Adapting Generic Web Structures with Semantic Web Technologies: A Cognitive Approach

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ABSTRACT

The research described in this paper focuses on adapting generic Hypermedia Environments with the use of Semantic Web technologies. The use of machine understandable semantics in Web applications is increasing significantly, ranging from semantic search queries to personalized product recommendations. Given the significance of human factors in Web structures' transformations, we propose an Ontological Web Personalization and Adaptation Mechanism based on users' cognitive parameters. This mechanism consists of a number of interrelated components; modeling users based on their cognitive parameters and providing content adaptation based on semantics. An RDFa schema has been designed that enables standard annotations in any XHTML Web-page, thus making structured data available for the adaptation process, but also for any service or tool that supports the same standard. Our work has been positively evaluated using an existing commercial Web-site that was filtered through the adaptation mechanism based on users' cognitive parameters.

1. INTRODUCTION

Advances in Web-based oriented technologies and services are taking place with a considerable speed around the world. As communications and IT usage become an integral part of many people's lives and the available products and services become more varied and sophisticated, users expect to be able to personalize a service to meet their individual needs and preferences.

Furthermore, the plethora of information and services as well as the complicated nature of most Web structures intensify the orientation difficulties, as users often lose sight of their original goal, look for stimulating rather than informative material, or even use the navigational features unwisely. As the eServices sector is rapidly evolving, the need for such Web structures that satisfy the heterogeneous needs of its users is becoming more and more evident [1].

In recent years, there has been a rapid growth in research and experiments that work on personalizing computer-mediated platforms, according to user needs and indeed, the challenges ranging in this area are not few. A challenge is to design a comprehensive and expressive user model composed of cognitive parameters that can be used in Web systems. Based on that user model, engineers will design and develop personalized and adaptive interfaces and software. This will enable easy access to any content while being sufficiently flexible to handle changes in users' context, perception and available resources, optimizing the content delivery while increasing their comprehension capabilities and satisfaction.

At a more technical level, a challenge is to study and design structure of meta-data (semantics) coming from the providers' side, aiming to construct a Web-based personalization mechanism that will serve as an automatic filter adapting the received hypertext/hypermedia content based on the comprehensive user profile. The final system will provide a complete adaptation and personalization Web-based solution to users satisfying their individual needs and preferences.

Henceforth, this paper describes a Personalization and Adaptation mechanism that consists of three main sections; i) description of an Ontological Cognitive User Model (OCUM) for modeling users' unique cognitive parameters that could be used in any online computer mediated application, returning an optimized adaptive result to users, ii) an adaptation mechanism that maps the OCUM with semantically annotated web objects based on an RDFa content schema for smart web objects, and iii) description of an RDFa content schema that enables standard annotations in any XHTML Web-page, thus making structured data available for the personalization and adaptation process, but also for any service or tool that supports the same standard. An evaluation of the expected impact of the content reconstruction concludes the paper.

2. BACKGROUND

Effective personalization of content involves two important challenges: accurately identifying users' comprehensive profiles and mapping any hypermedia content in such a way that enables efficient and effective navigation and presentation during the adaptation process.

Today's most popular Web-sites (http://www.alexa.com) like Google, Microsoft Live, Yahoo, Amazon, eBay, BBC news etc. primarily use customization techniques where users have direct control and explicitly select between certain options. In the same line, personalization is driven by the system which tries to serve up individualized pages to users according their profiles and needs. Although, personalization is used by many of these popular Web-sites (especially Google), the techniques they maintain are lying under the predetermined customization of services or products and not to the actual personalization and dynamic reconstruction of content based on user preferences. User preferences might be extended beyond the traditional characterizations of users that might include intrinsic cognitive values that could be considered as the control factors for an efficient adaptation process.

Many search engines/systems, such as Google Personalized Search (http://www.goggle.com/psearch), build a user profile by means of implicit feedback where they adapt the results according to the search history of users. Many systems employ search personalization on the client-side by re-ranking documents that are suggested by an external search engine [2, 3]. Since the analysis of pages in the result list is a time consuming process, these systems often take into account only the top ranked results. Also, only the snippets associated with each page in the search results is considered as opposed to the entire page content.

One increasingly popular method to mediate information access is through the use of ontologies [4]. Researchers have attempted to utilize ontologies for improving navigation effectiveness as well as personalized Web search and browsing, specifically when combined with the notion of automatically generating semantically enriched ontology-based user profiles [5].

One such system is OntoSeek [6], which is designed for content-based information retrieval from online yellow pages and product catalogs. OntoSeek uses simple conceptual graphs to represent queries and resource descriptions. The system uses the Sensus ontology [7], which comprises a simple taxonomic structure of about 50,000 nodes.

Another similar system developed by Labrou and Finin [8] uses Yahoo! [9] as an ontology. The system semantically annotates Web pages via the use of Yahoo! categories as descriptors of their content. The system uses Telltale [10, 11, 12] as its classifier. Telltale computes the similarity between documents using n-grams as index terms. The ontologies used in the above examples use simple structured links between concepts.

A richer and more powerful representation is provided by SHOE [13, 14]. SHOE is a set of Simple HTML Ontology Extensions that allow WWW authors to annotate their pages with semantic expressed in terms of ontologies. SHOE provides the ability to define ontologies, create new ontologies which extend existing ontologies, and classify entities under an "is a" classification scheme.

Google has also recently announced (http://www.google.com/webmasters/tools) that their search engine is going to support enhanced searching in Web-pages, by using RDFa and Microformats embedded in XHTML. Google states that the extra (structured) data will be used in order to get results for Product Reviews (e.g. CNET Reviews), Products (e.g. Amazon product pages), People (e.g. LinkedIn profiles) and any other types of resources will be made public through the data-vocabulary.org (http://rdf.data-vocabulary.org/rdf.xml).

However, the abovementioned ontologies do not utilize user centric personalization approaches in the sense of considering intrinsic user values, such as cognitive characteristics for the adaptation of Web content.

3. A PROPOSED ONTOLOGICAL ADAPTATION MECHANISM

Web Personalization and Semantics are two research areas that attempt to provide solutions to user problems related to content navigation and presentation. They both employ specialized approaches and techniques for alleviating difficulties and constraints imposed by the Web.

Key factors that are employed by personalization mechanisms for filtering user profiles and adapting content accordingly are based on cognitive parameters. On the other hand, Semantics contribute to the whole adaptation process with machine understandable representation of user profiles and web content.

Therefore, the main scope of this section is to bring together the abovementioned considerations and propose an Ontological Adaptation Mechanism (OAM) (Fig. 1) that is composed of three main layers; i) User Profile Layer, ii) Adaptation Mapping Layer, and iii) Web Content Layer.

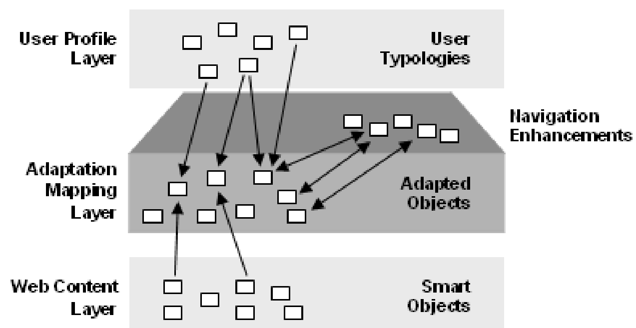

Figure 1. Ontological Adaptation Mechanism

The first layer of the OAM is the User Profile Layer; responsible to model users' cognitive typologies. In a high level view, each user typology is a semantically defined object (RDFa object) that contains all the intrinsic cognitive parameters of users. On the other end of OAM; the Web Content Layer model's any hypermedia Web content with specific meta-characteristics using again an RDFa vocabulary to annotate specific areas of an XHTML document as Smart Objects. The middle layer; the Adaptation Mapping Layer is responsible for mapping the User Typologies of the User Profile Layer with the Smart Objects of the Web Content Layer. Based on this mapping, all Smart Objects of an XHTML document are adapted (i.e. show content in a diagrammatical form in case of an Imager) and extra navigation enhancements are provided to the end-user.

For example, a user has been identified of a particular typology in the User Profile Layer. Furthermore, any semantically annotated Web content will be derived in the Web Content Layer. Finally, the Adaptation Mapping Layer will map the semantic user typology with the semantic Web content providing an adapted result as well as additional navigation enhancements.

The following sections will explain in more detail how each layer utilizes the theoretical conceptualization of the Ontological Adaptation Mechanism.

3.1 User Profile Layer

The User Profile Layer implements the Ontological Cognitive User Model (OCUM). OCUM is based on the theoretical conceptualization of a comprehensive model in the field of Web personalization and adaptation, which integrates cognitive parameters and attempts to apply them on a Web-based environment. The particular cognitive concepts have already been proposed by the authors and positively evaluated in the information space [15].

This model consists of an optimized series of cognitive parameters and tends to further enhance user profiles (considered the main filtering elements for Web personalization systems), that could be used in any hypertext computer-mediated platform in order to return a more enhanced user-centric result by reconstructing (adapting) any content coming from the provider.

The main uses of this model are: 1) to enable consistent implementation (and interoperation) of all hypertext computer-mediated systems that use human factors as their main filtering element, based on a shared background vocabulary, and 2) to play the role of a domain ontology that encompasses the core human factors elements for hypertext computer-mediated systems and that can be extended by any other individual or group.

Table 1 shows a sample of the OCUM's vocabulary. The full RDFa vocabulary can be found online in (http://www4.cs.ucy.ac.cy/adaptiveweb/rdf.xml).

Table 1. OCUM RDFa Vocabulary

```
<rdfs:Class rdf:ID="Person">
  <rdfs:comment>Represents a Person,
living/fictional.</rdfs:comment>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/1999/02/22-
rdf-syntax-ns#Resource"/>
</rdfs:Class>
<rdf:Property rdf:ID="name">
  <rdfs:domain rdf:resource="#Person"/>
</rdf:Property>
<rdf:Property rdf:ID="title">
  <rdfs:domain rdf:resource="#Person"/>
</rdf:Property>
<rdf:Property rdf:ID="affiliation">
  <rdfs:domain rdf:resource="#Person"/>
</rdf:Property>
….
<rdf:Property rdf:ID="imagerverbal">
  <rdfs:comment>The level of cognition of a person regarding
imager and verbal can be specified by a string literal or a Person
instance.</rdfs:comment>
  <rdfs:domain rdf:resource="#OCUM"/>
  <rdfs:range>
    <owl:Class>
      <owl:unionOf rdf:parseType="Collection">
            <owl:Class rdf:about="#Person"/>
            <owl:Class rdf:about="xsd:string"/>
      </owl:unionOf>
    </owl:Class>
  </rdfs:range>
</rdf:Property>
```

This vocabulary consists of a number of classes and properties which describe a user's profile. With regards to the sample vocabulary shown in Table 1, the main class of this vocabulary is Person that represents a living or fictional person. The Person class has the following basic properties: i) "name" property; the Person's name, ii) "title" property; the Person's title (i.e. Prof. or Managing Director), iii) "affiliation" property; the Person's affiliation. A Person class has also the following properties with regards its Cognitive Style parameters: i) "imagerverbal" property; the level of cognition of the Person regarding imager and verbal, ii) "wholistanalyst" property; the level of cognition of the Person regarding wholistic or analyst, and iii) "workingmemory" property; the Person's working memory capacity.

In this respect, the Person class, for example, in the RDFa instance (Table 2) is the main entity. Specializations of the Person entity are the Cognitive Styles, the Working Memory and Personal Detail entities.

Table 2. RDFa Instance of a User's OCUM

```
<div xmlns:v="http://www4.cs.ucy.ac.cy/adaptiveWeb/rdf/#"
typeof="v:Person">
  <div>
      <span property="v:name">John Smith</span>
      <span property="v:title">Managing Director.</span>
      <span property="v:affiliation">AWeb Solutions</span>
  </div>
  <div>Cognitive Style
      <span rel="v:imagerverbal">Imager</span><br />
      <span rel="v:wholistanalyst">Analyst</span>
  </div>
  <div>Working Memory
      <span rel="v:workingmemory">Low</span>
  </div>
</div>
```

3.2 Adaptation Mapping Layer

The Adaptation Mapping Layer is responsible for mapping the Users' Typologies of the User Profile Layer with the Smart Objects of the Web Content Layer. A Web Browser (Mozilla Firefox) Extension has been developed in order for the browser to recognize and implement the extended content objects (Table 5) and map them with the user's OCUM instance (Table 2).

Our main goal in this section is to show in a more detail how a Web browser should interpret the SmartObject of the RDFa schema (Table 4) and adapt the containing information based on the user's OCUM and consequently the abovementioned cognitive factors. Based on Tables 2 and 5 (Web Content Layer), the Web browser combines the user's OCUM with the containing information of the SmartObject entity, adapting the content.

The adaptation process involves the transformation and/or enhancement of a given raw Web-based hypertext content (provider's original content) based on the impact the specific human factors have on the information space [15] (i.e., show a more diagrammatical representation of the content in case of an Imager user, as well as provide the user with extra navigation support tools). Figure 2 shows the possible Web-based hypertext content transformations / enhancements based on the mapping process that take place during adaptation process based on the influence of the human factors and the theory of individual differences.

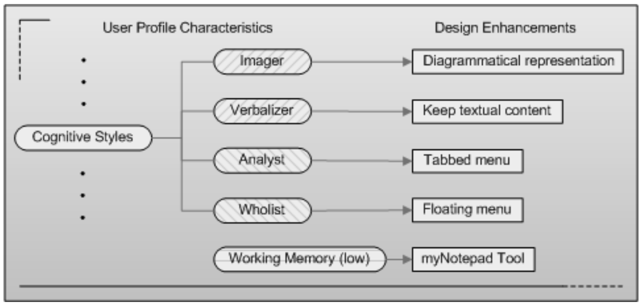

Figure 2. Hypertext Content Transformations / Enhancements

Based on figure 2, the meta-characteristics of a user profile are deterministic (at most 3); Imager or Verbalizer, Analyst or Wholist and Working Memory level (considered only when low).

For a better understanding, a user that happens to be an Imager gets a diagrammatical representation of the containing information of SmartObject. The "about" attribute is used by the Web browser to distinguish the logical meaning of a sentence when creating the diagrammatical representation. In other words, the "about" attribute is used for sub-elements of a SmartObject. As we will see furthermore, the "about" attribute is interpreted differently by the browser when the user types change. On the other hand, when a user is a Verbalizer (prefers text instead of diagrammatical representations), no changes are made to the containing content of SmartObject. Furthermore, if a user is an Analyst, the information will be enriched with a tabbed menu to be easier accessible. The menu will consist of the SmartObject sub-elements. Each sub-element along with the "title" property (see Table 5) is used in this case to create the tabbed menu with the title of each sub-element comprising an item of the menu.

Each sub-element is added to the tabbed menu and is used as a dynamic link to the containing information of the particular entity. The same logic of transformation is used when mapping the SmartObject with a Wholist user. In this case, a dynamic floating menu with anchors is created so to guide the users on specific parts into the hypertext content while interacting. Again, the sub-elements comprise the menu's items.

Finally, when users happen to have a low working memory level, the browser will provide them with the "myNotepad" tool (temporary memory buffer) for storing a section (sub-element's content) of the page and keep active information that is interested in until the completion of a cognitive task at hand.

3.3 Web Content Layer

The third layer of OAM; the Web Content Layer models any web content that comes from the provider. An RDFa schema (Table 4) has been designed that enables standard annotations in any XHTML Web-page, thus making structured data available for our framework's adaptation process, but also for any service or tool that supports the same standard. Table 5 shows an instance of the RDFa content model.

Table 4. Content Model RDFa Vocabulary

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF>
<rdfs:Class rdf:ID="SmartObject">
  <rdfs:comment>Represents an adaptive object based on users'
cognitive styles.</rdfs:comment>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/1999/02/22-
rdf-syntax-ns#Resource"/>
</rdfs:Class>
<rdf:Property rdf:ID="name">
  <rdfs:domain rdf:resource="#SmartObject"/>
</rdf:Property>
<rdf:Property rdf:ID="category">
  <rdfs:domain rdf:resource="#SmartObject"/>
</rdf:Property>
<rdf:Property rdf:ID="summary">
  <rdfs:domain rdf:resource="#SmartObject"/>
</rdf:Property>
<rdf:Property rdf:ID="title">
  <rdfs:domain rdf:resource="#SmartObject"/>
</rdf:Property>
<rdf:Property rdf:ID="content">
  <rdfs:domain rdf:resource="#SmartObject"/>
</rdf:Property>
</rdf>
```

The above vocabulary consists of a number of classes and properties which describe an adaptive object based on users' cognitive styles. The main class of this vocabulary is SmartObject that represents an adaptive web object. This class has the following properties: i) "name" property; the concept's name, ii) "category" property; the concept's category, iii) "summary" property; the summary description of the concept, iv) "title" property; the title of the concept's sub-element, and v) "content" property; the concept's sub-element content. The "about" property (Table 5) is used by RDFa to distinguish different sub-elements of the concept.

Table 5. RDFa Instance of a Content Object

```
<div xmlns:v="http://www4.cs.ucy.ac.cy/adaptiveWeb/rdf/#"
typeof="v:SmartObject">
    <span property="v:name">Sony</span>
    <span property="v:category">13' Laptop</span>
    <span property="v:summary">2.5GHz CPU Intel Core 2 Duo,
4GB RAM, 250GB HD</span>
    <div about="/sonyvaio/sz/memory">
        <span property="v:title">Memory Information</span>
        <span property="v:content">4GB Memory RAM, 250GB
Hard Disk</span>
    </div>
    <div about="/sonyvaio/sz/cpu">
        <span property="v:title">CPU Information</span>
        <span property="v:content">2.5GHz CPU Intel Core 2
Duo</span>
    </div>
</div>
```

In order to evaluate the system's performance as well as the impact of our model's dimensions into the information space, we have designed and authored an experimental environment in the application field of eCommerce. The eCommerce (Web) environment that has been developed used the design and information (hypermedia) content of an existing commercial Web-site of Sony Style.com. This Web-site provides products' specifications of the Sony Company, and in general is very representative of the sites that we inspected in our high level analysis since it stands in between a serious layout and an aesthetically rich form of presentation. We have developed an exact replica of the Sony Vaio Notebooks section in sonystyle.com.

4. EXPERIMENTAL EVALUATION

The following section describes the experimental design and the results that support the notion of personalization and the use of OAM in generic Web-based hypertext environments.

4.1 Methodology & Design Implications

For the purposes of our research a within participants experiment was conducted, seeking out to explore if the personalized condition serves users better at finding information more accurately and fast. A pilot study that involved a between participants design demonstrated inconsistent effects, suggesting that a within subjects approach would yield more robust results.

The number of participants was 89; they all were students from the Universities of Cyprus and Athens and their age varied from 18 to 21, with a mean age of 19. They accessed the Web-based hypertext environments using personal computers located at the laboratories of both universities, divided in groups of approximately 12 participants. Each session lasted about 40 minutes; 20 minutes were required for the user-profiling process (real-time psychometric tests), while the remaining time was devoted to navigating in both hypertext environments, which were presented sequentially (as soon as they were done with the first environment, the second one was presented).

The hypertext content was about a series of Sony laptop computers: general description, technical specifications and additional information were available for each model. As stated in the introductory section, we considered that the original (raw) version of the environment was designed without any consideration towards cognitive style preferences, and the amount of information was so high and randomly allocated that could increase the possibility of cognitive overload. The personalized condition addressed these issues by introducing as personalization factors both cognitive style and working memory span.

The psychometric materials that were used are the following:

1. Cognitive Style: Riding's Cognitive Style Analysis, standardized in Greek, assessing the Imager/Verbalizer and Wholist/Analyst dimensions.
2. Working Memory Span: Visuospatial working memory test, examining participants' ability to temporarily store visual figures.

In each condition, users were asked to fulfill three tasks: they actually had to find the necessary information to answer three sequential multiple choice questions that were given to them while navigating. All six questions (three per condition) were about determining which laptop excelled with respect to the prerequisites that were set by each question. There was certainly only one correct answer that was possible to be found relatively easy, in the sense that users were not required to have hardware related knowledge or understanding.

As soon as users finished answering all questions in both conditions, they were presented with a comparative satisfaction questionnaire; users were asked to choose which hypertext environment was better (1-5 scale, where 1 means strong preference for environment A and 5 for environment B), regarding usability and user friendliness factors.

The dependent variables that were considered as indicators of differences between the two hypertext environments were:

1. Task accuracy (number of correct answers)
2. Task completion time
3. User satisfaction

At this point a few clarifications about the methodology are necessary:

1. Users did not know which the personalized condition was, nor were they encouraged to use any additional features.
2. To avoid training effects, half of the users received the raw condition first (considered as environment A), whilst the other half started the procedure with the personalized (again considered as environment A).
3. To avoid a possible effect of differences in difficulty of each set of three questions, they were alternated in both environments. Due to a design error, the division was not in half, but 53 participants received the first combination and 36 the alternated. However there was not observed any effect; all questions were proven of equal difficulty- to the extent that this is possible of course.

The within participants design, finally, allowed the control of differences and confiding variables amongst users.

4.2 Results

The most robust and interesting finding was the fact that users in the personalized condition were more accurate in providing the correct answer for each task. The same user in the raw condition had a mean of 1 correct answer, while in the personalized condition the mean rose to 1.9.

Since the distribution was not normal and the paired samples t-test assumptions were not met, Wilcoxon Signed Ranks Test was performed, showing that this difference is statistically significant at zero level of confidence ($Z= -4.755$, $p=0.000$). This is probably a very encouraging finding, implying that personalization on the basis of these factors (cognitive style and WMS) benefits users within an eCommerce environment, as long as there are some cognitive functions involved of course (such as information seeking).

Equally interesting is the fact that users in the personalized condition were significantly faster at task completion. The mean aggregated time of answering all three questions was 541 seconds in the raw condition, and 412 in the personalized. A paired samples t-test was performed ($t(88)=4.668$, $p=0.000$)

demonstrating significance at zero level of confidence. Again, this second dependent variable (time) shows that the personalized hypertext environment is more efficient.

As it concerns the satisfaction questionnaire, 31 users leaned towards the personalized environment, 38 had no preference while 20 preferred the raw. This descriptive statistic is merely indicative of whether participants would consciously observe any positive or negative effects of the personalized condition.

A considerable percentage leaned towards that condition (or at least users did not seem somehow annoyed by such a restructuring), but overall it cannot be supported that they were fully aware of their increase in performance, as shown by the abovementioned findings.

5. CONCLUSIONS & FUTURE TRENDS

The basic objective of this research paper was to introduce a cognitive approach to Web Personalization based on an ontology that contains users' cognitive factors. Accordingly, a human factors' ontology has been designed and developed using RDFa, and could be used in any Web-based application for returning an optimized adaptive result to the user. Their specific influence and the Web design enhancements and hypertext content transformations have been described and positively evaluated in the eCommerce domain.

It was clearly demonstrated that users' information finding was more accurate and efficient, both in terms of providing correct answers to the task questions and in task completion time. These findings reveal that our approach turned out to be initially successful, with a significant impact of human factors in the personalization and adaptation procedure of Web-based hypertext and hypermedia environments.

Even though the evaluation of the OCUM concept in the eCommerce domain is really encouraging for the validity and integrity of the relation within and between these cognitive dimensions and their effective impact in the information space, this ontology can only be considered as a proposal. Main goal is to initiate and drive this research to a concrete human factors ontology that can be used in any hypertext computer-mediated system enhancing one-to-one services delivery based on an efficient user-centric dynamic content reconstruction (adaptation).

Sub consequently, another major future step of our work, besides improving and extending the methodology of our experiments in a commercial / services Web environment, is the integration of emotional processing parameters, which involves the use of sensors and real-time monitoring of emotional arousal (Galvanic Skin Response and Heart Rate).

Finally, even if the Sony site is quite a representative Web-site of how information is distributed in the Web, further testing on various types of Web-sites and other computer-mediated platforms is required in order to establish a rigid connection between human factors and information processing in Web-based hypertext/hypermedia environments.

6. ACKNOWLEDGMENTS

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