Self-Adapting Web-based Systems: Towards Universal Accessibility

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Abstract. This paper discusses the employment of self-adaptation techniques in WWW-based interactive systems, as a tool for ensuring their universal accessibility. The paper first elaborates on the underpinnings of universal accessibility and their relevance to Web applications and services. Then it provides a contextual definition of self-adapting systems and an account of how self-adaptation relates to accessibility. Subsequently, different adaptation approaches that may be employed on the Web are presented, as well as their potential correlation to accessibility solutions. Finally, the application of some of the proposed approaches in the development of Web-based information systems is presented.

Keywords. Universal accessibility, self-adaptation, adaptability, adaptivity, WWW.

1. Introduction

The term *universal accessibility* has been associated with the efforts to provide computer-based interactive applications and services accessible by the broadest possible end user population, including people with disabilities. At the core of these efforts lie two closely interrelated Human-Computer Interaction (HCI) challenges: (a) enabling potential end users to attain sufficient access to the system, so as to successfully engage in effective and efficient interaction; and, (b) further enhancing user interaction with the system, so as to meet the individual abilities, skills, requirements and preferences of each user.

To attain these challenges, a number of currently prevailing HCI assumptions need to be revisited. One such critical assumption relates to the popular notion of designing for the "average" user. With the shift of the paradigm from business computing to communications-intensive, group centred, collaborative and co-operative activities in a global information space, it is evident that the notion of an average user is becoming less popular than the days when the computer was primarily a calculation intensive device or a tool for productivity enhancement ([Stephanidis et al., 1998b]). Consequently, the objective of designing for the average user, which characterised information technology products in the past, will incrementally be replaced by the more demanding and challenging objective of designing to cope with diversity. In other words, if the study of universal accessibility is to be contextualised as a mandatory usability requirement, its scope in the design, development and evaluation phases should be extended to reflect the requirements of the broadest possible end user population and the variety of contexts.

To this end, the study of people with disabilities, is especially relevant, not only from the point of view of demographics and the shared social responsibility, but also due to the fact that the case of accessibility presented by disabled and elderly people constitutes the cutting edge in user interface software and technology ([Stephanidis et al., 1998b], [Vanderheiden, 1997]). It should be noted that in the past, the problem faced by disabled and elderly people was not only lack of access to interactive computer-based products and services, but also low quality of interaction, in the cases where access was granted.

Thus, the normative perspective adopted in this paper is that the study of accessibility requirements of disabled and elderly people[1], is likely to bring about a new understanding of human interaction with information intensive artefacts resulting in a new generation of products which will be improved in their usability, will be intuitive to use and will be accessible by the broadest possible end-user population (i.e., universal accessibility). It follows, therefore, that any reasonable account of the integration of disabled and elderly people in the emerging interaction-intensive paradigm should concentrate equally upon the notions of universal access and interaction quality. In the following section, we will briefly discuss both these requirements in the context of Web-based applications and services.

In this paper we are concerned with accessibility in Web-based applications and services, investigating how adaptation may provide the ground upon which generic solutions to *universal accessibility* can be based.

2. Self-adaptation and accessibility

The notion of systems which can adapt according to various requirements and criteria, or even upon request, is not new. The recent literature contains numerous cases in which adaptation techniques have been used to improve the performance of existing computing systems, or to enable the exploration of new dimensions in computing, in application domains such as networking, decision support, information retrieval and classification, etc.

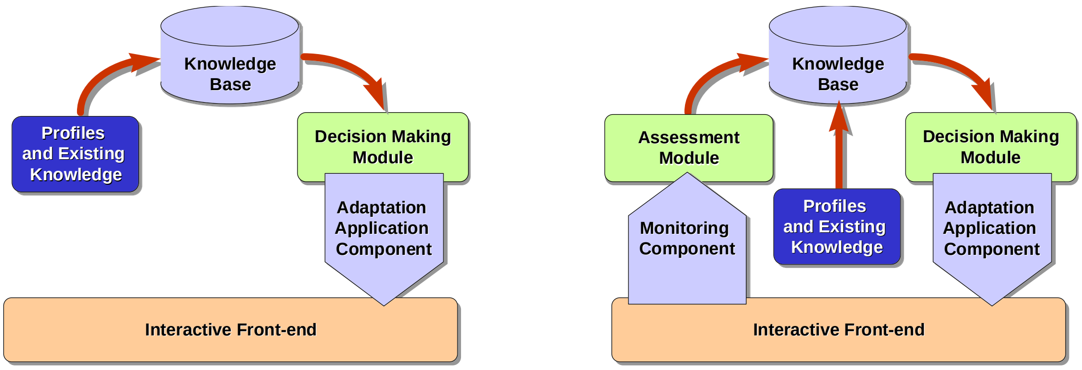
The term *self-adaptation* is used in this paper to denote those variations of system-controlled-adaptation capable systems ([Dieterich et al., 1993]), that are able to implement adaptations themselves, irrespective of the policy they employ in ensuring user control over them. *Self-adaptation* can be classified along different adaptation dimensions, including, but not limited to: the policy employed in providing user control over adaptations, the knowledge utilised by the system to decide upon required adaptations, the decision making process utilised in mapping existing knowledge to adaptation decisions, etc. The terms, *adaptability* and *adaptivity* are often used to denote specific attributes of self-adaptation capable systems, along many of the above dimensions. In the context of this paper, the terms are used as follows.

Adaptability refers to self-adaptation which is based on knowledge (concerning the user, the environment, the context of use, etc.) available to (or, acquired by) the system prior to the initiation of interaction, and which leads to adaptations that also

[1] It is important to note at this point that the requirements of disabled and elderly users have been continuously under-served by technological changes ([Muller et al., 1997]); this renders their treatment even more compelling in the context of the emerging Information Society.

precede the commencement of interaction. Figure 1(a) depicts a generic view of system architectural properties required to support adaptability.

Adaptivity refers to self-adaptation which is based on knowledge (concerning the user, the environment, the context of use, etc.) that is acquired and / or maintained by the system during interactive sessions (e.g., through monitoring techniques), and which leads to adaptations that take place while the user is interacting with the system. Figure 1(b) depicts a generic view of system architectural properties required to support adaptivity.



(a) General system architecture support for adaptability

(b) General system architecture support for adaptivity

Figure 1: General system architecture support for adaptability and adaptivity.

It has already been claimed that the issue of ensuring universal accessibility of interactive applications and services by all users, can be viewed as the synthesis of two separate, but closely inter-related challenges: enabling potential end users to attain sufficient access to the system, so as to successfully engage in effective and efficient interaction with it; and, further enhancing user interaction with the system, so as to meet the individual abilities, skills, requirements and preferences of each user. The current research focus, on the employment of adaptability for the treatment of primary access problems, will, in the very near future, have to be extended to also consider adaptivity as a tool in ensuring continuous, uninterrupted access to interactive systems.

Along this line, *adaptability* can be viewed as a tool in providing *direct accessibility* in current systems. Interactive systems that support direct accessibility depart from the current paradigm of relying on third-party software, or post-development modifications towards accessibility. Instead, they are designed so as to encapsulate the necessary facilities to support different interaction styles, media, modalities, etc., and conditionally activate, or enable them through adaptability techniques. *Adaptivity* on the other hand, cannot be employed in the same manner as adaptability. It requires that interaction between the user and the machine has already been established, and strives to enhance the interaction by monitoring it and drawing conclusions about the user (including, for example, user characteristics, possible difficulties in interacting with the system, interaction plans and intentions, task performance, personality traits, etc.) [Grunst et al., 1996]. The employment of adaptivity can, consequently, address a different set of issues than adaptability, including, but not limited to the following: fine-tuning interaction facilities and input / output modalities to better suit identified usage patterns, or potential interaction problems (e.g., adjusting the speed of speech in auditory interfaces); raise the awareness of users to specific system functionality;

provide assistance to the user towards the successful completion of interaction tasks; prevent, where possible, errors from happening; automatically correct errors; identify and replicate long, or tedious recurring interaction patterns; decrease the complexity of a system by conditionally "hiding" part of its functionality; modify the interaction environment to better suit the user's conceptual model of the system; etc.

2.1 Web accessibility through self-adaptation

One of the main peculiarities of the Web in terms of interactivity, when compared to more traditional computing environments, such as windowing systems, is the difficulty in drawing a clear line where the interface ends and the content starts. The specification of any single Web page (in effect an instance of a hyper-document), mixes together what has been traditionally considered information content, along with interactive behaviour of that very same information content.

Looking at Web documents, we can distinguish their components into: (a) ones that solely support the presentation of information; (b) ones that are solely intended for manipulating, and navigating through, information; and (c) ones that combine both roles. Of the three categories above, in the context of this paper, we will classify (b) as part of the user interface, (a) as part of the information content, while (c) will be treated in the next sections as both user interface and content. It follows therefore that Web accessibility requires self-adaptations both at the level of the interface and that of the content.

2.2 Accessibility through adaptations at the user interface level

The normative view of the user-computer interaction process identifies three levels at which it is realised [Hoppe et al., 1986], namely, semantic, syntactic and lexical. Adaptations maybe related to any of those levels.

The lexical level of interaction is perhaps the most prominent one at which accessibility by persons with physical impairments can be treated. In contrast to the current approach[2], universal accessibility requires that the interface is capable of rendering itself accessible to all the potential end users. Possible adaptation approaches that could be employed to meet this goal in Web application interfaces, include:

- Incorporation of support for, and conditional activation / deactivation of multiple interaction modalities, mostly based on the user profile.
- Capability to automatically modify the presentation and conceived behavioural attributes of interactive elements.

The syntactic level of interaction has been the main focus of user interface adaptation research in recent years. Although quite a large amount of related research has been reported in the literature, there is not enough empirical evidence yet to inter-relate specific categories of syntactic-level adaptations with interaction situations in which they are mostly beneficial. This is due to the high dependency between syntactic adaptations and application context, as well as due to the lack of appropriate methods for empirically comparing adaptable and adaptive system (this is true not only for

[2] Prevailing practices focus on either employing third-party software to provide access to the interface of a mainstream application, or developing applications with specialised interfaces for specific categories of disabled people.

comparing such systems between each other, or with their "static" counterparts, but also for comparing different adaptation policies within a single system). Examples of syntactic-level adaptations of relevance to Web-based user interfaces include:

- Support for alternative task structures
- Support for alternative syntactic paradigms
- Adaptable and adaptive help facilities
- Task guidance (guided interaction)
- Task simplification
- Awareness prompting
- Adaptive error prevention and correction
- Automatic replication of recurring interaction patterns

Adaptations at the semantic level of interaction have not been treated to equal length with their syntactic-level counterparts. They also suffer from lack of strong empirical evidence to support their employment in given circumstances, and also from lack of an adequate number of experimental or real-world systems that employ them.

Interaction semantics relate to what the user perceives as the prevailing interactive embodiment of the computer (e.g., desktop, book, rooms), as well as the functionality that should be available. Adaptations at this level mainly concern the overall interactive metaphor(s) used to embody different functional properties of the system[3]. Recent advances in Web technologies have made it possible for a metaphor to be either embedded in the interface of Web applications and services, or characterise the overall interactive environment. For instance, using a metaphor to develop a suitable visualisation of a collection of related documents and the hyper-links between them is an example of embedding metaphor in the user interface. In contrast, developing an interface which allows the user to exclusively interact with hyper-documents through book-, rather than desktop-related concepts (such as table of contents, chapters, index, etc.) implies using a metaphor to characterise the overall interactive embodiment of the computer. Adaptation may be used not only to select and instantiate suitable interactive metaphors for different users and tasks, but also to individualise interaction, by modifying only part of the metaphoric environment, in order to convey domain-, or system-specific concepts in a more coherent, or easier to attain form.

2.3 Accessibility through adaptations at the content level

Although the area of adapting information content has received considerable attention in the recent past ([Brusilovsky, 1996], [Barrett et al., 1997], [Saiz et al., 1998], [Negro et al., 1998], [Stefani and Strapparava, 1998]), little has been done in the direction of addressing accessibility ([Fink et al., 1997]). To facilitate the discussion, we will use Brusilovsky's classification of adaptation technologies in adaptive

[3] This use of the term *metaphor* should be distinguished from the case of embedding metaphoric properties into a user interface without modifying the overall interactive embodiment to be conveyed.

hypermedia ([Brusilovsky, 1996]), which distinguishes between adaptive presentation and adaptive navigation support[4].

Adaptive presentation

This is the core of content adaptation on the Web, and concerns only the exclusively non-interactive portions of hypermedia documents. Of the most popular and well explored methods of content adaptation that falls within this category is the adaptive selection of the nature and level of detail of information that gets presented to the user. Techniques that can be employed in achieving this effect at the content level include [Brusilovsky, 1996]: conditional text; stretch-text; explanation variants; fragment and page variants; frame-based adaptations; etc. In the context of attaining universal accessibility, all of the above methods can be of use, under the following two perspectives:

- they can be used to provide users with additional information which is known to be of interest to them, either due to its relevance to specific user (dis-)abilities (e.g., physical space accessibility information in on-line accommodation reservation services), or due to the users' interests, expertise and domain-specific knowledge (e.g., an on-line tutoring system could provide detailed technical descriptions of processes to users with high expertise); along the same lines, information which may confuse users, or be deemed irrelevant, or unnecessary, with respect to their current task, or general profile, can be withheld by the system, being in effect "hidden" from the user;
- extending on the above perspective, the same methods can be used to explicitly assist users in gradually familiarising themselves with the system semantics, thus embedding into the system the capability to "tutor" the user, assisting them in progressively attaining the required expertise to make full use of the available facilities and functionality.
- A closely related theme in content adaptation is the selection of an appropriate medium and modality in which to present information to the user. Although, this is a very promising field in terms of accessibility, it has not been thoroughly explored yet, mainly because it presupposes that all information provided by the system is available in multiple modalities, or in a modality from which it can be easily transformed to others (which is the case of simple text). Another limiting factor is that there are not yet any robust and tested approaches to constructing systems that are capable of presenting information in a medium-, and modality-independent manner. Nevertheless, the accessibility benefits that could result from the employment of the specific adaptation technique are of major importance for disabled users incapable of attaining information through particular sensory channels, as well as for the presentation of information in alternative, more appropriate forms to cater for the specific context of use and the physical characteristics of the technology platform utilised.

Also related to the content-adaptation methods being discussed is the case of not modifying information itself, but the structure of the hyper-documents containing it, or

[4] Although the aforementioned classification does not differentiate between interface and content, as it views hypermedia systems as a whole, such a separation is implicitly introduced in this section for the needs of this paper.

even the structural properties of how hyper-documents relate to each other. There are many reasons for undertaking such a strand of adaptations. For example, in the case of disabled people, it is obvious that a single structure cannot be usable to all potential users. Intra-, and inter-document structure, however, is also known to affect how users perform in accessing information, irrespectively of disability.

Adaptive navigation support

Brusilovsky identifies five main goals that can be achieved through the provision of adaptive navigation support ([Brusilovsky, 1996]): global guidance, local guidance, local orientation, global orientation, and management of personalised views in information spaces. These goals, coupled with the requirement to support different browsing strategies as these emerge from individual differences between users ([Catledge and Pitkow, 1995]), constitute a strong incentive for exploring the relevance of adaptive navigation support to accessibility.

Global guidance is appropriate in those cases that there exists a "global" information goal and browsing the system is the way to find the required information ([Brusilovsky, 1996]). By offering global guidance, a system can support and direct the user in attaining the overall interaction goal, thus significantly enhancing its accessibility, in terms of interaction semantics. In other words, global guidance can facilitate users with little, or no experience in the system, to sustain effective and efficient interaction sessions, from the very beginning.

A more limited, but also far more easier to attain goal, is to provide users with local guidance, i.e., to identify the information seeking plan of the user that is currently employed and adapt the navigation support offered according to that. This goal is easier to attain at a local level because it can concentrate solely on user characteristics such as abilities, skills, requirements, preferences, interests, etc., and the recent interaction history ([Waern, 1997]), without introducing them in a global system context, where they would have to be further interpreted in terms of the global interaction goal. However, being easier to reach does not limit the utility of addressing this goal. Its greater strength concerning accessibility lies with the possibility to "direct" the user into an artificially "smaller" information space than the actual one, where all the required information resides. This could be of extreme usefulness for users with cognitive difficulties, as well as for users with limited attention span, resulting either from specific impairment, or from the context of use (e.g., consider the case of a person working at a help desk and looking for specific pieces of information in a corporate database, while having to attend to other duties in parallel).

Related to local navigation support is the goal of providing local orientation to users, i.e., assisting them to comprehend "what is around and is his, or her relative position in the hyperspace" [Brusilovsky, 1996]. In doing so, adaptation techniques such as link annotation, link hiding and link sorting are the most relevant ones. The main idea is again to confront the user only with information that is relevant, and to further manipulate the presentation of such information so that the most important pieces are encountered before less significant ones. In similar ways to local navigation support, it is possible to utilise "static" characteristics from a user's profile (i.e. characteristics that seldom change within one interaction session, or at all), with dynamically collected knowledge about the state of interaction, in order to decide what type of orientation support is required by different users and user categories. By successfully assisting users in orienting themselves at the local level , a system can reduce the cognitive overload entailed in the users' doing so unassisted, which could in many cases be overwhelming, introducing an additional barrier to accessibility.

Global navigation support, on the other hand, is more focused in assisting users to understand the structure of the overall hyperspace and their absolute position within it. As far as accessibility is concerned, the above is closely related to the goal of enabling the user to develop and sustain personalised views of the information space. The accessibility challenge that is to be met in both cases is to enable users to comprehend the overall structure of the system, the similarities and differences between its components / portions, and the actual facilities each of them represent. Adaptation techniques that could be employed towards this end include the provision of adaptive maps that provide an "external" view of the system, as well as the annotation and conditional presentation of links, while the user has an "internal" view of the system.

3. The ACTS AVANTI project: A case study

The EC ACTS AVANTI AC042 project (see Acknowledgements), which was concluded in August 1998, aimed to address the interaction requirements of individuals with diverse abilities, skills, requirements and preferences (including disabled and elderly people), using Web-based multimedia applications and services.

The AVANTI project advocated a new approach to the development of Web-based information systems. In particular, it put forward a conceptual framework ([AVANTI, 1995]) for the construction of systems that support adaptability and adaptivity at both the content and the user interface levels. The AVANTI framework comprises five main components[5] (see also Figure 2): (a) a collection of multimedia databases accessed through a common communication interface (Multimedia Database Interface - *MDI*) and contain the actual information; (b) the User Modelling Server (*UMS*), which maintains and updates individual user profiles, as well as user stereotypes; (c) the Content Model (*CM*), which retains a meta-description of the information available in the system; (d) the Hyper-Structure Adaptor (*HSA*), which adapts the information content, according to user characteristics; and, (v) the User Interface (*UI*) component, which is capable of tailoring itself to individual users. The co-operation between the main architectural components of the AVANTI system are presented in Figure 2. The following short scenario (also depicted in Figure 2) presents the typical "route" of a request for a hypermedia document in the system:

① The user requests a hypermedia document. The user interface forwards this request to the content adaptation component (HSA).

② The HSA matches the request to an appropriate hypermedia document "template", assembles the (adapted) document taking into account user- and content-related information that is provided by the user modelling component (UMS), and propagates the adapted document to the UI.

[5] ICS-FORTH, with which the authors are affiliated, has been the partner in the AVANTI consortium responsible for the design and implementation of the user interface component of the AVANTI Information Systems. Other consortium partners (see Acknowledgements) have been responsible for the development of other modules.

③ The UI interprets the hypermedia document, transparently retrieves multimedia objects from the AVANTI databases via the multimedia database interface (MDI), and finally presents the requested hypermedia page to the user, employing appropriate (accessible) interaction and presentation facilities.

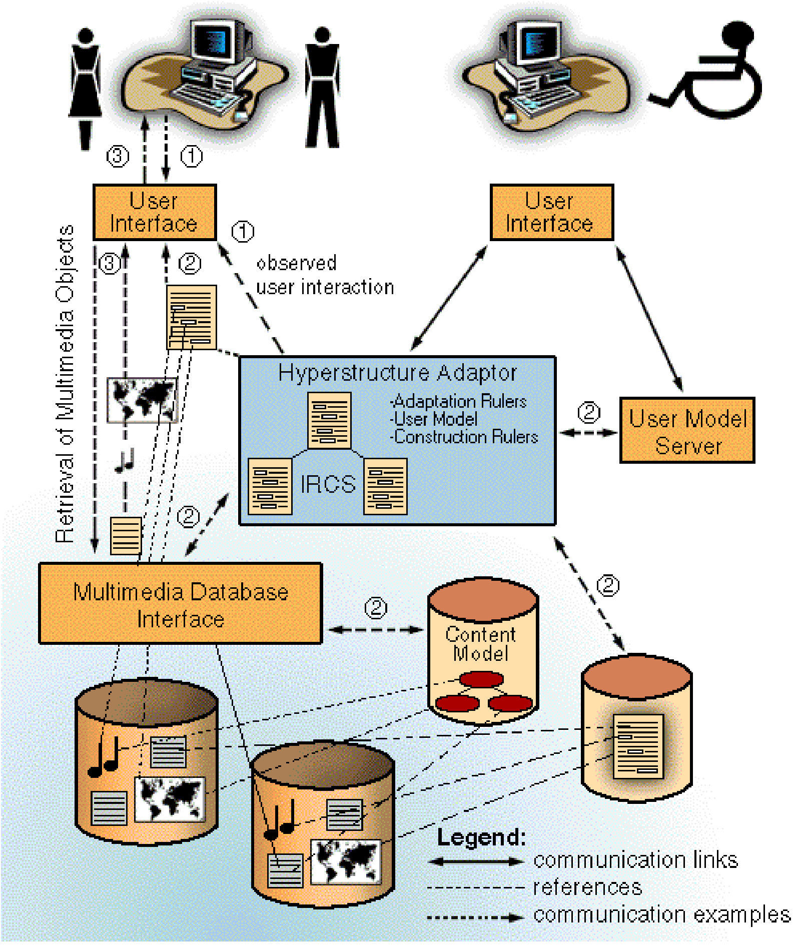


Figure 2: The AVANTI System.

The above conceptual framework has been applied in the development of three information systems, in the context of the AVANTI project itself: (a) the Siena information system ([Del Bianco, 1998]), offering touristic and mobility information to residents and visitors of the city of Siena in Italy, (b) the Kuusamo information system ([Penttila and Suihko, 1998]), providing information on travelling and accommodation in Kuusamo and its surroundings, and (c) the Rome information system ([Ghetti and Bellini, 1998]), aimed at providing guidance to citizens, tourists and pilgrims travelling to Rome. The target user categories of the project were able-bodied people, blind people, and people with light and severe motor impairments.

3.1 Content-level adaptations in AVANTI

Content adaptations are supported in AVANTI through the Hyperstructure Adaptor (HSA) ([Fink, 1997], [Nill, 1998]) which dynamically constructs adapted hypermedia documents for each particular user, based on assumptions about the user characteristics and the interaction situation provided by the User Model Server (UMS) component ([Schreck and Nill, 1998], [Kobsa and Pohl, 1995]). The documents are constructed from static elements, and alternative hypermedia objects. The HSA assembles the adapted documents employing a set of adaptation rules and information acquired from the user model (i.e. assumptions about user-relevant characteristics such as knowledge, interests, preferences), and / or content-related information about multimedia objects from the Content Model and Multimedia Database Interface components.

The degree of support for, and the type of, content-level adaptations in the three information systems developed in the context of AVANTI are summarised in Table 1. The user characteristics that trigger appropriate adaptation types at the content level, mainly concern the type of disability, the expertise and the interests of the user, while the resulting adaptations mostly concern alternative presentation using different media (e.g., text vs. graphics, alternative colour schemes); additional functionality (e.g., "shortcuts" - adaptive links to frequently visited portions of the system; conditional presentation of technical details; and "role-taking" facilities - allowing users to identify themselves as having a particular disability, or active interest in one), different structure and different levels of detail. It is interesting to note that the knowledge about the user and the interaction session is mostly based on information acquired dynamically during run-time (e.g., navigation monitoring, user selection, explicit user invocation), with the exception of the initial profile of the user, which is either retrieved from the UMS, or acquired through a questionnaire during the initiation of the interaction.

3.2 User interface-level adaptations in AVANTI

The User Interface (UI) component ([Stephanidis et al., 1998a]) of AVANTI is intended to provide interactive views of adaptive multimedia Web documents. The distinctive characteristic of the AVANTI UI is its capability to dynamically tailor itself to the abilities, skills, requirements and preferences of the users, to the different contexts of use, as well as to the changing characteristics of users, as they interact with the system. The AVANTI UI also features integrated support for various "special" input and output devices, along with a number of appropriate interaction techniques that facilitate the interaction of disabled end-users with the system.

The UI component is common to all three information systems developed within the AVANTI project, and does not operate, or adapt upon domain-specific knowledge. Adaptations are based on a mixture of user characteristics retrieved from user profiles (or provided by the user through an appropriately tailored interactive session), and dynamic assumptions concerning the state of interaction, provided by the UMS. The user characteristics that are retrieved from profiles include: (a) *physical abilities*; (b) the *language* of the user; (c) the *familiarity of the user* with the Web in general and the AVANTI system itself; (d) the overall *interaction target* (i.e. speed, comprehension, accuracy, error tolerance, or any combination of these); and, (e) *user preferences* regarding specific aspects of the application and the interaction. Information about the user that is dynamically inferred by the UMS, includes: (i) *familiarity with specific tasks*; (ii) *ability to navigate* using the documents' navigation elements; (iii) *error rate*; (iv) *disorientation*; (v) *user idle*.

Table 1: Content-level adaptations in AVANTI.

Method of acquiring knowledge	Characteristics	Adaptation type
	interest in location / type of building	• link annotation • closest interesting places
navigation monitoring		• disability-related additional information
	disability(-ies)	• alternative page structure • alternative help pages
questionnaire	expertise in: • computers • AVANTI • area	• additional navigation guidance
role-taking buttons		• role-taking buttons availability • technical-details button availability • alternative text
explicit invocation by user	disability + expertise	• additional information (non-disability related) • different levels of detail
	interest	• criteria for searching accommodation • presentation and actual content of search results • alternative information content
system calendar	season	• colour- and graphic-scheme
user selection		• additional links
		• “shortcuts”
	specific interest + navigation pattern	• interest modification
		• alternative inter- and intra-page navigation facilities

Legend:

- Siena Information System (blue arrow)
- Kuusamo Information System (green dotted arrow)
- Rome Information System (red dashed arrow)

The categories of interface adaptation supported by the AVANTI UI include: (1) support for different *interaction modalities and input / output devices*; (2) automatic adaptation of the *presentation of interaction elements*; (3) *task-based adaptive assistance*; (4) *awareness prompting*; (5) limited support for *error prevention*; (6) limited support for *metaphor*-level adaptation. Table 2 summarises the dependency between user-, and usage context knowledge and the adaptations that are triggered upon that knowledge in the AVANTI UI component.

It is interesting to note that, although at present, most of the adaptations at the user interface level are associated with the provision of accessibility to people with sensory, or motor disabilities, the architecture of the respective module allows for easy additions to the adaptation logic, as the latter is maintained externally to the interface ([Stephanidis et al., 1997], [Stephanidis et al., 1998a]). In other words, it is possible to add, or modify adaptation rules by altering the external "rule base" (and possibly the user modelling component, if an entirely new piece of information needs to be inferred), without revisiting the actual implementation of the interface.

Instances of self-adaptation in AVANTI

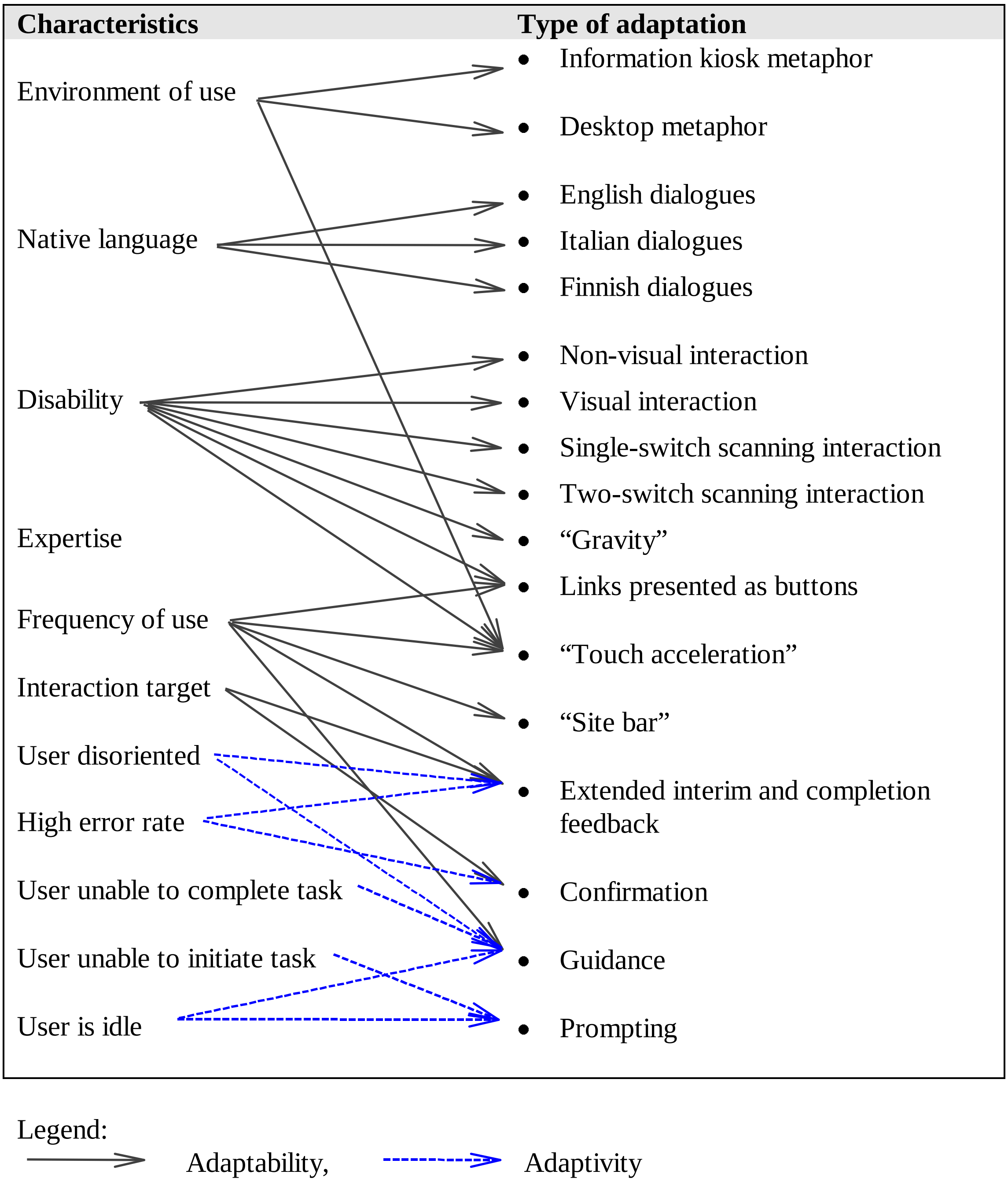
To illustrate some of the concepts of self-adaptation, we provide some instances of adaptability and adaptivity of the AVANTI user interface in Figure 3. In particular, the figure illustrates: (a) a "typical" instance of the interface, resembling generic rendering applications; (b) a mixture of adaptations at the syntactic level (enabled "site-bar", explicit feedback for the "add bookmark" operation) and lexical level of interaction (links presented as buttons, instead of as underlined text); (c) activation of scanning interaction facilities for motor-impaired users; (d) scanning-enhanced on-screen keyboard for text input by motor-disabled users; (e) a guidance dialog presented to the user due to the detection of the user's inability to complete a specific task; and, (f) and (g) a second case of task guidance provision, within the dialog encapsulating the user task to which guidance refers.

As instances (e) and (f and g) illustrate, AVANTI has also explored different approaches to applying adaptations and introducing them to the user, as well as different approaches to ensuring that the user retains final control over what gets modified into the system and how. Although initial results from informal testing show that some of these approaches have practical value, further user-based evaluation is required before one can formally assess the value of such self-adaptations according to different criteria.

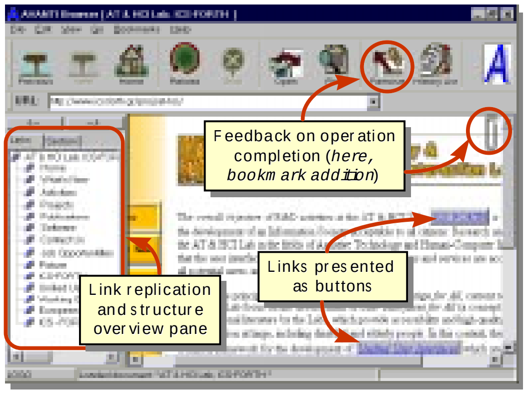
4. Discussion and conclusions

This paper has addressed the relevance and the envisioned utility of employing self-adaptation techniques to increase the accessibility of Web-based applications and services by the population at large. The normative perspective of the paper is that accessibility should be recognised as a crucial quality requirement in the emerging Information Society. In this context, and in view of the fact that the Web is becoming a pervasive medium that is rapidly penetrating an increasing range of human activities, it is absolutely necessary to ensure that all potential users can attain and sustain equitable and high-quality access to Web applications and services.

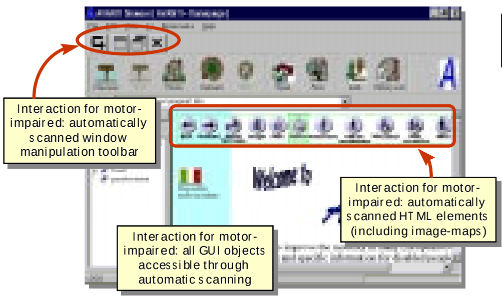
Table 2: Interface-level adaptations in AVANTI.



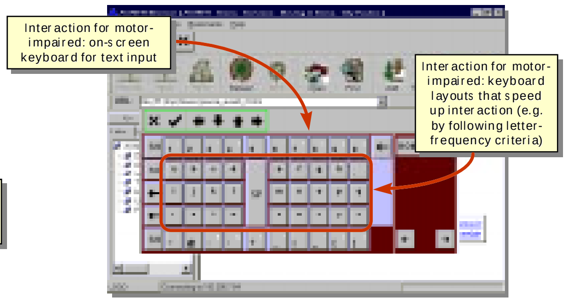
(a) Conventional instance of the interface.



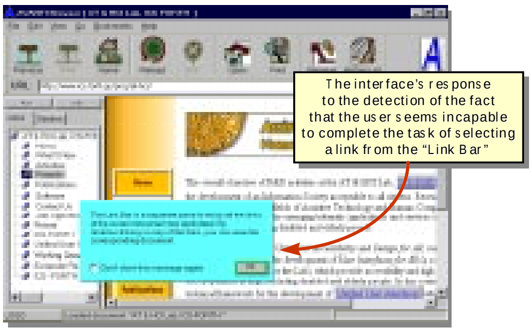
(b) A mixture of adaptability features activated.



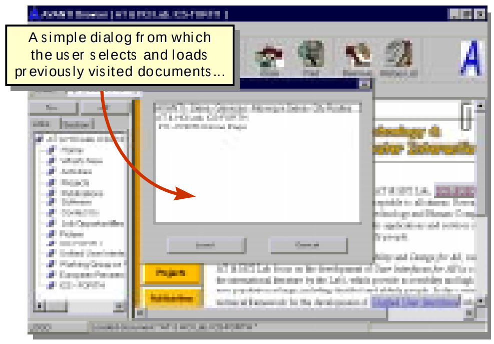
(c) Scanning for switch-based interaction.



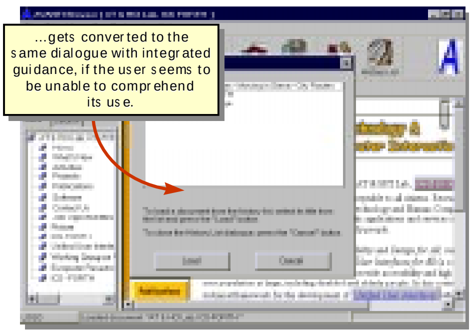
(d) On-screen “virtual” keyboard for text input.



(e) Instance of external task guidance.



(f) Instance of embedded task guidance (*before*).



(g) Instance of embedded task guidance (*after*).

Figure 3: Instances of interface adaptation in AVANTI.

In this respect, accessibility becomes a universal requirement for the population at large, rather a niche requirement of people with disabilities.

Though, there have been several recent efforts in this direction, the above goal is hardly met. As technology evolves and the range and nature of human activities that can profit from computer mediation increases, we will repeatedly have to re-assess what we know, what is possible and what is “good”.

This, however, is a continuous process, characteristic of evolution, and, therefore, should not be used as an argument against the employment of adaptation. By taking the first steps in this direction, we can set the foundations for rendering new technologies a priori accessible as they become available, instead of maintaining the current practice of treating accessibility as an afterthought.

In this direction, it is also necessary that considerable effort is invested in tools that will support and facilitate the *design*, *implementation* and *evaluation* of self-adapting systems. As these three phases of the development life-cycle differ significantly in adaptation-capable software, when compared with their “static” counterparts, current tools do not sufficiently address the new range of requirements. Indicative problems that need to be addressed, and are not covered by existing methodologies and techniques, include for example:

- appropriately enhancing user-centred design processes to arrive at multiple, alternative, or complementary design artefacts that cater for the full range of intended user categories and contexts of use;
- designing for individualisation, without user intervention;
- implementing systems so that alternative design artefacts may coexist in a single implementation;
- deferring dialogue management of interactive systems to run-time components, rather than hard-wiring it into the system;
- appropriately enhancing user-based evaluation techniques, so as to be able to assess both the value of a self-adapting system as whole, but also the appropriateness and usefulness of adaptations on a per-user basis; etc.

In the future, it is expected that interface-, and content-adaptation will become a prominent target in Web-related research and development efforts. Though the issues identified in this paper will continue to pose challenges, additional ones are likely to emerge as the Web turns into an evolutionary information repository and a primary medium for communication. In this context, organisational and social issues are expected to complement accessibility, usability and performance targets, thus extending the type, scope and nature of the required adaptations.

In conclusion, it is important to iterate that the *capability* of any interactive system to *adapt* any specific aspect of interaction, or information, does not necessarily imply the *necessity*, or, for that matter, the *usefulness* of doing so. This is no different in the Web. It follows, therefore, that any adaptation capability should be treated as a *tool* in accommodating specific design problems, and should be treated with care, as exaggerations in the employment of adaptations could significantly compromise the usability, user-friendliness and overall acceptability of the system.

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