Computational Science and Information Technology: Distance Education and Training

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1. Introduction

This report brings together some of the issues needed for training and education in the area of Computational Science and Information Technology. We discuss curriculum, delivery and authoring. We focus on commercial solutions rather than the advanced Garnet and ECCE research systems described in [1] and [3].

Over the last years we have offered courses both in simulation (parallel computing) and information (Internet) technologies. These are both needed as many fields are now integrating both issues – for instance one needs XML based technologies to record data and assimilate this into large-scale simulations. As seen in portals, one needs modern management technology to keep track of the increasingly complex process of computation. We have three major online core courses from the last year and a half: CPS1: http://old-npac.csit.fsu.edu/projects/cps615spring00/ (computational science taught at ERDC Graduate Institute Spring 2000) and two new courses from FSU: IT1 at http://aspen.csit.fsu.edu/it1spring01/ and IT2 at http://aspen.csit.fsu.edu/it2spring01/. The last two update information technology courses that were very popular when taught from Syracuse to Jackson State from 1997-2000. They are supported by an online technology resource http://aspen.csit.fsu.edu/windsnow/webtech/. The last course IT2 has particular focus on XML, which is very useful in defining the interoperable datastreams and interfaces needed for multidisciplinary applications.

The curriculum used in distance education needs "only" to be web-based. Currently most of our experience has been with rather simple authoring tools such as basic HTML, exported PowerPoint, WebCT and Blackboard. Note the latter two commercial systems produce visually appealing pages that however typically lack rich multimedia and interactive characteristics for the content. We are encouraged by the developments of standards like SVG (XML based standard format for 2D vector graphics) as the best authoring products from Adobe and Macromedia should soon support this format (there is a prototype Flash to SVG convertor, Adobe Illustrator allows SVG output, we are working on a PowerPoint to SVG filter). Such a development would allow one to develop high quality web pages and export using their standards compliance to guarantee that the content will survive changes in vendors and products moving on Internet time. These ideas are expanded in sec. 3.1. We suggest looking at core courses (MPI training, base Java course above) and spending the effort to author them in a more interactive format. Courses whose content is still changing rapidly should probably stick with approaches like PowerPoint requiring less investment in authoring.

ADL (http://www.adl-net.org) and IMS (http://www.imsproject.org) have produced learning object standards, which address the structure of curricula above the web page. They define a natural hierarchical arrangement as summarized in sec. 3.3.

They discuss the metadata that link pages to course modules and define prerequisites, objectives, and completion requirements. There are also standards for user related data (administrative and grading) and tests and quizzes. Thus ADL and IMS standards have currently no overlap with the authoring issues discussed above. Thus it makes sense to pursue both goals simultaneously – high quality authoring and standards compliant learning objects.

There is a common type of page – namely basic "content" surrounded by "decoration". The decoration would be adverts or pointers to other Yahoo goodies for a Yahoo portal page. For an education page (as say produced by WebCT or Blackboard or in fact systems we built earlier) the decoration is a bunch of buttons accessing services such as "chat room", "class resources", "send mail to instructor", WebTop Services (search etc.) and links to other content (Next, Previous, More Detail). This page structure is best thought of as a portal. The curriculum part is classified as a unit in IMS or ADL. The 'decorated' page should not be directly stored but generated when the portal is invoked.

The delivery can be implemented using a combination of audio video conferencing and shared document collaboration systems. It is hard for any one system to be best in both areas and we recommend looking at each separately. In the first area summarized in sec. 3.2 and [2], we can choose between solutions at different levels of capability. At the high-end, the Access Grid from Argonne is pre-eminent while the low-end HearMe system illustrates modern Voice over IP desktop conferencing. We can use either our research system Garnet or commercial WebEx, Placeware and Centra to support shared curriculum pages. Garnet is designed to support both the advanced authoring (Macromedia flash) and management standards (IMS,ADL) discussed in sec. 3.3 of this report. However in this report we only discuss the commercial systems WebEx, Placeware, Centra and Latitude in section 4.

In summary we have summarized a strategy that supports the emerging object standards, high quality authoring, portals and the best delivery systems. In the following we first discuss some general technology and collaboration issues and then in sections 3 and 4 describe the topics summarized above.

2. Collaboration and its Technology

2.1 Background References

One can get further information from several available web resources including a white paper produced for ARL – [11] on collaboration issues specific to this laboratory. General remarks can be found at the Web site http://aspen.csit.fsu.edu/collabtools/ and at a report written for ERDC in May 2000 [9]. The first web site has a detailed technology review [12] and several presentations associated with tutorials given in this area. Published papers on collaboration technology can be found at [6] [7]. Discussions of curriculum can be found at [4] [5] and [8].

2.2 Collaboratories

We wish to build web-based support for people to interact with each other and with other resources: computers, documents, and instruments. This was originally called a Collaboratory by Bill Wulf in a famous Science article in volume 261, 13 Aug 1993. We must do this while technology is rapidly changing and while we are not certain what collaborative tools, scientists and students will actually use i.e. the requirements are not known. In this report, we focus on a set of successful capabilities where some consensus exists as to what they do and how they look to users – these are typically (now) commercialized. There are also some clearly useful technologies and standards on which to build – we will cover some of these. Note that in developing an academic or government program in this area, we need to identify those areas where there is a potential requirement that industry will not provide (or render our solution invalid) in next year or so. These include special features of training, HPCC and science. Support of hand-held devices is so poorly understood that in spite of strong commercial interest, it remains a good research area.

We suggest that there are now some pretty good distance education and more general collaboration solutions and that now is a reasonable time for groups to invest in learning and using some of the tools. Clearly capability, performance and robustness will improve but there seems to be consensus in several areas. We see time and money invested now will give groups a useful knowledge basis for using future systems. The original ARL white paper discussed the differences and similarities between support of training, administration and research. Any use of collaborative systems should take this into account in choosing what to do. For instance today, most commercial education systems emphasize asynchronous collaboration where the dominant business use (even in training) are the synchronous systems WebEx and Centra.

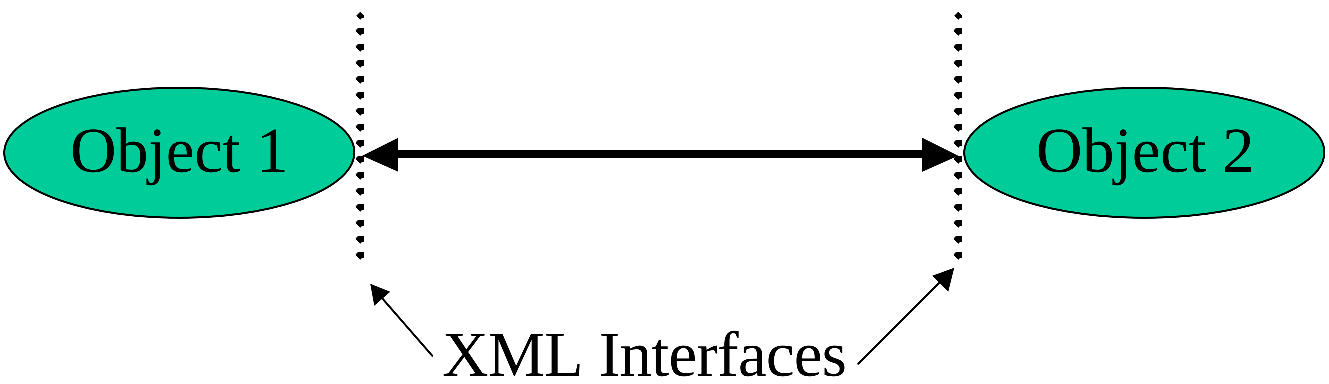
We will not discuss application areas in detail as we focus on web-based (distance) education and training. Important areas that will drive the collaboratory area include:

1) Distance Education including advanced seminars and training
2) Help desks including
    - Microsoft helping a user debug problem on their home PC (connected to Internet)
    - MSRC consulting staff interacting over distance in real time with a user with a program bug
    - Yahoo staff answering in depth questions from users browsing either Yahoo's knowledge or shopping sites
3) Scientists brainstorming difficult research issues in distributed locations
4) Virtual communities around the world from children chatting to each other or integration of distributed organizations (such as nearly all large laboratories)
5) The members of the Indian Nation remaining in their homeland but participating electronically in modern economy ("digital.indigineousworld.org")
6) Support of HPCMO through a distributed PET team.
7) Crisis Management and Command and Control for Military
8) For a single user, "collaboration" between different input devices. This includes case where a scientist controls a specialized display with a PDA controller or a wheelchair shopper accessing the mall kiosk from a hand-held keyboard.

In the following subsection 2.3, we discuss some key base technology trends and approaches. We believe that the Object Web should be the basis of any modern system; typically one programs in Java as it has best software engineering properties and defines interfaces and data structures in XML using a multi-tier architecture. There are some important Internet trends, which suggest where systems will go – these include the increasing bandwidth and latency of networks (Gilder's law) and the growing use of Palmtop devices [3].

2.3 Distributed Objects and Technology Trends

Any electronic artifact is by definition an (distributed) Object whether it be an instrument delivering data, a computer, an online user, a computer program or even the most common object – the basic web page. As shown in the figure below, even as objects are programmed in Java, their interfaces and the object metadata will be defined in XML.

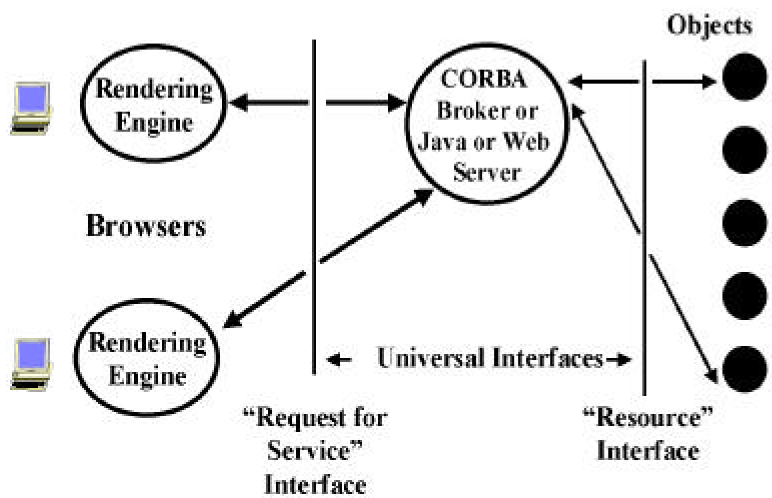


The basic approach is the same whatever the object model: COM, CORBA, Jini/RMI, SOAP(.net), or even DMSO's HLA. In each case, systems are built in multi-tier fashion so the front end rendering and back end functionality are disassociated

In the picture below, we show an example of a software object being defined in XML.

```
<?xml version="1.0"?>
<!DOCTYPE application SYSTEM "ApplDescV2.dtd">
<application  id="disloc">
<target id="osprey4.npac.syr.edu">
 <status installed="Yes"/>
 <installed>
   <CmdLine command="/npac/home/webflow/GEM/JAY/dis2loc"  />
   <input>
     <inFile Path="/npac/home/webflow/GEM/JAY/" Name="disloc.output"/>
     <source Host="osprey4.npac.syr.edu" Path="/npac/home/Jigsaw/WWW/tmp"
           Name="disloc.out"/ >
   </input>
   <output>
     <outFile Path="/npac/home/webflow/GEM/JAY/" Name="simplex.input" />
     <dest Host="osprey4.npac.syr.edu"
           Path="/npac/home/webflow/GEM/JAY/simplex/" Name="s.in" />
   </output>
   <stdout Host="aga.npac.syr.edu" Path="/npac/home/haupt/webflow/history/"
           Name="job2001.out" >
   <stderr Host="aga.npac.syr.edu" Path="/tmp/" Name="haupt_job2001.err" >
 </installed>
</target>
</application>
```

As described in the earlier cited papers, collaboratories naturally combines the concepts of collaboration – or sharing objects – with portals – or web-based domain specific resources i.e. discovering, cataloging, invoking and rendering objects. Thus we sometimes talk about "collaborative portals" as the natural implementation



As shown above, a multi-tier architecture separates objects (on right) from the middle-tier where brokers and collaboration servers lie and on the left clients. Note collaboration servers provide the illusion of the popular peer-to-peer architecture. Objects on one client appear to be reflected in the display of other clients; nearly always this is "just" done through the mediation of a server. Many application areas are currently setting XML based coarse grain object standards. One example is the work of IMS and ADL in the area of education and training (http://www.adlnet.org). We will not discuss these standards here in detail although the tutorial web site does have separate link (http://aspen.csit.fsu.edu/collabtools/imsadlieeejan01.html) discussing this and we briefly summarize the issues in section 3.3. This is definitely an important area but for instance the lack of agreement as to how to collaborate implies that the requirements of this capability are not included in the current IMS/ADL standards. Note using object technology is essential to allow powerful approaches to managing and providing services in a sustainable fashion that leverages the best available commercial infrastructure.

The continued improvement in performance and capability is important. Not only do we have Moore's law that CPU performance roughly doubles every 18 months but also Gilder's law that claims that network bandwidth increases 3 times faster than this. Gilder in his recent work *Telecosm* (September 2000, Free Press, ISBN: 0684809303, #184 in Amazon Sales) colorfully expresses this as the Telecosm eclipsing the Microcosm (the title of his earlier work on the CPU revolution). This observation says that the multi-server models needed for powerful collaboration will scale and in fact there could be a growing trend to more server side rather than client side computing. The network bandwidth will also support increasing multi-media content for conferencing and higher visual impact pages. This trend will enable growing use of PDA's linked to the servers with the confluence of cell phone and personal digital assistant markets propelling new capabilities. It is predicted that by 2005, 60 million Internet ready cell phones will be sold each year and 65% of all broadband Internet accesses will be via non-desktop appliances.

These observations motivate our interest in multi-device collaboration with PDA's and desktop clients in the same sessions [3].

2.4 Nature of Collaboration

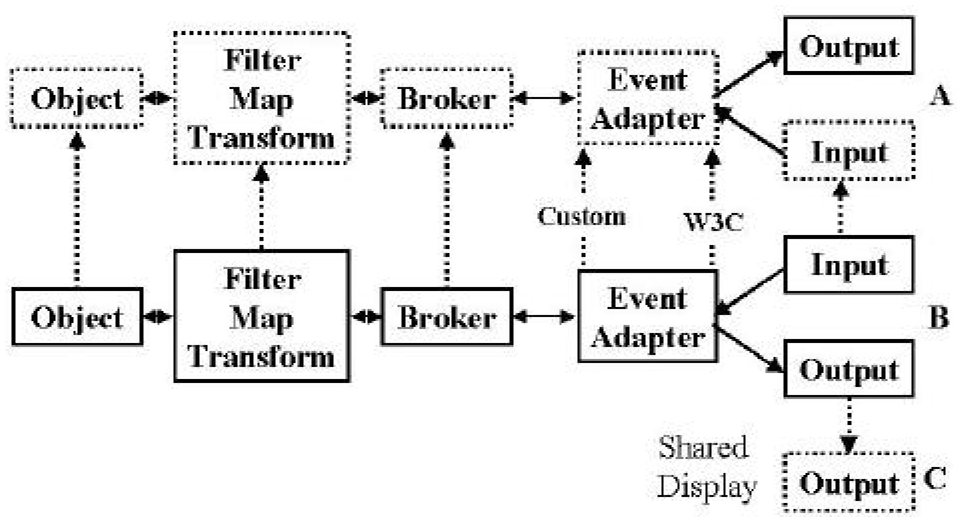
As already mentioned collaboration just means sharing and we identify three classes of capability

1) Share the participants: Audio/Video Conferencing
2) Basic Tools: email, Instant Messenger, Bulletin Boards, White board
3) Shared resources i.e. shared objects, which can be documents, computer programs, data streams or visualizations. The basic tools correspond to the special case where the shared object is a text message or simple drawing.

The objects can be shared in several ways, which trade off ease of use versus flexibility versus ease of implementation. There are three object-sharing styles, which we will discuss in this report.

1) *"True" shared event:* actually all these methods are shared event but differ in the events being shared. This initial case corresponds to sharing the events defining state of object being shared.
2) *Shared display:* Events contain updates to frame buffer
3) *Shared export:* Convert (rendering of) object to some standard form that is more flexible than bitmap of *shared display*. Build a custom sharing for this exported form. The commercial WebEx system uses "a patented sharing of virtual printer" which is roughly equivalent to sharing export to PDF.

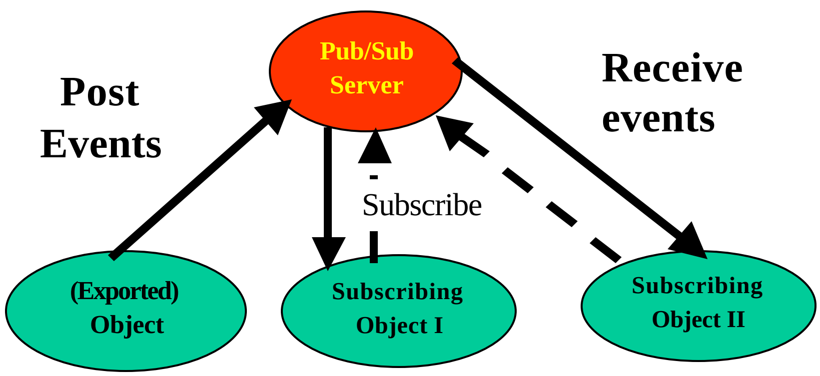
The area of collaborative visualization [10] shown below can illustrate these choices.



We have a master user B sharing with other users A and C. There is a visualization pipeline formed by the computer program (object on the left above) where its output and input wend their way through multiple filters (tiers) until they are finally rendered on the particular client device which could be different for each user. As shown above by vertical arrows, one can share "object" at any stage in pipeline. The simplest case (user

C) is *shared display* when the final frame buffer is shared. The basic *shared event* collaboration shares the original object – perhaps replicating it but then exchanging state information. The user A has maximal flexibility as he or she can choose to use or ignore B's visualization state change. In particular A has no need to use the same display device as B; B could be a high end CAVE, A on a PDA. *Shared export* corresponds to one of the intermediate arrows where one is inside the pipeline at a stage where the format is some standard such as HTML, PDF, Java2D or 3D, SVG (Scalable Vector Graphics). Then one can build a generally useable collaborative viewer for this intermediate form and produce a powerful environment in a re-usable fashion. The above figure illustrates why building collaboration systems is difficult. Even if we agree on what needs to be done i.e. in this build a shared visualization, there are many ways to do it and we can only find out what to do by building experimental systems and seeing how they are used.

Finally if we share objects and we have a lot of them, then we must have management capabilities so we can store catalog and retrieve them. This management capability needs to be linked with the collaboration system and in some applications has special requirements like those to store grades and homework in learning systems.

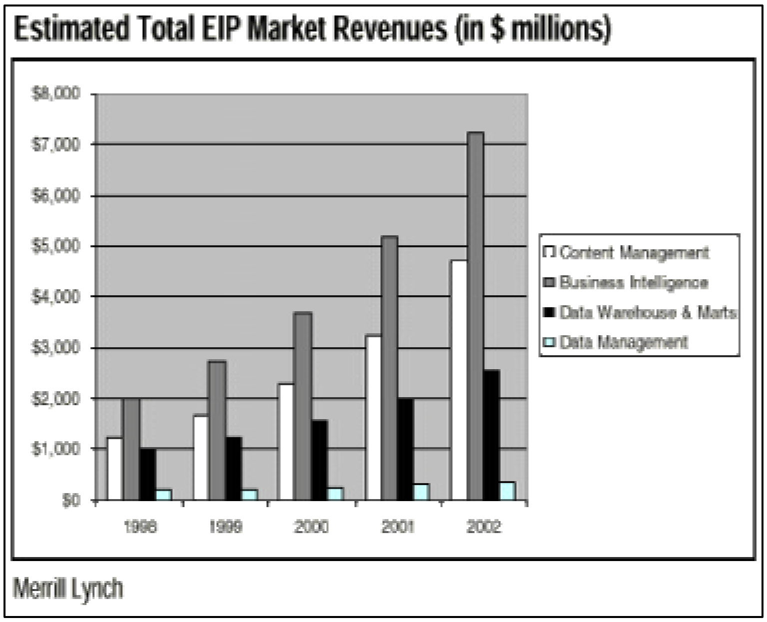


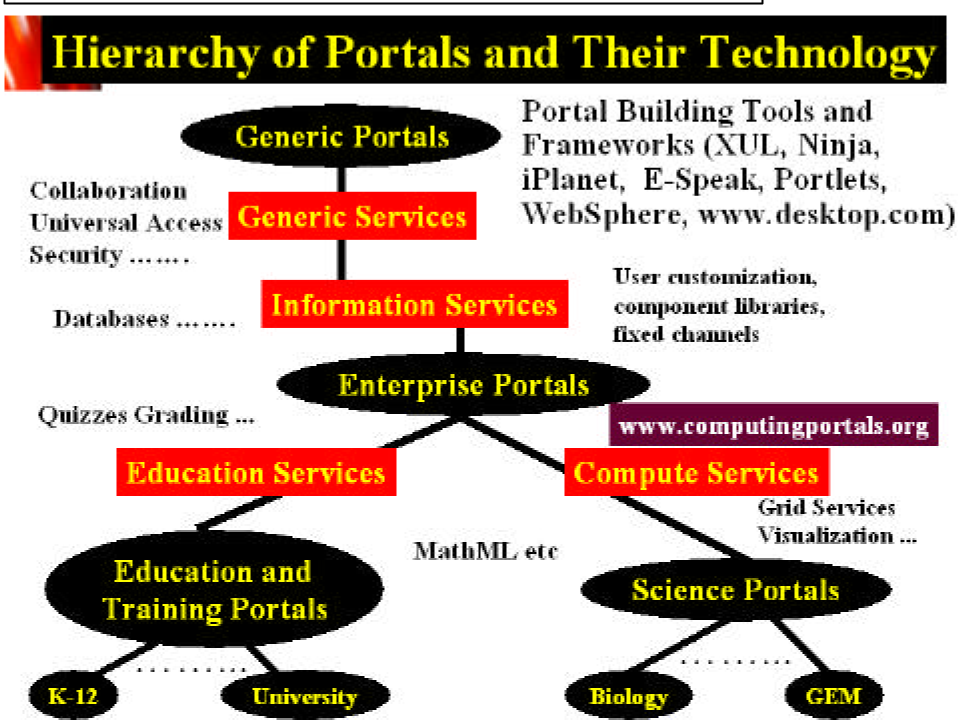
Now we discuss a critical distinction between synchronous (real-time) and asynchronous collaboration. Note that the Web is full of objects – Web pages sitting on Web servers – and these support asynchronous collaboration gotten when somebody posts a web page and later somebody else looks at it in their own time. One of the attractions of web-based collaboration is this incredibly simple but powerful asynchronous model. Note that by replacing a web document by a "CGI script" or servlet (web interface to program, database etc.) implies that the web supports general multi-tier object sharing. We can abstract this capability as the Publish/Subscribe mechanism shown above and make it more useful by adding some mechanism (automatic email, instant messenger or word of mouth) to tell the collaborating client when new information is posted. Adding synchronous collaboration to this model "just" involves providing "real-time" notification and automatic update for changed objects. Of course this is not easy to do reliably and conveniently.

There are some important capabilities described in the long report [12] but omitted here. This review covers instant messengers – a popular component of collaboration, which are similar in function to text chat rooms. They have some special value to notify students and teachers to wake up – the class is starting. It also covers an asynchronous module of importance – namely calendars and scheduling systems. Note that in both messengers and calendars there are emerging standards, which will enable the interoperability of these capabilities between different systems.

2.5 Collaborative Portals

Yahoo first popularized portals but recently they have been applied to Enterprise





information systems as discussed in a report by Merrill Lynch. This forecasts a growth in this software area up to some $15B per year in 2002 as shown in the first figure of this subsection. We see these developments as very important as they will drive the technology we use. Distance education is “just a collaborative portal” and information is the core of education. Thus we expect Enterprise technology to impact that in education. We see that already with database and Lotus Notes being used in several important education portals. To a lesser extent computing portals are also impacted by these pervasive developments; in this case there are rather more domain dependent objects and so less overlap

As shown above, we see computing and education portals being built on top of infrastructure designed for commodity and information portals. As these commercial activities are still developing rapidly one must expect a significant amount of experimentation needed until consensus best practice emerges. Further we can wait until industry gets is right; we must monitor what goes on carefully and adjust directions as necessary.

3. Distance Education and Training

3.1 Authoring Models for Web Pages

We have discussed how collaborative services depend on the nature of the object being shared. For a shared Web page, the object is authored in some fashion or other. This can be Word, PowerPoint, a native HTML editor or a high end possibly multimedia page produced with Macromedia or Adobe tools. We expect that sophisticated web pages will grow in importance especially in areas like education where collaboration technology can increase competition and the potential audience. Market pressures will demand that providers provide the best possible learning environments. In the long report [12], we review Macromedia technologies where Flash and Shockwave are perhaps the most popular high-end authoring systems. The current tools are not well tuned for education where one needs to make a lot of similar pages, which can be easily updated to take account of changing curricula in rapidly evolving fields like computer science. We expect that the situation will improve as powerful XML based systems using XSLT style sheets become available; here it is interesting that Macromedia has acquired Allaire and its leading database driven template system Cold Fusion.

Authoring style is important for collaboration systems as good sharing is obviously harder for the more complex web pages produced using Flash and other such technologies – for instance one needs not just to share the page but also the interactive controls. Here there are several important developments in the Web Consortium W3C standards community (http://www.w3c.org). The W3C Document Object Model or DOM defines precisely the object structure of W3C compliant Web pages. The DOM definition is only just being completed with the key (for collaboration) event characteristics coming out in the level 2 and 3 W3C DOM specifications. This should alleviate the well-known difficulties coming from the very different DOM implementations in Microsoft and Netscape browsers. Unfortunately at the moment, no browsers support the latest standards and with an 87% market share, Internet Explorer is not tracking these changes actively. The Netscape 6 browser was recently released but it still too immature for serious work although it does have excellent W3C standards compliance – even here it only supports level 1 of the DOM at this stage. We stress the possible importance of SVG – the W3C Scalable two-dimensional Vector Graphics standard. All Adobe products of relevance can export to SVG and this company has a free SVG viewer as a plugin to Netscape and Microsoft browsers. Flash has an open format with a prototype SVG converter available from the University of Nottingham. PowerPoint can also be converted to this syntax although the current Office 2000 exports to VML – Vector Markup Language that was a precursor of SVG. We are working on this conversion but less elegantly and efficiently, one can produce SVG export from PowerPoint by going through Windows metafiles and Adobe Illustrator as intermediate forms.

SVG is important for any 2D visualization and scientific whiteboards – we are using it for the whiteboard available with our Gateway portal [13]. We believe both the authoring and visualization community should study SVG. It could be very important for interoperability.

There are several other important standards that affect authoring. MathML is the new standard for mathematics; SMIL is a complete syntax for incorporating multimedia into web pages; OpenOffice (http://www.openoffice.org) is Sun's effort (through their StarOffice product) to define standards for productivity tools; WML is potentially important for content aimed at wireless devices. The W3C also has a major effort in universal access that should be tracked. We are in a transition time with many important developments that will eventually enable sophisticated pages to be manipulated and shared in standard fashion. We see that now is a reasonable time to explore use of technologies like Flash as it is now clear how they will escape their current proprietary base and so investment in such material will have a long-term future.

3.2 Audio-Video Conferencing

In our experience with the use of Tango in distance training, audio-video conferencing was always problematical and the area most likely to lower the quality of the session. The essential problem is audio for this requires negligible bandwidth (a few kilobits per second) but high quality of service as the human ear is very sensitive to audio distortion. The current Internet does not support quality of service – one must "buy it" with bandwidth and hope that the packets get through. In the case of video, there is less of a problem for although the bandwidth needed is higher than for audio, the eye is much more forgiving of broken images especially if these are "just postage stamp talking heads". Quality of service is less critical for video. Remember that we transmit the curricula material separately from the multi-media and this will always be high quality.
In [2] we describe in detail the HearMe approach to desktop audio. This is a low-end solution that enables an arbitrary mix of conventional phones and Internet audio streams to participate in a conference. All sources are digitized for later replay. It is ironic that conventional telephones have both quality of service and handsets with echo cancellation; they tend to outperform Internet solutions. This audio supports the G.723 (modem) and higher quality G.711 standard codecs. Ref. [2] also describes the radically different approach of Argonne/NCSA's Access-Grid technology aimed at large rooms linked by high quality networks. This system supports multiple high-quality audio and video streams and each client needs 20 megabits per second network bandwidth. We see this as the premier high-end system aimed at a rather different model than HearMe; the Access

Grid supports interacting communities whereas HearMe is aimed at the classic collaborating desktop scenario.

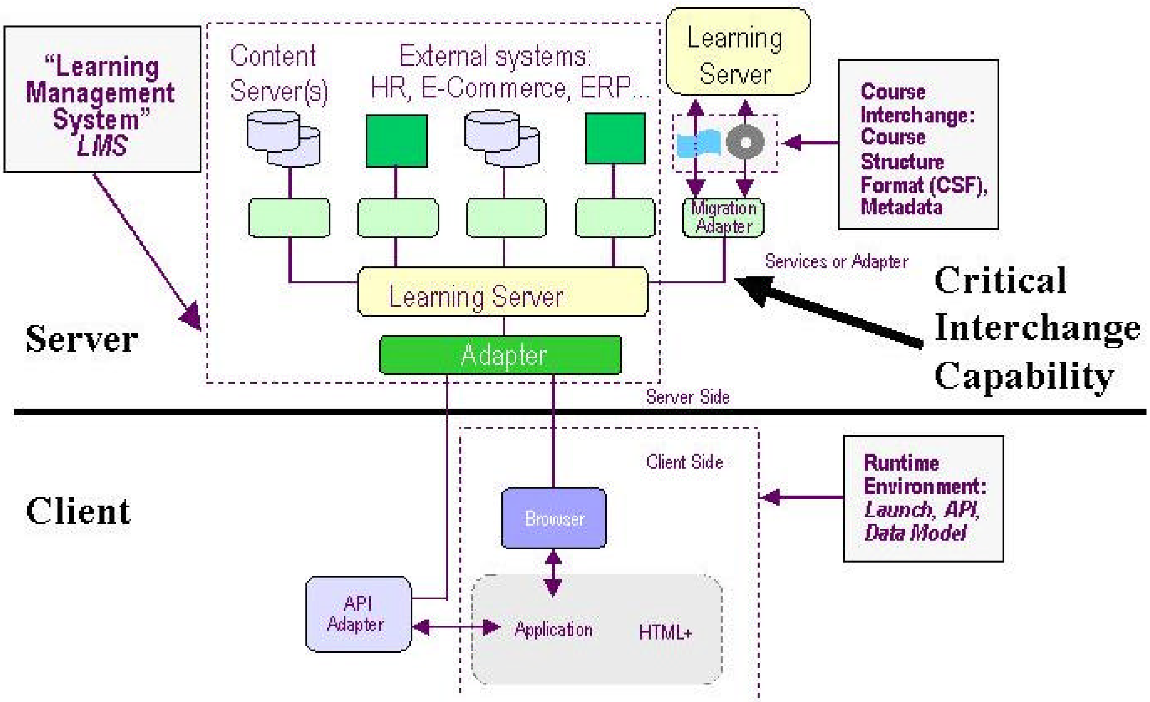
We note that in the desktop case, the value of postage stamp video is not clear. The much richer Access Grid video has clear value but is only possible on high speed networks and with significant technical support. We need to review available desktop video solutions and we have not completed this task yet.

We note that the multi-media codecs used in conferencing are different from those optimized for Webcasts and streaming multi-media. The latter need not support interactive exchanges and can use much larger client side buffers (several seconds) with corresponding improved fault tolerance. We are building a converter to translate the archived "voice objects" in HearMe from G.711/723 to RealAudio format for better playback. One important issue is interoperability and there are two important standards H.323 and SIP described in [2]. Currently the Access Grid does not support these standards, which is in our opinion a weakness although there are ad-hoc methods to tie non Access Grid (AG) clients into an AG session.

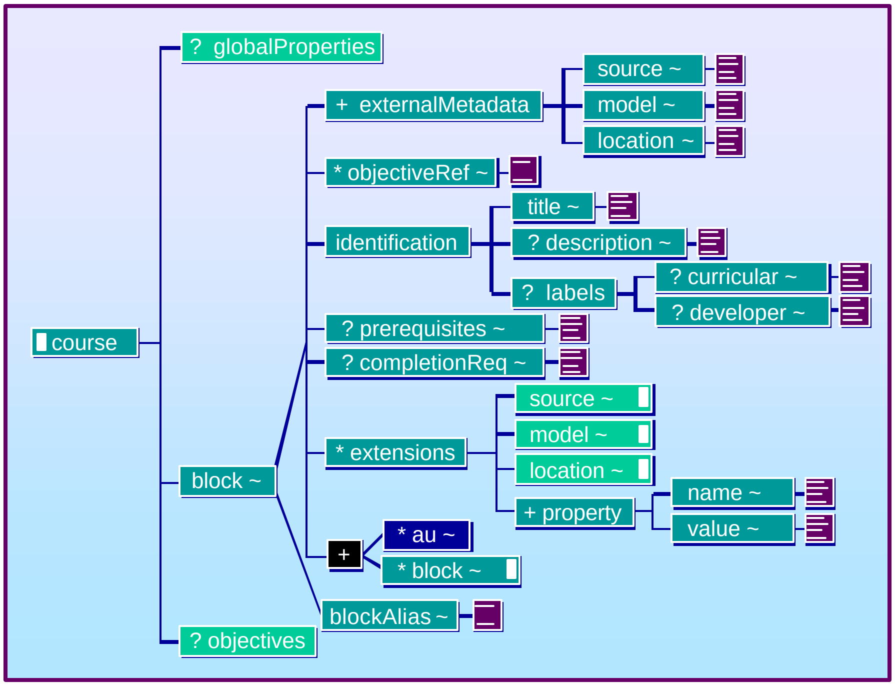
We note that the FSU, ERDC and Jackson State AG deployment could be tested by delivery of distance classes or training sessions.

3.3 Learning Objects and their Management

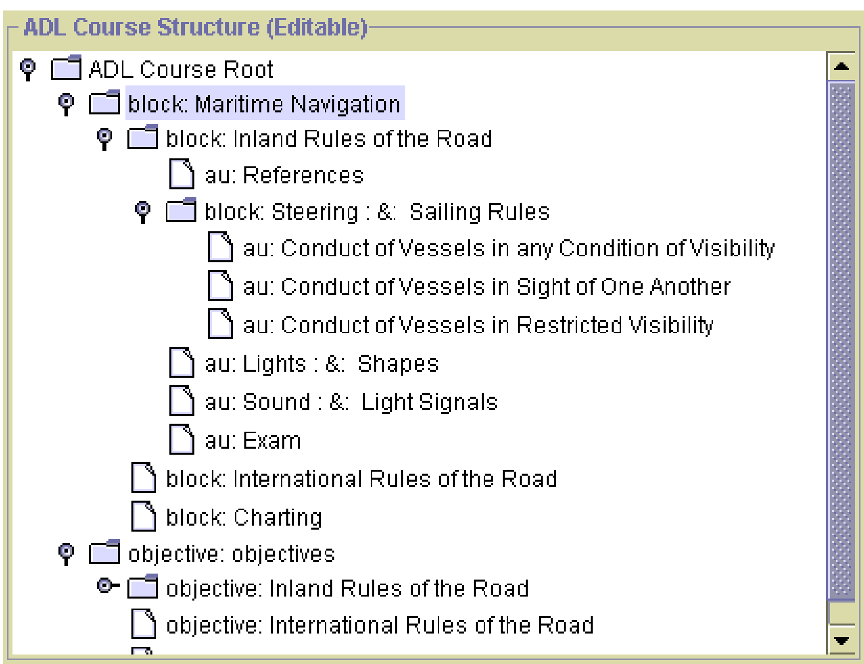
Learning Management Systems are designed to act as document repositories and provide other services such as support of student registration, quizzes, glossaries, group email, homework submission and grading. A typical architecture is shown below



The client server interface is used to define "learning object" standards by IMS (http://www.imsproject.org) and ADL(http://www.adlnet.org) in the educational and DoD training communities respectively. Interestingly these efforts use the rather dated client server model rather than the modern multi-tier architecture adopted in state of the art systems. Nevertheless these standards are important as the certainly identify key features of learning objects even as we think more experience will be needed before sustainable standards can be agreed. We surely are at the beginning of the era of distributed and distance learning and must expect substantial experimentation before agreed approaches and standards emerge. In the picture below, we show a fragment of the DoD SCORM standard for course material. Highlights include a recursive hierarchy (defined by the *block* and leaf *au* attributes) and education specific attributes including prerequisites, completion requirements and course objectives. This diagram shows a typical display of an object structure produced by modern XML tools. As an aside note, we believe that the recent introduction of XML Schema will greatly help this type of work as they are a much more powerful object specification methodology than the previous DTD syntax. Following the general SCORM learning object structure, we show a sample given by ADL of a military training example. Note that these standards go down to the "Web Page" as the basic unit and so provide specification that can help decide what material to share but does not address the nature of the sharing. The W3C DOM can take over and used to define the collaboration of Web Pages and their internal document fragments. We consider object standards critical for collaboration as you can only effectively share information if you have enough metadata to specify its access and internal structure.



The current standards include metadata originally developed by IEEE, which are aimed at defining the properties of educational objects thought of as "documents" (author, title etc.) with as shown in figure additional packaging standards on how to form lectures, modules, courses, degrees etc. from the basic curricula units.



IMS has a major effort to define tests and quizzes but it seems that this may be too much detail in an area still being developed. For instance the clever CAPA system for personalized questions (http://capa4.lite.msu.edu/capa-bin/class.html) is not currently supported. Nevertheless the issues raised in these test and quiz standards will always be important and used in future work. IMS also includes enterprise properties (such as standards for personal information), which must be important.

It is interesting that WebCT and Blackboard are popular with educational institutions given their limitations in terms of authoring model and collaboration capabilities. One reason is that they provide a model suitable for the less experienced user with limited online authoring skills. We doubt if this can be a long-term rationale as we believe that there will be growing pressure for the highest quality learning environments and more emphasis on high end authoring. In many areas one needs laboratories – both say in physics but more relevantly for DoD computer science needs programming laboratories. In our distances classes with Jackson State we used the rather old Virtual Programming Laboratory VPL (http://old-npac.csit.fsu.edu/projects/VPL/vpl-publications.html) which was quite effective. This area deserves more attention.

One concern with systems like WebCT and Blackboard is the realism of their goal of providing a "complete solution". With rapidly changing technology and even requirements as users experiment with new systems, a modular approach could be more sustainable. For instance Balsoy and Sen (http://aspen.csit.fsu.edu/collabtools/senthesisdraft.html) produced an effective system to support registration, grading and homework submission.

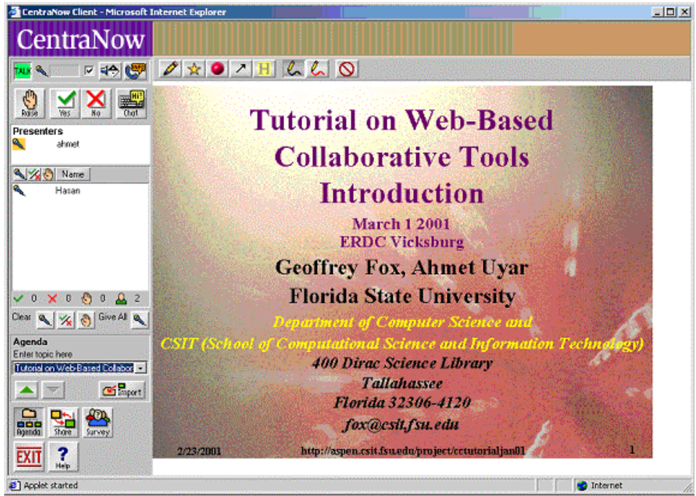
4. Commercial Web Conferencing Tools

4.1 Introduction

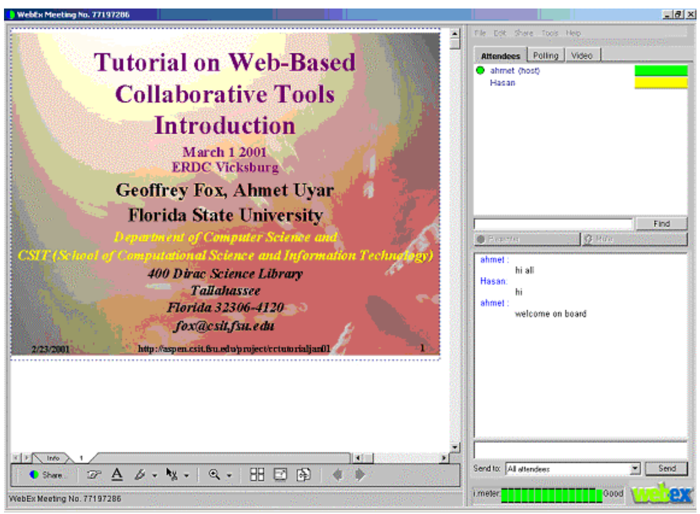
As we have remarked the most successful commercial conferencing companies support synchronous collaboration. Applications are to education, training, seminars and intracompany discussions such as briefing the sales force with a new product. These are the structured scenarios we found successful with Tango interactive. The commercial tools support very similar capabilities in each application. Typically a presenter can do a power point slide show, ask some questions through an online chat and get the answers from audience, annotate on the slides, write and draw pictures on a blackboard, and demo an application during a virtual meeting. Audience can either ask questions by talking when given permission or through the chat. The voice is transmitted either through Internet or using teleconferencing. Some conferencing tools also provide video streaming.

There are several web conferencing tools on the market today with varying capabilities. In ref. [12] we evaluated some of the most important ones and give a summary here. The pictures below show the rather similar interfaces that have evolved in the leading systems: Centra, WebEx and Placeware.

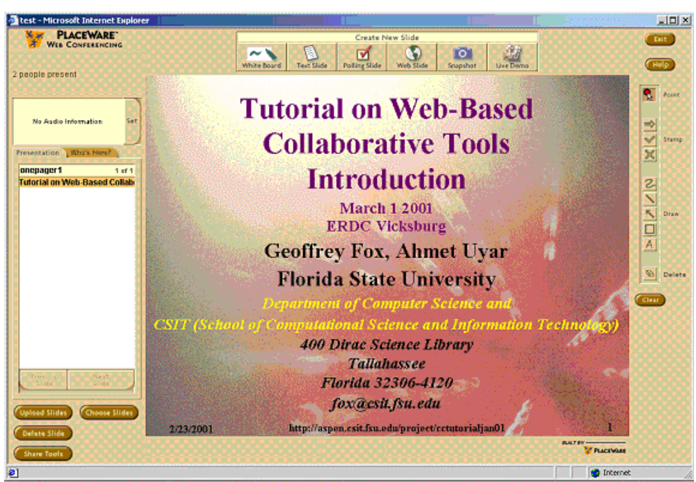
Centra:



WebEx:



Placeware:



Synchronous Virtual Environments are offered by WebEx Centra Placeware Latitude and NetMeeting featuring shared display and shared export (for PowerPoint). These systems have limited but nontrivial functionality in the areas of archiving, export models, management and PDA support. In the survey of sec. 4.2, some of the capabilities have not been examined deeply – sometimes because they were not available in the "free version" we used. VNC offers a public domain shared display capability described in ref. [12]. Note that VNC was designed for a "different problem" – a systems czar doing administration on multiple remote machines i.e. the master computer viewing display of a (single) client. It has not been optimized for one master display being shared with many clients as needed in distance training. Note customer help desk support (including remote consulting for the MSRC's) needs the first model where the master computer views the client display. Further this case typically one only has a few session members – perhaps even just two. Such help desk applications are an important business area for some of the commercial products – including WebEx and http://www.expertcity.com/

In both shared export and shared display capabilities of the reviewed systems, there is built in support for annotation. Note the importance here of sharing objects with scalable displays. Then one can place the annotation in the correct place on each client display whether or not they are each viewing at the same magnification. PDF and SVG are scalable in this sense as is a fixed format like a shared frame-buffer or a GIF/JPEG export. HTML is not scalable as different browsers can lay out the same page in different ways that do not preserve relative positioning. All systems have some sort of chat and whiteboard tools and Audio/Video conferencing. Centra has a built in Windows audio with a Java front end. WebEx currently uses a product from Lipstream, which has similar structure to the HearMe system described in section 3.2.

4.2 Summary Comparison of WebEx, Centra, PlaceWare and Latitude

	WebEx	**Centra**	**PlaceWare**	**Latitude**
Website	http://www.webex.com	http://www.centra.com	http://www.placeware.com	http://www.latitude.com
Access	Browser	Browser	Browser	Browser
Shared Export	Any printable document can be shared. Anyone can zoom in or out. Uses vector based image format. Anyone can annotate (no pointer problems).	Only Power point slides supported. No resizing or zooming. PPT slides converted to gif images. Anyone can annotate	Only Power point slides supported. No resizing or zooming. PPT slides converted to gif images. Anyone can annotate	PowerPoint, Excel, Word
Shared Display	Any application or entire desktop can be shared. Anyone can share applications given the permission. Annotation is possible (only drawing curves, no texts or geometric shapes) Remote control is supported. The quality is fair. The performance is best.	Any application or entire desktop can be shared. Presenter or co-presenters can share applications. Shared application can be any size. No annotation. No remote control. The quality is good. The performance is fair.	A selected rectangular area on the desktop is broadcasted to clients. Anyone can do shared display given the permission. No annotation. No remote control. The quality is good. The performance is fair.	Y but client software required
Shared Web Browsers	No.	No	Limited support. It does not provide a synchronized web tour nor does it pass the events such as page down or up. Only points the browsers to a common URL initially.	Not evaluated.

Annotation tools	Y	Y	Y	Y
Textual chat	Y	Y	Y	*
Whiteboard	Y	Y	Y	*
Polling/Voting	Y	Y	Y	N/A
Q&A (1:1 chat from student to presenter)	N	N	Y	N/A
Audio	Uses either phone or third party audio such as Lipstream	**Built in Audio** Half Duplex (CentraNow) Full Duplex (CentraOne and Symposium)	No audio except Phone	N
Video	Y (presenters only)	Y	N	N
Automatic notification of schedule	Y	N	N	Y(via fax or e-mail)
Recording of sessions	WebEx Recording & Playback enables recording and playback of live sessions. All annotations, shared display and whiteboard discussions are recorded and replayed during the playback.	Centra Recorder™ lets users to record live sessions and Centra Producer™ lets users edit recordings frame-by-frame. We did not test any of these.	Voice played back either using Real Player or Windows Media Player and content is shown on the browser as gif images synchronously. Gif images are static and no movement is played back.	Y
Client requirements	Java-enabled browser. Automatic installation of client when accessed for the first time.	Java-enabled browser for Centra Conference. Separate client for Centra Symposium.	Java-enabled browser.	(The MeetingPlace Data Conference Option) - One of the following T.120 applications (for hosts only): NetMeeting, SunForum, HP Visualize, SGImeeting

				- Java-enabled Web browser (Internet Explorer, Netscape Navigator) to load MeetingPlace WebShare.
Platforms	Windows; Mac (with limited functionality); JAVA	Windows	Windows; Solaris; Mac (officially not supported; no audio)	Windows
Plug-In	Y	Y	N	No client software needed but available
Free version	Yes (up to 4 participants, Application sharing limited to 10 min)	Y (up to 5 participants)	Yes (up to 25 participants for 15 days)	N

*Integration with standards-based T.120 applications, such as Microsoft NetMeeting, lets users to share and collaborate on documents, whiteboard and chat.

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