Supporting Interface Adaptation: the AVANTI Web-Browser

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Abstract. The increasing use of Internet and the World Wide Web as a primary medium for communication and access to information is creating numerous opportunities and challenges for the population at large and especially for people with disabilities. The importance of supporting information exchange between *all* potential users in the context of the emerging Information Society has, therefore, increased significantly. This paper focuses on the employment of user interface adaptation techniques, for the provision of accessibility and high-quality interaction to Web-based applications and services to able-bodied, blind and motor-impaired users. The work reported has been conducted in the context of the ACTS AC042 AVANTI project of the European Commission.

Keywords: user interface adaptation, web-based applications for people with disabilities, unified user interface development

1. INTRODUCTION AND BACKGROUND

The emergence of the Information Society and the increasing use of the Internet and the World Wide Web introduce new dimensions in the field of Human-Computer Interaction, necessitating the design of user interfaces which provide *accessibility* and *high-quality interaction* to *all* potential users, including people with disabilities [Stephanidis 96].

Current approaches to the provision of accessibility to computer-based applications and services are mainly based on adaptations to existing systems, or on “dedicated” developments targeted to specific user categories [Savidis 95]. Along the same lines, attempts to provide accessibility in the Web environment are usually based on adaptations that can roughly be separated into three different levels: alternative access systems; the information content and structure; the user interface [Treviranus 96].

Support for alternative access systems involves the integration of special I/O devices (e.g. alternative keyboards, voice recognition systems, screen magnifiers, screen readers, Braille displays), as well as adaptations of interaction techniques (or provision of alternative ones) in the operating system or the graphical environment (e.g. [Microsoft 95], [Microsoft 96]). Adaptations at the level of the information content mainly concern the provision of guidelines for Web authors, towards the development of more accessible HTML documents (e.g. [Vanderheiden 96], [Richards 96], [Gunderson 96]). At the level of the user interface to the Web (browsers), adaptations mainly concern either the employment of the accessibility options provided by the operating system in conjunction with alternative input/output devices, or the development of special-purpose browsers for specific categories of disabled people (e.g. the *pwWebSpeak* browser for blind users [pwWebSpeak]). Moreover, text-based browsers (e.g. *Lynx* [Lynx] and *W3-Emacs* [ACT Centre 96]) are also utilised in cases where alternative input / output devices are not available in the graphical environment.

The rapid evolution of technology, however, restricts considerably the scope of such "reactive" approaches, since it may be technically difficult, or even not feasible, to apply them. Furthermore, applications or services developed / adapted for specific categories of disabled users may incur high costs and address relatively small portions of the market, thus becoming impractical from a cost / benefit point of view [Stephanidis 95a].

An alternative approach to overcoming the above limitations, would be to cater for differing user requirements and preferences during the early design and development phases of (Web based) computer systems [Akoumianakis 97]. In this context, following the principles of "Universal Accessibility" and "Design for All", the concept of "User Interfaces for All" has been proposed, as the means to ensure user interface accessibility and to meet the individual abilities, requirements and preferences of the user population at large, including disabled and elderly people [Stephanidis 95a].

The Unified User Interface Design methodology (U^2ID) has been defined as the vehicle to efficiently and effectively serve the goal of user interfaces for all [Stephanidis 95c], [Stephanidis 97b]. Following U^2ID, only a single unified user interface is designed and developed, which comprises alternative interaction components, appropriate for different target user categories. This single design artefact may have multiple instantiations during initiation of interaction (adaptability), in order to ensure accessibility for a wide range of users. Moreover, each interface instance is continuously enhanced at run-time (adaptivity), in order to provide high-quality of interaction to *all* potential users (Figure 1) [Stephanidis 95b].

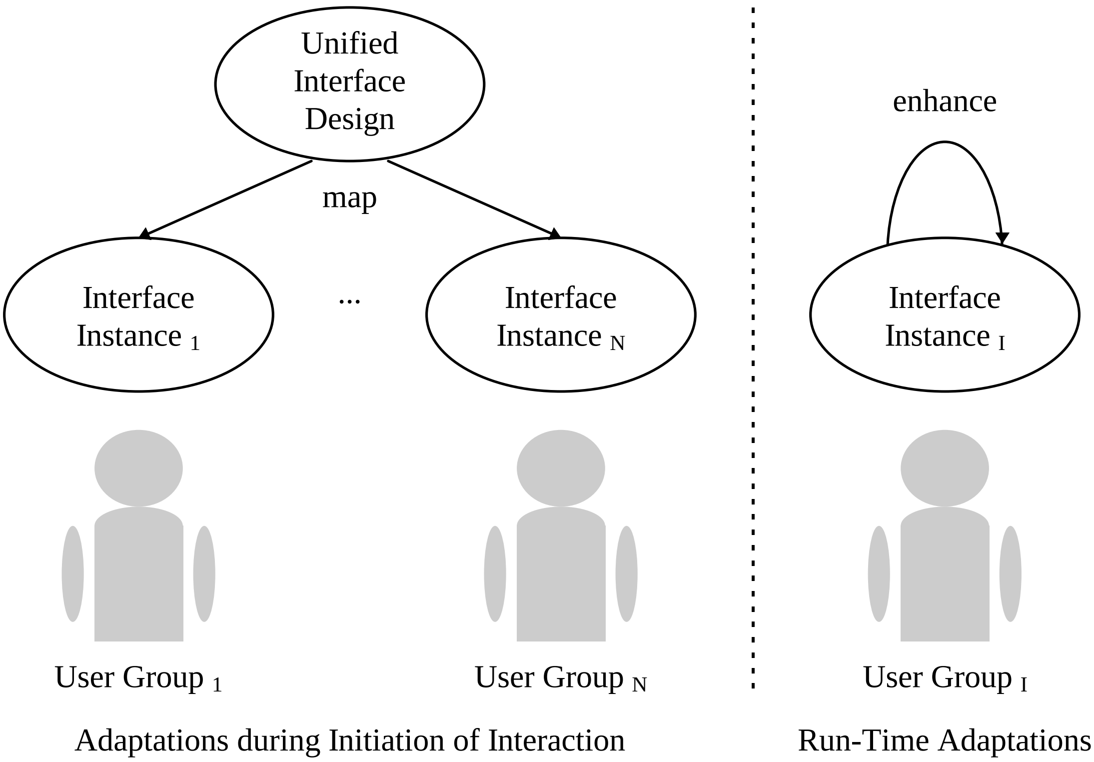

Figure 1 - User Interface Adaptability and Adaptivity following the U^2ID Methodology

This paper focuses on work conducted in the context of the ACTS AC042 AVANTI project of the European Commission, towards the development of interfaces to multimedia telecommunication applications and the Web, which are accessible and usable by a wide range of users. In particular, based on the U^2ID methodology, a Web browser has been designed and implemented to act as the front-end of an information system, where lexical and syntactic adaptability and adaptivity techniques are employed to meet the requirements of able-bodied, blind and motor-impaired users.

2. ADAPTABLE AND ADAPTIVE INTERACTION ON THE WEB

Figure 2 depicts the overall architecture of the AVANTI system, showing the different modules which are utilised in the provision of adaptable and adaptive interaction. There are three main modules, namely:

- a collection of multimedia databases which are accessed through a common protocol (HTTP) and provide mobility information for disabled people; a multimedia database interface has been defined, providing the necessary abstraction for accessing the different databases [AVANTI 97b];
- the AVANTI server which: (i) maintains knowledge regarding the users (*user model server*); (ii) retains a *content model* (e.g. relations between entities) of the information system; and, (iii) adapts the content and presentation of the information to be provided (content adaptation), according to user characteristics (*hyper-structure adaptor*) [AVANTI 97c];
- the unified browser interface, which is capable of adapting itself to the abilities, requirements and preferences of individual users.

Adaptability and adaptivity at the user interface level are supported through the co-operation of the user interface and the User Model Server (UMS) [Fink 97]. In particular, the user interface continuously monitors user interaction and notifies accordingly the UMS. Monitoring data concern lexical level events (e.g. mouse presses and keystrokes) and their respective task context, as well as syntactic level information, such as task initiation, task completion and task termination. The UMS, in turn, draws inferences on user states (situations), and successively updates a knowledge space. The updated knowledge is used by the user interface to decide upon and self-adapt.

2.1 Adaptation Dimensions

Two dimensions of adaptations are addressed within the user interface of the AVANTI system, with relation to:

- the *time* that adaptations take place, i.e. whether adaptations take place during the initiation of interaction (adaptability), or at run-time (adaptivity), and
- the *level of interaction* at which adaptations are applied, i.e. syntactic and lexical level adaptations.

Thus, four types of adaptations can be distinguished: lexical adaptability, syntactic adaptability, lexical adaptivity and syntactic adaptivity.

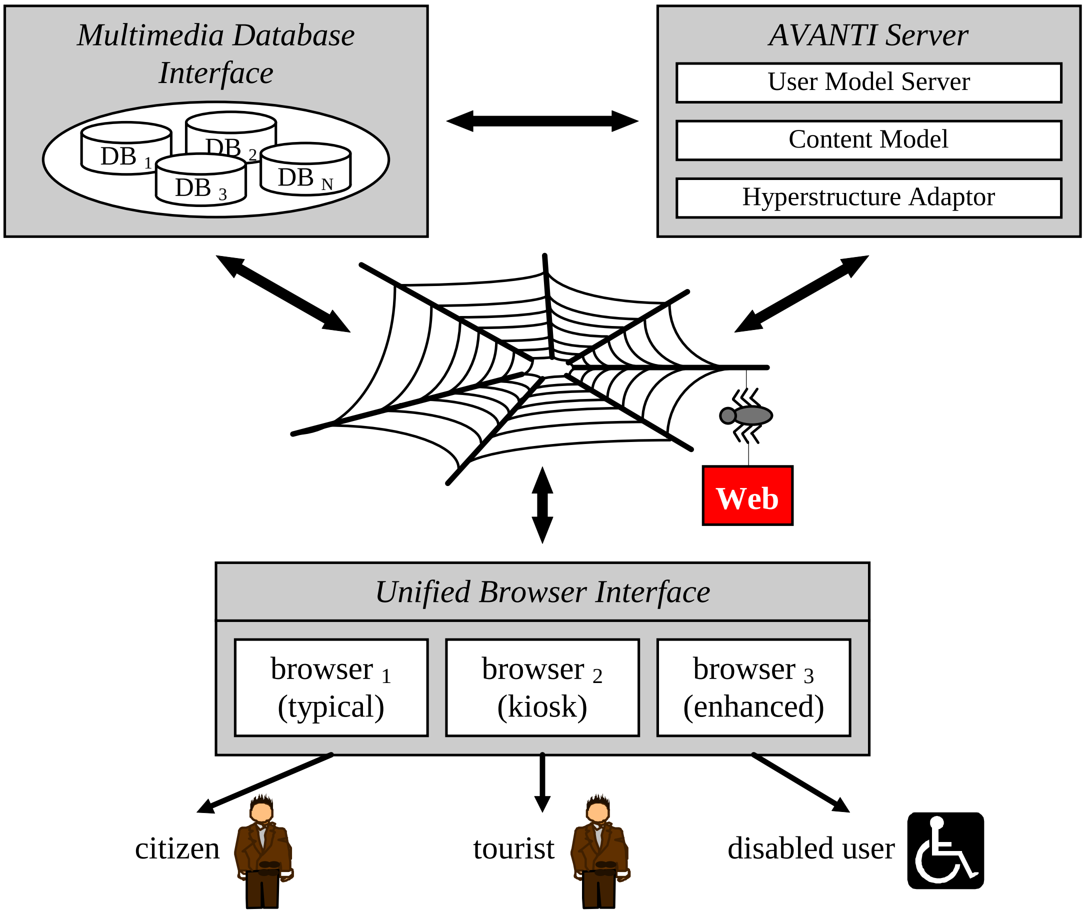

Figure 2 - Overall Architecture of the AVANTI system

In the present context, *adaptability* refers to the process of selecting / modifying (aspects of) the user interface during initiation of each interaction session, according to user characteristics that are known prior to interaction (e.g. user abilities) and are assumed to remain unchanged within a single session (e.g. particular user expertise).

Adaptivity, on the other hand, refers to the process of selecting / modifying (aspects of) the user interface dynamically, according to *dynamic user characteristics* and *situations* that are detected at run-time.

Syntactic level adaptations concern the selection of different *styles* for each abstract interaction task. In particular, following the U^{2}ID methodology, the user tasks that can be performed through the user interface of the AVANTI system have been hierarchically structured and incrementally decomposed in a polymorphic fashion, defining alternative styles and task hierarchies, according to requirements and preferences of different user categories. In other words, different styles define alternative ways in which a specific task can be realised. For example, selection of a file in a graphical interface can be realised through a "tree" representation of the file system, or through a "folder"-based representation, which correspond to two alternative styles. Moreover, specific file operations, within each of the above styles, may require the user to either select the file and then the operation to be performed on it (object-action model), or vice-versa (action-object model), resulting in two sub-styles for each primary style. Styles can be either compatible or incompatible to each other (depending on whether they can be simultaneously active), and are synthesised through the operators **BEFORE**, **OR**, **XOR**, * (simple repetition) and **+** (absolute repetition) [Savidis 97].

During the design stage of the browser, it was found that certain styles exist that need to be included in the decomposition of most of the tasks. These styles are not specific to browsers and can be expected to be equally common in other types of applications. Styles in this category include:

- explicit feedback, either during task performance (interim feedback) or after task completion (completion feedback);
- confirmation, which may belong to one of two types: either a brief request for explicit approval before the system carries out an action, or a more elaborate explanation of the possible consequences / side effects of the action, in conjunction with the request for approval;
- guidance, which provides help for the completion of a task (e.g. the sequencing of actions, the types of data required in each field, etc), when, for example, there is evidence that the user is unable to complete this task;
- prompting, which provides information concerning the initiation and completion of a specific task, when, for example, there is evidence that the user is unable to initiate this task.

Lexical level adaptations concern the selection of interaction object attributes for each task, or style. In particular, the lexical level interface objects of each style can be instantiated with multiple attributes. The attributes of the interaction objects that are subject to adaptations include scanning (for severely motor-impaired users), font, colour and size parameters for the case of visual interaction, and speech, sound and presentation parameters for the case of non-visual interaction. Moreover, lexical level adaptations concern the selection of the appropriate overall metaphor of interaction. Two metaphors have been designed and developed so far, namely a “Public Information System” and a “Web-Browser” metaphor.

The *“static” user characteristics* (i.e. characteristics for which knowledge exists prior to interaction), that have been selected after an initial requirements analysis phase to serve as the basis for adaptability, include:

- physical abilities, i.e. whether the user is able-bodied, blind or motor-impaired;
- the language of the user (the system is available in English, Italian and Finnish);
- familiarity of the user with: computing, networking, hypermedia applications, the Web and the AVANTI system itself;
- the overall usage target: speed, ease, accuracy, error tolerance;
- user preferences regarding specific aspects of the application and the interaction; e.g. whether the user prefers a specific style for a given task; or the preferred speech volume when links are read; etc.

The characteristics listed above were selected so as to ensure that adequate knowledge exists for the system to cater for a wide range of users, taking into account not only possible disabilities, but also characteristics that differentiate individual users -that may in general belong to the same broad category- between each other. It should be noted that, in the current state of the system, the above characteristics are acquired through an initial “questionnaire” session; future versions of the system are foreseen to employ more automated solutions (e.g.

smart-cards).

The *dynamic user characteristics* and *situations* that are taken into account in adaptivity have also been selected after the initial requirements analysis phase, and concern:

- familiarity with specific tasks (i.e. the user's capability to successfully initiate and complete certain tasks);
- ability to navigate using the documents' navigation elements;
- error rate, differentiated between three levels at which errors may occur: the lexical (e.g. user mistyping), the syntactic (e.g. user performed two interdependent actions in the reverse order than required), or the semantic level (e.g. user expects an action to have different results than it actually does);
- disorientation, i.e. the user does not understand the current state of the interface; this situation is detected when, for example, the user tries to perform tasks that are not enabled, or continuous user actions do not initiate system actions (e.g. mouse presses in "non-interactive" areas of the interface);
- user idle; this situation is detected when the user does not initiate any actions for a period of time, while, in the same period, there is no system action pending;
- repetition of interaction patterns; for example, if the user continuously chooses to hide / close dialogues that provide extensive feedback, the user interface could be notified and subsequently decide to refrain from providing extensive feedback dialogues altogether.

A set of syntactic adaptability and adaptivity rules has been defined and associated with each user task, providing the mechanism for the selection of appropriate interaction styles. Lexical level adaptations are also realised through respective rules, that assign different values to the attributes of the realised interaction objects. Figure 3 presents an example task decomposition for a task, namely "Go To Previous Document", together with the syntactic adaptability and adaptivity rules that specify the conditions under which each style is being activated, while Figure 4 presents examples of lexical adaptability and adaptivity rules (the whole set of rules has been defined in [AVANTI 97a])

2.2 The Adaptation Mechanism

The adaptation mechanism is comprised of sub-components which collectively allow for rule-based adaptation decisions to be made. It is based on a two-fold approach, which is briefly discussed below:

- First of all, the implementation of the user interface must be carried out in a task-, and style-aware manner, i.e. the design knowledge and alternatives of the task decomposition and dialogue design must be clearly represented in the actual interface. In the AVANTI system, this is achieved through special *task* and *style* constructs that incorporate facilities through which the application of adaptations becomes possible (such adaptations include, for example, the deactivation of a style and the subsequent activation of another one).
  Furthermore, at the lexical level, the interaction elements need to be "enhanced" in a way that will allow for the automatic modification of their characteristics at run-time. In the AVANTI system, this is achieved through special "proxy objects" that

implement such functionality and are “attached” to actual interaction elements, thus resulting in adaptations at the lexical level of interaction.

- The second prerequisite for the development of the adaptation mechanism is the existence of a decision mechanism, which will undertake the task of parsing, maintaining and evaluating adaptation rules. The decision mechanism must be accessible in two different fashions: firstly, it must be available for consultation on issues such as the style that should be used for the instantiation of a specific user task, or the characteristics (attributes) that are appropriate for a newly created interface element; secondly, it must be capable of automatically triggering modifications both at the syntactic and lexical levels of interaction; these modifications are the result of alterations in the decisions caused by knowledge updates inferred by the UMS.

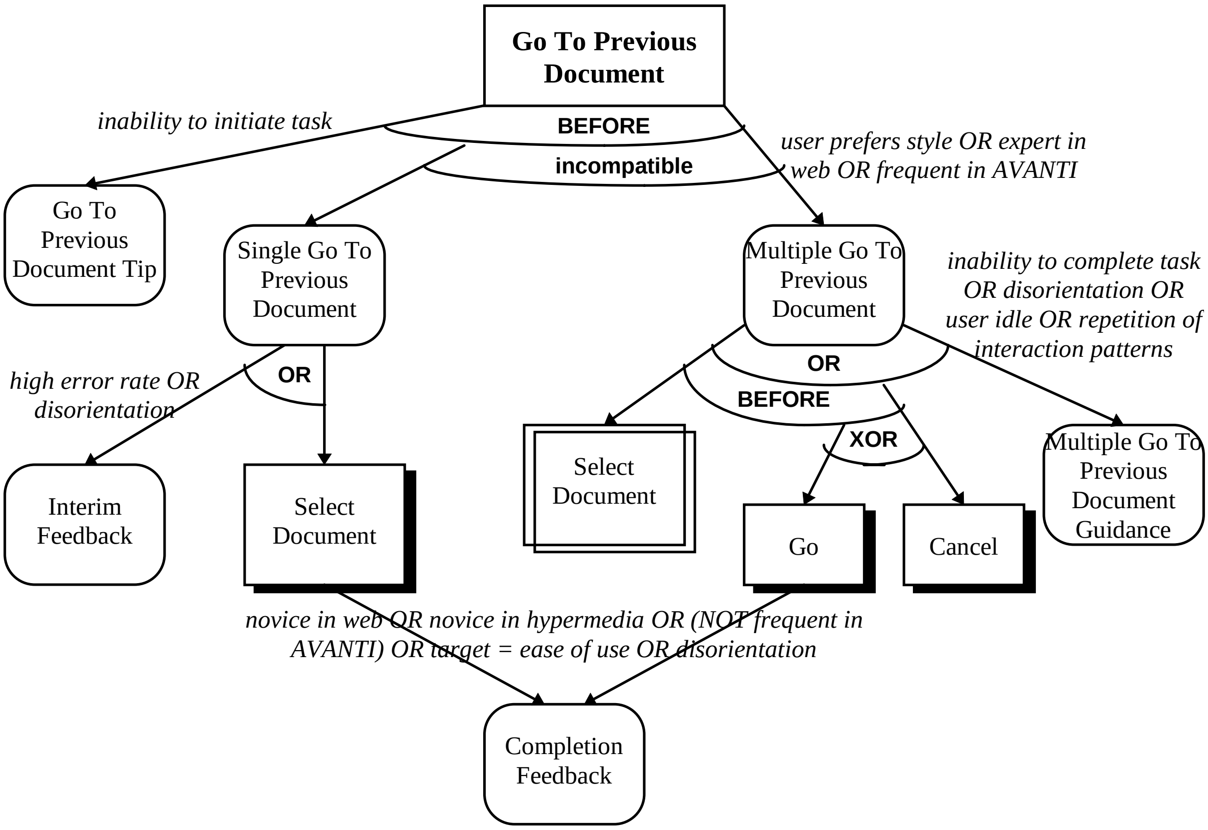

Figure 3 - Example of Task Decomposition into Styles

	Adaptability Rules		
IF	novice in hypermedia	*THEN*	LinkType = Button
IF	novice in computing **AND** motor impaired	*THEN*	ScanRate = Slow
IF	novice in computing **AND** motor impaired	*THEN*	Font = Large **AND** Size = Large
	Adaptivity Rules		
IF	high error rate **OR** inability to navigate	*THEN*	ScanRate = Slow
IF	disoriented **OR** user idle	*THEN*	SpeechVolume = High

Figure 4 - Examples of Lexical Adaptability

The decision mechanism that has been developed for the AVANTI system adheres to the above description and is comprised of the following sub-components:

- the *syntactic adaptability rule base,* which retains the task- and style-related rules, referring to “static” user characteristics and preferences;
- the *syntactic adaptivity rule base*, which retains the task- and style-related rules, referring to dynamic user characteristics and situations;
- the *lexical adaptability rule base*, which retains the lexical element-related rules, referring to “static” user characteristics and preferences;
- the *lexical adaptivity rule base*, which retains the lexical element-related rules, referring to dynamic user characteristics and situations;
- the *knowledge space*, which maintains knowledge on “static” and dynamic user characteristics and preferences.

2.2.1 Adaptability

As adaptability is based on user characteristics and preferences that are known prior to interaction and are, in any case, assumed to remain static throughout a single interaction session, the corresponding rules can be evaluated during the initiation of the system and the resulting decisions can be directly applied for the instantiation of the interaction dialogues. The procedure followed is depicted in Figure 5:

- A task *x* is triggered, either automatically (e.g. during system start-up), or as a response to a user action.
- The embedded communication facilities of the task structure consult the decision mechanism for the appropriate style(s) to be instantiated. The parameter passed is the identification of the task itself.
- The syntactic adaptability rule base consults the knowledge space for the “current” user characteristics and preferences and evaluates its rules. The result returned is a (list of) style(s) that should be instantiated.
- The task structure invokes the styles specified in the previous step, passing them any required application-specific parameters.
- Any instantiated style creates / modifies specific “portions” of the user interface, comprised of individual interactive components that are at some point created for presentation to the user. The communication facilities embedded to the proxy adaptation object attached to each such component, consult the decision mechanism for the appropriate attributes to be implemented (e.g. size, colour, volume). The parameters passed to the decision mechanism in this case are the task and style to which the component belongs, as well as the class / category of the component (e.g. VisualButton, NonVisualTextReviewer).
- The lexical adaptability rule base consults the knowledge space for the “current” user characteristics and preferences, and evaluates its rules. The result returned is a list of attribute-value pairs that represent specific attributes of the component class and the respective values for the object that initiated the consultation.
- The interface component applies the attributes to itself and proceeds to complete the steps required for its initialisation and presentation to the user.

A main characteristic of the way in which adaptability is achieved (as opposed to adaptivity), is that communication between the decision mechanism and the user interface is initiated by the user interface constituents.

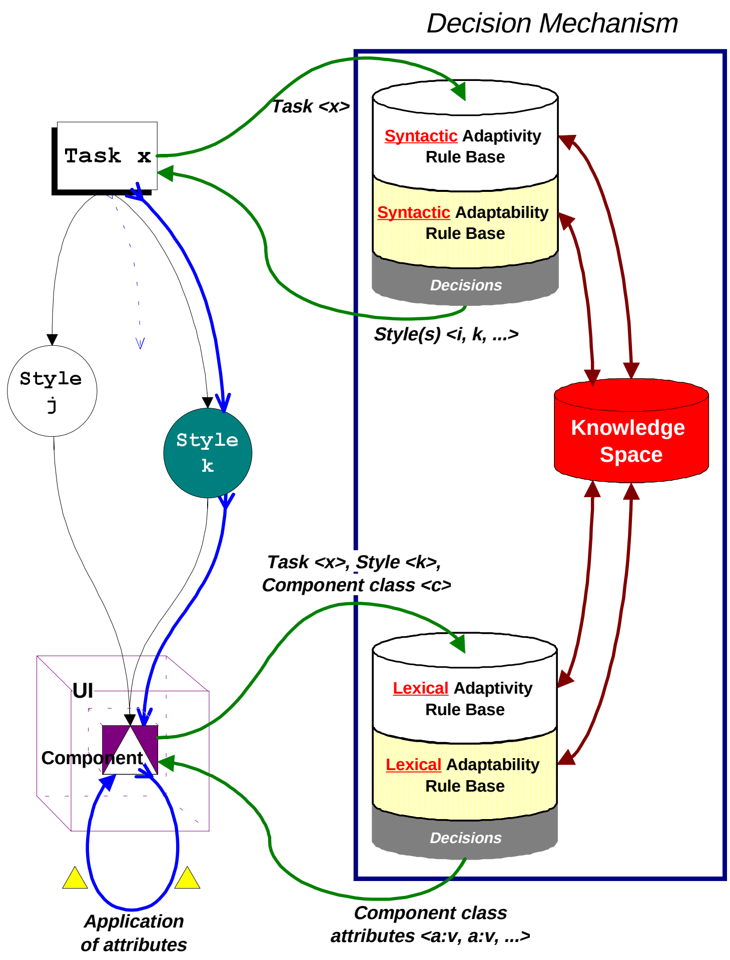

Figure 5 - The Adaptability Mechanism

2.2.2 Adaptivity

Adaptivity is applicable at run-time and cannot be initiated by the interface constituents, as they do not have knowledge of changing user characteristics and situations (even if they did, it would be highly ineffective to embed the necessary knowledge in these constituents, so as to make it possible for them to "know" when to request re-evaluation of the corresponding rules). It is thus necessary, that the decision mechanism can trigger the adaptations itself. The procedure followed in the case of adaptivity, is depicted in Figure 6:

- The UMS utilises monitoring data sent continuously by the user interface, and makes inferences on dynamic user characteristic(s) or situation(s) and informs accordingly the user interface decision mechanism (more specifically, it communicates new situations to the user interface knowledge space through a standard communication module [AVANTI 97a]).
- The knowledge space triggers the re-evaluation of rules in the syntactic and lexical adaptivity rule bases.
- Once the evaluation mechanism of the syntactic adaptivity rule base is triggered by the

knowledge space, all rules that (partially, or entirely) depend on the modified knowledge are evaluated. This may result in new decisions regarding the styles that should be used to instantiate specific tasks, and notification is sent to the affected task structures accordingly.

- When a task structure receives notification from the decision mechanism that a different set of styles should be used for its instantiation, it performs two distinct steps: (i) it stores this piece of information for use in future invocations, and (ii) it checks whether it is currently active (i.e. if its corresponding task is being carried out by the user); if so, it may be necessary to dynamically deactivate certain styles and possibly also activate alternative ones in their place.
- In parallel, the evaluation mechanism of the lexical adaptivity rule base is triggered by the knowledge space, and all rules that (partially, or entirely) depend on the modified knowledge are evaluated. This may result in new decisions regarding the values of the attributes that certain interface objects (participating in specific tasks and styles) should have, and notification is sent to the affected objects accordingly.
- When an affected object receives notification from the decision mechanism that a different set of attributes should be exhibited, it applies the new attributes to itself, possibly after retracting any other conflicting attributes set in the past.

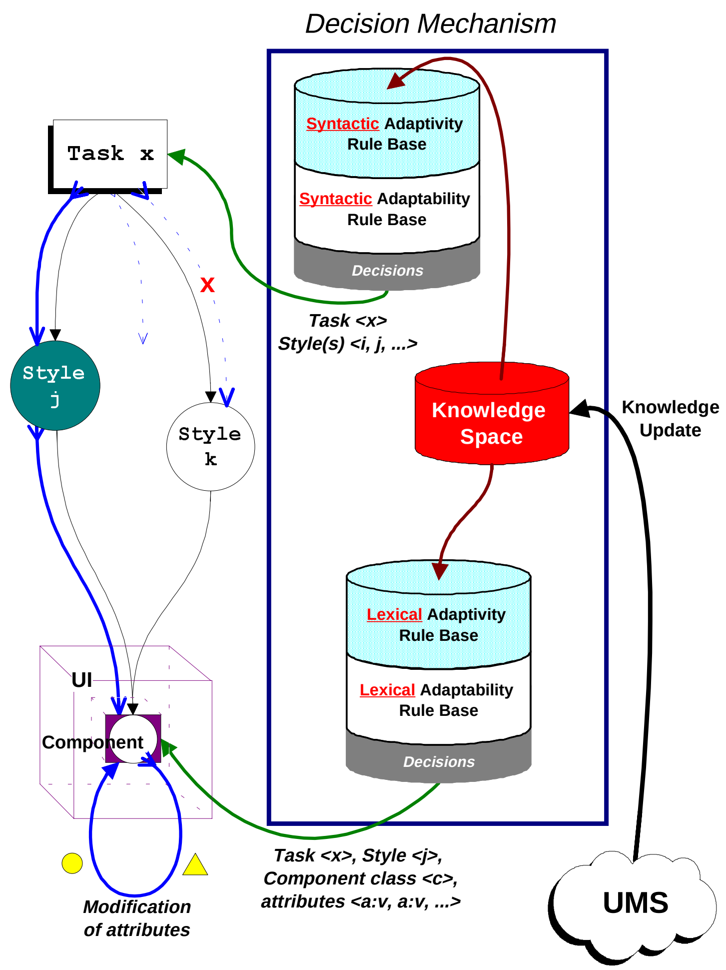

Figure 6 - The Adaptivity Mechanism

Central to the overall adaptivity mechanism is the communication with the UMS, which actually triggers the modifications in the user interface, by dynamically providing inferences drawn from knowledge provided through monitoring, as well as through user group stereotypes and static user-specific characteristics [Fink 97].

3. THE UNIFIED BROWSER INTERFACE

The design and development process described above has resulted in the construction of a browser, whose unified interface can adapt itself to suit the requirements of three user categories: able-bodied, blind and motor impaired. Adaptability and adaptivity are used extensively to tailor and enhance the interface respectively, in order to effectively and efficiently meet the target of interface individualisation for end users.

Special purpose input/output devices have been integrated into the system to support blind and motor-impaired individuals, including:

- binary switches;
- speech input (command recognition);
- joystick and touch-tablet input;
- Braille display output;
- speech output;
- digitised audio output; and
- special keyboard functionality.

Additionally, the unified browser interface implements features that are considered new to Web browsing applications, that assist and enhance user interaction with the system. Some of these features have been used in hypermedia navigation systems and have proven to be of great assistance to users, but have not been implemented in existing browsers; others have been developed specifically for the AVANTI system. Such features include:

- Enhanced history control for blind users, as well as linear and non-linear (graph) history visualisation for sighted users;
- Resident pages that enable users to review different pieces of information in parallel;
- Link review and selection acceleration facilities;
- Document review and navigation acceleration facilities;
- Enhanced mechanisms for document annotation and classification;
- Enhanced intra-document searching facilities.

Figure 7 contains a screen shot of the prototype AVANTI user interface. Styles that have been activated due to adaptability decisions include:

- enabling of the scanning mechanism for use by severely motor impaired users (extra window manipulation toolbar in ❶, and scanning focus in ❹);
- representation of links as buttons (as opposed to more "traditional" browser representations, as highlighted or underlined text) to facilitate interaction by users novice in hypermedia ❷;
- activation of the link-bar (a separate pane containing all the links in an HTML page), for easy review and selection by motor-impaired users ❸.

Furthermore, in the screen shot the activation of a style is shown ❹ which provides interface usage information to the user, as a result of an adaptivity decision triggered by the fact that the user is not making “correct” use of the interface (in this specific case, manually revisiting a document, whereas the user could have used the history mechanism for the same purpose).

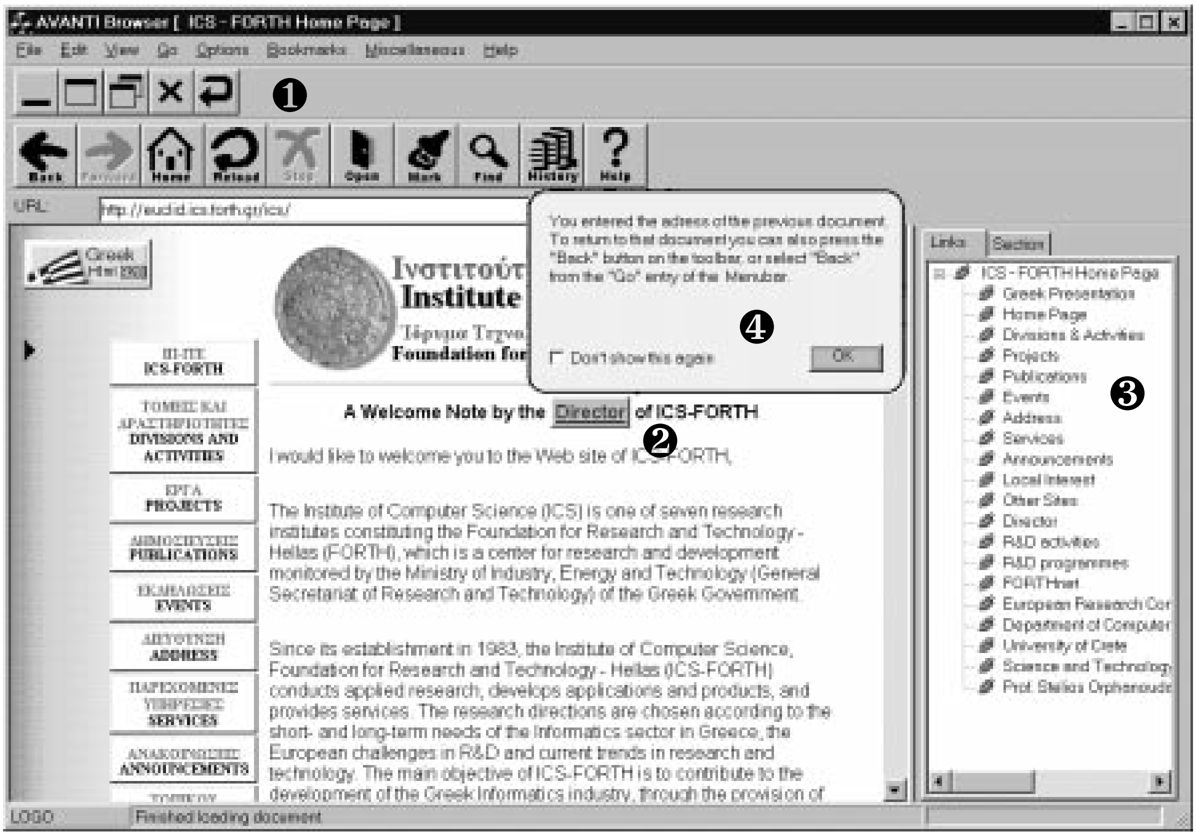

Figure 7 - A screen shot of the prototype AVANTI user interface

4. CONCLUSIONS AND FUTURE WORK

In this paper, we have presented work carried out in the context of the AVANTI project, for the development of a Web browser that provides accessibility and high quality of interaction to both able-bodied and disabled users. This is achieved through the employment of lexical and syntactic adaptability and adaptivity techniques at the user interface, following the U^2ID methodology. The prototype version of the system is currently under evaluation through user trials that have been planned to test the effectiveness and usability of the overall system, both in laboratory and field trials. In parallel, initial evaluations of adaptability and adaptivity per se are under way.

Future work involves the integration in the current system of alternative decision making mechanisms for adaptability and adaptivity [Karagiannidis 97], [Karagiannidis In Press], as well as standardisation activities regarding Web accessibility by all [Stephanidis 97a].

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