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World Wide Presentation and Critique of Design Proposals with Web-PHIDIAS

In this paper we describe Web-PHIDIAS, a network-centric design environment based on the PHIDIAS HyperCAD system. Web-PHIDIAS uses the backend of PHIDIAS as a hypermedia database engine to serve up VRML models, HTML pages and Java applets over the Web. In particular, it uses the Web (1) to present 3D models of design proposals using VRML; (2) to present rationale for these proposals; and (3) to get comments on the proposals and their rationale from viewers anywhere in the world.

These comments are automatically stored in a server-side hypermedia database where they are linked to the models and rationale that they refer to. The proposal presenter can opt to have Web-PHIDIAS make these comments part of the public presentation so that other viewers throughout the world can comment on the comments. Perhaps most important is the fact that a Web site implemented with Web-PHIDIAS has no persistent HTML pages or forms. All presentations of data over the Web are created "on the fly" by the server-side part of Web-PHIDIAS using HTML and Java. User input is obtained using an authoring interface created in Java.

La présentation et la critique de propositions de design avec le système Web-PHIDIAS

Dans ce papier, nous décrivons Web-Phidias, un environnement de design centré-sur- réseau, basé sur le système HyperCAD PHIDIAS. Web-PHIDIAS utilise une partie de PHIDIAS comme engin de banque de données hypermédia pour construire des modèles VRML, des pages HTML, et des applets Java, destinés à paraître sur le Web. En particulier, Web-PHIDIAS utilise le Web pour (1) présenter des modèles 3D de propositions de design en utilisant le VRML; (2) pour présenter le raisonnement derrière ces propositions; et (3) pour obtenir des commentaires de partout dans le monde au sujet de ces propositions et leurs raisonnements.

Ces commentaires sont automatiquement placées dans une banque de données hypermédia, côté-serveur, d'ou elles sont liées aux modéles et aux raisonnements auxquelles elles réfèrent. Le présenteur de la proposition de design a l'option de rendre ces commentaires accessibles au monde entier, grâce à Web-PHIDIAS, et de les inclure dans sa présentation. Ainsi, d'autres gens peuvent commenter les commentaires. Peut -être le plus important est le fait qu'un site Web développé avec Web-PHIDIAS n'a pas de pages HTML ou de formes permanentes. Toute présentation de données à travers le Web est crée 'sur le vol' par la partie côté-serveur de Web-PHIDIAS, en utilisant HTML et Java. Les données entrées par l'utilisateur sont obtenues grâce à une interface-auteur crée en Java.

introduction

Since the 1970s we have built hypertext / hypermedia systems to promote the argumentative approach to design first proposed by Rittel (Rittel 1970). This approach aims to improve design by bringing a greater breadth and depth of argumentation to bear on the shaping of design solutions. The great *breadth* of argumentation means a wider spectrum of opinion about the various issues dealt with in a design project. The greater *depth* means more extensive and careful thinking and discussion about such issues.

The ubiquity and power of the World Wide Web provides a powerful tool for promoting argumentation in design. Though the Web has to date largely been a one-way communication medium–i.e. a publication medium–there are many signs that this is not its ultimate destiny. Tim Berners-Lee, inventor of the World Wide Web, has himself complained that he never intended the Web to be merely a publication medium. It was originally meant to be a vehicle for collaborative authoring and critiquing of ideas (Levin 1996). There are indications that many people in academia and industry are now working to transform the Web into something that comes closer to realizing the potential that Berners-Lee originally envisioned: an electronic environment for the discussion of ideas.

We have attempted to tap the potential of the Web as a means for creating, presenting, justifying, critiquing and defending design proposals. In particular, we have sought to use the Web as a way of enhancing the argumentative character of design by using Web-based software to increase the breadth and depth of the reasoning that goes into design. But this requires more functionality than the Web alone provides currently. Our approach to adding this functionality has been to use our PHIDIAS software (McCall, Bennett and Johnson 1994) in combination with Java, VRML and other standard Web-based technologies to create a software system that we call simply Web-PHIDIAS.

In this article we begin by explaining our prior work on PHIDIAS and network-centric CAD. We also discuss the background of our work on the design of space-based habitation. We then discuss the first part of our project: a Web-based version of PHIDIAS that we developed for NASA. Following this, we explain how we have built on that system to create software that uses PHIDIAS as a hypermedia database for: (1) the presentation of design proposals in the form of organized collections of VRML models, (2) the justification of these proposals using rationale from the designer and from NASA's large set of design requirements and guidelines, and (3) the elicitation of comments from users over the Web, the storage of the comments in the PHIDIAS database and then the publication of them on the Web for others to comment on.

We conclude by analyzing the potential of the Web for promoting an argumentative approach to design and by explaining our planned future work on building full-blown CAD capabilities and knowledge-based computation into the Web-PHIDIAS system.

background

The PHIDIAS system represents the current stage of a more-than-20-year project aimed at developing argumentative hypertext systems to aid designers. Our first hypertext prototype, called PROTOCOL, was completed in 1978. In 1981 we started on a new prototype called MIKROPLIS and completed it in 1985. These first two systems dealt only with text. Since text-only systems have very limited usefulness as aids to architectural design, in 1986 we began developing CAD-graphics to use in combination with MIKROPLIS. The CAD and hypertext were finally coupled together in 1990 to make the first PHIDIAS system. This system was completely rewritten several times to create a highly integral hypermedia-based system architecture that offers three basic types of functionality: knowledge-based computation, hypermedia navigation and CAD graphics. As part of this effort, the media capabilities of the system were extended to support on-screen video, voice annotation, and raster images in a wide range of formats.

The explosive growth of the World Wide Web was for us, as for many other hypertext researchers, cause for both celebration and concern. Celebration, because the Web demonstrated what prophets of hypertext like Ted Nelson and Douglas Engelbart had claimed since the 1960s: that this

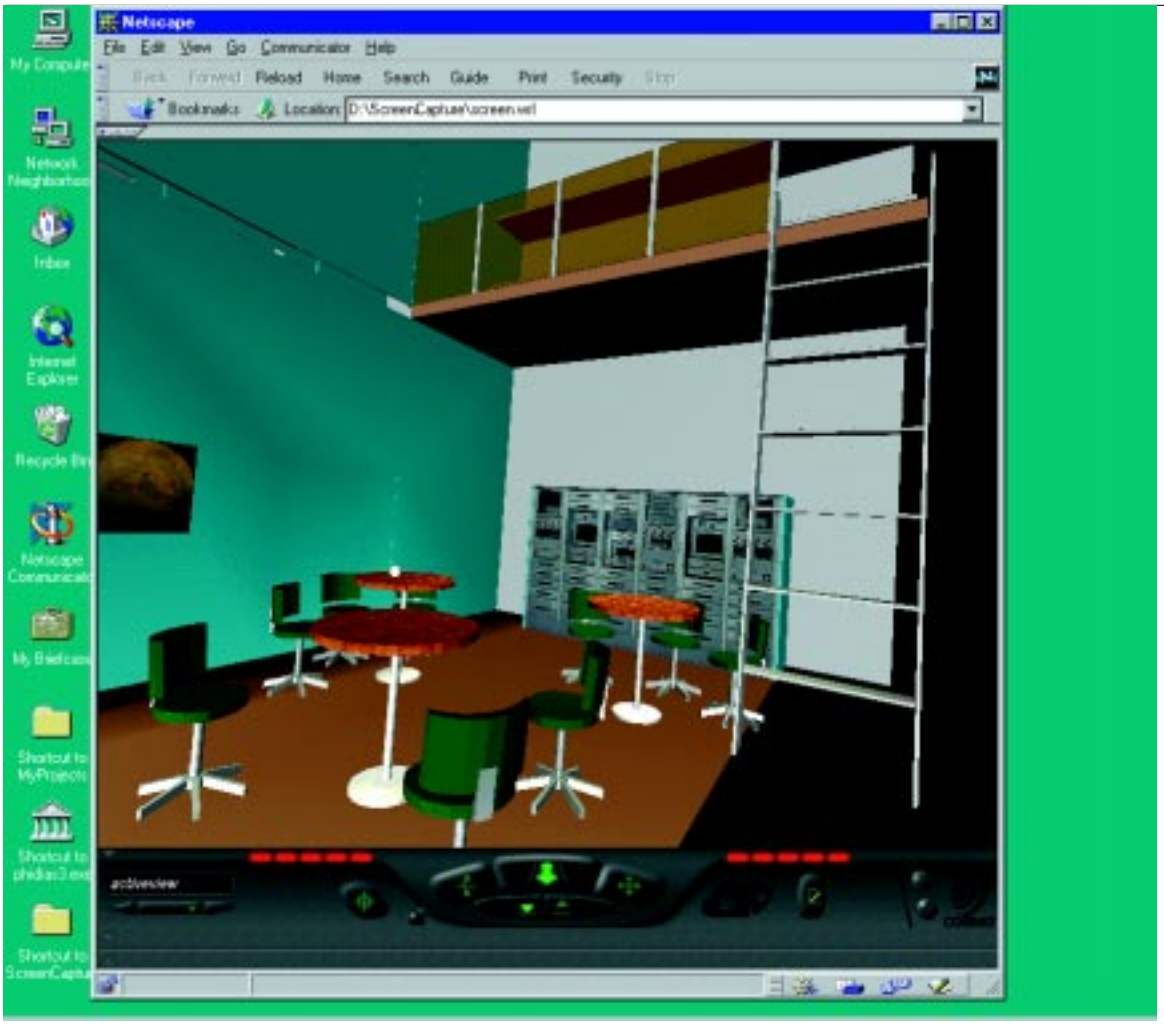

Figure 1. View of the galley-wardroom area of the Mars Habitat designed by Sonja. The model is shown in Netscape Navigator running the Cosmo 2.0 VRML browser from Silicon Graphics, Inc. People viewing this 3D model on the Web can explore the entire habitat and can at any point click on various objects in it to retrieve relevant rationale for the design. Clicking on the floor shown in the above view will, for example, retrieve the rationale for the design of the entire galley-wardroom area. Clicking on the racks shown on the back wall retrieves only the rationale for their design.

new type of software could profoundly transform information technology and even society (Nelson 1974)(Engelbart 1963). The Web was cause for concern, however, because all those who had developed hypertext / hypermedia systems were suddenly forced to explain why their own systems were not made irrelevant by the Web's existence. Even though many research prototypes offered more sophisticated functionality than was to be found on the Web, the overwhelming popularity of the Web made it impossible for any other system to compete with it.

We decided not to fight the Web but to join it. We saw that the value of our hypertext work

ultimately lay in a synergetic combination of PHIDIAS with the Web. The Web has many capabilities that PHIDIAS does not have by itself, the most conspicuous being worldwide distribution of and access to information. PHIDIAS, on the other hand, offers a range of functionality not found on the Web. These include fine-grained hypermedia structure, seamless integration of authoring and browsing, inheritance of hypermedia networks, knowledge-based computation and CAD-graphic editing and display.

We set out to implement all of PHIDIAS' capabilities on the Web. Some have now been implemented; others will likely take several more years of work. To date we have enabled PHIDIAS to function as a server-side hypermedia database that can "talk" to various software "clients" over the Web. As explained below, this gives PHIDIAS the capability of creating HTML pages from its data and sending these pages over the Web. It also gives PHIDIAS the ability to communicate with Java applets that can both receive information from PHIDIAS and send information to it to be stored in its database. CAD capabilities of PHIDIAS over the Web are currently limited to the sending of linked and annotated collections of VRML models to Web browsers. Other capabilities of the stand-alone (non-Web) version of PHIDIAS are still being implemented.

On the surface, it might seem that the capabilities of the current version of PHIDIAS on the Web could be implemented easily with off-the-shell software. For example, a number of database systems now have the capability of serving as content managers for Web sites. Like PHIDIAS, they generate Web pages "on the fly," thus, like Web-PHIDIAS, dramatically simplify the task of managing large collections of Web-based information. But a PHIDIAS database is unlike existing commercial databases in one crucial respect: it is designed to manage large collections of links. Conventional databases, including the more sophisticated ones, fall very short in their support for linking. It is possible to implement links in such databases, but such implementations are almost invariably ad hoc uses of the database engines for tasks they were not designed to support. PHIDIAS, by contrast, was designed solely for the purpose of managing large collections of linked data. The advantage that PHIDIAS provides is in its support for managing data having arbitrary structure. It is especially useful for handling hierarchical databases but in principle can handle data of arbitrary structural complexity.

The link-handling deficiencies of conventional database technologies have been documented in detail by researchers who develop the types of database engines known as hyperbase management systems–e.g., (Schnase 1993) and (Schuett 1990). Perhaps the central tenet of hyperbase researchers has been that large-scale link management is a highly complex and error-prone task that cannot be done effectively in an ad hoc manner. Link management must be explicitly incorporated into other concepts of database management.

Commercial development of Web-based software has ignored research on hyperbase systems. Instead, legacy database systems–designed with no thought to hypermedia–have been hastily retrofitted to serve up Web pages. The situation now is similar to that of the 1980s in which database researchers and developers stubbornly dismissed hypermedia as an approach to organizing large collections of information. The explosion of the Web in the mid-1990s forced the database community to pay attention for the simple reason that it put on line the largest collection of information ever created. Now, however, the same stubborn refusal to consider hypermedia for data management has resurfaced in the design of software to manage Web sites. We predict the outcome will be the same as last time: hypermedia will ultimately triumph over conventional database management as the way to serve up Web-based data.

The issue that might just force the use of server-side hypermedia engines is interactivity of Web pages. Over the past few years we have seen Web pages become more dynamic–e.g., with animations. Now we are seeing Web pages become interactive. This interactivity typically requires a finer level of granularity than the page-level granularity that the Web began with. In particular, much of the interactivity of the next generation of Web pages is likely to center around two crucial technologies: the Document Object Model (DOM) and

Figure 2. Clicking on the floor has brought up Sonja's rationale for her design of the galley wardroom. It also brings up critical comments made by two other people who saw the model on the Web. These comments have not been made in response to Sonja's rationale but have instead been made directly in response to the VRML model. Sonja's rationale includes a Web hyperlink (shown in blue text) to rationale in the Man-System Integration Standards, NASA's extensive document of legally mandated requirements, guidelines and considerations for the design of space-based habitats. In the lower right-hand corner of the box containing Fritz's comment there is a yellow square containing a black triangle. This indicates that someone has made comments about Fritz's comment. Clicking on that square with cause display of those comments. Note that all the commentary is shown in a Java applet window rather than in a Web browser. Using Java rather than a browser enables more fine-grained control of the display and more interactivity with the user.

the Extensible Markup Language (XML). Both DOM and XML are based on finer-than-page-level granularity. For database systems to work easily with DOM and XML, they will need to handle both (1) orders of magnitude more "chunks" of information than current Web-databases handle and (2) the myriad links that connect these "chunks." We believe that hypermedia will be the technology of choice for this task for the same reason that the World Wide Web is not a giant relational database: to handle linked collections of information well, you need a hypermedia system, not a (conventional) database system.

We are working to position PHIDIAS as a Web-hyperbase system that can play a role in creating the next generation of interactive Web sites. In the following sections we describe our first steps in putting PHIDIAS on the Web in projects that we

did for NASA and one of its contractors.

our work on space-based habitation

For the past eight years we have tested our systems in the domain of space-based habitation. We have worked closely with the Johnson Engineering Corporation (JE), a NASA contractor for more than 20 years. This collaboration has in turn enabled us to work with personnel at the Johnson Space Center on electronic dissemination of the Man-Systems Integration Standards (MSIS), a large document containing requirements, guidelines and other rationale for design of space-based habitats. The MSIS provides the basis for all contract work on design of spacecraft interiors, space stations and extraterrestrial surface habitats.

our prior work

Over the past several years we have been working on various network-enabled CAD prototypes in preparation for implementing a full-blown version of PHIDIAS on the Web. One of these used knowledge-based computation in combination with communication over a network to create "argumentative agents," that facilitated coordination and collaboration in design (McCall 1996). This system prototyped some of the functionality that we hope ultimately to implement in a system for Web-based collaborative design. Unfortunately, its technology provided no direct "upward path" toward implementing such functionality over the Web. It used stand-alone versions of PHIDIAS that communicated over a local area network. To create a truly Web-enabled system, we had to fundamentally redesign certain aspects of the PHIDIAS system.

We also produced a prototype of a system that could use VRML models, Java and the Web to enable Web-based collaborative design (Knapp 1996). This system was useful for "cutting our teeth" on some basic Web functionality. But it was merely an initial "proof-of-concept" prototype that had only a very small fraction of the functionality of the stand-alone PHIDIAS system.

In the work described below we have for the first time begun implementation of a serious, Web-based version of PHIDIAS. We say "serious" because the foundation for the project is provided by a Web-enabled version of PHIDIAS that is more than an academic prototype. It is a system that we developed under commercial contract for NASA and which is in use on a daily basis to run a Web site at the Johnson Space Center. Several years of effort went into to converting PHIDIAS from its prior "academic" form into an "industrial strength" software product that could function reliably under conditions of year-round, round-the-clock use.

In the sections below we describe two phases of our work on Web-PHIDIAS. The first involved creation of the system that runs the NASA Web site. The second involved building an academic prototype on top of the NASA system. The first phase was aimed at putting a conventional, decimally numbered government document on the Web. The second phase used the Web-based version of PHIDIAS created in the first phase to support Web-based presentation and evaluation of design proposals.

the website for nasa

NASA has for years produced the Man-Systems Integration Standards (MSIS), a multi-volume document of standards, requirements, guidelines and considerations for design of spacecraft interiors and space-based habitats. A special version of this document is created for each major project that NASA engages in. For example, an MSIS version known as SSP 50005 provided the basis for design of the International Space Station.

The MSIS is nominally focused on ergonomic considerations for design–in particular, the human interface with physical systems. In actuality, however, the MSIS includes a vast range of design considerations, including utility, social interaction, psychological factors and even aesthetic considerations. The reason for this breadth seems to be that the full spectrum of life's concerns become crucial to crews that are to live in very tight quarters for great lengths of time in potentially lethal, extraterrestrial environments. It is simply not safe to ignore any factor that affects the quality of life for people in such circumstances. Thus, while on the surface the MSIS might appear to have the engineer's narrow focus on the purely "functional" aspects of design, we have found that in fact, MSIS provides a good basis for a broader view of the

Figure 3. Clicking on the hyperlink in Sonja's rationale brings up the Web-PHIDIAS version of the Man-Systems Integration Standards and associated NASA video that we implemented using a streaming video server from RealNetworks. NASA's information potentially plays a powerful role in supporting Sonja's defense of her design decisions, but critics of her solution might also use NASA's information to attack her design. This empowers all participants in the debate, because NASA's rationale is the product of more than 30 years of systematic research, iterative design and analysis of mission experience. Any relevant information located anywhere on the Web might also be linked-in by Sonja or online viewers to support their arguments about the design. Since NASA's information is read-only, we have displayed it as an HTML page in a Web browser. Such pages are generated "on the fly" by the Web-PHIDIAS system when users click on links to NASA's information. Users can view well over a thousand pages of such information, yet NASA's site actually has no persistent collection of Web pages.

value of information in improving the quality of built environments. The size and breadth of the MSIS in combination with the extraordinary amount of time, effort and care that have gone into its creation have provided a useful test-bed for our computer systems, which are intended to aid designers by providing them with useful, argumentative information.

Anyone with an interest in space-based habitation can obtain a paper copy of the MSIS at no charge merely by calling or sending mail to the Flight Crew Support Division (FCSD) of the Johnson Space Center in Houston, Texas. Along with the paper-based MSIS, the FCSD also gives out a videotape entitled, "Living and Working in Space," that illustrates many points of the MSIS using film footage taken on Shuttle and Skylab missions.

This paper-and-videotape distribution scheme has a number of intrinsic problems. For one thing,

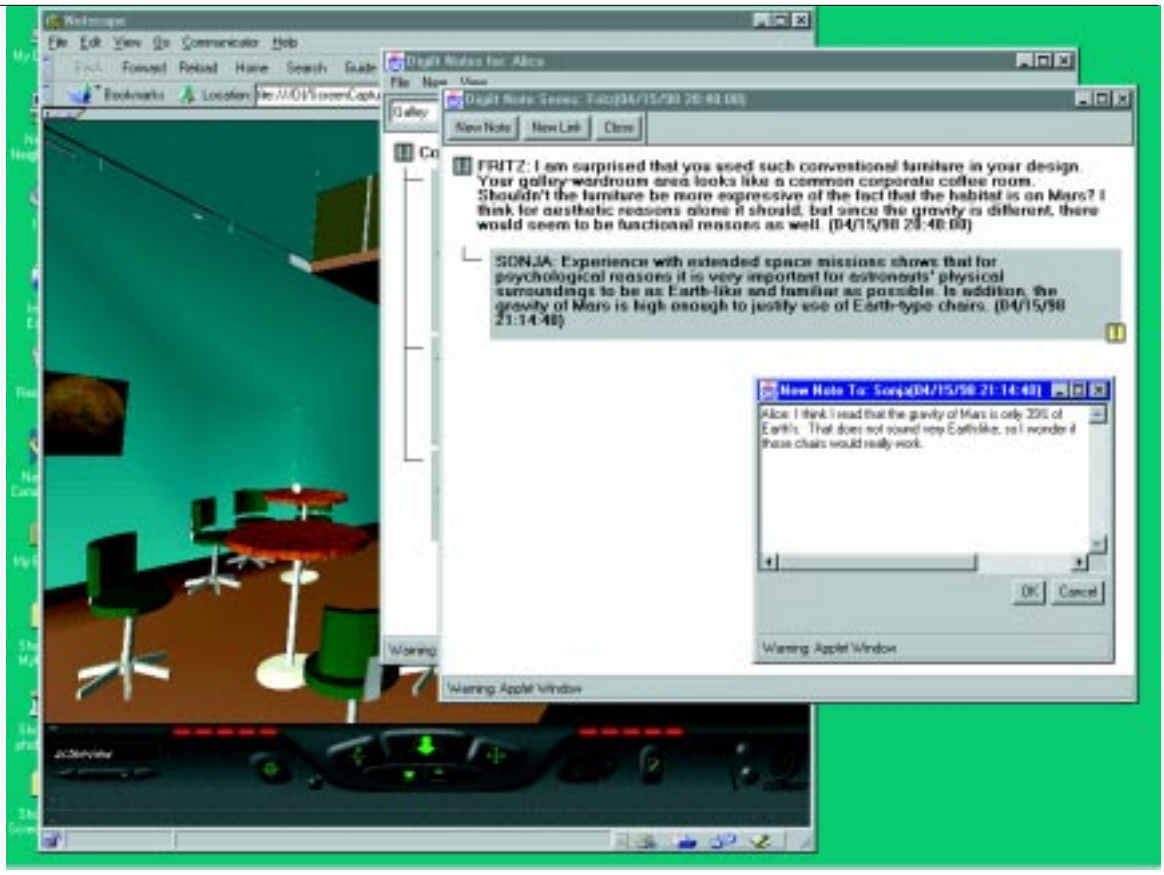

Figure 4. Here we see that Sonja has responded to Fritz's criticism of her choice of furniture for the galley-wardroom. Her comment is shown in gray beneath Fritz's. We also see, however, that Alice is creating a counter-argument to Sonja's response. Alice's comment is shown in the authoring interface provided by the Java applet. When Alice clicks the "OK" button her comment will be transmitted over the Internet to the Web-PHIDIAS "back-end," which then stores the comment in a hypermedia database and makes it immediately available over the Web. As this figure illustrates, the argumentation among participants in the on-line critiquing session can produce a deep hierarchy of comments on comments on comments.

it is expensive. The document is revised every year and that means that updates must be sent out every year. A related problem is that NASA has no way of recalling the out-of-date versions that are floating around in contractors' offices. There is thus a very serious danger that contractors will do expensive and life-critical contract work on the basis of an out-of-date version of the document. Finally, though the videotape contains short video clips for many different sections of the MSIS, there is no practical way for users to view the video clips appropriate to specific MSIS paragraphs. (The current procedure involves looking up video-to-text links in "Appendix H" of the document, where one finds a multi-page table that, for example, explains that Paragraph 3.4.5.6.1.g is illustrated by a video clip to be found running from 22 minutes and 3 seconds to 24 minutes and 45 seconds into the videotape.)

In 1993 we proposed to solve these problems by creating an Internet-based version of the MSIS using the PHIDIAS system. We were funded by NASA for this project for three years, but primarily because they were interested in a computer-based version of the MSIS–e.g., for a CD-ROM version of the document. The Internet part of it they were originally much less enthusiastic about, apparently because it was considered too "futuristic." As the project progressed, however, the tidal wave of interest in the World Wide Web hit; and the person in charge of the Flight Crew Support Division began to see the Web as the ultimate means for distribution of the MSIS. As a consequence, we got an additional short contract that enabled us to create a fully Web-based version of the MSIS.

At first, it was not clear to NASA that PHIDIAS was needed to put the MSIS on the Web. The desktop publishing program used to create the paper MSIS had been upgraded by its maker with the capability of saving its files as HTML. In addition, special functionality had been added that enabled automatic creation of (1) both full-sized and thumbnail versions of every illustration in a document; (2) a table of contents; and (3) hyperlinks for the illustrations and the table of contents. A Web-enabled version of the MSIS or any other document could thus be created literally at the press of a mouse button. What conceivable need could there be for PHIDIAS?

The answer to this question became apparent once people actually tried to create a Web-based version of the MSIS using the desktop publishing software. The result was that each of the fourteen chapters of the MSIS was put on *a single* Web page–except for big chapters which were put on two, unconnected pages. Most of these Web pages were several hundred screen-pages in length. With illustrations, they could easily take more than half an hour *per page* to download. In addition, the illustrations–black-on-white line drawings, originally designed for copying on a Xerox machine–were converted by the system into black-and-white, rather than gray-scale format, thus making the illustrations completely illegible after the reduction to thumbnail size. This approach to creating Web documents is what is known in the software industry as "a non- starter."

As a consequence of this failure of what NASA calls the COTS (commercial off-the-shelf) software solution for creating a Web-based MSIS, we were awarded a contract to do the job using PHIDIAS. A competent, conventional approach to creating this Web site would have required the creation of nearly two thousand separate Web pages, each stored in a separate HTML file. But since the MSIS is modified at least once a year and since there is an elaborate system of cross-references between sections of the MSIS, a conventional approach based on HTML-files could easily have turned into an administrative nightmare. The approach we chose eliminated such problems by using PHIDIAS (1) to create subsets of the MSIS document in response to requests from users; (2) to package the requested information into HTML pages "on the fly" and then (3) to send the information over the Web to the users who requested it. As mentioned above, this is the same basic strategy used by database management systems that act as content managers for Web sites–e.g. content channels. The crucial difference is that PHIDIAS is able to navigate through the structure of the document and compute subsets of the document based on this structure. To our knowledge, no commercially available database system can do this. PHIDIAS accomplishes this navigation and structuring using its unique, built-in, navigational language that we call LINQ (Language for Inference, Navigation and Query) (McCall 1994).

To enable users to access the NASA video over the Web we used a RealNetworks' streaming video server. This by itself, however, would not have provided reasonable access the video relevant to given paragraphs of the MSIS. To solve this problem we simply broke the video into separate clips which we linked directly to the relevant sections of the document. To view a video clip illustrating a given paragraph in the MSIS a user need only click on the link to the video that is embedded in the document with the paragraph. A sample page from our Web-based MSIS is shown in Figure 3.

the current prototype

Once the Web-PHIDIAS system had been cre-

ated for NASA, we were able to develop new prototypes on top of it that used its functionality in new ways that were not of immediate interest to NASA. One was to use the system to serve up structured collections of 3D objects in VRML format. Since PHIDIAS is a hypermedia system, its database is a collection of nodes that are linked together in various ways. Each node in a database can be data of any single data type: text, raster image, video clip, or whatever. A node can also be a VRML model. These models can be linked together in a variety of ways and coupled to textual annotations, images or any other type of data. PHIDIAS thus provides a way of managing and presenting a collection of models that make up a complex presentation. We were anxious to exploit this potential as a basis for presentation of design proposals via the Web. Figure 1 shows part of the proposal for a Mars Habitat designed by one of the authors of this article (Sonja Holmes). This model, called Mars Habitat-1, is a VRML node within a fairly complex Web-PHIDIAS presentation of alternative schemes for Martian habitats.

The model shown in Figure 1 represents only a *preliminary* proposal for a Martian habitat. The purpose for putting the Mars-Habitat presentation on the Web is to elicit evaluative comments from people over the Web so as to assist Sonja in revision of the design. But presenting the model alone is not sufficient. To be properly understood by those who view it, the model must be accompanied by rationale from Sonja that explains and attempts to justify the various features of its design. Figure 2 shows rationale that Sonja has given on her design of the galley-wardroom area of the habitat. Beneath this are shown criticisms that two people have made of her design. These comments were submitted over the Web to the Web-PHIDIAS database which has stored them and published them as part of the discussion of the model. The hope here is that by using the Web to obtain comments, we are likely to obtain a wider range of opinion about the design proposal–thus achieving the greater breadth of argumentation that Rittel had advocated in design.

Figure 3 shows how the Web can also be used to increase the depth of argumentation. In that figure we see that Sonja has augmented her own reasoning with arguments from the MSIS. She has done this by using a citation link in her argument that launches a new Web page containing information from the MSIS Web site that we created for NASA (but here shown running on a server in Colorado). Note that she could also have used any other information to be found on the Web to support her case.

The 30 years of effort that has gone into researching the information in the MSIS enables Sonja to design and defend her proposals using far more sophisticated arguments than she could muster on her own. On the other hand, her critics could quite possibly also use the MSIS and other Web-based information to argue against her. The net effect of the use of Web in this context is to raise the level of sophistication in the discussion.

Figure 4 shows the interface for authoring comments over the Web. This figure also shows how Web-PHIDIAS supports discussion and debate among participants in the presentation and evaluation on Sonja's proposal. We see in the figure that Sonja has responded to a criticism of her proposal. But we see this from the perspective of a third participant, name Alice, who takes issue with Sonja's response. In particular, we see that Alice has used the Java-based authoring interface to type in a comment on Sonja's response and is just about to send this comment to the Web-PHIDIAS database. As soon as it is received by Web PHIDIAS it will be made available for viewing throughout the world over the Web.

conclusion and future work

In this paper we have explained how the Web-PHIDIAS system utilizes the resources of the World Wide Web to increase the range and depth of the argumentation about design decisions. In particular, we have shown how this might work for the case of design of a Mars habitat. Web-PHIDIAS uses the PHIDIAS HyperCAD system as the server-side component of a client-server system whose clients are Web browsers that display HTML and run Java applets and VRML browsers. With this system we were able to increase the breadth of design argumentation by increasing the number and variety of people who could critique a design proposal represented as a structured collection of VRML models. People from anywhere in the world can thus participate in the evaluation of design propos-

als. We increased the depth of the argumentation by providing both the designer and the online evaluators of the proposal with an extensive and well-thought-out collection of design principles that NASA has developed over a period of three decades. These principles can be used by all participants in the evaluation process to raise the level of quality of the argumentation used in the evaluation.

Our future plans include implementing on the Web the remainder of the functionality in the standalone PHIDIAS. This includes a full-blown CAD interface in Java–something aided by the recently developed Java 2D and 3D Application Programming Interfaces. Our future work will also include the implementation of PHIDIAS' knowledge-based critics and argumentative agents. This will in turn require us to substantially augment the capabilities of the LINQ, our navigational language, so that it can function as the means of communication between a Java client and a Web-PHIDIAS server.

In moving to a more fully functional version of Web-PHIDIAS, we plan to abandon both VRML and HTML to implement all our functionality in Java. Currently, however, Java's performance is unacceptably slow and its "write once, run anywhere" claim remains unjustified. As a consequence there has been a widespread backlash against Java. We can only hope that by the time we finish implementing the full version of Web-PHIDIAS these issues will have been resolved.

Whether Java's succeeds or fails, Web technology seems certain to remain in flux for a good many years to come. The consequences for us are almost entirely on the client side of our system; thus the design of user interface to our system is likely to be risky for several years at least. Dramatically less risky is the server side of our system, for this primarily involves evolution of the PHIDIAS hypermedia engine, a technology we understand very well. While the functionality required of Web-PHIDIAS will change as rapidly as the Web changes, we anticipate that the architecture of our hypermedia engine will not have to change dramatically. The fine-grained structure of the existing PHIDIAS system is well-suited to supporting future needs for interactivity in Web pages.

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