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# Towards a user-adapted information environment on the Web

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**Abstract:** Due to the tremendously increasing popularity of the World-Wide Web, hypermedia is going to be the leading online information medium for some years to come and will most likely become the standard gateway for citizens to the "information highway". Already today, visitors of web sites are generally heterogeneous and have different needs. The aim of the AVANTI project is to cater hypermedia information to these individual needs by adapting the content and the presentation of web pages to each individual user. The special needs of elderly and disabled users are also partly considered. A model of the characteristics of user groups, individual users, usage environments, and a domain model are exploited in the adaptation process. One aim of this research is to verify that adaptation and user modeling techniques that were hitherto mostly used for catering interactive software systems to normal-abled users also prove useful for adaptation to users with special needs. The evaluation of the effectivity, efficiency, and acceptance concerning the individualized presentation of information is also part of the project. Another original aspect is the development of a network-wide user modeling server that can concurrently accommodate the user modeling needs of several applications and instances of an application within a distributed computing environment.

**Keywords**: Adaptive hypermedia, individualization, adaptability, adaptivity, disabled users, user modeling, user model server

## 1 Introduction

The aim of the AVANTI[1] project is to develop and evaluate a distributed information system that provides hypermedia information about a metropolitan area (e.g., about public services, transportation, buildings) for a variety of users (e.g., tourists, citizens, travel agency clerks,

[1] AVANTI is a collaborative R&D project partially funded by the European Commission within the ACTS programme [4].

elderly people, blind persons, wheelchair-bound people, and users with (slight) forms of dystrophy) with different interests, knowledge, and abilities. The system can be accessed from people's homes, travel agencies, public information kiosks, and on the go, leading to different hardware platforms, software environments, network speeds, and environmental surroundings. In order to cater to the different user needs and usage environments, AVANTI exploits methods and tools developed in the context of adaptive and adaptable systems during the last few years. Internal models of user groups, individual users, usage environments, and a domain model help adapting the content and presentation to each user's individual needs.

So far, existing adaptable and adaptive systems considered mostly users with "normal" physical, sensorial, and cognitive abilities (see [20] for an exception). However, people with special needs, like the disabled and elderly, should also be given the opportunity to take advantage of computer-mediated information, which is already indispensable at many workplaces and increasingly also becomes relevant in public places and at home. Access to information in hypermedia form is particularly important since it is likely to become the standard gateway to electronic information.

Computer access for people with special needs has therefore been a research issue since many years. Considerable efforts have been put into making software systems usable by people for whom they were originally not designed (e.g., access to graphical user interfaces for visually or manually impaired users) and into developing databases with dedicated information for the disabled (e.g., information on wheelchair accessibility of public transportation, or verbal descriptions of paintings in major museums) that supplements already available data collections that do not take people with special needs into account. These solutions are mostly restricted to very small populations of disabled users and are therefore usually fairly expensive due to the small number of potential customers. It seems, however, that techniques from the area of adaptable and adaptive interactive systems can be employed to tailor generic interactive software systems suited for a broad range of user groups, including many disabled and elderly people. This approach not only seems theoretically more satisfactory, but may also be economically more viable than isolated dedicated solutions.

# 2 User Needs

Investigations on user needs that were reported in the literature or carried out in the context of AVANTI [2] have shown a considerable heterogeneity of the different user groups mentioned above. Moreover, individual differences in user needs have also been encountered. Some examples may illustrate this:

- For users interested in a specific subject, more detailed information should be provided, like a link to an assessment of a painter in a web-based virtual museum. If the user lacks this specific interest, such information should not be presented in order to lower the efforts necessary for building a mental model of the current hypermedia page and to reduce the negative consequences of the well-known hypermedia phenomenon of serendipity [9, 22, 27].
- For laypersons like tourists in a travel booking scenario, a technical term like 'check-out time' should be augmented by an explanation. Normally, this is not necessary for domain experts like travel agents.

- For users with low-bandwidth network access (e.g., via a slow modem), information with high data volume (e.g., videos, high-resolution pictures) should be replaced by less demanding, but nevertheless appropriate equivalents, in order to reduce download times. The response time of a hypermedia system is extremely critical from the point of view of usability [23].
- For blind users, the modality of the presented information must be changed to tactile and/or audio output. Moreover, supplementary orientation and navigation aids, like an additional table of content containing all internal and external links on a hypermedia page, are helpful for this user group [15].
- For wheelchair-bound users, information concerning the accessibility of premises (e.g., the existence and the dimensions of ramps and elevators, the type and width of doors) is important and should therefore be automatically provided.
- For users with (slight) forms of dystrophy, the man-machine interface (i.e., the interaction objects and associated manipulation techniques) should be adapted accordingly, i.e., made less sensitive to erratic hand movements.

When implementation issues are considered, it becomes obvious that all these needs can hardly be addressed within the scope of a single project. Consequently, we focused the further investigation on mainly mobility-related user requirements in the metropolitan areas of Siena (Italy), Rome (Italy), and Kuusamo (Finland) and consolidated the findings.

# 3 Scope of Adaptability and Adaptivity

In order to cater to different user needs, information systems can be tailored manually by the system designer (or possibly the user) or automatically by the system. Systems that allow the user to change certain system parameters, and adapt their behavior accordingly, are called adaptable. Systems that adapt to users automatically based on monitoring the users' interaction during runtime are called adaptive[2]. Both features, adaptability and adaptivity, are provided by the AVANTI system:

- *Adaptability and adaptivity within the user interface*
  We integrate and implement (special) I/O devices (e.g., macro mouse, Braille display, speech synthesizer), visual and non-visual interface objects, and associated interaction techniques [26].
- *Adaptability and adaptivity within hypermedia pages*
  We implement the adaptation of the information content, information modality, information prominence, orientation and navigation aids, and links to other hypermedia pages [5].

Whereas the first group of adaptations aims at enabling and improving the overall access to the information system, the second group of adaptations aims at individualizing one specific hypermedia system. In the rest of this paper we will focus on the latter since this seems to be a

[2] A similar definition can be found in [24].

rather novel approach which complements existing solutions that aim at providing access to the WWW for everyone, including users with disabilities [29, 7].

# 4 User and Usage Model

In order to provide user-oriented adaptivity, a so-called 'user model' is maintained by the AVANTI system which contains assumptions about relevant characteristics of an individual user like:

- *Physical and sensorial abilities*, like the user's ability to overcome physical obstacles of any kind (e.g. stairs, narrow passageways), to select an interface element from the user interface, or to perceive graphically presented information.
- *Interests and preferences*, like the user's interest in accessibility information about premises (e.g., availability of ramps and lifts), detailed information about the history of sacral buildings, or preferences for certain information modalities (e.g., graphics, video).
- *Domain knowledge*, about prominent reference points like squares, churches, bridges and the infrastructure in the metropolitan area of interest.
- *Competence in handling computers*, like the ability to manipulate interface elements within a WIMP (Windows, Icons, Menus, Pointer) interface in order to achieve a desired goal.
- *Competence in handling the AVANTI system*, like knowledge about the orientation and navigation aids and the adaptation mechanisms in AVANTI.

Different methods for acquiring assumptions about the user have been discussed in the literature [8]. In AVANTI, assumptions will be acquired based on the following sources of information:

- An *initial interview* allows for the acquisition of primary assumptions [16] about the user and is therefore a valuable source of information for initially assigning the user to certain user subgroups (see the 'stereotypes' below).
- Certain *dialog actions* performed by the user can be exploited for the acquisition of primary assumptions. For instance, if the user requests an explanation for a technical term then it could be assumed that she/he is not familiar with it [18].
- Based on primary assumptions about the user and additional information about the application domain, the system can draw *inferences* in order to acquire further assumptions about the user. For instance, if the user requests more than once detailed information on the history of some churches, she/he can be assumed to be interested in churches, and this detailed information will henceforth be automatically provided.
- So-called '*stereotypes*' [25] contain assumptions about interesting characteristics of user subgroups (e.g., tourists, blind users). If certain preconditions are met, a stereotype can be activated for a specific user which means that the assumptions contained in the stereotype become assigned to the user.

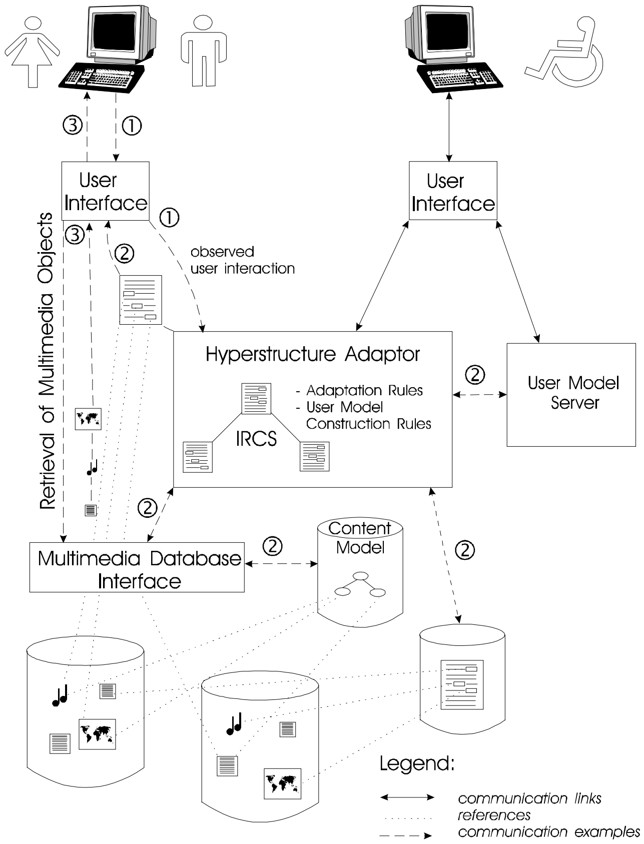
In order to support technically motivated adaptivity, a so-called 'usage model' is maintained by the AVANTI system which contains information about relevant aspects of the system's usage like:

- *User interface characteristics*, to provide alternative task structures according to specific physical and/or sensorial abilities of the current user [3].
- *Network charcateristics*, like the available bandwidth and the offered QOS (Quality Of Service).

Apart from information that is a priori available, like the environment of a specific terminal or the functionality available within a user interface of a specific type, most of the information in the usage model is extracted at run-time from hypermedia page requests via the HTTP protocol [10]. Examples include the field "User-Agent" in the HTTP header containing the type of user interface initiating the request as well as network probes [13] which are injected into transmitted hypermedia pages by the backend of the AVANTI system.

# 5 Overview of the System Architecture

The following figure shows the architecture of the AVANTI system:




In the following, we will focus on the functionality of and the cooperation between the main architectural components of the AVANTI system, namely the *User Interface* (UI), the *Hyperstructure Adapter* (HSA), the *User Model Server* (UMS), and the *Multimedia Database Interface* (MDI) within the scenario of a request for a hypermedia page. The numbers refer to those in the figure:

① The user requests a hypermedia page. The UI forwards this request to the HSA.

② The HSA fetches the requested hypermedia page from secondary storage. The markup language used within this page is a subset of and an extension to HTML [28] named 'Information Resource Control Structure' (IRCS). Apart from static elements, an IRCS page may contain optional and alternative hypermedia objects, and also groups of hypermedia objects with an associated layout like a page header, toolbar, etc. An example for an optional element is supplementary information on wheelchair accessibility. Examples for alternative elements are technical vs. non-technical descriptions and a picture of a painting vs. its textual description.
The processing of these optional and alternative elements is controlled by *Adaptation Rules*, which can take information from other system components into account, namely assumptions about user characteristics (e.g., knowledge, interests, preferences) from the UMS, and content-related information about multimedia objects from the *Content Model* (CM) via the MDI. Information about the current user's session (e.g., previously requested IRCS pages, previously provided input) is available as well. A second group of rules that may be contained in this IRCS page are *User Model Construction Rules*. They control the formation of so-called primary assumptions about the user (i.e., assumptions which are directly derived from the user's interaction with the hypermedia page). Primary assumptions are directly reported from the HSA to the UMS.
The HSA interprets the requested hypermedia page and the Adaptation Rules, generates an adapted page (which is compliant to standard HTML) and hands it over to the UI for presentation.

③ The UI interprets the hypermedia page, retrieves multimedia objects from the AVANTI databases transparently via the MDI, and finally presents the requested hypermedia page to the user. [3]

The communication between all active components is carried out via the HTTP protocol. On top of it, a restricted and slightly enhanced version of KQML (Knowledge Query and Manipulation Language [11]) [17], a high-level communication language and protocol which is independent of the hardware and software platform, is used for communication with the UMS.

The main advantages of this architecture include the following:

- Already existing software in the area of the WWW (e.g., communication libraries, browsers, servers, proxies, web development environments, and database gateways) can be partially or fully used for the development of AVANTI components.
- Most WWW browsers available today can access the AVANTI system and take advantage of the individualization features at the contetn level.
- All active components within AVANTI can be distributed according to organizational and technical requirements. These mostly technically motivated decisions don't affect user's mobility: a user model and the corresponding user model server are located during user's

[3] As pointed out before, the UI is able to perform additional adaptations (e.g., use alternative I/O devices, visual and non-visual interface objects and associated interaction techniques) which are not further discussed here.

login into the AVANTI system. Both services mentioned take advantage of an HTTP-based name service for resolving symbolic references at run-time [14].

- Widely used security standards [6] like SSL (Secure Sockets Layer) and SHTTP (Secure HTTP) may be used in the communication between the HSA and the UI. For this purpose, the HSA takes advantage of certain HTTP servers like those from Netscape Corporation [21].

The HSA and the UMS are central constituents of the AVANTI architecture. Their development does not have to be started from scratch since already available software can be employed as a basis, including WebObjects [1] for the HSA and BGP-MS [16] for the UMS.

# 6 The BGP-MS User Model Server

In AVANTI, user models reside entirely in a User Model Server (UMS). The most important reasons for this include the following:

- The centralized management of user-related information offers the user and other AVANTI components (i.e., UI, HSA) location-independent access to the most recent user-related information.
- Synergetic effects with respect to user-related information can be expected (e.g., the UI can take advantage of assumptions acquired by the HSA and vice versa).
- The HSA and the UI can become totally relieved of user modeling tasks and can take advantage of sophisticated run-time services of the UMS like:
    - incremental construction of user models based on primary assumptions and dialog acts
    - drawing inferences (so-called secondary assumptions) based on primary assumptions and their relationships
    - include/exclude sets of typical assumptions about user groups (so-called stereotypes) on the basis of activation and deactivation rules
    - consistency maintenance

BGP-MS [16] was choosen as a basis for the envisaged UMS for several reasons:

- The scalable functionality puts three representation paradigms at the disposal of the user model developer. Terminological logic will be used in AVANTI. If necessary, first order logic or modal logics could be added in order to enhance the representational and inferential capabilities of the user model.
- The flexible managament of stereotypes is supported. This includes a wide range of activation and deactivation rules.
- Different kinds of user information (e.g., interests, knowledge, abilities) can be stored in different representational structures, efficiently retrieved and employed for inferences.
- The interface is based on messages and can therefore be organically enhanced.

Nevertheless, the current version of BGP-MS has been substantially enhanced in order to establish a network-wide user modeling service. A prototype of the UMS has been made available which offers the following additional features, relative to [16]:

- Access as a network-wide service through a restricted and slightly enhanced version of KQML [17]. The choosen implementation KAPI (KQML Application Programmer's Interface [14]) has been substantially revised. Special emphasis has been paid to the name service contained therein, which, for example, allows a UI to dynamically locate and access the UMS that hosts the model of a particular user.
- Support for hosting the models of several users at a time.
- Efficient dispatch of incoming and outgoing KQML messages, and associated UMS functionality.
- Availability on Allegro Common LISP for Windows/PC [12]. The most recent version of BGP-MS has been ported from CMU Common LISP [19] on SUN workstations to Allegro Common LISP for Windows NT/95.
- Simultaneous support for modal operators representing separate knowledge spaces within a user model (i.e.,“user believes“, “user wants”, “user can”, “user prefers”).

Moreover, a domain-specific user modeling system has been implemented for the field trials in AVANTI, which comprises of models of individual users and user groups, stereotype activation and deactivation rules, inference rules, and consistency maintenance rules.

# 7 Summary

An adaptable and adaptive hypermedia information system has been presented that caters not only to normal-abled, but also to several kinds of disabled users. “Access for All“ to hypermedia systems seems to be very important since this medium is likely to play the role of a gateway to electronic information and services in the next few years, both in professional and domestic environments. Extending the current adaptability and adaptivity mechanisms in such a way that users's physical, sensory, and cognitive abilities as well as his technical environment are taken into account seems to be more promising than providing *post factum* access for user groups for whom the system was originally not designed.

# 8 References


1. Apple Computer, Inc. WEBOBJECTS 3.5/ENTERPRISE OBJECTS 2.2 DOCUMENTATION. 1998. Available at http://developer.apple.com/techpubs/enterprise/WebObjects/WebObjectsTOC.html.
2. AVANTI Deliverable DE001 - User groups' needs and requirements. Project Report, Brussels, 1996.
3. AVANTI Deliverable DE012. Report on Rules. Project Report, Brussels, 1997.
4. AVANTI Home Page. 1998. Available at http://www.avanti-acts.org/.

5. Brusilovsky, P. Methods and Techniques of Adaptive Hypermedia. User Modeling and User-Adapted Interaction 6(2-3), 1996, pp. 87-129.
6. Cain, A. Web Security - Technologies for Security, Authentication, and Privacy on the World-Wide Web. Tutorial Notes, Fifth International World-Wide Web Conference, Paris, May 1996. O'Reilly & Associates, Inc., Sebastopol, CA, 1996.
7. Center for Applied Special Technology. Assistive Technology Vendors. 1996. Available at http://www.cast.org/resources.htm#atvendors.
8. Chin, D. N. Acquiring User Models. Artificial Intelligence Review 7, pp. 185-197, 1993.
9. Conklin, J. Hypertext: An Introduction and Survey. IEEE Computer, September 1987, pp. 17-41.
10. Fielding, R., Gettys, J., Mogul, J., Frystyk, H., and Berners-Lee, T. Request for Comments: 2068, Category: Standards Track. 1997. Available at http://www.w3.org/Protocols/rfc2068/rfc2068.
11. Finin, T. W., Weber, J., Widerhold, G., Genesereth, M., Fritzson, R., McKay, D., McGuire, J., Pelavin, R., Shapiro, S., and Beck, C. Specification of the KQML Agent-Communication Language. 1993. Available at http://www.cs.umbc.edu/kqml/papers/kqmlspec.ps.
12. Franz Inc. ALLEGRO CL for Windows. Berkeley, CA, 1995.
13. Fuller, R., and de Graaff J. J. Measuring User Motivation from Server Log Files. Proceedings of the Microsoft conference "Designing for the Web - Empirical Studies", Redmond, WA, 1996. Available at http://www.microsoft.com/usability/webconf.htm. or http://is.twi.tudelft.nl/~graaff/publications.html.
14. KAPI. 1996. Available at http://hitchhiker.space.lockheed.com/pub/aic/shade/software/KAPI/.
15. Kennel, A., Perrochon, L., and Darvishi, A. WAB: World-Wide Web Access for Blind And Visually Impaired Computer Users. New Technologies in the Education of the Visually Handicapped, Paris, June 1996 and ACM SIGCAPH Bulletin, June 1996. Available at http://www.inf.ethz.ch/department/IS/ea/blinds/.
16. Kobsa, A., and Pohl, W. The User Modeling Shell BGP-MS. User Modeling and User-Adapted Interaction 4(2), pp. 59-106, 1995.
17. Kobsa, A., Fink, J., and Pohl, W. A Standard for the Performatives in the Communication between Applications and User Modeling Systems (draft). 1996. Available at ftp://ftp.informatik.uni-essen.de/pub/UMUAI/others/rfc.ps.
18. Kobsa, A., Müller, D., and Nill, A. KN-AHS: An Adaptive Hypertext Client of the User Modeling System BGP-MS. Proceedings of the Fourth International Conference on User Modeling, Hyannis, MA, pp. 99-105, 1994.
19. MacLachlan, R. A. (ed.) CMU Common Lisp User's Manual. School of Computer Science, Carnegie Mellon University, Pittsburg, PA, 1992.

20. McCoy, K., Pennington, C., Suri, L. English Error Correction: A Syntactic User Model Bases on Principled “Mal-Rule“ Scoring. Proceedings of the Fifth International Conference on User Modeling, Kailua-Kona, Hawaii, 1996.
21. Netscape Corporation. Server Central Index Page. 1998. Available at http://home.netscape.com/comprod/server_central/index.html.
22. Nielsen, J. The Art of Navigating through Hypertext. Communications of the ACM, vol. 33, no. 3 (March 1990), pp. 296-310.
23. Nielsen, J. Usability Engineering.Academic Press Inc., San Diego, CA, 1993.
24. Oppermann, R. (Ed.). Adaptive User Support - Ergonomic Design of Manually and Automatically Adaptable Software. Lawrence Erlbaum Associates, Inc., Publishers, Hillsdale, NJ, 1994.
25. Rich, E. User Modeling via Stereotypes. Cognitive Science, 3, pp. 329-354, 1979.
26. Savidis, A., Stephanidis, C. Developing Dual User Interfaces for Integrating Blind and Sighted Users: the HOMER UIMS. Proceedings of the CHI’95 Conference on Human Factors in Computing Systems, Denver, Colorado, May 7-11, 1995.
27. Schaumburg, H., Issing, L. J. Lernen mit Hypermedia: Verloren im Hyperraum? HMD - Theorie und Praxis der Wirtschaftsinformatik. No. 190, pp. 108-121, 1996.
28. World Wide Web Consortium. HyperText Markup Language. 1997. Available at http://www.w3.org/MarkUp/.
29. World Wide Web Consortium. WAI Reference List on Web Accessibility. 1997. Available at http://www.w3.org/WAI/References/.