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Supporting individual situation awareness in Web-environments

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Samenvatting

Gebaseerd op “Web-technologie” is een nieuw gebruikersinterface-paradigma ontwikkeld: de “Network User Interface” (NUI). Dit paradigma biedt nieuwe mogelijkheden voor de interactie met diensten voor informatie en commercie, maar brengt ook nieuwe problemen met zich mee zoals desoriëntatie en moeizame navigatie. De veronderstelling is dat een deel van deze problemen veroorzaakt wordt door beperkingen in de “situation awareness” (SA). Gebaseerd op ergonomische ontwerpprincipes en scenariospecificaties zijn drie ondersteunende functies voor een NUI ontwikkeld: “categorising landmarks”, een “history map” en een “navigation assistant”. Terwijl de eerste functie een meer klassieke manier is om de SA van gebruikers in het algemeen te ondersteunen, omvatten de andere twee nieuwe concepten voor het ondersteunen van de individuele SA. De ondersteunende functies worden momenteel geëvalueerd om vast te stellen in hoeverre ze de gebruiksvriendlijkheid verhogen en om hieruit ontwerprichtlijnen af te leiden voor navigatieondersteuning.

Summary

Based on new Web-technology a new user interface paradigm is being developed: the Network User Interface (NUI). This paradigm provides new possibilities for the interaction with services for information and commerce, but it also introduces new problems such as disorientation and laborious navigation. The assumption is that some of these problems are caused by limitations of the situation awareness (SA). Based on human factors design principles and scenario specifications, three support functions were developed for a NUI: categorising landmarks, a history map and a navigation assistant. Whereas the first function is a more classical way to support users’ SA in general, the other two comprise new concepts for supporting individual SA. Currently, the support functions are being evaluated to establish how much they improve usability and to derive design guidelines for navigation support.

1 Introduction

More-and-more people have access to an increasing amount of Web-based services for information and commerce. They appear in a wide variety of domains such as electronic public counters for government information, electronic publications of publishers, theatre-booking agencies, travel information services, telemarketing, teleshopping, telebanking, and company Web-sites to communicate with interested parties. Notwithstanding the diversity, there are some main generalities across such applications with respect to service supply, user interface, user tasks and usability bottlenecks.

The *service supply* may originate from manufacturers or producers themselves excluding distributive trades. The contact with an individual customer can become rather direct via the World Wide Web. This may lead to a chain reversal in which the customer orders a specific “customised” product that is being made after this order (such as custom-made jeans or an individual assembled PC). Further, specific companies for electronic service distribution appear while content providers provide the information and other products. The information sources or databases are situated at several locations and interconnected via several paths, while the database content is timely and dynamic.

The *network user interface* (NUI) contains hyperlinks to corresponding information providing information in several formats, such as text, graphics, photos, audio and video, and these interfaces can provide various communication functions. In the 80's, its precursor, the Graphical User Interface (GUI), became familiar to more and more users who did not have specific computer expertise. In particular the direct manipulation, provided by such interfaces, was shown to improve the usability for non-expert users. Currently, user interface technology is developing in a new direction mainly due to the utilisation of the Internet via the so-called World Wide Web. Web-browsers can be used to search for multimedia information in databases via a network. These browsers are more-and-more an integrated part of the user interface, involving a new ‘look-and-feel’ for which standards are being set. For example, users can navigate in a 3D-world, can interact with 3D objects and can be informed about process changes from remote systems by intelligent agents. The NUI offers a browser-like interface for navigating through local and remote file systems. It can display ‘Java applets’ and other dynamic Web content that may be updated automatically. The NUI will blur the increasingly irrelevant distinctions between native/cross-platform and local/remote applications.

The *user tasks* of Web-based services consist of monitoring or exploring whether possible important information is present, assessing the meaning and relevance of the information given the current situation and task objectives, and, if needed, making decisions based on this assessment such as further exploration or buying a product. Several search strategies can be distinguished with network user interfaces. In a ‘random search’ there is no particular order observable. By ‘scanning’ users sample different parts of the hypermedia databases without systematically exploring any part in depth. In ‘spike exploration’ the users follow link pathways, although the search may not be directed to any specific goal, and sidetracks are evident in the trace of the user’s search. Finally, in ‘searching’ exploration follows pathways in a directed manner towards an information-seeking goal. Fewer diversions down sidetracks occur in searching (Sutcliffe, 1995).

The concept of Situation Awareness (SA) has been defined and used in several ways to study task performance in complex environments in which relevant information changes continuously (such as in aviation, process control and ground transport; Endsley, 1995). The World Wide Web (WWW) is such an environment and the SA concept may help to analyse and solve some of the current user problems: inefficient navigation, disorientation and loss of overview (Nielsen, 1995). The U-WISH (Usability of Web-based Information Services for Hypermedia) project aims at a user-centred design method for web-based services that minimises these problems[1]. In this project, cognitive engineering techniques are being used to develop and test new support concepts for NUIs and to derive design guidelines based on the test results (Neerincx et al., 1999). This paper presents the first concepts that were developed with these techniques: NUI aids that support SA and, consequently, improve navigation through Web-services. Section 2 describes the cognitive engineering framework that is being used and applied to develop three NUI aids in section 3. Section 4 discusses the status and plans of the research on navigation support.

2 Cognitive engineering

A large number of guidelines have been developed in the field of human-computer interaction that may guide software development, but there is some overlap and there are blind spots (Ratner et al., 1996). Since the NUI technology is relatively new, empirical-founded guidelines and style guides are hardly available for Web-based services in particular. Furthermore, for a number of existing guidelines it is not clear *how* they should be addressed in the software development process. The general SA-guidelines of Van Erp (this issue), for example, may be hard to apply for user interface designers. To overcome these problems, a cognitive engineering framework is being applied to develop and structure guidelines for web-based services.

[1] Several partners of the Dutch Telematics Institute participate in this project: the research institutes TNO-HFRI, CTIT and CWI, and the companies KPN, Océ, Cap Gemini and Rabofacet.

According to this framework, interface design is a top-down process consisting of two phases that provide the corresponding user interface specification at two levels. In the first phase, based on users' goals and information needs, the system's functions and information provision are specified (i.e. the *task level* of the user interface is established). In the second phase, the control of the functions and the presentation of the information is specified (i.e. the "look-and-feel" or the *communication level* of the user interface is established). The following design principles are ordered in the same hierarchy: the task and communication level.

Human factors principles at the task level:

1. *User adaptation:* The user interface design should take account of both the general characteristics of human perception, information transfer, decision making and control, and the specific user characteristics with respect to education, knowledge, skills and experience.
2. *Goal conformance:* The functions and function structure of the user interface should map, in a one-to-one relation, on users' goals and corresponding goal sequences. Functions that users don't need should be hidden for these users.
3. *Information needs conformance:* The information that is provided by the user interface should map, in a one-to-one relation, on the information needs that arise from users' goals. Irrelevant information should not be presented to the users.
4. *User's complement:* The user interface should provide cognitive support to extend user's knowledge and capacities.
5. *Use context:* The human-computer interaction should fit to the envisioned use context and/or situation (e.g. a speech interface should not be designed for noisy environments).

Human factors principles at the communication level (Williges et al., 1987).

1. *Compatibility*: dialogue styles should correspond to the knowledge, skills and expectations of the users so that the amount of information re-coding is minimal (cf. intuitive).
2. *Consistency*: the differences in dialogue should be minimal within a user interface.
3. *Context*: the user interface should provide information about the context of the active function.
4. *Structure and pattern*: imposed dialogue sequences should correspond to users' strategies so that they can navigate through the interface easily.
5. *Feedback*: the user interface should provide the user with feedback about the current action and the result.
6. *Interaction load*: the user should be able to process the information that is provided by the interface without excessive mental effort.
7. *Support*: the support should be integrated in the task performance and should provide "entrances" for the different types of user questions.
8. *Flexibility and maintenance*: it should be possible to accommodate individual differences among users through adaptation (user-initiated or automatic) or user tailoring of the interface.

3 Development of navigation support

According to the first two human factors principles for interfaces at the task level (user adaptation and goal conformance), central characteristics of the users and their goals are identified below to identify user requirements for navigation support.

3.1 User requirements

User adaptation

Individual cognitive differences play a role in how well users are able to efficiently use computer systems. The *spatial ability* and memory of users prove to affect the performance of computer-based tasks. Users with poor spatial ability have more problems with navigation in Web-sites, requiring extra search and navigation support (Chen & Rada, 1996; Czaja, 1997). Höök et al. (1996) found that spatial ability is related to the time spent in completing a set of tasks in a large, hypermedia, information structure. Particularly, certain aspects of spatial ability were related to the ability to navigate in hypermedia, namely those related to solving spatial problems mentally rather than solving spatial problems in the physical world. Figure 1 presents one of the screens of a software application for testing mental spatial ability. Participants in our research receive a sequence of such screens in a fixed time schedule. Within 15 seconds, a participant has to determine which of the four peripheral images is identical to the central image (by clicking on the image) or has to decide that no image is identical (by clicking on the none or ‘geen’ button). We will conduct experiments with the spatial ability test to investigate the assumption that people who show worse spatial ability will also show worse navigation. These people may need more navigation support or more simple navigation structures. Eventually, the test may be used to establish an adaptive interface for the individual user.

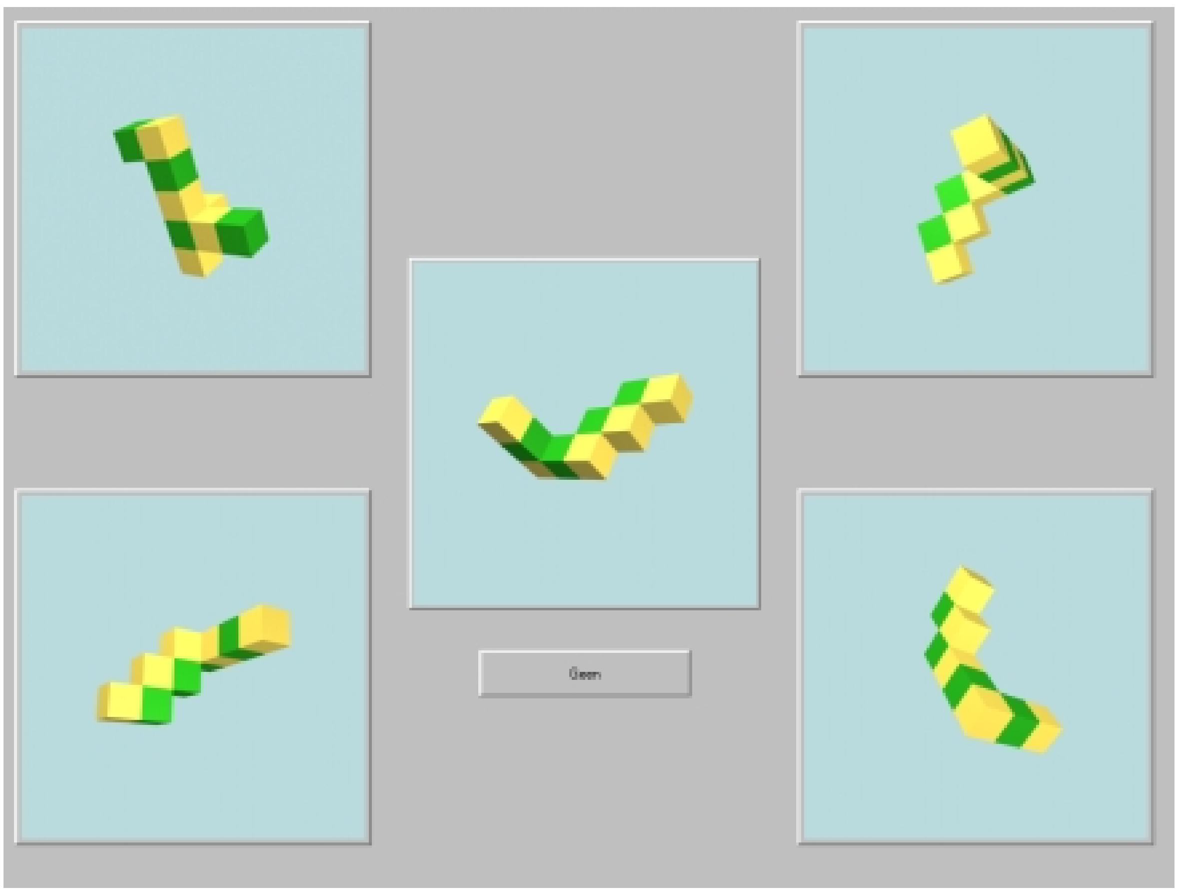

Figure 1: Example screen of spatial ability test.

Goal conformance
Three task dimensions are distinguished that need a specific kind of user interface support to comply with the ‘goal conformance’ principle.

- *Goal specificity*. Human behaviour is (hierarchically) goal-directed. The ‘low-level’ specific goals have a clear predefined end-state that specifies its successful accomplishment. The term ‘closed task’ is sometimes used to describe the performance of users with such goals. An example of a specific goal is ‘book a ticket for Star Wars IV for tonight’. Non-specific goals have an end-state that is not completely predefined at the start of the task execution. Therefore, such tasks are sometimes called ‘open’ tasks. An example of a non-specific goal is ‘plan an activity to go out tonight’. The goal specificity proves to affect the effectiveness and efficiency of users’ task performance in hypertext environments and the corresponding beneficial effects of indexing and overview support such as graphical maps (Chen & Rada, 1996). For non-specific goals, users need to decompose the goal into specific sub-goals and to consider and integrate information from several sources. Non-specific goals are particularly cumbersome to perform in Web-environments, due to the large amount of information and the lack of task knowledge. By ‘chunking’ data to meaningful information objects (i.e. categorisation) experts can attain a high task performance level due to efficient data sampling and information processing. Categorisation of information in the NUI can help to explore, refine and shape the general goal and to establish a successful navigation path. Furthermore, a NUI that has knowledge of the user’s non-specific goal and the content of the Web-based service can help the user to focus on those parts that may provide relevant information by providing “short-cuts”.

- *Situation-driven tasks.* Tasks can be more or less directed by the internal goals of the user or the situation. In situation-driven behaviour the goals are continuously triggered by external events that take place in the environment. Although SA consists of a user’s knowledge of the state of the environment at any point in time, this knowledge includes temporal aspects of that environment, relating to both the past and the future (Endsley, 1995). Provision of history information in the NUI can help to memorise the relevant experiences and to understand the current situation. Furthermore, pointing to information that is relevant in the current situation (i.e. for the current user goal and services’ content) can be very helpful.
- *Task-set switching.* Switching is often required for optimal task management and interleaving is an important aspect of human-computer interaction (Cypher, 1986). However, users are inclined to concentrate on one task (and neglect another task with the corresponding objects such as alarms) till the task is completed (“cognitive lockup”). Furthermore, switching can be a major mental load factor in itself. A NUI that provides knowledge of the dynamics in the Web-based service, including history information, can help users to focus on a new task and, subsequently, to return to the first one.

Summarising, three types of support needs were identified: categorise, memorise and set focus. Table 1 shows the relation of these needs to the task demands in terms of non-specific goals, situation-driven tasks and task-set switching, and to the three SA levels of Endsley (1995): perception, comprehension and projection. It should be noted that projection comprises other prediction types in Web-environments than in ‘classical’ SA domains. In aviation for example, projection refers to the prediction of a future state, such as the distance of another aeroplane, which is affected by both the changes in the environment and the human actions that will be performed. In Web-environments, projection refers to the prediction of the destination of a navigation route that is affected by the environment and the human actions that will be performed. The problem does not have to be that the environment is changing during task performance, but that its elements are unknown or changed recently.

Table 1: Three types of support needs are distinguished per task dimension and SA level: categorise, memorise and set focus.

SA level	Non-specific goal	Situation-driven task	Task-set switching
Perception	categorise according to goal hierarchy	categorise environmental dynamics	categorise according to task sets
Comprehension	memorise decomposition path	memorise task context	memorise switching state of previous task
Projection	set focus on specific goal	set focus on new information object or state	set focus on task set

3.2 Three support concepts

The previous section described the user needs for three types of navigation support. Existing support functions that could fulfil these needs were identified and assessed on their utility. This analysis showed that landmarks, sitemaps, bookmarks and agents cover the user requirements for navigation support partially. These functions were subsequently refined into three new support concepts that address the requirements for categorisation, memorising and setting the focus better: categorising landmarks, history map and navigation assistant.

The *categorising landmarks* cover style elements linked to the structure of the site, such as visual landmarks (Bakker, this issue; Vinson, 1999) or musical navigational cues, ‘emons’ (Nemirovsky & Davenport, 1999). Such cues are added to the user interface to support the users in recognising their presence in a certain part of a web-site (i.e. it orders information into categories that are meaningful for the user task). We use background colours to distinguish different branches of a hierarchical Web-site structure next to the header and index information, and background sounds to indicate different regions in a 3D world. This should help the users to perceive the information in meaningful clusters and prevents the user from getting lost.

The *history map* is an add-on to a web-based service. The basis for the history map is a sitemap: a graphical representation of the structure of a web site where the layout elements (colour, placement, and size type) indicate how the information is clustered and structured. Sitemaps cover many representations from a simple text-based list overview with indentations (i.e. a table of contents) to complex graphical maps using colours and symbols. Sitemaps may offer other functionality such as a ‘you are here’ marker to indicate the location of the page currently being viewed in the overall structure. They may also be ‘clickable’ so that the map itself becomes a navigation aid. The history map consists of a clickable sitemap extended with indications of the areas that a user has previously visited: visited items are colour-coded and the longer ago they were visited the more faded the colour will be. The link with the brightest background colour indicates the current location. This memory aid should improve users’ comprehension of the service’s structure in relation to their task and provide information about the status of their various sub-goals.

The *navigation assistant* consists of another add-on to a web-based service. The assistant has knowledge of the domain (the content of the web-based service) and current user (such as interests, profession, education, age and transport constraints). By means of this knowledge the assistant is able to dynamically provide advice to the individual user. The advice consists of hyperlinks to information that is relevant for that specific user at that specific state. This interface concept should help the user to focus on relevant information for the current task.

3.3 Design of support functions

Three different test services are being used in the U-WISH project to apply the support concepts and test their effects on navigation performance (see Figure 2). First, a service for theatre information and booking is used: the Virtual Music Centre (VMC) of CTIT. Due to the innovative dialogue techniques (e.g. natural language dialogues, speech interaction, Virtual Reality) and the diversity of the potential users, VMC provides a number of possibilities for the study of success and failure factors of Web-based services. Second, a test version of a company web-site for TNO-HFRI is used[2]. The results of a first evaluation showed the advantages of some support functions (in particular the general interface structure, the menu layout, and the headers), but also some remaining problems for users (in particular choosing the optimal search strategy). Third, a test site of a public counter for municipal and government information and services is being used ('Overheidsloket 2000'). This system is particularly interesting because the potential

[2] It should be noted that this is not the current TNO-HFRI site on the World Wide Web.

users are all citizens who can be inexperienced with computers and not very apt to use computers.

Figure 2: The three Web-based services of the U-WISH project for the development and test of user support concepts.

The support functions are being designed and implemented for al three services. The categorising landmarks are style elements added to the current structure of the web-site and virtual environment. Whereas the design of this support function is rather straightforward, the design of the other two functions has more degrees of freedom. Figures 3 and 4 provide the human-computer co-operation models for the history map and navigation assistant (De Greef & Neerincx, 1995; Neerincx & De Greef, 1998). These models show that the users can interact with the web server or the support function, and that the support function ‘logs’ user requests (such as an URL-address). The web server provides the response to the request such as a specific Web page. Two example instantiations of these models are described below (see Carroll, 1995, for the application of scenario-based design techniques).

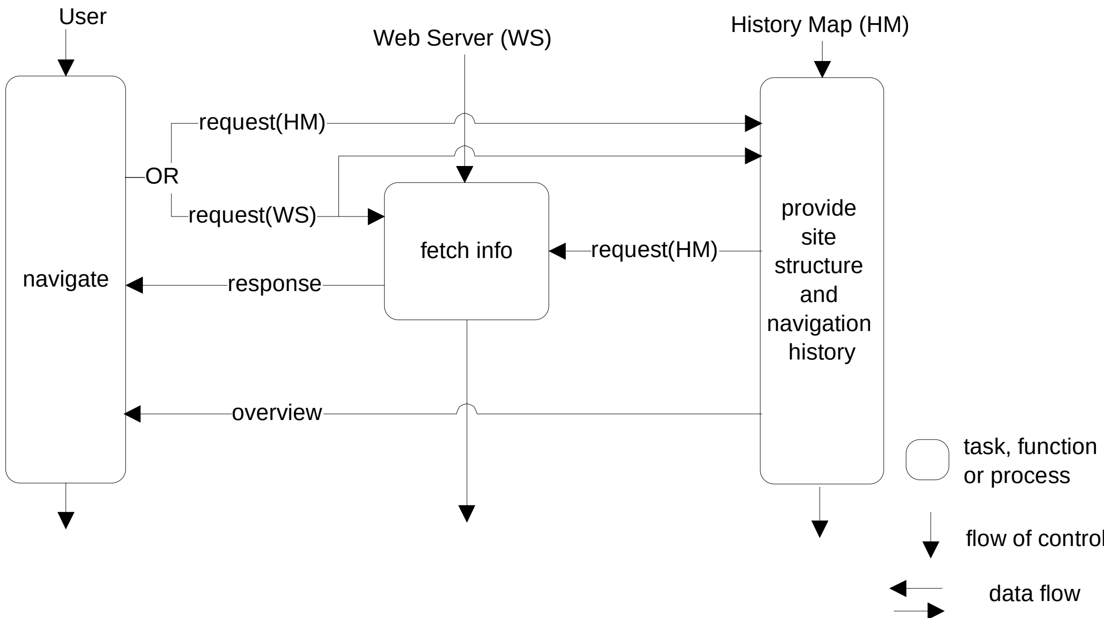

Figure 3: The joint execution behaviour of three actors: user, web server and history map.

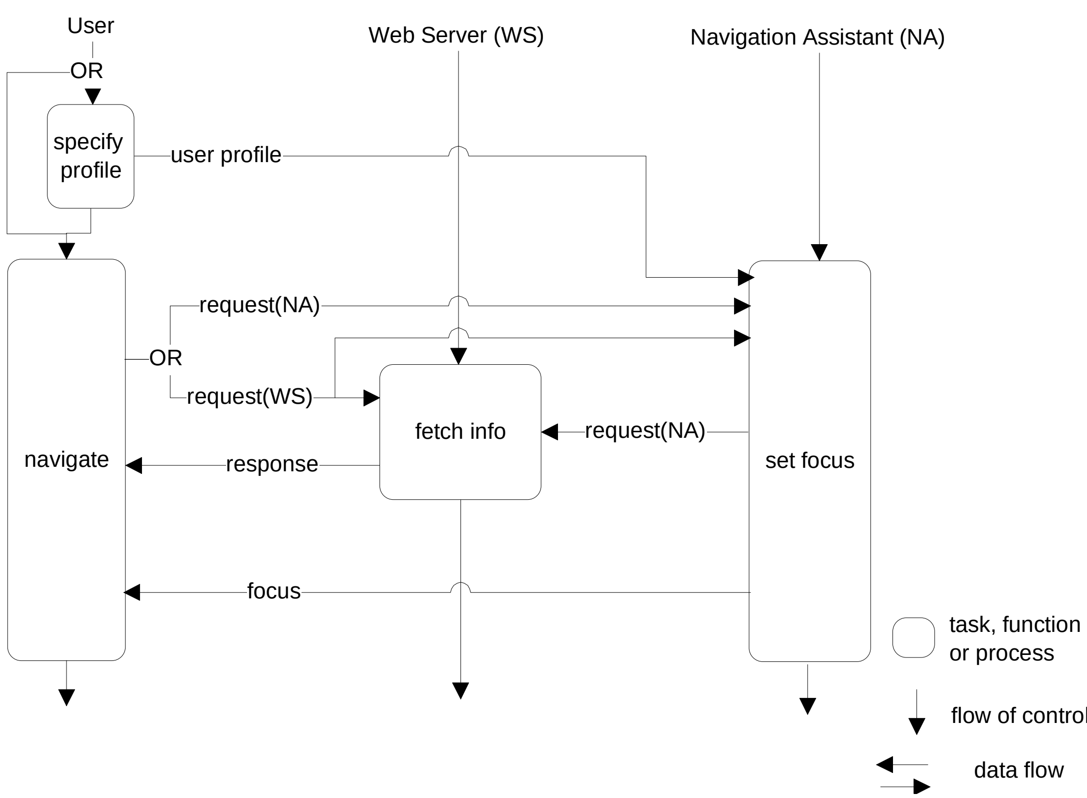

Figure 4: The joint execution behaviour of three actors: user, web server and navigation assistant.

History Map scenario. The user is a science journalist writing an article about the 50th anniversary of the TNO Human Factors Research Institute. He decides to visit the web-site to gather some background information about the institute. Once arrived at the web-site he notices a frame on the right side of the main-page (see Figure 5). This frame contains a clickable list of all available pages. The journalist visits the pages of interest. The pages he visited are coloured yellow. The less bright the colour the longer ago the page was visited. This system provides the journalist with an overview of the information that is available on the web-site and which pages he visited before in the same session. When all interesting pages are marked, the journalist stops navigating the site and starts to write the article.

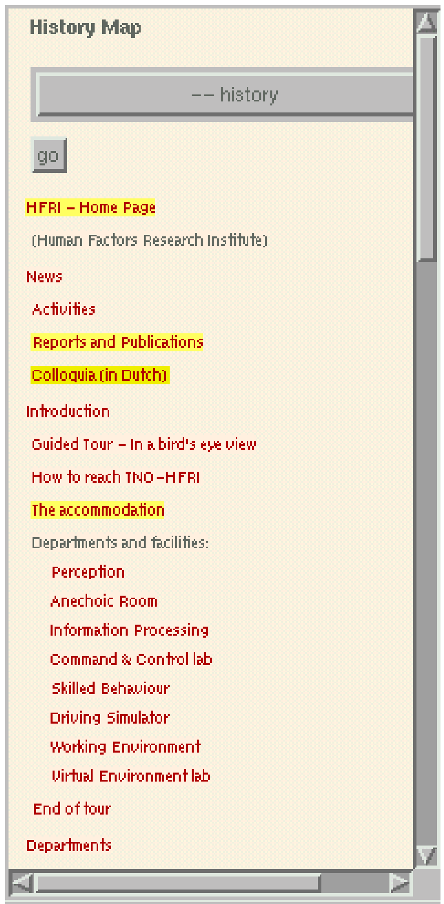

Figure 5: History map of a user that visited HFRI-Home Page, Reports and publications, Colloquia, and The accommodation.

Navigation assistant scenario. The user is a psychology student at Utrecht University specialised in experimental psychology. She is looking for a place that can offer an interesting internship. A professor tells her about the TNO Human Factors Research Institute and the student decides to take a look at their web-site. Once arrived at the web-site she notices a frame at the bottom of the main page (see Figure 6). This frame contains the assistant that provides hints based on information about user’s personal situation. The student tells the assistant that she is a student and that she is interested in human error in particular. Once she has provided this information the user can ask the assistant for a hint. In this situation the assistant will advise her to visit the page of the cognition group. The student decides to follow the hint of the assistant. The assistant takes her to the cognition page. While reading this page, the student decides that TNO might be an interesting place for an internship and she sends an e-mail to the head of the cognition group.

Figure 6: The assistant of the TNO-HFRI web-site at the start of the dialogue and after the input of the student.

4 Discussion

This paper presents interim results of ongoing research on usability of Web-based services: support concepts and example implementations. With respect to situation awareness, it proposes to improve orientation and navigation in Web-environments by general *and* personalised information provision on situation dynamics. Based on general human factors principles for the design of user interfaces, current navigation support functions were refined into three new concepts: categorising landmarks, history map and navigation assistant. Whereas the first function is a more classical way to support users' SA in general, the other two comprise new concepts for supporting individual SA. At the SA level of perception, categorisation of information and services can help to overcome information overload and getting lost. At the levels of comprehension and projection, memorising the task history and setting the focus on specific elements of the Web environment complements the lack of user's task knowledge. Table 2 summarises current navigation bottlenecks per SA level and presents the proposed remedies with support functions. It should be noted that the implementations comprise first test versions. The current navigation assistant is, for example, rather passive in the interaction. In future, the assistant will probably actively suggest or prompt actions and options to the user based on the user's profile and navigation behaviour. The basis of such human-computer co-operative task performance is a shared SA: the user provides its interests and current goals, whereas the assistant has knowledge of the services' content and navigation history. Based on this knowledge, the assistant points to the new parts that may be of interest for the user.

Table 2: Three support functions for navigation in Web-based services.

SA Level	Bottleneck	Remedy	Support function
perception	info overload, getting lost	categorise	categorising landmarks
comprehension	lack of task knowledge (goal structure, context)	memorise	history map
projection	lack of knowledge of Web-elements (content, dynamics)	set focus	navigation assistant

Previous research showed the importance of adequate information provision. A consistent header in the Web pages of a company site on the World Wide Web proved to provide insight in the Web-site content thereby optimising navigation. Furthermore, a menu consisting of a button matrix led to more explorative search than a "classic" menu list. These aids were based on general principles for interface design and, consequently, could also be included in a different type of application: the user interfaces for controlling and supervising experiments in future space laboratories (Flensholt et al., 1999). In a similar way, the support functions of Table 2 are generic and can be applied to a broad scope of web-based services.

In conclusion, support concepts were developed and first example implementations were provided. Currently, the implemented functions are being evaluated to establish how far they improve usability (Lindenberg & Neerincx, this issue), to derive design guidelines for navigation support, and to improve the support concepts. Eventually this should result into a usability handbook for Web-designers such as the handbook that is being developed for designers of payload interfaces for space laboratories (Flensholt et al., 1999).

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