A Multimedia System for Authoring Motion Pictures

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ABSTRACT

MAD (Movie Authoring and Design) is a novel design and authoring system that facilitates the process of creating dynamic visual presentations such as motion pictures and lecture-demonstrations. MAD supports the process by enhancing the author's ability to structure and modify a presentation and to visualize the ultimate result. It does this by allowing both top-down design and bottom-up creation with a hierarchical multimedia document representation; by supporting the flexible inclusion and combination of words, images, sounds, and video sequences; and by providing real-time playback of the best approximation to the ultimate presentation that can be produced at any stage of the design process.

MAD represents a paradigm shift from traditional methods of authoring and producing motion pictures. Its development therefore requires in-depth observation of a variety of users working on a variety of filmmaking projects. After describing the key concepts underlying MAD and the current, second-generation prototype software, we describe a number of interesting applications of MAD. In doing so, we review how we have worked with users in an iterative design process and how studies of the work of these users have informed key design issues.

Keywords

Multimedia systems, multimedia documents, multimedia authoring tools, applications of multimedia, iterative design, user-centred design.

BACKGROUND

Computer technology has been used increasingly in motion picture production over the past decade. One of the most significant uses has been in *post-production*, including the very successful digital video storage, editing, and assembly systems (e.g., Avid, [4]). *Pre-production* application systems have included word processors and specialized script writing systems, systems for the design of storyboards, project management tools and spreadsheets used for planning and budgeting, and a variety of other authoring tools to be discussed below. Movie archiving and retrieval systems such as Media Streams (Davis, [11]) provide powerful mechanisms for describing video sequences with certain characteristics, for locating them in video archives, and for "repurposing" them. Yet there has been no system that allows the design and management of words, images, sounds, and video for visualization during the pre-production and production phases of a motion picture. As we shall see, providing design, management, and visualization support facilitates creative thought in the development of dynamic visual presentations for many kinds of applications involving many kinds of users.

Our concept (see also Rosenthal and Baecker, [37]; Rosenthal, [36]) has been influenced by precedents and ideas from other disciplines. In creating documents with word/outline processors, we can work either top-down and bottom-up, changing the approach from moment to moment, while there is always a viewable, printable document. In creating music with computers, we use systems that transact in melodies, timbres, rhythms, scores, and waveforms to define sounds, with a common underlying data representation and interchange format — MIDI (Loy, [22]). In creating software, we employ a variety of representations, both textual and graphical, at various levels of abstraction (Martin and McClure, [25]; Price, Baecker, and Small, [34]), and use these representations to support software development as a cooperative process.

As with word/outline processors, MAD supports both top-down design and bottom-up multimedia document creation. As with digital music, MAD provides a common data representation and interchange format. As with software creation, MAD incorporates a variety of visual representations in an attempt to facilitate creativity by users.

We now proceed to a discussion of MAD's design goals. We follow this with a discussion of the implementation, and a comparison of our approach to relevant research and to commercially available multimedia authoring tools. We review our iterative

design process, and describe how the system has evolved in response to feedback from our users. We then present a number of novel and sometimes surprising uses of the technology. The paper concludes with a discussion of current and planned work.

KEY DESIGN GOALS
Design goals for the Movie Authoring and Design system are:
• *Idea structuring* — the ability to develop movie ideas both top-down and bottom-up and to modify the structure with ease as new ideas arise
• *Multimedia support* — the integrated handling of scripts, dialogue or narration, music, sound effects, storyboards, and video shots
• *Visualization* — the inclusion of aids to visualizing the film, as for example being able to request a real-time preview of the movie or an approximation to it at any stage in the film development process
• *Interchange representations* — the provision of mechanisms for importing, exporting, and sharing movies and their constituent elements with other software and systems to aid communication and collaboration. (This topic will be discussed in the next section, Implementation.)

Idea Structuring
Films have complex structure. In traditional filmmaking, a substantial amount of time and effort is devoted to organization. Individuals will bring different cognitive styles to the organization and authoring process. This manifests itself in two ways, in terms of film structure and in terms of the script development process.

Some moviemakers will think of their films as a linear succession of ideas, sequences, or shots. Others will articulate concepts in terms of a hierarchical structure. For example, their films may consist of acts, which may consist of scenes, which may in turn consist of shots.

Some moviemakers want to have a high-level script outline written before becoming entangled with lower-level details: a top-down approach would accommodate this thinking style. On the other hand, as the film is developed, an outline will no longer be sufficient for expressing ideas; one may then want to work bottom-up adding more and more detail in a structured manner. Other filmmakers will work bottom-up from the outset, collecting material and then looking for methods of arranging and structuring it. Thus a good movie authoring tool must allow the user to work top-down *or* bottom-up as required, and to work at whatever level of detail is desired. A hierarchical structure facilitates this goal.

Multimedia Support

In the production of motion pictures, various documents are produced, such as written scripts and the sequences of sketches known as storyboards. The properties and uses of these various items are discussed in detail by Katz [21].

Scripts implemented on modern multimedia computers such as the Apple Macintosh can include more than just text, for these machines support additional "data types" such as pictures, digitized video clips, and sounds. Thus one should be able to pick up a microphone and record the narration, and be able to include sketches representing storyboard frames. One should be able to digitize video sequences corresponding to material already shot. A good movie authoring tool will allow the user to attach these elements to the script, and manipulate all this data in a uniform and integrated fashion. MAD does all of this.

MAD also supports multiple sound tracks which may be mixed together, such as dialog, background music, and sound effects. "Commentary tracks" allow layered discussion and metadiscussion in the style of the PREP editor (Neuwirth, Kaufer, Chandhok, and Morris, [30]). Users can add commentary tracks which, for example, discuss plans for the film. However, instead of being simple text comments, these commentary tracks can use MAD's facilities to include multimedia elements such as voice annotations, and the commentary tracks retain a direct tie-in to the underlying film structure. These multiple-track mechanisms may be applied either to particular items in the hierarchy or to the entire film. An application illustrating their use appears below.

Visualization
Despite the flexibility of working at any desired level of detail there remains an overview problem. A film has a certain character: elements of the film which step outside that character may not contribute to the film. Therefore a need exists to visualize the evolving "feel" and character of the film as it is developed. A crucial aspect of this is the timing and pacing of the action, an area where amateur filmmakers often have particular difficulty.

A good movie authoring tool should contain facilities for assisting the user in maintaining both an overview of the developing film and a good sense of how it is progressing. MAD has a "play" facility which allows an approximation to the final form of the film to be viewed on the user's workstation at any time. This can help prevent the author from being surprised at aspects of the final result by being aware of the emerging character of the film during scriptwriting. It will also allow an author to present the developing script as a dynamic demonstration of ideas in process for a film that has not yet been made.

Multiple representations of multimedia documents are also aids to visualization. Movie authoring tools should provide a variety of representations beginning with those that have emerged out of traditional filmmaking practice, such as scripts, storyboards, and movie playback.

IMPLEMENTATION

The current version of MAD (version 2.4) runs on an Apple Macintosh computer with System 7.5 and QuickTime 2.0 or later.

Idea Structuring

Apart from the content of the individual items, MAD resembles most of all an outline processor, structuring a document as a hierarchy of items (Figure 1). Although MAD imposes no structure, items and subitems often represent "acts," "scenes," and "shots", and have a variety of multimedia elements attached to them. New items can be inserted into any desired position in the hierarchy. Items can be moved from place to place within the hierarchy, taking all their subitems with them. Like a text outliner, MAD allows the user to contract items to exclude lower levels of detail. Similarly, the user can zoom in on a single item, in effect hiding higher levels of abstraction in order to focus on a particular portion of the multimedia document.
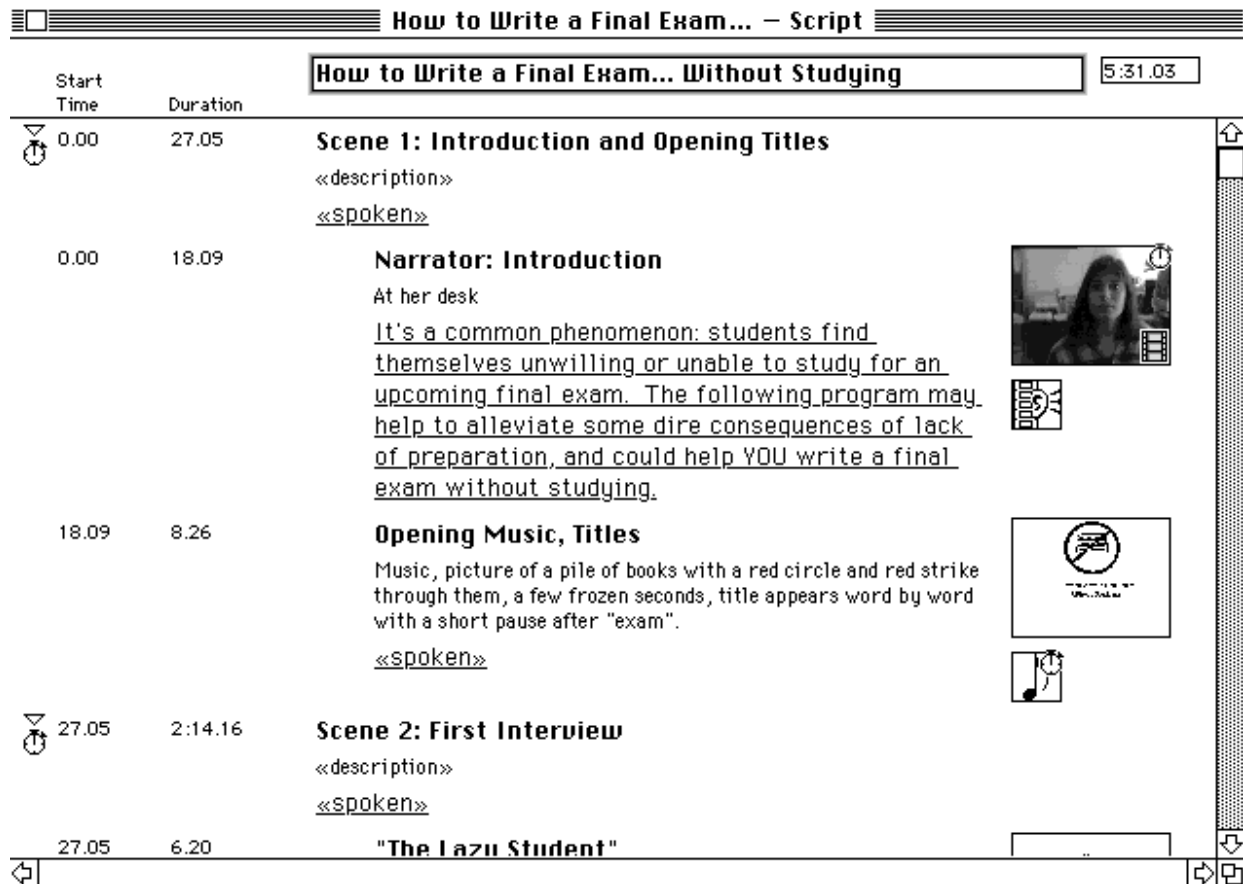

Figure 1: The script view. Hierarchical structure of items is indicated by indentation of the text. Each text item has 3 fields — title, screen directions, and narration or dialogue, and may also optionally have spoken text, music, storyboard frames, and video elements attached to it. These are noted at the right edge of the script.

The structure of the MAD document and its on-screen representation are kept separate, permitting multiple simultaneous views of the document. Currently supported view-types are Script, Storyboard, and Playback, but because of the separation between model and view, it is relatively straightforward to add new representations. The Script view is primarily intended for writing, and the items are arranged vertically, with indentation indicating their depth within the hierarchy (Figure 1). The Storyboard view hides most of the textual content of the items, replacing them with a grid-like arrangement of the graphical elements from each of the document's items (Figure 3). The Play view displays items sequentially, with each item being on screen for its indicated duration (Figure 2).

Multimedia Support

Each item can have attached to the script text various multimedia elements — still pictures; recorded narration, dialogue, commentary, music, or sound effects; and digitized video. Multimedia elements can be created in many ways. PICT and MacPaint files can be imported as storyboard frames; pictures can be drawn with MAD's rudimentary sketch editor. QuickTime movies can be imported with or without sound, and can be excerpted within MAD. Sound can be recorded, and narrative or descriptive text can be entered. Timing for the items can be based on their attached multimedia elements, or can be specified explicitly, when imported video or audio is not present or is not representative of the plans for the final film.

Visualization

MAD's multiple views are tools for visualization. Since each is parameterized, there are actually entire families of Script, Storyboard, and Play views. For example, only including the titles in the script view allows us to see a compact representation of the outline of the film. Other examples include varying the size of the frames in the storyboard view, and specifying whether dialog and director's notes are to be visible in the playback view.

The system also keeps track of timing information. Time is represented using hours, minutes, seconds, and frames as in SMPTE time code. Each item has associated with it two times: a start time and a duration. The start time is simply based on the duration of all preceding items in the movie. The duration for an item can be calculated in a number of different ways. If the item has an attached sound or video element, its duration can be used to determine the item's duration. If the item has subitems, the duration can be calculated from the duration of those subitems. Finally, the user can explicitly enter an item's desired duration. This is particularly useful in the early stages of a document's evolution, when an author may have planned lengths for the various scenes, but as yet have little or no material. In version 1 of MAD, each item had an actual duration and a planned duration, but this feature was difficult to explain to users, and in version 2 only the actual duration is included. Examples of how durations are used in planning and visualization are presented below.
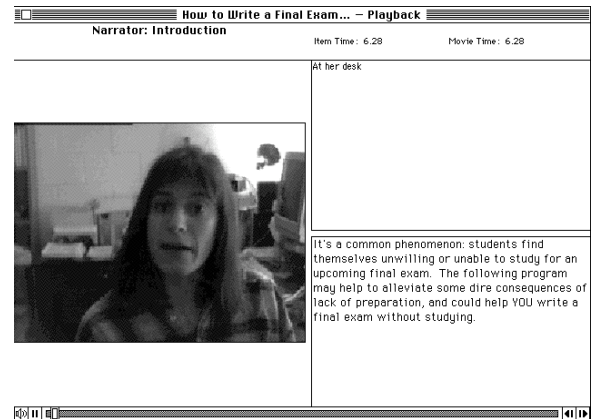

Figure 2: One of MAD's play views. Visuals, narration or dialogue, and screen directions appear in separate screen areas.
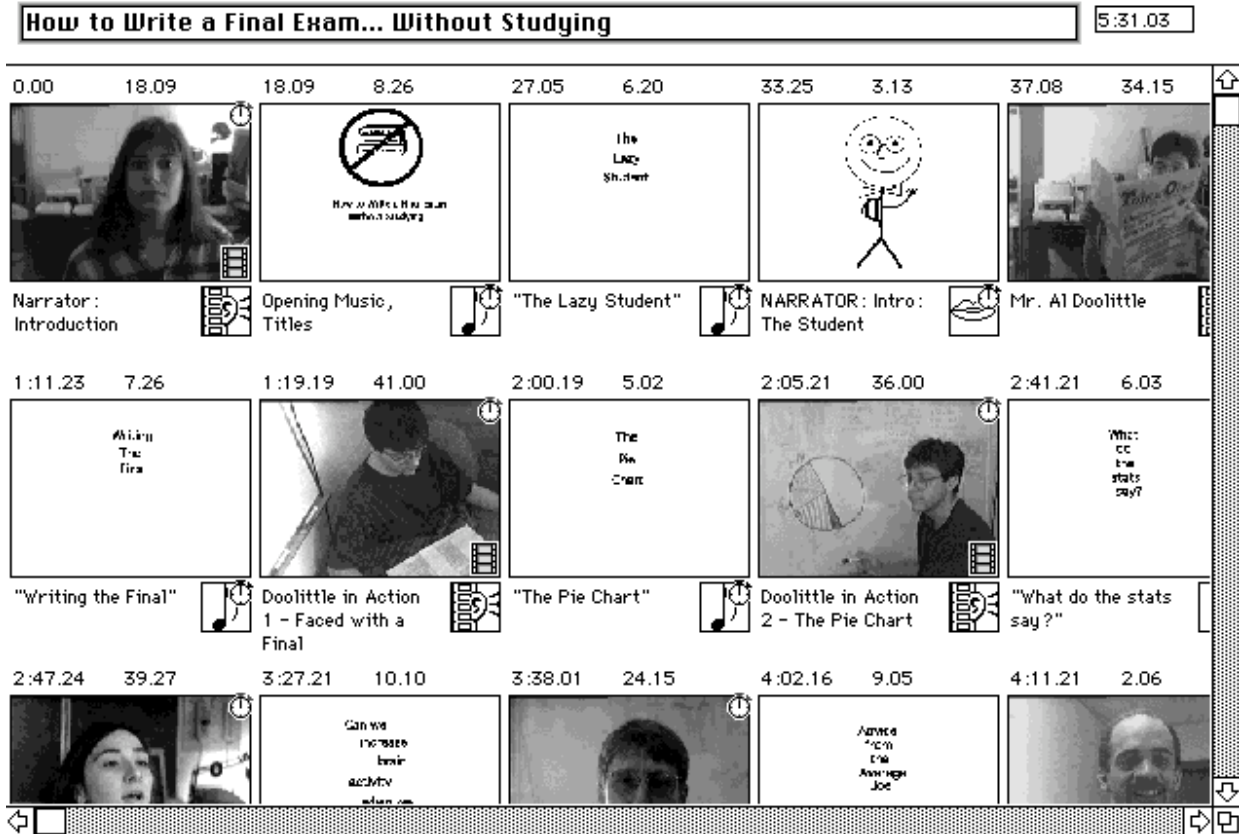
Figure 3: A storyboard view. All MAD views are parameterized. In this case we have specified the size of the storyboard frames and the additional details to be included in this view of a film by Naomi Friedlander.

MAD also supports varieties of playback which have different affordances for movie authors. For example, one very useful feature allows a viewer to see part of an item, then skip forward to the next item, which in turn can be viewed in its entirety or interrupted to skip forward to the following item. Use of this capability feels very much like flipping through the chapters of a multimedia book.

Interchange Representations

MAD documents are stored in files, and this alone provides an interchange representation of an author's ideas for a film. Two users can therefore collaborate on a film by exchanging MAD files. Furthermore, since MAD movies are represented as standard QuickTime (Apple Computer, [3]) files, they can be played back on a variety of non-Macintosh platforms. This also makes it possible for MAD movies to be viewed by other applications, integrated into World Wide Web pages, and played back by Web browsers.

COMPARISON TO OTHER WORK

Systems that support the entry and editing of textual or graphical representations of documents in some application domain are generally known as document editors, computer-aided design systems, or authoring tools. There is some relevant research from the academic literature.

Woolsey [42] suggests ways to develop multimedia based on precedents from "print, audiovisuals, speeches, activities, materials, and expression." Davenport, Smith, and Pincever [10] propose the use of film terminology and concepts for the organizing of video clips. Pea [31] describes a multimedia authoring toolkit consisting of programs for multimedia database access, storyboarding, and video-clip editing. Mills, Cohen, and Wong [29] propose an innovative Hierarchical Video Magnifier which allows users to view linear storyboards of fine levels of film detail while still seeing storyboards that provide an awareness of temporal context.

Ueda et al. [39] report on the use of computer vision techniques for the automatic computation of video structure, such as by cut detection and object tracking. Hardman, van Rossum, and Bulterman [18] and Hardman, van Rossum, Jansen, and Mullender [19] describe a system for structured multimedia authoring that employs both a hierarchy view of components and subcomponents and a channel view of what is happening over time.

Hudson and Hsi [20] present a kind of "multimedia through demonstration" system in which presentations are defined by "walking through" a screen presentation. McKay and Pagani [28] propose a novel system that incorporates scanning paper storyboards and coupling them to an interactive video editing subsystem. Geissler [15] report on browsers, maps, history lists, and tours as aids to navigation and visualization of movie-only hyperdocuments.

We have also recently completed a study of commercial multimedia authoring tools. These cluster into eight categories:

Script Writing Software
Script writing software (see, e.g., BC Software, [8]) is specialized to the task of facilitating the writing, editing, formatting, and printing of movie and television scripts.

Storyboard Design Software
Storyboard design software (see, e.g., PowerProduction Software, [33]) aids users in creating pictorial representations of a movie or presentation. Digitized graphics can be created, rearranged or removed in order to aid in creating and visualizing a concept.

Personal/Home Graphics Software
Personal/home graphics software (see, e.g. Delrina, [12]) provides children and adults with tools to create and maintain personal multimedia documents, such as journals, photo albums movies, and animation (see, e.g., Halgren, Fernandes, and Thomas, [17]).

Desktop Video Software
Desktop video software tools allow users to convert recorded video to a digitized form or digitally record live footage. Digitized film editing tools (see, e.g., Adobe, [1]) allow scenes to be cut, copied, pasted, faded in, faded out, merged, and modified.

Presentation Graphics Software
Presentation graphics software tools (see, e.g., Adobe, [2]) provide users with methods of organizing and exhibiting slide shows which can incorporate multimedia elements.

Multimedia Authoring Tools Without Scripting
Multimedia authoring tools without scripting languages (see, e.g., Pierian Spring, [32]) allow users to create non-interactive or interactive multimedia presentations without requiring or allowing the use of programming.

Multimedia Authoring Software With Scripting
Multimedia authoring tools with scripting languages allow users significant flexibility in tailoring all sorts of presentations, including interactive ones. An example is Director (MacroMedia, [23]), which employs a theatrical metaphor in a low-level visual scripting environment in which the behaviour of graphical elements known as cast members is arranged with respect to a timeline, or score.

Professional Multimedia Authoring Software
Professional multimedia authoring software allows users to create intricate and diverse presentations, either interactive or non-interactive. The previous two categories accomplish these tasks as well; however, this category was added to represent a more expensive class of tools which have more extensive functionality (see, e.g., MacroMedia, [24]).

Interpretation
MAD draws upon much of this prior art. For example, we heed the advice of Woolsey, Davenport et al., and Pea in drawing upon the traditions and terminology of film and other precedent disciplines. We share with Hardman et al. a commitment to the authoring of structured multimedia documents using a variety of metaphors and views. We share with Mills et al. and with Geissler an interest in novel representations of video content.

Yet MAD differs significantly from other existing filmmaking and multimedia systems. Unlike current script and storyboard tools used in film pre-production, it provides integrated multimedia support and real-time visualization capabilities. Unlike current desktop video software and presentation software, it incorporates a full motion picture metaphor. and is designed for use in pre-production and production. Unlike existing multimedia authoring tools, it facilitates and encourages a strong concern for narrative and dialogue structure. And, although the current implementation is only a start in this regard, MAD incorporates a rich and expanding set of visual representations of motion pictures designed to aid in imagining and visualizing film concepts. The system that is closest to the spirit of MAD is a low-end commercial digital movie creation system called QuickFLIX (Radius, [35]), which lacks a script view but does have a storyboard view and a timeline view.

OUR ITERATIVE DESIGN PROCESS
Although we have studied traditional filmmaking processes and achieved useful insights, especially about the roles of visualization and collaboration in the authoring process (Venkatacharya, [40]), we explicitly did *not* want to replicate traditional filming processes, especially the typical separation between pre-production and production.

MAD introduces a paradigm shift in the making of motion pictures. It allows the easy intermingling of pre-production and production. It allows film concepts to be made tangible, demonstrable, and accessible in a way not possible with traditional technologies. It

encourages tight artistic control by an "author" over all aspects of a production — words, images, and music. It also encourages the interaction by members of a creative team through an artifact representing the planned production in a way not possible with traditional technologies, in which words, music, still images, and moving pictures appear in separate media.

We therefore felt we had to build and refine a working and functional (not "smoke and mirrors") prototype in order to convey the concept before we could make the best use of domain expertise and user feedback. From the outset, we adopted a user testing methodology (McGrath, [26]) that eschewed the internal validity of standardized designed tasks in favour of the external validity of free form exploration by users seeking to make real films of their own devising. We have employed a variety of interview and observational techniques to study and learn from our users' experiences. Both adults and children have worked with MAD on over twenty-five 2- to 10-minute movie making projects, seven of which we describe below in the context of a discussion of applications of MAD.

The first project to be described (and actually the first executed) was a plausibility argument to show that we were on the right track. We used MAD ourselves in designing an 8-minute movie, and learned much about what we had done right and how much we still had to do. The second project was an extended study in which we videotaped 3 film-makers working on 2 films over 16 hours, and analyzed their work process both quantitatively and qualitatively. Based on insights derived in these two major uses of the system and several minor uses, as well as some screen design prototyping exercises, we planned and carried out a reimplementation of much of the system's interface and internals.

The third project was our use of MAD to plan and write a lecture-demonstration of MAD. The fourth project consisted of participant observation of the creation of short films by an 11-year-old and a 12-year-old. The fifth project involved video taping a small group of novice filmmakers working for 3 hours on the high-level structure of a film they were about to make.

The sixth and seventh projects are still ongoing or being analyzed. The former project involved 24 seventh-graders learning to make short movies using MAD and other multimedia tools during a 2-week summer camp under our guidance as participant-observers. In the seventh project, we were also participant-observers, but here school children and their teacher were using MAD to help them think about and discuss how they learn. Qualitative and occasionally quantitative analysis have yielded design insights which we shall discuss below.

APPLICATIONS OF MAD

MAD is a versatile tool that can be used for many different purposes including:
• Sketching, designing, thinking about, blueprinting, authoring motion pictures
• Developing, presenting, and selling film, video, advertising, and multimedia concepts
• Brainstorming, planning, structuring, and executing lecture-demonstrations and multimedia presentations
• Teaching filmmaking to novices; novices learning filmmaking
• Kids making films
• Encouraging and facilitating reflection on and dialogue about classroom practices by students and teachers
• User interface prototyping
• Usability testing of new technologies
• Multimedia messaging over the Internet.
Let us now look at each of these uses in turn. Most of the uses will be illustrated with a real example.

Authoring Motion Pictures

In September 1993 MAD was used to design a movie (Baecker, Glass, Mitchell, and Posner, [5]) to demonstrate the SASSE collaborative writing system we were developing (Baecker, Nastos, Posner, and Mawby, [6]). The senior author had previously produced a number of short films.

First a very top-level outline of the film was defined, a listing of the acts of the production. Next, shots for the first few acts were proposed. We then took each of the acts in turn and began to draft suitable narration for the script. The narration was recorded so that times could be estimated and judgments made about film flow, timing, and pacing.

The material required three kinds of shots. Shots of the narrator were indicated in metatext describing the shot and also in "storyboard frames" containing text only. Longer descriptive metatext was entered as shooting instructions for the camera crew that would later film user interactions with the SASSE system. Finally, where suitable video clips existed, we imported them into MAD and viewed them in the context of the emerging production.

Playback of the movie was of course incomplete, but display of the script, reading of the narration, display of the storyboard, and screening of the video clips in correct order and with correct timing sufficed to convey a good sense of the whole and to guide the authoring process.

We used MAD for roughly 6-8 hours in this way. Because the film crew was coming the following day, and MAD at this point didn't deal with hard copy or still images very well, two members of the team switched to a traditional word processor and markups

of paper printouts to produce a final script and shooting instructions for the director and film crew. After filming was completed, a traditional computer-based editing console was used for title generation and post production.

Despite the flaws of the early prototype, MAD allowed us very efficiently to develop and refine a concept for the movie, write and edit the script, revise the script after hearing how it sounded and how it flowed, and preview likely video sequences for inclusion in the film in the context of a playback of a very rough but continually improving approximation to what the final film would be like.

On the other hand, there was clearly much room for improvement. For example, we could see the utility of allowing audio and video tracks belonging to one item to start at different times, a serious complication to our very simple item model which we still have not undertaken.

An example of another MAD motion picture is illustrated in Figure 4. Requirements for its production caused us to generalize our model of audio tracks so that they could be attached to items located anywhere within the movie hierarchy.
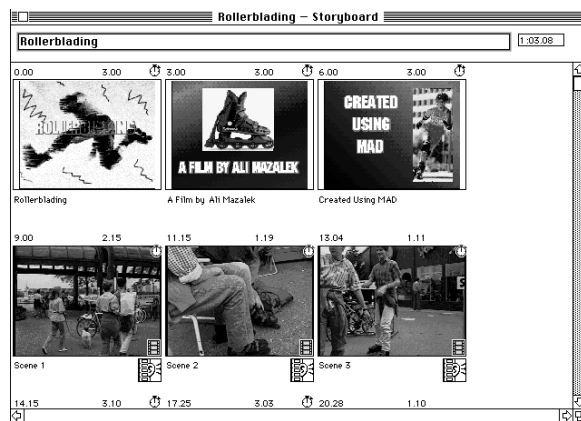

Figure 4. A partial storyboard for Alexandra Mazalek's rollerblading film. This was developed in MAD primarily with pre-existing footage.

Pitching Film Proposals
In the summer of 1994, three undergraduate students (two who had never made movies before and one moderately experienced film-maker) entered a user interface design competition for which they had to create a variety of materials documenting their research, designs, and user testing. One of these materials was to be an ten- to fifteen-minute interactive presentation of their interface design in MacroMedia Director, and another was to be a ten-minute video describing the design and testing process.

MAD assist the students very effectively with their authoring process. In 16 hours with MAD, and additional work off-line, they created a fairly complete script and production plan for the video and to some extent for the interactive presentation (Figure 5).

The students were videotaped with 4 cameras while they were working with MAD. We analyzed the tapes for MAD feature use and took supplementary notes using MacSHAPA (Sanderson et al, [38]), an application program for the Macintosh that controls a VCR and facilitates notetaking about a tape's interesting events.

The test proved to be a rich source of information, confirming the usefulness of some features, identifying serious problems with others, and also suggesting that some future directions we had in mind were likely to be of value. Of particular interest was the use these individuals made of multimedia presentations of film concepts for purposes of communicating and "selling" ideas among themselves. This suggests that the "play" feature may be effective for "pitching" ideas for films, videos, and multimedia presentations to collaborators, managers, clients, and potential sponsors.
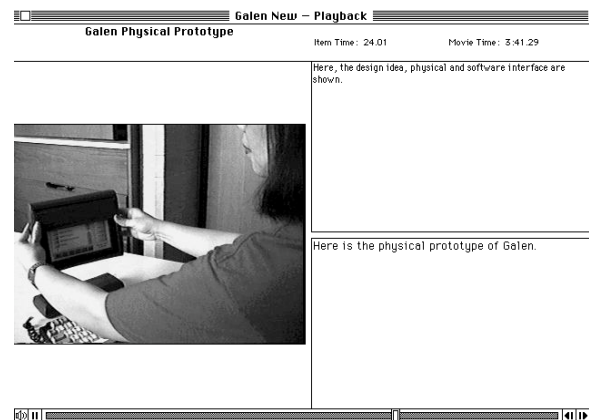

Figure 5. Image from a film documenting Project Galen. This project submitted a prototype of a hand-held, Internet-connected device for patient medical education to an international design competition.

Planning Lecture-Demonstrations
In April 1996 we were planning a demonstration of MAD (Friedlander, Baecker, Rosenthal, and Smith, [14]) for the SIGCHI Conference. Our 30 minute presentation was intended to contain lecture and demonstration, high-level concepts and low-level detail, creation in real-time of a MAD movie as well as review of already completed motion pictures.

We used MAD to aid in the brainstorming, planning, outlining, and writing of the script for the lecture-demonstration. The evolving script represented the working model for our talk. Because it was tangible and printable, we were able to print it, review it, and

conceptualize it. Because it was editable, we were able to modify and evolve our concept with ease.

Of particular utility was the ability to record narration or dialogue and insert it into the script. We used this to ad lib portions of the talk and then review how they felt in the context of the evolving whole.

Kids Making Films
In August 1995 an 11 year old girl (Aha) and a 12 year old boy (Ethan) separately created movies using MAD.
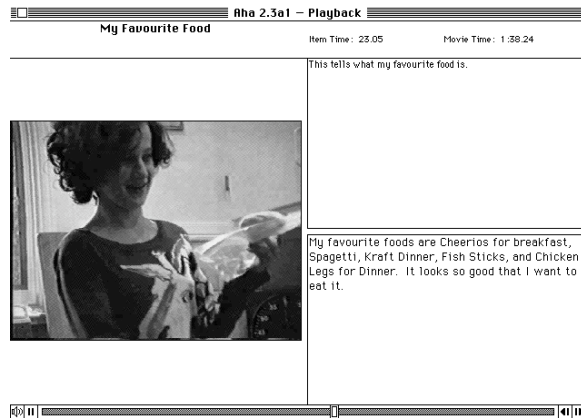

Figure 6: Image from Aha's movie This playback view shows narration and director's notes.

In her first hour with MAD, including being introduced to the system, Aha wrote a rough script for a 2 minute film, "A Movie About Me," based on a template we had created which provided a rough outline for an autobiographical movie and ideas for possible scenes. She recorded visual placeholders for all scenes on video, and thus had completed a "draft" of her movie. She then went out and did the location shooting implied by her script. Finally, she returned to the lab to digitize various video shots and still photos and assembled the result into a final movie (Figure 6). Total time expended was roughly 8 hours.

Ethan used MAD during 3 sessions totaling approximately 9 hours, creating a movie about Arab Mythology based on material from a book. He had decided to organize scenes using roughly the same outline as found in the book. Short introductions to the material were included among narrated passages from the book. After considering visuals to accompany these passages and how to include sound effects, Ethan drew some pictures, recorded some sound effects, and shot some more video. The result was an interesting movie (Figure 7) that allowed him to explore the use of a variety of multimedia resources.
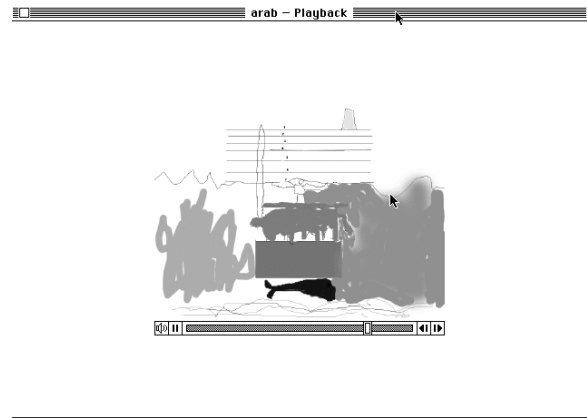

Figure 7: Image from Ethan's movie. Here we see the more movie-centred playback view in which only images are shown.

In these projects MAD accommodated two radically different approaches: Aha's film was organized hierarchically, and was composed predominantly of video footage, much of this shot on location, as well as some scanned photographs. Ethan's movie was organized linearly, and was composed predominantly of recorded narration over still drawings, with some video footage and sound effects.

As always, these users forced us to challenge assumptions we had made. We had viewed MAD as a design, authoring, and visualization tool, not as a production tool, so we had not implemented the ability to output the final result to videotape. Our young users insisted upon having copies they could take home, so we happily added this feature.

Teaching and Learning Filmmaking
In May 1995 another group of students at the University of Toronto were selected to present a novel interface design at an international competition. None of the participants had any filming experience. The group used MAD to help design a video presentation during 2 work sessions totaling approximately 6 hours in length, about 3 of which were solely dedicated to using MAD.

The analysis of videotapes made of the sessions showed that MAD helped the group with its idea development. Initially, they had no script for their video and no concept of what should be included in the final product. After working with MAD for 40 minutes they had outlined their film in terms of 6 scenes and had given each a title, brief written descriptions of what would be shot and what would be said, some improvised spoken narration, and a sketch or digitized image as a visual reference. For the first time, they were starting to see how they might organize the film and what the final product could look like.

The target length of the movie was 10 minutes. Since the duration of a scene could be chosen from various candidate durations (such as the length of a movie or narration attachment) or manually entered, the group was able to visualize more easily how close they were at any one time to reaching target durations for particular scenes.

For example, when working on a scene intended to be 30 seconds long, where 10 seconds of video footage had been recorded and where 20 seconds of narration had been scripted, the group members were now able to visualize how much time remained of the allocated 30 seconds once the video clip and narration had ended. As inexperienced filmmakers, they found this very valuable, particularly because MAD allows visualization of the timing of multiple media streams in parallel, in this case video and narration, and also of the timing of items *in context*, that is, with respect to their inclusion in a sequence of items.

Following up both on this experience and on the work of Aha and Ethan, we decided to carry out a more significant test of our hypotheses that MAD provides an excellent environment for teaching principles of filmmaking and multimedia creation, and that it can be quickly learned and effectively used by school children. Thus in July of 1996 we used MAD in a multimedia summer camp held in Toronto.

The camp was designed to test MAD in a classroom-like setting where groups of students would work together to learn new technologies and use their creativity to produce movies. We compared MAD to a control condition consisting of a word processor and a digital movie editor. The editor allows a computerized "cut" and "paste" of digital video and easy creation of digital movies but does not provide MAD's organization and media integration capabilities.

We hypothesized that MAD, compared to the control condition, would allow students to make movies faster, to explore more variations within their movies, to learn more about filmmaking, and to make better movies, and that students would prefer MAD.

The camp counselors (4 camp counselors, and 3 camp assistants, selected from the high school that hosted the camp) were trained in the use of the software. They made two movies using the same software conditions as the campers (i.e., control and MAD). Following the training, a pre-camp was held with a different group of campers. This pilot study enabled us to refine our methodology and data collection methods and also served to give the counselors valuable experience.

For the actual camp, a total of 24 campers were randomly picked from among interested grade 7 students from a local school district. The camp was run for a two week period with twelve students attending each week. The students were divided into four groups of three. Assignment was controlled to ensure that students were from different schools and that the computer experience across groups was balanced. Each group made two movies, one in each software condition. Half of the groups were randomly assigned to each of the two orders of working with MAD and the control software.

A wide variety of experimental instruments were used. These include raw video footage, digital records of movies at various stages, paper artifacts, several questionnaires, discussions with campers and counselors, paper logs and audio journals, and video records of some of the students' interactions and work.

The camp was a success. The children learned how to make movies, produced two interesting pieces of work in each group, and enjoyed the experience. As expected, MAD proved useful and usable for the task. Initial analysis of the campers' questionnaires indicates that campers found MAD easier to use for movie-making than the control software (t=1.64, 21; p<.059), and that 91% of the campers preferred MAD (9% had no preference). Further analysis of this study, including insights into work process, appears in Baecker et al. [7].

Supporting Reflection on Classroom Process
In February of 1996, Dr. Andrew Cohen, a post-doctoral researcher spending part of his time with our group, began an innovative application of MAD in the Nashville Public Schools. MAD's multimedia authoring tools allow the process of classroom activities to be (a) captured by students and teachers themselves, and (b) easily reflected upon and voice annotated by the viewer. Annotated videos can also be the object of inquiry by teachers.

Groups of two or three 11- and 12-year old school children and their teacher record on videotape seven to ten minutes of their own collaborative mathematics problem solving process. They enter this sequence into a MAD movie, and then review it, producing a meta-movie in which each student overlays as an additional audio track his or her interpretation of what was going on. The result becomes a tangible, shareable, discussible artifact embodying the collaborative learning process. As it evolves, it engages student and teacher alike in reflection on and enhanced understanding of that process (Cohen et al, [9]).

Dr. Cohen's approach builds on other attempts to use video as an aid for reflecting on classroom practice. For example, viewing videos of one's own and a peer's teaching practice has been shown to be effective in motivating change in classroom practice (e.g. Fredrickson, [13]), while viewing videos of expert

teaching practice has been shown to facilitate 'noticing' relations between theory and practice (Michael et al., [27]). However, MAD allows students and teachers to take over the process of reflection and allows the documents to be archived and reviewed with annotations for continual professional development as opposed to short duration workshops. Cohen plans further studies of this kind involving groups of teachers as well as groups of students.

User Interface Prototyping

User interface designers often produce animated or video scenarios in the early stage of conceiving and prototyping new systems and interfaces (Vertelney, [41]). Because MAD encourages a thoughtful, structured development of an audio-visual presentation, it affords significant advantages for uses of this kind.

Usability Testing of New Technologies

Imagine you are making a film called "X". To do so in MAD, you open a window called X and engage in various activities such as writing dialog, recording sounds, and digitizing video. MAD allows you to work on several movies concurrently, so you also create a film called "The Making of X." In this meta-film, you enter various remarks about your ideas and thought processes in designing X. You can also enter screen snapshots that represent stages in the development of X's script, and can even record video depicting your work on X. Furthermore, you can also document problems in the process, whether these are conceptual issues in the design of the film, features desired but currently lacking in MAD, or bugs in MAD. We have used MAD in this way to good effect. Since MAD can be so used in conjunction with applications other than MAD itself, MAD is a useful general tool for usability testing.

Multimedia Messaging Over the Internet

Finally, our newest endeavor is to explore high-bandwidth multimedia collaborative environments. The goal here is to investigate the affordances of "multimedia mail" for communication and collaboration. Here we are attempting to link together a multimedia representation of the knowledge about and the problems collaborators are working on, with their discourse (textual, audio and video) about that problem. This work capitalizes on the fact that MAD stores films as QuickTime files. Therefore, MAD movies can be played back by standard QuickTime players including those incorporated in other applications such as Netscape. This makes MAD the "messaging" tool for constructing and refining multimedia messages to be transmitted over the Internet.

As an example of an investigation in progress, consider the work described above with teachers and students using MAD to produce and reflect upon their mathematics problem solving in the classroom. Our goal is to establish communities of teachers and students in geographically distributed regions discoursing about teaching and learning. Using MAD, however, the teachers and students would not only be able to talk about what their doing, but they would be able to make the process of teaching and learning visible to the community as a conceptual anchor for their discussion. Rather that have that discussion solely in a written mode, teachers and students could make use of the additional rich communicative affordances of multimedia formats.

SUMMARY AND CONCLUSIONS

We have completed a prototype of MAD, observed its use in over twenty-five short productions, redesigned the user interface based on these experiences, and re-engineered it for greater reliability and flexibility. MAD has proved useful, usable, and robust for small filming projects. It has been used successfully and enthusiastically and with only minutes of training time by amateur filmmakers as young as 11 years old who have never made a movie before. Careful observation and study of individuals working on these projects has yielded significant insights into system functionality and user interface and into ways of thinking and working while using MAD, which in turn has enabled us to improve MAD through an iterative design process grounded in realistic user experiences.

FUTURE RESEARCH

Our major current goals are:
• to explore further the use of MAD both by novice and professional filmmakers
• to extend the uses of MAD to allow the creation and annotation of informal video documents
• to extend the mechanisms by which such statements and records can be transmitted via Internet transmission and viewed via remote playback
• to enhance MAD's capability to manage libraries of video sequences and to represent alternate "takes" when the filmmaker is not sure how best to express an idea.
• to extend MAD's metaphors and representations to support the creation of dynamic visual sequences with mechanisms other than scripts and storyboards
• to investigate collaboration in the process of designing movies with MAD (see, for example, Gidney, Chandler, and McFarlane, [16]).

One major stream of research deals with process and representation. We have to date identified four major approaches to authoring motion pictures:
• a script-based approach, typically used by the screenwriter
• a storyboard-based approach, typically used by the production designer

• an available shot-based approach, used by directors and editors
• a flow- and timing-based approach, used by directors and cinematographers.

Each approach requires different visual representations of the movie and different interface mechanisms. Our hypothesis is that a system that supports these four points of view will support different cognitive styles as well as collaboration among different supporting disciplines. We anticipate that supporting a greater variety of working styles will enhance creativity by allowing filmmakers to switch modes of work as is suitable for authoring different portions of the film. For example, film sequences can be entered and edited using the storyboard view as well as with the script view.

We have identified many professional uses for MAD, in the creation of dramatic, documentary and training films and video, in the design of animated films, in the planning of radio shows and museum exhibits, and, ultimately, in the creation of interactive multimedia. MAD can be used both in production and in pre-production, for sketching concepts ("dynamic film treatments"), selling concepts, developing concepts ("animated scripts"), and executing concepts ("rushes in context").

Yet lately we have begun to believe that the major impact of MAD may be in working with amateur authors, storytellers, filmmakers, and communicators. We anticipate children working on video scrapbooks and diaries, messages to parents and politicians, documentation of what and how they have learned, and statements about themselves and the world in which they live. They will then be able to write their creations to video tape, and, increasingly, be able to ship them as video mail over the Internet to friends, electronic penpals, and other children located elsewhere in the world.

We shall investigate in the next 2 years if students can go beyond the basic use of the tool to a more sophisticated discipline which involves the careful crafting of various media representations such as script or storyboard, which may involve collaborative work by multiple contributors bringing different skills to the endeavor, and which must involve thoughtful critiquing and iteration upon the result in order to produce the best possible product. If we can achieve this, we believe that tools such as MAD supported with reasonably straightforward learning materials can enable a powerful and compelling new classroom literacy for telling stories, exploring concepts, and expressing ideas.

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