ABSTRACT

Based on three years of user feedback, a design team at IRIS embarked on a project to enhance Intermedia to better support small groups of collaborators, particularly those involved with document review and revision. Towards this end, we defined user-level requirements for the new functionality. The result of this process was the design and implementation of InterNote. One aspect of InterNote involves a fundamental extension to Intermedia's navigational linking paradigm. Instead of simply being able to traverse links, users are now also able to transfer data across the links using a technique we call warm linking. In this paper we describe extensions to our hypermedia framework to support annotative collaboration, including the user interface of the new linking functionality and the InterNote extension. Finally, we discuss our plans for future work.

I. INTRODUCTION

Working together to create materials is a familiar activity in a wide range of settings. The evolution of these materials, such as joint research papers, software design documents, or information for use in the classroom, frequently depends on group consensus. Drafts are produced, these drafts are reviewed, and new drafts are produced. We see the annotative collaboration process [Trig86] as consisting not only of commenting, questioning, and critiquing others' work, but also of assimilating these "notes" back into the original material to create a new version. It is a process that includes both the review and the revision cycle.

As groups of users begin to develop materials ranging from small information networks to entire on-line books within our Intermedia hypermedia desktop environment, their need for more efficient and effective collaboration tools is apparent. Currently, users are writing papers and developing software design and issues materials jointly within Intermedia. A group at Johns Hopkins University is even importing an entire medical textbook into Intermedia, working together to create the connecting network of links and to revise the text and illustrations. Many working groups link comments to a core set of documents, spawning on-line discussions within the context of the jointly owned materials. Professors creating course materials within Intermedia find that their task is almost always a group effort with student assistants. Text documents, structured graphics figures, timelines, and scanned images (created using InterWord, InterDraw, InterVal and InterPix respectively), and the linkages between them, are prepared and revised incrementally. More detailed descriptions of Intermedia are available in [Garr86, Meyr86 and Yank88].

In the version of Intermedia in use in our field trials, users wishing to attach an annotation to any selection in a document can do so by linking an empty document of
any type to the selection and entering the annotation in that document. This process, however, requires multiple user actions. The user must select a portion of the original document, choose the "Start Link" command, open a new document from the "New" application window, enter the annotation content, select a portion of the annotation content, and choose the "Complete Link" command. The multiple-step process for attaching an annotation proves frustrating when a reviewer only wants to attach small, quick annotations. Similarly, to incorporate a change suggested in an annotation, the document author has to use the generic "Copy" and "Paste" commands, copying the desired section from the annotation document and pasting it in the correct location in the original document. This, too, is a multiple-step process. Also there is no way to mark the annotations that have been incorporated so that the author can keep track of which annotations still need to be viewed.

Motivated by the amount of group work currently being done in Intermedia, we decided to investigate and implement tools to better support annotative collaboration in our environment. The first phase of this project resulted in the development of an annotation facility called InterNote. Before we began designing InterNote, we looked at some studies of annotation styles and usage [Brow84, Krau86, Nie184]. We also investigated a number of currently available software products and research prototypes which support annotative collaboration [Brod, Brow82, Cont, Dene, Main, Trig86, Wang]. We found that a number of systems provided varying levels of support for the review process, but no systems supported both review and revision. In addition, we found little or no support for annotation management and simultaneous multi-user annotation.

Of the systems that supported the review process, we were specifically interested in the range of tools that could be used to create annotations and the range of document types that could be annotated. We were also interested in the granularity of data with which an annotation could be associated and the level of multi-user support provided. We found that all the systems provide for textual annotations. Some give users the ability to overlay the document being annotated with text, some allow the text to be added in a separate window, and some allow for a combination of both. In addition to textual annotations, some systems provide a palette of graphical mark-up tools, facilities to create "hand-written" annotations with a tablet and "pencil," or even mechanisms to attach voice annotations to a document. In terms of document types that a user can annotate, some systems only allow for the annotation of text documents while others allow users to annotate any type of document.

Most systems that allow the user to annotate any type of document first take an electronic snapshot of the document, creating a bitmap version of it. The reviewer then annotates the snapshot, using one set of annotation tools, regardless of whether the original document was text, graphics, a spreadsheet, etc. While this approach is powerful for the annotator, the author cannot simply copy and paste annotations into the original document. The author can only use the annotated document as a reference, either on-line or printed, for the process of revising the original document. If the author has changed the document since the snapshot was taken, the annotations will reference an out of date version.

The type of elements to which an annotation can be attached defines the annotation granularity. Systems that make a bitmap copy of the document allow annotations to be attached to any coordinate location on the page. The annotation granularity for systems that do not take this approach varied from an entire page to one or more document objects (words, sentences, paragraphs, graphics objects, etc).

A few systems also provide some type of multi-user support. For example, Context [Cont] allows the author to assign a unique identifying tag to each document reviewer, so that each reviewer's comments can be easily identified. MarkUp by Mainstay [Main] allows an author to specify a list of reviewers. A bitmap copy of the document to be marked up can then be sent over a network to each of the reviewers. When the reviewers
are finished, the author is able to merge all the comments into a single marked-up version. This version can either be printed or can be viewed electronically, side-by-side with the original. Such a feature is useful because it allows multiple people to review a document simultaneously, but it has limitations. Specifically, reviewers cannot look at each others suggestions, and the author cannot see a reviewer's comments until he or she submits the marked up copy.

From our analysis of current systems and the group work users are currently doing, we established general goals for extensions to Intermedia to support annotative collaboration. These goals were to provide a set of intuitive reviewing tools and to provide, at the same time, integrated revision and annotation management capabilities. With Intermedia as our base, we already had the functionality for creating links between fine-grained selections in multiple document types and the support for multiple users linking to and from a document simultaneously. In addition, we could take advantage of Intermedia's shared desktop folder hierarchy. Intermedia provided us with a powerful framework on which we could build support for annotative collaboration beyond what was available in any one of the existing systems.

In this paper we present our requirements for supporting annotative collaboration, followed by a description of the user interface. We then go on to describe our plans for future research.

II. REQUIREMENTS

Based on our general goals, we identified a set of high-level user requirements that we wanted our design to address. We broke these requirements down into three categories: general requirements, annotator requirements and author requirements. These categories are intended to help organize sets of functionality and are not meant to imply an actual differentiation among users. As with all other Intermedia functionality, no distinction is actually made between types of users. In the course of a single session, one user may be both an annotator and an author, depending on the task they are trying to accomplish.

A. General Requirements

Our most basic requirement was to design a general-purpose annotation facility within the existing Intermedia environment. We believed that the method for creating and viewing annotations had to be identical across all applications, current and future. From this it also followed that users had to be able to create annotations of any document type. For example, an annotator should be able to suggest revisions on a graphics document using graphics editing tools. Regardless of the type of document being annotated, however, we felt it was likely that users would want to add textual commentary alone or in conjunction with the suggested revisions. We found that in our own annotations, we frequently attempted to justify a suggestion with a sentence or a phrase. In other words, we realized that there were two major types of annotations: suggested changes in the same data type as the original document, and textual commentary for notes, comments, non-specific suggestions, and justifications [Nie84]. The annotation functionality, therefore, had to provide a set of text-editing capabilities along with the editing tools of the original document.

Regardless of the way a document is annotated, we wanted to be sure that an author or an annotator could see the source of the annotation and the annotation simultaneously. The author of a document, the annotator or another reviewer also had to be able to either annotate an existing annotation or make a navigational link to or from an existing annotation. In addition, a user had to be able to print the annotations both separately and in conjunction with the document.

Another crucial requirement was that the annotation functionality fit in with Intermedia's existing functionality, especially the linking mechanisms, and be fundamentally
integrated into the existing application architecture. We wanted users to learn as few new skills as possible in order to use the new annotation features and we wanted developers to be able to write new applications that would take advantage of the annotation functionality with minimal programming effort. In the Intermedia system, all applications participate in navigational linking by implementing a small linking protocol interface. We wanted to extend the existing linking protocol very slightly so that all applications could also participate in annotation. By implementing this extended protocol, a developer has to be able to easily provide users with the ability to annotate documents created with their new application.

B. Annotator Requirements

As described in the introduction, it was possible, before the addition of annotation features, for users to annotate existing Intermedia documents. The major difficulty involved the number of steps it took to do so. Our major requirement from the annotator's perspective was that the creation of annotations be a one-step process. By making a selection and issuing a single command, an annotator had to be able to enter textual commentary or suggest specific editing changes. These editing changes might include a range of changes from rewording a sentence to resequencing an animation.

Intermedia documents are by definition dynamic. They can be updated at any time by the original author or by any collaborator with the appropriate access rights. We felt it was crucial for the system to provide some facility for contention management. In other words, if the author is updating a document at the same time another user is annotating it, the author may end up with comments and corrections on an out-of-date document. The system had to be able to resolve these types of edit/annotate collisions and allow multiple users to annotate the same document simultaneously.

Since it is often useful for one reviewer to see comments made by a previous reviewer to avoid duplication of effort, we wanted annotators to be able to see other users' annotations [Nie84]. On the other hand, if an annotator preferred working on a clean copy of the document, he or she had to be able to hide the annotations created by others.

C. Author Requirements

The most basic requirement we defined for authors was the ability to automatically incorporate a suggested change, such as a sentence rewording or spelling correction. This mechanism had to be faster and more direct than using the "Copy" and "Paste" commands, particularly as some documents could have literally hundreds of annotations.

We also wanted the system to allow the author to keep track of which annotations had been incorporated. When a document has been reviewed by more than one person, this problem is exacerbated, particularly if the annotations suggest conflicting revisions.

As an author edits a document, the annotations had to stick with the document objects with which they are associated until intentionally deleted. For example, if an author inserts a new sentence before a paragraph that contains annotations, the annotations had to stick with their paragraph.

If more than one person reviews a document, the author had to be able to merge the annotations so that they could be viewed in the order in which they appear in the document. Authors also had to be able sort annotations so that they could view one person's annotations at a time, view annotations by date, or view only the annotations that had not yet been incorporated. An author may want to do a number of things besides incorporating a specific annotation while revising the annotated document. The author may want to delete the annotation, delete the reference to the annotation, but still save it somewhere, or leave the annotation as is.
III. USER INTERFACE

With these high-level user requirements, we were able to design and implement an extension to Intermedia called InterNote. InterNote provides a consistent user interface for annotating all Intermedia document types. For annotators, InterNote provides the "Create Annotation" command, which links an annotation to any selection in an Intermedia document. The command also copies the selection into a "Note" window, so that the annotator can immediately make copy-editing changes or suggest a reordering. Authors use the "Incorporate Annotation" command to revise the document with the suggested changes from the annotation.

When we were designing the "Create Annotation" and "Incorporate Annotation" commands, we decided to extend Intermedia's navigational linking paradigm rather than build a special-purpose annotation and incorporation tool just for InterNote. The extension we designed combines navigation and data transfer into a single action. We call this action warm linking. Warm linking allows a user to not only traverse a link from a selection in one document to a selection in another document but also to transport data across the same link. Before explaining the details of the user interface of InterNote, we describe the warm linking user interface in more detail.

A. Warm Linking

The concept of warm linking is a variation of the master/instance relationships of computer aided design (CAD). In CAD applications, when a master component is changed, all instances of that component are automatically updated. In integrated software products, such as Lotus' Jazz, the term Hot View was introduced to describe this kind of automatic update facility. The user could place a hot view of chart or spreadsheet in a word processing document that would automatically update when the underlying data changed [Jazz85]. In the hypertext arena we have the ability to create links – associative relationships between objects – so it seemed natural to refer to links that provide automatic updating in addition to navigational linking as hot links. Purely navigational links, or cold links, are at the other end of the spectrum because they do not involve data transfer. Warm links fall in the middle ground. Rather than having the system automatically update the data at the other end of a link, the user has to explicitly update the remote data.

In Intermedia, links are made between selections of document objects. These selections are called link anchors. Visible markers are placed next to the anchors at both endpoints of the link. To traverse a link, a user selects a marker and picks the "Follow" menu command (or double-clicks on the marker). Similarly, to transfer data across a link, a user selects a link marker and issues one of the warm linking menu commands, either "Push" or "Pull." The "Push" command copies the content of the link anchor associated with the selected link marker and pastes it at the other end of the link, replacing the contents of the remote link anchor. "Pull" has the opposite effect. The command copies the contents of the remote link anchor and replaces the contents of the link anchor associated with the selected marker. In other words, data can be transferred in either direction across a link by asking the system to copy data from one end of a link, traverse the link, and paste the data at the other end of the link. These actions are diagrammed in Figure 1.

Because warm linking has many applications beyond creating and incorporating annotations, we provide the functionality as a system-wide feature. For example, when writing a paper, an author can link the illustrations in an InterWord document to the original versions stored in InterDraw documents. If the author revised an illustration in a previous session, he or she can "Pull" the revised illustration across the link into the InterWord document. Similarly, the author can revise one of the illustrations by following the link from the InterWord document to the InterDraw document and editing the illustration. The author can then "Push" the updated illustration across the link back into the InterWord document.
Figure 1. In the top diagram, the square in Document A is linked to the circle in Document B. The existence of the link is indicated by the markers above the circle and the square. Document A is the active document. The other two illustrations show what happens if a user selects the link marker in Document A and issues either the "Pull" or "Push" command.

With the addition of warm linking to Intermedia, all links in the system can be used for both navigation and data transfer. In the following section, we describe the user interface of InterNote and how warm linking is used both to create the content of annotations and to allow authors to incorporate annotations.

B. InterNote

Annotations to Intermedia documents are made using Notes. To create a note, the user makes a selection in a document and picks the "Create Annotation" menu command. A document that has been annotated is called a draft. All annotations for a particular draft are automatically kept in a Note Folder associated with the document. Note Folders are similar to other folders found on the desktop, but they contain additional information specific to annotations, such as the status of each annotation. Note Folders are particularly useful for sorting and organizing annotations. Intermedia allows only one person to edit the content of a document at a time, but any number of people can create links to or from a document simultaneously. Similarly, any number of users can attach Notes to a document at the same time.

Once a document has been annotated by one or more users, the author of the document can incorporate any changes suggested in a Note using the "Incorporate Annotation" command.
Notes

The structure of a Note allows the annotator to make both direct editing changes to a copy of a selection from a draft and to provide textual commentary that might explain or justify the suggested change. For this reason, a Note consists of two frames: the Incorporation Frame and the Commentary Frame, as shown in Figure 2. Figure 3 depicts a sample session with InterNote where the author is viewing three Notes to determine whether or not to incorporate them into the draft of an InterWord document.

![Figure 2. A Note window.](image)

![Figure 3. An InterWord document with three Notes attached.](image)

The Incorporation Frame occupies the top portion of the Note window. In this frame, annotators enter specific suggestions to replace a section in the draft. To make a comment or suggest a change in the draft, the annotator selects one or more text, graphics or timeline objects and chooses the "Create Annotation" command. "Create Annotation" performs a number of actions. First, a new Note window is opened and a link is established between the annotator's selection in the draft and an insertion point in the Note's Incorporation Frame. A marker is placed next to both anchors, indicating the existence of a link. Next, the annotator's selection in the draft is "Pulled" across the link.
into the link anchor in the Incorporation Frame. To the annotator, it appears that the Note
window opens with an exact copy of his or her selection linked to the original selection.
As with all other links in Intermedia, this link may be followed in both directions. If the
annotator wants to add textual commentary without suggesting a change, it is easy to
delete the contents of the Incorporation Frame or make an annotation to an insertion point
in the draft.

The editing tools available to annotators in the Incorporation Frame correspond to the
editing tools available in the draft. For example, if a user is annotating an InterDraw
document, the Incorporation Frame of the Note will have a full set of graphics editing
tools. By editing the copy of the original selection in the Incorporation Frame, the
annotator indicates to the author of the draft that the change can be used as a replacement.
The author may then decide to incorporate this change when he or she is revising the
document. The process of incorporating annotations is discussed in more detail below in
the section Revising an Annotated Document.

The Commentary Frame in the lower portion of the Note window is used for textual
commentary. This may include general suggestions for revising the draft, specific
explanations of the editing changes made in the Incorporation Frame, and so forth. Unlike
the contents of the Incorporation Frame, authors cannot automatically incorporate the
contents of the Commentary Frame. The author must use the "Copy" and "Paste"
commands to include any text from the Commentary Frame in the draft.

Just like any other Intermedia document, a Note itself can be annotated. An annotation
may be attached to any selection in a Note window. This allows one annotator to
comment on another annotator's suggested revisions or commentary.

After an annotator has created a number of Notes for a document, he or she has the option
of saving Notes individually or all at once. Unlike other types of Intermedia documents,
Notes are automatically named when they are saved to help simplify the annotator's job.
The name is derived from the first line of text in the Commentary Frame. If there is no
commentary in a Note, the name is either based on the contents of the Incorporation
Frame, if it contains text, or the name of the draft. Annotators can always change the
default name.

Note Folders

To prevent desktop clutter, annotations are stored in a special Note Folder which is at the
same level in the folder hierarchy as the annotated draft. Each document that has been
annotated will have a single Note Folder associated with it, no matter how many people
have annotated the document. The Note Folder is automatically created and opened the
first time a document is annotated. All subsequent annotations are then stored in the Note
Folder, so they may be easily found and organized.

The name of the Note Folder is derived from the draft name. For example, if the draft
name is "Proposal," its Note Folder would be named "Proposal Notes." Each individual
annotation is represented as a row in the Note Folder. If multi-level annotations (i.e.,
annotations on annotations) have been created, they are also stored in this Note Folder.

To see the link markers that indicate which elements of a document have been annotated,
the Note Folder for that document must be open. Closing a Note Folder hides the
annotation markers.

Notes are displayed in the Note Folder in a table format with the column headers: Title,
User, Date, Processed, Status, and Order. There is also a Type column, but no header is
displayed for this in the table. Each row in the table represents a single annotation. The
name of the draft that corresponds to these annotations is shown on the right side of the
Note Folder's Status Bar. Figure 4 shows a Note Folder with all its components.
Figure 4. A Note Folder.

The columns of the Note Folder hold the following information:

**Type**  
A small icon representing the type of the annotation (i.e., InterWord, InterDraw, InterVal, etc.). The type is determined by the editor that is used in the Incorporation Frame.

**Title**  
A system-generated title for the annotation taken from the first few words in the Commentary Frame.

**User**  
The user ID of the annotator.

**Date**  
The date and time that the annotation was created. The time is not displayed if the Note Folder window is too narrow.

**Processed**  
The check box contains an "x" if the annotation has been handled by the document author and is blank if it has not. Details on processing annotations are provided below.

**Status**  
The status of an annotation may either be "Held" or "Detached." Details on assigning status to annotations are provided below.

**Order**  
This column contains a number (beginning with 1) that reflects the position of the annotation in the document. For InterWord documents, annotations are numbered in the normal reading order (left to right, then top to bottom). Other logical ordering schemes are used in each of the Intermedia documents.

The rows of a Note Folder can be sorted, using up to three of the column headings. This feature allows the user to group Notes for different purposes. For example, sorting the rows by the "Status" and "Processed" columns, would enable the user to determine which Notes had been "Held" but not "Processed."

Revising an Annotated Document

If a document has been annotated, authors may revise the document based on suggested changes and commentary. The revision process includes reading the annotations,
determining whether or not to incorporate the suggested changes, and making editing changes to the document based on the commentary in the attached Notes.

To look at annotations, the author must first open the corresponding Note Folder. This action parallels the opening of a Web View in order to follow links, which is a standard Intermedia action. The Web View is discussed briefly below. Once the Note Folder is open, annotation markers appear in the draft. Notes can be opened by following links from the annotated document or by double-clicking on their names in the Note Folder table. If the author is not certain of the location in the draft referred to by a Note, he or she simply has to follow the link from the Note window to the document. The block of text or graphics at the other end of the link will be highlighted. This highlighted area indicates the extent of text or graphics that will be replaced if the author chooses to incorporate the suggested change from the Note's Incorporation Frame. The author can easily change how much will be incorporated or replaced by changing the block extent either in the annotation or in the draft.

The author can incorporate a suggested change by transferring the data across the link between the annotation and the draft. If a Note is the active window, the author can "Push" the contents of the Incorporation Frame into the original document, thereby replacing the contents of the existing link anchor (the selection the annotator made when creating the annotation). Likewise, if the annotated document is the active window, the author can "Pull" the contents of the Incorporation Frame into the document. The result is identical. So that users do not have to remember the difference between pushing and pulling data, we provide an "Incorporate Annotation" command that either pushes or pulls the data across a link, depending on whether a Note window or a draft window is currently active. The "Incorporate Annotation" command also marks the annotation as "Processed."

When the data from the Incorporation Frame of the Note replaces the data in the document, the link anchor in the draft now consists of the revised data. This is crucial for two reasons. First, the link between the Note and the draft remains intact so that any commentary in the Note window can still be found by following the link. Second, the author may discover that a different annotator has suggested a better revision. If this is the case, the revision of the other annotator can be incorporated, thereby replacing the revision suggested by the first annotator.

The author can always undo the incorporation and return to the original document state by using the "Undo" command one or more times.

Managing Annotations

To accommodate different working styles, we provide authors with a number of facilities for handling annotations. One option is to open an annotation, examine its contents and then close it. In this case, the annotation remains linked to the document and has a status of "Held." All annotations are given a status of "Held" when they are initially created. Another option is to delete the annotation. This is done by selecting the name of the Note in the Note Folder and choosing the "Delete Document" command (the same command used to delete any other Intermedia document). Once an annotation is deleted, it is no longer represented in the Note Folder. At times, however, an author may want to save an annotation, but not have it linked to the draft any longer. In this case, the author has the option of disconnecting it. This is done by using the "Unlink" command (the same command used to disconnect navigational links). When an annotation is disconnected, its status in the Note Folder is changed to "Detached." The last option is to keep some or all of the annotations attached (i.e., "Held"), but indicate the ones that have been dealt with by manually placing an "x" in their Processed Check Box (see the Note diagram above). This box is automatically checked if the author uses the "Incorporate Annotation" command.
One step in managing annotations is for the author to decide on their status as he or she opens, reads, and incorporates them. To aid this process, the author can also organize the Note Folder by sorting the Notes based on any three of the Note Folder column headers. For example, the author may want to sort the annotations by the order in which they appear in the document or sort them based on user ID and the date of creation so that all the annotations created by one person are brought together in the order that they were made.

Annotation Links in the Web View

Since we anticipated that potentially hundreds of Notes would be attached to a single document, we needed to devise a mechanism for viewing Notes in the Intermedia Web View. This window displays a history of the user's path through a set of linked documents and a map showing the current document and all other documents connected to it (for a detailed description of the Web View see [Uti89]). To avoid cluttering the Web View, we decided to compact the annotation information by displaying the Note Folder rather than each individual Note in the map portion of the Web View. If a web is open when a user opens an annotated document, a single icon representing the Note Folder will appear in the map (this feature is not yet implemented). This folder icon is connected to the document's icon, indicating that the document has at least one annotation attached to it, as shown in Figure 5.

Figure 5. The proposal to use the folder icon to reduce clutter in the Web View is illustrated above. The InterWord document called "Article" is currently active on the user's screen (it is the last item in the path). This document has annotations attached to it as well as two InterDraw documents. The highlighting of the link line to "Article Notes" indicates that the user has selected a marker in the "Article" document that is connected to a Note stored in the "Article Notes" Note Folder.

No differentiation is made between annotation markers and other link markers, because, once created, there is no functional difference between the two. The only way to differentiate between them without following the links is to use the Web View. If a user selects a marker in a draft and an annotation is attached to it, the link line to the Note Folder will be highlighted in the Web View. If a user selects a marker and sees that both the link line to the Note Folder and link lines corresponding to other documents are highlighted in the Web View, then the selected marker has both standard and annotation links emanating from it.
With the exception of the Web View, InterNote has been fully integrated into the existing Intermedia environment. While we have been successful in achieving the level of integration we specified in our end-user requirements, we believe there is still a significant amount of additional work necessary to effectively support annotative collaboration. The following section goes on to describe some of our plans for future extensions to Intermedia in this arena.

IV. FUTURE RESEARCH

Informal evaluation of InterNote by a group of early users led us to draw the following conclusions. The "Create Annotation" interface was found to be simple and effective. Annotators tended to make the same number of suggestions for editorial changes; however, they tended to support those suggestions more extensively with commentary. While the interface supported editorial changes and attached commentary, the annotators found it difficult to suggest structural changes, such as reordering whole paragraphs of text.

We recognize that different styles of annotation interfaces might be more appropriate for different types of annotation tasks. For example, text in a separate window, such as a Note, might be best for a two or three paragraph comment, while drawing lines, arrows and circles directly onto the document might be best for suggesting revisions to an architectural drawing. It might also be useful for an author or annotator to switch between the different interfaces with ease and with no loss of information.

We are actively pursuing alternate interfaces for the annotation process. In particular, we have been exploring the notion of "layers of acetate" that an annotator can lay over the draft. The annotator can then make suggestions via lines, arrows and circles for structural changes to the document in addition to using proofreaders' symbols for conventional document markup. Unlike the mark-up implementations that exist today, we believe that it is possible to allow authors to incorporate suggested changes, and with judicious use of color, to view multiple annotators' comments simultaneously. We also believe that it is possible to have the markings on the acetate layer "stick" with the objects to which they refer, even after further editing by the author.

Because users should be able to switch between the different interfaces with ease and with no loss of information, we are trying to develop a Common Annotation Format to represent annotations in an interface-independent way. This Common Annotation Format must retain the specific contents for all parts of an annotation in a structure which will be compatible with all implemented interfaces.

Regardless of what interface is used, we feel that authors must be able to print reasonable hard copies of their drafts, complete with annotations. Printing linked documents is, in general, a hard problem in hypertext systems. One possible solution is to print the draft with annotations appearing as foot or end notes. Just as in regular foot/end notes, annotations would be tied to their locations in the draft via corresponding superscripts or textual bracketed labels. This seems feasible when the draft contains text; however, when considering annotated documents of types other than text, it is hard to devise a logical printing layout that is independent of the document type.

Our small trial emphasized the need for a number of communications tools to help groups of annotators and authors coordinate their efforts. It became clear that more than simple electronic mail is necessary. A user should be able to know at any time whether anyone else on the system has a document open for annotation or editing. There should be facilities for synchronously communicating with users currently working on the same task, as well as asynchronously sending messages to users not currently working.

One of our underlying assumptions while designing InterNote was that the focus of a group's editorial efforts is a single source document. In a hypertext environment, this may
not always be the case. The group may wish to comment on the existence and placement
of links between documents, as well as a document's content. We plan to explore the issues
of printing annotated documents and annotating the links between documents in the
future.

While much work has been accomplished over the years in studying the structure and
interactions involved in group work, very little has been done to integrate the notion of
groups into desktop environments. We plan to work on developing simple and intuitive
interfaces for users to create and modify both permanent or ad hoc work groups [Finh89].
We hope, in the long run, that applications will be developed where the single-user
version is considered a special case of a group version where the group size is one.

V. CONCLUSION

For annotation systems to be effective, they must blend into a user's daily working
environment, rather than overtake or displace it. If annotation systems, groupware
systems, or hypermedia systems work only in a limited domain, they are simply not as
useful as they could be.

Assuming that the daily working environment for the remainder of the 1980s and a good
part of the 1990s will be based upon the desktop metaphor of multiple applications
running simultaneously and generating documents that appear in overlapping windows on
a screen, we must make sure that any annotation systems that are created work over the
totality of that environment. Stated succinctly, group annotation functionality must be
integrated fundamentally into an already existing application architecture.

Specifically, just as our Intermedia hypermedia philosophy holds that all applications can
provide navigational linking by implementing a small linking protocol interface, it
follows that all applications should be able to provide annotation facilities by
implementing an even smaller annotation interface protocol. By implementing this
protocol, a developer can provide users with the ability to annotate documents created
with the developer's new application. Similarly, when users obtain a new application,
they can be assured that it will have annotation functionality, since annotation is a
fundamental part of the environment.

To this end, by extending our existing hypermedia framework to include support for
annotative collaboration in the form of warm links and annotation commands, we were
able to meet most of our requirements. Most significantly, we were able to provide
consistent annotation functionality across all applications within the Intermedia
environment, regardless of data type.

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