# A Semantic Approach of an Adaptive and Personalized Web-based Learning Content – The case of AdaptiveWeb

Panagiotis Germanakos[1], Nikos Tsianos[1], Zacharias Lekkas[1], Constantinos Mourlas[1], Marios Belk[2], George Samaras[2]

[1]Faculty of Communication and Media Studies,
National & Kapodistrian University of Athens, 5 Stadiou Str, GR 105-62, Athens, Hellas
{pgerman, ntsianos, mourlas}@media.uoa.gr

[2]Computer Science Department, University of Cyprus, CY-1678 Nicosia, Cyprus
{cs03mm2, cssamara}@cs.ucy.ac.cy

## Abstract

*Adapting to user context, individual features and behaviour patterns is a topic of great attention nowadays in the field of Web-based and mobile learning. A challenge is to design personalized interfaces and software enabling easy access to the learning content while being sufficiently flexible to handle changes in a user's context, perception and available resources. This paper presents a Web-based adaptation and personalization system, AdaptiveWeb, that uses cognitive aspects as its core filtering element. The proposed system focuses upon the creation of a comprehensive user profiling that combines parameters that analyze the most intrinsic users' characteristics like visual, cognitive, and emotional processing parameters as well as the "traditional" user profiling characteristics and together tend to give an optimized adapted and personalized result to the user. The use of semantics enables the openness of the system as adequately described in the paper.*

## 1. Introduction

The user population is not homogeneous, nor should be treated as such. To be able to deliver quality knowledge, systems should be tailored to the needs of individual users providing them personalized and adapted information based on their perceptions, reactions, and demands. One of the key technical issues in developing personalization applications is the problem of how to construct accurate and comprehensive profiles of individual users and how these can be used to identify a user and describe the user behaviour. The objective of user profiling is the creation of an information base that contains the preferences, characteristics and activities of the user.

There are some noteworthy applications in the area of Web personalization that collect information with various techniques from the users based on which they adapt the services content provided. Such systems, mostly commercial, are amongst others the Broadvision's One-To-One[2], Microsoft's Firefly Passport (developed by the MIT Media Lab), the Macromedia's LikeMinds Preference Server, Apple's WebObjects, etc. Other, more research oriented systems, include ARCHIMIDES [1], WBI [7, 8], BASAR [9] and mPERSONA [11]. Significant implementations have also been developed with regards to the provision of adapted educational content to students using various adaptive hypermedia techniques. Such systems are amongst others, INSPIRE [6], ELM-ART [10], AHA! [3], Interbook [2], and so on.

In the proposed system, AdaptiveWeb, we extend the notion of the user profile, incorporating the *User Perceptual Preference Characteristics*, that serve as the primal personalization filtering element. This approach emphasizes on critical factors that influence the visual, mental and emotional processes that mediate or manipulate new information that is received

The project is co-funded by the European Social Fund and National Resources - (EPEAEK II) PYTHAGORAS and the Cyprus Research Foundation under the project EKPAIDEION (#ΠΛΗΡΟ/0506/17).

[2] www.broadvision.com

and built upon prior knowledge, respectively different for each user or user group. These characteristics, which have been primarily discussed in our previous publications [4, 5], have a major impact on visual attention, cognitive and emotional processing that takes place throughout the whole process of accepting an object of perception (stimulus), until the comprehensive response to it.

This paper emphasizes upon how the AdaptiveWeb System's basic components interact with each other, describing actual code instances and pseudo code used (with the use of metadata) for achieving content adaptation. The content adaptation process is based on a comprehensive user profiling construction, that incorporates intrinsic user characteristics, such as user perceptual preferences (visual, cognitive and emotional processing parameters), on top of the "traditional" ones (such as name, age, education, etc.), that is considered necessary for the provision of an optimized personalization Web-based result.

## 2. The AdaptiveWeb System

Based on the abovementioned considerations, an adaptive Web-based environment is overviewed trying to convey the essence and the peculiarities encapsulated. The current system, AdaptiveWeb[3] [17] (see Fig. 1), is a Web-based and mobile Web application. It is further detached into a number of interrelated components, each one representing a stand alone Web system briefly presented below (the technology used to build each Web system is ASP .Net):

### 2.1 User Profiling Construction

To get personalized and adapted content, users have to create their comprehensive profile. Responsible for this part is the "User Profiling Construction" component. At this point the users have to give their "Traditional" and Device / Channel Characteristics and further complete a number of real-time tests (attention and cognitive processing efficiency grabbing psychometric tools) as well as answer some questionnaires [12, 13, 14, 15, 16] for generating their cumulative profile. Furthermore, our main concern is to ensure openness and interoperability within and between the system's components. Using XML for implementing the users' profile seems to be the best way to achieve this since it enables the extendibility we need and enhances functionality and integration among systems' components.

[3] http://www3.cs.ucy.ac.cy/adaptiveweb

We have designed a Web Service (a software system designed to support interoperable Machine to Machine interaction over a network) for retrieving the users' comprehensive profile. Depending on the needs of a third party system that interacts with our system through this middleware; calculations are made and are finally exported in XML.

### 2.2 Content Authoring and Adaptation Process

The second component, the system's "Semantic Web Editor", is still under study and construction. Using this component the provider will be able to create his / her own content by defining objects that will be embodied in a given content.

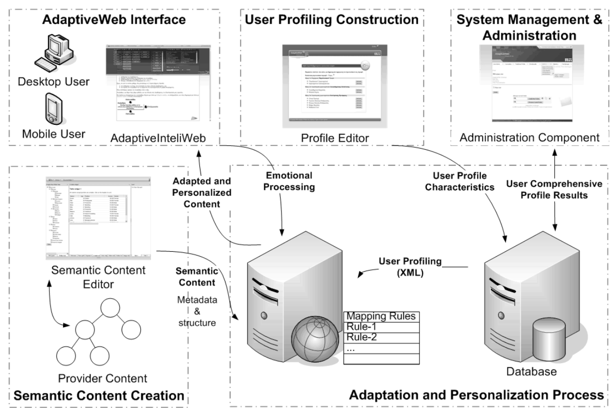

**Figure 1. AdaptiveWeb System Architecture**

The content structure has to be "well-formatted" and the objects have to be "well-defined" (based on given semantic tags) by the editor in order to give the best results to the end-user. The technology that will be used for creating the personalized content is a more expressive semantic web language like OWL or RDF used for describing data and to focus on the relation between them. The author of the page uploads the content on the system's database, which will be mapped after with the system's "Mapping Rules". The system's "Mapping Rules" are functions that run on the AdaptiveWeb server and comprise the main body of the adaptation and personalization procedure of the provider's content, according to the user's comprehensive profile. In this section, all the system's components interact with each other in order to create and give personalized and adapted content to the end user.

For experimental purposes, we have currently authored an e-learning multimedia environment with a predefined content for adaptation and personalization. This environment includes a course named "Introduction to Algorithms" and is a first year e-learning course environment that aims to provide students with analytic thinking and top-down methodology techniques for further development of constructive solutions to given problems.

To get a better insight of the adaptation process and how data flows, we hereafter depict how the personalized content (the “Introduction to Algorithms” predefined environment) interacts with the Comprehensive User Profile, using specific mapping rules. Fig. 2 shows the whole adaptation process.

When users want to see adapted and personalized content they have to give their credentials for retrieving their profile. In this particular example, the user happens to be an Imager / Wholist with regards to the Cognitive Style, has an average knowledge on the subject (computer knowledge) based on his traditional characteristics, has an Actual Cognitive Processing Speed Efficiency of 1200msec, a fair Working Memory Span (weighting 5/7), and (s)he has a High Emotional processing. Using these preferences the data - implications correlation diagram (correlation / mapping of the UPPC parameters with selected tags characterizing the Web-based content on the information space) is evaluated.

Every Web-page is detached into standalone objects, each one having special characteristics. In our example, the user visits the “webPage_Y” Web-page. First, the main XML document of this Web-page is retrieved which contains all the needed information for building the Web-page; that is, (i) the page details like the url of the page, an abstract description, author’s details, etc., (ii) the page’s layout which is a predefined HTML document (designed from the provider) keeping information of specified divisions / frames in the page for positioning each object and (iii) all objects (text, image, audio, video etc.) that comprise the content of the Web-page (see Fig. 2).

At this point we have all the information we need for adapting the content; the data - implications correlation diagram based on the user’s comprehensive profile and the content description of the particular Web-page. The next step is to map the implications with the Web-page’s content, for assembling the final version of the provider’s content. Interpreting the user’s data - implications correlation diagram results in the following conclusions: (a) the user is an Imager, (b) gets 60% of the content which has an average complexity because (s)he happens to have a medium speed of processing and average knowledge of the particular subject (computer knowledge) and (c) a high level of anxiety, the content will be presented in Font-Size 12 and Bold Font-Weight. These are suggested initial values to further proof the assumptions we made.

Mapping this information with the main content description XML instance of “webPage_Y.xml”, leads yet to another conclusion, that two objects should be presented on the Web-page; “object_X” and “object_Y”. Each object has special characteristics (tags); an ID which is unique across all the system determined by the Web-site category which belongs to (i.e. Introduction to Algorithms), the object’s type (text, image, video, audio etc.), the object’s content format (Theory, Description, Example, etc.), the layout structure which defines the objects should be placed in each division / frame (Introduction, Main Body, Conclusion). Each object, depending on which division it belongs to, is assigned a unique value in the form of a tuple, i.e. (Intro,1), (Intro,2), (Intro,3), where the first attribute represents the division in which the object should be placed while the second represents the complexity of the object. Finally, the XML instance also consists of the object’s actual content for a text object or the source file of an image, audio, video object.

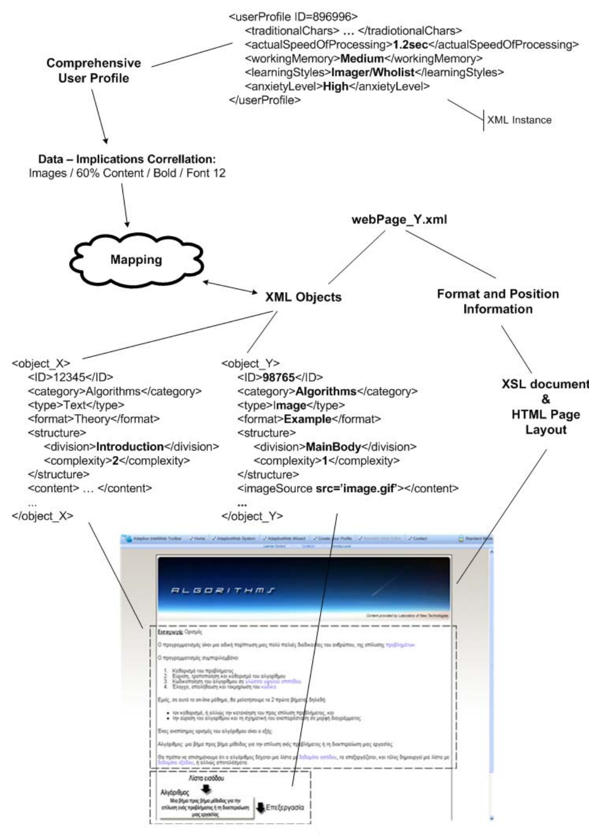


**Figure 2. The Adaptation Process**

If an object has navigational support (extra description of a definition), we further relate each object’s definition with a navigation support object which has a unique ID and the definition's content description.

Furthermore, Fig. 3 shows the mapping process (concerning the cognitive style) using our example; explained in pseudo code.

```
Algorithm : Mapping Process Phase
Input: User's data-implications correlation diagram
(contentAmount, fontSize, fontWeight, cognitiveStyles),
webObjects, XSL document, HTML layout
Output: Generate an Adapted and Personalized Web-page
Execute these steps (top-down):
  1) For each structure division (Introduction, MainBody,
     Conclusion)
        Filter out the implication's contentAmount of the
        webObjects in ascending order based on their
        complexity (<complexity>)
  2) For each remained object, make a further filtering based on
the object's <type> tag
      If (cognitiveStyleType1 = Imager)
        Filter out the image objects
      Else if (cognitiveStyleType 1 = Verbalizer)
        Filter out the text objects
      If (object has NavigationSupport Tag){
            var wordDefinitionObject =
                      retrieveWordDefinitions(objectID)
            var navigationSupportType;
            if (cognitiveStyleType 2 = Analyst)
                getNavigationSupportType(objectID)
                Show description in popup up window
            else if (cognitiveStyleType 2 = Wholist OR
              cognitiveStyleType 2 = Intermediate)
                getNavigationSupportType(objectID)
                Show description in tooltip on mouse over
      }
  3) Format each object based on the fontSize and fontWeight and
the XSL (eXtensive Stylesheet)
  4) Position each object in the right structure division based on
the HTML layout document
```

**Figure 3. Mapping Process Example (pseudo code)**

The content adapts according to the users' preferences. The new, adapted content loads then onto the users' device. While navigating, the users are able to change their anxiety level through a dynamic slide bar on the system's toolbar. By changing their current anxiety level, the server is alerted and a new data - implications correlation diagram generates with a new adaptation process taking place.

So far, we have presented how adaptation of the actual raw content of the Web-page is achieved matching the comprehensive user profile with the content description XML document using specific mapping rules. The next step is to elaborate on how the system's auxiliary tools (navigation support and learner control) are affected and altered through the adaptation and personalization process.

The subsection below will explain in more detail the AdaptiveWeb Environment, namely Adaptive-InteliWeb, where all personalized content is shown along with the extra navigation support and learner control that differ according to each user's profile.

### 2.3 Viewing the Adapted Content - The AdaptiveInteliWeb Environment

The last component of the architecture is the AdaptiveWeb User Interface, namely AdaptiveInteli-Web, which is a Web application used for displaying the raw or personalized and adapted content on the user's device. The main concept of this component is to provide a framework where all personalized web sites can be navigated. Using this interface the users navigate through the provider's content. Based on their profiling further support is provided to them with the use of a slide-in panel at the top of the screen, containing all navigation support and learner control attributes adjusted accordingly.

Users log in the system providing their username and password to see adapted content. The corresponding profile loads onto the server and in proportion with their cumulative characteristics the content of the provider maps with the "Mapping Rules", as described before.

Based on theory [18], Analysts have a more analytic way of think; thus the navigation support provided (analytic description of definitions) is in popup windows, so they can manage the entire lesson, along with its definitions by themselves. In the learner control support (that is, the slide-in help panel from the top of the page) is a linkable sitemap of the whole e-learning lesson, plus the entire lesson's definitions in alphabetic order and an anxiety bar for changing their current anxiety level.

On the other hand, Wholists tend to have a wholistic approach of learning [18]; thus the navigation support and learner control support is more restricted and is specifically provided for guidance. The analytic description of a definition is only shown in a tooltip when they move their mouse over it and the learner control shows them only the current chapter's pages they learn and lets them navigate only to the next and the previous visited pages.

## 3. Preliminary Evaluation

### 3.1 System's Performance

To measure system's performance, functional behaviour and efficiency of our system we have run two different simulations with 100 threads (users) each: (a) users retrieving raw content without any personalization and adaptation taking place and (b) users interacting with adapted and personalized content. In the second scenario, a significant increase of functions and modules ran, compared to the first one (raw content scenario), like user profile retrieval, dynamic content adaptation, learner control dynamic tools, navigational support etc.

Based on the simulations made we assume the following: (i) Deviation for raw content is 72ms and for personalized content 110ms. This difference is expected since the system uses more functional components in the case of personalized content like profile loading, dynamic content, etc. Thus, this consumes more network resources causing the deviation of our average to be greater than that of the raw content test. The deviation is not considered to be significantly greater and thus this metric result is proving the system to be stable and efficient; (ii) the throughput for the raw content scenario was 14493.16957Kb/min while for the personalized content was 17951.51859Kb/min. Based on the latter results, the system is again considered efficient mainly due to the fact that the difference in throughput between the two scenarios is minimal. Taking in consideration that major component functionality is used in the case of personalized content this small difference suggests the efficiency of the system; (iii) the same arguments are true in the case of the average response times. The average response time for the raw content scenario was 138ms while for the personalized content was 183ms. This difference is again marginal that proves the efficiency of the system.

Furthermore, the evaluation of the system's positive effect on users' performance was implemented through an e-learning multimedia environment. Factors such as previous knowledge and experience were controlled by choosing the subject of algorithms, in which students at our department traditionally perform poorly.

### 3.2 Users' Performance based on parameters used

The experiment we conducted (estimate time per experiment, approx. 1h 15min), consisted of a sample of 232 undergraduate students, who were provided with matched and mismatched environments, depending on the factor we were controlling on each phase of the experiment. Our main hypothesis was that students in matched environment perform better than those in the mismatched condition. The initial evaluative results were really encouraging since users that were provided with information matched to their UPPC characteristics performed better (see Fig. 4). The match / mismatch factor was their cognitive style (imager / verbalizer, wholist / analyst) at phase I of the experiment, while phase II estimated the effect of matching actual cognitive speed of processing (time availability based on their type, fast / medium / slow), and working memory span (complete or broken content provision depending if they had high / medium / low capacity). The aforementioned differences in performance are all statistically significant.

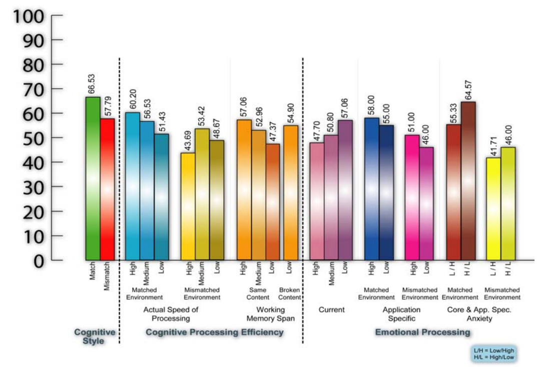


**Figure 4. Users' performance in matched and mismatched conditions**

Moreover, in many cases there is a high correlation between the dimensions of the various factors of our model, validating the psychometric tools we have used. This fact also demonstrates the effectiveness of incorporating a variety of human factors in Web-based personalized environments. Finally, emotional processing, and more specifically anxiety, turned out to be an equally important factor; medium levels of anxiety are supportive of increased performance, while aesthetics and extra navigation support helped significantly students that were highly (not extremely though) anxious, always in terms of performance.

## 4. Conclusion

The basic objective of this paper was to introduce a combination of concepts coming from different research areas all of which focusing upon the user. It has been attempted to approach the theoretical considerations and technological parameters that can provide the most comprehensive user profiling, under a common filtering element (User Perceptual Preference Characteristics), supporting the provision of the most apt and optimized user-centered Web-based multimedia result. Eventually, this paper made an extensive reference to the comprehensive user profiling construction and presented an overview of the AdaptiveWeb system indicating the data flow between its various stand alone components.

The current system has been initially evaluated both at system's response time performance and resources consumption, as well as with regards to users' learning performance. We have conducted a number of experiments to load test functional behaviour and measure performance of our system with controlled environments measuring average response times, throughput, deviation and median, ran by 100 threads (users). With regards to the users' learning performance, we identified a correlation of cognitive processing speed and visual attention processing efficiency of users as well as intrinsic parameters of emotionality, with the parameters of online content.

The system has been proved effective and efficient not only regarding the information flow within and between the various standalone system's components but also in respect to the actual output data gathered which reveals that the whole approach turned out to be initially successful with a significant impact in the Personalization and Adaptation Procedure.

The initial evaluative results were really encouraging for the future of our work since we found that in many cases there is high positive correlation of matched conditions with performance, as well as between the dimensions of the various factors of our model. This fact demonstrates the effectiveness of incorporating human factors in Web-based personalized environments. We will further also investigate constraints and challenges arise from the implementation of such issues on mobile devices and channels.

We will extend our study on the structure of the metadata coming from the providers' side, aiming to construct a Web-based personalization architecture that will serve as an automatic filter adapting the received content based on the comprehensive user profiling. The final system will provide a complete adaptation and personalization Web-based solution to the users satisfying their individual needs and preferences.

## 5. References


[1] Bogonicolos N. et al. (1999). ARCHIMIDES : an intelligent agent for adaptive-personalized navigation within a WEB server. *Proceedings of the 32nd Annual Hawaii Intl. Conf. On System Science*, HICSS-32. Vol 5.

[2] Brusilovsky, P., Eklund, J. & Schwarz, E. (1998). Web-based education for all: A tool for developing adaptive courseware. Computer Networks and ISDN Systems. *Proceedings of the 7th International WWW Conference*, 14-18 April, 30(1-7), 291-300.

[3] De Bra, P. & Calvi, L. (1998). AHA ! An open Adaptive Hypermedia Architecture. *The New Review of Hypermedia and Multimedia*, 4, Taylor Graham Publishers, pp. 115-139.

[4] Germanakos, P, Tsianos, N, Lekkas, Z, Mourlas, C, and Samaras, G. "Capturing Essential Intrinsic User Behaviour Values for the Design of Comprehensive Web-based Personalized Environments", *Computers in Human Behavior Journal*, Special Issue on Integration of Human Factors in Networked Computing (2007), doi:10.1016/j.chb.2007.07.010

[5] Germanakos, P., Tsianos, N., Mourlas, C., & Samaras, G. (2005). New Fundamental Profiling Characteristics for Designing Adaptive Web-based Educational Systems. *Proceeding of the IADIS International Conference on Cognition and Exploratory Learning in Digital Age (CELDA2005)*, Porto, December 14-16, pp. 10-17.

[6] Papanikolaou K.A., Grigoriadou M., Kornilakis H., & Magoulas G.D. (2003). Personalizing the Interaction in a Web-based Educational Hypermedia System: the case of INSPIRE. *User-Modeling and User-Adapted Interaction*, 13(3), 213-267.

[7] Maglio, P. & Barret, R. (2000). Intermediaries Personalize Information Streams, *Communications of the ACM*, Vol. 43(8), pp. 96-101.

[8] Barret, R., Maglio, P. & Kellem, D. (1997). How to Personalize the Web, Proc. CHI 97.

[9] Thomas, C. & Fischer, G., (1997). Using agents to personalize the Web, *In proc. ACM IUI'97*, pp. 53-60, Florida Usa.

[10] Weber, G. & Specht, M. (1997). User Modeling and Adaptive Navigation Support in WWW-Based Tutoring Systems. *Proceedings of User Modeling '97*, pp. 289-300.

[11] Panayiotou, C., and Samaras, G. (2004). mPersona: Personalized Portals for the Wireless User: An Agent Approach. Journal of ACM/ Baltzer Mobile Networking and Applications (MONET), special issue on "Mobile and Pervasive Commerce", (6), 663-677.

[12] Riding R. (2001). Cognitive Style Analysis – Research Administration, Published by Learning and Training Technology.

[13] Cassady, C. C. (2004). The influence of cognitive test anxiety across the learning–testing cycle, Learning and Instruction, 14 (pp. 569–592).

[14] Goleman, D. (1995). Emotional Intelligence: why it can matter more than IQ. New York: Bantam Books.

[15] Salovey, P. & Mayer, J. D. (1990). Emotional intelligence, Imagination, Cognition, and Personality, 9 (pp. 185-211).

[16] Smith, B. & Caputi, P. (2005). Cognitive interference model of computer anxiety: Implications for computer-based assessment, Computers in Human Behavior, 21, (pp. 713-728).

[17] P. Germanakos, N. Tsianos, Z. Lekkas, C. Mourlas, M. Belk, and G. Samaras, "An AdaptiveWeb System for Integrating Human Factors in Personalization of Web Content", *Demonstration in the Proceedings of the 11th International Conference on User Modeling (UM 2007)*, Corfu, Greece, June 25-29, 2007.

[18] Sadler-Smith E. & Riding R., (1999). Cognitive style and instructional preferences. Instructional Science Volume 27, Number 5, September 1999, pp. 355-371(17).