Relations can best be viewed in 3D information landscapes and node-link tree visualizations. Additionally, the indented list and distortion visualizations have a good performance on the task of viewing relations. The final task of history is mainly tool-dependent, however the node-link tree, indented list, space-filling, and 3D information landscape visualizations facilitate in returning to previously visited concepts or individuals, and sometimes show the click path of the user.

Although the 3D information landscape and node-link tree visualization score high on most tasks, we opt for another kind of visualization. As 3D visualization introduces a lot of complexity, and the node-link tree visualizations do not maximize screen space, we aim for a hybrid algorithm that implements ideas from focus and context distortion, zooming, node-link trees, and space-filling visualizations. This matches our objectives, because we aim for a visualization that enables users to quickly gain an overview of the product assortment, allows for zooming, shows details on demand, maintains a history, and maximizes screen usage.

2.2.2 Ontology Navigation

All static hierarchical presentations have their limitations as to the quantity of information they are capable of presenting on a finite display space [3]. For large information spaces, the navigation and interaction features have a high influence on the success of the visualization tool. Navigation is tool-dependent and not influenced by the visualization technique or category. Zooming increases the loss of the context where the user is in the navigation space (as defined by the ontology) and where the user came from. Navigation features that remember and visualize the path of the user can prevent the loss of context. Movement and rotation in a visualization create disorientation and decrease the building of a cognitive model of the ontology. Navigation features who are clear and intuitive for the user can prevent the disorientation.

As we aim to visualize the product assortment of a Web shop in a Web browser, the visualization should represent the shop products. Unlike tag cloud visualizations, we want to structure the visualized information (products) using their categorization. Product assortments can grow large in size, so to prevent clutter and increase the opportunity to gain an overview, the visualization should show small parts of the information (product assortment). Users can expand categories and zoom in the information without losing context. The tasks we find of importance for our ontology visualization are: overview, history, zooming, and details-on-demand based on the tasks described in [38]. Overview and history are important to gain an overview of the ontology and thus of the Web shop and the assortment. Zooming is important for users to find the product of interest. The task of details-on-demand is important for users to gain information about a product of interest and to select the product to purchase. From [38] we identify the need of navigational features that remember and visualize the navigation path of the user through the ontology, navigation signs relating to the current position in the Web shop, and the opportunities to zoom into categories or navigate back to an overview.

2.2.3 Web-Based Visualization techniques

Only a few Web-based visualization tools are described in recent and extensive surveys [17], i.e., GObar [19] and Visual Pivot [35]. The GObar tool is publicly available and visualizes the gene ontology top-down (a node-link tree visualization). It is provided with a search engine and the visualization is based on the technique of Scalable Vector Graphics (SVG) [6]. Visual Pivot (a node-link tree visualization) is a Web-based visualization technique for structures composed of multiple overlapping hierarchies, called polyarchies. Visual Pivot uses a scripted Web page in a Web service architecture.

To our knowledge there is one other Web-based ontology visualization described in [16]. The authors propose an ontology-driven visualization of maps and make use of the SVG technology. Geographical Information System (GIS) data is transformed into ontologies based on Ontology of Transportation Networks (OTN), a technique the researchers developed themselves to transform Geographic Data Format (GDF) from GIS to an OWL ontology. The OWL ontology is visualized using SVG, which can be viewed with a special plugin for Web browsers. The SVG technology allowed for high quality vector graphics, can easily serve as GUI, and uses the popular XML syntax. The approach of this research is interesting for our current purpose since the transformation from ontologies to visualization with SVG is proven and documented.

There are many ontology visualization techniques available, but none of them are suitable alone to be used in a Web shop, and based on our survey only three techniques are Web-based. We notice that the visualization of ontologies is complex and that ontologies are not always easy to browse. In this research we will propose a framework for an ontology-based Web shop with an easy-to-use navigation and a visualization that reduces the cognitive load of consumers and helps building a cognitive model to improve the wayfinding through the Web shop.

3 Methodology

Before developing our framework, we determined how to evaluate our approach. In literature, we can find many proposed instruments for assessing electronic commerce systems, e.g., [24, 37]. We refer to the three evaluation goals proposed in [7], as this approach has been shown to be a very effective tool to measure the effectiveness of electronic systems. Furthermore, the authors of [7] evaluate a new interface versus a traditional interface of a regular shop, which is the same setting we have for this paper. The newly developed interface in [7] is tested on efficiency, user satisfaction, and unexpected results or confusions amongst users.

3.1 RegularShop

We compare the interface of our OntoNavShop approach with a mocked traditional interface [21, 23, 22, 39], RegularShop. The interface supports an indented list view to visualize the categories inside the Web shop. RegularShop maintains an product assortment identical to OntoNavShop, implements identical Web shop functionalities, and shares the same coloring scheme. As a result, we can compare the visualization and navigation through the product assortment, all other aspects being the same in both Web shop interfaces.

3.1.1 Efficiency

We measure the efficiency of the interfaces with usability metrics applied to specific tasks. A task requires the user to find a specific product in one assigned Web shop. The tasks start by entering the Web shop on its home page. Before that the participants receive a description summary of the specific product to search. The summary states the product name, the product description, and a small image of the product. The tasks end when the user adds the specific product to the shopping list. The usability metrics are implemented inside the Web shops and register the start time and end time of a task, compute the duration of the task difference between end time and start time, and register the number of links the participant has clicked navigating through the Web shop before adding the product to the shopping list. Every participant is assigned with four tasks involving two Web shops (the OntoNavShop approach and the traditional interface) and two products. The first product is used to familiarize the participants with both Web shop interfaces. The second product is used to collect our research results, which we use to falsify or accept our (null-)hypotheses. We cross-validate the results by changing the order of the Web shops, i.e., the first participant starts in the OntoNavShop approach and continues to the traditional interface, the second participant starts in the traditional interface and then moves to the OntoNavShop approach, the third participant starts in the OntoNavShop approach and then goes to the traditional interface, and so on.

We assess the efficiency of the interfaces with two hypotheses, each using one usability metric: task time and, respectively, number of clicks. We aim with our approach to reduce the time consumers need to find the product of their interest, and to reduce the number of clicks involved in this process. This implies the consumers would gain a better overview of the Web shop and can navigate more easily through the product assortment. Hypothesis 1 assesses the interface efficiency in time:

> H_{alt}^{time}: The browsing and navigation through the OntoNavShop consumes less time than through the RegularShop.

The null-hypothesis states there is no time difference between both interfaces:

> H_{null}^{time}: There is no difference in time for browsing and navigating through the OntoNavShop and the RegularShop.

The second hypothesis assesses the interface efficiency by the number of clicks:

> H_{alt}^{click}: The browsing and navigation through the OntoNavShop needs less clicks than through the RegularShop.

The null-hypothesis states there is no difference between both interfaces:

> H_{alt}^{clicks}: There is no difference in the number of clicks for browsing and navigation through the OntoNavShop and the RegularShop.

In order to test the hypothesis we use the one-tailed paired Student's t-statistic. The time and the number of clicks are normally distributed dependent variables. We compute the mean μ, the standard deviation σ, the number of results n, the t-statistic with the number of freedom angles x ($t(x)$), and the one-tailed p-value. We reject the null-hypotheses if the results are significant, having a p-value lower as 0.05.

3.1.2 User Satisfaction

We measure the user satisfaction with the interface of our approach by comparing our interface to the traditional interface of RegularShop and by comparing our interface to the Web shop interfaces of the participants previous experiences. Therefore, we ask the participants six questions based on a 5-point Likert scale, ranging from totally disagree (1) to totally agree (5). The goal of our approach is a Web shop that attracts consumers, decreases the cost of information search, and facilitates the consumer in gaining an overview. The first three questions compare the interface of our approach with the traditional interface of RegularShop:

1. I prefer navigating and browsing through OntoNavShop compared to RegularShop.
2. OntoNavShop allows me to find products more easily compared to RegularShop.
3. OntoNavShop allows me to gain a better overview of the product assortment compared to RegularShop.

The third hypothesis states the Web shops are not equally preferred and the difference is significant.

> H_{alt}^{pref1}: The browsing and navigation in OntoNavShop or RegularShop is not equally preferred and the variations are statistically significant.

The third null-hypothesis determines if the participants prefer both Web shops equally.

> H_{null}^{pref1}: The participants preferences for browsing and navigating in OntoNavShop or RegularShop are equally distributed.

The next three question asked to the participants compare the interface of our approach to the interfaces of the participants experience with Web shops:

4. I prefer navigating and browsing through OntoNavShop compared to other Web shops.
5. OntoNavShop allows me to find products more easily compared to other Web shops.
6. OntoNavShop allows me to gain a better overview of the product assortment compared to other Web shops.

The fourth hypothesis states the Web shops are not equally preferred and the difference is significant.

H_{alt}^{pref2}: The browsing and navigation in OntoNavShop or existing Web shops are not equally preferred and the variations are statistically significant.

The fourth null-hypothesis determines if the participants prefer the OntoNavShop and the Web shops of their experiences equally.

H_{null}^{pref2}: The participants preferences for browsing and navigating in OntoNavShop or existing Web shops are equally distributed.

Using a χ^2-test, we compute the critical χ^2 value associated with the 0.05 probability level. We assume in the third and fourth hypotheses that both interfaces are equally preferred. If the results for the three questions are skewed and the critical χ^2 value is lower as 0.05, than the variance in preference is too large to occur by chance, and the third and fourth null-hypotheses are accepted. In this case, the variations in the dataset are statistically significant. In case of significant variations in the dataset, we determine which Web shop interface is preferred by investigating the dataset. When at least half of the results are in the category agree, we can determine that the OntoNavShop is preferred. If at least half of the results are in the category disagree, we can determine that the alternative Web shop interface (either RegularShop or Web shops of the participants experience) is preferred.

3.1.3 Specific Problems

We measure the specific problems with the interface of our approach with an open question: "Do you have any remarks or comments on the OntoNavShop interface (the layout, navigation, browsing, or searching)?" This allows the participants to describe the issues they experienced using the interface of our approach.

3.1.4 Questionnaire

We developed an online questionnaire for the three evaluation goals as follows. First, the questionnaire introduces the research and describes both Web shop interfaces. In the next phase, the questionnaire collects data on the participants: gender, age, their experience with Web shops ("have you purchased a product or service from a Web shop in the previous six months?", with yes/no answer, and "how many products or services have you bought online in the previous two years?", with answer in ranges: 0/1-3/4-6/7-9/10-15/15+). Continuing the questionnaire, the participants retrieve a summary of the first product (needed for task 1 and task 2). Then, in task 1 the participants enter the first Web shop. After completing task 1, the participants continue to the second Web shop for task 2. After completing task 2, the participants view a summary of the second product, and continue to task 3 and task 4. The usability metrics are implemented in both Web shops. In the next phase, the online questionnaire measures the user satisfaction with the six preference questions. The final question assesses the issues with the interface of our approach. In the end, the questionnaire stores all results in a comma separated file. Having defined the navigation problem of Web design, the opportunities of ontology visualization, and the methodology we apply to evaluate our approach, we continue describing the framework of our approach, which we call the OntoNavShop framework, in the next section.

4 OntoNavShop Framework

This section describes the OntoNavShop Framework as follows. First, we describe the ontology, which is the cornerstone of our approach. Then, we discuss the proposed visualization and navigation techniques for presenting the ontology product assortment. Last, we explain the functionalities added to a Web shop that employs the previously described presentation techniques.

4.1 Ontology

The ontology of OntoNavShop is the knowledge base of the Web shop and is filled with products, product specifications, and categories. We use the OWL DL sublanguage of OWL, because compared to RDFS, OWL DL does allow for inverses and cardinalities, which are useful for products presentations. Furthermore, OWL DL is a decidable language. OWL DL expressions correspond to Description Logics (DL) expressions that we use for our information specifications throughout this paper. We assume that a successful shop carries a broad product assortment, and that the categorization of the products helps the consumers find the products of their interest. When the categorization is recognizable and intuitive, the consumer can navigate straightforward to the relevant product: the product of the consumer's interest.

As depicted in Figure 1, containing a simplified snippet of our ontology, there are two main concepts defined: 'Category' (containing the categories inside the Web shop), and 'Product' (containing the products inside the Web shop). Each product is an individual of the concept 'Product'. The products are categorized according to the pyramid principle. The upper categories describe many products and subcategories, and each subcategory is more specific and describes less products and subcategories. For example, 'Bathroom', 'Bedroom', 'Kitchen',

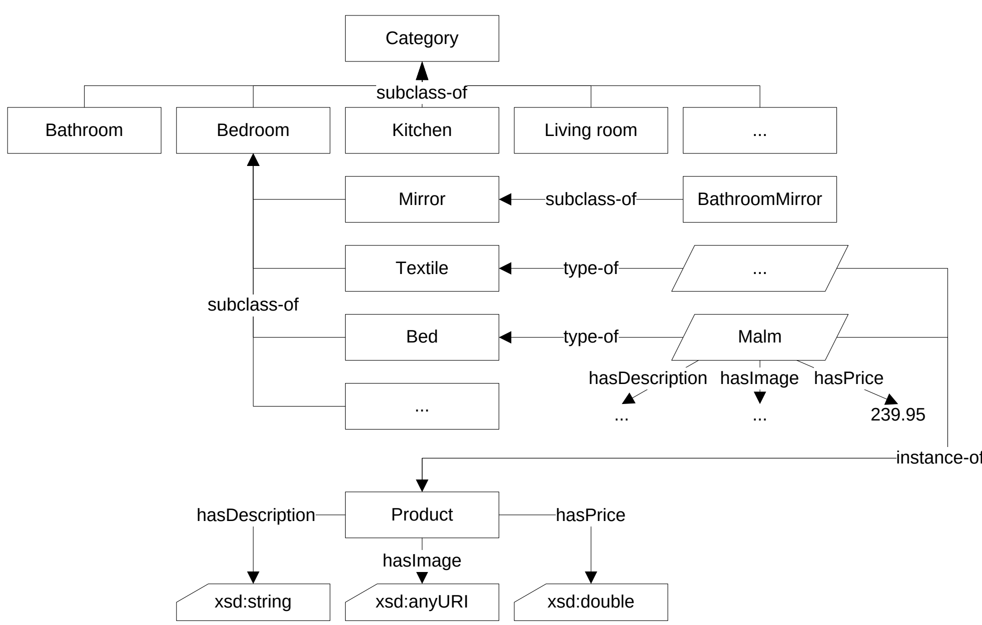

Fig. 1. A simplified snippet of the OntoNavShop ontology.

and 'Living room' are four main categories of a home furnishing shop. The 'Bedroom' department is subdivided into 'Bed', 'Textile', and 'Mirror'. Furthermore, 'Malm' is a type of 'Bed'. This is represented in DL as follows:

$$Malm : Bed$$

$$Bathroom \sqcup Bedroom \sqcup Kitchen \sqcup LivingRoom \sqsubseteq Category$$

$$Bed \sqcup Textile \sqcup Mirror \sqsubseteq Bedroom$$

Every product is categorized by the transitive `rdf:type` relation. Let us define the subcategory 'BathroomMirror', which has two super-categories: 'Bathroom' and 'Mirror'. 'Mirror' was a subcategory of 'Bedroom', therefore the category 'BathroomMirror' is a sub(sub)category of 'Bedroom'. This is written in DL as following:

$$BathroomMirror \sqsubseteq Bathroom$$

$$BathroomMirror \sqsubseteq Mirror \sqsubseteq Bedroom$$

Note that in the above representation, the subclass-of relationship should not be strictly interpreted, but instead it should be viewed as a sub-category relation, as used in taxonomy representations.

Let us consider another example and define that all products must have a price with the data type property 'hasPrice'. The domain of the 'hasPrice' property is 'Product' and the range is data type 'xsd:double'. Besides, all products have a description and an URL referring to their image. These data type properties, 'hasDescription' and 'hasImage', have the domain 'Product' and range data type 'xsd:string', and 'xsd:anyURI', respectively. This is described in DL as following:

$$\geqslant 1\ hasPrice \sqsubseteq Product$$

$$\top \sqsubseteq \forall\ hasPrice.xsd{:}double$$

$$\geqslant 1\ hasDescription \sqsubseteq Product$$

$$\top \sqsubseteq \forall\ hasDescription.xsd{:}string$$

$$\geqslant 1\ hasImage \sqsubseteq Product$$

$$\top \sqsubseteq \forall\ hasImage.xsd{:}anyURI$$

Now, the ontology contains the product assortment of a Web shop. All categories and products are described in the ontology. Next, we have to decide upon the visualization of this ontology.

Although we mainly use the type-of ontological relationship, we do have another advantage from using ontologies: the increasing support of important search engines (e.g., the schema.org project by Google, Bing, and other large search engines). Furthermore, more Websites started to make use of product ontologies, e.g., as specializations of the GoodRelations ontology (which has been embedded recently in schema.org). While we did not make full use of the various relationships existing in the domain ontologies, we do extract from them the type-of relationship, which we exploit in our context.

4.2 Visualization and Navigation

The goal of the visualization is to facilitate the user in exploring the information inside the ontology, the Web shop assortment. According to [13], an intuitive visualization significantly reduces the cognitive load of users in complex structures. We perceive the Web shop as a complex structure, each Web shop has a unique interface and product assortment. In every new Web shop the consumers are challenged to search the products of their interest. In order to fulfill this task, the users of the Web shop need to gain an overview of the Web shop structure [18].

Navigation and visualization are intertwined, each one influences the other in the information exploration process. A good visualization of the categories and products in a Web shop is not sufficient for selecting the best visualization technique. The user has to navigate through the shop, selecting categories of his or her interest, and browse for product information. Navigation allows the user to build a cognitive map of the Web shop, the cognitive map in turn, enables the consumer to re-find products in another visit.

We aim to select visualization and navigation techniques that help the user in building a cognitive map. Shneiderman summarizes the visual information-seeking methodology as: "overview first, zoom and filter, then details on-demand" [38]. Consumers visiting a Web shop for the first time are trying to gain an overview of the Web shop. The users are often questioning themselves what type of products are offered, where they can find the products of their interest, etc. According to the next phase of the Shneiderman mantra, consumers want to zoom and filter: the consumer clicks in a specific direction of the Web shop, most likely to view a subset of the assortment of the Web shop. Sometimes the consumer has a budget or a clear preference for size, color, or any other product property, and so the consumer wants to use a filter mechanism to find desired products. With a (or a few) click(s) the user can request details on-demand of the product: how much does it costs?, what is the size?, or what color does the product have?, etc.

For the OntoNavShop framework, we choose visualization techniques that can be used with the information-seeking methodology of [38]. Apart from that, we have to address the issue of whitespace and aesthetics. The disadvantage of whitespace is the inefficient use of the screen. A good visualization algorithm optimizes the use of the screen by either using all the available screen space or minimizing the visualization. Techniques that minimize screen space are preferred, since these techniques are more effective. The aesthetic of a Web shop is of influence on the success of the site and can only be measured subjectively. Algorithms described as having a high aesthetic value according to the research participants are preferred [38]. Visualizations where the screen is cluttered, concepts and relations are overlapping, are considered as having low aesthetics. The visualization and navigation goal is thus defined by means of six properties: cognitive map, overview, zoom and filter, details on-demand, efficient use of screen, and aesthetics.

[26] proposes a circular view of trees and graphs. The drawing is intuitive: every node is visualized inside a circle. Subtrees connected with a node are displayed in circles with smaller radii around the node. Figure 2 is an example of the circular view. The algorithm is based on the classical tree visualization algorithm of [34]. The circular view algorithm first computes the relative position and scaling factors of nodes relative to their ancestors, bottom-up. Second, the algorithm traverses the tree top-down and computes the absolute x-y

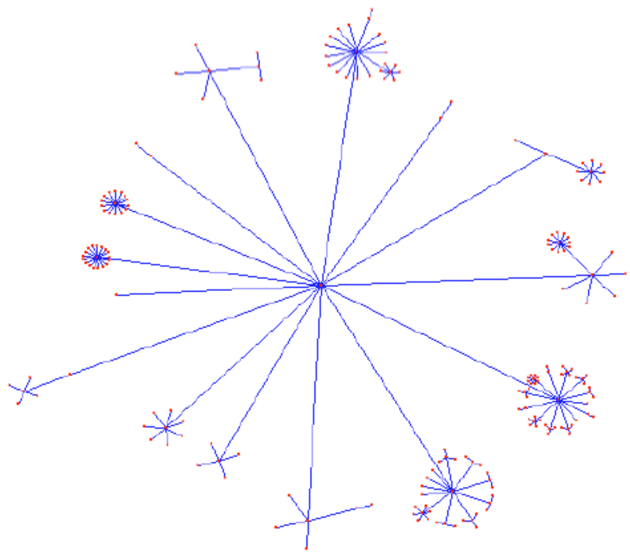

Fig. 2. An example of a circular view.

coordinates using the scaling factors and relative positions. The description of the algorithm is intuitive and simple, however according to the researchers the implementation of the algorithm is complex [26]. As a result only few applications of the algorithm are known.

The visualization can easily be applied to a focus and context (or fish-eye) view. If the algorithm is used for visualizing subtrees, the algorithm is also classified as zoomable. Another option is to select another node as root, which shifts the focus of the tree or graph. The algorithm has two disadvantages, in visualizing large ontologies the lower nodes are visualized in small circles and the edge length decrease exponentially, and the visualization contains a lot of white-space.

Applying the circular view algorithm for the visualization of the product assortment of a Web shops allows to visualize the super-categories using large objects, while subcategories are visualized as children inside their super-categories. This allows the user to gain an overview and build a cognitive map. Categories further away from the root are visualized in small sizes. The algorithm can zoom in categories by changing the root of the visualization. The visualization can display subtrees, filtering out all super nodes. Applying the fish-eye technology, the user is able to extract more detailed information on nodes. The algorithm fills up the screen starting from the center, however the allocated screen is a square, therefore a lot of whitespace remains in all corners. We consider the excessive whitespace as an inefficient use of the screen. According to [26], the circular view algorithm has a high score for aesthetics.

The circular view algorithm includes zoom and filter, details on demand, and has good aesthetics. The algorithm generates a lot of whitespace, which is not effective for using the maximum available screen space, but provides a good overview of the information. To our knowledge, there is no visualization technique more suitable for our goals, therefore we chose to use the circular view algorithm to visualize the product assortment ontology to the consumer.

4.3 Web Shop Functionalities

The Web shop framework only implements the necessary functionalities for our research: detailed product information and a shopping list. A 3D visualization, user recommendations, and related products are features that increase Web shop profit and traffic, however these features are not necessary for our investigation. Once the consumer has found a relevant product in the Web shop, the consumer either wants to add the product to the shopping list or obtain more information on the product. The product information Web page shows the consumer the product name, description, price, and picture. This information is stored inside the knowledge base of the product assortment ontology. The shopping list collects the products the consumer wants to buy; the user can add and remove products to the shopping list. The shopping list must be visible to the consumer while browsing through the Web shop.

5 OntoNavShop Tool

The Jena Semantic Web toolkit [25] allows to manipulate and reason with OWL ontologies. It is an Application Programming Interface (API) for Java. Jena, originally developed by the HP Labs Semantic Web Programme, has been used for numerous applications, amongst other in the Hermes framework [10, 36], partially developed us. Using Jena we create the ontology assortment with the concepts 'Category' and 'Product', and the data type properties 'hasDescription', 'hasImage', and 'hasPrice' as described in the previous section. The ontology is filled with the IKEA product assortment, an assortment well-known worldwide.

Using a Web crawler, we collected the following data from the IKEA Web shop for all products: the super-category name, category name, product name, product description, product price, and the URL of the product image. For every category we collected the super-category name and the category name. The dataset contains 6,373 products and categories with many duplicates. As we aim for a medium sized Web assortment (100 - 1,000 products) we chose to trim the dataset. Also, we need to remove duplicate product names: for example in the current data set the bookcase named BILLY occurs in three colors with two different prices. Characters as "Ö", "Ä", and "Å", "\", and "+" are adjusted as the Jena technology does not accept these characters. We apply the following operations to clean the dataset:

1. Remove duplicate products (products with identical product names, descriptions, and prices).
2. Remove identical product names in a category.
3. Remove illegal characters "\" and "+".
4. Change characters "Ö", "Ä", and "Å", to "O", "A", and "A", respectively.

After these operations, the dataset contains 146 categories, 156 subcategory relations, and 477 distinct products. We fill the ontology with the trimmed dataset by inserting all super-categories, subsequently all subcategories, and last, all products with the product descriptions, prices, and image URL's.

5.1 Visualization and Navigation

In the literature, we found the usage of the Scalable Vectorized Graphics (SVG) technology to visualize XML documents. [16] uses the SVG technology for visualizing a map of the transport network. The SVG files are written in XML, which is readable by both machines and users. Also, the SVG format is a recommendation of the World Wide Web Consortium (W3C). SVG is supported by all major browsers (Firefox, Opera, Safari, and Chrome), except for Internet Explorer. With the usage of the Adobe SVG Viewer plugin, Internet Explorer is able to visualize SVG files. The lack of support of the SVG technology by Internet Explorer is considered as a disadvantage. However the XML-graphics of the SVG allows for both graphics and navigation, and integrates with other W3C standards, such as the HTML, CSS, and JavaScript. Therefore, we choose to use the SVG technology. As for Web servers, we are choosing for a technology that allows for server scripting. The Apache Tomcat server supports HTML and Java Server Pages (JSP), which is compatible with the Java-based Jena technology. We built our application as an Apache Tomcat servlet.

The circular view algorithm of [26] computes the x and y coordinates for the circle's centers, which represent categories and products in the product assortment ontology. The algorithm is divided in two steps: first, compute the relative position and scaling factors of the nodes (categories or products) to their direct ancestors (the super-categories) bottom up. Second, compute the absolute x-y coordinates top-down. Conforming to the rule of 7 [28], we visualize at most 7 categories and a maximum of 7 subcategories (i.e., products) in a category. If necessary, for extra categories or products we use the guided tour paradigm by inserting an extra virtual "more" element, which links the next to-be-visualized subcategory/products. For the following visualization an extra "back" element is inserted, which allows one to navigate back to the previous visualization.

5.1.1 Converting to SVG

The core of a Web shop is formed by its products. The circular view visualization is aimed to visualize a circle with the product (or category) name. Because the products are the most valuable information inside a Web shop, we chose to show tooltips with the product description and a small picture if the user hovers with the mouse over a product circle. We create the tooltips with JavaScript. The JavaScript is executed while loading the SVG visualization and responds if the users points the mouse over an SVG element that has the manually created `<DESC>` and `<IMGURL>` elements. In this event, the JavaScript visualizes a rectangle box with a gray border. Inside the box the product description and a small image of the product are present.

The circular view algorithm computes the absolute x and y coordinates of our widgets (text and circles). Using the SVG `<CIRCLE>` and `<TEXT>` element, the circles and their titles are inserted in the SVG animation. Circles are assigned with the x and y coordinates, the radius, the background color, the border color, and the border width. Text elements are filled with information on the x and y coordinates (center coordinates for circles and top-bottom coordinates for text), the font-size and color, and the font family. Because text and circles are overlapping each other in the visualization, we chose to first add the circles to the SVG visualization, and second the text, in this way the text is always visible over the circles.

To differentiate the hierarchy in the visualization more clearly, the displayed products and categories are visualized in three different text-sizes and four different colors. The root category is visualized in light blue and a large font-size. A subcategory is visualized in medium blue and a medium font-size. Subsubcategories are visualized in dark blue with a small font-

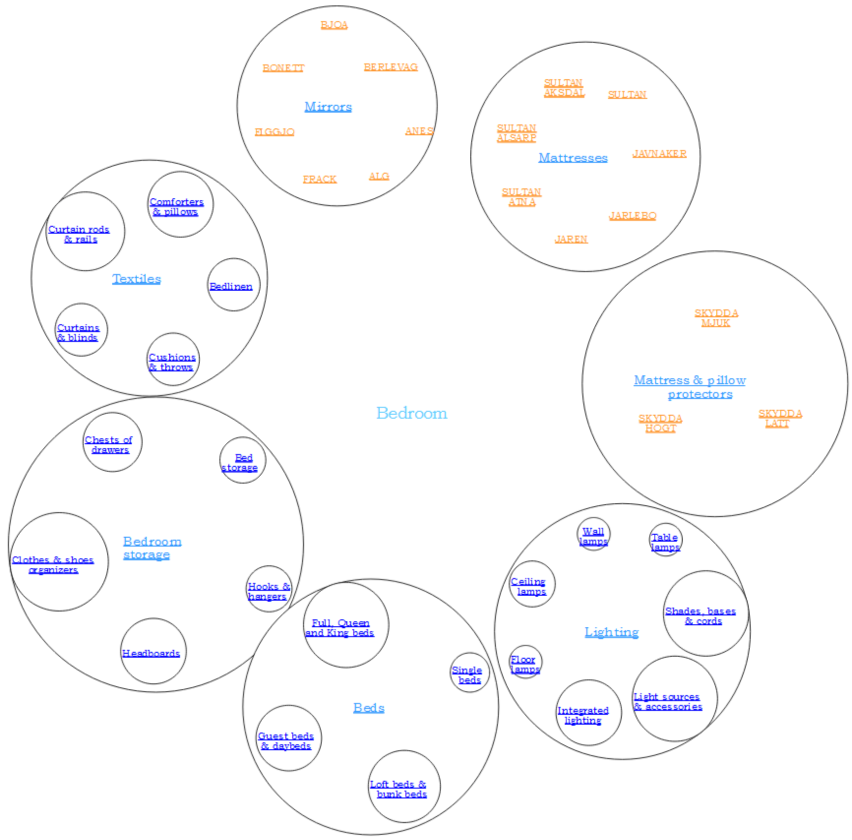

Fig. 3. OntoNavShop category ‘Bedroom’ (visualization by the circular view algorithm).

size. Products are colored orange with a small font-size. This color scheme emphasizes the hierarchy of super- and subcategories and differentiates the product circles from the category circles. Figure 3 displays the circular view of the root ‘Bedroom’ in an SVG visualization. We group the `<CIRCLE>` and `<TEXT>` elements together in a `<G>` element and add a navigation link to these elements: the `<XLINK>` element. Categories link to a new visualization where the selected category becomes the root node. Products link to the product information page.

5.2 Web Shop Functionalities

The product information page presents the consumer with all information about the product in the ontology. The ontology contains the product, a product description, the product price, and an URL referring to the image location. The product information page collects the above properties and presents the consumer with a button to add the product to the shopping list.

The product information page is built similarly to the product information page in the IKEA Web shop. The display is divided in two, with on the left side a large image of the product and on the right side: the name in capitals, the product description, the price, and the ‘Add to shopping list’ button. Figure 4 shows the product information page of the MOLGER mirror.

Fig. 4. OntoNavShop product information page.

The product information page holds the 'Add to shopping list' button, which adds the product to the shopping list. The shopping list contains a quantity of 1 or 0 of a product. This design choice was done as the shopping list only has a decoration value, the Web shop is constructed for research purposes, users are not able to actually buy the products. Therefore a simple shopping list was implemented to give the users a look and feel of an actual Web shop.

5.2.1 Shopping List

The shopping list is a collection of products the consumer has collected during the Web shop visit. The shopping list is added to the session of each consumer in the Apache Tomcat Web server. The session variable is holding a unique reference to the product, the product name, description, price, and a link to the image location. The unique reference allows us to extract all product information from the ontology, however querying the ontology is slow, therefore we chose to store all information for each session in the session variable.

The shopping list is shown on the right side of the Web shop while the consumers are browsing through the assortment or view more information on products. The products and the prices are listed as a table with a final row that computes the total price of all products in the shopping list. The products are listed by their names, and the names are linked to the product information page. The final column of the table displays a remove button, in order for the consumer to remove the product from the shopping list. Figure 5 displays a shopping list.

5.3 Benchmark Web shop

As discussed in Section 3, we use the benchmark Web shop RegularShop, which is a Web shop that has the same product assortment as the OntoNavShop. The RegularShop implements identical Web shop functionalities as OntoNavShop, however navigation through the product assortment differs from OntoNavShop, as is the presentation of categories and products in RegularShop.

Shopping list:

Product	Price	
FRAJEN	$ 7.99	Remove
JANSJO	$ 29.99	Remove
KOPPLA	$ 5.99	Remove
SKYDDA HOGT	$ 19.98	Remove
Total:	$ 63.95	

Fig. 5. OntoNavShop shopping list.

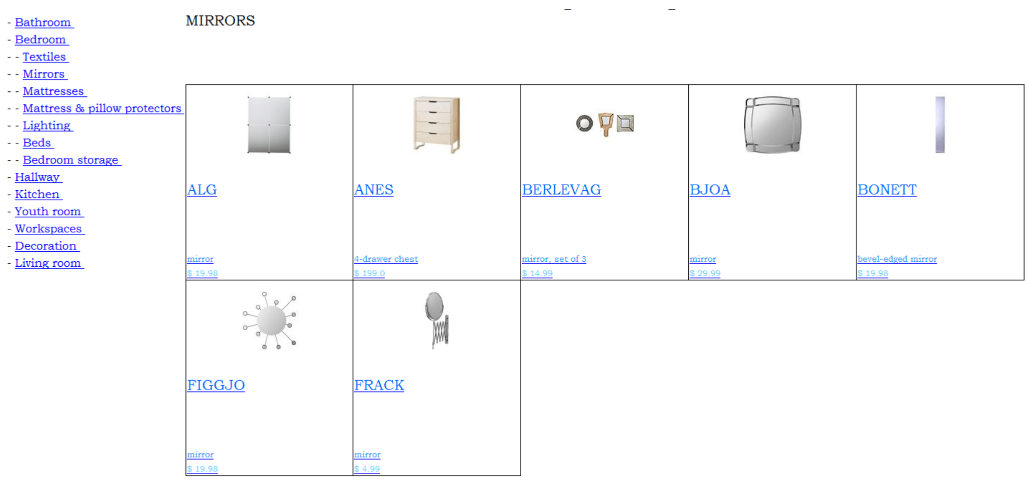

Fig. 6. RegularShop, products in the 'Mirrors' category (a subcategory of 'Bedroom').

5.3.1 Navigation

RegularShop incorporates a list view of categories on the left-hand side of the screen, i.e., an indented list view that is similar to the Windows Explorer view and multiple Web shop designs [21, 22, 23, 39]. Categories containing subcategories can be expanded in the list view, and categories exclusively filled with products are visualized in the center of the screen. By default, the center of the screen is empty. For a category with no subcategories, the center of the screen is filled with the products inside the selected category. The products are visualized with a maximum of five products per line. The information is similar to the OntoNavShop visualization, the product names, descriptions, and medium product images are shown. Figure 6 previews the product visualization in RegularShop.

The number of category layers visualized by the OntoNavShop and RegularShop differs. In the OntoNavShop two layers of categories are visualized: the subcategories of the root category, and the subsubcategories (i.e., the subcategories of the subcategories) of the root category. RegularShop visualizes one layer of categories: the subcategories of the root category. We have chosen to visualize one layer in the RegularShop, because the one layer indented list visualization of subcategories matches traditional Web shop interfaces. Visualizing two layers of subcategories results in an expanded indented list, which is not alphabetically organized. Used for large product assortments, the list grows larger as the screen height, and therefore requires scrolling. As a result, the user cannot gain an overview of the assortment. A strong point of the circular view algorithm [26] is the overview users gain with the visualization of large trees. This advantage is lost if the algorithm is used for visualizing one layer of categories. Therefore we have decided to visualize two layers of categories at-a-time.

5.3.2 Web Shop Features

The RegularShop is equipped with similar features as the OntoNavShop, namely: the product information page, the shopping list, and a disabled checkout procedure. The product information page is almost similar to the product information page in the OntoNavShop, there are a few alignment differences due the variety of techniques used. The RegularShop is

Fig. 7. RegularShop, product information page.

programmed in HTML only, and the OntoNavShop product information page is visualized as an SVG graphic. The structure remains unchanged, on the left side is the presentation of the product in a large image, on the right-hand side is the product name, the product description, the price of the product, and a button to add the product to the shopping list. The coloring and font-sizes are identical in the two Web shops. Figure 7 displays the product information page of the MOLGER mirror in RegularShop.

6 Results

51 subjects participated on the research, of which 21 females and 30 males. All subjects are between the age of 14 and 37 years old, most of the participants are between the age of 21 and 28 years old. Figure 8 shows the distribution of the males and females per age category.

All subjects have purchased at least one product in a Web shop in the previous six months. 25 participants bought less than 10 products in the previous two years and 26 participants bought 10 or more products in the previous two years. Figure 9 shows the subjects experience with online shopping by the number of products or services the subjects have bought in the previous two years, where the answers were formulated in ranges as described on the x-axis.

6.1 Tasks

The participants performed four tasks, where a task requires the participant to find and add a given product (Erbium ceiling lamp and Branas basket) to the shopping list of the Web shop (OntoNavShop and RegularShop). Before the task starts, the subject is introduced to the product. Next, the participant can start the task by entering the Web shop. The task stops when the user has added the product to the shopping list of the Web shop. The usability metrics measure the time in seconds and count the number of clicks the subjects need to complete a task. Figure 10 summarizes the time results per task in a box plot. Figure 11

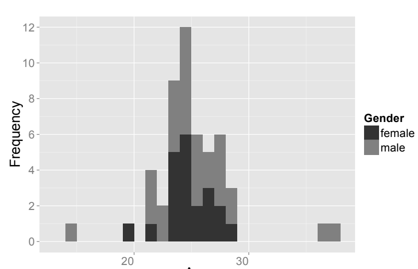

Fig. 8. The age and gender distribution of the participants.

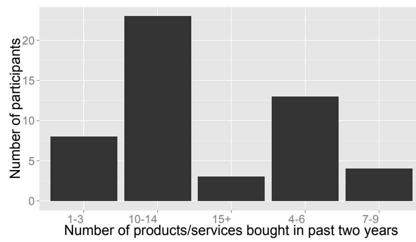

Fig. 9. The experience with online shopping among the participants.

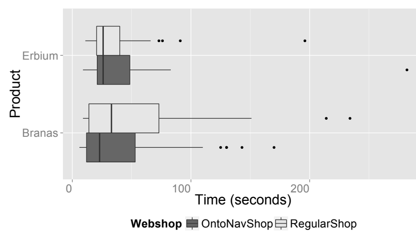

Fig. 10. Box plots of the search time for each product and Web shop.

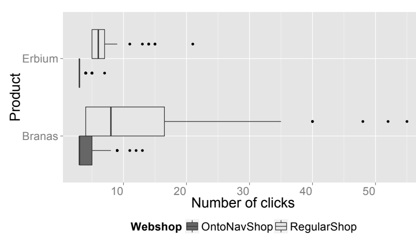

Fig. 11. Box plots of the number of clicks for each product and Web shop.

summarizes the click results per task in a box plot. The lower whisker represents the minimum time or clicks needed, the upper whisker the maximum time or clicks used. The black line on the left side of the boxes represents the first quartile, the dark colored box the second quartile, the light colored box the third quartile, the black line on the right side of the box represents the fourth quartile, and the median is represented inside the box where the colors change.

6.2 User Satisfaction

All subjects received questions regarding their preference for the OntoNavShop (see Section 3.1.2). The first three questions required the subjects to compare the OntoNavShop with RegularShop. The next three questions required the subjects to compare the OntoNavShop with Web shops from their experience. The results are shown into the chart of Figure 12.

6.3 Specific Problems

The online questionnaire also covered specific problems by asking the following questions: "Do you have any remarks or comments on the OntoNavShop interface (the layout, navigating,

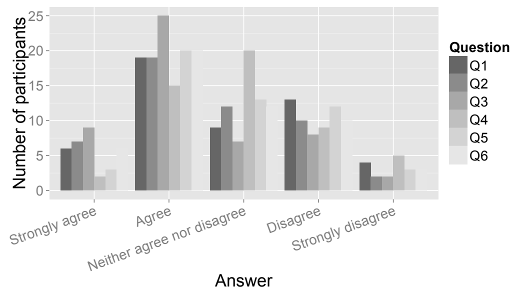

Fig. 12. A histogram of the participants preferences.

browsing, or searching)?" to the 51 participants. The following comments (with their number of users in parentheses) were received:

- OntoNavShop needs a big screen to browse (feedback from 3 users),
- not used to "think" in circles, difficult to gain an overview (feedback from 2 users),
- use more colors (feedback from 1 user),
- a low price is more important than a great design (feedback from 1 user).

7 Discussion

In this section, we discuss the results that we obtained from the questionnaire. We start off with an analysis of the participants. The participants can be described as young adults between the ages of 21 and 28 years old. The male/female distribution is a little skewed towards males (59% males and 41% females). The research focuses on online shoppers of both genders, thus we assume the subjects of this research represent a subgroup of the online shoppers: the young adults. Since the research questionnaire was spread over the campus of the Erasmus University Rotterdam, the age representation is explained by the ages of students. The 14 year old participant is the only exception and is probably an error of a student filling in the questionnaire.

This subgroup of young adults has one important advantage over other age groups for our research: the participants are assumed to be familiar with computers, the Web, Web shops, and online shopping. We find evidence for this assumption in the fact that all participants bought at least one product in the previous six months. Specifically, half of the participants (51%) have purchased 10 or more products in the previous two years. Based on this knowledge, we can say that all subjects have experience with Web shops and online shopping. Therefore, subjects can compare the OntoNavShop interface with Web shop interfaces of their own experiences.

7.1 Tasks

Let us discuss the tasks results, beginning with the time measurements and continuing with the click path results. For both results, the first and second task (searching for the Erbium ceiling lamp in the two Web shops) are used as training, to make the participants familiar with both interfaces. The third and fourth task (searching for the Branas basket in the two

Web shops) results are used to test the hypotheses with a one-tailed paired t-test. We use a Student's t-test because we have a nominal variable (OntoNavShop versus RegularShop) and one measurement variable (one of the usability metric variables: time or number of clicks).

7.1.1 Time

The first and second task, which require the participants to search for the Erbium ceiling lamp, are used for familiarizing the participants with the interface. With the second search (the third and fourth task), for the Branas basket, the subjects had some experience with both Web shops, thereby reducing the cognitive load. The OntoNavShop has the lowest search time, and the RegularShop has the longest search time. The most subjects needed less time finding the product in the OntoNavShop. Using the one tailed paired t-test, we determine whether the participants could find the Branas basket in less time in the OntoNavShop. The mean difference task time ($\mu = 11.69$, $\sigma = 71.20$, $n = 51$) is not significantly greater than zero, one tail $p = 0.1233$, does not provide evidence that the participants find the Branas product in less time using the OntoNavShop interface. The 95% confidence interval about the mean difference is (-8.34;31.71), meaning that 95% of consumers using the OntoNavShop interface need 31 seconds less to 8 seconds more time than they would need using the RegularShop interface.

Based on the one tail p-value of 0.1233 we accept H_{null}^{time}, i.e., there is no difference in time for browsing and navigating through the OntoNavShop and the RegularShop. Even though we do not have enough evidence to confirm that OntoNavShop is significantly faster for browsing and navigation through the product assortment than the RegularShop, in this experiment OntoNavShop did turn out to be faster on average. Because the OntoNavShop visualization shows more information than the RegularShop interface, respectively two layers of categories versus one layer of categories, the information content and cognitive load is higher for a few users of the OntoNavShop interface. As a result, we assume that the results reflect the higher cognitive load with sometimes (but not often) higher task times for the OntoNavShop.

7.1.2 Number of Clicks

Applying the one tailed paired t-test to the search for the second product (task 3 and task 4) we obtain the mean number of clicks ($\mu = 9.10$, $\sigma = 14.56$, $n = 51$) and a one tailed $p = 0.0000$. The p-value shows that participants need significantly less clicks to add the relevant product to their shopping list in the OntoNavShop. The 95% confidence interval about the mean difference is (5.00;13.19), meaning that 95% of consumers using the OntoNavShop interface need 5 to 13 clicks less than they would need using the RegularShop interface.

Because the number of click results obtained from the tasks are unfair, we adjust the data. The results are unfair, because the minimum number of clicks differs in each Web shop for the two products. The first product could be added to the shopping list with a minimum of 3 clicks in the OntoNavShop, while the minimum number of clicks for the same product in the RegularShop is 5 clicks. The minimum number of clicks for all products and Web shops are collected in Table 1. To make the comparison more fair, we subtract the minimum number of clicks from the corresponding task. Besides, the difference in the minimum number of clicks, the OntoNavShop product assortment visualization allows the participants to view two layers at a time, instead of one layer. In other words, the participants can click on the subsubcategory 'Bed' directly (1 click) from the initial visualization in the OntoNavShop, while they need 2 clicks in the RegularShop visualization (first the subcategory 'Bedroom' and second the subsubcategory 'Bed'). Therefore, we divide the number of click results for all tasks performed in the RegularShop by 2.

Using the adjusted data and a one-tailed paired t-test on the third and fourth task, we obtain a mean number of task clicks ($\mu = 3.27$, $\sigma = 7.86$, $n = 51$), and a one tail $p = 0.0023$. Based on this p-value we conclude that the OntoNavShop remains significantly faster, by using less clicks, in browsing and navigation than the RegularShop. The 95% confidence interval about the mean difference is (1.05;5.48).

Based on both the one tail p-values of the original data ($p = 0.0000$), and the adjusted data ($p = 0.0023$), $H^{\mathrm{clicks}}_{null}$ is rejected and $H^{\mathrm{clicks}}_{alt}$ is accepted, i.e., the browsing and navigation through the OntoNavShop needs less clicks than browsing and navigation through the RegularShop. The OntoNavShop interface allows the users to browse and navigate faster, in less clicks, than the RegularShop interface. With these results we conclude that the OntoNavShop product assortment visualization allows the users to gain a better overview of the product assortment.

7.2 User Satisfaction

The subjects preference towards the OntoNavShop is measured in six questions, the first three questions measure the subjects preference between the RegularShop and the OntoNavShop, the fourth, fifth, and sixth question measure the subjects preference between OntoNavShop and previous Web shops of the subjects experience. Answers are based on a 5-point Likert scale, therefore the data is ordinal scaled. The preferences are skewed towards positive answers in preference for the OntoNavShop. We will test the significance using the χ^2-test. The χ^2-test compares the expected responses (both Web shop interfaces are equally preferred) with the actual responses. First, the totally disagree and disagree data are grouped into a group disagree, and all totally agree and agree data are grouped into a group agree. Then the critical χ^2 value with the 0.05 probability level is computed.

Based on the critical χ^2 values for preference 1, 2, and 3 we conclude that the preferences are not equally distributed and the variation is statistically significant. Therefore we reject $H^{\mathrm{pref1}}_{null}$ and we accept H^{pref1}_{alt}, i.e., the browsing and navigation in OntoNavShop or RegularShop is not equally preferred and the variations are statistically significant.

Analyzing closer the results we notice that in all three questions, the agree group collects 50% or more of all preference results. Therefore we conclude that the participants prefer the OntoNavShop for browsing purposes, in finding products more easily, and for gaining an overview compared to the RegularShop. Based on the critical χ^2 value for the 0.05 probability level for preference 4, 5 and 6 we notice that the dataset has insignificant variations for question 4 and 5. Based on the critical χ^2 value for question 6 the results are not equally distributed, and we notice that over 50% of the participants think they can find products more easily in the OntoNavShop than in existing Web shops. Since the dataset of two of the

Table 1. Minimum number of clicks per product and Web shop.

	Erbium	Branas
OntoNavShop	3	3
RegularShop	5	4

three preference questions have insignificant variations, we accept H_{null}^{pref2} and reject H_{alt}^{pref2}, i.e., the participants preferences for browsing and navigating in OntoNavShop or existing Web shops are equally distributed.

7.3 Specific Problems

The first comment received from users was related to the visualization size. Three participants thought that the OntoNavShop visualization needed a big screen. We agree on this comment, however one can note that the visualization depends on the number of layers that are visualized. The OntoNavShop tool visualizes two layers of the product assortment tree, as a result a lot of information needs to be presented. It is a strong point of the circular view algorithm that the screen does not get cluttered with information, but on the other hand, the visualization can grow to large sizes.

The second comment, noted by two participants, was upon the circular view visualization. The subjects had difficulties gaining an overview because they are not used to "think" in circles. These views are understandable, within the Western world we are used to read text from left to right from lines from top to bottom on a page. In the OntoNavShop visualization it is difficult to determine where to start reading, also because the categories are not sorted alphabetically. However, we disagree with the opinion of these two subjects in having difficulties gaining an overview, our data suggests that users of the OntoNavShop gain an overview more easily, since most of the participants need less clicks to perform the tasks in the OntoNavShop.

One participant wanted to see more colors in the OntoNavShop. The OntoNavShop tool used text coloring for differentiation of super- and subcategories or products. Furthermore, the background was filled white and all other texts and lines are in black color. Our research focus is on the product assortment visualization, and we wanted to keep the color scheme simple, so that coloring does not distract the participants in the designed experiment. The "price is more important" comment is certainly true, however, it does not represent the focus of this research.

8 Conclusions

In this research, we recognized the navigation problem of Web shops and the opportunities offered by ontology visualization for solving this problem. Based on domain ontologies we developed a product assortment visualization framework for a Web shop named OntoNavShop, in which products and product categorizations are stored in an ontology. Our OntoNavShop approach uses the ontology to infer super- and subcategories of products and categories. Using the circular view algorithm of [26] with some adaptations, the OntoNavShop approach is able to visualize the graph (tree in our case) of the product assortment ontology. The circular view algorithm visualizes the children of a node inside a circle around the node, therefore allowing the user to gain a better overview of the data, in our case the product assortment. Furthermore, we implemented the OntoNavShop framework into the OntoNavShop tool: a fictive Web shop filled with a subset of the assortment of the IKEA Web shop. To our knowledge there are three Web-based implementations for visualizing ontologies, but none of them used for Web shops. With respect to this, our approach is unique and adds a new solution for product visualization in Web shops.

In order to evaluate our approach, we designed an online questionnaire, which was completed by 51 participants. The participants were asked to complete four tasks, each task required the participant to add one given product to the shopping list of one Web shop. Two products were selected from our product assortment for these tasks. During the tasks, the questionnaire measured the time and number of clicks the participants needed to complete the task. With these statistics we could measure the efficiency of the OntoNavShop using a one-tailed paired Student's t-test. We noticed that the participants use less time navigating and browsing through the OntoNavShop than in the RegularShop, however the results are not significant with a confidence level of 95%. We argue that the difference is due to the visualized information content, which was higher with the OntoNavShop interface where two category layers are visualized. As a result, the cognitive load for the OntoNavShop interface was higher for some of the participants.

Measuring the efficiency in the number of clicks, the participants used less clicks in the OntoNavShop to complete their tasks. This result is significant on the 95% confidence level. Based on this result we conclude that the OntoNavShop allows the users to gain a better overview of the product assortment. Both average time and number of clicks measures are smaller for OntoNavShop, but statistical significance is achieved only for the latter measurement.

The user satisfaction was measured comparing the OntoNavShop to the RegularShop and comparing OntoNavShop to Web shops of the participants experience. The online questionnaire used three questions that compared the preference of navigating and browsing, how easy it is to find products, and the ability to give a good overview of the product assortment. The results are analyzed with a χ^2-test, and we conclude that the answers are not equally distributed and the variations are statistically significant. The participants prefer the OntoNavShop over the RegularShop based on the skewed distribution, where over 50% of the participants agreed with all three preference questions.

All participants had a previous experience with Web shops, which allowed them to compare the OntoNavShop interface with Web shop interfaces of their experience. For this comparison, the same questions were used. On average the participants did prefer the OntoNavShop, but the results were not proven by the critical χ^2 value on the 0.05 probability level. With exception of the sixth preference question, the answers for the fourth and fifth preference questions was found to have insignificant variation.

The specific problems with the OntoNavShop interface were collected using an open question and most of 51 participants did not report specific problems. Three participants noticed problems related to the size of the visualization, and two participants identified problems regarded gaining an overview using a circle-based visualization. Based on the results obtained from the questionnaire on the user satisfaction, we consider both problems as minor and as possible further research.

In summary, we developed a framework and a tool for visualizing product ontologies for Web shops. Our approach allows users to gain an overview of the product assortment more easily than traditional Web shops, and the subjects are more satisfied browsing and navigating with the used circular view-based interface.

Our current research can be extended in several directions. First, we plan to use a different type of product assortment. The IKEA product assortment is well-known and relatively large, where the subtrees of the main categories have many nodes. It is interesting to experiment with a medium-sized product assortment, such as the product assortment of a supermarket. Compared to IKEA, the categorization of such a shop is more specific and has more layers that contain only a few nodes (i.e., categories).

Another suggestion regards the flexibility of the framework. At the moment the OntoNavShop visualizes two layers of categories and products. We expect the user satisfaction to improve when users can determine the number of visualized layers or the maximum number of visualized nodes at a moment on the user screen. Adaptation of the user interface to the user preference has proven useful in the past [4]. Additionally, the rising popularity of mobile devices stresses the need for (interactive) visualizations optimized for smaller screens.

The most promising future work concerns applications of the ontology functionalities, e.g., building recommender systems [27]. Combining an ontology-based recommender system with our OntoNavShop Web shop can create a more advanced Web shop exploiting ontologies to a larger extent than ever before and thus contributing to an increased user satisfaction.

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