Building an Adaptive Web-based Educational Environment Considering the User Perceptual Preference Characteristics

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Abstract. There is a growing body of empirical evidence to suggest that users tend to make poor decisions in traditional educational systems as the navigational freedom given to the user leads to comprehension and orientation difficulties in the sense that users may become spatially disoriented, lose sight of educational objectives, skip important content, choose not to answer questions, look for stimulating rather than informative material or simply use the navigational features unwisely. Since the user population is relatively diverse, such traditional static hypermedia applications suffer from an inability to satisfy the heterogeneous needs of the many users. Moreover, with the growth of mobile and wireless communication allowed service providers to develop for users new ways of interactions through a variety of channels in an anyhow, anytime and anywhere manner, but developing also more demanding requirements. This paper makes an extensive reference to adaptive hypermedia considerations and techniques. It investigates the emergence of the mobile and wireless technology and the "new" user profiling requirements that arise, with visual, emotional and cognitive processing parameters incorporated. Eventually, it proposes an adaptive Web-based educational environment based on the user perceptual preference characteristics identified.

1. Introduction

The explosive growth in the size and use of the World Wide Web as well as the complicated nature of most Web structures may very well in orientation difficulties, as users often lose sight of the goal of their inquiry, look for stimulating rather than informative material, or even use the navigational features unwisely [1, 2, 3, 4]. Adaptivity is a particular functionality that alleviates navigational difficulties by distinguishing between interactions of different users within the information space [2, 5]. Adaptive Hypermedia Systems employ adaptivity by manipulating the link structure or by altering the presentation of information, based on a basis of a dynamic understanding of the individual user, represented in an explicit user model [2, 1, 3, 4, 6]. Over the last 10 years, researchers in adaptive hypermedia and Web systems have explored many user modeling and adaptation methods. With the emergence of wireless and mobile technologies new devices and communication platforms, other than PC-based Internet access are becoming available making the delivery of knowledge available through a variety of media. Inevitably, the user requirements are elevated to an "anytime, anywhere and anyhow" basis, and adaptation must not only take into account the explicit user model, but also the context (location, time, computing platform, bandwidth) of their work

[20, 21], as well as other user perceptual preference characteristics, like visual attention, cognitive and emotional processing parameters.

The aim of this paper is to present an overview of adaptive hypermedia in the general context of Adaptive and Intelligent Web-based Educational Systems, and to identify the technological challenges and constraints that need to be addressed. It will further discuss some primary mobility and adaptive hypermedia cross-road considerations as well as the "new" user profile that incorporates other than the "traditional" user characteristics (like user perceptual preference characteristics), and the semantic Web-based educational content that includes amongst others the perceptual provider characteristics. Lastly, having analyzed the aforementioned concepts it will define an adaptive Web-based educational environment presenting some key implementation considerations.

The paper is structured in 5 sections. Section 2 gives an overview of adaptive hypermedia in the broader context of Adaptive and Intelligent Web-Based Educational Systems. Section 3 describes primary mobile and adaptive hypermedia cross-road considerations. Section 4 presents an Adaptive Web-based Educational Environment, and section 5 concludes this paper.

2. Adaptive Hypermedia Overview

In the 1997 discussion forum on Adaptive Hypertext and Hypermedia, an agreed definition of adaptive hypermedia systems was reached after Brusilovsky [2] as follows: "By Adaptive Hypermedia Systems we mean all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible and functional aspects of the system to the user" [2, 6]. A system can be classified as an Adaptive Hypermedia System if it is based on hypermedia, has an explicit user-model representing certain characteristics of the user, has a domain model which is a set of relationships between knowledge elements in the information space, and is capable of modifying some visible or functional part of the system based on the information maintained in the user-model [2, 5, 6, 9]. In 1996, Brusilovsky identified four user characteristics to which an Adaptive Hypermedia System should adapt [6, 3]. These were user's knowledge, goals, background and hypertext experience, and user's preferences. In 2001, further two sources of adaptation were added to this list, user's interests and individual traits, while a third source of different nature having to deal with the user's environment had also been identified. Generally, Adaptive Hypermedia Systems can be useful in application areas where the hyperspace is reasonably large and the user population is relatively diverse in terms of the above user characteristics [3, 4, 5, 6]. A review by Brusilovsky has identified six specific application areas for adaptive hypermedia systems since 1996 [3]. These are educational hypermedia, on-line information systems, information retrieval systems, institutional hypermedia and systems for managing personalized view in information spaces. Educational hypermedia and on-line information systems are the most popular, accounting for about two thirds of the research efforts in adaptive hypermedia.

2.1 Adaptive and Intelligent Web-based Educational Systems (AIWBES)

Adaptive systems attempt to be different for different students and groups of students by taking into account information accumulated in the individual or group student models. Intelligent systems apply techniques from the field of Artificial Intelligence (AI) to provide broader and better support for the users of Web-based educational systems. A review by Brusilovsky [10] identified five major technologies used in AIWBES [11], having immediate roots in two well established research fields – Adaptive Hypermedia and Intelligent Tutoring Systems (ITS). Since their application in the Web context was relatively straightforward, these technologies were the first to appear in AIWBES and can be considered as "classic" AIWBES technologies. The three new Web-inspired technologies are: Adaptive Information Filtering, Intelligent Class Monitoring, and Intelligent Collaboration Support.

2.1.1 Adaptive Hypermedia

Adaptation effects vary from one system to another. These effects are grouped into three major adaptation technologies - adaptive content selection [5], adaptive presentation (or content-level adaptation) [2, 1, 3, 11, 10, 6, 4, 12, 5, 7, 13, 14, 15] and adaptive navigation support (or link-level adaptation) [2, 1, 3, 11, 10, 6, 4, 12, 5, 7, 13, 14, 15]. The first of these three technologies comes from the field of adaptive information retrieval (IR) and is associated with a search-based access to information. When the user searches for relevant information, the system can adaptively select and prioritize the most relevant items [5]. The idea of adaptive presentation is to adapt the content of a page to the characteristics of the user according to the user model [2, 1, 3, 12, 14]. With such techniques the content is individually generated or assembled from pieces for each user, to contain additional information, pre-requisite information or comparative explanations by conditionally showing, hiding, highlighting or dimming fragments on a page [1]. The granularity may vary from word replacement to the substitution of pages to the application of different media [12]. Adaptive presentation techniques have been classified into: (a) adaptive multimedia presentation, (b) adaptive text presentation, and (c) adaptation of modality [12, 5, 14]. Adaptive navigation techniques have been classified according to the way they adapt the presentation of links, ranging from methods that restrict the user's interactions with the content to techniques that aid the user in their understanding of the information space, aiming provide either orientation or guidance [2]. Orientation informs the user about their place in the hyperspace while guidance is related to a user's goal. These techniques are: direct guidance [2, 14]; adaptive link sorting [2, 14]; adaptive link hiding [2, 14]; adaptive link annotation [14]; adaptive link generation [3, 5]; and map adaptation [6].

2.1.2 Intelligent Tutoring

Intelligent Tutoring Systems (ITS) investigates the development of Adaptive and Intelligent Educational Systems. The goal of ITS targets at exploiting the knowledge about the user, and teaching strategies to support flexible individualized learning and tutoring. A review of ITS carried out by Brusilovsky in 1990 identified three core ITS technologies: curriculum sequencing, intelligent analysis of student's solutions and interactive problem solving support [11, 10]. Since 1990, only one technology, example-based problem solving support, was added to this list to classify a functionality that was not covered by the core three [10]. The goal of curriculum sequencing technology (or instructional planning technology) is to provide the student with the most suitable individually planned sequence of topics to learn and learning tasks (questions, problems, etc.) to work with [11, 10]. In most of ITS systems with curriculum sequencing it is possible to distinguish two levels of sequencing: high and low. High-level sequencing or knowledge sequencing determines the next learning subgoal: next concept, set of concepts, topic, or lesson to be taught. Low-level sequencing or task sequencing determines the next learning task (problem, example, test) within current subgoal. Intelligent analysis of student solutions deals with students' final answers to educational problems no matter how these answers were obtained. To be considered as intelligent, a solution analyzer must perform knowledge diagnosis, to decide whether the solution is correct or not, find out what exactly is wrong or incomplete, and possibly identify which missing or incorrect knowledge may be responsible for the error, providing the student with extensive error feedback and updating the student model accordingly. Interactive problem solving support is a more powerful technology implemented in interactive tutors. Instead of waiting for the final solution, the student is provided with intelligent help on each step of problem solving. The level of help can vary from signaling about a wrong step, to giving a hint, to executing the next step for the student. The example-based problem solving technology is the newest one. This technology is helping students to solve new problems not by articulating their errors, but by suggesting them relevant successful problem solving cases from their earlier experience such as examples explained to them or problems solved by them earlier [10].

2.1.3 Adaptive Information Filtering

Adaptive information filtering (AIF) is a classic technology from the field of Information Retrieval. Its goal is finding a few items that are relevant to user interests in a large pool of (textbased) documents. On the Web this technology has been used in both search and browsing context. It has been applied to adapt the results of Web search using filtering and ordering and to recommend the most relevant documents in the pool using link generation. While the engines used by AIF systems are very different from adaptive hypermedia engines, at the interface level Web-based AIF most often use adaptive navigation support techniques. There are two different kinds of AIF engines – content-based filtering and collaborative filtering. The former relies on document content while the latter ignores the content completely attempting instead to match the users who are interested in the same documents. Being very popular in the field of information systems, AIF has not been used in educational context in the past as the amount of learning content was relatively small and the need to guide the user to most relevant material was well supported by adaptive sequencing and adaptive hypermedia. However, the Web with its abundance of educational resources has made AIF very attractive for educational systems [11].

2.1.4 Intelligent Monitoring

Intelligent class monitoring is another technology motivated by Web-based Education (WBE). In the WBE context a “remote teacher” can’t see the signs of understanding and confusion on the faces of the students. With this severe lack of feedback it becomes hard to identify troubled students who need additional attention, bright students who need to be challenged, as well as the parts of learning material that are too easy, too hard, or confusing. Intelligent class monitoring systems attempt to use AI to help the teacher in this context. This stream of work was pioneered by HyperClassroom that used fuzzy technology to identify "deadlocked" WBE students [11].

2.1.5 Intelligent Collaborative Learning

Intelligent collaborative learning (ICL) is an interesting group of technologies developed at the crossroads of computer supported collaborative learning (CSCL) and ITS. While early work on intelligent collaborative learning was performed in pre-Web context it's the Web and WBE that provided an increasing demand for this kind of technology. Technologies for adaptive group formation and peer help attempt to use knowledge about collaborating peers (most often represented in their student models) to form a matching group for different kinds of collaborative tasks. Early examples include forming a group for collaborative problem solving and finding the most competent peer to answer a question. Technologies for adaptive collaboration support attempt to provide an interactive support of a collaboration process just like interactive problem support systems assist an individual student in solving a problem. In contrast, virtual students technology is comparatively old. Instead of supporting learning or collaboration from a position of someone superior to students (a teacher), ICL introduces different kinds of virtual peers such as a learning companion or even a troublemaker [11].

3. General Mobility and Adaptive Hypermedia Cross-Road Considerations – The User Profiling Imperative

The "Mobile" generation is now extending the basis of the adaptation in a multi-channel and multi-device accessibility by adding models of context such as location, time, computing platform and bandwidth to the classic user model and exploring the use of known adaptation technologies to adapt to both an individual user and a context of their work [7]. User interfaces must now be friendlier enabling active involvement (information acquisition), giving control to the user and provide easier means of navigation supported by the small screens of the mobile devices and enable adaptation of hypermedia, multi-media, and multi-modal user interfaces. Adding to the challenges of classic hypermedia applications the fact that these devices are handled in a more 'personal' basis by the user, other characteristics like the user perceptual preference characteristics must be taken into consideration in order to deliver a more comprehensive adapted result. Consequently, user profiling is becoming more and more important considering different users with different needs and expectations. This means that they may probably want better personalized services to save them time and trouble, or that they may require different level of entrance according to different levels of group awareness, or that they may probably need multiple profiles according to their status. Therefore, capabilities like bandwidth, displays, and text-writing must be taken into account when developing such educational-based services.

User profiling can either be *static*, when it contains information that rarely or never changes (e.g. demographic information), or *dynamic*, when the data change frequently. Such information is obtained either *explicitly*, using online registration forms and questionnaires resulting in static user profiles, or *implicitly*, by recording the navigational behaviour and / or the preferences of each user. In the case of implicit acquisition of user data, each user can either be regarded as a member of group and take up an aggregate user profile or be addressed individually and take up an individual user profile. The data used for constructing a user profile could be distinguished into: (a) the *Data Model* which could be classified into the *demographic* model (which describes who the user is), and the *transactional* model (which describes what the user does); and (b) the *Profile Model* which could be further classified into the *factual profile* (containing specific facts about the user derived from transactional data, including the demographic data, such as "the favourite beer of customer X is Beer A"), and the *behavioural profile* (modeling the behaviour of the user using conjunctive rules, such as association or classification rules. The use of rules in profiles provides an intuitive, declarative and modular way to describe user behaviour [22]).

Additionally, in the case of a mobile user, by user needs it is implied both, the *thematic preferences* (i.e., the traditional notion of profile) as well as the characteristics of their personal device called *"device profile"*. Therefore, here, adaptive personalization is concerned with the negotiation of user requirements and device abilities. As Web developers regard personalization as the best way to filter out unnecessary or irrelevant information for their users, some argue on issues like it may restrict the extent and the variety of information users receive, that people often do not have well-defined preferences, they need to answer detailed questions to personalize their Web pages, that the recommendation process is a black box for end users and so on [23]. But, could the user profiling be considered complete incorporating only these dimensions? Do the designers and developers of Web-based educational applications take into consideration the real users preferences in order to provide them a really personalized Web-based educational content? Many times this is not the case. How can a user profiling be considered complete, and the preferences derived optimized, if it does not contain parameters related to the user perceptual preference characteristics. By user perceptual preference characteristics we mean the visual attention, cognitive and emotional processes taking place throughout the whole process of accepting an object of perception (stimulus) until the comprehensive response to it. It includes all the visual, mental and emotional processes that are liable of manipulating the newly information received and building upon prior knowledge, that is different for each user or user group. It has to be noted at this point that the user perceptual preference characteristics are directly related to the "traditional" user characteristics since they are affecting the way a user approaches an object of perception.

It is true that nowadays, there are not researches that move towards the consideration of user profiling incorporating optimized parameters taken from the research areas of visual attention processing and cognitive psychology. Some serious attempts have been made though on approaching e-Learning systems providing adapted content to the students but most of them are lying to restricted analysis and design methodologies considering particular cognitive learning styles, including Field Independence vs. Field Dependence, Holistic-Analytic, Sensory Preference, Hemispheric Preferences, and Kolb's Learning Style Model [24], applied to identified mental models, such as concept maps, semantic networks, frames, and schemata [25, 26]. In order to deal with the diversified students' preferences such systems are matching the instructional materials and teaching styles with the cognitive styles and consequently they are satisfying the whole spectrum of the students' cognitive learning styles by offering a personalized Web-based educational content.

Based on the aforementioned statements, it should be mentioned that adaptive personalization could be concerned here as the negotiation of user requirements and device abilities. The issue of adaptive personalization, and consequently user segmentation is a complex one. User segmentation divides the user population into heterogeneous, mutually exclusive subsets who share common user profile characteristics (i.e. demographic, psychographic, and individual and psychological characteristics). Some of these issues become even more complicated once viewed from a mobile user's perspective, when wireless communication media and mobile device constraints are involved, like small size, bandwidth constraints, processor computing power, memory and storage space, small screen, high latency and data entry constraints [18, 8, 7, 5, 19, 20, 17, 21]. Such issues include, but are not limited to: *What content to present to the user, how to show the content to the user*, *how to ensure the user's privacy*, *how to create a global personalization scheme*. Consequently, having researchers in mind the continuous rising of complexity with regards to the design and implementation of Web-based educational applications should develop more advanced adaptation and personalization techniques that would take advantage of these constraints to the broader benefit of the more comprehensive user profiling characteristics identified.

4. Implementation Considerations of an Adaptive Web-based Educational Environment

Based on the abovementioned considerations, an adaptive Web-based educational environment is presented trying to convey the essence and the peculiarities encapsulated.

The current architecture, depicted in Figure 1, is composed of four main interrelated modules. Each *module* for the purpose of the infrastructure functionality may be composed of *components* and each component may be broken down into *elements*, as detailed below:

4.1 Entry Point and Content Reconstruction Module

It is the primary module and the user access interface of the system and is called 'Entry Point and Content Reconstruction'. It accepts multi-device (enables the attachment of various devices on the infrastructure, such as mobile phones, PDAs, desktop devices etc. identifying the characteristics of the device and the preferences as well as the location of the user (personalization / location based) and multi-channel (due to the variety of multi-channel delivery i.e. over the Web, telephone, interactive kiosks and so on, this module will identify the different characteristics of the channels) requests. It is directly communicating with the '"New" User Profiling' and 'Semantic Web-based Educational Content' modules exchanging multi-purpose data. It consists of two components each one assigned for a different scope:

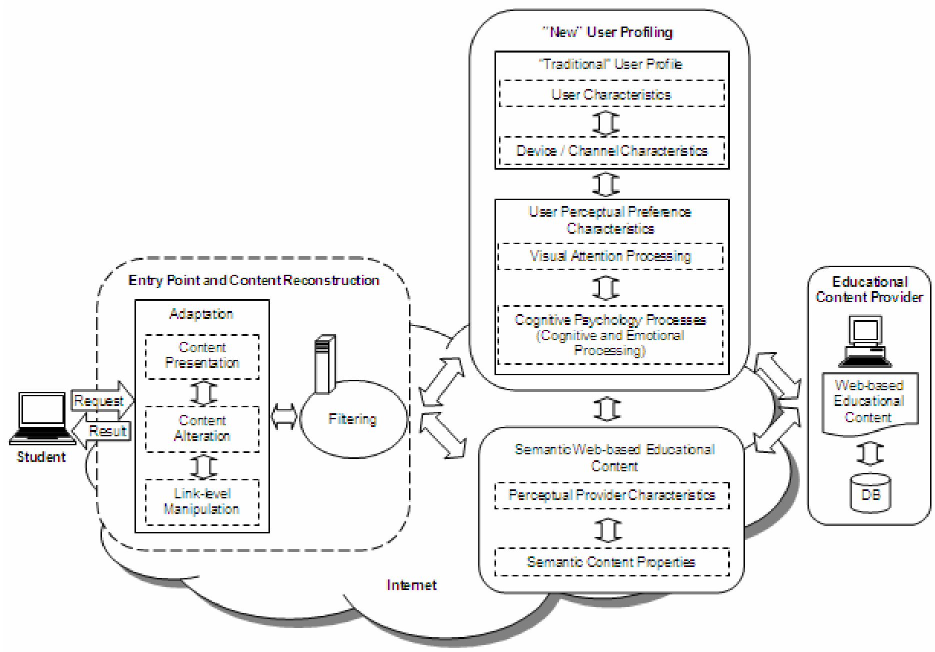

Figure 1. Adaptive Web-based Educational Content Architecture

- *Adaptation*: This component comprises of all the access-control data (for security reasons) and all the information regarding the user profile. These might include user preferences, geographical data, device model, age, business type, native language, context, etc. It is the enter point for the user enabling the login to the architecture. This component is directly communicating with the '"New" User Profiling' module where the actual verification and profiling for the user is taking place. Once the whole processing has been completed it returns the adapted results to the user. It is comprised of three elements:
  - *Content Presentation* (or Adaptive Presentation): It adapts the content of a page to the characteristics of the user according to the user profile and personalization processing. The content is individually generated or assembled from pieces for each user, to contain additional information, pre-requisite information or comparative explanations by conditionally showing, hiding, highlighting or dimming fragments on a page. The granularity may vary from word replacement to the substitution of pages to the application of different media.
  - *Content Alteration* (or Adaptive Content Selection): When the user searches for a particular content, that is, related information to his / her profile, the system can adaptively select and prioritize the most relevant items.
  - *Link-level Manipulation* (or Adaptive Navigation Support): It provides methods that restrict the user's interactions with the content or techniques that aid the user in their understanding of the information space, aiming to provide either orientation or guidance (i.e. adaptive link, adaptive link hiding / annotation). Orientation informs the user about his / her place in the hyperspace while guidance is related to a user's goal.

- *Filtering*: This component is considered the main link of the 'Entry Point and Content Reconstruction' module with the '"New" User Profiling' and 'Semantic Web-based Educational Content' modules of the architecture. It actually transmits the data accumulated both directions and it makes the low-level reconstruction and filtering of the content, according to the Web personalization processing characteristics, delivering the content for adaptation according to the user segmentation.

4.2 "New" User Profiling Module

This is the main module of the architecture and it is called '"New" User Profiling' module. At this module all the requests are processed. This module is responsible for the custom tailoring of information to be delivered to the users, taking into consideration their habits and preferences, as well as, for mobile users mostly, their location ("location-based") and time ("time-based") of access. The whole processing varies from security, authentication, user segmentation, educational content identification, user perceptual characteristics (visual, cognitive and emotional processing parameters) and so forth. This module accepts requests from the 'Entry Point and Content Reconstruction' module and after the necessary processing and further communication with the 'Semantic Web-based Educational Content' module, either sends information back or communicates with the next module ('Educational Content Provider') accordingly. This module is comprised of the following two components:

- *"Traditional" User Profile*: It contains all the information related to the user, necessary for the Web Personalization processing. It is directly related to the User Perceptual Preference Characteristics component and is composed of two elements:
  - *User Characteristics*: This element is directly related to the Device / Channel Characteristics element and provides the so called "traditional" characteristics of a user: knowledge, goals, background, experience, preferences, activities, demographic information (age, gender), socio-economic information (income, class, sector etc.) and so forth. Both elements are completing the user profiling from the user's point of view.
  - *Device / Channel Characteristics*: This element is referring to all the characteristics that referred to the device or channel the user is using and contains information like: Bandwidth, displays, text-writing, connectivity, size, power processing, interface and data entry, memory and storage space, latency (high / low), and battery lifetime. These characteristics are mostly referred to mobile users and are considered important for the formulation of a more integrated user profile, since it determines the technical aspects of it.
- *User Perceptual Preference Characteristics*: This is the new element / dimension of the user profile. It contains all the visual attention and cognitive psychology processes (cognitive and emotional processing parameters) that completes the user preferences and fulfills the user profile. User Perceptual Preference Characteristics could be described as a continuous mental processing starting with the perception of an object in the user's attentional visual field and going through

a number of cognitive, learning and emotional processes giving the actual response to that stimulus, as depicted in Figure 2, below.

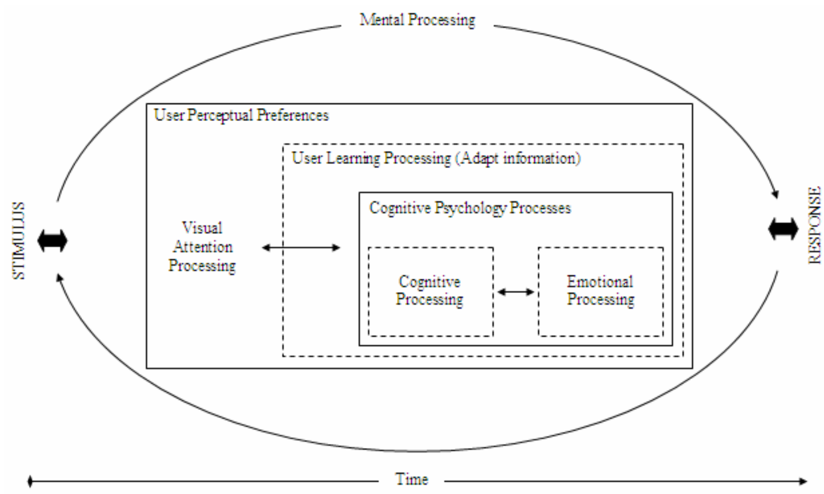

Figure 2. User Perceptual Preference Characteristics

It is considered a vital component of the user profile since it identifies the aspects of the user that is very difficult to be revealed and measured but, however, might determine his / her exact preferences and lead to a more concrete, accurate and optimized user segmentation. It is composed of two elements:

- *Visual Attention Processing*: It is responsible for the tracking of the user's eye movements and in particular the scanning of his / her eye gaze on the information environment. It is composed of two serial phases: the pre-attentive and the limited-capacity stage. The pre-attentive stage of vision subconsciously defines objects from visual primitives, such as lines, curvature, orientation, color and motion and allows definition of objects in the visual field. When items pass from the pre-attentive stage to the limited-capacity stage, these items are considered as selected. Interpretation of eye movement data is based on the empirically validated assumption that when a person is performing a cognitive task, while watching a display, the location of his / her gaze corresponds to the symbol currently being processed in working memory and, moreover, that the eye naturally focuses on areas that are most likely to be informative.
- *Cognitive Psychology Processes*: It is composed of cognitive and emotional processing parameters. Cognitive processing parameters could be primarily determined by (a) the control of processing (refers to the processes that identify and register goal-relevant information and block out dominant or appealing but actually irrelevant information), (b) the speed of processing (refers to the maximum speed at which a given mental act may be efficiently executed), and (c) the working memory (refers to the processes that enable a person to hold information in an active state while integrating it with other information until the current problem is solved). Many researches [27, 28] have identified that the speed of cognitive processing and control of

processing it is directly related to the human's age, as well as to the continuous exercise and experience, with the former to be the primary indicator. Therefore, as it is depicted in Figure 3a, the processing development speed increases non-linearly in the age of 0 – 15 (1500 m/sec), it is further stabilized in the age of 15 - 55-60 (500 m/sec) and decreases from that age on (1500 m/sec). However, it should be stated that the actual cognitive processing speed efficiency is yielded from the difference between the peak value of the speed of processing and the peak value of control of processing, as it is depicted in Figure 3b.

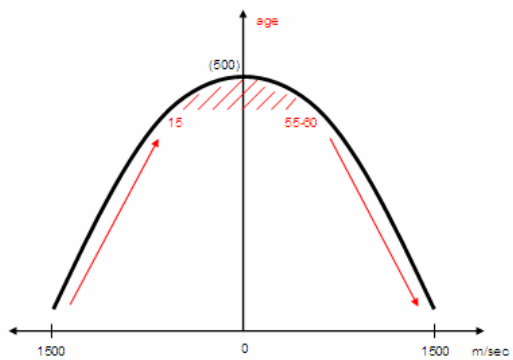

Figure 3a. Speed of Processing

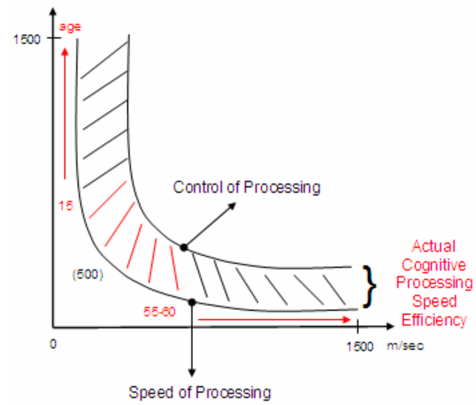

Figure 3b. Actual Cognitive Processing Speed Efficiency

At this point should be made a reference to the cognitive learning styles which represent the particular set of strengths and preferences that an individual or group of people have in how they take in and process information. A selection of the most appropriate and technologically feasible learning styles are taken into consideration, such as Witkin's Field-Dependent and Field-Independent and Kolb's Learning Styles, being in a position to identify how users transforms information into knowledge (constructing new cognitive frames) and if they could be characterized as a converger, diverger, assimilator, accommodator, wholist, analyst, verbalizer, or imager.

The emotional processing consists of these parameters that could determine a user's emotional state during the response process. These may include extroversion (extraverts are sociable, active, self-confident, and uninhibited; while introverts, are withdrawn, shy, and inhibited), agreeableness (agreeable individuals are generous, warm, kind, and forgiving, whereas individuals low in agreeableness are suspicious, impatient, argumentative, and aggressive), conscientiousness (conscientious individuals are organized, ambitious, determined, reliable, and responsible; while individuals low in conscientiousness are distractible, lazy, careless, and impulsive), neuroticism (individuals high in neuroticism are confident, clear thinking, alerts and content), open to experience (individuals who are open to experience are curious and with wide interests, inventive, original, and artistic; individuals who are not open to experience are conservative, cautious, and mild), understanding of emotions (is the cognitive processing of the emotions; it is the ability of understanding and analysis of the complex emotions and the chain reactions of the emotions, that is how an emotion generates another), regulation of emotions (is the control and regulation of the personal and other people's emotions for the emotional and intellectual development; it is the human's ability to realize what is hidden behind an emotion, like fear, anxiety, anger, or sadness, and to find each time the most suitable ways to confront them), and self control (includes processes referring to the control of attention, the provision of intellectual resources, and the selection of the specialized procedures and skills liable for the evaluation of a problem's results or a decision's uptake; it is a superior control system that coordinates the functioning of other, more specialized control systems).

Eventually, as it can be further observed, these parameters formulate a three-dimensional approach to the problem as it is depicted, in Figure 4.

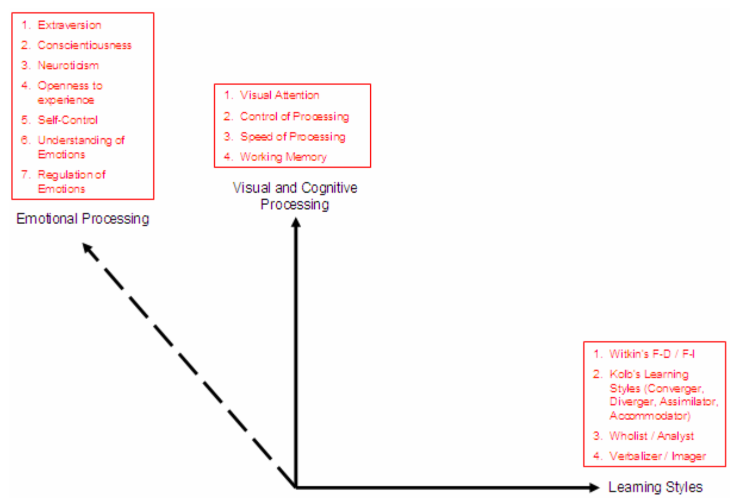

Figure 4. Three-Dimensional Approach

4.3 Semantic Web-based Educational Content Module

This module is based on metadata describing the content (data) available from the 'Educational Content Provider' module. In this way a common understanding of the data, i.e. semantic interoperability, openness, is achieved. The data manipulated by the system / architecture is described using metadata that comprises all needed information to unambiguously describe each piece of data and collections of data. This provides semantic interoperability and a human-friendly description of data. This module is also directly related to the '"New" User Profiling' module providing together the most optimized adaptive Web-based educational content result. It is consisted of two components:

- *Perceptual Provider Characteristics*: It identifies the provider characteristics assigned to the Web-based educational content. They are involving all these perceptual elements that the provider has been based for the design of the content.

- *Semantic Content Properties*: This element performs the identification and metadata description of Web-based educational content based on predetermined ontologies. It is implemented in a transparent manner removing data duplication and the problem of data consistency.

4.4 Educational Content Provider Module

This is the last module of the architecture and is directly connected to the '"New" User Profiling' and 'Semantic Web-based Educational Content' modules. It contains transition mechanisms and the databases of Web-based educational content as supplied by the provider without been through any further manipulation or alteration.

The proposed Adaptation Web-based Educational Content Architecture will allow users to receive the Web-based educational content in an adapted style according to their preferences, increasing that way efficiency and effectiveness of use.

Indisputably, in order for the latter consideration to be accomplished, a further filtering of the aforementioned parameters, and especially of the "New" User Profiling module, has to take place so that the final optimized model is achieved. Once this established, a test in the form of a questionnaire will be constructed which will attempt to reveal user perceptual preference characteristics. These features along with the "traditional" user characteristics could complete the "New" User Profile and therefore adaptation schemes could be adjusted to deliver even more personalized Web-based content accordingly. The next step is to identify what is the correlation between the various users and / or user groups and if it would be feasible to refer to the term 'users' segmentation' (users sharing similar "new" user profiling characteristics) providing them with predetermined personalized content or treat users separately and adjust content as the adaptation processing evolves. In either case, personalization mechanisms will be based upon these parameters and considering users' device / channel characteristics and the semantic content will provide them with the corresponding adapted result. Eventually, this methodology will be implemented with adaptation and personalization algorithms and paradigms so to automatically gather all the related information and construct the "new" user profiling giving the users the adapted result without their actual intervention.

5. Conclusion

When referring to adapted Web-based educational content provision it is implied that the content adaptation and personalization is based on a concrete and comprehensive user profile that covers all the dimensions and parameters of the users' preferences. However, there is still the view that if a provider knows the users "traditional" characteristics and channel / device capabilities can design and offer an apt personalized result. Most of the times though the providers tend to design educational applications based on their own preferences and what they think should be offered. The concept of adaptation and personalization is much more complicated than that. A profile to be considered complete must contain the user perceptual preference characteristics that mostly deal with intrinsic parameters and are very difficult to be technologically measured. Visual attention (that can be thought of as the gateway to conscious perception and memory) and cognitive psychology processes (cognitive and emotional processing parameters) should be in combination investigated and analyzed in a further attempt to complete the desktop and mobile users' preferences.

This paper presented an extensive review of adaptive hypermedia in the general context of Adaptive and Intelligent Web-based Educational Systems. Moreover, the mobile and adaptive Web challenges and cross-road considerations have been investigated, identifying the problem of personalization and supporting the view why the provision of adaptive content, based on a comprehensive user profile, is considered critical nowadays. The last section overviewed an adaptive Web-based educational content environment that emphasizes on the combination of the aforementioned adaptation concepts and technologies, the "new" user profile that incorporates the user perceptual preference characteristics, and the semantic educational content. The basic objective of this architecture is to approach the theoretical and technological considerations and parameters that could provide the most comprehensive user profiling supporting the provision of the most apt and optimized adapted Web-based educational result.

References

[1] De Bra P., Brusilovsky P., & Houben G. (1999). *Adaptive Hypermedia: From systems to framework*, ACM Computing Surveys 31(4).

[2] Eklund J., Sinclair K. (2000). *An empirical appraisal of the effectiveness of adaptive interfaces of instructional systems*, Educational Technology and Society 3 (4) 2000, ISSN 1436-4522.

[3] Brusilovsky P. (2001). *Adaptive Hypermedia*, User Modeling and User-Adapted BInteraction 11: 87-110.

[4] Brusilovsky P. (1996). *Adaptive Hypermedia: an attempt to analyse and generalize*, In P. Brusilovsky, P. Kommers, & Streitz (Eds.), Multimedia, Hypermedia, and Virtual Reality, Berlin: Springer-Verlag, 288-304.

[5] Brusilovsky P., Nejdl W. (2004). *Adaptive Hypermedia and Adaptive Web*, © 2004 CSC Press LLC.

[6] Brusilovsky P. (1996). *Methods and techniques of adaptive hypermedia*, User Modeling and User Adapted Interaction, 1996, v6, n 2-3, pp 87-129.

[7] Brusilovsky P. (2003). *From Adaptive Hypermedia to the Adaptive Web*, G.Szwillus, J.Ziegler (Hrsg): Mensch & Computer 2003: Interaktion in Bewegung, Stuttgart: B. G. Teubner, 2003, S. 21-24.

[8] Alatalo T., & Peraaho J. (2001). *Designing mobile-aware adaptive hypermedia*, A paper for the 2nd session of the adaptive hypermedia workshop, ACM Hypertext conference.

[9] Kavcic A. (2000). *The role of user models in adaptive hypermedia systems*, [online], http://lgm.fri.uni-lj.si/~alenka/papers/Melecon2000.pdf.

[10] Brusilovsky, P. (1999). *Adaptive and Intelligent Technologies for Web-based Education*. In C. Rollinger and C. Peylo (eds.), Special Issue on Intelligent Systems and Teleteaching, *Künstliche Intelligenz*, 4, 19-25.

[11] Brusilovsky P.,& Peylo C. (2003). *Adaptive and Intelligent Web-based Educational Systems*, International Journal of Artificial Intelligence in Education 13 (2003) 156-169.

[12] Conlan O., Lewis D., Higel S., O'Sullivan D., & Wade V. *Applying Adaptive Hypermedia Techniques to Semantic Web Services Composition*, [online], http://wwwis.win.tue.nl/ah2003/proceedings/www-5/.

[13] Bailey C., Hall W., Millard D., & Weal M. (2002). *Towards Open Adaptive Hypermedia*, In Proceedings of the Second International Conference on Adaptive Hypermedia and Adaptive Web Based Systems, Malaga, Spain, LNCS 2347, Springer, pp. 36-46.

[14] Brusilovsky, P. and Pesin, L. (1998). *Adaptive navigation support in educational hypermedia: An evaluation of the ISIS-Tutor*, Journal of Computing and Information Technology 6 (1), 27-38.

[15] Bulterman D.C.A., Rutledge L., Hardman L., & Ossenbruggen J. *Supporting adaptive and adaptable hypermedia presentantion semantics*, Database Semantics 8 Submission.
[16] Synodinos D., & Avgeriou P. (2003). *The art of multi-channel hypermedia application development*, Proceedings of MobEA WS, allocated with WWW2003 conference, Budapest, Hungary.
[17] Billsus D., Brunk C., Evans C., Galdish B., & Pazzani M. (2002). *Adaptive interfaces for ubiquitous Web access*, Communications of the ACM, Vol. 45, No. 5.
[18] Freire J., Kumar B., & Lieuwen D. (2001). *WebViews: Accessing Personalized Web Content and Services*, ACM 1-58113-348-0/01/0005.
[19] Billsus D., Pazzani M., & Chen J. *A learning agent for wireless news access*, [online], http://www.fxpal.com/people/billsus/pubs/iuinews.pdf.
[20] Panayiotou C., & 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”.
[21] Samaras G., Andreou M., Panayiotou C., & Pitsillides A. (2004). *Time Based Personalization for the Moving User*.
[22] Adomavicious G., & Tuzhilin A., (1999), *User Profiling in Personalization Applications through Rule Discovery and Validation*, ©ACM 1999 1-58113-143-7/99/08.
[23] Wang J., & Lin J., (2002), *Are personalization systems really personal? – Effects of conformity in reducing information overload*, Proceedings of the 36th Hawaii International Conference on Systems Sciences (HICSS’03), 0-7695-1874-5/03, © 2002 IEEE.
[24] Yuliang L., & Dean G., (1999), *Cognitive Styles and Distance Education*, Online Journal of Distance Learning Administration, Volume II, Number III.
[25] Ayersman D. J., & Reed W. M., (1998), *Relationships among hypermedia-based mental models and hypermedia knowledge*, Journal of Research on Computing in Education, 30 (3), pp.222-238.
[26] Reed W. M., Ayersman D.J., & Liu M., (1996), *The effects of students’ computer-based prior experiences and instructional exposures on the application of hypermedia-related mental models*, Journal of Educational Computing Research, 14 (2), pp. 175-187.
[27] Demetriou A., Efklides A., & Platsidou M., (1993), *The architecture and dynamics of developing mind: Experiential structuralism as a frame for unifying cognitive development theories.* Monographs of the Society for Research in Child Development, 58 (Serial No. 234), 5-6.
[28] Demetriou A, & Kazi S., (2001), *Unity and modularity in the mind and the self: Studies on the relationships between self-awareness, personality, and intellectual development from childhood to adolescence*. London: Routdledge.