Large Image Files in Publishing Systems

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ABSTRACT

The problems of large (1-100 MB) image files clearly influence practically all technical solutions in publishing systems. This is true not only in the choice of a processor, bus or memory capacity, but also in coding, display, input, interfacing and output. Adequate solutions are sought for all types of publishing systems from DTP software and workstations to CEPS. How this is done in present practical systems and in product development is discussed in this paper. Future trends are predicted for both hardware and software. Short response times, easy, automated, operation and transparent user interfaces are vital criteria for the feasibility of these systems. Increasing quality and image resolution stress the importance of optimized work flow and image representation.

INTRODUCTION

In the short history of the publishing applications of digital image science we can easily distinguish different generations of systems. In the era of minicomputers in late 1970s there were some few early attempts by Prof. Schreiber's (MIT) group, using DEC equipment, and sponsored by Associated Press (NY Office) using the prototype, and the joint project of US based Optronics - a scanner vendor - and by Helprint, a major gravure printer in Helsinki, aiming at a full four-colour system [Man]. Large image files were a major problem.

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After years of development, both of these systems were discarded mainly because of the capacity and speed restrictions of the hardware and non-standard software. Both projects produced a huge amount of useful know-how which was later applied by other groups and vendors.

Then came - and still is [Kal,84], [Gas,88], [Joh,85] - the era of CEPS (Colour Electronic Prepress Systems) in which the host processors were minicomputers and which were sold from about 1980 on to large repro and printing plants. The too dedicated software and the less open architectural features of CEPS were the main arguments of the third wave vendors who built their systems on standard operating systems of the workstations [Vir, 89] and personal computers [Söd, 89], which we now call DTP Colour Systems [Häm, 89] ,[Buck,90].

Then comes the concept of device-independent colour [Buc,90] in which the picture is fully portable from system to system. Portability means more protocol data and the files are larger. If the coding of the image data calls for compression, it has to be standard. Very efficient or new compression methods are not likely to be accepted with device independence.

THE LARGE FILES

Image resolution

The spatial resolution of a digital image system can be defined as the number of picture elements (pixels) per linear length or area unit of a physical medium (e.g. pixels/mm). This measure is adequate to describe the input and output scanning processes. Alternatively, the number of pixels in the image or the number of pixels in the horizontal or vertical direction is used to specify the resolution. This is an adequate measure to describe image gathering with electronic cameras and to process digital images. The graey level resolution or pixel depth indicates how many grey levels or colours are used in the image representation, often expressed as bit/pixel. 1 Byte (256 grey levels) is used for one of the three or four colour components.

The size of a non-compressed digital image file is easy to calculate by multiplying the spatial resolution with the pixel depth. The size of the compressed file is obtained by dividing the raw data file by the compression factor, which ranges from 2 to 50 and up.

Resolution of printed pages

The size of a digital file representing a typical size A4 four-colour printed image is easily be calculated. By the rule of thumb of 2 x 2 pixel samples per screen matrix, a typical output screen of 60 l/cm and a pixel depth of 8 bit (256 grey levels) per CMYK component , we get:

File size = (2 pixels/l x 60 l/cm)^2 * 21 cm * 29.7 cm * 4 colours * 1 Byte/ colour*pixel = 36 million bytes = 36 MB.

Even if the single images on a page that contains mainly text are significantly smaller than A4, the whole page is processed as a image by the RIP at the outputting stage. The output unit will have to process this amount of data.

The file sizes are increasing. Some CEPS manufacturers have already included greater colour precision into their systems (10 - 12 bits/colour component). New adaptive screening algorithms require significantly more than 4 samples per screen matrix to modulate the shape of the screen dot according to the image content [For, 88]. Frequency modulated screening will further increase the requirement for resolution [Fis, 89].

Video and HDTV

Video technologies are used increasingly in publishing systems. At present video printing demands medium sized files [Söd,88]. According to the CCIR 601 standard for the studio digital component video the luminance component (Y) is digitized into 720 samples per line the chrominance components (U and V) into 360 samples, 8 bit s deep each [CCI,82]. An NTSC image with 480 visible horizontal lines will thus take up 691 KB, and a PAL picture with 575 visible lines 828 KB. This implies that an RGB image must be digitized with 720 samples per component to meet the 601 standard which gives file sizes of approx. 1 MB. Most of the present frame grabbers reach this accuracy. The file sizes are still reasonable compared to high-quality printing - which, of course, is reflected in image quality.

HDTV technology with 1125 - 1250 lines increases image resolution roughly fivefold giving file sizes of around 3 MB. A television image format that is independent of line and frame rates is developed in the Open Architecture Television program at the MIT Media Laboratory [MIT,90]. This technology works with pictures which have 2,000 lines and more and with frame rates from 24 to 100 per second. With the open architecture, television and video systems offer the same range of resolution as the present publishing systems. We have to be prepared to handle image files of about 10 - 100 MB in future communication systems.

PROCESSING OF LARGE IMAGE FILES

Special hardware structures are required to process large image files. Data throughput has to be high enough to make response times short. The throughput of the entire processing chain has to be balanced in order to avoid serious bottle-necks. Pipe-lining, parallelism, fast buses and networks are principal methods to keep a steady and rapid work flow.

Dedicated CEPS systems succeed in maintaining a high work flow throughout the reproduction process. The input scanner can function at full capacity because the job is prepared at special preparation stations before scanning (pipelining). The attaching of the originals to the drum, the scaling and cropping parameters as well as the tonal range and reproduction curves are measured in advance at the presetting stations. The scanner functions as a robot according to these preset values.

In high performance systems image processing takes place on powerful workstations with rapid internal buses and dedicated hardware for parallel and pipeline processing . To reach a high processing speed, both source and destination image pages have to fit into the semiconductor image memory thus to minimise the data shuffling between disc memory and image memory. Based upon the calculations of the previous chapter, an image memory of 60 to 100 MB is required. Another way to reduce disc transfer times is to use several parallel read/write heads and a suitable organisation of image data (e.g. a tile structure). This solution is used in the latest generation of CEPS.

In addition to large image memories, high processing power is needed to manipulate the images with real-time responses. To avoid this problem early CEPS systems and some current DTP systems first process a low-resolution version of the picture and repeat the operations on the full resolution image in the final batch run. However, this does not provide the user with a WYSIWYG interface (What You See Is What You Get), that is increasingly required today. On the other hand, the latest hardware development e.g. transputers, offers a good way of implementing powerful parallel processing architectures, of which SIMD (Single Instructions, Multiple Data) and MIMD (Multiple Instructions, Multiple Data) are the most relevant. Some dedicated systems already offer realtime processing of full-resolution images.

The output drum scanner in the new CEPS uses a large format (up to A0), which increases the output rate. Image compression and video tape mass memories have been used in the CEPS already for several years to increase the storage capacity. Compression is also used in DTP systems. Optical fibre transmission (FDDI with 100 Mbit/s) is used to transfer image data rapidly between different system units [Loc, 90]. Even though Crosfield is currently the only manufacturer to use fibre transmission in their GALAN network, two other major CEPS manufacturers agreed at Drupa 1990 to supply Beta-versions of their IFEN-interfaces (Intercompany File Exchange Network) in 1991 .

Current Mac and PC based DTP systems have significantly lower throughput rates than the CEPS. There is no preparation of the input scanning job, the image processing is normally done on standard Mac or PC hardware with no parallel processing and using medium-rate internal bus and disc transfer times. The image output is slowed down by the PostScript RIP process, even if the RIP units are becoming faster. This does not imply, that the DTP-systems are inadequate for all image processing in graphic arts. A low-speed system may be as cost effective in some application as a faster, yet more expensive.

Unix-based standard workstations (HP, DEC, SUN etc.) offer more processing power than Mac and PC based personal computers. An additional advantage is that the central memory can be expanded to form an adequately large image memory to keep several pages in memory the simultaneously. However, the other limitations mentioned for the DTP systems also apply to most of the workstation platforms.

COMPRESSION METHODS

Image compression is an important tool to get the file size down to a more manageable dimension. There is a lot of literature on image compression. For a survey of Graphic Arts applications, see [Söd,83][Joh,85] [Blue,87]. Image compression removes, totally or partly, the redundant data inherent in the greyness and colour dependency between adjacent pixels. In addition, the compression schemes take advantage of the way the human visual system processes information. The compression factor varies between 2 and 50 or even more.

Reversible schemes lose no information, but the compression ratio is fairly low - under 5 for grey-level pictures. Irreversible algorithms compress more efficiently at the cost of losing some information. However, the loss of information is often almost invisible to the human eye. In addition to this trade-off between the compression factor and quality, there are other evident trade-offs: compression factor *vs* coding speed and coding speed *vs* hardware complexity of the coder/decoder.

There are different schemes for line art, tone and colour images. The coding of two-level line art is well established and uses standardized run-length type algorithms achieving compression rates around 15. Tone pictures can to a certain extent be compressed by simple schemes like reducing the number of pixels and grey levels and by using nonlinear quantization. More adequate tone compression methods are divided into three main categories:

* predictive methods
* transform methods
* coding of uniform areas

In addition to these, there are lots of other compressions methods, of which *block, vector* and *pyramid coding* are the most important. Block coding, i.e. BTC, is applied in the teleproofing system presented at this conference [Söd,91].

Predictive methods

The simplest way of removing redundant information from tone pictures is to code the grey level difference between the pixel value and its prediction as calculated from the neighbouring pixels. As the differences are unevenly distributed - small differences are of course more common - a Huffman-type variable length coding of the differences brings clear savings. With this DPCM-scheme, a tone picture can be compressed reversibly on an average 2.5 times. DPCM is used e.g. in telephoto transmission systems.

Transform methods

Transform methods give considerably greater compression ratios than predictive methods. In these methods an image is transformed blockwise into a spatial frequency space, where the frequency components express how periodical spatial patterns are represented in the picture. By coding the high frequency components corresponding to high periodicities, more roughly than the low frequency components, a compression factor of 10-25 is achieved for b/w and up to 50 for colour [Söd,83].

The so-called JPEG-algorithm (Joint Photographic Expert Group), which is proposed as an ISO standard, is based on a cosine transform with some adaptivity in the quantization of the frequency components. As a transform scheme in general, the JPEG algorithm is computationally heavy and requires hardware implementations to run in real time. Many current image processing systems have built-in such semiconductor JPEG chips for rapid compression. Other systems use slower software implementations.

The JPEG algorithm leaves some open options that relate to the colour transform, taking place before the cosine transform as well as to the quantization of the components. In a recent study at our laboratory, the following colour spaces were compared: with RGB images the video colour spaces (YIQ, YUV, CCIR), CIE-Lab and Karhunen-Loeve [Ylä,91]. The methods were compared both theoretically by correlation analysis and experimentally.

A visual inspection of the decompressed hardcopy images (compression factor around 15) was carried out by a group of observers. The evaluations showed that the video colour spaces are most optimal with JPEG-compression of RGB images, whereas CIE-Lab is less orthogonal and more complicated to calculate. The Karhunen-Loeve space - although statistically orthogonal - is not perceptually uniform showing artefacts around the edges. As expected, the plain RGB-space causes the most serious compression artefacts. The evaluations also suggest the same quantization accuracy for luminance and chrominance components, while with perceptually uniform colour spaces like CCIR undersampling of the chrominance component can be used.

Area coding

Area coding schemes promise an even higher compression than the transform methods. In these methods homogeneous areas are characterised by parameters like constant greyness, colour or texture. By just coding the geometric shapes of the areas and the content with a few parameters, compression ratios of several hundred are reached. The difficulty is to find homogeneous areas in natural images. In practise this method leads to rather large approximations. An advantage compared to other schemes is that image operations can be executed on the compressed picture. Operations like size changes and rotations are then be very rapid. There are commercial programs which apply this scheme.

A very compact way of characterizing areas is to use fractals, which are iterations of a basic pattern. Fractal schemes achieve compression ratios of up to 1,000, but they are associated with the same inaccuracy as area coding in general.

MASS MEMORY TECHNOLOGIES

Large image files require vast mass memories for storage. Mass memories are either magnetic and optical. Both techniques are rapidly developing and occasionally joined to form hybrid solutions like magneto-optical discs. In general, magnetic techniques are better established and cheaper, whereas optical memories offer larger storage capacity on-line and longer archiving times.

Magnetic mass memories include large hard disks (up to 1 GB), tape streamers (some hundred MB), Digital Audio Tape (around 1 GB) and video tape (several GB) modified for data storage. Video tapes, preferably the 8 mm format, are widely used in CEPS system for the storage of high quality colour pictures.

Optical storage provides a higher data densities than magnetic media. Mass memories can be divided into ROM (Read Only), WORM (Write Once Read Many Times) and rewritable. Another ortogonal division can be made between analog and digital storage. Analog coding is used for video storage. These divisions produce the taxonomy in table 1.

	Read-Only	**WORM**	**Rewritable**
Analog	Video disc	Recordable video disc	Under development
Digital	CD-ROM (550 MB) CD-I , DVI Photo CD(100 pictures)	Recordable CD-ROM WORM disc (6 GB) Digital paper (1 TB)	Magneto-optic disc (800 MB)

Table 1. Taxonomy of the main optical memory types

When hundreds of digital WORM discs are collected into jukeboxes, storage capacities over of 1 TB (1000 MB) are reached. Digital paper, which is a polymer-based medium, also achieves 1 TB, when a tape reel.

These figures imply that current storage media do not set any technical limits on the storage of image files. However, there are of course economical trade-offs. The most significant one is between the storage cost and the retrieval time - e.g. a DAT-tape offers about 25 times lower cost per stored bit than the WORM disc, but the retrieval time is much longer, on the average around 20 seconds [Söd,90].

It may be assumed, that the mass memories will expand their capacity per price factor more rapidly than the rise in the size of the image file. Taking into account the developing compression technology, mass memories of the future will allow the establishment of vast archives of colour images with a quality that gives a high-quality reproduction in print [ibid].

DISPLAY CONTROLLERS AND RESOLUTIONS

The resolution of current image monitors is approximately 1000 * 1000 pixels both in dedicated CEPS and standard DTP. All new systems support non-interlaced refreshing of the monitor image, which means that the whole image is recreated in 1/60 to 1/100 second. When the monitor signals are the picture source - as in the teleproofing system built at our laboratory [Söd, 91] - the digitizer of the analog signals has to digitize a 1000*1000 pixel image in 60 to 100 times a second.

The current manufacturing limit for CRT based image monitors is around 2000 * 2000 pixels, but these monitors are still rare. The emerging flat display technologies will most probably provide the 2 Kpixel resolution and higher at a reasonable price.

The current display resolution is thus not able to display all pixels of a typical image page at once. The usual solution is to crop the picture or to minify it. The cropping especially combined with zooming and scrolling can confuse the user. A convenient way, employed in some systems, is to simultaneously show both the cropped part of the picture and the location of this part in a minified picture version. The minified version cannot be used in pixel operations like tracing and retouching.

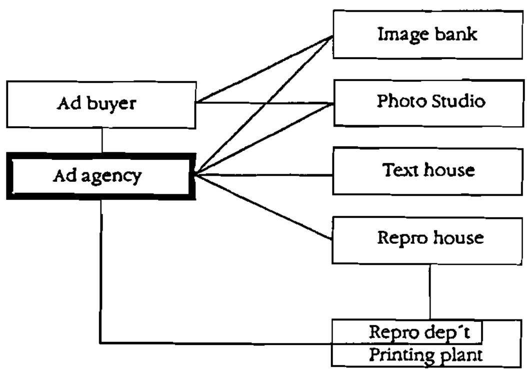
Because of the high resolution of the images in graphic arts and the relatively slow advances in CRT monitor resolutions, there are no means for displaying the image in full-resolution the near future. However, the impact of this drawback can be minimized by proper design of the user interface.

WORKFLOW, LINKING AND INTEGRATION

The production of colour printing has been an expensive process. It is not only the problem with high resolution, large files or precise colour definition but also the complicated structure of colour page jobs. This job complexity closely follows each step of increased power of image processing and correction features of the CEPS. The traditional workflow in a typical high quality *professional* colour-page production is for example (*fig. 1*):

* The marketing department of an *ad buyer* subcontracts an ad agency to produce a series of ads for a campaign in printed mass media. Campaigns may include other media i.e. a media mix.
* A designer of the *ad agency* acquires picture originals as a part of the advertisement material (sources vary from *photo studios* to *image banks* or to the customer's existing picture *archives*)
* A series of *studio* originals is produced and delivered to the ad agency or to the ad buyer. Work with page layouts continues.
* A *reprohouse* is contracted to produce final page and colour separations in full size and resolution (adapted to the printing,and paper/ink combination of a known commercial printing plant or several printers). Final prepress proofs are accepted by the buyer.
* The *printing plant* prints and mails the final product (magazine, newspaper, ad print or catalogue).

Traditional workflow



Future workflow
(extreme integration of design and production)

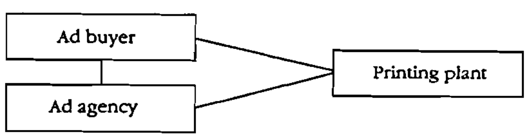


Figure 1. Traditional vs. future workflow.

This complicated workflow causes high costs, yet produces a high professional reproduction quality - if everything fits. At least in many less requiring products colour print production will be much simpler. Proofing can be a remote service [Söd,91] in which a complete monitor image of a CEPS or a DTP Colour system is transferred in a digital network from the repro or photo studio to the ad agency or to the ad buyer.

Design and production will be integrated from originals to more or less final pages. Document and product *specifications* and *digital management* (from prepress to printing and mailing) will make the placing of printing orders both faultless and faster.

Integration of the workflow is basically at a level we like to call *between systems* - the other two levels being *within* systems and *inside* basic systems/computers (*fig. 2*). Integration between the systems (i.e. changes in the work flow and practices) is the most demanding process and will be supported by the progress at the two other levels.

Both the publisher and the ad or print buyer will benefit from these innovations as they are gradually brought into the colour production market. Many products are expected to be developed and supported by the vendors of colour systems, document management and DTP.

Integration and *linking* take place in the high-capacity and high-quality production systems of the repro and printing plants since CEPS and DTP worlds can export image formats (DDES, TIFF, EPS) which are known in other systems [Dun,89],[Kar,90]. These tailored linking solutions are becoming easier and several commercial products are available on the CEPS market (Crosfield, Hell, Itek, Scitex, Screen). This will help the CEPS to survive and the DTP Colour to penetrate the professional repro market.

OPI (Open Prepress Interface) bridges between DTP and CEPS systems bring together the best of the two worlds - the pagination capabilities of the DTP systems and the fast handling of high-quality images in the CEPS systems. An overloading is avoided by using a low-resolution version of the image in the DTP pagination.

Integration takes place at all levels, also *inside* the basic systems. The basic PCs or workstations include more and more image and type possibilities. We talk about *device -independent colour, portable type and page description languages (PDLs).* Today most commercial computer systems include, in addition to the operating system, a windowing unit, and an efficient user interface . As pointed out by e.g. [Del,90], a typical page display and output solution includes a display PDL (e.g. Display PostScript or True Type), and a related output driver all integrated into the operating system.

Integration

* Between the systems
(changes in work flow)

** In the systems (linking)

***Inside the basic systems (inclusion)

Figure 2. Different levels of integration

CONCLUSION

Our purpose was to show how much the main difference between text and image processing - the file size - has influenced the design of the systems. Image files are large and becoming even larger. Their portability has been improving and standards are applied widely. Mass memories increase their capacity faster than the growth in image size. Image compression has become a useful module. Standard processors of the computers are supported by special processor chips and boards without sacrificing the compatibility of the entire system. Large image files are still a considerable bottle-neck of all professional publishing systems.

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