ImagePlus Workstation Program

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IBM's ImagePlus™ system is designed to permit the capture, storage, management, and retrieval of documents through digital imaging. The ImagePlus Workstation Program is that portion of the ImagePlus system that controls the user's workstation. This paper describes the challenges that were posed in designing an ImagePlus Workstation, and the approach taken by the development group to solve them. The primary design goal was to deliver operational performance for image processing in a cost-effective workstation, while permitting the user maximal control in viewing and manipulating scanned documents. The solution chosen implemented a Personal System/2® workstation that operates with a System/36, Application System/400®, or System/370 Multiple Virtual Storage host.

Despite the widespread use of computers in business today, most enterprises still cope with a significant number of documents on paper. Many reasons exist for this, but the costs and delays associated with the storage and retrieval of paper files are strong motivations to limit their use. The IBM ImagePlus™ system was designed to permit the capture, storage, management, and retrieval of documents through digital imaging.

The ImagePlus Workstation Program (IWP) is one component of the whole ImagePlus system, and in particular is the software component of user workstations. It controls the user's workstation and host-workstation communications, provides the end-user interface, and executes the image processing functions required for the capture, display, and printing of documents whose images have been put in digital form.

The key design criterion for an ImagePlus Workstation[1] and the IWP was that they form a cost-effective and high-performance subsystem for handling document images. Early in the design, it was resolved that the most cost-effective solution would be a host-workstation configuration. To permit wide access to data and centralized management, the document images would be stored on a System/36, Application System/400® (AS/400™), or System/370 Multiple Virtual Storage (MVS) host. It was also resolved that the images would be in a compressed form for storage and for communications between the host and workstation in order to reduce the data transmission and storage requirements and costs.

Thus, to minimize host-workstation communications and the user's response time, a system design was adopted whereby only compressed images are

passed between the workstation and host. Further, a new coprocessor was utilized in the workstation for image compression and decompression, for scanner or printer attachment, and for driving the display. The result is a high-performance workstation for the ImagePlus system that meets key design goals and that should serve as a useful base for future extensions.

The fundamental goal of the ImagePlus system is to help enterprises manage and eventually eliminate paper documents. Since documents are vital to every business, the ImagePlus system must be reliable, accurate, and very usable to be of value. Furthermore, it must be fast enough to yield an increase in productivity over the current handling of paper and must be able to deal with the wide range of documents encountered in a typical business setting.

There were three key performance challenges to consider.

Design considerations

Requirements. There were key requirements that had to be taken into account in the design of the ImagePlus Workstation. The design had to provide:

- A reliable 10-pages-per-minute image capture subsystem. This system had to be able to scan thousands of pages per day with sufficient quality in a production environment so as to permit the disposal of the paper originals. The system must also be able to handle the wide range of size and quality in documents that might be found in a typical mailroom.
- A six-pages-per-minute image printing subsystem
- Emulation of a host 3270/5250 session[2]
- A display of a full image page, within one second of receipt from the host
- A concurrent display of the emulation session
- Subsecond image display paging (i.e., a rate typical of a text-processing system)
- Support for text and image overlays[3]
- Fast (100 kilobytes per second) host communications
- Compliance with a document data stream structured according to an architecture

Performance. There were three key performance challenges to consider. Each one is now discussed.

Subsecond image display. Since a typical 8.5- by 11-inch page contains 456 kilobytes of data, processing this volume of data with a subsecond page flip rate posed difficulties, given the price point that workstation design was based on.

Ten-pages-per-minute image capture. Although the scanner chosen can operate at a rate of approximately 1.2 seconds per page, a throughput rate of 10 pages per minute also requires very efficient handling of the scanned images, an easy-to-use end-user interface, and high-speed communications to send the documents to the host for storage.

Six-pages-per-minute image printing. This rate posed problems, because the conventional attachment of a printer to a workstation (through a serial or parallel port) entails several minutes of transmission per page.

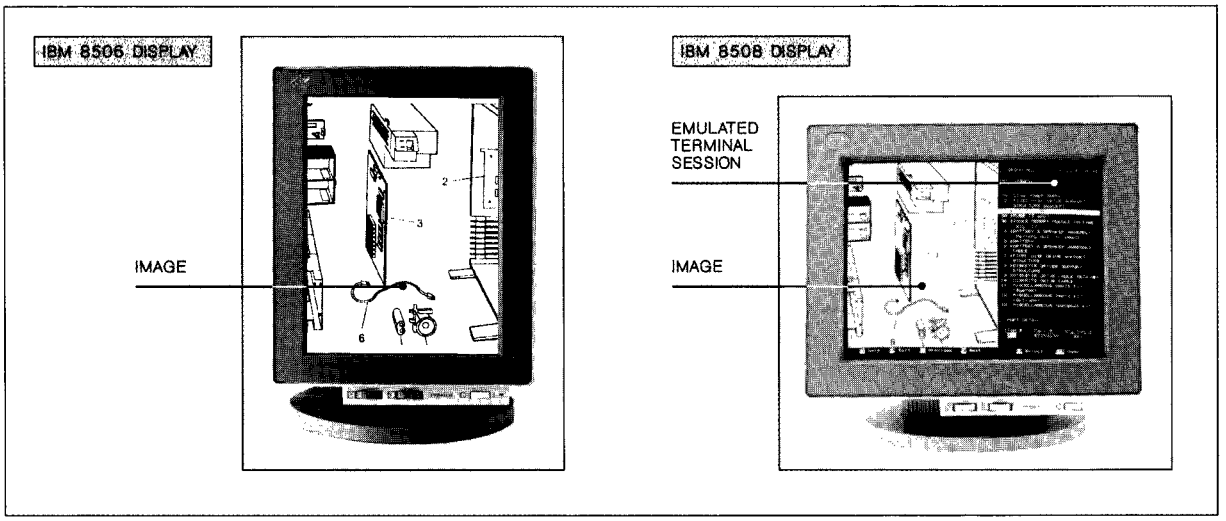
The design solution presented in this paper was derived using these three performance challenges as primary goals.

Cost. To provide a cost-effective ImagePlus Workstation, the low-cost Personal System/2® (PS/2®) Model 50Z was selected as the price-point workstation. This workstation is a tabletop model, uses a 12-MHz 80286 processor, has one megabyte of memory, and includes three Micro Channel® expansion slots.

Given this price-point workstation and the performance and function required, it was necessary to include an image coprocessing adapter that would also serve to provide connections to the scanner and printer. This design point was required to provide the peripheral attachments and communications from the three slots available in the PS/2 Model 50Z.

To minimize memory requirements, the Personal Computer Disk Operating System (PC DOS, or DOS) was chosen; however, this selection created some additional challenges since a digitized page image contains typically 456 kilobytes of data, and DOS has a 640-kilobyte limit for program and directly ad-

Figure 1 Sample display configurations



dressable data. Thus the need to deal with these large data objects and to load high-speed communication, emulation, and application programs necessitated designing around the memory issue.

Usability. The ImagePlus Workstation had to be highly usable, implying simple operation, fast response time, and quality imaging. Simple operation meant that workstation operations must be easy to learn. The response time must be fast, so as to provide an advantage over the use of paper-based document handling. The document imaging must also be of good quality to ensure that the document information is captured in the images (to permit the elimination of the existing paper documents). The user must also be able to view an entire page at once, with sufficient resolution to be able to clearly see most business document text. The displayed image should be displayed at (or near) its original size.

Since the quality of paper documents varies widely, the document images should be displayed to the operator at scan time. This permits the operator to visually verify the scanned image quality, and to handle the diverse range of document darkness, color, and contrast found in a variety of documents.

A typical business document often contains multiple pages. It is also quite often necessary to refer to several documents simultaneously. To be highly usable, the workstation must be able to handle multipage documents and many documents at once. The workstation must also permit the user to correct common errors that might occur during the capture of multipage documents (e.g., by rescanning, reordering, deleting, and adding pages).

The *primary* goal in making this application usable was to provide a performance level that would allow processing of images of pages at a speed similar to what can be obtained when handling the actual paper copies. However, other usability concerns were also important. These concerns included:

- Single format display: The image display contains nothing but the image and information areas at the top and the bottom of the display. No menus or other user interactions are required to view an image (see Figure 1).
- Multiple monitor options: The user can have the image presented on a separate display (IBM 8506) or on a large composite display (IBM 8508). On the 8508 display, the image may be presented beside an emulated terminal session (3270 or 5250), as illustrated in Figure 1. Other options are also available, such as using the 8508 display to show two images side by side, using the full size of the 8508 display as a single image display space, and placing the emulated terminal session screen area on either the left or the right side of the

Figure 2 Example of ruler line

Request Sense Data					
Sense Key	Additional Sense Code	Additional Sense Qualifier	Description	Scanner Disabled	Information Bytes Seq. Id. No.
0	00	00	No additional information		
5	20	00	Invalid command operation code		
5	20	80	Invalid scanner unique (Gemini) command		
5	25	00	Unsupported Logical Unit		
6	29	00	Power-on Reset		
4	47	00	Parity Error on SCSI		
4	4C	00	Logical Unit Failed Self-		

screen, with an option to hide this information in order to temporarily use the entire surface for image display.

- Page viewing: Single keystrokes permit the user to page forward or backward, at either a page level or a document level. Many other often-used functions (such as go to the first page or to the last page) are available as single keystroke functions. A sample of other functions include:
  - Zoom—An approach similar to moving a magnifying glass over a page was adopted. The size of the magnified area is variable under end-user control. Its speed is similar to the speed at which one might move a real magnifying glass over a piece of paper.
  - Rotate—A function to rotate a displayed page in 90-degree increments is provided. Each rotation is performed in a small fraction of a second.
  - Ruler line—This function provides a movable horizontal line to highlight areas of the displayed image. This feature is useful when columns of data are being processed. (See Figure 2.) Note that the height of the ruler line can be varied by the end user.
  - Page marking—Often when processing a large number of pages, several key pages need to be marked as ones that will likely be viewed again. This facility lets users mark a page in such a way so that they can quickly return to it without having to browse through other pages.
  - Configurable functions—A default keyboard and keypad layout was provided, which assigns keys to functions. This layout was based primarily on experience gained in the early prototype work. The IWP configuration functions, however, permit users to tailor this default layout to the one most suitable for a particular installation.
  - On-line help—Extensive on-line help was provided. A separate help panel was made available to give additional information for any message issued, as well as to give general-purpose help for overall usage information.

For further information regarding the facilities provided by IWP, see the *PS/2 ImagePlus Workstation Program Operations Guide*.[4]

Development approach

During the development phase of this project, the advice of customers was often solicited with regard to further defining requirements and was invaluable in all areas relating to ease of use and overall usability. This direct communication with customers is a highly recommended approach, particularly in the development of a system that has many usability design issues.

The approach taken was to build prototypes of the workstation early in the development cycle and have them evaluated by real end users. Two prototypes were delivered to customers: one that operated with a System/370 MVS host, the other with a System/36 host. The experience gained with these prototypes was used to build the ImagePlus Workstation Program (released in September 1989). This DOS product is able to operate with a System/36, AS/400, or System/370 MVS host through configuration options.

Design details

To achieve the performance, cost, and function requirements outlined earlier, two key implementation steps were taken. They were:

1. Parallel processing—When a document is sent to the workstation for display, a series of operations must be performed prior to display of the first page. Operations such as receiving the document data, parsing through the structures in the document, decomposing the document into a set of pages, decompressing the image data for a page, and modifying the resolution of that data to match the display device can take a noticeable amount of time. More important, the user may well be nonproductive during this time. IWP minimizes this wait time by performing some of the tasks in the PS/2 processor and others in the IBM Image Adapter/A processor. This division permits processing of the tasks in parallel. For example, since the PS/2 processor handles communication and the Image Adapter/A processor performs decompression, the decompression of the first part of a page may be performed in the Image Adapter/A processor while the latter parts of the page are still being received. IWP utilizes this form of parallel processing wherever possible.
2. Working set concept—Since users require access to many pages, and perhaps many documents, IWP introduced the concept of a working set. A working set is the collection of all of the pages and documents existing in the workstation at one time.[5] Users have access to the multiple pages or documents either by paging or by selection from a table of contents. In order to provide this function, PS/2 extended memory was utilized to hold the compressed image pages. To provide for more pages in the working set than could be contained in available PS/2 extended memory, the PS/2 hard disk is used to hold the overflow. By maintaining direct pointers to each page within the IWP application, IWP provides high-speed access to pages regardless of whether they are currently in extended memory or on the hard disk.

Image Adapter/A. To achieve the processing speed required, a new image adapter card was utilized, the IBM Image Adapter/A. This adapter, developed by the IBM Hursley laboratory, enables the attachment of high-resolution displays required by the workstation. An additional memory option is available for scanning and printing or to increase the performance of the workstation.

The adapter contains a high-performance RISC[6] processor with additional hardware for specialized image operations. The adapter has a high-bandwidth display drive capability, enabling a display of 1600 by 1200 pels with four shades of gray.

In addition to its image coprocessing and display capabilities, the Image Adapter/A is used to attach scanners and printers. This option allows it to be attached to either an IBM 3812 Pageprinter and achieve a printing rate of nine pages per minute, or to an IBM 4216 Model 20 Personal Pageprinter, a low-cost laser printer capable of printing four to five pages per minute. For scanning, either the Bell and Howell COPISCAN™ scanners or the IBM 3117/3118 scanners can be attached. With the Bell and Howell scanners, a scanning rate of 10 to 15 pages per minute is possible.

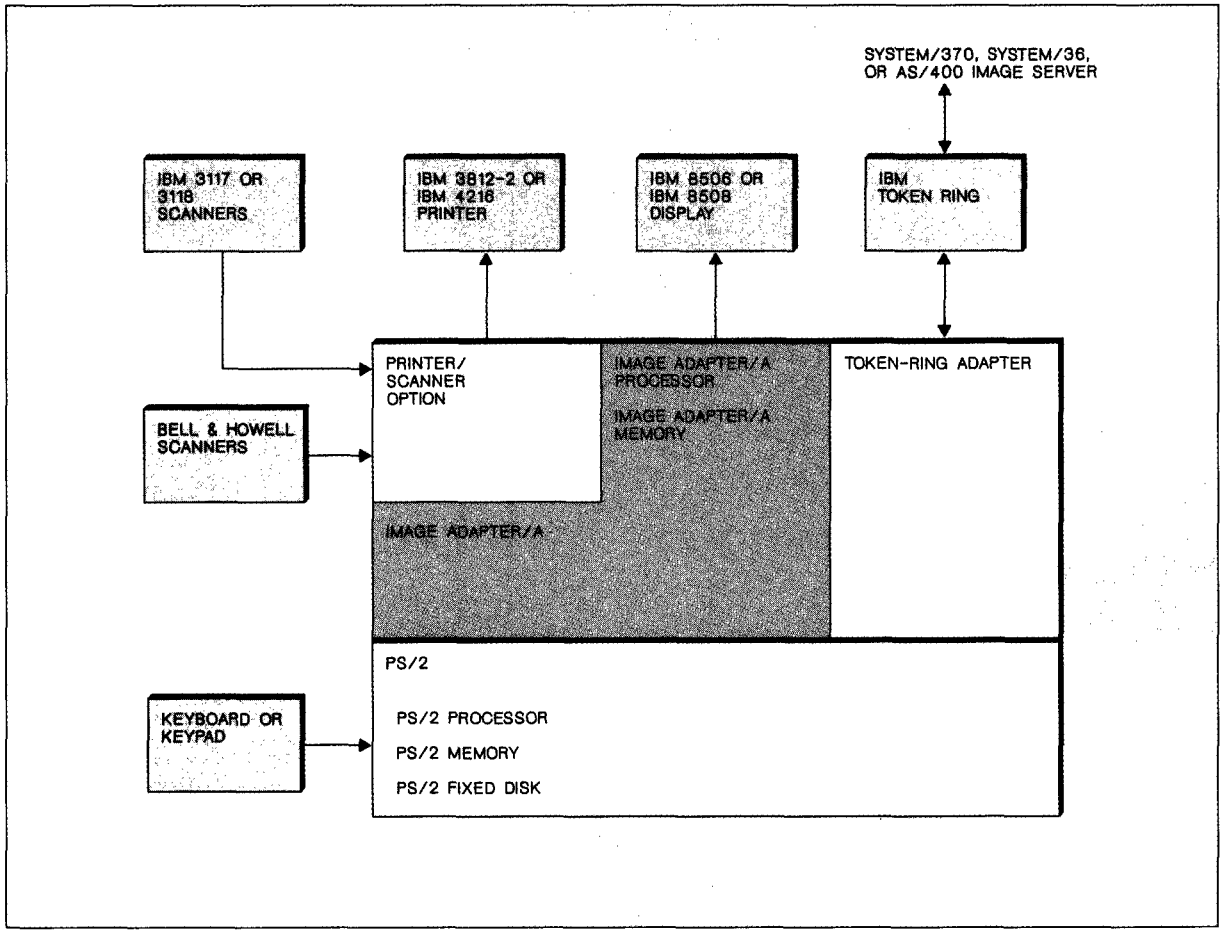
An overview of the ImagePlus Workstation hardware configuration is shown in Figure 3.

Image compression. A key consideration affecting a digital imaging system is how accurately the source is sampled (sampling density and resolution). Also important, since sampled image data often contain much redundancy, is the form of image compression used. Today, the storage and communications advantages resulting from the use of image compression far outweigh the costs of conducting the compression and decompression (for bilevel business documents).

For the ImagePlus system, it was decided that 200 dots per inch bilevel would be the nominal sampling rate. This rate permits most business documents to be adequately captured. Given this sampling, an 8.5-by 11-inch page yields approximately 456 kilobytes of data. Fortunately, these data can typically be compressed by a factor of 10. The image compression technique utilized was the IBM Modified Modified READ (MMR) algorithm.[7] An alternative option is the CCITT (International Telegraph and Telephone Consultative Committee) Group 4 facsimile (FAX) compression technique, which may be selected when the IWP program is installed. Both algorithms give nearly identical compression ratios.

Document and object content architecture. The ImagePlus system was designed to be a storage system for very large numbers of documents; therefore, significant attention was paid to the format (data stream architecture) of the stored data. All data generated by the IWP are defined by Systems Appli-

Figure 3 Hardware block diagram



cation Architecture™ (SAA™) Common Communications Support.[8] Specifically, the Mixed Object Document Content Architecture (MO:DCA)[9] is used to define the document structure, and the Image Object Content Architecture (IOCA)[10,11] is used to define each image page.

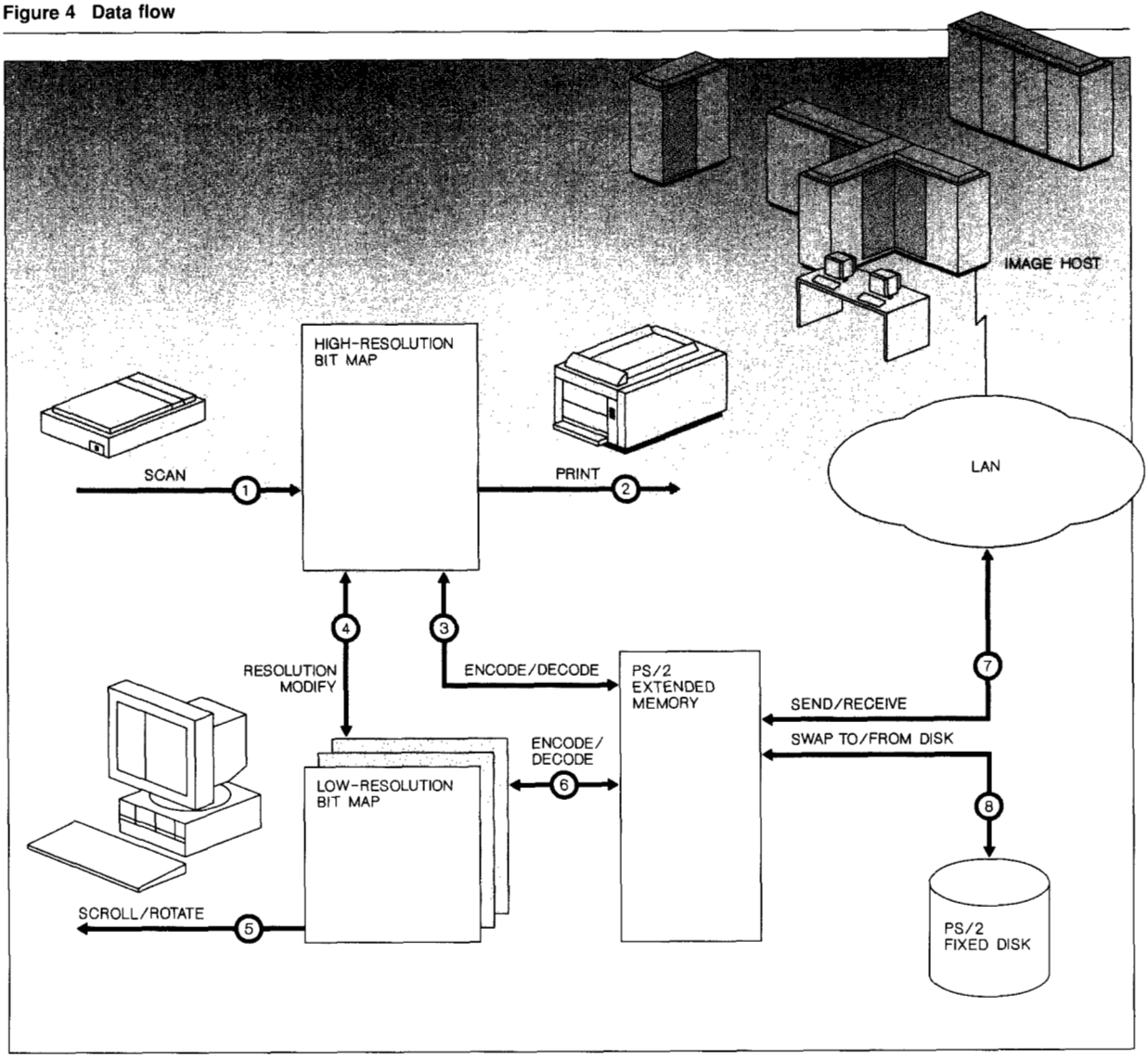
Although the emphasis in ImagePlus is the handling of images, it is also important that it be capable of receiving text objects within a document. These text objects are formatted according to the Presentation Text Object Content Architecture (PTOCA)[12] and can be created by the host ImagePlus application.

One of the key features of this architecture exploited by the IWP is the ability to define pages that are composed of local data and of references to external data resources (i.e., overlays). This feature provides the ability to store a page of text that may be presented along with a prestored image. The prestored image may be a (blank) form that is referenced by many text objects. Since this feature provides a means of storing text pages without repeated storage of a common form, considerable savings in storage media and communication bandwidth can be obtained. (Text pages typically use 20 to 30 times less storage than compressed image pages.)

Communication architecture. The IWP has two separate communication components, each designed for local area network (LAN) attachment. LAN attachment provides the high-speed communication facility necessary to achieve performance requirements.

In Multiple Virtual Storage/Enterprise Systems Architecture (MVS/ESA™) configurations, a Systems Net-

Figure 4 Data flow



work Architecture (SNA) LU 6.2 protocol[13] is used to communicate between the IWP and the Object Delivery and Management (ODM) program. In AS/400 configurations, the IWP utilizes functions provided by AS/400 PC Services for communication with the Workfolder Application Facility (WAF).

The ImagePlus system also gives users some quality and cost options versus performance options. Typically, a user captures the incoming image at 200 pels per inch (ppi) bilevel. This image is compressed and saved at the host. For the best quality display, its resolution is modified and it is anti-aliased[14] to 100 ppi with four shades of gray. For faster performance, however, the user may save both the 200 ppi compressed image and a 100 ppi bilevel compressed copy of the image. The latter contains significantly less data, permitting faster retrieval of a lesser-quality version of the image.

Data flow. Since image pages involve large amounts of data, the primary criterion for achieving high performance is to keep the data path as short as possible. The following two examples, in conjunc-

tion with the data flow illustrated in Figure 4, show the data flow for typical scan and display operations. The numbers in parentheses correspond to the numbers in the figure.

Data flow for scan operation. Uncompressed image data are received from the scanner (1) as the paper is passed through. These data are read directly into the high-resolution bit map[15] in the Image Adapter/A memory.

Since the sampling rate provided by the scanner is 200 pels per inch and the resolution of the attached display is 100 pels per inch, a resolution modification process must take place (4). The input data to this process is the contents of the high-resolution bit map. The output of this process is placed into the low-resolution bit map.[16]

Note that the image has been captured and displayed completely under control of the image adapter processor and that the image has not left the memory of the adapter.

While the image is being viewed (quality-checked) by the operator, the encode operation takes place.[17] The compressed data resulting from the encode operation are placed in PS/2 extended memory (3).

The page-scan operation is repeated until all pages of the document have been scanned. At this time the pages are assembled into a document format and sent to the attached image host (7).

Data flow for display operations. A document is received from the image host (7). The document is broken down into a series of pages, and each page is stored in PS/2 extended memory. If all of PS/2 extended memory has been allocated by pages previously received, the pages are written to the PS/2 fixed disk (8).

Display attachment hardware in the image adapter is used to display the contents of the low-resolution bit map on the attached display device.

If no page is currently being displayed, the first page received is decoded[18] and its resolution is modified to the display resolution. The data resulting from this operation are placed into the low-resolution bit map.

Display attachment hardware in the Image Adapter/A is used to display the contents of the low-resolution bit map on the attached display device.

Once one page has been displayed, the remaining pages may be displayed upon operator demand. Note that, depending on the amount of memory available in the image adapter, there may be room for multiple low-resolution bit maps. If so, a different low-resolution bit map is used for each page display request. Having different bit maps provides response times of less than 100 milliseconds when a request is made to view a page again. Once all of the low-resolution bit maps have been used, a subsequent paging request will reuse one of the bit maps. The bit map reused is the one that was referenced least recently.

Internal design. Figure 5 illustrates the manner in which the dual processor capability is used. The PS/2 portion of the application consists of a number of processes that operate from queues. A task dispatcher passes control sequentially to each process, as long as any work is queued for that process.

The Image Adapter/A manager is used to start tasks that run in the image adapter and to take the appropriate action when these tasks are completed. In the Image Adapter/A, a simple dispatcher is provided to route requests to the appropriate task. The image adapter section of the application can run only one task at a time, and each task must run to completion.

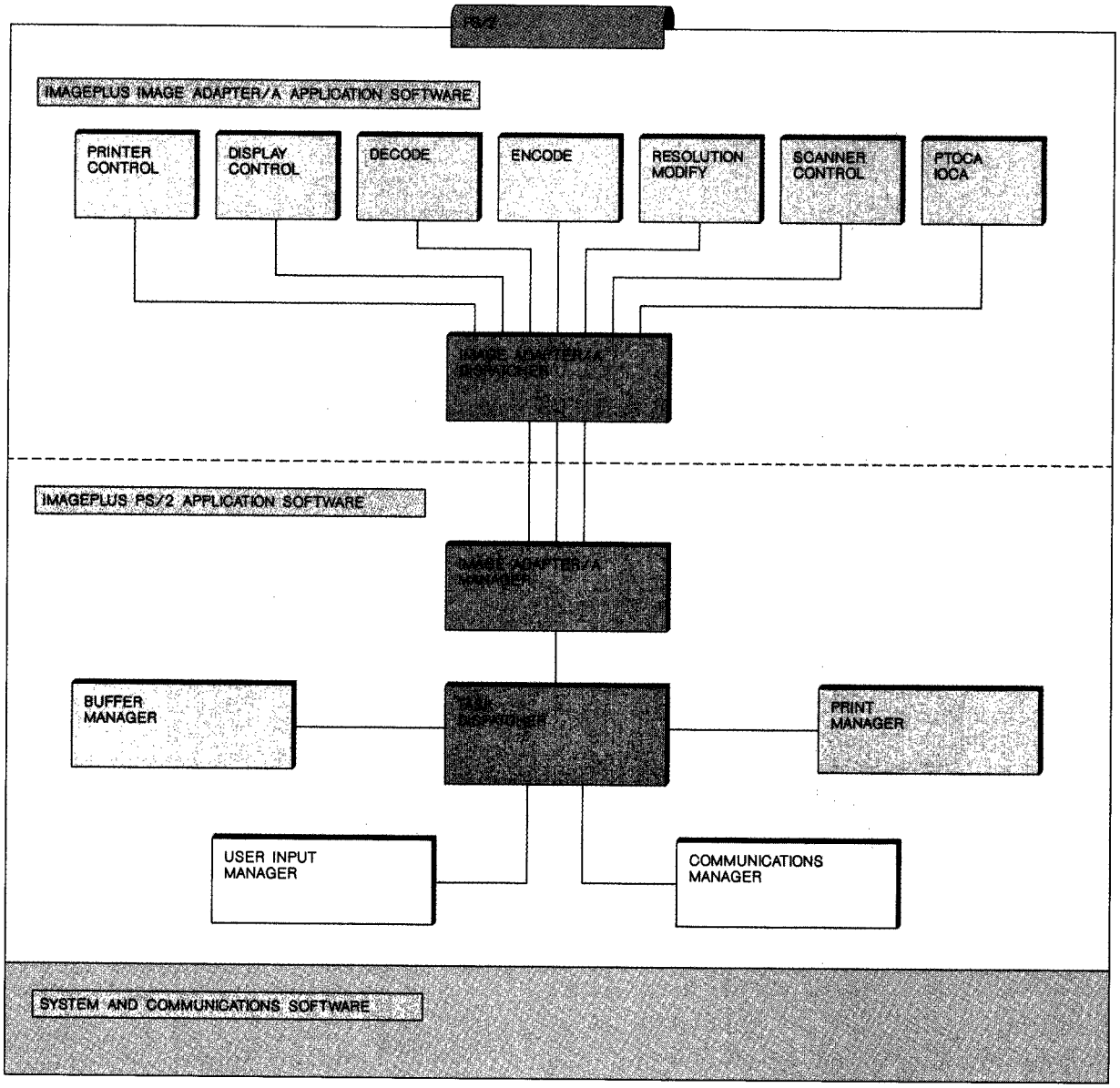
An important benefit of having a separate coprocessor is the ability to overlap operations. For example, receipt of document pages can occur simultaneously with the decompression and display of a page already in the system. This overlap is possible because the LAN communications are managed by code operating on the PS/2 processor, whereas the decompression and display code operates on the image adapter.

Concluding remarks

The combination of a low-cost PS/2 and a separate image coprocessor provides a suitable hardware base for meeting the stated requirements. The DOS operating system, along with an application specifically designed to maximize performance, can provide a workstation solution that permits handling of documents in image form in a highly productive manner.

In March 1990, IBM announced a statement of direction for a version of the ImagePlus Workstation Program based on Operating System/2™ (OS/2®). This version will conform to Systems Application Architecture and Common User Access architecture and will exploit features of OS/2 such as multitasking and the Presentation Manager™. Enhanced device sup-

Figure 5 Software block diagram



port and new data types, such as color image and audio, are also planned.

Acknowledgments

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Also, the following IBM locations have made significant contributions to the ImagePlus Workstation design solution: The IBM Thomas J. Watson Research Center was the source for the image-related algorithms, and provided assistance in the imple-

mentation of the algorithms. The Image Adapter/A card developed at the IBM Hursley laboratory provided the key hardware facility for delivery of the image function at the performance levels required. The IBM Charlotte laboratory provided the high-performance software required in the 3812 printer to meet print performance objectives.

Cited references and notes

1. ImagePlus Workstation refers to the entire workstation component, including the PS/2 with its attached peripherals and the system software. ImagePlus Workstation Program, or IWP, refers to the application software necessary to perform the required ImagePlus functions.
2. Emulation refers to the connection to the host character-based applications. 3270 sessions are used to connect to Multiple Virtual Storage/Enterprise Systems Architecture (MVS/ESA) hosts, whereas 5250 sessions connect to AS/400 hosts.
3. Overlays are generally preprinted forms. For example, a common insurance form may be used as an overlay, and the text to be displayed (client name, policy number, etc.) would be merged onto the overlay.
4. *PS/2 ImagePlus Workstation Program Operations Guide*, SC09-1324, IBM Corporation; available through IBM branch offices.
5. Currently IWP supports a working set of up to 999 pages. The maximum number of documents supported is limited only by the total number of pages; that is, 999 documents could be in the working set if they were all single-page documents.
6. RISC stands for Reduced Instruction Set Computer and is a technique for achieving faster performance in processors.
7. K. L. Anderson, F. C. Mintzer, G. Goertzel, J. L. Mitchell, K. S. Pennington, and W. B. Pennebaker, "Binary-Image-Manipulation Algorithms in the Image View Facility," *IBM Journal of Research and Development* **31**, No. 1, 16–31 (January 1987).
8. *Systems Application Architecture, Common Communications Support Summary*, GC31-6810, IBM Corporation; available through IBM branch offices.
9. *Systems Application Architecture, Common Communications Support, Mixed Object Document Content Architecture Reference*, SC31-6802, IBM Corporation; available through IBM branch offices.
10. Y. Hakeda, "The Image Object Content Architecture," *IBM Systems Journal* **29**, No. 3, 333–342 (1990, this issue).
11. *Architectures for Object Interchange, Image Object Content Architecture Reference*, SC31-6805, IBM Corporation; available through IBM branch offices.
12. *Architectures for Object Interchange, Presentation Text Object Content Architecture Reference*, SC31-6803, IBM Corporation; available through IBM branch offices.
13. *Systems Network Architecture, Transaction Programmer's Reference Manual for LU Type 6.2*, GC30-3084, IBM Corporation; available through IBM branch offices.
14. This technique converts higher-resolution bilevel images to a lower resolution, using the additional data to produce shades of gray.
15. The high-resolution bit map is an area of Image Adapter/A memory used to hold uncompressed images at their capture resolution.
16. The low-resolution bit map is an area of Image Adapter/A memory used to hold uncompressed images at their display resolution.
17. Encoding is the process of creating a compressed copy of an image from an uncompressed copy.
18. Decoding is the process of creating an uncompressed copy of an image from a compressed copy.

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