Distributed Knowledge Modeling through the World Wide Web

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Abstract

Knowledge modeling involves the management of many knowledge sources often geographically distributed. The World Wide Web is a distributed hypermedia system available internationally through the Internet. It provides general-purpose client-server technology which supports interaction through documents with embedded graphic user interfaces. This article reports on the development of knowledge modeling tools operating through the web to support knowledge acquisition, representation and inference through semantic networks and repertory grids. It illustrates how web technology provides a new knowledge medium in which artificial intelligence methodologies and systems can be integrated with hypermedia systems to support the knowledge processes of professional communities world wide.

1 Introduction

The development of knowledge-based systems involves knowledge acquisition (KA) from a diversity of sources often geographically distributed. The sources include books, papers, manuals, videos of expert performance, transcripts of protocols and interviews, and human and computer interaction with experts. Expert time is usually a scarce resource and experts are often only accessible at different sites, particularly in international projects. Knowledge acquisition methodologies and tools have developed to take account of these issues by using: hypermedia systems to manage a large volume of heterogeneous data; interactive graphic interfaces to present knowledge models in a form understandable to experts; rapid prototyping systems to test the models in operation; and model comparison systems to draw attention to anomalous variations between experts.

However, existing knowledge acquisition tools are largely based on personal computers and graphic workstations, and their use in a distributed community involves moving software and, often computers, from site to site. The process of building and testing knowledge models across a distributed community would be greatly expedited if wide-area networks could be used to coordinate the activities at different sites. The initial objective of the work reported in this article has been to use the World Wide Web to support distributed knowledge acquisition by porting existing knowledge acquisition tools to operate through the web. A further objective has been to use the web on a continuing basis to support distributed knowledge media in which the acquisition, representation and application of knowledge become an integral part of the activities of a professional community.

The combination of web and knowledge-based systems technologies will make artificial intelligence systems widely accessible internationally and allows innovative knowledge-based multimedia and groupware systems to be developed. The next section gives an overview of the web architecture and protocols, and following sections illustrate how knowledge acquisition systems have been ported to the web to operate in a distributed client-server environment.

2 Semantic Networks as Client Helpers

The graphic representation of formal knowledge structures in semantic networks is common in most knowledge acquisition tools because experts find it easier to understand and critique the knowledge model when presented in diagrammatic form. The GUI available through HTML is currently inadequate to support diagrammatic editing, but existing semantic net tools can be interfaced to the web as client helpers. They can then use the web as a multimedia data management system for informal knowledge that is linked to the formal structures developed from it. Figure 1 shows WebMap, a semantic network editor, in the front window communicating with a web browser in the rear window. The web document shown is a paper on intelligent manufacturing systems (Tomiyama, 1992) that defines the logic underlying the international IMS collaborative research program. The definitions in the document are being translated into formal knowledge structures in the semantic network.

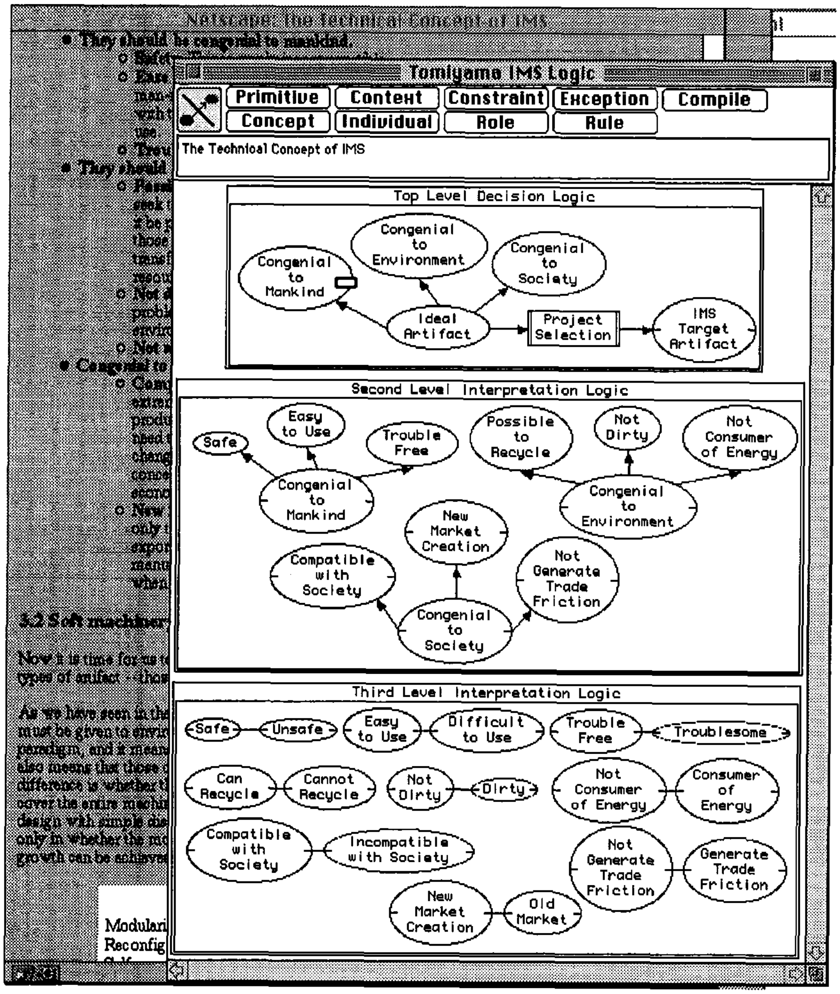

Figure 1 Generation of a semantic net linked to a web document

The knowledge engineer has annotated the document with HTML anchor tags making the significant definitions available through hypertext links. When she clicks on a link in the web browser to access a definition the browser scrolls to that definition and also transmits its URL (uniform resource locator) to the semantic net editor. The knowledge engineer copies text from document, pastes it to the editor to name a knowledge element and clicks on one of the buttons at the top of the editor to create a graphic representation of that element. The editor automatically stores the URL sent by the browser as data attached to that element, so that the formal structure is linked to the original text and can be used to access it on the web. For example, in Figure 1 the cursor is over the concept "Congenial to Mankind" and has changed to a button shape to indicate that linked data is available. Clicking on the concept sends a request through the browser to the server to show the relevant text which appears at the top of the browser as shown.

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3 Semantic Networks Uploaded as Clickable Maps

The use of a semantic network editor as a client helper enables formal knowledge structures to be developed but does not in itself make them available through the web for inspection by others at remote sites. This is done by providing a facility in WebMap for uploading the knowledge structure from the helper to the web server using the capability of the browser to post data to the server under control of the editor—the knowledge engineer simply selects the "Upload" option in a popup menu that appears when she clicks outside the knowledge structure.

WebMap at the server is then able to transmit the knowledge structure as an image in the Compuserve GIF format which acts as a clickable map in any web browser without requiring access to the editor.

Figure 2 shows the semantic network of Figure 1 being used as a clickable map. The cursor is again over the concept "Congenial to Mankind" and has changed to a hand to indicate that linked data is available. Clicking on the concept sends a request to the browser to show the relevant text which will appear at the top of the browser as before.

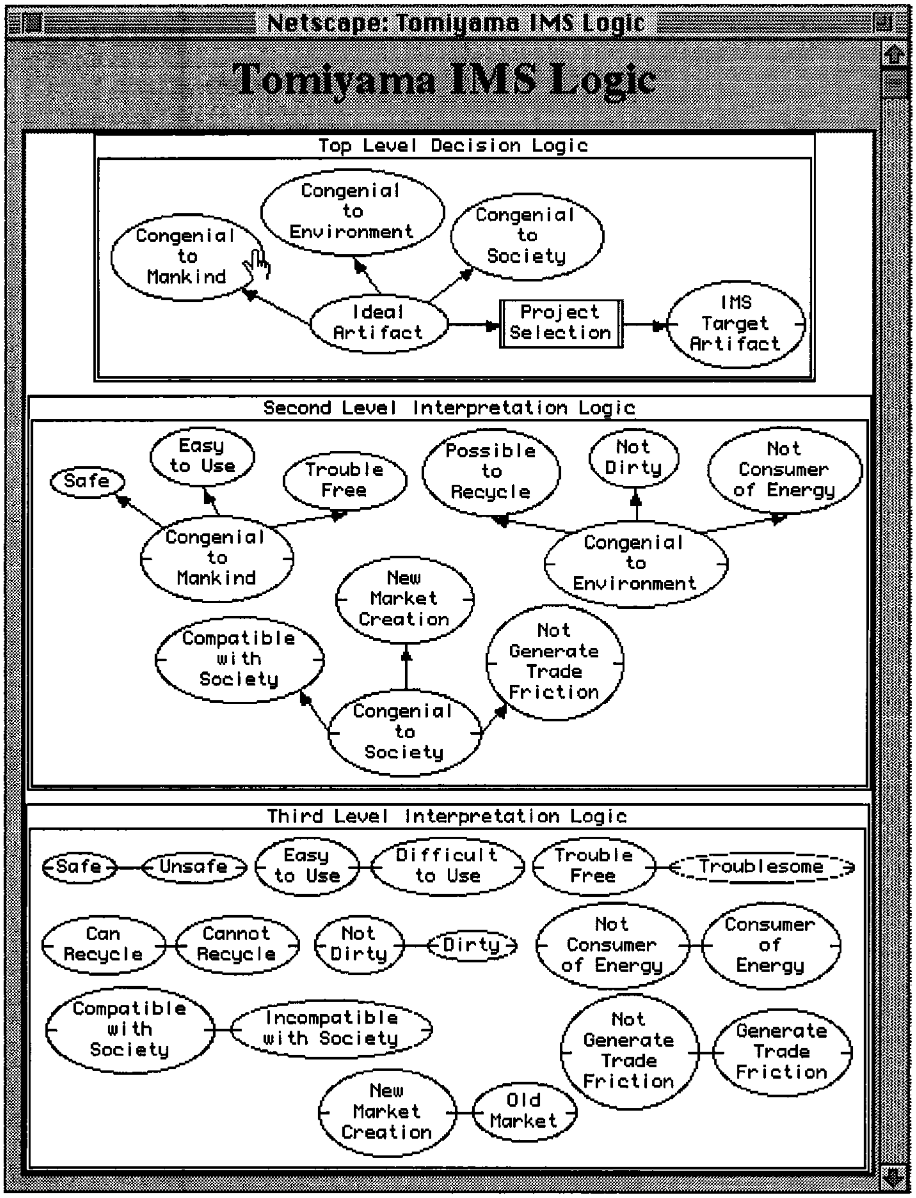

Figure 2 Semantic net uploaded to web as a clickable map

Thus, the knowledge structure developed locally can be made available globally together with its linked derivation so that knowledge acquisition and validated can proceed on a distributed basis. The network uploaded is the full data structure so that it also becomes available for download to those having the semantic network editor, and it can be compiled at the server to run as part of a knowledge base operating through a server gateway and accessible through the web.

4 Repertory Grid Client-Server Implementation

Repertory grids based on personal construct psychology (Kelly, 1955) have been used for knowledge acquisition since the early years of knowledge-based system development (Shaw and Gaines, 1983; Boose, 1984) and have been refined over the years to support increasingly complex knowledge structures (Boose, Bradshaw, Koszarek and Shema, 1993; Gaines and Shaw, 1993). Since grid elicitation tools are used directly by experts it would be very useful to have them accessible through any personal computer or workstation with access to the web. This is feasible because the primary data input format is through rating scales, and this can be done effectively by using popup menus which are available through the HTML GUI.

Figure 3 shows the initial screen of WebGrid, a repertory grid elicitation tool, operating through the web using a standard web browser and requiring no client helpers. The HTML form requests the usual data required to initiate grid elicitation: user name; domain and context; terms for elements and constructs; default rating scale; and a list of initial elements. It also allows the subsequent screens to be customized with an HTML specification of a header and trailer—this capability to include links to multimedia web data is also used to allow annotation, text and pictures, to be attached to elements.

When the user clicks on the "Done" button at the bottom, the browser transmits the data entered to the remote server which passes it through its CGI to a specialist knowledge acquisition auxiliary server. The server processes the data and generates an HTML document that it returns to the browser resulting in the screen shown in Figure 4 eliciting a construct from a triad of elements.

The user clicks on a radio button to select an element which she construes as different from the other two, enters terms characterizing the construct, and clicks on "Done". The server generates the screen shown in Figure 5 which places a popup menu rating scale alongside each element enabling the user to rate each one along the new construct. She is also able to change the terms used if they seem inappropriate in the context of all the elements, and to change the ratings of the already entered elements if appropriate.

Clicking on the "Done" button in Figure 5 sends the ratings back to the server which generates the status screen shown in Figure 6. This draws the user's attention to matching constructs, suggesting a new element be added to break the match, to matching elements suggesting a new construct be added to break the match, and also offers the opportunity to elicit another construct from a triad of elements. The elements and constructs are listed in selection boxes allowing selected items to be deleted and edited, new items to be added, matches to be shown, and HTML annotation to be added to elements. Further buttons enable the data elicited to be saved or to be displayed or analyzed in various ways.

The knowledge acquisition server is designed to operate on a stateless basis in which data is not normally stored at the server unless it is specifically uploaded. This is achieved through the server storing all the grid data in hidden fields in the HTML document which do not display but are returned to the server along with the entered data.

The results of analysis are usually presented as graphic output. This is generated at the server, converted to GIF format and returned to the client where it can be examined and saved if required. Figure 7 shows the output returned when the "FOCUS" button is used to develop a hierarchical knowledge model clustering related constructs and elements (Shaw, 1980).

The cluster analysis shows that systems satisfying "IMS research target" tend to be "reconfigurable" and involve "machine intelligence". The rules produced by clicking on the "Induct" button confirm this as a logical conclusion in that "reconfigurable" and "machine intelligence" imply "IMS research target". New cases can be entered and matched against existing ones using an analysis similar to FOCUS, and conclusions can be drawn about them based on the rules developed by "Induct". Thus, the web-based knowledge modeling system can be used to elicit and evaluate knowledge bases for various sub-domains of a knowledge-based system.

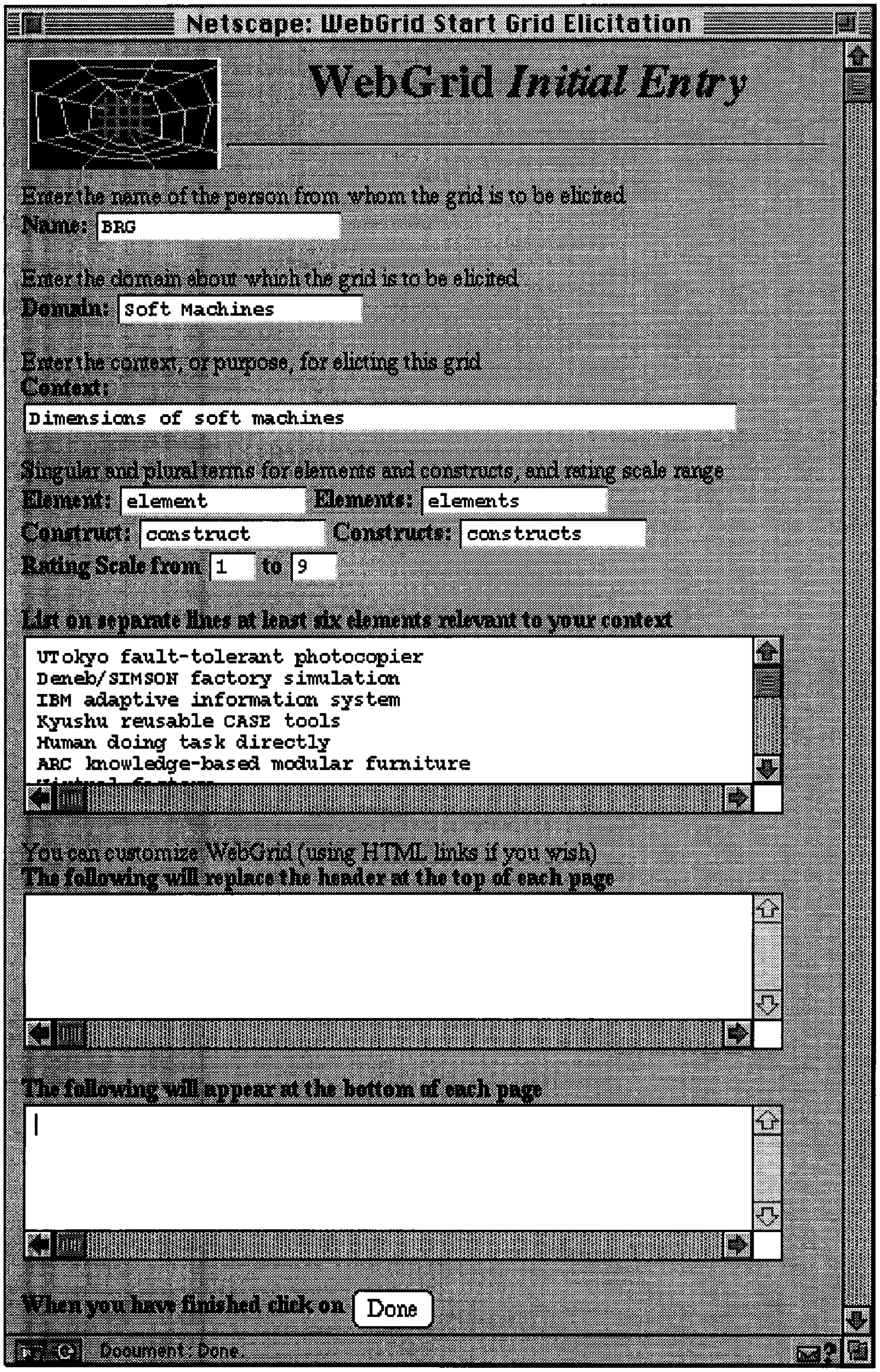

Figure 3 Repertory grid elicitation initial screen

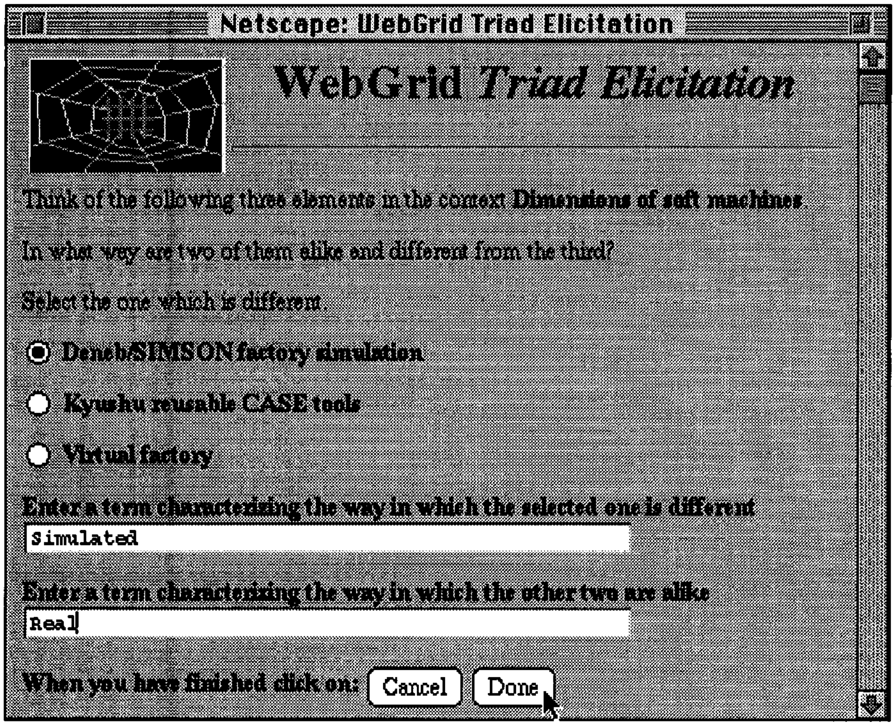

Figure 4 Construct elicitation from a triad

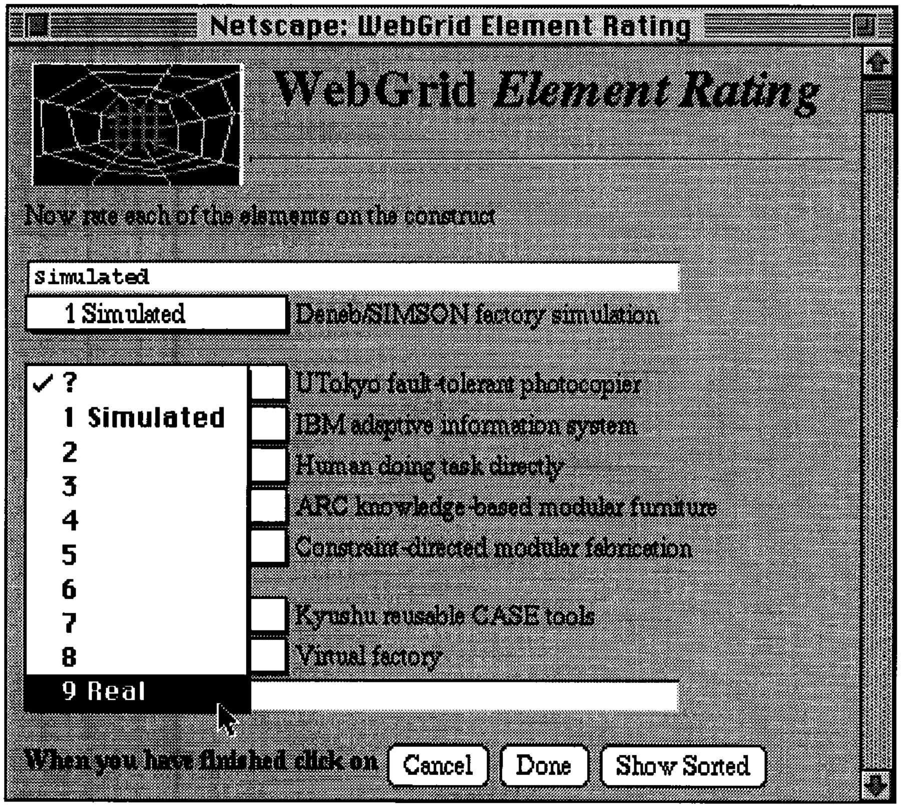

Figure 5 Rating elements on constructs

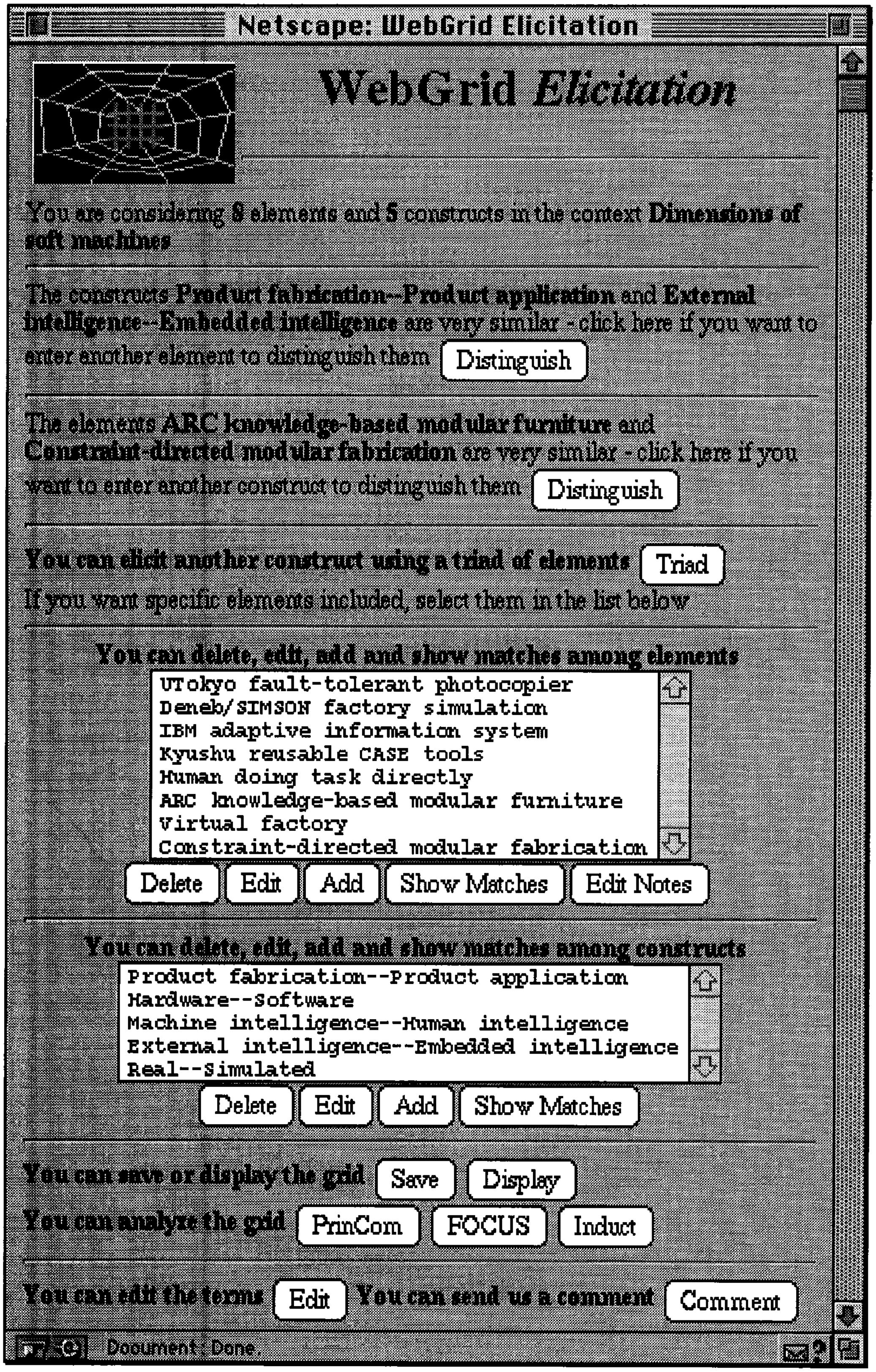

Figure 6 Status screen showing matches

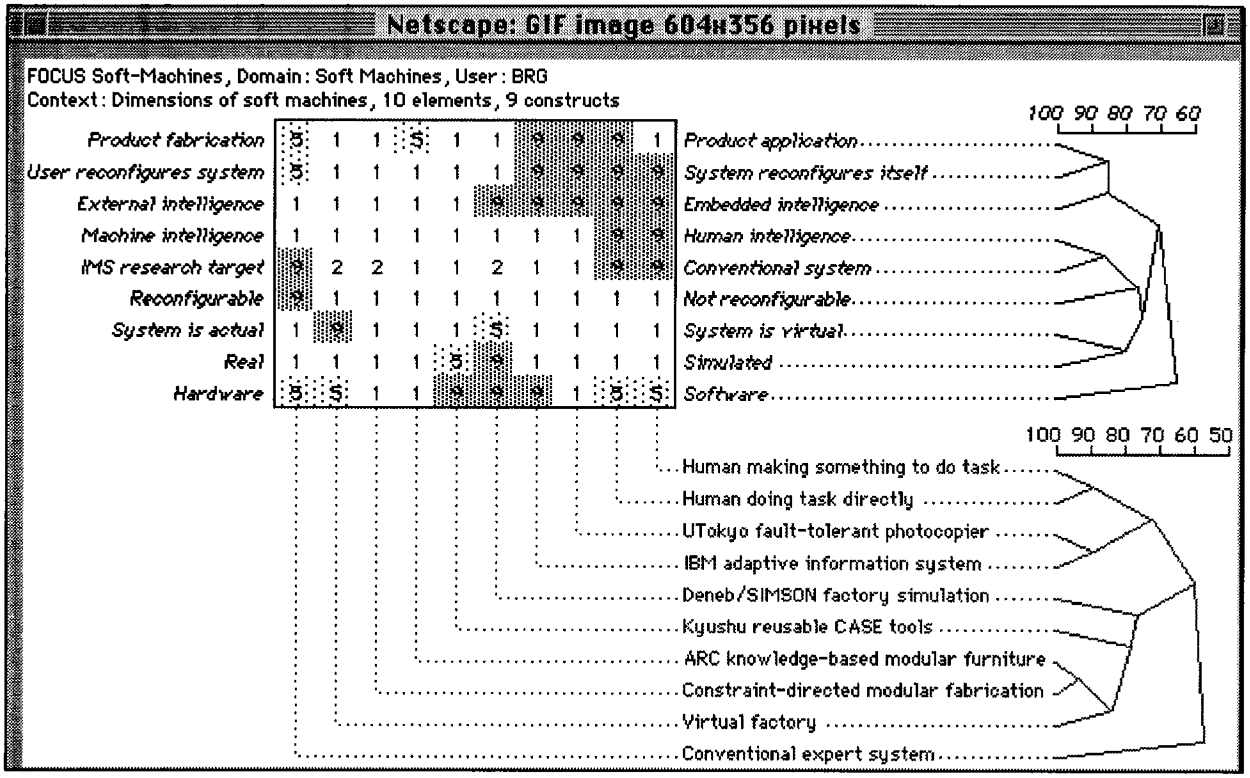

Figure 7 FOCUS cluster analysis of grid

5 Group Comparison of Repertory Grid Conceptual Structures

Once knowledge acquisition tools are available on the web it becomes possible to support distributed knowledge acquisition in which experts and knowledge engineers at different sites collaborate in developing a knowledge-based system. The repertory grid system described above has been extended to support the comparison of knowledge structures using an extension of the consensus-conflic-correspondence-contrast methodology described by Gaines and Shaw (1989).

When a grid has been developed by an expert at one site, another expert at another site can develop a grid based on it, either attempting to rate the elements on the other expert's constructs to evaluate consensus and conflict, or developing her own constructs to evaluate correspondence and contrast.

On the status screen a new "Compare" button becomes available underneath the analysis buttons in the lower part of the screen. Clicking on this generates the analysis shown in Figure 8 where each construct in the new grid has been matched with the closest corresponding construct in the original grid and the degree of match has been graphed on the right.

This enables the experts to see where they have corresponding constructs either providing different terms for the same distinction or indicating some underlying relation, for example a causal link. They can also see the constructs and elements where they do not have correspondence and about which they may have difficulty in communicating.

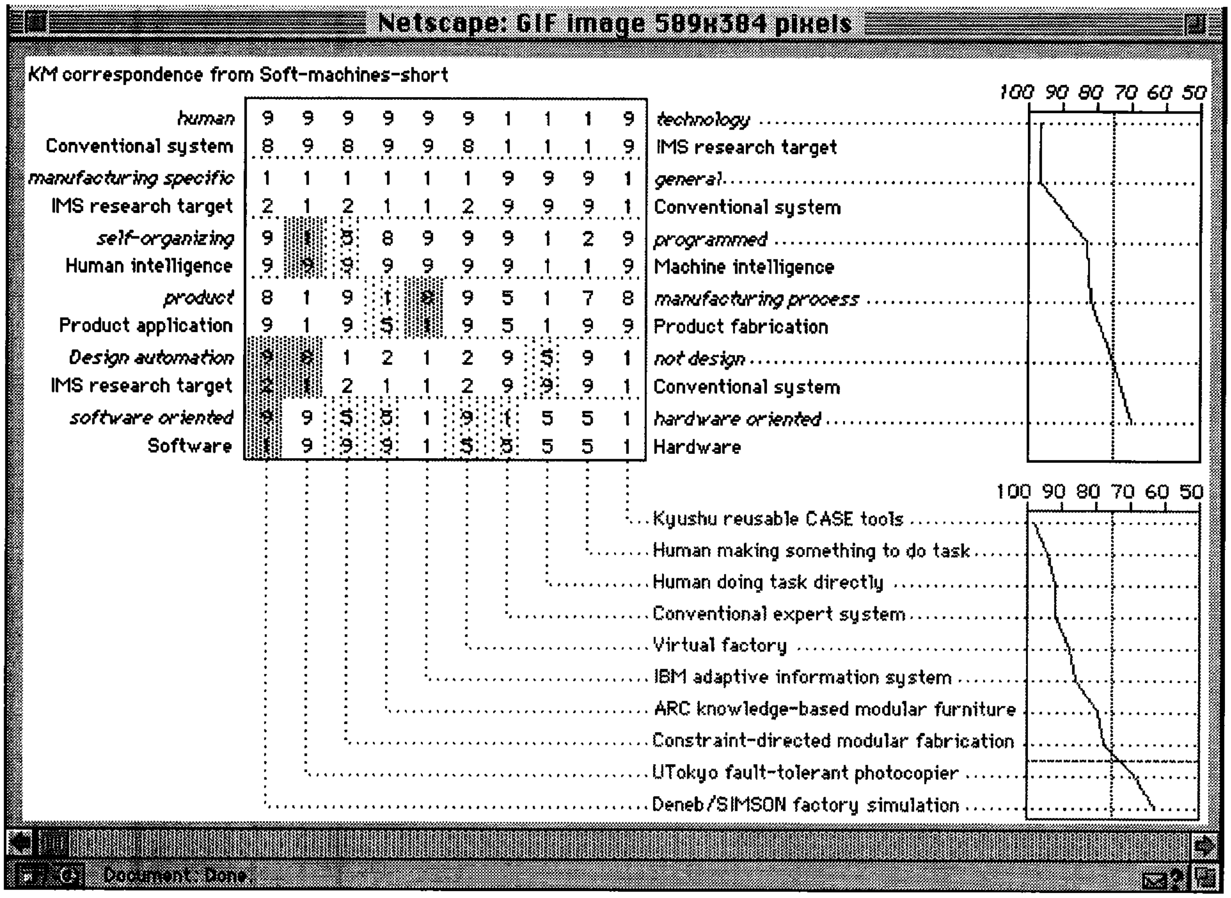

Figure 8 Comparison of grids from two experts

6 Conclusions

The wide range of technologies developed in artificial intelligence research have the potential to support knowledge-based across many disciplines, but access to them is currently not widely available. The technologies, tools and protocols developed for the World Wide Web make it possible to provide knowledge acquisition, representation and inference systems internationally to anyone with access to the web. Such knowledge-based technologies integrate naturally with other applications and hypermedia systems to provide a distributed knowledge medium capable of supporting the knowledge processes of professional communities.

This article has illustrated what is possible through examples of the development of knowledge modeling tools operating through the web to provide knowledge acquisition, representation and inference through semantic networks and repertory grids. These systems were developed primarily for locally managed projects, and their availability has only been advertised through specialist list servers for the knowledge acquisition and personal construct psychology communities. However, in the period July-December 1995 WebGrid was accessed from 674 different sites in 30 countries.

The web is essentially an anonymous medium and we do not track the activities of outside users. However, occasionally users contact us to discuss their applications and, if the local network goes down, we receive mail from serious users reporting the problem and requesting notification of when the KA programs will be available again. An interesting example of serendipitous use was a masters student in Holland studying operators' models of nuclear reactors who came across the grid elicitation system on the web in September, used it with his experts to elicit their conceptual models, and included these in an additional chapter in his thesis for examination in October—the web certainly accelerates research processes.

Web technology is improving rapidly, and many of the limitations of the current HTML graphic user interface will disappear when customized downloadable widgets become available through Sun's (1995) Java and Microsoft's (1994) OLE technologies. The scope for developing new systems through the integration of knowledge-based and other technologies from many different research groups will greatly increase as the web becomes used increasingly to make those technologies widely accessible. The social nature of knowledge processes will also become a significant factor in system development when it is possible to make those systems an integral part of the operation of major professional communities.

Acknowledgments

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URLs

WebGrid can be accessed online at
http://tiger.cpsc.ucalgary.ca/WebGrid

WebMap software is available at
ftp://ksi.cpsc.ucalgary.ca/KSI/Demos/KMap.sea.hqx

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