Note: Preproposal and Reviewer comments are appended. This is for your convenience

Note: Already material is too long and will get longer when essential missing material is added. We can quite easily shorten section 3. So don't worry about this now …

Todo:

All: Review general sections 0(Summary) 1(Introduction) 2(project overview) 4.2(timelines/deliverables) 4.3(Management). Please suggest references.

Note sections 2 and 3 currently only have significant customized input from Syracuse and Trace Center

All: Review roles in sec 4.1

Lipson/Latham: Review Interface Technology in sec 3.3

Lipson: Review support of physically disabled

Caldwell: Describe Knowledge structure in sec. 3.1. Critique description in Sec. 2

DO-IT/CAST: Develop in sec. 2 and/or a new subsection in sec. 3, a deployment and assessment strategy

Thank you. I need initial replies by Sunday night May 2 as I am on travel most of May ….

A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

Summary

This multidisciplinary collaboration will develop and research a knowledge network that is accessible to individuals with a wide range of disabilities. We combine expertise in collaboration, object Web, human computer interfaces, education and cross disability access. Our team includes researchers in the fundamental building blocks as well as groups capable of deploying novel technology to the targeted user community. Our knowledge network is built on principles developed on the study of successful learning environments. This network is organized in terms of distributed information objects built with a Cross-Disability-Accessible Document Object Model (DOM) compatible with proposals of the Web Consortium W3C. Further our approach will involve building an operational CDAKN (Cross-Disability-Accessible Knowledge Network) testbed based pragmatically on iterative improvement of existing technologies for collaboration and interfaces. This KN will initially be used by the project team as a collaboratory to both build the KN itself and to design and prepare cross disability versions of existing successful web based training material. The same testbed will be used to deliver distance education with both computer and the natural sciences curricula and so extend the testing and assessment of the KN and develop further important capabilities.

The research issues addressed in this project include the architecture of CDAKN and implications for a CDA DOM; the integration of knowledge agents with collaboration and human-interface technology; and the design of customizable interfaces. The major outcome of the proposed research will be knowledge on how easy or difficult it is to create CDAKNs, how to

build knowledge by integrating distributed informational objects, how to identify barriers, and how to overcome them. This will be quantified through the CDADOM design principles that we will share and evolve with the international research and standards organizations. The main practical outcome of this project will be the creation of a prototype CDAKN, which could serve as a model for further research and be ready for widespread deployment and further testing.

1. Goals and Guiding Principles

The basic goal of the proposed work is to build a Cross-Disability-Accessible Knowledge Network (CDAKN) and then evaluate and advance its effectiveness in both distance education in science and technology curricula and for scientific collaboration. This goal and the project are based on the following principles:

1. People need to be integrated into society and its activities irrespective of physical disabilities.
2. Web technologies and pervasive communication infrastructure provide a universal backbone for which one can build more effective cross-disability access (CDA) with specialized perception and expression capabilities optimized for individuals.
3. The ‘anyplace’ characteristic of the Internet is particularly attractive for individuals with disabilities, who may find their geographical location limited. Thus Internet collaboration is especially important for building knowledge networks involving individuals with disabilities.
4. Best practice in information system standards, especially the work of the W3C including their document object model (DOM http://www.w3.org/DOM/), provide an organizing framework on which to build towards cross disability access.
5. The Trace Research and Development Center (trace.wisc.edu) in Wisconsin has pioneered the principles of universal design for computer interfaces and brings a broad national knowledge network. Their contacts with the Web Consortium W3C allow us to both influence and be influenced by key national standards.
6. The Grouper laboratory (http://www.cae.wisc.edu/~grouper/) at Wisconsin has developed key concepts to build teaming in knowledge networks with novel and successful ways of synthesizing knowledge from information both for general collaboration and for K-12 learning environments.
7. Syracuse University has developed a state-of-the-art collaboration (TangoInteractive http://www.npac.syr.edu/tango) system with an architecture supporting customized cross disability delivery.
8. Science, mathematics, engineering and technology (SMET) education is a national priority, for which cross disability universal participation is highly desirable.
9. DO-IT (Disabilities, Opportunities, Internetworking, and Technology at University of Washington http://weber.u.washington.edu/~doit/) and CAST (Center for Applied Special Technology http://www.cast.org) are recognized for their pioneering work for applying and evaluating technology to help those with disabilities both in educational and job training areas. Their contacts will give team appropriate testbeds for our CDAKN's.
10. The best practice interface technology for sensory and physically disabled individuals is available through the team with Syracuse's low cost technology and deployment projects (http://www.pulsar.org/ TNG/NeatTools) allowing us to extend the KN to those with severe muscular disabilities.
11. Distance education, including both teachers and students with disabilities, exemplifies the

general goal of implementing societal functions in a way that allows universal participation.

12. There is obvious synergy with telemedicine applications including education as part of rehabilitation and here the Rehabilitation Engineering Research Center at Catholic University (http://www.hctr.be.cua.edu/RERC/) brings innovative interfaces and broader testbed activities.
13. Distance education provides an attractive early testbed for new technology, because it has a natural structure that puts less stress on base hardware and software technologies. We have shown this in Syracuse's successful distance education experiments between Syracuse and Jackson State (historically black college in Jackson, Mississippi) using TangoInteractive.
14. Scientific research collaborations increasingly depend on electronic communication. A CDAKN can advance science by inclusion of team members regardless of geographical location or (dis)ability.

Bringing these themes together, this project proposes to explore the proposition that multisensory interactive collaborative environments can be created, which allow participation by individuals who have different types of physical and sensory limitations, acquired either at birth, through adventure or as a result of aging. Specifically, we propose to create a knowledge network to both explore this issue and to act as a test bed for the topic.

In implementing this project we will actually create two knowledge networks. One will be based around the topic of science education. This area is chosen because it represents an already existing base of knowledge, which can be used as a test bed early in the project to explore these issues. A second knowledge area and network will be established over the course of the project, and will be focused on the topic of cross-disability access to collaborative environments and collaboratories.

Using these two test beds, we will proceed to explore both the issues surrounding access to multimodal environments (visual, auditory, and interactive) by individuals who have visual, auditory and manipulative limitations, and, research into strategies for addressing access by these groups.

Although, it is a common assumption that systems cannot be designed, which are simultaneously useable by individuals with multiple disabilities, we have found that not to necessarily be the case. We have, for example, developed multimedia touchscreen kiosks, which are simultaneously useable by individuals with low vision, who are blind, who are hard of hearing, who are deaf, who have reading problems, who cannot read, and who have physical disabilities involving both weakness and severe thetosis. Moreover, the technologies have been transferred to commercial production and currently are in airports, libraries, and will soon be distributed nationwide in voting booths.

The challenges posed by interactive collaborative environments are much more severe, but we have high expectations that this project will lead to both pragmatic solutions and a series of very interesting research questions and technology challenges. Moreover, we expect more people without disabilities to benefit from this research than people with disabilities, even though people with disabilities are the primary target of the research. This is simply because of the nature of providing more flexible interfaces and cross-modality translation capabilities. For example, the beneficiaries will include all mobile computing users, any users wanting to interact with systems verbally, anyone using artificial agents (which are inherently deaf and blind), and anyone wishing to access information in hostile or constrained environments.

In the following three sections we describe the proposed projects in detail, give technical background in sec. 3 and finally describe in sec. 4 management issues.

2. Cross Disability Access Knowledge Network

2.1: Project Methodology and Activities

We propose to research the issues underlying CDAKN's by building such as a system and evaluating two distinct types of testbed. Firstly the scientific collaboration testbed formed by this proposal team itself. Secondly and more broadly, we will establish a KN aimed at science and mathematics education with cross disability access.

The project can be divided into three phases, which correspond roughly to the each year of the three-year proposal. Firstly we build the scientific collaboration KN using existing technology and experiment with different approaches to cross disability interfaces aimed at two particular user classes -- the blind and those with severe physically disabilities. Note that it is understood in the universal access field to be important to target all disabilities and so although it is defocusing, we will where possible target the full population as only this can verify that our approach is sound. In the second year we will use a natural extension of our existing collaborative system to deliver a set of science and mathematics courses around the country. In the third year we will deploy a more sophisticated knowledge integration framework and build cross disability access for it. Throughout the project we will do extensive evaluation and iteratively feed results of this process into our technology and testbed activities. We will test the generality of our ideas by investigating relevance to related knowledge networks such as telemedicine and to emerging interfaces including virtual reality. Section 3 has many technical details and in this section we just try to describe the broad principle and activities.

We make one important assumption. Namely our KN will be built by the integration of people and information. We assume that the information is all web-based and that the knowledge network is built around the Web. There are many important forms of web-based information but we will focus on that which can be organized in terms of the W3C document object model. This roughly says we assume that we will use web pages built in terms of (advanced) HTML. This allows us to a quantitative framework for our CDAKN in terms of the sophisticated albeit not yet completeW3C document object model. Note that the Web gives us a successful model for retained knowledge that is ready to be shared at a distance and the DOM in some sense quantifies this information model. However the Web does not yet have a consolidated, successful, process model for computer supported collaborative work or more specifically for teaching and learning. We intend to build on the current courses being successfully taught at a distance via TangoInteractive as another technical building block. The "best practice" knowledge model underlying this project also includes the work done by the GROUPER lab in defining and partially ordering math skills.

The W3C DOM specifies hierarchical dynamic organization of document fragments with an event model and a defined interface to scripting languages enabling browsing and interpretation of user interactions. Scriptable style sheets allow one to customize dynamically cross disability rendering of information. Systematic use of XML with domain specific ontology is a key concept as it allows one to give a more precise expression of knowledge and its cross disability rendering. Formally a major deliverable of our project will be enhancements of the W3C DOM to support cross disability access and this product will be disseminated and discussed through the W3C working groups. The Web Content Accessibility Guidelines that will be released soon by the W3C are an important contribution and we want to build on them and address their limitations. The W3C work provides a good guide for cross-disability success in learning resources, which are to be used asynchronously in self-directed learning. Building on the lessons from successful Tango courses, this project will be able to extend the scope of cross-disability-access technology to more dynamic (including synchronous) cases.

Note that although the key information and knowledge representation underpinnings, W3C DOM and XML, are still evolving, they are implemented well enough in existing version 4 and 5 browsers with dynamic HTML and JavaScript, that we can build our testbeds. Note we emphasize information represented in XML and HTML as these have a unifying DOM -- our approach can be generalized to Java applets and other sophisticated web environments but this will not be our major emphasis. We will however use authoring system such as PowerPoint, which have only modest web export although this is improving. This allows us to reuse investment in teachers knowledge of existing tools.

Initially, we will form the initial collaborative network using TangoInteractive with the cross disability knowledge domain being the material defining this project. We will identify prototypes of the educational material to be used in the later testbed deployment phases of the project. As described in sec. 3.1, we have tentatively chosen course modules from computer science and physics as the basis of our CDAKN for the testbeds. We need to develop methodologies to allow web technologies work across disabilities particularly in an interactive environment. We will analyze our initial information resource and rendering devices from three points of view:

1. *Are the "documents" themselves flex-modal?* -- in particular can they be viewed visually or auditorially and have all of the information presented? Further can all of the manipulations necessary be done across disability via text commands i.e., from the keyboard or assistive device used by the physically disabled - this would also make them operable by voice.
2. *Are the players that are used to present the information cross-disability accessible?* Can they be controlled via text (i.e., from the keyboard)? Further do they have a way of visually representing any captions, which are built into the material to accompany any auditory presentation? Do they provide self-voicing for those who cannot see (best) and are they compatible with screen reading technologies so that they can be read if viewed on a platform that has screen readers?
3. *Are the interaction channels cross-disability accessible?* In distance education and collaborative environments such as TangoInteractive, there are audio and visual channels that allow direct communication and interaction between the parties. We need to make provision for all of the audio channels to be translated into visual form by translating speech to text, identifying speakers and support translation of multiple people speaking at the same time by having multiple text blocks appearing on the screen. Other non-speech sounds must also be translated and presented. Finally visual information is described and if possible and appropriate presented tactilely. Generalizing, this implies making basic collaborative functions of TangoInteractive cross disability. Initial work has been done by ATRC from Toronto on WebCT Chat and whiteboard tools. Special tools such as the "raised-hands" applet of TangoInteractive would of course also need to be modified to be universally accessible. We also expect to develop tools that allow participants in the CDAKN to better support universal rendering by imposing more formal structure and by

asking participants to present key material in multi-modal form.

The essential technical idea is that TangoInteractive shares the XML (initially HTML) specification of information and this is mapped using the web scripting API of Tango separately on each client workstation to modify the style sheets used. In the first year we will focus on the existing DOM using the conventional JavaScript API to meet the goals described above. We will use the Syracuse's NeatTools software to build appropriate device interfaces. We will of course have to evaluate and chose from existing or modify interface devices that can support the desired cross-disability rendering. Trace will lead this in the sensory impaired area while for the physically disabled, Catholic University will co-develop interface technology with Syracuse team, and will develop assessment ‘instruments’ for formative evaluation.

Concurrently with this technical activity, another major thrust will study the organization of the educational material into knowledge domains. A focus of this project is the process by which knowledge evolves as a topic (unit knowledge domain) and flows through a life cycle from research to teaching to textbook and heap of recombinant courseware modules, which we view technically as forming a shareable object space. To make them accessible to people with disabilities, they need certain minimum information content (redundancy). To make them easy to share at commodity prices, we layer the object spaces as much as possible on current Web data formats and the emerging document object model interoperation norm of the W3C. A key to having recombinant modules is that the modules have a strong enough external view or summary knowledge component, so that planning can be done which integrates modules with both coverage of the desired instructional domain and continuity in terms of meeting prerequisites. As described in sec. 3.3, we will develop infrastructure, which supports the cross disability development and rendering based on the pioneering work of the Grouper laboratory at Wisconsin in defining how to do the "determine corrective feedback" or "review the game films" phase. Each of the knowledge refinement stages produces a more tightly integrated set of information units which is technically easier to express in XML and give a more precise universal rendering. The articulation of what it takes to comprehend the domain is progressively more thorough and expressed in more widely accessible terms as the domain migrates down this path. We provide support for the continuous upgrading of retained knowledge as a byproduct of transmitting the knowledge.

As an example take the case of blind students and/or teachers. Here, we will add support to TangoInteractive for an automated "orientation view" (who's there, what's happening) comparable to the role of the "table of navigation" in the DAISY/NISO digital talking book. This is missing information for blind usability, replacing the visual maintenance of orientation via the shared GUI panels. The latter is a good example of a bottom-up definition of an accessible knowledge corpus. There was substantial participation from blind people and people expert in serving the blind so that the process was effective. Articulating the relationships among the discourse fragments provides a higher level of knowledge consolidation and makes the course experience more ready to re-use and re-combine.

As part of this integration thrust, we will extend the archiving capability of TangoInteractive to be cross disability so we capture material in multiple renderings and in the original XML form. This capture will be non-invasive and capable of immediate review. It is well known (c.f. the general accessibility of information in Usenet FAQ documents) that questions people actually ask before they know are the key to making knowledge accessible.

These activities will start in the first year and will be ongoing with continual gathering of requirements from user, content and technology points of view. In year 2, there will be a limited deployment with education sessions organized by CAST and DO-IT. At this stage we will start to formalize our work in terms of new design principles for such a DOM which will provide important extensions to the current World Wide Web Consortium model which does not have cross disability built into it. For instance, currently terms such as "onclick" or "onkeydown specify event handlers but this is clearly not in CDA form. TangoInteractive traps all DOM events for sharing with its JavaScript interface and we will define a more abstract syntax, which defines user events structurally rather than in terms of an explicit I/O device. This will lead to a CDADOM where content and events are specified abstractly with mappings on conventional machines leading to familiar handlers. Although we will use the concept of a CDADOM to guide the project, it would be too ambitious to fully implement such an extended DOM. Our research and testbed experience will, however, help in the future revision of current document object models in order to become truly CDA.

As always in such projects, there will be ongoing experimentation motivated by the research objectives which imply hypotheses concerning CDA, KN (functionality, effectiveness, usability) and formative evaluation with consequent refinement. For example, can users who are abled, blind, deaf, or quadriplegic access the CDAKN and keep up with one another in interactive sessions? We will identify problems and take corrective design actions in an iterative fashion. The project will include quantitative performance assessment in Tango and in NeatTools interface programs (event tracking, database recording, data analysis). In this way we can strive toward developing a CDA-multimedia-interactive KN.

We will emphasize evaluation of both our concepts and separately of the particular realization in terms of TangoInteractive. The primary criteria to be used in evaluating the success of the techniques are:

- The ability of the individuals with functional limitations to participate side-by-side with their peers who do not have disabilities. This would include the ability of these individuals to get similar information from the experiences, and to score similarly on tests of comprehension of materials or interactions.
- The reported benefit of the techniques to individuals who do not have any type of functional limitations. This criterion is very important as if the techniques and strategies do not have inherent benefit for everyone, than their promulgation is likely to be slow and limited.

It should be noted that this project does not propose to fully solve these issues. It does propose to have a significant impact on defining the key issues and identifying all of the “low-hanging fruit”. This, in itself, can be of tremendous benefit to the two user groups (both with and without disabilities), as the more difficult issues are addressed.

Note that our approach making material universally accessible implies a model for information specification, which allows us to deliver material at a distance. This has obvious value to the disabled and will be an ongoing theme of the testbed activity. In the final year of the work, the major initial thrusts (cross disability representation and knowledge integration) will be firmly linked and we will deploy and evaluate the cross disability knowledge synthesis and archiving capabilities described above and in section 3.

We will of course, continue to experiment and plan for further work, which seems likely to be attractive in this important emerging area. In such a rapid moving field, we cannot predict well even a year or so in the future but areas in which we will experiment include more general (than W3C) object models such as those implied by Java applets and sophisticated multimedia authoring systems.

2.2 Project Outcomes and Research Issues

The fundamental outcome of the proposed research will be *knowledge* on how easy or difficult it is to create CDAKNs, how to identify barriers, and how to overcome them. The main practical outcome will be the creation of the CDAKN itself – the first of its kind. This will serve as a model for further research and for widespread application of CDAKNs. We intend careful evaluation of its effectiveness and continual improvement of it during and beyond the proposed work. . We intend to sustain the project and its results for the long term, and will seek continued funding from NSF and other sources, while bringing in additional partners for broader implementation and testing. For instance, as we continue to stress truly universal access, we can mention the area of accessibility by people with learning disabilities and non-readers. We expect that the research methods of the GROUPER laboratory and the practical experience of CAST will allow techniques developed in this project, to be extended to these groups.

Another substantial outcome will be the research generated by the technology and knowledge integration thrusts needed to build the CDAKN. Computer science research issues addressed in this project, include: a) architecture of CDAKN and implications for a CDADOM, b) Knowledge synthesis and its universal specification, c) Linkage of collaborative systems to knowledge and information resources and d) abstract specification of customizable interfaces and modular interface hardware.

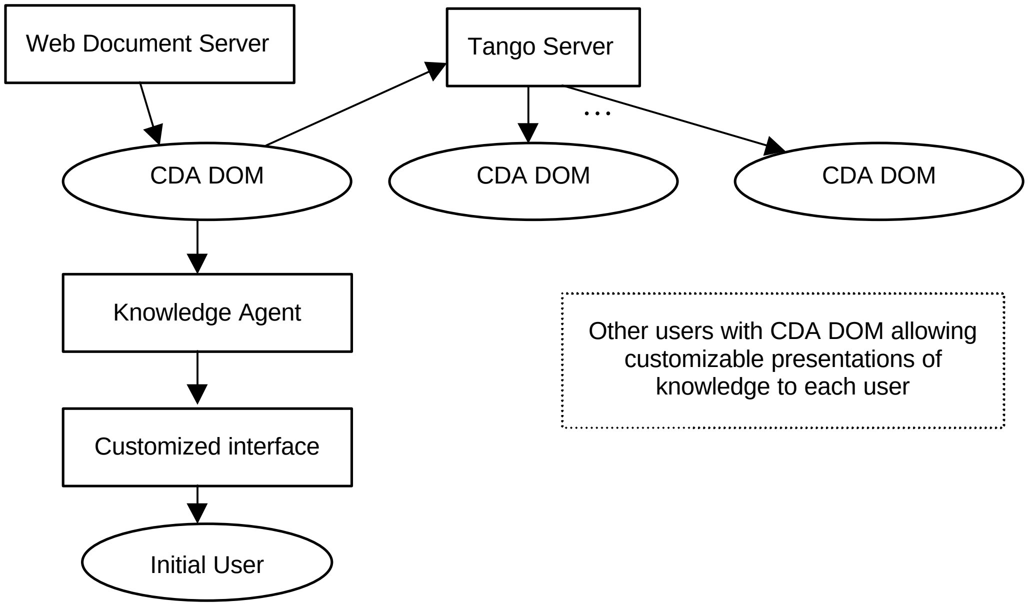
In the companion research area of universal access, we can also identify important research issues, which will be addressed in this project. These include

- How can interactions, which are heavily speech laden, be presented so that individuals who are deaf can interact on equal footing?
- What strategies can be used to offset the inherent delays in any translation process produced, when such delays inherently destroy interaction patterns in active discussions?
- How can the fact, that the audio tracks from individuals are available as discreet audio signals, be capitalized on to provide multiple-parallel conversational tracks, especially when people are speaking simultaneously? These need to be perceivable not only by individuals who were deaf or hard of hearing, but also helpful for all members of the interaction?
- How can visual props and presentational materials be made accessible in real time to individuals who are blind? What are the gestural and real time visual events which accompany typical collaborative interactions, and can be done to prevent them from breaking down the ability of individuals who have low vision or blindness to participate in interactive collaborations or educational endeavors?
- How can pre-scripted pseudo real time interactions be capitalized on, to enhance accessibility of collaborative instructional materials? (E.g., instead of being an actual live interaction, the student is interacting with an intelligent agent which acts out scripts or responds along with pre-recorded or pre-programmed schemas.) TangoInteractive already allows instant replay of all sessions and we need to provide an intelligent cross disability interface to this.

We will make extensive use of the Web for dissemination of project information and free software (TangoInteractive and NeatTools). Information on how to obtain low-cost modular interface hardware will also be provided. This would include computer interface boxes and sensor kits and other commercial components listed in the Trace Resource Book, as appropriate.

Traditional-style presentations, publications, and workshops will also disseminate project results using the developed CDAKN methodology to make our knowledge truly universal.

A final major outcome of this CDAKN research and development project will be that



users with disabilities will have far greater opportunities for SMET education (active learning in constructivist paradigm, lab participation, lifelong learning) and SMET careers.

3: Technical Background

3.1: Knowledge Domains of the CDAKN

As described above, the CDAKN will be used in two distinct roles. Firstly the team of content and technology developers (Syracuse/CUA/NRH), designers (Trace, Grouper) and outreach sites (CAST, DO-IT) will use it to define the project itself and to develop initial CDA educational modules. Secondly the outreach sites will use the CDAKN to deliver material of increasing sophistication in both education and literacy modes. We have chosen to use material already developed, but not universally accessible at present. Our first area is Internetics, which is a curriculum developed by co-PI Geoffrey Fox that combines computational science and modern information /communication technologies. This is a popular course and easiest test case as all the material is already prepared in XML and stored in a database with the architecture described in the following section. Another major focus is *Science for 21st Century*, a large- enrollment course at Syracuse developed by PI and others with modular approach to teaching science in an integrated way to non-science majors. Two current NSF grants, associated with this course, support development of interactive Web-based educational modules; see http://www.simscience.org and www.phy.syr.edu/courses/CCD_NEW/. We will stress the *Science for 21st Century* modules, as these are broadly useable at both high school, undergraduate and general science literacy levels. It will also give us examples of a knowledge domain making extensive use of web links not developed internally and so requiring special cross disability attention.

3.2: TangoInteractive Background

TangoInteractive (or Tango; http://www.npac.syr.edu/tango) is an advanced, powerful, and extensible Web collaboratory, and is perhaps the most flexible of systems of its type. It is not aimed at exploring research issues in collaborative system design, but rather at exploring applications such as those proposed here. In this regard, great effort has been put into making the base infrastructure quite robust, so that it can be used outside a tolerant research environment.

Tango is written in Java, but supports collaborative applications in any language. Further Tango is fully integrated with Web browsers, and this provides the basis of convenient, familiar interfaces. To run Tango, one starts the system from a browser and connects to a Tango server. Both the client and server code for Tango are freely available on CD-ROM or from our Web site, which also contains the well documented API's for C++, Java, Java Beans, and JavaScript. Once in the system, the user can select from over 25 collaboratory applications to work on projects with partners, play a game of Bridge or Chess, take a class at a virtual university, create and use a public or private chat room, conduct a videoconference, view a movie, or surf with friends using the powerful shared browser. It is possible to do all this at the same time, in any combination, and multiple copies of applications such as chat rooms can be launched. Further, Tango can provide shared sessions for either client- or server-side applications. The latter include both shared (Web-linked) databases (as in Oracle-based WebWisdom curriculum management system) and shared CGI scripts (as in our integration of NCSA's Biology Workbench with Tango). We believe that no other collaboratory system, public domain or commercial gives you so many applications under such consistent and simple session and floor control.

Besides running Java applets under Tango, one can run JavaScript-based client-side Web applications. Moreover, in Tango the user can take an arbitrary HTML page and automatically turn it into a shared entity. To build a 3D VRML world, populate it with avatars, and let them interact, Tango provides support via two integration modes: VRML JavaScript nodes and External Authoring Interface. Applications written in C or C++ (e.g. PowerPoint) can also be readily adapted to run collaboratively under the Tango API. In this proposal, we will use the C++ interface of Tango to link the NeatTools specialized interfaces. Note that the shared collaboration model of Tango allows each client to have different views of the same shared application, and this is essential for cross disability access. Shared display systems such as Microsoft's NetMeeting are less flexible.

3.3: Systems Architecture and Software Infrastructure

3.3.1 Pragmatic Object Web

As discussed in sec. 2, we intend to build and deploy a CDAKN, which means that we must make particular choices in today's rich and evolving technology world. We do this in the context of a knowledge model described in sec. 3.1 with technology choices based especially on the open standards of organizations like W3C. However limitations in commercial systems (e.g. bugs and unimplemented features in web browsers) means that these lofty principles must be leavened with practical and sometimes ugly implementation choices. Further although we will articulate and test general architecture principles in this project, we must build on existing software to develop systems which are appropriately robust and functional. Thus we intend to build on two key NPAC technologies, TangoInteractive and WebWisdom, developed to support distance training but with no delivered cross disability support. We believe this is justified not only because of our familiarity with them but because they exhibit two key capabilities. WebWisdom supports the managed integration of distributed educational objects while TangoInteractive's (unique?) collaborative JavaScript API naturally allows cross disability interfaces to Web documents. Where it is necessary to reference the resultant system, we will term it *CDAWebWisdom*.

Our proposed software will be built around an emerging architecture for distributed systems that we call the "Pragmatic Object Web". This notes the ongoing convergence of web and distributed object technologies to form what is usually called the object web. This is currently approached from four major points of view: CORBA (from an Industry Consortium) the Object Management Group, Java from Sun Microsystems, COM from Microsoft and a set of technologies from the web consortium W3C including XML and a document object model (DOM). These approaches are somewhat complementary but often competitive and in constructing real systems, we pragmatically propose to use the best of each approach – this assumes that some complex unpredictable worldwide process will blend these four giants into a composite distributed system architecture and technology base. Our pragmatic approach appears more likely than any other to lead to systems that are both powerful today and likely to be quite consistent with future changes. These ideas are described in a book that we are writing "Building Distributed Systems on the Pragmatic Object Web" which gives examples and detailed discussion of the concepts.

Both the hardware and software infrastructure of the object web is changing with remarkable speed and so our plans are necessarily tentative especially in out years. However we believe that the activities discussed below illustrate our approach and in some sense represent a lower bound to our goals for they do not require any major new object web base technology developments. Of course, we will take advantage of any significant new relevant technologies that become available during the performance period and modify our plans accordingly.

The object web revolution has been driven as much by the adoption of open standards such as HTML, JDBC (Java database connectivity standard) and IIOP (CORBA protocol) as by the more obvious remarkable software artifacts and technologies such as browsers and the Java language. These object web standards and technologies appear to offer significant potential for improvements in cross disability access. In particular the object web standards allow the development of a more structured uniform information space wherein reusable universal access interfaces can be developed and used in a wide variety of circumstances. Although this potentially possible, it is by no means guaranteed as an unguided haphazard development of object web applications could lead to a situation actually worse than that now with increased information served by more and not less data structures. As a relevant example, XML technology could allow the definition of the structure of glossary items used to support more or less all education and training applications. We could then optimize cross disability access for this structure. On the other hand, it is also possible for each web site to develop and use a different XML syntax for their glossary and force the costly and inefficient scenario with a separate cross disability access mechanism in each case. We intend in this proposal to carefully design XML structures to best represent the information in our knowledge network and to allow accurate cross disability rendering.

3.3.2: Architecture of *CDAWebWisdom*

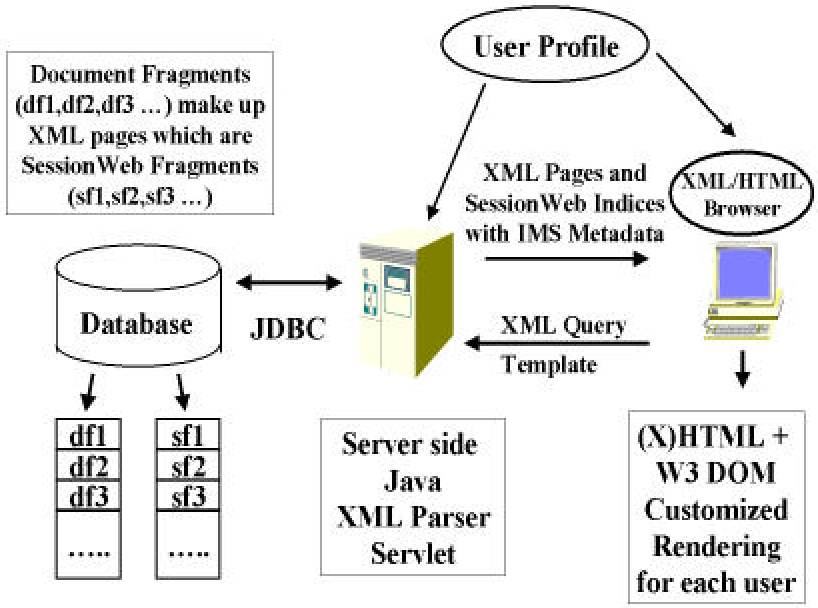


fig.1: Architecture of Cross Disability Rendering

This proposal aims to help and accelerate the development of common information structures that can both express the application in a general fashion and support well cross disability interfaces. In this fashion, our project will help the development of both cross disability access and the ongoing activities defining key object web standards. The Trace center is already a participant in the key W3C object model discussions. Our CDAKN is built on the concept that knowledge is formed iteratively by successive organizations of base information "nuggets". These are viewed technically as "distributed educational objects" with a four level navigation scheme described below. Cross disability access is needed for both the unit information objects and perhaps even more importantly for their synopsis and indices describing their integration into knowledge. We support the knowledge management by using conventional databases (in our case Oracle) to store persistent information objects and their dynamic organization. Java servers using JDBC map the stored object model into the user view, which is accessed (as in modern web-linked databases) through XML templates. XML is converted into HTML either on the server or (increasingly in the future) browser. The XML/HTML Web documents are shared through TangoInteractive, which allows client profiles to optimize the rendering of both the information nuggets and their synopsis. This pragmatic mix of conventional databases, Java Servers, and XML specification of knowledge and information objects illustrate *CDAWebWisdom*'s technical choices. JavaScript is used to capture interactive events and allow cross disability rendering of dynamic information objects, which respect the web document model (DOM). Currently this DOM is rather erratically designed and implemented by Netscape and Microsoft but we expect the recent W3C proposals to bring more power and uniformity during the time period of this project.

TangoInteractive can share essentially any distributed object with its defined API's to multiple languages but we stress web pages here as these are natural realization of shared information for the activities in this project. However this is more general than appears at first sight, because web pages can be the user interface to general server or client side objects – databases (as above), CORBA object brokers, CGI Scripts (as in TangoInteractive's shared web form interface to NCSA's Biology workbench), etc.

3.3.3: Collaborative Knowledge and Cross Disability Rendering

TangoInteractive manages the sharing of educational objects and allows each client to optimize its view of the information based on user preferences and capabilities of the client machine and network connection. This capability is available in any system using a shared event collaboration model, which allows separation of display and shared object specification. As a simple example, a client with a low bandwidth network connection would request the low resolution version of an image and one serving a user with impaired vision, the audio augmentation of this image. As shown in fig. 1, we encapsulate this optimized choice of document fragment rendering in terms of a user profile, which can be implemented as a knowledge agent. Collaborative systems like TangoInteractive can be used to share distributed objects between different users or between different display devices for a given user. This replication of object between different display modalities can be implemented within a single machine or between multiple machines serving a single user. Note that although it may seem extravagant, using multiple machines for a given user is quite practical given the rapidly decreasing hardware prices. In fact, we regularly use this strategy when teaching, so that one puts the key functionalities of audio/video conferencing, chosen curriculum page and chat/white boards on different machines assigned to the teacher. Students in this example typically view the curriculum on their own lab machine while a single machine handles audio and video for collocated students.

3.3.4: Integration of Asynchronous and Synchronous Learning Models

We note that our model for information includes both asynchronous and synchronous modes supported in a common fashion for cross disability access. We assume that in each case, students and teachers access curriculum material stored as web pages or more generally distributed objects on web servers, object brokers or equivalent. Asynchronous or self-paced learning occurs when each participant accesses this material in his or her own time. Synchronous learning occurs when this same material is replicated among a class and discussed interactively. This model allows a single approach to cross disability access, which is independent of learning model.

3.3.5: Two Level Navigation Model for Distributed Objects

We start with a conventional hybrid information object model and define a distributed information object by a tuple (*Page_URL*, *Component_DOM*). This approach views information as a collection of document fragments (labeled by *Component_DOM*) arranged in pages labeled by *Page_URL*. When one uses a backend database, this conventional label is mapped into a reference to a database cell and distributed objects can be constructed at any level of granularity as a collection of the contents of multiple cells. Each cell corresponds to a document fragment specified in XML at the client side and converted in a Java servlet to a JDBC access to the database. Pages are accessed through web address, file location, CORBA or Java naming service or whatever hierarchical naming scheme evolves on the object web. A "*Page*" is, for information underlying traditional education, the basic curriculum unit. It is a "screenfull" or "foil" which is discussed by the lecturer or studied by the student as a single unit with cross referencing between concepts not requiring tiresome browsing and reloading of the browser page. The conventional hierarchical labeling of *Page_URL* seems quite natural for future web education and training with, some name like university/ college/ department/ program/ course/ lecture. However the information within a given page is much less structured and consists of some often-haphazard arrangement of multimedia information nuggets. Further fragments within the page can be repositioned dynamically using dynamic HTML as evolved in the W3C DOM.

This two level model will be used in our initial work in this project as it essentially represents current practice. We will support a limited view of knowledge integration at this stage with all participants allowed to browse the hierarchical page structure and to dynamically arrange pages into new information streams. The XML templates that define the interface to document fragments in the database will be extended to support customized rendering as shown in fig. 1.

3.3.6: Four Level Navigation Model Supporting Knowledge Integration

As part of this project, we will investigate a new approach to document object models, which is designed to support both an easier definition of the overall structure of the document and the dynamic linkage of input-output devices to components. We return to the hierarchical structure labeled by the tuple (*Page_URL, Component_DOM*). We wish to support the hierarchical grouping of information described in section 3.1. In this regard we consider a four way grouping of information – namely the Internet or *World Wide Web*, the *SessionWeb*, the *Page* and the *document fragment*. As emphasized earlier, we will follow the market place in the area of resource discovery and coupling to the hierarchical URL namespace defining the *World Wide Web*. We will use appropriate metadata such as those proposed by Educause's IMS project to integrate educational objects to the topology of the resource-discovery world. Here however, we focus on the natural organization of knowledge in a “session” such as is found in a lecture or a single self study activity. We now discuss this limited fine grain or local *Session Wide Web,* which we abbreviate to *SessionWeb*. This is a subset of the (pragmatic) object web whose transactions are the natural units of learning and whose contents are persistent objects whose methods support such transactions. For instance for a lecturer, the *SessionWeb* consists of all pages relevant to a particular lecture as well as all their subcomponents. This local *SessionWeb* is of course likely to be dynamically updated with outside links as topics come up during the lecture. We include in this concept all local navigation both within pages and within the document space of a given learning session. In particular this definition allows the lecturer to pick and choose between presentation material with an order that is determined in real-time. This contrasts with clumsy frameset technology and the static sequential order convenient in most systems (e.g. PowerPoint) today. In a more general browsing activity, a student learner's *SessionWeb* would be less structured and roughly consist of all pages and components stored in the browser cache. In this way, we can customize the display to accommodate different learning styles for each student. Technically the *SessionWeb* is quite small and so able to support richer linkage and access models using very fast client side technologies such as Java and JavaScript with the data structures stored in memory.

One approach to the *SessionWeb* that is attractive today is based on Sun Microsystems JavaSpaces and Jini technologies but these are of course only illustrative of appropriate technologies and better choices may become available. We can suppose that the local *SessionWeb* forms a JavaSpace, which includes both the curricula material defined above and all relevant input-output devices. JavaSpaces are built on top of a resource registration and discovery service Jini, which offers its leasing concept to support dynamic component structure and applet download of interfaces to support dynamic device capabilities. In this model, the user profile in fig. 1, comes from a knowledge agent performing a matching service between the curricula and interface entries in the JavaSpace. As explained above, the agent will also effectively generate the dynamic "index" supporting navigation between components. Assistive technology will include worldview inference services in these agents which are AI functions which map an under-documented XML document DOM tree into the richer *SessionWeb* with adaptive views supported by the best current practice ontology for universal *SessionWeb Objects* that will emerge as the conclusions of this research. These tools build on and extend the capabilities of the W3C/WAI Evaluation and Repair Working Group to which the Trace Center is a major contributor (http://www.w3.org/WAI/ER).

Note that this architecture illustrates the Pragmatic Object Web with multiple object models coexisting. Java provides the content and display device registration and discovery. We expect to use XML to define the properties of the JavaSpace components and of course HTML to define final layout. The base educational objects can perhaps be served from a CORBA object broker and originate (as in PowerPoint) with a COM specification.

We will build a prototype of such a rich *SessionWeb* object model linked to TangoInteractive. This will be in last half of the project after we have further experience from using the existing W3C DOM. We expect this *SessionWeb* model to give considerable insight to future designs of object models with richer navigation models supporting the knowledge structure discussed in sec. 3.1, with definition of document components and their dynamic linkage as well as their interface to input-output devices.

There are many important projects investigating educational objects but few looking as here at their management and organization supporting *intra*- and *inter*-object navigation and cross disability access. We believe our research will build on and extend the existing practice as seen in projects such as IMS (Educause), ADL (DoD) and CILT (NSF) incorporating cross disability access in all fashions encompassing different user capabilities, different client machines and different communities (from K-12 to continuing education).

We believe that the *SessionWeb* is unique in its characteristics, which include an architecture that is opportunistic and adaptable to underlying technology shifts; consciously inclusion-driven design; and a framework that has great potential for "understanding power". The *SessionWeb* makes "found" collections of resources more coherent as integrated by the standard services, as well as more adaptable across interface modalities. This knowledge-based open object architecture is thus more compatible with new communities nucleated on the Internet and their rapid construction of knowledge formation (consolidation and dissemination) infrastructure. The result is that the Internet realizes its full potential as a catalyst for accelerated knowledge generation.

3.3.7: Range of Authoring Strategies

We will look at cross disability access for the following types of educational pages which show increasing sophistication in terms of authoring tools and hence internal W3C DOM structure.

1) HTML Pages where below we expand on the special capabilities that one gets from shared dynamic HTML supported by modern Netscape and Microsoft browsers.
2) PowerPoint exported to the web using Microsoft's Internet Assistant and modest restructuring (with a server side filter described below) to better define object components (labeled by *Component_DOM*).
3) PowerPoint accessed via COM components, which allows one to properly define a base object model. Existing web-linked database technology allows one to export this to the web

using XML templates. One can also integrate material from PowerPoint with other web components such as audio-video renditions of the teacher and class discussions. This approach also gives one a clean object structure defined in XML rather than the heuristic choices that need to be made in interpreting the HTML tags in the cases 1) and 2) above. The XML version allows support of the multi-resolution images and cross disability access discussed earlier.

4) We will elaborate the object structure seen in pages of the types 1) through 3) in various ways, such as through the addition of glossaries, notes and quizzes in fashions popularized by tools like WebCT. We can implement these using modern XML, dynamic HTML, and Java technology and so keep a consistent document object model. We allow both database repositories and dynamic web pages to link in such material where one can choose between either independent views or shared display between teacher and students. As always this material supports either synchronous or asynchronous views of curricula.
5) Java applets are used in some of the best interactive educational curricula and these are well supported with our existing collaborative technology. Authoring of such shared applets is simplified if they are constructed according to the Javabean design frameworks. Then *Tango Bean* technology automates the sharing of events represented by the standard Javabean rules. We do not expect to stress this importance choice as it would a major extension of our object model to include user interfaces defined by Java rather than the XML/HTML technology and W3C object model on which this project is focussed. Looking deeply at such Java based educational objects, using perhaps UML to define an initial object model would be an important follow-on project.
6) There are other important authoring systems such as Macromedia Authorware, which is quite popular and can be very successful if substantial courseware effort is invested. We do not expect to explore pages developed in such fashion as it does not seem easy to represent them at present in a terms of an XML based web document object model.

3.3.8 Research Issues

We emphasize that the basic linkage of TangoInteractive to pages of this type will be available through work funded at NPAC by other sources. Thus this proposal focuses on studying the cross disability issues for the different document object structures. TangoInteractive is particularly well suited for this study as it has a native JavaScript interface, which can access the full W3C DOM structure. For instance, we can identify the images contained in a document and so manage the rendering of these in the modality required by the user. TangoInteractive also captures all events in a page and so precisely shares all form input and output. Again this control of form fields and buttons, allows it manage alternative cross disability text and button input or output display devices on the different clients sharing the form. We can illustrate the difference between page types 2) and 3) in sec. 3.3.6. In case 2), one must use a heuristic to distinguish the image which corresponds to the PowerPoint slide web export from those images which are buttons defining “home”, “next”, “previous” etc. In case 3), the XML structure defines exactly which image is which as XML defines the document structure. It also allows one to associate with image multi-resolution and sonified versions.

So what’s wrong with this approach? Well many things no doubt but here we note one flaw in the current document object model. Even though it does indeed define reasonably the individual page components, it does not link them in a rich and robust fashion. In current systems, the relationship of DOM components requires an understanding of the page layout and the dynamic structure of any DHTML which must be either done heuristically or by an approach such as 3) above which essentially captures the COM structure in XML. In general, good cross disability access requires both a definition of the individual components and their relationship (such as order of presentation) as well a clear definition of alternative forms needed in cross disability access. For instance, document elements at the level of paragraphs and table cells may appear un-modified as compared across audio and screen views, but at any larger scale the morphing between views will involve different presentation flow and different levels of articulated connectives. The connection information will be more overt in the oral/aural view and more implicit in the visual view, and we need a DOM that easily expresses and supports the different depths of cut as the different display modalities slice the underlying view-invariant world model. As another simple example of the difficulties with the current DOM, suppose a participant puts their cursor at a particular point in a viewed page. We can recognize ("capture") this event and so in principle realize it in different modalities for cross disability access. Unfortunately in the current DOM, the cursor position is usually tagged by its pixel position on the browser page and not by what you want -- its relationship to the content of the page. The latter is of course clear to the sighted viewer and we can propagate this information to other sighted users by replicating both pointer position and content pages with the same layout. This illustrates how in current DOM, components are essentially linked implicitly by the layout of the HTML page -- something, which at present can only be addressed heuristically and imprecisely. In our initial work, we will for instance address this difficulty by breaking text pages up to into small fragments (using <DIV> and <SPAN> tags) and relating pointer positions to these components. Images are dealt with by displaying them in a Java whiteboard which correctly captures the position of pointer in image space and not in browser page space as with current version 4 browsers. This example also illustrates that support for cross disability access is relevant for users without disabilities as the reliance on HTML layout, implies for instance that TangoInteractive cannot directly share such pointer information between clients of different types (PC's and UNIX, or even PC's with different browsers). So cross disability (for people) access is also helpful in ensuring universality between client machine types.

3.4 Assistive Devices and Cross Disability Interfaces

NeatTools Background. We have been developing NeatTools, a visual-programming and runtime environment, for interfacing humans and computers (www.pulsar.org; http://www.pulsar.org/ed/manuscripts/mmvr7/MMVR99_paper_5.htm). It enables users to input information to a computer through various kinds of sensors and devices and, among other things, displays the information in the form of text, graphics, audio, video, or other methods. One constructs a dataflow network (visual program) in this environment by dragging and dropping objects (modules) from an on-screen toolbox to the desktop workspace and then connecting these with input or output controls and control of parametric lines. Editing and execution of programs occur simultaneously, so that no compilation is necessary.

NeatTools is written in C++ on top of a Java-like cross-platform application programming interface (API) so that it can run on multiple platforms including Windows 95/98/NT, Unix, Irix, and Linux. Macintosh will be supported once its multithreaded operating system is released. NeatTools is simple, object-oriented, network-ready, robust, secure, architecture neutral, portable, high-performance, multi-threaded, extensible, and dynamic. It can interface with serial, parallel, and joystick devices (and see below). Other significant features include Internet connectivity; display of time signals; mathematical and logic functions; character generation; multimedia; Musical Instrument Device Interface (MIDI) controls; and a visual relational database with multimedia functions. A developer's kit, for writing new external modules, is also available online for those proficient in object-oriented programming in C++.

Devices Background. We have also developed the palm-sized TNG-3 hardware interface box, which detects signals from sensors and switches. Both TNG-3 and the latest version, TNG-3B, have 8 analog and 8 digital input channels and stream data to the serial port of a personal computer at 19200 baud. We also have a working bench prototype of TNG-4, which has more capacity and versatility, with 8 analog and 22 digital lines that are dynamically bidirectional. In other words, each digital line can serve as an input or an output, and this can be dynamically reconfigured at any time within NeatTools by manual or automatic control. We have used *NeatTools* to interface various types of hardware devices to TNG-3, including displacement potentiometers, photocells, magnetic sensors (Hall Effect transducers), pressure transducers, and bend sensors. The customizable and extensible features of these modular hardware and software systems are important for the project goal of extending such technology to accommodate users with a broad range of disabilities.

4: Project Structure

4.1: Project Team

The P.I. Lipson will naturally be responsible for overall coordination of the project. However his group will also lead the identification and development of the special assistive interfaces and their needed device drivers. NPAC will be responsible for the software system architecture needed for the prototype testbeds developed in this project. These include continual enhancement of TangoInteractive to support cross disability rendering of web documents respecting the evolving W3C document object model. The database backend, XML/HTML views of it and archiving learning sessions will be supported by NPAC.

The Trace Center will address the issues that arise in creating CDA multi-modal interactive environments and ensure the project is integrated with the standards development at W3C and IMS. The Group Performance laboratory at Wisconsin will work with Trace to translate and generalize their formal model of "teach and analyze" knowledge networking so that it becomes the base knowledge representation used in the deployed testbeds and supported by the software system .

Catholic University will co-develop interface technology with the Syracuse team, and will develop assessment 'instruments' for formative evaluation. Their work will provide alternative rendering of the knowledge network and so enable more quantitative assessment of the chosen human computer interfaces.

CAST (Boston) and DO-IT (U Washington) will be responsible for identifying appropriate users and deploying and evaluating with necessary assessment infrastructure the testbed developed by the collaboration.

Note that Gregg Vanderheiden and Geoffrey Fox are team leaders in the joint Alliance/NPACI EOT (Education, Outreach and Training) activity in areas of universal access, learning technologies and graduate education. We expect to use the EOT teams as an informal resource throuhout the project.

4.2: Management Structure

The PI and co-PIs will together constitute an executive committee that will jointly coordinate the project. They will meet at least monthly using TangoInteractive in a multimedia videoconferencing mode with as developed the cross disability support to be designed and built in this project; the meeting agendas will be posted in advance on the Web. When appropriate, other team members at the various sites—including those with disabilities—will participate during part of these meetings to present results and raise any issues of general concern. In any case general meetings will be conducted online at least bimonthly. Continual communications among all participants will take place by e-mail, telephone, and Web page postings (with e-mail alerts). An enlarged technical committee will also be formed and will communicate similarly.

In addition, the results, and plans of the project will be maintained on cross disability Web sites at all participating institutions to compare notes and progress at our various sites. As stated in the project description, the mode of collaboration itself will constitute part of our study of cross disability knowledge networks.

The main project will be divided into subprojects in the following areas:

- Knowledge Integration and Network Design
- Software and Systems Infrastructure (Tango and NeatTools)
- Assistive Devices and Cross Disability Interfaces
- Science Education
- Deployment
- Assessment

As summarized in sec. 4.1, individual members of the executive committee will be assigned to be in charge of one or two of these respective areas. Overall management will be organized and tracked using a program like Microsoft Project to establish goals, targets and assigned roles to the team members.

4.3: Timelines and Deliverables

To be done ….

For your Convenience -- Reviewer Comments

KDI Preproposal Panel Summary

Preproposal Number: 9976583

PI: Edward Lipson

Institution: Syracuse University

Title: A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

Strengths:

The vision of this project is extremely important to promote diversity in science and technology. The use of web-based technology needs to be accessible to individuals with different types of disabilities. This is an excellent research team that has already proven its ability to work together and to integrate research and education. There is a specific plan and a good likelihood the plan will be achieved, given the previous successes of the research team

Weaknesses:

The technical jargon was quite high, sometime too high to reconstruct what the researchers were trying to accomplish. The proposal should be more concrete on the design and evaluation of the project. The proposal should reflect that the researchers have awareness of the background literature and that they are making new contributions to knowledge networking. They should specify the spectrum of diversity of the target population, given that there are hundreds of types of disabilities. The budget should be carefully considered, especially in the case of postdocs and technicians.

Panel Recommendation:

__x___ Encourage Submission of Full Proposal

_____ Discourage Submission of Full Proposal

Individual Reviewers' Comments:

PROPOSAL NO.: 9976583

INSTITUTION: Syracuse University

NSF PROGRAM: KDI/KN

PRINCIPAL INVESTIGATOR: Lipson, Edward D.

TITLE: A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

RATING: Very Good

REVIEW:

Intellectual Merit

Good interdisciplinary research team. Project aims to use the web to make science and technology curriculum accessible to individuals with cross-disabilities. The pre-proposal constantly refers to a knowledge network but does not clearly describe the knowledge content nor the network. The research will explore the design and effectiveness of web-base course materials for individuals with cross-disabilities.

Broader Impact

Impact on teaching and learning of science and technology. The precise student audience is not clear. The curriculum suggested is science and technology for scientist majors.

Integration of Research and Education YES

Integrating Diversity into NSF Programs, Projects, and Activities YES

PROPOSAL NO.: 9976583

INSTITUTION: Syracuse University

NSF PROGRAM: KDI/KN

PRINCIPAL INVESTIGATOR: Lipson, Edward D.

TITLE: A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

RATING: Very Good

REVIEW:

The reviewer rated this proposal 'Very Good'. The proposal was well presented, with concrete goals relevant to KN, and offers accessibility to much technology for those traditionally left out. The proposal is original, it offers a 'first of its kind' CDAKN, and laudable in its goals. The proposal is concrete, detailed and articulate, and well organized. The stated goals are of a fundamental and strategic nature, and in line with stated KN goals. The proposed research is directly targeted at those with a range of disabilities, and directly addresses educational issues (distance education and science). The research will allow a disadvantaged minority of people, namely the disabled, access to much of the technology currently being developed for the majority, thus permitting them better social integration into their increasingly technologically-oriented society. The research is basic, and as such, offers a starting point for broader based research and application for cross disability accessible knowledge networks. Any society benefits from allowing a maximal number of its members to contribute to that society. This project directly facilitates the inclusion of people who can contribute, and who are only looking for the means to do so.

PROPOSAL NO.: 9976583

INSTITUTION: Syracuse University

NSF PROGRAM: KDI/KN

PRINCIPAL INVESTIGATOR: Lipson, Edward D.

TITLE: A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

RATING: Good

REVIEW:

This proposal on cross-disability accessible knowledge networks is well organized and presented. There is a clear focus on education and collaboration in using the tools being developed in the research while they are being developed and refined. They will build on core technologies such as TangoInteractive as well as NeatTools. There is a clear statement of the inclusion of under-represented minorities (disabled persons) and the research is likely to have a substantial impact advancing our understanding in this area.

PROPOSAL NO.: 9976583

INSTITUTION: Syracuse University

NSF PROGRAM: KDI/KN

PRINCIPAL INVESTIGATOR: Lipson, Edward D.

TITLE: A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

RATING: Good

REVIEW:

The interdisciplinary research team will develop and investigate a knowledge network that is accessible to individuals with different disabilities (called a Cross-Disability-Accessible Knowledge Network, CDAKN). The attention to populations with disabilities is of course a positive strength of this proposal. It was difficult for me to reconstruct the concrete plans for technology development, methods, and data analysis because the proposal had a high density of jargon and it was frequently unclear why some of the off-the-shelf software components would be thrown together in the system. How will this research advance science and technology? That was not obvious; the project seemed to be more of an exercise or an application of how existing technology can be used, than a solution to some critical challenges that face usage of internet technology by disabled populations. How will the researchers trace (measure) the usage and interaction patterns of the disabled individuals? The specification of the model in the figure is too vague to reconstruct what the design is all about. How is this model an advance over existing technologies? The goals, unique design features, methods, and analyses need to be more concretely specified. It is my understanding that there is a large variability in the nature of disabilities, so large that common disabilities are not the norm; there are catalogues of thousands of devices that help very specific disabilities (not a few dozen). Perhaps NeatTools will be able to accommodate the diversity. The team of researchers covers the expertise that appears to be needed for this project.

PROPOSAL NO.: 9976583

INSTITUTION: Syracuse University

NSF PROGRAM: KDI/KN

PRINCIPAL INVESTIGATOR: Lipson, Edward D.

TITLE: A Cross-Disability-Accessible Knowledge Network for Education and Collaboration in Science and Technology

RATING: Very Good

REVIEW:

Although the project summary reads like a complete list of NSF buzzwords generated by an intelligent grant writing program, the authors do have in their favor some actual web-based realizations that I found interesting. I have doubts on whether one project can pretend to help with several disabilities, 'someone who pretends to solve all problems is a charlatan', but I guess even if a few are addressed it is worth the try. I don't see actually in the project who the testbed of people with disabilities will be, there needs to be a complete section on evaluation and diffusion. The budget suffers from overinflation of the number of postdoctoral and other professionals compared to the amount of senior personnel's time available for overseeing their work.

For your Convenience -- the Preproposal

Project Description

The basic goal of the proposed work is to build a Cross-Disability-Accessible Knowledge Network (CDAKN) and then evaluate and advance its effectiveness a) in distance education in science and technology curricula and b) for scientific collaboration. This goal and the project are based on the following principles:

1. People need to be integrated into society and its activities irrespective of physical disabilities.
2. Web technologies and pervasive communication infrastructure provide a universal backbone for which one can build more effective cross-disability access (CDA) with specialized perception and expression capabilities optimized for individuals.
3. The ‘anyplace’ characteristic of the Internet is particularly attractive for individuals with disabilities, who may find their geographical location limited. Thus Internet collaboration is especially important for building knowledge networks involving individuals with disabilities.
4. Syracuse University has developed state-of-the-art collaboration (TangoInteractive) and universal-interface (NeatTools/TNG[serial interface box]/sensor/transducer) technologies.
5. The Trace Research and Development Center (trace.wisc.edu) in Wisconsin has pioneered the principles of universal design for computer interfaces and brings a broad national knowledge network to augment the prototype communities built at Syracuse. The CDAKN will be based largely on technology developed at Syracuse for “interactive collaborative environments,” combined with accessibility strategies developed by the Trace Center.
6. Science, mathematics, engineering and technology (SMET) education is a national priority, for which universal participation is highly desirable.
7. Distance education, including both teachers and students with disabilities, exemplifies the general goal of implementing societal functions in a way that allows universal participation.
8. Distance education provides an attractive early testbed for new technology, because it has a natural structure that puts less stress on base hardware and software technologies. We have shown this in our successful distance education experiments between Syracuse and Jackson State (historically black college in Jackson, Mississippi) using TangoInteractive.
9. Scientific research collaborations increasingly depend on electronic communication. TangoInteractive is fundamentally a collaboratory system that is optimal for long-distance collaboration among researchers. A CDAKN based on Tango and NeatTools can advance science by inclusion of team members regardless of geographical location or (dis)ability.

Research Program

We intend to contribute to research in collaboration technologies, the design and architecture of CDAKNs, and new approaches to cross-disability interfaces for multimedia material. Our approach is to use a testbed that will implement a CDAKN, and then evaluate and iteratively improve it. We will use the testbed both as collaboratory among the project team members, and to deliver cross-disability education. This program will be implemented stepwise as follows. First, we will gather initial requirements for CDAKN from both user, content and technology aspects. We will use the concept of a CDA Document Object Model (DOM) to categorize the information flowing in the CDAKN. A major result of our project will be new design principles for such a DOM which will provide important extensions to the current World Wide Web Consortium (W3C) DOM which does not have cross disability built into it. Although we will use the CDAKN to guide the project, it would be too ambitious to fully implement such an extended DOM. Our research and testbed experience will, however, help in the future revision of current document object models in order to become truly CDA. We will integrate universal interface design (Wisconsin) implemented as a knowledge agent linking the interface technology and collaboration software (Syracuse) to produce prototype CDAKN for particular disabilities. Again, the knowledge agent will initially be simple and will be refined as the project progresses.

We will first set up a general collaboratory starting with project members, and their natural contacts through NCSA Alliance/NPACI/EOT, Trace Center, Center for Applied Special Technology (CAST, in Boston area), Catholic University (Corinna Lathan et al., and National Rehab Hospital; their new "Telerehab" Rehab. Engineering Research Center grant explicitly included NeatTools in proposal; Trace director Gregg Vanderheiden serves as advisor for this new RERC), and DO-IT (Disabilities, Opportunities, Internetworking, and Technology) at University of Washington (Sheryl Burgstahler, director). This team will plan and implement the broader use of the CDAKN, which will involve specific educational activities in both computer science and the natural sciences. This will use material already developed, but not universally accessible at present. Our first area is Internetics, which is a curriculum developed by co-PI Geoffrey Fox that combines computational science and modern information/communication technologies. Our major focus is *Science for 21st Century*, a large- enrollment course at Syracuse developed by PI and others with modular approach to teaching science in an integrated way to non-science majors. Two current NSF grants, associated with this course, support development of interactive Web-based educational modules; see http://www.simscience.org and www.phy.syr.edu/courses/CCD_NEW/. We will start with the *Science for 21st Century* modules, as these are broadly useable at both high school, undergraduate and general science literacy levels. Note that Gregg Vanderheiden and Geoffrey Fox are team leaders in the joint Alliance/NPACI EOT (Education, Outreach and Training) activity in areas of universal access, learning technologies and graduate education.

Participants on this project—including students and scientists with various disabilities—will use the CDAKN both to attend these courses and, within the core group, to actually research and develop the CDA technologies and educational material in a process of bootstrap and progressive optimization. We will hold conventional and CDAKN workshops to involve others in this area, disseminate lessons, and provide training in universal interface and collaboration methods. We will also produce research publications and presentations, and continually post results and issues on our Web sites for communication, feedback, and dissemination.

The research issues include: a) architecture of CDAKN and implications for a CDADOM, b) integration of knowledge agents with collaboration and human-interface technology, and c) determination of customizable interface approaches and effectiveness using visual programming environments and modular interface hardware.

Methodology

The representative core technologies on this project include TangoInteractive and NeatTools/TNG/devices (see below). Both systems are, in general, highly modular and adaptable, and can work very well together. An early technical objective will be to integrate Tango and NeatTools and then do preliminary multimodal testing of the emerging CDAKN.

We will leverage the new NEC Foundation grant (Syracuse) to include students with disabilities in Syracuse, Washington DC, Minneapolis, Seattle (DO-IT), Madison (Trace), and

Boston (CAST; www.cast.org; consultant here). Further, we will adapt interactive Java-based science education modules (see URLs above; some already in Tango) from two NSF-funded grants at Syracuse to become CDA. These are associated with *Science for the 21st Century* course offered by the Syracuse Physics Department. Meanwhile, the Trace Center will address the issues that arise in creating CDA multimedia interactive environments. Catholic University will co-develop interface technology with Syracuse team, and will develop assessment 'instruments' for formative evaluation. CAST (Boston) and DO-IT (U Washington) will begin testing by diverse users. Besides its core role in the CDAKN, Tango will be used for project communication, design, and bootstrapping/optimization of CDAKN. We will also set up representative CDA distance-learning courses (or, at least, exemplary class sessions, such as seminars) in SMET fields.

The research emphasis throughout the project will be based on hypotheses concerning CDA, KN (functionality, effectiveness, usability) and formative evaluation with consequent refinement. For example, can users who are abled, blind, deaf, or quadriplegic access the CDAKN and keep up with one another in interactive sessions? We will identify problems and take corrective design actions in an iterative fashion. The project will include quantitative performance assessment in Tango and in NeatTools interface programs (event tracking, database recording, data analysis). In this way we can strive toward developing a CDA-multimedia-interactive KN.

Outcomes

The fundamental outcome of the proposed research will be *knowledge* on how easy or difficult it is to create CDAKNs, how to identify barriers, and how to overcome them. The main practical outcome will be the creation of the CDAKN itself – the first of its kind. This will serve as a model for further research and for widespread application of CDAKNs.

Another substantial outcome will be our KDI research on this CDAKN to evaluate its effectiveness and continually improve it during and beyond the proposed work. This will serve as foundation for continued research (KDI/CDA/KN). We intend to sustain the project and its results for the long term, and will seek continued funding from NSF and other sources, while bringing in additional partners for broader implementation and testing.

We will make extensive use of the Web for dissemination of project information and free software (Tango and NeatTools). Information on how to obtain low cost modular interface hardware will also be provided. This would include our computer interface boxes and sensor kits and other commercial components listed in the Trace Resource Book, as appropriate. Project results will also be disseminated by traditional-style presentations, publications, and workshops.

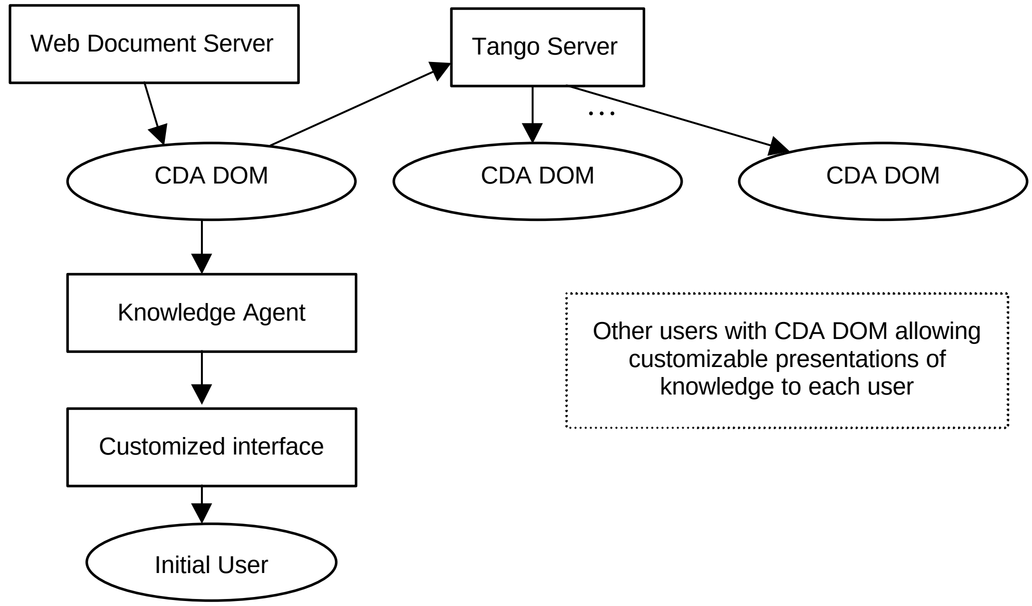
A final major outcome of this CDAKN research and development project will be that users with disabilities will have far greater opportunities for SMET education (active learning in constructivist paradigm; lab participation; lifelong learning) and SMET careers.

Knowledge of the CDAKN

The CDAKN will be used in two distinct roles: a) initially by team of content and technology developers (Syracuse/CUA/NRH), designers (Trace) and outreach sites (CAST, DO-IT) to develop initial CDA educational modules, starting with *Science for the 21st Century* course material (note that we have 2 NSF funded grants for this work; see above); and b) at outreach sites, to deliver material of increasing sophistication in both education and literacy modes.

Technology of the CDAKN

Overall Architecture. We will describe information as stored in the client computer in terms of a (generalized) document object model CDADOM, based initially on the current W3C proposals



(www.w3.org/DOM/). The architecture is shown below. The capability of TangoInteractive to support client-dependent views of information will be used to produce optimized displays for each user, depending in general on both physical capabilities and prior knowledge. This customization is supported in two ways. First, a traditional knowledge agent employs a user profile to broker the custom conversion of information (stored in CDADOM) to client-dependent knowledge. This essentially involves processing text and images in the original document. Second, we process the event handlers for user interaction and convert abstract content appropriately (e.g. text and images to audio for the blind). Event handlers are typically specified by "onclick" or "onkeydown," but this is clearly not in CDA form. Initially, we will map, in the Tango (which traps all DOM events for sharing with its JavaScript interface) interface to NeatTools, such classic input devices to those appropriate on this client. As a result of this study, we will propose a more abstract CDADOM where content and events are specified abstractly and on conventional machines mapped to text, images, onclick, etc.

TangoInteractive Background. TangoInteractive (or Tango; http://www.npac.syr.edu/tango) is an advanced, powerful, and extensible Web collaboratory, and is perhaps the most flexible of systems of its type. It is not aimed at exploring research issues in collaborative system design, but rather at exploring applications such as those proposed here. In this regard, great effort has been put into making the base infrastructure quite robust, so that it can be used outside a tolerant research environment.

Tango is written in Java, but supports collaborative applications in any language. Further Tango is fully integrated with Web browsers, and this provides the basis of convenient, familiar interfaces. To run Tango, one starts the system from a browser and connects to a Tango server. Both the client and server code for Tango are freely available on CD-ROM or from our Web site, which also contains the well documented API's for C++, Java, Java Beans, and JavaScript. Once in the system, the user can select from over 25 collaboratory applications to work on projects with partners, play a game of Bridge or Chess, take a class at a virtual university, create and use a public or private chat room, conduct a videoconference, view a movie, or surf with friends using the powerful shared browser. It is possible to do all this at the same time, in any combination, and multiple copies of applications such as chat rooms can be launched. Further, Tango can provide shared sessions for either client- or server-side applications. The latter include both shared (Web-linked) databases (as in Oracle-based WebWisdom curriculum management system) and shared CGI scripts (as in our integration of NCSA's Biology Workbench with Tango). We believe that no other collaboratory system, public domain or commercial, gives you so many applications under such consistent and simple session and floor control.

Besides running Java applets under Tango, one can run JavaScript-based client-side Web applications. Moreover, in Tango the user can take an arbitrary HTML page and automatically turn it into a shared entity. To build a 3D VRML world, populate it with avatars, and let them interact, Tango provides support via two integration modes: VRML JavaScript nodes and External Authoring Interface. Applications written in C or C++ (e.g. PowerPoint) can also be readily adapted to run collaboratively under the Tango API. In this proposal, we will use the C++ interface of Tango to link the NeatTools specialized interfaces. Note that the shared collaboration model of Tango allows each client to have different views of the same shared application, and this is essential for universal access. Shared display systems such as Microsoft's NetMeeting are less flexible.

NeatTools Background. We have been developing NeatTools, a visual-programming and runtime environment, for interfacing humans and computers (www.pulsar.org; http://www.pulsar.org/ed/manuscripts/mmvr7/MMVR99_paper_5.htm). It enables users to input information to a computer through various kinds of sensors and devices and, among other things, displays the information in the form of text, graphics, audio, video, or other methods. One constructs a dataflow network (visual program) in this environment by dragging and dropping objects (modules) from an on-screen toolbox to the desktop workspace and then connecting these with input or output controls and control of parametric lines. Editing and execution of programs occur simultaneously, so that no compilation is necessary.

NeatTools is written in C++ on top of a Java-like cross-platform application programming interface (API) so that it can run on multiple platforms including Windows 95/98/NT, Unix, Irix, and Linux. Macintosh will be supported once its multithreaded operating system is released. NeatTools is simple, object-oriented, network-ready, robust, secure, architecture neutral, portable, high-performance, multi-threaded, extensible, and dynamic. It can interface with serial, parallel, and joystick devices (and see below). Other significant features include Internet connectivity; display of time signals; mathematical and logic functions; character generation; multimedia; Musical Instrument Device Interface (MIDI) controls; and a visual relational database with multimedia functions. A developer's kit, for writing new external modules, is also available online for those proficient in object-oriented programming in C++.

Devices Background. We have also developed the palm-sized TNG-3 hardware interface box, which detects signals from sensors and switches. Both TNG-3 and the latest version, TNG-3B, have 8 analog and 8 digital input channels and stream data to the serial port of a personal computer at 19200 baud. We also have a working bench prototype of TNG-4, which has more capacity and versatility, with 8 analog and 22 digital lines that are dynamically bidirectional. In other words, each digital line can serve as an input or an output, and this can be dynamically reconfigured at any time within NeatTools by manual or automatic control. We have used *NeatTools* to interface various types of hardware devices to TNG-3, including displacement potentiometers, photocells, magnetic sensors (Hall Effect transducers), pressure transducers, and bend sensors. The customizable and extensible features of these modular hardware and software systems are important for the project goal of extending such technology to accommodate users with a broad range of disabilities.