DYNAMICALLY ALTERABLE VIDEODISC DISPLAYS

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ABSTRACT

To date, the field of training has used the traditional "media" of books, motion pictures, and computers for development of training programs, though each has its own distinct advantages and disadvantages. Now, the combination of computer graphics and computer controlled videodiscs provides a new medium for the display of images, text, and sound. Materials are presented on computer-formatted video "pages" of high quality text and color images, which may be single illustrations or sync-sound movies.

Data is stored on the optical video disc in the forms of pictures, sound, and digitally encoded data; interaction is via a touch sensitive video screen that allows control of page format, level of complexity, style of presentation, and individual annotations. The system is characterized by the qualities usually associated with books, but augmented by the dynamics, sound, and color of the videodisc. The prototype presented is for training in the operation, maintenance, and repair of an automatic transmission, though it may serve as a model for other systems.

This research has been produced at the Architecture Machine Group at Massachusetts Institute of Technology, part of the emerging Arts and Media Technology program.

KEY WORDS: computer graphics, digital video, optical videodisc, interactive systems, training, human-machine interface.

1.0 Introduction

Many training manuals offer hundreds or thousands of pages of small print text with occasional illustrations as the only avenue of learning how to maintain and repair complex devices. This approach works for some highly motivated people, but for many it creates a larger problem than the initial challenge of peforming the correct repair. And even those manuals that are clearly written and well illustrated are limited by the intrinsically flat, static, and silent nature of the book.

Efforts at developing improvements led to combinations of programmed workbooks, filmstrips, audio cassette recorders, etc. but unfortunately many of the drawbacks were unremedied. Training films and videocassete "learning labs" added some dimensions, but still limited the user's opportunities for interaction and digression. Some traditional values were often lost in the trade, compounded by technical problems of projector threading problems, tape damage, and lackluster programming material.

The computer-aided instruction field (CAI) emerged, and software systems became more individualized and viewer controlled, but lacked good imagery, and were often restrictive in terms of the "branches" a user could select. Full blown computer-based simulators created a responsive and often highly realistic environment, but usually at great expense.

The optical videodisc under computer control offers the ability to create training systems that have the best features of books, movies, and computers while surpassing their individual limitations. A training manual that provides movies with live sound, narrated slide shows, interactive device simulators and a reference encyclopedia in addition to the traditional pages-of-text-with-pictures creates a rich resource for learning. A user can train in the preferred manner and pace, and maintain his or her interest while learning to understand the subject and perform competent repairs.

The "Movie Manuals" project at the M.I.T. Architecture Machine Group is such a system, which uses dynamically alterable videodisc displays to produce the varied environment needed for training in maintenance and repair. Optical videodiscs under computer control exploit the disc's full potential as a storage medium for pictures, sound, and data at extremely high density. The user's interface to the system provides natural, easily learned techniques for access to the wide range of information available. The system in progress is the prototype for a personalized, portable toolbox aid in the context of operation, maintenance, and repair of an automatic transmission [1].

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2.0 Disc Operation and System Organization

The videodisc is a technology that has been under development for over twenty years [2], and has resulted in consumer and industrial devices of various different formats [3], [4]. It is a device that utilizes a cheap, standardized technology driven by a mass consumer market, but it is also a powerful computer peripheral that stores color images, high quality sound, and digital data, all randomly accessible in a short time.

The disc's random access feature, and its ability to display a single frame indefinitely are its most dramatic advantages over film or video tape. These make possible freeze frame, and variable speed play in forward or reverse. Dual audio tracks allow stereo sound, or separate use of each track, or a mixture. Most importantly, the order and even the speed of the imagery need not be predefined and unchangeable [5].

The Movie Manual system is based on the laser optical-reflective disc format (adopted by DiscoVision Associates, N. V. Philips, Sony, Pioneer, and Magnavox). The system utilizes two players with identical discs which allow simultaneous output and search in a double buffering manner. Images from one of the discs (selected by a computer controlled switcher) are mixed with computer generated graphics, and displayed on a standard video monitor, which has a touch-sensitive overlay. The monitor, along with loudspeakers, constitutes the user station (see Figure 1). This arrangement has proved useful for previous training applications [6], and spatial/mapping simulators [7] [8].

3.0 System features and Use

The videodisc and computer-based Movie Manual is the intersection of three well known instructional media -- books, cinema, and the computer. It borrows familiar features from all three as a basis for inventing new features with a familiar feel.

3.1 The Movie Manual is a book

Books are nearly ideal devices, dense in information, inexpensive, and portable. Videodiscs, too, are a uniquely dense medium, with one side's capacity of 54,000 frames -- full color pages of a book thicker than any encyclopedia. Digitally encoded data on videodisc enables even more dense storage of text.

The contents of a book are presented in a highly organized form, but without demanding that the reader either follow that form, or procede at a fixed pace. Familiar navigational aids, such as the table of contents, section headings, and the index, enable searching and random access of specific materials. A page, or still frame, on an optical videodisc can be scanned over and over until it makes sense, or flipped over on the way to something more interesting.

Constructs for scanning and flipping and other book use behaviors have been preserved in the Movie Manual. Stroking a corner of the touch-sensitive display in one direction advances to the next page, while the opposite direction produces the previous page. Video bookmarks and "dog-ears" are easily remembered by the computer for personal landmarks, and can even be given temporal or informational modifiers; the user need never run out of fingers for temporarily holding places.

The Movie Manual system includes a frame buffer for displaying digitally stored text and graphic controls keyed over video. With software no more complex than a rudimentary paint program, the Movie Manual user can make written and graphical annotations as simply as writing notes in the margin of a book (see Figure 2). In highlighting text, scribbling comments or questions, or drawing moustaches on pictures, the user makes the movie manual his own, an object as intimate and personal as an old worn paperback.

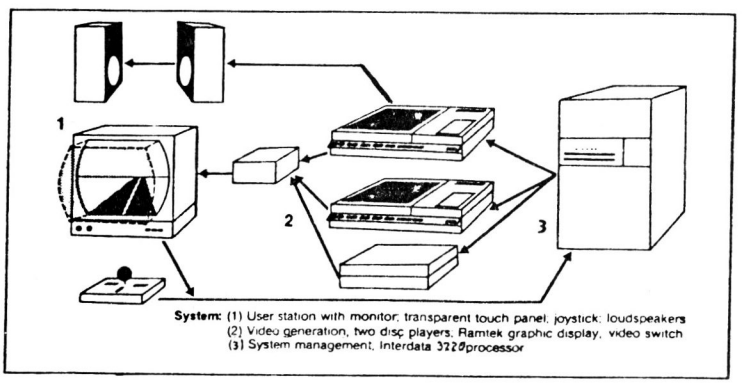


Figure 1. - System Configuration

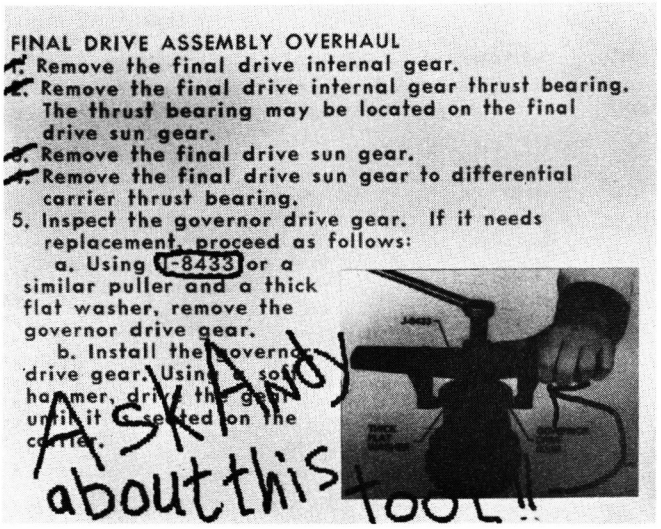


Figure 2. - Written Annotations

3.2 The Movie Manual is a movie

As an instructional aid, cinema (film and video) can convey the flow of activity that books can only describe. This is particularly relevant for maintenance and repair manuals where the viewer can observe nuances of behavior such as the amount of torque to use in tightening a bolt, or how freely a bearing assembly should rotate, which are lost in text or numeric description. Sound brings a new dimension to the learning experience both as incidental data -- the clicks of a socket wrench defining the speed of disassembly -- or explicative narration. Naturally, the videodisc retains all of these features.

Small-format videotape introduced a new era of portability and ease of operation to cinema production and viewing. Users could more easily control the rate and sequence of presentation by stopping and repeating segments of a tape, or scanning forward. Optical videodisc provides even more extensive control on a medium that, unlike videotape, is virtually impervious to wear. Freeze framing, reverse play, and variable playing rates are features available to the Movie Manual viewer to permit detailed study of live sequences.

3.3 The Movie Manual is a personal computer

Timesharing operating systems made significant computing power and storage available as personal, immediately responsive resources. The personal computer returns us full circle to the single-user computer, but in a potentially portable and inexpensive format. As an individual resource, the computer has been the foundation for instructional systems that base their behavior on the current context and the user's past performance. In the worst cases, this has been little more than programmed instruction where the computer administers the questions and answers. More ingenious systems, like Logo and Plato, encourage the user's desire to explore and create his own learning environment, showing that one of the best ways to learn is to teach others (i.e., the computer) what to do.

For the Movie Manual, a transmission simulator was created [8a] which allows the user to vary the inputs to the transmission (e.g., gear selection, throttle position) and observe the outputs at various stages as torque and rpm's (see Figure 3). Sub-assemblies of the transmission, such as the planetary gears and the torque converter, are modelled as black boxes in the overview simulation, but may be "opened up" for experimentation by request. All of the software necessary to describe the simulator mathematically and graphically can be included on the videodisc as digital data, and might also include an audio track of the sound of the engine as the car speed varies. The disc-based simulator provides two powerful modelling features. First, the simulator is "differentially expandable" in that the sub-assemblies or functional parts may be developed to different degrees of complexity, as the user chooses. Second, the limit of complexity does not end at some detailed schematic diagram, but in fact goes all the way to "live" movie imagery of actual parts functioning in a working environment, complete with synch sound.

Conversation with a computer is traditionally conducted through a keyboard, and for programming and word processing tasks this is probably most efficient. For more heuristic tasks, with fuzzy queries and sketchy approximations, a less rigorous syntax is desirable, one more attuned to natural human conversation and gesture. The transmission simulator is controlled through direct touch interaction with its computer graphic elements, via a touch-sensitive display. An inexpensive, limited vocabulary speech recognizer may also be used for common commands such as "faster!", or "stop" or "help".

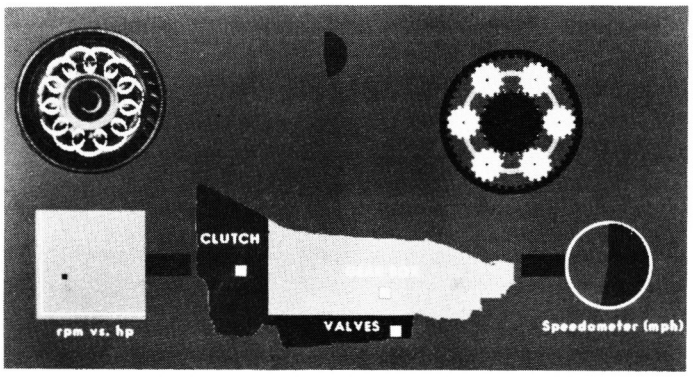
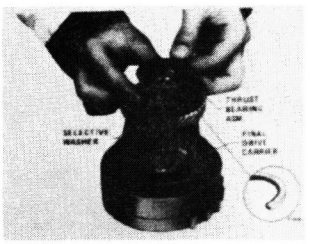


Figure 3. - Transmission Simulator

3.4 The Movie Manual is a new medium

The Movie Manual project borrows interaction features from books, cinema, and computers as instructional media to provide a familiar, comfortable environment for users, and as a foundation for inventing new manners of human-machine conversation. An instructional system that puts new users through mysterious rites of initiation with arbitrary command syntaxes or procedures is bound to lose their attention in short order. But if a comfortable rapport is quickly established, new features can be revealed that delight the user, and encourage him to venture into new ground.



FINAL DRIVE ASSEMBLY

The final drive assembly is a planetary gear set consisting of a final drive internal gear which is splined to the transmission case, a final drive sun gear which is splined to the final drive sun gear shaft, and the final drive planetary pinions which are located in the differential and final drive carrier assembly. This gear set operates in reduction at all times. Power through the final drive sun gear shaft drives the sun gear in a clockwise direction. Since the final drive internal gear is splined to the case and will not rotate, the differential and final drive carrier assembly will rotate in a clockwise direction.

Figure 4. - Text Keyed Over Videodisc

Perhaps the most ubiquitous display surface of all is the page, with text, graphics, and illustrations. In the Movie Manual, these page elements exist independently on the videodisc. Text is stored digitally, in ASCII format, or in pre-composed pages on single videodisc frames with open windows for illustrations. Several different illustrations might occupy the same frame (see Figure 4); a page of text is then keyed over the multi-image frame, revealing the selected illustration through the open window. Graphical page design elements, such as borders and column rules, are also stored digitally as computer graphic primitives. This digital video "cut-and-paste" approach permits dynamic page composition, personalized to the user. For example, the user may select a more readable type font for display of the ASCII text, or decree that illustrations be for a left handed point of view (see Figure 5).

With the inherent dynamics of videodisc and computer, passive page elements of the Movie Manual can become active, as the name "Movie Manual" would imply. In the simplest form, a static page is accompanied by spoken narration from the videodisc audio track. At the user's touch, a quarter page photograph bursts into action as a sync-sound movie, demonstrating the repair process described on the same page. The quarter page movie can be played in slow motion, forward or reverse, or expanded into a full frame for detailed study.

Schematic diagrams are familiar illustrations in instructional texts, useful for abstracting complex processes or assemblies into easily understood graphic representations. But a single diagram can only show a single viewpoint of a device, or a single state in a device's operation. Movie Manual diagrams are active elements. A transmission part might be represented as a series of photos or line drawings of the part from different views, ordered on videodisc so that the user may change viewpoints smoothly, to turn a part around or even disassemble it into an exploded view by touching it.

The visible entry to the simulator is through its use as a functional schematic diagram, showing the overall flow of power through the transmission; the illustration on the page becomes a computing surface when touched. Some elements in the diagram are active input controls (e.g. a throttle peddle, a gear select lever), which determine the input parameters to the simulator. Other elements represent the outputs of the simulator that change as the state of the system changes. Thus, a page illustration need no longer be a permanently fixed element, but can respond to the user's touch, and retain the impression of that touch for as long as the user desires.

Words, too, are active elements in the Movie Manual. Touching a word might activate one of many functions. New words can explain themselves by retrieving their definition from the builtin glossary. Similarly, a word or phrase is an entry into the index, where other occurences of the word may be found and examined; the index itself is a vast cross-reference of the information on the videodisc Movie Manual. There is nothing new about glossaries and indexes. However, the speed of the computer with the dense, random access of the videodisc brings these resources literally to the user's fingertips in an instant. Then, as book conventions or constructs, the glossary and index become invisible parts of the data base; touching a word doesn't go to an index, but to what an index would provide for that word.

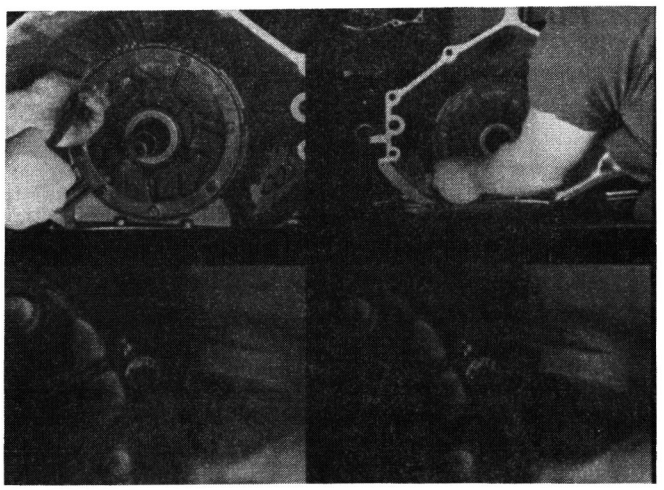


Figure 5. - Right-hand / Left-hand Alternatives

3.5 Functional forms of the Movie Manual

The Movie Manual introduces some new presentational forms that intentionally have the flavor of familiar forms of familiar media. There is yet a major leap to be made in organizing these forms into coherent educational experiences for the user. Three general schema for presentation are being investigated: the tutorial, the lab kit or simulator, and the encyclopedia. This set is in no way exhaustive, nor are the elements mutually exclusive. Still, they provide a useful framework for developing and evaluating new means of interaction and organization.

The simulator allows the user to learn the fundamentals of operation of the device; furthermore, the complexity of the model can be expanded to more closely approximate the actual behavior of a real device. Through this successive revealing of more information as it is needed, the user can build his or her own mental model, and develop it to whatever level of detail is comprehensible.

The encyclopedia provides a wealth of information about the topic that may be less related to actual repair procedures, but more relevant to an understanding of the historical development of the device, factors that determined the use of one technique over another, influential personalities, famous examples, anecdotes, etc. This makes the scope of the Movie Manual much more broad and interesting than just a tutorial, and more powerful as an educational tool.

The tutorial itself explains the procedures for maintenance and repair. It begins with a touch sensitive Table of Contents that serves as a visual overview of the information available, displayed in a picture of the transmission itself. The user locates the topics contained by "finger-browsing ", and each topic is highlighted on the image while descriptive text appears above in the frame (see Figure 6).

The predecessor project to the Movie Manual created viewer-controlled tutorials, but was characterized by cinematic rather than book-like qualities [9]. The Movie Manual retains the notions of a book through many of the interactions; but motion pictures are also used when advantageous. The backbone of the tutorials is a collection of "pages" which are composites of computer-generated text overlaid on images from the videodisc.

This text comes from huge amounts of digital data encoded into the video signal on the disc. This taps the high bandwidth capacity of the disc to put digital information in part or all of each frame, as a distributed data base that accompanies the images and sound. It is retrieved by a real-time decoding device which reads a block of data from a given set of lines in the frame. Discussions of the encoding and decoding schemes can be found in project related publications [10], [11].

4.0 Disc Production

Frequently asked questions about videodiscs are "How were the materials prepared?" and "What were the production costs?" The answers vary depending on the particular application, the need for cetain qualities on the disc, and the time spent in planning. It is fair to say that some advance planning goes a long way towards organizing and scheduling production work, and simplifying the editing process. Some costs may be reduced by anticipating bottlenecks due to lab processing, special services, and shipment of materials.

There are three components to be considered for a disc: (1) Visuals, (2) Sound, and (3) Digital Data. The majority of discs to date have been mainly concerned with the first two. But digital data is used on every disc, and is clearly one of the most powerful features of the disc yet to be fully utilized.

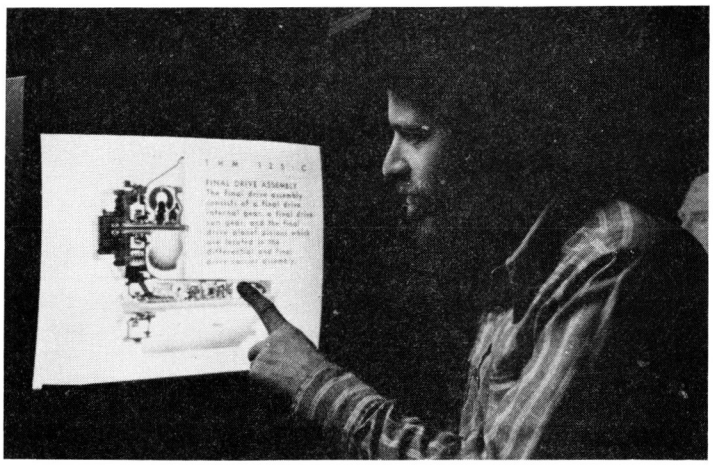


Figure 6. - Touch-sensitive Table of Contents

(1) Visuals - The original material can be film, videotape, slides, filmstrips, photographs, drawings, medical X-rays, in short anything displayable to the human eye. If original material has to be filmed or photographed, questions about travel to locations, lighting, film type, equipment, permission, etc have to be considered. Storyboards for interactive "non-linear" cinema require plans for multiple shots of the same scene, slow frame rates, or other unusual techniques. Slides, photographs and other "still frame" material must ultimately be transferred to film or videotape for final editing. As an example, the pictures used as page insets were shot from a copystand onto 35mm slides, then transferred to 35mm "cine" format (half frame) via an animation camera (see Figure 7a). Special effects film was produced by optically reducing existing full-frame film, and placing multiple "windows" into the frame for use as live movies within a page (Figure 7b).

(2) Sound - The disc can accommodate stero sound or two distinct soundtracks or a mixture; for live film segments the "synch-sound" must be laid out for one or both tracks. Narration should be scripted and if necessary timed to match the appropriate footage.

(3) Digital data - The most basic examples are the frame numbers, represented in the vertical blanking interval of each frame; also the "white flag" codes used by the player for still frame control. Discs made for consumer players can also include

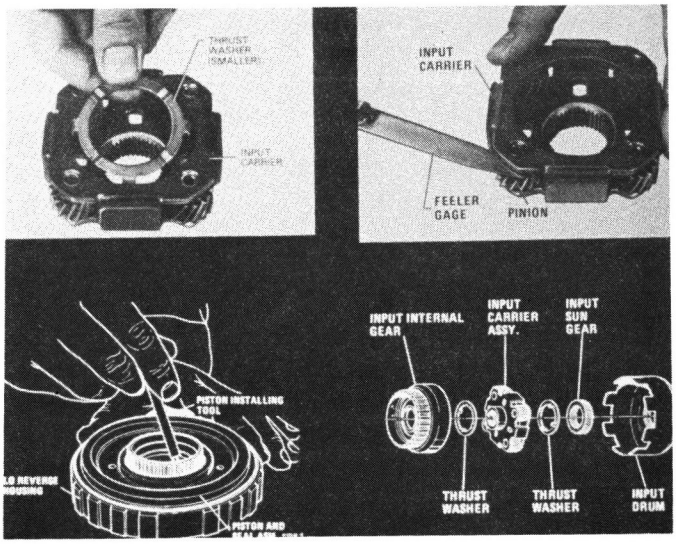


Figure 7a. - Quarter-frame Page Insets

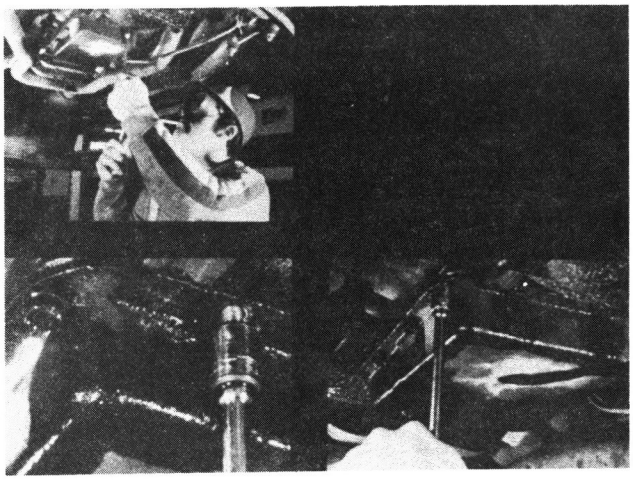


Figure 7b. - Quarter-frame Live Movies

"chapter stop" codes to cause the player to halt at predetermined frames. Discs designed for industrial players with on-board microprocessors can have digital data "dumps" located in the audio track which are loaded into the processor and can then search to frames showing numbered menus for viewer selection, play designated frames or sequences after viewer input, etc.

However, these examples do not take advantage of the huge storage capacity of the disc. Encoded data may be used to store text for overlays, numeric databases representing the contents of the disc, digitized images or sound, etc. Data encoded in this manner can reach densities of almost 10**9 bytes per disc side [12]. Several blocks of approximately a quarter of a million characters of text each were stored at several places on the disc, occupying only several seconds of video. This suggests the potential for the disc as a publishing medium that can distribute data in cheap, high volume, and durable units, readable with devices that could cost only a fraction of the price of a standard televison set.

When all the materials for the disc have been assembled, they are edited together for mastering. This includes both selection to fit into the available space, but also ordering for optimal access times for stills, etc. The discs are manufactured (in this case by DiscoVision Associates of California), and then combined with the system for operation.

5.0 Directions for further work

As it stands, the interactive videodisc has demonstrated excellent qualities for the development of training systems. These systems can retain the best qualities found in books, motion pictures, and computer-based trainers while making possible new techniques never before available. The user has the ability to learn at a preferred pace and level of complexity, choose the style of presentation, and alter and personalize the material.

But further investigation into novel storyboarding and production techniques is necessary to expand the styles of presentation. Further variations of interaction are possible by making the entire picture an active surface; image processing techniques can be used to identify boundaries of regions in the picture, and data can be associated with each region. For example, touching a tool being used for repair will acess an explanation of that tool's use. In a real work environment, the mechanic will most likely be standing at a bench, with his hands occupied with tools or dirty with oil. The use of tracking sensors for pointing and gesture may be explored in conjunction with speech recognition.

Finally, new technologies may allow new forms of visualization. One such possibility is "PLZT" controlled-shutter stereo video glasses. By viewing a standard monitor with specially generated displays, the user can see shapes and spatial relationships in true color stereo [13]. With the availability of "write-once" videodiscs that are now operating in prototype form, systems will be able to record video images on-site to store visual reminders, illustrations not in the existing database, etc [14].

The alternative forms that evolve from these developments may prove to be not only engaging and effective, but fundamentally different from any experience yet devised.

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