INTERFACES FOR E-LEARNING: COGNITIVE STYLES AND SOFTWARE AGENTS FOR WEB-BASED LEARNING SUPPORT

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Abstract

The amount, range and quality of information available to students and other academic users have increased enormously in recent years. Consequently, it is possible for individuals to either suffer from information overload or to get lost in cyberspace while trying to locate relevant information. This paper looks at the relevance of cognitive styles and software agents to human computer interaction and interface design. Each student has a cognitive profile which can help the individual develop his or her learning skills and strategies in the light of useful self knowledge. The combination of prior knowledge of an individual's cognitive style with the technical solutions offered by adaptive and intelligent interfaces suggest a possible way forward with respect to the problems of information overload experienced when using the Web. The application of a particular view of cognitive styles to information handling and interface design is considered. Adaptive interfaces and Internet agents are looked at in relation to moving towards more individual designs for interacting with the Net and Web.

Keywords

e-learning, cognitive styles, software agents, adaptive interfaces

Introduction

This paper looks at the problem of effective student access to information resources from networks. More specifically it looks at the relevance of cognitive styles, adaptive interfaces and software agents to accessing information from the Internet and the World Wide Web. This will be done by attempting to identify and define the attributes of a type of interface that would help assist users in efficiently handling the increasingly large amounts of information available to them via networks. For the purpose of this paper, three main themes will be explored: adapting the interface to the user, using personalised information retrieval agents and identifying and using individuals' cognitive styles to develop an information retrieval strategy implemented via the interface. The relationship of these elements to the problem of accessing relevant information from the Internet and World Wide Web will be considered. This will be done by attempting to identify and define the attributes of a type of interface that would help assist users in efficiently handling the increasingly large amounts of information available to them via networks.

Cognitive Styles and Learning Styles

The relevance of an individual's cognitive style and learning style to that person's performance in a range of learning situations has been explored by many authors over the years (Kolb, 1985; Honey & Mumford, 1992; Riding, 1991, 1997; Laurillard, 1979, 1993; Ford 2000). Although the terms have been used interchangeably (Sadler-Smith, 1996; Riding, 1996), learning styles can be considered to cover a much broader range of approaches to learning. They often consider factors that can vary for the individual, e.g. an individual's learning style could differ according to the

subject s/he is studying, the mode of assessment employed or even the amount of time available. The possibility of variance over time and learning situation can call into question the relevance of attempts to use *individual* learning styles to inform the development of computer-based learning materials (Valley, 1997). It is considered that cognitive styles are more fundamental to the individual's personal and psychological makeup. Sadler-Smith (1996) considers learning styles and cognitive styles to be "fundamentally quite distinct and having differing but complementary implications for the design of teaching".

A recent volume draws together the various strands and provides a comprehensive overview of the work on cognitive styles (Riding & Rayner, 1998). An excellent review of the field and its evolution is also provided by Rayner and Riding (1997). Further work relates cognitive styles to developments in the Internet (Riding & Rayner, 1995) and technology-based training (Riding, 1996). Riding often uses Tennant's (1988) definition of cognitive style as "an individual's characteristic and consistent approach to organising and processing information" (Riding, 1995; 1991). From this perspective, cognitive style is considered to be a central and unchanging part of the individual's personal and psychological makeup or "a fixed characteristic of an individual" (Riding, 1996). It should be noted that cognitive style differs from learning style that can be considered to vary over time and space (Valley, 1997). Sadler-Smith considers learning styles and cognitive styles to be "fundamentally quite distinct and having differing but complementary implications for the design of teaching" (Sadler-Smith, 1996). If cognitive styles are individual and non-changing then they could provide a important element for designing more individualised interfaces and helping the individual deal with information overload.

Cognitive Styles and Information Overload

The amount, range and quality of information available to students and other academic users have increased enormously in recent times. This information can be regarded as a resource of great educational significance. However, it can be suggested that it is not a true resource until users possess the required skills, knowledge and suitable interface to maximise its utility (Palmquist & Kim, 2000). Although access to the WWW and its data sources has become easier via tools like Google, Quickclick, Atomica and Ask Jeeves, their use can be a double-edged sword. They identify and facilitate access to numerous data sources but also increase access to vast amounts of relatively unstructured information. As one observer commented: "Knowing that all of the information is out there, but not knowing exactly how to find it, can make the Web browsing experience quite frustrating" (Bigus & Bigus, 1998).

The ability of large amounts of information to "overwhelm and disable rather than liberate and enable" was pointed out rather earlier (Fitzgerald, 1994).

This scenario has particular relevance for those studying in higher education. The move towards active learning means that students will increasingly need to search for and download information from networked sources. In response to the problem of potential information overload, an increasing number of software agents have been made available to help the user in the search for the right information (Maes, 1994; Cheong, 1996). The particular type of software systems considered here are interface agents and Internet agents (Nwana, 1996). Adaptive interfaces can also be considered to be one type of interface agent.

Student information requirements vary. In addition, the knowledge and behaviour of students with respect to the learning process can change both over time and at the same time (Riding, 1995). Given this scenario, it is possible to suggest a need to develop interfaces that help each student to reflect on, identify and develop:

- her/his broad information needs;
- the clarification of those needs in a way that helps specify key information attributes; and
- the attributes to help reduce the search space and increase the precision of the information retrieval process.

The identification and use of cognitive styles and learning strategies combined with adaptive and intelligent interfaces can help facilitate the achievement of these goals. It is suggested that providing interfaces, which can both adjust according to the different needs of different users and send out agents to identify and retrieve relevant and useful information, can help do this.

Cognitive Styles and Interface Design

Over a period of twenty years and in many studies, questions that relate to the problems of interface design for learning materials have been consistently asked. These include:

- How does the structure of the material to be learned interact with style?
- Does the mode of presentation of the material affect learning?
- What effect does the type of content have on style and learning? (Riding & Rayner, 1998)

In terms of the physical organisation and external appearance of the learning material, studies by Douglas and Riding (1993), and Riding and Sadler-Smith (1992) related learning performance to material organisation and viewing (and hence possible interface design) to factors such as the size of the viewing window, the inclusion of headings and overviews of material and the step size of learning material, i.e. the physical layout.

Other studies (Riding & Ashmore, 1980; Riding & Douglas, 1993; Riding & Mathias, 1991) found that the mode of presentation as represented by verbal, pictorial or auditory modes affected learning performance according to cognitive style. Riding & Rayner (1998) commented that:

> In terms of content type, individuals appear to learn best when information can be readily translated into their preferred verbal-imagery mode of representation. It is of interest to note that not only the mode of presentation, but also the content itself, affects learning performance to an extent that it is of practical significance.

Dimensions of Cognitive Style

In an extensive overview of the work on learning and cognitive styles over the past 30 years, Riding and Rayner (1998) attempted to classify and integrate much of the earlier work in this field. They argued that many of the different labels used to categorise cognitive styles and learning styles were "different conceptions of the same dimension". A range of classifications were compared and contrasted with each other. Two principle cognitive style dimensions were identified.

- **Verbal-Imagery** - an individual's position on this dimension determines whether that person tends to use images or verbal representation to represent information when thinking.
- **Wholist-Analytic** - an individual's position on this dimension determines whether that person processes information in parts or as a whole. (Riding and Rayner, 1998)

The two styles are seen as independent and Riding has developed a software package, the Cognitive Styles Analysis (Riding, 1991) that allows the user to quickly and easily measure the cognitive style of individuals on both dimensions.

Measuring Cognitive Style and Implications for Interface Design

The Cognitive Styles Analysis test is easy to administer taking only about 10-15 minutes for each individual to complete. The verbal-imagery dimension is tested using pairs of words which are compared according to colour or category. The wholist-analytic dimension is tested by presenting the user with two similar images at once. The user has to determine whether the images are the same or if the first is included in the second. Over the past decade, Riding and others have extensively investigated the cognitive style construct using the Cognitive Styles Analysis test (Riding & Read, 1996; Russell, 1997; Pillay, 1998). The tests have been done on a variety of age groups and in different settings and have consistently suggested that the cognitive style of an individual can affect learning related elements such as:

- preferred format of instructional material (Pillay, 1998);
- learning in a vocational training environment (Russell, 1997);

- preferred mode of working (Riding & Read, 1996); and
- the effectiveness of book or hypertext (Wilkinson, Crerar & Falchikov, 1997).

It is therefore suggested that individuals with different cognitive styles could benefit from interfaces which could be adapted to the individual's style. This would modify the interaction between the user, the computer system and the communications network according to the cognitive style of the user and related information requirements. The result would be to improve the user's ability to assimilate the information being accessed.

Software Agents and Intelligent Agents

The term "intelligent agent" refers to a form of human computer interaction which uses software agents which have some component of "intelligence" built into them (Wooldridge & Jennings, 1998). The similarity between intelligent help systems, adaptive systems (considered a form of the application of interface agents) and explanation systems is explored by Benyon and Murray (1993). Although it is recognised that there are also differences, it is suggested that these systems share the same high level architecture with the overall architecture containing three different models - the user model, the domain model and the interaction model. The user model, which is the most complex of the three, contains cognitive, profile and student models of the user.

Interface and Internet Agents

At the Media Lab at MIT, a wide range of projects is underway which consider different roles and types of software agents (Maes, 2001). Maes considers the range of applications agents can assist with as being very broad indeed. Possible application areas include the scheduling of meetings, help in selecting films, music and books, information filtering for email and the information retrieval possibilities considered here (Maes, 1994).

Agents can be thought of as software assistants which perform tasks for the user (Keeble & Macreadie, 2000; Maes 1994). Following this, intelligent agents can be seen as agents with an AI component (e.g. an expert or knowledge-based module or system) embedded within a conventional system. The intelligent agent is then able to provide support and advice for the main system, though the range and potential of the intelligent agent field is much broader than this.

Interface and Internet/ information agents are two of the main categories of agent type that usually emerge from different classification schemes (Nwana, 1996, Wooldridge & Jennings, 1995). Maes considers that the main area of concern is the development of interfaces that "make human-computer interaction easier and more effective" (Maes, 1994), and also considers the types of solutions that may be offered by the AI community, including learning interfaces and interface agents. When looking at the potential of software agents to help reduce information overload, the same author develops the argument that different types of agents can help users in several ways. It is possible to develop agents which can monitor events, do things on behalf of the user, collaborate with other users and so on. In doing so they often conceal the fact that the task may be complex and difficult.

Discussion: Interfaces for Learning Support

The process of learning is a multidimensional, multi-process activity. One important aspect is the identification, location, organisation and use of information and its transformation into knowledge. As stated, an increasingly significant source for this information is the WWW. As its importance grows, so does the need and ability to perform the identification, location, organisation and use process. The WWW, browsers and search engines provide unrefined tools, very useful but prone to lead to information overload. They are also increasingly time-consuming, especially when communications traffic is busy. To help solve this problem, many agent-based information retrieval systems are currently being developed. Early applications started as systems to enhance the user's ability to make sense of the web, but now the functions are becoming more focused. These include applications like Aberdeen University's ELVIS (Enhanced Learning Visitor Information Systems)

which provides a personalised brochure of travel information on a town or cities shopping, restaurant, cultural and entertainment facilities (Edwards *et al.,* 1997). The user enters the details for a particular destination and leaves the system. The information is delivered later in the form of a brochure after the agent has completed searching the Web. A development of ELVIS is the same institution's MAVA (Multi-Agent Visitor Advising) that takes the assistant analogy further by attempting to "reason about the likely success of a user query, and if necessary, adapt the query" (Edwards *et al.,* 1997).

Interfaces and Agents to Support Learning

One of the main areas of commercial interest in the application of agent-based technology is the provision of "personal assistants" (Maes, 2001; Nwana, 1996). If the same approach is considered for helping to support student learning then it is possible to state a case for the integration of the elements covered in sections 2 to 4. The adaptive interface or interface agent can help tailor the information presented to the specific and individual needs of the user. The software agents (autonomous and decision making) can be initially configured to perform particular tasks for the student, based on the cognitive style and learning needed for the tasks in hand. The cognitive styles analysis should be used in conjunction with the student and domain models developed for the adaptive interface. These models could then be integrated to provide a sophisticated mode of individualised interaction with the Internet and the World Wide Web. What is needed is a system which both helps the student to interact with the Web to obtain information and then organise and use that information. The system that might emerge could be something along the lines of an Interactive Learning Environment (Arshad, Kelleher & Ward, 1995).

For the student involved in the new learning environments of the contemporary university, a similar metaphor can be applied to the process of supporting student learning or helping active learning. That metaphor would be of a learning assistant, or perhaps an information assistant in this case. The aim would be related to that of Maes' personal assistant (Maes, 1994). The role of the agents would be to help individual students to function effectively with different and more student-centred resources. A fully developed Student Information Manager (SIM), taking some of the functions from Maes' personal assistant could perform the following services:

- electronic mail filtering;
- class and meeting scheduling;
- assignment information searching;
- appropriate information presentation;
- book and article recommendation; and
- management of information student resources, including indexing, cross-referencing and updating for consistency.

Several systems are currently being developed which include some of these elements. A measure of the effectiveness of using software agents for online learning has been described by Thaiupathump, Bourne and Campbell (1999). The authors use the term knowbots (knowledge robots) to describe this type of agent and their purpose is to help automate aspects of online workshops in order to help the facilitator. In addition, the authors looked at the impact of the knowbots on learner satisfaction and facilitation time. Elsewhere, a different perspective from that of cognitive styles is taken when considering the cognitive aspects of agent based learning environments (Baylor, 2001). Using MIMIC (Multiple Intelligent Mentors Instructing Collaboratively), the author considers issues of control in such environments. One version of MIMIC contains two software agents, an Instructivist Agent and a Constructivist Agent, which are designed to facilitate the mentoring of pre-service teachers. Chatterbots are another class of agents that are being adapted use in learning situations (Knode & Knode, 2000). The agents are configured to act as intelligent tutors. The aim is to provide agents which "provide content appropriate for individual lessons and can perform other tasks automatically, such as opening web pages, reading text, running other programs, answering questions and providing instructions". Several of the agents used in this study are available from the Botknowledge website.

The above functions are likely be both appropriate and necessary if students, as seems likely, become more involved in active learning. By definition, each student will develop her or his own self-constructed database of learning materials. We may all be in danger of drowning in a sea of information and if students are not to become lost in unstructured information 'lakes' of their own construction then the development of the above type of aids will become of paramount importance. For the moment, we will remain with the concerns of the interface design related to cognitive style.

Initial Empirical Work

Initial work has taken place with 70 students undertaking a Human Computer Interaction unit. The students worked mainly on the cognitive profile and interface development aspects suggested above. A range of qualitative and quantitative measures were used to get the students to engage with the design process and reflect on the role of their own cognitive styles in that process. These included the Cognitive Styles Analysis test, log files of each student's interaction with a set of interfaces design in different styles, reflective journals and both the documentation of plus the actual interfaces produced. The results of this work are currently being analysed with reference to moving on to the agent-based aspects of the learning environment design. These findings will be discussed more fully at the conference.

Conclusions

It would appear that the cognitive style of each individual has an important impact on how each person internally represents and processes information. Cognitive style then, could be an important factor in the design of more effective individual interfaces. The development of agent-supported interfaces and learning environments would further help support the student in the demanding activities of online and e-learning. Problems continue to exist with the overall development cycle (Hook, 2000), but continued work in this area will help overcome them.

The current political, organisational and social changes occurring in higher education provide serious challenges for allocating resources to reorganising student learning. Many institutions are combining the need for change driven by decreasing resources with the potential offered by information technology developments to support student learning. This produces additional problems in the form of easy access to enormous amounts of relatively unstructured data and information. It is suggested that modelling and combining knowledge of an individual's cognitive style and integrating that with adaptive interface design and the use of Internet agents provides a possible solution to some of these problems. This paper has looked at the relevance of cognitive styles, adaptive interfaces and software agents to interface design and human computer interaction with reference to accessing information from the World Wide Web. An attempt was made to draw together the above themes to provide an approach to using cognitive styles and software agents to help inform the development of suitable individual interfaces and learning environments. This could be a significant factor in the production of environments that would help students to learn more effectively by locating and processing information from the Web and other networks in a more efficient manner.

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