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AN INTELLIGENT INTERACTIVE VISUAL DATABASE MANAGEMENT SYSTEM FOR SPACE SHUTTLE CLOSEOUT IMAGE MANAGEMENT

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ABSTRACT

This paper provides status on an applications investigation of the potential for using an expert system shell for classification and retrieval of high-resolution digital, color space shuttle closeout photography. This NASA funded activity has focused on the use of integrated information technologies to intelligently classify and retrieve still imagery from a large, electronically stored collection. In this paper a space shuttle processing problem is identified, a working prototype system is described, and commercial applications are identified. A conclusion reached is that the developed system has distinct advantages over the present manual system and cost efficiencies will result as the system is implemented. Further, commercial potential exists for this integrated technology.

INTRODUCTION

Research under way at the University of Central Florida (UCF) College of Engineering's Intelligent Multimedia Applications Laboratory (IMAL) is directed at the investigation of the feasibility and integration of knowledge-based (expert) systems technology to facilitate the use of a large microcomputer-based collection of high-resolution digital photographic images. Specifically, a NASA-sponsored research project focuses on the collection, compression, classification, storage, retrieval, and transmission of high-resolution Kennedy Space Center (KSC) space shuttle ground processing still color photographs ([1],[2],[3]). The following briefly describes this application.

Application Background

For each space shuttle ground processing cycle, approximately 35,000 chemically developed 8 x 10 inch still photographs (including copies) document all significant pre-launch and post-landing activities. These pictures are an integral part of NASA's quality control and reliability program that assists space shuttle systems engineers in verifying "go for launch" and the condition of the orbiter after landing.

Photographs of key subsystem elements of space shuttle systems (orbiter, main engines, external tank, solid rocket boosters, and ground support equipment) are contained in a permanent collection of almost two million pictures. Included in these detailed photographs are pumps, rocket nozzles, connectors, cabling, control panels, mechanical assemblies, protective tiles, and valves. Presently, this collection is manually catalogued and stored in notebook binders, file cabinets, and storage boxes.

When a KSC systems engineer, or other user, needs an individual photograph or a group of related photographs, a search is performed by expert staff specialists. The present system allows network and network protocols to satisfy the demanding network traffic. The use of XTP and FDDI may provide a solution. However, more research need to be done in order to incorporate existing networks to XTP and FDDI.

Remote Data Acquisition

Data Acquisition has many applications in industry. Some of these applications such as air tunnel analysis require large amount of data acquisition and transmission through computer network. This will inevitably create a bottleneck effect on the network. The use of XTP and FDDI provides a potential solution to improve the performance of the network traffic and thus facilitate the data flowing.

CONCLUSION

After performing the audio and video experiments in our testbed, the results have indicated the use of XTP and FDDI on multimedia transmission is feasible. Several potential commercial applications are described. As multimedia will become an important industry in our nation, more research in multimedia transmission is needed in order to provide an edge over our competitors.

We will cooperate with Carnegie Mellon University and University of Virginia to conduct more experiments in the future to utilize more powerful computers, operating systems, audio, and video equipment. These experiments will provide higher performance multimedia transmission, benchmarks, research data, and new technology to industries.

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manual searches by mission number, key space shuttle elements, work authorization numbers, or by unique image accession number. Retrieval is difficult or impossible without this information. Frequently, the needed photo or set is found only after a time-consuming search. This effort is repeated at other NASA and contractor locations around the country.

Retrieved processing photographs have been used to answer critical configuration processing questions on numerous occasions. They have also eliminated the need for expensive space shuttle disassembly or inspection in closed or hazardous locations. As should be evident, the cost of misplaced or lost shuttle photographs is very high when compared to a study indicating that even a misfiled document in an average business costs $125, and each lost document costs $350-$700 [4].

Because of the importance of these photographs, NASA-KSC has sponsored research to investigate more cost-effective methods of system improvement, including the use of expert systems for the critical classification and retrieval phases of the Image Database Management System (IDBMS) life-cycle process.

Knowledge-Assisted System Enhancement

Theoretically and practically, the use of knowledge-based, or expert, systems has potential to positively impact NASA image classification and retrieval. This is important because of the large quantity of photographs involved and their difficult to describe technical orientation. In the NASA-KSC environment, staff specialists have, over the years, developed heuristics for image classification and retrieval tasks not commonly known or documented. For example, experienced classification specialists have learned to recognize which objects in technically oriented space shuttle subsystem pictures are important and which are not. Retrieval specialists also develop an understanding of the logical sequence systems engineers and quality technicians use to location required images. This knowledge is not possessed by less experienced, substitute, or newly hired classifiers or retrievers who replace those that are sick, transferred, or retired.

Another researcher shares the view that an expert system, functioning as a decision-aid to help inexperienced users, can improve the effectiveness and efficiency of image classification and retrieval for this class of users [5]. Importantly, several other researchers ([6],[7],[8]) agree that such on-the-job task domain expertise provides an ideal environment for expert systems application success.

PROTOTYPE DEVELOPMENT

A prototype that integrates expert system technology with an IDBMS has been developed for multi-mission NASA space shuttle color image classification and retrieval tasks. The system consists of two modules, one for image classification; the other, for image retrieval. They are named NAPSAC for NASA Photograph System to Aid Classification; and, PRAISE, for Photo Retrieval And Identification System Expert [3].

Knowledge acquisition was accomplished by UCF-IMAL researchers who met with KSC classification and retrieval domain experts. Numerous interviews were conducted using widely-recognized knowledge acquisition and structuring methods ([8],[9],[10]). Resultant image processing paradigms, decision criteria, descriptor attributes, and heuristics were structured, modeled, and converted into code using LEVEL5 OBJECT (an object-oriented expert system development tool). This expert system shell was chosen because of its capabilities for:

- Developing rule-based and object forms of knowledge representations.
- Manipulating and displaying user-friendly bitmapped images.

- Creating hypertext and object-oriented interfaces.
- Calling external programs needed to access relational databases (in this case, dBASE III PLUS) and image storage devices.
- Integrating with IBM microcomputer hardware and Microsoft Windows software.

Image Classification

The classification module uses the expert system development shell's hypertext and object-oriented features. For example, during image classification, a cataloger views a hierarchy of bitmapped object images of space shuttle elements on various screens as shown in Figure 1. The screen at the first level pictures the entire space shuttle configuration. "Hyperregions" (shown as dashed boxes) outline major shuttle elements (objects)--the orbiter, external tank, solid rocket boosters, and ground support equipment. Screen notes (not shown) provide user instructions. If the cataloger uses a mouse selection device to point-and-click on the orbiter hyperregion, the orbiter is displayed on a second level screen where the bitmapped orbiter object and its forward fuselage, payload bay, and tail section hyperregions are outlined.

After further point-and-click selection (for instance, to the forward fuselage hyperregion), a third level screen displays the forward fuselage with flight deck, middeck, and lower deck hyperregions. A fourth level selection (for example the flight deck of the forward fuselage) allows final object selection of specific subsystems (for example, hand controller or pilot control panel). Only four levels of object hyperregion image displays are implemented in this prototype classifier system. The reason being that four levels of classification appears more than adequate, after user testing, to accommodate image processing paradigms, decision criteria, descriptor attributes, heuristics, and data requirements which were identified during the knowledge acquisition process. No required information appears lost with this level of specificity.

A database record is automatically created as a result of the cataloger's manual input of selected image data and navigation through the bitmapped object images. Image record information includes work authorization numbers, vehicle and mission information, photographic image data, and a sequential image number which is assigned by the expert system. A photo description area is available for special cataloger notes or comments. Aspect and sub-aspect entries are entered automatically as a result of point-and-click selection. Image record database information is stored on a hard disk, and the images are stored separately in a compressed mode on a mass storage device.

Image Retrieval

The retrieval module allows engineers and other casual users to locate and display space shuttle processing images that have been previously classified and stored. The image retriever expert system works much as the classifier does except that it does not create database records.

During the image retrieval process, the user is first allowed to directly input selected attribute values such as a KSC photo or work authorization number, if known, for immediate image retrieval. If this information is unknown, the vehicle name, mission number, and/or photo acquisition information are identified. Next, the screen sequence of bitmapped space shuttle images described for the classifier and illustrated in Figure 1 is used (with point-and-click operation). Attribute values (for example, orbiter, forward fuselage, flight deck) are automatically constructed by the expert system shell to serve as search query criteria for image retrieval. Like the classifier, four screen displays levels in the prototype system were found by KSC users to provide needed retrieval capabilities.

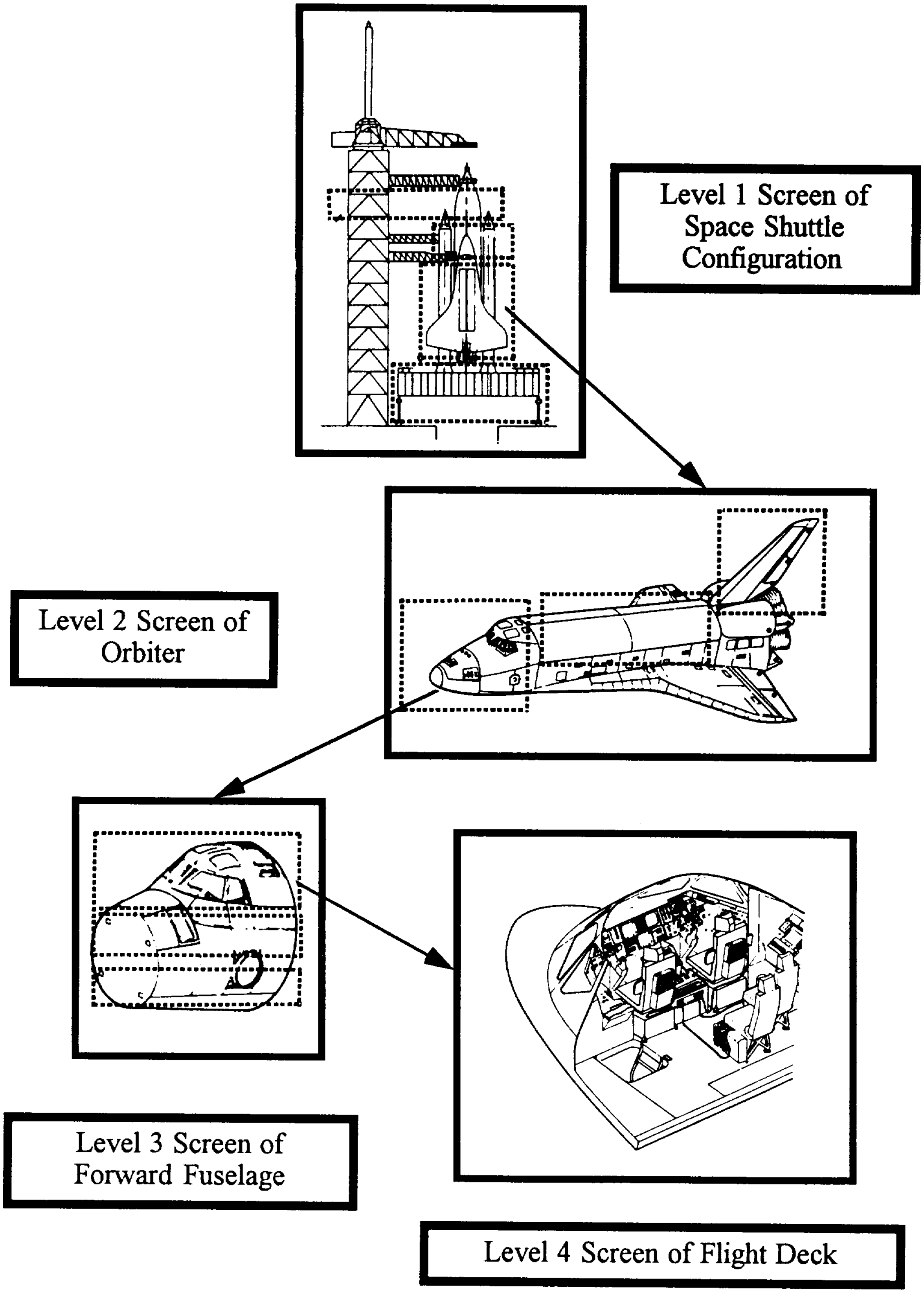

Figure 1. Diagram of classifier/retriever screens with hyperregions indicated.

After the query has been structured, the database record is searched using the known attribute values. Any "hits" are indicated in a counter screen display for the system user. These records are then used to retrieve thumbnail images from the image mass storage device for display. These surrogates allow the user to determine image relevancy.

Using the mouse, a user selects a desired thumbnail image. The system automatically uses the image number pointer in the database record to locate the desired image from data storage. Image object attribute values (e.g., KSC photo number, mission number, date, etc.) from the database record are first displayed. Then, the full screen, full color image is shown after decompression. This technique follows the cognitive model used by domain experts as well as that described by other researchers [11]. After viewing the image and its associated data, a user can choose to return to the screen of thumbnail images for additional selections or may choose to exit the session. Help text screens and instructional notes are available throughout the system.

The retriever and classifier prototype systems enable faster retrieval and classification of still photographs (when compared to the old system). Both eliminate or reduce many procedural steps, and the point-and-click feature greatly reduces many opportunities for human keyboard error. The expert system modules also enforce a standard terminology and single database repository, for the classification and retrieval of KSC image records. These improvements have the potential to eliminate or greatly reduce temporal classification variations, ensure consistency in classifier and uses orientation, and provide a more user-friendly environment.

PC-LAN VERSION

The prototype classification and retrieval modules work well for a one-user, single location system. However, space shuttle ground processing activities are spread over twenty-five square miles in at least six different KSC facilities. In addition, during pre-launch preparation and post-landing operations, engineers at locations throughout the country have responsibility for evaluating various space shuttle elements. A networked IDBMS is required to support the needs of these users.

A generalized PC-based local area network (LAN) prototype IDBMS design is shown in Figure 2. It is consistent with another researcher's assertion that there are advantages to an open architecture which enables seamless image and data access through the use of powerful servers and related desktop technology [5]. This architecture is organized into four primary modules: production station, file server, local user workstations, and remote workstations. The first three modules are connected by a high speed (16 megabits per second), token ring LAN network running under Novell Netware control. The remote workstations (the fourth module) will eventually be linked to the file server via high capacity communication links.

The purpose of the IDBMS production station is to input photographic images, update the record database using the classifier expert system, and compress images. Images can be captured by using either a high-resolution photographic color scanner, a television camera, or analog or digital still video electronic cameras.

The knowledge-assisted classifier is used to create a database record of the captured image during the acquisition process. Digital images are entered into the system directly from the photographic flatbed scanner or a digital still video system. An alternate method is to input analog images using a television camera (for 8 x 10 inch photographs) or an analog still video camera. For analog image digitization, a commercial analog-to-digital board in the production station microcomputer is used to create individual digital image files. Each of these files is then compressed

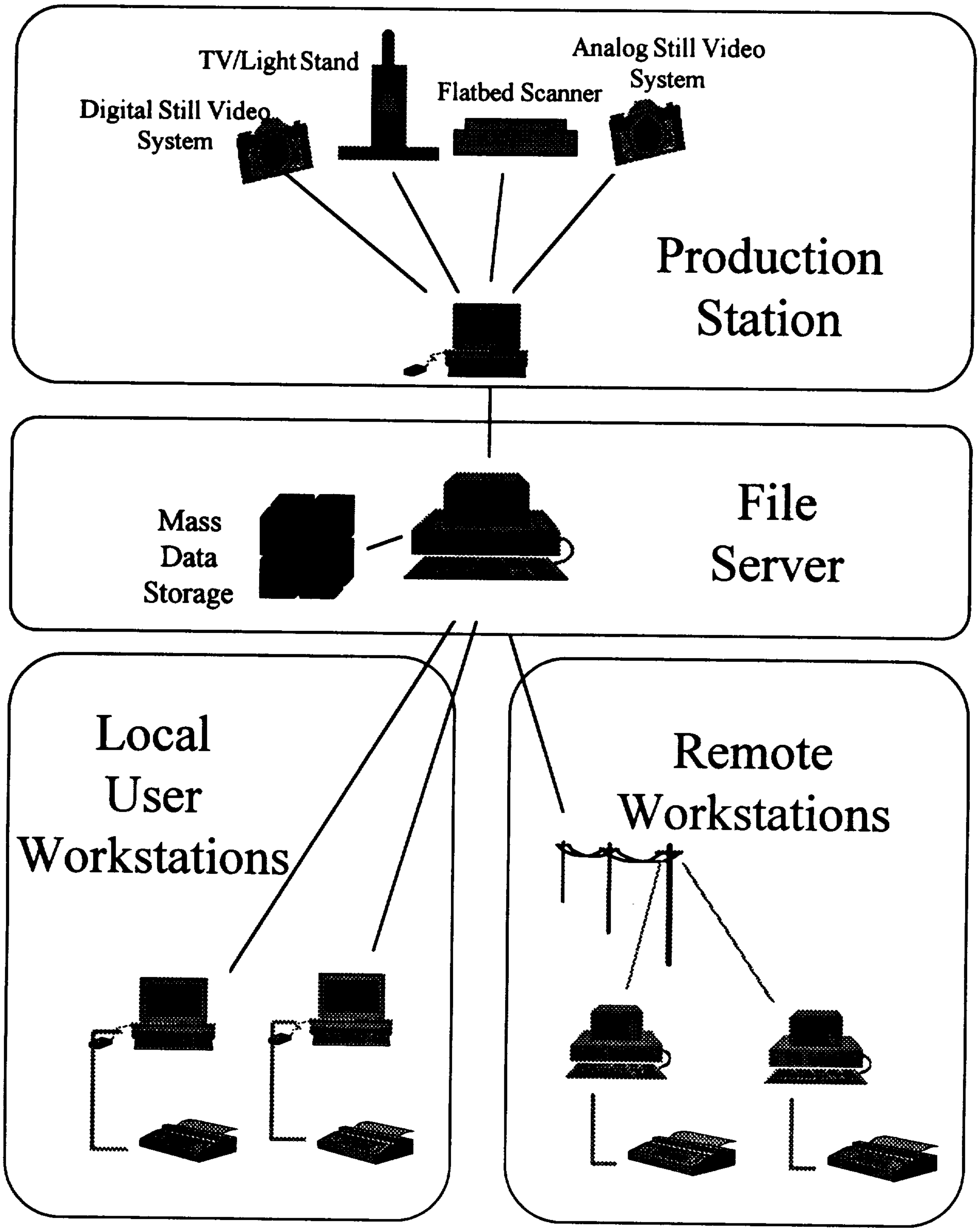

Figure 2. PC-LAN IDBMS.

by a JPEG-compatible board also located in the microcomputer. Compression ratios range from 30:1 to 35:1, depending on image complexity.

After image capture, analog-to-digital conversion (if required), and compression at the production station, image files are transmitted to the mass storage device attached to the file server. A one gigabyte erasable optical disk drive is used for mass image data storage for this prototype system. A higher capacity image storage device, in the terabyte range, would be required for an operational system. The database records used to locate images are stored as a database file on the file server's separate internal hard disk.

Images are retrieved for engineering and quality analysis at user workstations. The retrieval expert system, resident at each workstation, is used to build a database query for image retrieval and display. A query usually results in multiple hits which are displayed as bitmapped thumbnail pictures for user review and further selection. The desired image is then decompressed (using a JPEG-compatible board in each workstation) in real-time and displayed on a large high-resolution (1024 x 768 pixel), true color (24-bit) monitor. The image is printed, if needed, using a digital high-resolution color printer.

The final module in this architecture consists of remote workstations. They function the same as local KSC user stations for image retrieval and display, except that they are at various locations throughout the United States. During remote operation, engineers at these distant locations would access the KSC file server records database using the knowledge-assisted retrieval expert system resident on each workstation. In operation, compressed image files, retrieved from the image mass data storage unit, would be transmitted via existing high-speed transmission links from KSC to various user locations.

IMPORTANCE AND COMMERCIAL POTENTIAL

The paradigm shift of using PC-based networked digital image data and knowledge-based classification and retrieval instead of hard copy prints and manual image management is anticipated to result in a significant improvement in closeout image productivity and cost savings for NASA-KSC space shuttle processing operations. It is estimated that cost savings/avoidance of 50% are possible as a result of implementation of an interactive digital image management system using knowledge-based classification and retrieval.

Also significant is the commercial potential for use of these low-cost integrated technologies in a variety of private and public sector environments and applications. Potential environments include education and training, travel and tourism, commercial and residential real estate, medicine and dentistry, survey and construction, advertising and sales, and presentation and entertainment. Specific media requiring improved image management systems include education and training materials, medical X-ray and scanned data, satellite and aircraft imagery, high quality photographic collections, advertising and related graphic inventories, visual product images, and executive and corporate presentation materials. Important is the fact that developed software technologies are fully compatible with many existing private and public sector PC-based client-server computer environments. Implementation of visual database technologies will require application system analysis and design, domain-specific software development, and systems integration. As a result, potential exists to stimulate growth in a variety of small business computer service organizations and in the development of generic/industry specific software programs.

SUMMARY AND CONCLUSIONS

This paper has briefly reviewed features important to high-capacity photographic image data capture, classification, compression, storage, retrieval, and display. Also described was a NASA-KSC space shuttle ground processing prototype IDBMS under development which provides knowledge-based assistance for image classification and retrieval. Finally, a design for a networked PC-LAN IDBMS was presented. A conclusion reached from reviews of the prototype system is that it has distinct advantages over the present manual system and cost efficiencies will result as the system is implemented. Further, commercial potential exists for this integrated technology.

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THE TRUSTWORTHY DIGITAL CAMERA: RESTORING CREDIBILITY TO THE PHOTOGRAPHIC IMAGE

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Introduction

The increasing sophistication of computers has made digital manipulation of photographic images (as well as other digitally-recorded artifacts, such as audio and video) incredibly easy to perform and, as time goes on, increasingly difficult to detect. Today, every picture appearing in newspapers and magazines has been digitally altered to some degree, with the severity varying from the trivial (cleaning up "noise" and removing distracting backgrounds) to the point of deception (articles of clothing removed, heads attached to other people's bodies, the complete rearrangement of city skylines). As the power, flexibility and ubiquity of image-altering computers continues to increase, the well-known adage that "the photograph doesn't lie" will continue to become an anachronism.

A solution to this problem comes from a concept called Digital Signatures, which incorporates modern cryptographic techniques to authenticate electronic mail messages. [1] [2] ("Authenticate" in this case means you can be sure that the message has not been altered, and that the sender's identity has not been forged.) The technique can serve not only to authenticate images, but also to help the photographer retain and enforce copyright protection when the concept of "electronic original" is no longer meaningful.

Background on Digital Signatures

The concept of a digital signature builds upon a recent encryption technique called "Public Key Encryption" [3]. Older encryption/decryption schemes require that both the sender and receiver possess the same secret "key": the sender uses the key to transform the text message into ciphertext, and the receiver uses the same key to perform an inverse transformation on the ciphertext, revealing the original text message. If the correct key transforms the ciphertext into unreadable garbage, it is reasonable to conclude that either the wrong key is being used, the message has been altered, or the sender has been impersonated by someone ignorant of the correct key. The historic drawback to this secret key encryption scheme has been in the secure distribution of keys; key disclosure must occur out-of-band, either transmitted via an expensive alternate path or arranged when sender and receiver were proximate.

Public key encryption techniques differ in that they enable the recipient of a message to decrypt it using a key that is different from the one used by the sender to encrypt it. All public key cryptography is based on the principle that it is easy to multiply two large prime numbers together, but extremely difficult (taking perhaps centuries using today's supercomputers) to work backwards and uncover the factors that could have been used to generate the resulting number.

Public Key Encryption employs two different keys: a private key, which is held by the more security conscious party, and a corresponding public key, which need not be kept secret. The public key is generated based upon the private key, making the pair unique to each other.

The public key scheme is illustrated in Figure 1 and works as follows: to send a secret message that only the recipient can read, the recipient would first make his/her public key known to the sender through any non-secure medium, such as a letter, a telephone conversation, or a newspaper ad. Anyone wishing to send a secure message would encrypt the message using this public key and send it to the recipient. The recipient, having sole possession of the corresponding private key, is the only one able to decrypt the message. The need to transmit a secret key that both parties must possess beforehand has been eliminated. The tradeoff in this case is that, although only the recipient can read the message, anyone who obtains the public key can send a message with anonymity.[1]

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[1] The described scenario can also be used as the first step in a process of exchanging secret keys to allow for conventional secure message transmission, eliminating any of the drawbacks of the one-way authenticatability. [1], [4]