ADVISORY GROUP ON Computer Graphics

Evaluation of Image Capture Pathways for Multimedia Application

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Contents

Summary

Developments in image capture technology allow developers of multimedia applications to incorporate source material of varying physical characteristics. However the multimedia developer drawing up a specification for a capture system is faced with a bewildering choice of equipment for which there is little comparative information on the relationship between equipment specification and captured image quality. This report provides guidelines for decisions on the choice of appropriate capture pathways within the context of higher education.

This project evaluated two equipment scenarios, differentiated on cost for hardware with associated software, and PhotoCD origination for capturing images for inclusion in multimedia applications. Classes of image relevant to teaching in a range of university departments were identified. Original source material was captured using different hard copy and electronic media, digitised and stored on an optical disc. The different versions of each image were ranked against each other and qualitatively scored for spatial resolution (sharpness), colour faithfulness and contrast ratio. Standard charts used in broadcasting to test spatial resolution, contrast ratio and grey scale were used to provide quantitative assessment. The effect of compression and image manipulation are not considered in this report which is part of the ongoing research programme.

On the basis of the results obtained, guidelines were drawn up on systems specification and image capture for developers of multimedia application in higher education. The guidelines recognised that photographic, video and computing skills, and high quality source materials are as important as having suitable hardware if high quality images are to be obtained. Overall the results indicated that the best digitised image on the basis of the three established quality criteria was obtained from a combination of a 35mm slide or negative plus digitisation via PhotoCD. Of the other options there was no clear winner between video rostrum cameras and scanners. The use of the still video camera and single frames from a video tape failed to produce acceptable results. Whilst PhotoCD produced the best result for three dimensional subjects and flat art, for photomicrography the use of a rostrum camera offered the distinct advantage of being able to view the displayed image before capture.

Introduction

1.1 Terms of reference

Developments in image capture technology allow developers of multimedia applications to incorporate source material of varying physical characteristics. However the multimedia developer drawing up a specification for a capture system is faced with a bewildering choice of equipment for which there is little comparative information on the relationship between equipment specification and captured image quality. This report provides guidelines for decisions on the choice of appropriate capture pathways within the context of higher education.

Source material may vary from original objects such as biological specimens through hard copy sources like manuscripts, books, maps, photographic sources such as transparencies and film, to electronic sources like videotapes or video discs. There are a number of devices which can be used to capture images of the source material, although not all images can be captured by each device.

Six stages of image capture and processing were identified as follows:

1. Selection of source material
2. Initial capture (photographic or analogue)
3. Secondary capture (digital)
4. Manipulation in a photo re-touching software package (e.g. Adobe Photoshop)
5. Compression
6. Storage

Use of the term 'analogue' refers to electronic image capture where signal amplitudes are continuously variable. 'Digital' refers to signals recorded in bits, that are either 'on' or 'off'. The terms of reference for the project were to address the effects of various capture processes on image quality, stages 2 and 3 above. The project did not systematically address the effects of subsequent software manipulation, stage 4, or of compression after digitisation, stage 5, although both can affect the quality of the final displayed image.

In specifying a capture system it is necessary to achieve sufficient image quality to meet the required teaching/learning need within defined budgetary constraints. Quality as far as image capture is concerned is monitored by assessing three distinct facets of each image:

- Spatial resolution (sharpness)
- Colour (faithfulness to original)
- Contrast ratio (range of half tones).

The acceptability of a captured image is determined by the combined effects of these three facets.

As equipment choice is likely to be constrained by budget, the implications of two cost scenarios on the quality of image capture were assessed. The two systems were chosen as follows:

- Centralised Service Model: purchase of higher cost equipment justified by high throughput and intensive use.
- Departmental Model: in this scenario the facility is only likely to be used intermittently and consequently the purchase of high cost equipment is unlikely to be justified.

In addition, these two budgetary scenarios were compared with results obtained from the use of the Kodak PhotoCD system, for which no investment in electronic capture equipment by the institution is required.

1.2 Aims and objectives.

The aims of the project were to evaluate a range of hardware and associated software options for the capture of images for two equipment cost scenarios as defined above, and to draw up guidelines for the selection of appropriate systems for image capture by developers of multimedia applications in higher education.

The objectives were to identify:

- types of source material required as digitised images by developers of multimedia applications for higher education
- optimal pathways for capture of images bearing in mind feasibility, quality and cost
- the implications of two budgetary scenarios for hardware and associated software on the quality of the captured images.

2 Methodology

2.1 Comparative Pathways for Image Capture.

The project examined the effects on digitised image quality of capturing images using the capture routes shown in Figure 2.1. A representative subject for each type of source material was captured. Not all images can be captured using all the prescribed capture devices, e.g. the Canon Ion still video camera has an unsophisticated zoom lens unsuitable for connection to a microscope. Other mutually exclusive permutations of image and capture device are identified in later sections.

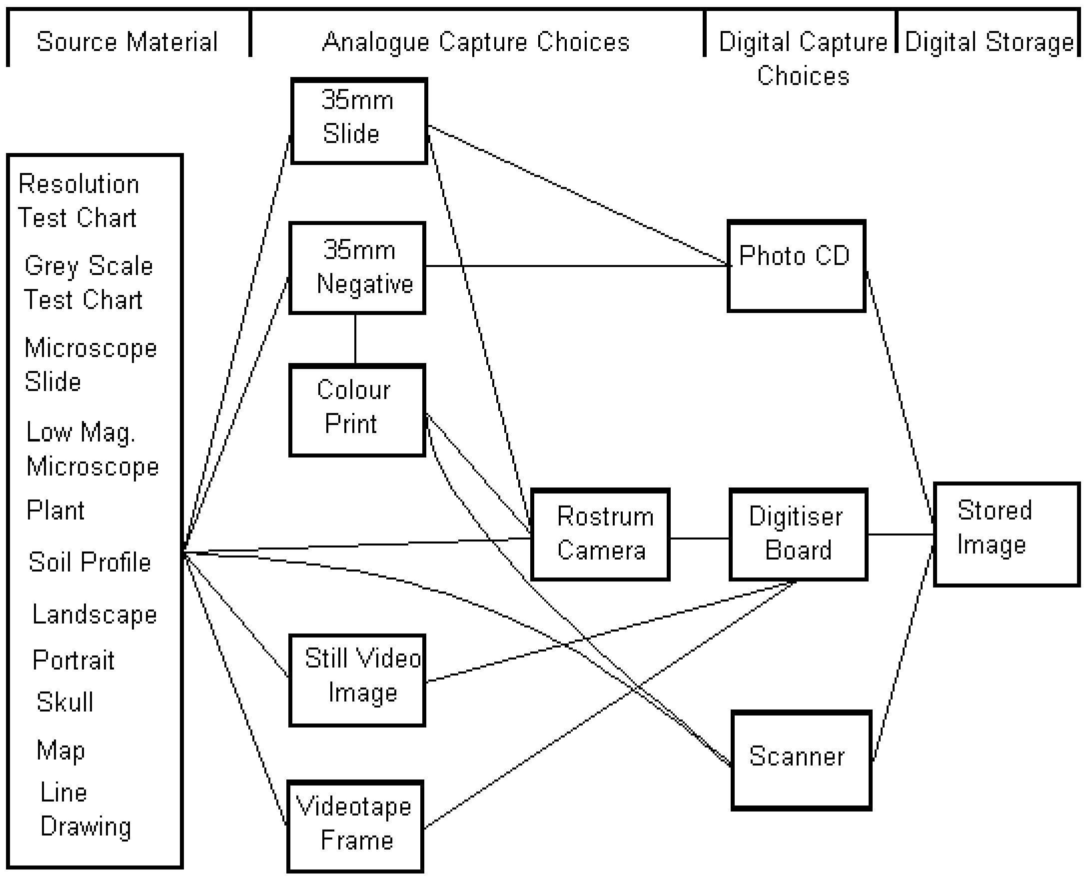

Figure 2.1 Capture options for various source materials and test charts

2.2 Image quality

2.21 Introduction

The quality of a digitised image is dependent on both the quality of the original source material and the adoption of a digitisation pathway which minimises quality loss. This study has worked with source material of as high a quality as practicable to effectively test the various capture routes. Quality judgements on the attributes of a particular capture path or piece of equipment were made by employing both quantitative and qualitative techniques. To isolate the effect of capture path on overall quality as defined in section 1.1, Spatial Resolution and Grey Scale test charts (standard throughout television broadcasting) were used for quantitative assessment of spatial resolution and contrast ratio respectively, while a qualitative assessment was made of the colour information in full colour images.

It would have been preferable to undertake a quantitative analysis of degradation in colour information but the project did not have access to a Spectraradiometer or similar device to enable such a study. It is intended that quantitative colour assessment should be included as part of the on-going research programme.

2.22 Quantitative measurement of quality - test charts

The standard Spatial Resolution test chart, used in broadcasting to assess vertical and horizontal spatial resolution and system frequency response, carries over satisfactorily for use with computer display monitors. This chart enables assessment of spatial resolution through testing the system's ability to differentiate between distinct black straight lines against a light background. When the lines merge together indistinctly then resolution is said to have reached its limit. As can be seen from the diagram, spatial resolution between 200 and 800 TV Lines can be assessed at various points across the screen and in this case horizontal resolution was measured in units of 25 lines."TV lines" are a unit of measurement to establish the number of discreet picture elements (in this case lines) that can be resolved horizontally and vertically over the full screen. Although originally designed for use with video scanning systems the chart does provide a convenient means of comparing the spatial resolving power of the different systems used for capture.

Where the lines converge moir patterning appears before resolution is measurably impaired. Moiré is a rainbow-coloured patterning introduced when lines in television picture content are closer together than the monitor is able to display, and it is commonly seen in television presenters' striped shirts before they learn not to wear that style. Moiré is not as apparent on a computer monitor as it is on a video monitor because on the computer monitor colour information comes from digital red, green and blue (RGB) signals rather than being a part of the analogue coded Phase Alteration Line (PAL) video signal. For this reason moir is not always a relevant factor in comparisons and on this project was eliminated on the video monitor by turning down the colour to give a truer assessment of spatial resolution.

The Grey Scale chart displays 9 half tone shades of grey between white and black - 11 shades in all. It is designed to assess whether the system can differentiate between steps all the way from black to white, but particularly at the extremes of the chart where contrast limitations are most apparent. This chart is also designed to test the ability of a colour capture device to show a grey image with no colour casts across the half tone range provided. A colour capture device utilises equal parts of the additive primary colours red, green and blue when reproducing a black, white and half tone image, and is effectively lined up to deliver good colour output when it displays an accurate and complete grey scale. For this reason broadcast television cameras are lined up initially on the Grey Scale chart and colour casts in particular half tones are revealed and eliminated. Depending on the number of half tones presented for grey scale resolution, it is reasonable to assume that those in between, and not specifically covered by the steps in the chart, would appear in any case.

2.23 Qualitative measurement of quality - full colour images

Subjective assessments were made of the remaining 9 full colour images based on the criteria of sharpness (a less precise version of spatial resolution), colour (faithfulness to earliest available version) and contrast ratio (ability to resolve perceived range of light and dark shades). These assessments were qualitative and were scored on a scale of 1-5 as follows:

5 Excellent
4 Good
3 Satisfactory
2 Poor
1 Unacceptable

Assessments were made on the above technical criteria by two members of the project team working together. All the high budget and PhotoCD versions of an image were displayed on screen together when scoring the individual images, and all the low budget versions were also viewed simultaneously. Assessment was made without reference to educational effectiveness in any specific context. The assessment of the images in a specific educational context using students was not possible due to the time constraints of the project but this is part of on-going research.

2.3 Source material

The selection of types of original source material for image capture was made on the basis of the likely requirements of different university faculties.

The 9 image types were:

- Microscope Slide
- Low magnification microscope specimen
- Plant
- Soil Profile
- Landscape
- Portrait
- Skull
- Map
- Line Drawing

The **Microscope Slide** was a biological thin section, mounted on glass, of the lactating mammary gland of a sheep, designed to be viewed through a high magnification microscope and in this case seen at 50x magnification. The magnification was the product of a 10x objective and 5x objective in the microscope and did not reflect displayed magnifications on 35mm film or video monitor. It required the resolution of a range of half tones stained magenta and some seemingly monochrome grey material. This slide demonstrated the effect of using a transmitted light source to illuminate an image; in this case at just over half power on its thyristor control, providing 'warm' illumination from the red end of the spectrum. For microscope work the same video rostrum camera head (a JVC TK-1280E, hereinafter designated Rostrum 2A), set to white balance automatically was used because of the need for a custom built adapter to interface the camera with the microscope. Usually a separate adapter is needed for each microscope used because the focal distance between the cameraÆs charge coupled device (CCD) and the eyepiece in the microscope is crucial. Each adapter can cost up to £500. The magenta staining in the slide tested the video system because historically tube television cameras have had difficulty resolving magenta, which is in the area between red and blue, although it is now recognised that this is less of a problem with CCD than with Tube cameras.

The **Low Magnification Microscope** specimen was an apical dissection of a developing ear of barley, designed to be viewed at low magnification and in this instance seen at about 12.5x magnification through the microscope. This image was side lit with a fibre optic source used at just over half power, with a piece of aluminium foil presenting its matte side providing a fill light.

The **Plant** was a flowering example of Charlock, captured with the sun high on a clear autumn day. Lighting conditions were ideal because a range of half tones and shadows had to be resolved. However it was difficult to isolate a single plant from its background because it was in a densely colonised field - a familiar problem for photographers in a biological context. It is recognised that in some circumstances it may be possible to remove the specimen for photography under studio conditions. On this occasion it made it difficult to separate the flower from its background in low resolution versions of the image.

The **Soil Profile** was part of the side of a granite quarry below Bennachie - a hill in Aberdeenshire - regularly used for teaching purposes by soil scientists at Aberdeen University. The section exhibited shades of light pink; not what a photographic printer would expect to reproduce accurately without some reference. The image was purposely captured out of direct sunlight because sunlight and shadow can interfere with perception of subtle colour shadings associated with soil profiles. For this reason it was not considered appropriate to consider contrast ratio with this subject, and accordingly only colour and spatial resolution assessments appear in the results.

The **Landscape** was a view looking north-west towards the hills from a point about two miles west of Tarland in Aberdeenshire. It showed a range of land uses from gorse and woodland alongside a burn, upwards through arable farmland to hill grazing, coniferous plantation and eventually heather moorland to the skyline. The sun was out and quite high, providing a range of half tones and possible shadow detail to test contrast.

The head and shoulders **Portrait** required capture of the mixture of primary colours associated with flesh tones, which although not identical between faces is nevertheless familiar as a concept to most of us. The subject was captured against a textured monochrome grey wall to reveal small colour shifts not immediately apparent on the face. No fill light was used on the unlit side of the face to test the amount of shadow detail resolvable by different methods of capture.

The **Skull** was chosen to exemplify capture of a three dimensional subject displayed under controlled studio lighting conditions. The subject was that of a male capercaillie which, although mainly monochrome, exhibited many shades of the colour associated with bone structure.

The **Map** detail was a section of the 1:250,000 Soil Survey of Scotland Soil Map, Sheet 5: Eastern Scotland. The physical dimensions of the example were chosen to provide legible names at initial capture when viewed full screen on the computer monitor. This particular map was chosen to test the ability of the capture systems to resolve subtle variations of colour required to differentiate between the mapping units.

The **Line Drawing** was a detail of a coloured Victorian engraving of the view through a microscope of a cryptogram, Volvox globator (The Rolling Sphere) which included subtle colour variations and fine line engraving.

2.4 Capture devices

2.41 Introduction

Equipment for image capture was chosen to fulfil two budgetary scenarios as defined in section 1.1:

- higher cost system - purchase justified for a centralised service - equipment suffixed by the numeral '1' in this report.
- lower cost system - purchase might be justified by an individual department - equipment suffixed by the numeral '2'.

In addition, these two budgetary scenarios were compared with the results obtained using the Kodak PhotoCD system.

Some of the capture devices used were common to both Central and Departmental models, and some specific to one or the other. Table 2.1 lists the equipment reviewed, and fuller descriptions of each item are given in following sections and in the Appendix.

Common	**Central**	**Departmental**
35mm Slide (analogue)	Rostrum Camera 1 (analogue)	Rostrum camera 2 (analogue)
35mm Negative (analogue)	Video Capture Board 1 (digital)	Video Capture Board 2 (digital)
Print (analogue)	Scanner 1 (digital)	Scanner 2 (digital)
Videotape Frame (analogue)	Still Video (analogue)	
PhotoCD (digital)		

Table 2.1 Capture Devices

The slide was designated the benchmark for quality. There is a need for such a benchmark because seasonal and lighting changes plus remoteness make it impractical to go back to check original source material in most cases. The colour slide, which is the actual film from the camera and in development is not prone to errors of interpretation as are prints from a negative. The other possibility would have been to use the negative but it is not practical to compare the other images against the negative.

2.42 Capture devices common to both resource models

The **35mm Slides** were shot on Kodachrome 64 film stock which has a resolving power of between 63 and 100 lines per millimetre (LPM) and an exposure latitude of less than + or - half a stop (Kodak trade literature).

35mm Negative. The film used was Kodak Ektar 100. It is half a stop faster than the Kodachrome 64 used for slide origination but the closest comparable stock, providing resolving power between 63 and 160 LPM despite the extra speed and with a much greater exposure latitude between -1 and +3 complete stops (Kodak trade literature). Designed for the provision of copies, colour negative film provides greater contrast range, colour temperature flexibility and exposure latitude than 35mm slide film, although it does introduce the possibility of errors in the copying process.

Photographic Prints were processed by Boots the Chemist, whose output conforms to British Standard 5750. The print size used as a standard in this project was 7 x 5ins. This minimises any loss of sharpness inherent in the texture of the emulsion on the paper, which might become apparent at smaller sizes.

All photographic capture was undertaken on Nikon F3 cameras with appropriate Nikkor lenses and filters.

The **Still Video** camera used was a Canon Ion RC-560 camera with an 8-24mm (3-1) integral zoom lens and a stated maximum resolution of 736 x 544 pixels and 450 TV lines. This camera is capable of recording 50 field (alternate television lines scanned) or 25 full frame images onto a small floppy disc and replaying them individually at a standard 1 volt of video peak to peak (75 ohms), either through its own board or through a video capture board for digitisation.

Single **Frames of Videotape** were selected from continuous recordings on Hi8 metal-E tape from a Sony Video Hi8 Pro Camcorder with 8-80mm zoom lens c/w macro facility.

All 35mm slides and negative images were also transferred onto PhotoCD at Photo-Technical Services, a local processing firm.

	£
Panrix 486DX 66MHz 16Mb RAM computer	2474.00
'Wizard' 9000VL 24 bit (true colour) video card	295.00
SVGA monitor	900.00
CD-ROM drive (multisession Photo CD compatible)	200.00
1Gb Read/Write Optical Disc Drive	1800.00
Video Monitor	600.00
Kaiser RS1 rostrum copy stand	200.00
Kaiser Tungsten copy lights (2 x 150w)	201.60
Master light box	131.00

2.43 Capture devices specific to the central resource model

		£
Rostrum camera 1	JVC KY-F30B 3x Charge Coupled Device (CCD) Rostrum Camera + 7-98mm zoom lens c/w macro and 6 diopter close up attachment	6240.00
Video capture board 1	Screen Machine II Video Capture Board	725.00
Scanner 1	Hewlett Packard Scanjet Iic Scanner	1675.00
Still Video	Canon Ion 560	1000.00

2.44 Capture devices specific to the departmental resource model.

		£
Rostrum camera 2	JVC TK-1280E 1xCCD Rostrum Camera+ 18-108mm zoom lens c/w macro and 3 diopter close up attachment	1100.00
Rostrum camera 2A	JVC TK-1280E 1xCCD Rostrum Camera no lens, adapted to the microscope	900.00
Video capture board 2	Videologic Captivator Video Capture Board	300.00
Scanner 2	Logitech Scanman Colour Scanner	306.00

Results

3.1 Quantitative results: test charts

The results of the quantitative assessment of the various image capture paths as measured by the Spatial Resolution and Grey Scale test charts are presented in Table 3.1.

Path	Resolution TV Lines	Grey Scale Half Tones
Maximum Test Chart Readings	800	11
Chart - Rostrum 1 - Digitise 1	375	11
Chart - Rostrum 2 - Digitise 2	300	11
Chart - Scanner 1	425	11
Chart - Scanner 2	375	9
Chart - Slide - PhotoCD	375	11
Chart - Neg - PhotoCD	400	11
Chart - Slide - Rostrum1 - Digitise 1	350	11
Chart - Slide - Rostrum2 - Digitise 2	350	11
Chart - Neg - Print - Rostrum1 - Digitise 1	325	11
Chart - Neg - Print - Rostrum2 - Digitise 2	300	10
Chart - Neg - Print - Scanner 1	425	10
Chart - Neg - Print - Scanner 2	425	9
Chart - Videotape frame - Digitise 1	250	9
Chart - Videotape frame - Digitise 2	250	9
Still Video - Board 1 - Digitise 1	n/a	9

Table 3.1 System Performance as measured by the Spatial Resolution and Grey Scale Test Charts

Unfortunately it was not possible to observe the spatial resolution chart with the Canon Ion Still Video camera because at 12" x 9" the chart was too small to fill the frame at the minimum focusing distance - an essential requirement for accurate quantitative results. The PhotoCD results are considered first and then the different equipment systems are reviewed.

Spatial resolutions achieved by PhotoCD transfers are misleadingly low where the whole of the test chart is displayed on the screen at one time (for a description of the PhotoCD system, see Appendix). The image derived from the print was marginally better than that achieved from the 35mm slide, 400 and 375 lines respectively, but significantly lower than the maximum of 800 TV lines provided by the chart. However, when the originals were examined the photographic print (and therefore the negative) and slide both resolved all 800 lines, and when the PhotoCD image was examined at its higher (photographic) resolution all 800 lines were present. Thus the limiting factor when viewing the whole chart image was the spatial resolving power of the display monitor.

PhotoCD images can be displayed in any one of 5 (sometimes 6) possible resolutions and if the whole image were to be viewed at the highest resolution at 1:1 magnification it would require an array of 16 (4 x 4) monitors to display it. Filling one screen with the complete image means that it is displayed at one sixteenth of its actual size, and at that size spatial resolution performance is limited by the resolution of the display monitor. However if the image is viewed at the PhotoCD photographic resolution (3072 x 2048 pixels) with only a small area of the actual image displayed on the monitor, maximum resolution is revealed. It was only when viewed at this higher resolution that the photographic versions (negative and slide) of the Spatial Resolution Chart revealed the maximum number of TV lines (800). PhotoCD versions of the Grey Scale Chart revealed the maximum number of half tones with no perceptible degradation.

For the various high cost and low cost system permutations the best results were consistently recorded by the Scanner 1 system which achieved 425 TV lines when capturing the Chart directly or a photographic print of it. Direct capture of the chart using Rostrum Camera 1 was slightly less satisfactory with only 375 lines resolved, whilst capturing a 35mm slide or print of the chart with the same system reduced the resolution to 350 and 325 lines respectively. The low cost systems delivered poorer spatial resolution from three of the six capture combinations (Chart - Rostrum - Digitiser; Chart - Neg. - Print - Rostrum - Digitiser; Chart - Scanner) and comparable results from the remainder (Chart - Slide - Rostrum - Digitiser; Chart - Neg. - Print - Scanner and Chart - Videotape Frame - Digitiser). The use of videotape frame capture pathways resulted in a significant loss of quality as measured in terms of spatial resolution compared with the other methods of capture.

The generally high results in Table 3.1 for the Grey Scale chart conceal the fact that while the number of half tones indicated were present as stated, they were often degraded. Progression along all capture paths did subjectively indicate a slowly worsening contrast ratio i.e. a loss of detail in either the very light or the very dark greys, or a loss of peak white or black. There were also cases where readings were less good at the top or bottom of a screen - an artefact not present in the original photographs of the charts which were all taken out of doors under an evenly bright cloudy sky. The higher cost systems all scored the maximum 11 half tones except for the scanned image of a print of the chart (10 half tones) and the still video and videotape frame (9 half tones). The low cost system tended to deliver fewer or degraded half tones when compared with the corresponding higher cost system, although for certain combinations of equipment the results were again similar.

3.2 Qualitative results: full colour images

3.21 Introduction

Two members of the research team worked together to agree upon a score which, given the variations that can exist in 'normal' colour vision, reduced the possibility for bias. When scoring the different versions of an image as many examples as possible were compared at the same time (see section 2.23). It was noted that when viewed singly many versions were quite acceptable, particularly for colour, whereas when compared as a group their individual shortcomings became apparent. A future development of the on-going research project will be to assess the various versions of the images in an educational context to see at which point quality falls to an unacceptable level.

Each image was rated on a five point scale (5 = Excellent) for sharpness (a subjective measurement of spatial resolution), colour (faithfulness to the original source material or analogue image of the source material when the original was not available) and contrast ratio (perceived range of half tones). An exception to this rule was the Soil Profile which was captured in lighting conditions deliberately designed to eliminate distracting contrast detail and therefore could not be rated for this attribute. The scores were then averaged and the results are presented in Table 3.2 of the qualitative scores for the 9 full colour images. Table 3.3 shows the breakdown of the individual scores. From left to right in each cell the figures indicate ratings for sharpness, colour and contrast ratio. The 35mm slides of the microscope slide did not achieve assessable quality and therefore there are no results present for this image in Tables 3.2 and 3.3.

Path	Microscope Slide	Low Mag. Microscope	Plant	Soil Profile ^	Landscape	Portrait	Skull	Map	Line Drawing
Source - Slide - PhotoCD	*	1.6	4.6	4	4.6	4	3.6	3.3	3
Source - Slide - PhotoCD	3.3	2	4.6	4	4.6	4	4.6	3	4.6
Source - Slide - Rostrum 1 - Digitise 1	*	1.6	2.6	3.5	3.6	4	3.3	3	4.3
Source - Slide - Rostrum 2 - Digitise 2	*	1.6	2	3	3	2.6	1.6	2.3	2.6
Source - Neg - Print - Rostrum 1 - Digitise 1	2.3	4	2.6	2	3.3	3	4	2.6	3.3
Source - Neg - Print - Rostrum 2 - Digitise 2	2.3	3.6	3	3	2.6	3	2.3	3.3	3
Source - Neg - Print - Scanner 1	2.3		3	2	2.3	3.3	2	2.3	2.6
Source - Neg - Print - Scanner 2	2.3		2.3	2	1.3	2.6	3	1.6	2
Source - Videoframe - Digitise 1			1	2	1.6	2	2		
Source - Videoframe - Digitise 2			1	1.5	1.3	1.6	2		
Source - Still Video - Digitise 1			1	2	1.3	2.3			
Source - Rostrum 1 - Digitise 1	#	#					4.6	3	2.3
Source - Rostrum 2A - Digitise 1	4	3					#	#	#
Source - Scanner 1								2.6	3
Source - Scanner 2								1.6	2

Table 3.2 Averaged qualitative scores for the 9 full colour images (^ average of 2 results, * images which failed to achieve assesable quality, # examples which were not technically possible)

Path	Microscope Slide	Low Mag. Microscope	Plant	Soil Profile ^	Landscape	Portrait	Skull	Map	Line Drawing
Source - Slide - PhotoCD	*	3 1 1	5 4 5	4 4 n/a	5 5 4	5 4 3	5 2 4	4 2 4	4 2 3
Source - Slide - PhotoCD	3 3 4	3 1 2	5 5 4	4 4 n/a	5 4 5	5 4 3	5 5 4	5 2 2	5 5 4
Source - Slide - Rostrum 1 - Digitise 1	*	3 1 1	3 2 2	3 4 n/a	4 4 3	3 5 4	3 4 3	2 3 4	4 5 4
Source - Slide - Rostrum 2 - Digitise 2	*	2 2 1	2 2 2	2 4 n/a	3 3 3	2 4 2	2 2 1	1 3 3	1 3 4
Source - Neg - Print - Rostrum 1 - Digitise 1	3 2 2	4 4 4	3 2 3	3 1 n/a	4 3 3	3 3 3	3 5 4	2 3 3	4 2 4
Source - Neg - Print - Rostrum 2 - Digitise 2	2 3 2	4 4 3	3 3 3	3 3 n/a	3 2 3	3 3 3	2 2 3	2 4 4	2 4 3
Source - Neg - Print - Scanner 1	2 3 2		3 3 3	2 2 n/a	3 2 3	4 2 4	2 1 3	3 2 2	2 3 3
Source - Neg - Print - Scanner 2	3 1 3		3 2 2	3 1 n/a	2 1 1	3 3 2	3 3 3	3 1 1	4 1 1
Source - Videoframe - Digitise 1			1 1 1	1 3 n/a	2 1 2	1 3 2	1 3 2		
Source - Videoframe - Digitise 2			1 1 1	1 2 n/a	1 1 2	1 2 2	1 3 3		
Source - Still Video - Digitise 1			1 1 1	2 2 n/a	1 2 1	2 3 2			
Source - Rostrum 1 - Digitise 1	#	#					4 5 5	3 3 3	2 3 2
Source - Rostrum 2A - Digitise 1	4 4 4	3 3 4					#	#	#
Source - Scanner 1								4 2 2	2 3 4
Source - Scanner 2								1 2 2	2 2 2

Table 3.3 Individual qualitative scores for the 9 full colour images (^ average of 2 results, * images which failed to achieve assesable quality, # examples which were not technically possible)

3.22 Comparison of capture systems

It can be seen from Table 3.2 that, with the exception of the Microscope images, all the PhotoCD transfers equalled or exceeded in quality the images captured by other systems. From Table 3.3 it is evident that in general terms PhotoCD scores for sharpness, colour and contrast ratio slightly exceeded the results from the scanners and rostrum cameras. In terms of contrast ratio, the PhotoCD system was able to capitalise fully on whatever information was present in images and particularly the extended shadow and highlight details afforded by negative versions, e.g. the landscape.

The comparision of the results in Table 3.2 for the rostrum camera systems with those for the scanner systems did not conclusively indicate whether one system was preferable to the other, although the balance was in favour of the rostrum camera systems. While qualitative comparisons of sharpness in Table 3.3 were not as conclusive as the quantitative spatial resolution measurements in Table 3.1, there were examples which reflected the test chart results. The map, when captured by rostrum camera and scanner directly from a photographic print, came out sharper from the scanner than the rostrum camera. The map detail was specifically chosen for its ability to test spatial resolution with its sharp edged detail and lettering, whereas other images like the landscape had no such well-defined hard edge content.

One strange result is worth noting individually. When the line drawing was captured directly by the scanners - a short and theoretically high quality path judging from the quantitative resolution chart result - the images were poor for sharpness and contrast ratio. On examination it was found that sharpness was there, but masked by the poor contrast. This was possibly caused by the extremely fine lines in the original artwork compared to the lines on the resolution chart. Traditionally television systems have had difficulty displaying very thin lines, which this subject had in abundance. When this particular image was looked at in Photoshop and its contrast greatly increased without changing the brightness, it was found that the lines were clearly there but that they would not appear without greatly exaggerating the contrast, and this severely compromised the content of the rest of the image.

Quality of those images captured using an early example of new technology (still video camera), and older technology (single videotape frame) were particularly poor. The Canon Ion camera is an early attempt to capture still images directly onto floppy disc with no intervening hard copy photographic process involved. In theory this short processing path should lead to good results. In practice the technical shortcomings of this new camera have still to be overcome. Sharpness, colour and contrast ratio all leave a great deal to be desired in comparison with more established media even with general subjects which were not intended to be specifically challenging.

The other method of capture which failed to come up to scratch was the single frame of videotape which with hindsight was pressed into service in an area for which it was not intended. In comparison with other versions of the images, for instance those captured on negative or slide film and transferred via PhotoCD, this one was poor in all the identifiable criteria, as was the Still Video version. However taken by itself, and considering the physical dimensions of the videotape used (8mm wide) for this analogue signal, the quality of the resulting images was surprisingly high. Inevitably there was a grainy look to the end result which may not be as noticeable with a continuously moving image. This has implications for the re-purposing of videotape material, and it does not necessarily apply to all videotape. Beta SP tape, for instance, may yield better results than Hi8 and some moving images may be more blurred than others, also lenses designed for the capture of moving images are often designed to lower toerances. Examples have to be assessed individually on their merits.

3.23 Comparison of high and low cost equipment

In isolated instances the better scores achieved with the low budget equipment exceeded the worst scores achieved with the high budget packages. As high and low budget versions were not initially compared together (see section 2.23) examples were re-examined to ensure that consistent standards were being employed and the original assessments were confirmed. Overall average figures for the capture of slides via Rostrum 1 were better than the figures for Rostrum 2. However a comparison of the results between Rostrum 1 and Rostrum 2, or between Scanner 1 and Scanner 2, did not conclusively indicate whether one cost system was preferable to another. Comparison of output of the two scanners may be questionable because the default resolution for screen display of the HP Scanjet IIc is 75 dots per inch (DPI) and for the Logitech Scanman Colour it is 100 DPI. The plant taken from the photographic print scored higher for colour quality on the low cost rostrum camera than on the higher cost system. The soil profile print was judged to be better in colour quality when captured by Rostrum 2 than Rostrum 1. Soil profiles call for very subtle colour rendition and it may be that the automatic white balance on the Rostrum 1 camera was not as comprehensive on this occasion as a manual colour balance for this particular image on Rostrum 2.

When the low budget Rostrum Camera 2 was carefully lined up by hand for a single image the quality was better in all three criteria - colour, contrast ratio and sharpness - than the output of the Canon Ion, which is an automatic still video camera for which no operational line up is possible. The results from the Canon Ion and the Videotape Frames were consistently deemed to be less good and would probably be unacceptable when quality was a factor compared to the other systems.

4 Discussion

4.1 Best capture method for the various categories of image

In pursuit of quality, represented by good spatial resolution, colour and contrast ratio, circumstances arose with the capture of particular image groups which would apply widely to the capture conditions surrounding any similar image. When considering the results the images divide naturally into 4 groups:

1. Microscope slide and low magnification microscope images (both captured using microscopes and artificial light).
2. Plant, soil profile, landscape and portrait (3 dimensional subjects captured using natural daylight)
3. Skull (3 dimensional subject captured under studio conditions using artificial light)
4. Map and line drawing (both flat art examples captured under studio conditions using artificial light)

It is suggested that the four groups of images identified comprise most of the image types likely to be encountered in a higher education context.

4.11 High and low magnification microscope images

Photomicrography is a specialised branch of photography and familiarity with the operation of the chosen microscope, light source(s) and selection of lenses proved to be important as the camera which simply records what it sees through the component parts of the microscope. All adjustments (e.g. composition, focus and colour temperature) are made to the microscope and its light source. Capture devices are required to react to these conditions.

Capturing the image of the source material with a colour slide or negative requires the photographer to wait until the film is developed for confirmation of success, and lack of experience can produce surprising results (see Table 3.2). In this project no suitable captured images were obtained using 35mm slide film. The most predictable and instantly accessible results were obtained when capturing with the Rostrum Camera 2A coupled to the microscope. The image can be viewed live on a video monitor in full colour and, provided relevant adjustments are available, the quality of the image displayed can be maximised before final capture. Success with this path is assured if there is confidence in the quality of image being displayed by the monitor. Slide film is not as tolerant of changes in colour temperature as the human eye or negative film, and if the microscope light source is an unknown quantity or the bulb is getting old results can be unpredictable. For this reason results obtained using the video rostrum camera on the microscope were preferable to those on 35mm slide. Although the lighting was perfectly acceptable to the Rostrum Camera 2A this was no guarantee of correct colour temperature for 35mm colour slide film.

As all adjustments to improve image quality are made to the microscope or its light source, skill in working with microscopes as well as photographic skills are required. Delly (Delly J.G. (1988) Photography throught the Microscope. Eastman Kodak Company (London) pp104) recommends not using negative film because of the difficulty of achieving faithful colour in a print if the technician does not have access to an original image for comparison, whereas slide film which only requires development and no manipulation should faithfully reproduce original colours provided correct filtration is established and used. However, in the results reported here greater success was achieved with the negative film.

Delly also suggests that there is more control of contrast inherent in black and white film than in colour. This could help to explain why the lighting setup for the barley apical dissection, which yielded good texture and contrast in the video rostrum version, gave very poor texture and contrast on a 35mm slide, rendering it unusable. Again the colour temperature of the light source needed to be a known quantity when capturing on slide film because of that mediumÆs lack of tolerance to fluctuations. Possibly because of the quality of the slide, or possibly because of the picture content (medium sized bright subject against a black background) the PhotoCD scanner 2000 for 35mm material would not focus on it and it had to be transferred using the larger format 4045 scanner, necessitating the purchase of another and more expensive Pro Photo CD Master Disc. It is not clear why the PhotoCD transfer from negative is so much worse than the rostrum transfer from the print which came from the same negative. Possibly it could be due to the fact that thePhotoCD operator who only has a very small preview window to work from on his monitor, making it difficult to see the detail required. This again indicates that the shortest number of copying stages does not necessarily mean the highest quality.

4.12 Plant / soil profile / landscape / portrait - images captured using daylight

These four images may be looked at as a group because they required the same general range of photographic and imaging skills to achieve a good result. The fact that PhotoCD versions of these originals came out on top in each case tends to bear out this view because no unusual specialist skills (like those called for by photomicrography) were required. Qualitative scores of 5 abounded because general photographic skills and an awareness of what things probably look like achieved acceptable versions of the same image. These, although not identical, when viewed singly would probably be acceptable to a viewer with anything like 'normal colour vision'. Putting all high or low budget versions of an image on screen together drew attention in a rigorous way to small differences in individual versions, and that is how these examples were assessed. It is stressed that the judgements made were technical and not designed to evaluate the images for their effectiveness in teaching.

Turning to characteristics of specific images, the soil profile was deliberately captured on an overcast day to minimise shadow distractions for the viewer, so contrast was deliberately minimised. Interestingly, most of the prints from 35mm negatives of the soil profile were unacceptable because with no colour reference, the print machine operator failed to achieve the rather unexpected pink colours in this particular quarry. The only prints that were acceptable came from a roll of film which also included a grey scale chart image exposed out of doors, and the operator had clearly set up on the grey scale before printing the soil profile. Full use should be made of the low cost Grey Scale reference cards (as produced by Kodak) to take on location to provide this form of reference, particularly for subjects with which the developer is unlikely to be familiar.

The portrait was designed to test specific aspects of image copying. No fill light or reflector was used to relieve shadow areas on the face. The intention here was to show up a poor contrast ratio and in fact all the paths performed quite well in this respect. In addition the background chosen was deliberately textured and monochrome to show up any colour shifts more obviously than might appear on the (full colour) face itself. This facet proved to be more of a test than the lack of fill light, particularly with the frame of videotape. Because of the texture in the background the multi-colour shift on the videotape may be connected with moiré patterning.

4.13 Skull - image captured under artificial light

This subject was fundamentally different from any of the others in that it was three dimensional and captured indoors under multiple artificial lights. Conventional lighting units mounted on a rostrum stand for flat art subjects are not appropriately sited for the modelling required by a three dimensional subject. In addition to the capture methods established for other subjects, the rostrum camera was taken off its stand and the skull experimentally lit by a variety of different methods. The benefit of using a rostrum camera for this was the ability to white balance (line the camera up for colour) to the light source in use at the time.

One lighting method involved the use of two 800 watt æRedheadÆ tungsten lights giving a known colour temperature output of about 3,200 degrees Kelvin. In the small studio these lights were too powerful as they were, so one thickness of Neutral Density 6 filter was used on them to cut down their output by 2 stops viewed through the camera lens. The slides when they came back showed that a considerable green cast had been provided by the Neutral Density filter which proved to be too great to eradicate from reversal film examples, but was treatable in negative examples. Slide versions of this subject exhibited a range of lighting variations from very warm colour temperature using anglepoise lamps with domestic 60 watt bulbs, through green from the Redheads with (alleged) neutral density filters on them, to bland overexposure and lack of modelling from the anglepoises with Photofloods. At the PhotoCD transfer stage the colour temperature latitude of the 35mm Ektar negative film stock proved predictably more flexible than the 35mm Kodachrome 64 reversal slide.

Eventually the most flexible light source for modelling, as the image was not too large, turned out to be two anglepoise desk lamps with domestic 60 watt bulbs. The result of capture on the KY-F30B was the best version for contrast ratio, best equal for colour and an image which was superficially very good for resolution, but on comparison with the PhotoCD transfer of a 35mm negative it marginally lost out because its sharpness looked artificially enhanced - a not uncommon problem with electronically generated images. These two versions, the video rostrum camera and the PhotoCD of a negative, turned out to be significant because they illustrated the strengths of two good capture paths, at least for this class of image.

4.14 Map / line drawing images

These two images can be taken together because of their flat art similarities. Both were captured using the longer capture paths used for many of the other images, but in addition shortened paths were taken directly via rostrum camera and via scanner, bypassing the various photographic options.

With the map, colour and resolution proved to be particularly taxing, given the nature of this particular example. All paths coped at least adequately with the subtle variations of colour required but overall results were variable, largely because of colour temperature problems mentioned in Section 4.13. Post digitisation processing through Photoshop could cope with minor variations, but major colour shifts made it difficult or impossible to recover original hues downstream. The immediacy of being able to look at the original and adjust the quality of the displayed image before capture is likely to be a preferred option in most cases. However, this measure of control provided by the rostrum camera was slightly tempered by its innate lack of spatial resolution power and a surprising lack of saturation in some colours, particularly blues. Scores were particularly close between pathways for this image class, but two capture devices were fundamentally unsuitable: the still video camera would not focus to fill the frame with a small map detail and would not have been able to resolve its fine detail anyway, and the names on the map would not have been legible at the selected magnification when recovered from the videotape.

Similar reasons precluded the use of these capture devices for the line drawing. Here, possibly because of the presence of a known white paper background, the green tinge provided by the filtered lighting source proved obtrusive and insurmountable in the slide, whereas the flexibility inherent in the negative made the same lighting condition correctable.

The other interesting version of this image was provided by the Scanman Colour scanner. Opinion was divided on spatial resolution, one reviewer feeling it merited 5 rather than 4, but both agreed that the script printing in the lower left corner of the picture was clearer than any version apart from 35mm negative and PhotoCD. The Logitech scanner clearly outperformed the high budget HP Scanjet IIc on this feature.

4.2 Making a choice of capture system

From Figure 2.1 it is possible to identify 9 possible image capture paths, which vary in the number of equipment components required:

Equipment-light paths
- Subject - 35mm Slide - PhotoCD - Storage
- Subject - 35mm Negative - PhotoCD - Storage

Equipment-rich paths:
- Subject - 35mm Slide - Rostrum Camera - Digitiser Board - Storage
- Subject - 35mm Negative - Print - Rostrum Camera - Digitiser - Storage
- Subject - 35mm Negative - Print - Scanner - Storage
- Subject - Still Video - Digitiser - Storage
- Subject - Videotape Frame - Digitiser - Storage
- Subject - Rostrum Camera - Digitiser - Storage
- Subject - Scanner - Storage

The equipment-light paths would require spending decisions based largely on a materials budget whilst the equipment-rich paths require investment based on predominantly capital expenditure. The latter keeps control within the hands of the university or department; the former may relinquish some control by utilising outside expertise for CD production while calling for heavier recurrent expenditure on per-image charges.

It is not possible to say that one system is the best for all applications. For example photomicrography benefits from the immediacy of a rostrum camera but this is not the preferred capture device for all other images. However, the system which provides consistently high quality for both the test charts and for a general range of subjects is PhotoCD, provided that original material is first captured on good quality slide or negative. There will be individuals who will prefer the control afforded by their own rostrum environment, but if use is made of the range of PhotoCD resolutions and advantage is taken of the large storage capacity of the discs, there is little that competes with it for quality and convenience at the present time. Kodak originally said that they would be introducing a scanner to capture hard copy (reflected light) images, and although prospective units have been tested none has yet been introduced into service. Kodak's expressed view is that the quality is not yet good enough. Currently the PhotoCD process is only able to cope with transparencies and negatives (transmitted light) from 35mm up to 4in x 5in.

Results from PhotoCD transfer, undertaken by a local company which leases the full range of the Kodak equipment, were predictably outstanding with some qualifications. It was found that being able to sit with the operator of the equipment and talk him through the transfers image by image was very beneficial. The operator himself suggested that he finds it easier to work with negatives than slides because of inherent contrast and colour dye flexibility in negative film stocks. It is unlikely that many potential users will have the luxury of working directly with the operator either because it is against company policy or because the cost of travelling is too great. Instead they will have to send their images away for transfer and thereby lose control of their valuable source material and leave quality issues in the hands of the transfer company.

PhotoCD could provide the answer to future proofing looked for by developers because there is more resolution in the file than the monitor can currently display. Creatively it is possible to consider comprehensive display of an image through the use of wide shot and any number of details with no loss of resolution. This course of action is also possible with a scanner, but there are implications for storage of large files, probably involving compression. PhotoCD has the benefit of requiring no extra compression beyond its own visually lossless routine. With a video rostrum camera flexibility is limited as the system requires the user to decide on composition of the image details at the capture stage. Zooming in after digitisation to recompose results in pixelation - proportional to the change in size.

Of the 5 different disc media used by Kodak for PhotoCD, the PhotoCD Master Disc for 35mm originals mastered on the Kodak Scanner 2000 can hold up to 100 images (some storage space is lost by transferring at different sessions) and the Pro PhotoCD Master Disc for 35mm up to 4ins x 5ins mastered on the Scanner 4045 stores between 30 and 100 images, depending on chosen image resolution and physical size of source image.

Comparing the results for the test charts in Table 3.1, of the serious contenders for digitisation (rostrum cameras, scanners and PhotoCD), the scanners significantly outperformed their respective rostrum cameras in terms of spatial resolution but less significantly in terms of contrast ratio. However when the general range of full colour images were assessed qualitatively in Table 3.2 and 3.3, these performance differentials were not maintained. The choice between scanner and rostrum camera is not so clear cut. What is clear is that PhotoCD is capable of at least equalling the best points of both alternatives. Often PhotoCD will have extra resolution in hand for display of image detail which might not be possible via rostrum camera or scanner.

Fortunately the high quality achieved by PhotoCD coupled with its ease of use makes it an ideal capture path for both experienced and inexperienced developers alike.

4.3 Critique of high and low budget equipment

4.31 Rostrum cameras plus their respective capture boards

Results from both rostrum cameras and their associated digitiser boards justified their selection. Control of composition, aperture, colour quality and contrast ratio were as expected at the camera end. With push button white balancing in the KY-F30B camera (camera 1) and simple but effective hue controls in the TK-1280E (camera 2) there was no need for extra colour correction, and enhancement would have been possible downstream using a software package. Experience showed that it was better to ignore the settings for saturation, contrast, brightness and red, blue and green offered by the Screen Machine II board. Standardisation on 51% for contrast, brightness, red, blue and green gave the benefits of a predictable starting point from which to set off into Photoshop. It was found necessary to increase saturation to 79% - again a standardised setting. These settings were achieved by trial and error since it was not possible to predict from the computer monitor screen what the outcome would be after digitisation. No such setting options were provided on the Captivator board. Instant access to results and no recurring costs per image complete the resources picture for rostrum camera operations. In Table 3.2 it can be seen that the results from Rostrum Camera 1 were not consistently better than those for Rostrum Camera 2 and consequently the large investment could not be justified on results alone. The benefits of Rostrum Camera 1 are ease of use, automatic line-up and controls designed for regular use compared with flimsy controls and time consuming set-up procedures with Rostrum Camera 2. Good results from Rostrum Camera 2 are heavily dependent on the skill and experience of the operator.

4.32 Scanners

The handheld Logitech Scanman was predictably more difficult to operate than the Hewlett Packard, requiring some dexterity and space to manoeuvre it. With some parts of images, particularly the black background to the dissection under the low powered microscope, the joins between scans were clearly visible. With some images, particularly the test charts, it either made a mess of stitching its passes together or was unable to find enough points of contact to do so.

5 Guidelines for Success in Image Capture

This project has demonstrated that it is important to attempt to maximise spatial resolution, colour quality and contrast ratio in image capture regardless of medium or system. Distinctions arise between media in the ways of achieving optimal quality in these areas, but as ideals to be aimed at they are standard to all media. The values obtained for these three criteria are the combined product of the effects imposed by the choice of equipment for capture and manipulation, and the expertise of the operator(s) involved.

Three main skills areas are indicated for the capture of images:

- Photographic
- Electronic (Video)
- Computer

The same skills are relevant for the post-digitisation manipulation of images and their incorporation into computer assisted learning software packages, although it has not been the remit of this report to consider that stage. On the basis of the results reported the following guidelines have been drawn up to assist staff capture high quality images for use in multimedia applications.

Selection of Source material

The first requirement is to select high quality source material for capture.

Capture

Successful capture depends on the operator having good photographic skills and an awareness of lighting techniques.

Analogue Choices 1 (35mm Slide, 35mm Negative, Colour Print)
In some photographic areas there is a trade-off between

- Slides which give faithful colour but no opportunity for manipulation of colour and contrast ratio until after digitisation
- Negatives plus prints which allow more control of colour and contrast ratio before and after digitisation, but require a
- reference (such as the Grey Scale chart or the original source material) for accurate reproduction

Analogue Choices 2 (Rostrum Camera, Still Video, Videotape frame)
Beyond photography, choices for analogue capture require some familiarity with video operations. These considerations are not intended to put off inexperienced lecturers who wish to process images - rather they indicate that an operator who gains experience processing images regularly should produce higher quality routinely.

Rostrum Camera	Pros	Immediate access to captured image. Easy to adjust the quality of the image at time of capture. High quality colour. Superior contrast ratio. No recurrent costs.
	Cons	Generally poorer resolution than scanner. Re-sizing may require recapture. Needs digitiser board to capture image.
Still Video and Videotape frame	Pros	Speed of access. Portability
	Cons	Overall quality (resolution, colour, contrast ratio) poor compared with other media.

Digital Choices: (PhotoCD, Digitiser Board, Scanner)
Familiarity with image capture skills are an asset, specifically familiarity with digitisation software.

PhotoCD	Pros	5 grades of resolution, allowing effective zoom to detail without return to original image. Excellent resolution colour, contrast ratio. Excellent results with slides or negatives, but negatives easier for operator because of inherent flexibility.
	Cons	Loss of control for user. Takes longer. Recurrent cost per image. Requires slides or negatives, no direct capture of source material.
Digitiser Board	Pros and Cons	as per Rostrum Camera.
Scanner	Pros	Generally superior resolution to rostrum camera. Most straightforward to use. Fast.
	Cons	Colour generally poorer than rostrum camera. Inferior contrast ratio.

Taking account of these guidelines the preferred paths for capture of specific classes of image were as follows:

Photomicrography	Image - Microscope - Video Rostrum Camera - Digitiser Board
3 dimensional subjects using natural or artificial light	Image - Slide/Negative - PhotoCD or Image - Video Rostrum Camera - Digitiser Board
Flat Art	Image- Slide/Negative - PhotoCD

Appendix Further equipment details

Equipment common to high and low budget scenarios

The Computer Terminal used to house the digitiser board and retouching software for both central and departmental resource models was a Panrix 486 PC with a Wizard 9000VL 24 bit (true colour) Video Card, SVGA Monitor and Photo CD-ROM Drive. File sizes tended to be very large for captured images prior to manipulation, so there was also a 1Gb rewritable Optical Disc Drive available. The photo-retouching software package used was Adobe Photoshop 2.5 for Windows, which included a range of particularly subtle enhancements to improve the look of images without making them appear 'unnaturally' enhanced. The SVGA Monitor was a ViewSonic 17in running at 800 x 600 pixels displaying 24 bit colour. Given the trade-off between number of colours, number of bits and number of pixels, this was a comfortable combination with which to work within the hardware package supplied by Panrix, which contained 16 megabytes of RAM and 2 megabytes of VRAM.

Common to both equipment resource models was a standard Kaiser RS1 rostrum copy stand with 1000mm column. A number of alternative light sources were available for attachment to copy stands. Reflected light sources were either 2 x 800watt Rank Strand Redhead focussable spots or 2 x Anglepoise lamps with standard 60 watt domestic frosted bulbs if lower light levels were required. 60 watt domestic bulbs provided a 'warm' light source from the colour temperature point of view, but the Redheads gave a predictable 3,000 - 3,400 degrees Kelvin. Alternatively the Anglepoises were used with small (275 watt) Photoflood lamps, rated at 3,200 degrees Kelvin, for the predictable colour temperature required by slide film, but they ran very hot in this mode which is only recommended for short periods. Transmitted light was provided by a Master 18 x 12in. (45 x 30cm) screen size lightbox. It was suspected that the fluorescent tubes inside had a blue spike in their spectral output but this was not a problem and these particular lightboxes are widely used for photographic display purposes. Both video rostrum cameras were white balanced with each light source as appropriate. If light output needed to be cut down, one thickness of standard Lee ND6 filter was used to reduce output by 2 full stops. Although this filter was not spectrally neutral the rostrum cameras white balanced to it, but slide film exhibited a green cast, which was 'massaged' in Photoshop but not totally cured after digitisation. We used one thickness of ND6 on the lightbox to reduce its brightness for comfortable working when capturing slides.

A high quality video monitor was necessary to maintain standards when working with variable processing paths. Analogue signals were particularly vulnerable to quality loss if manipulated prior to digitisation, and confidence in the quality of the analogue output of the rostrum camera before transfer was essential.

Photographic considerations

The film stock used for slides was Kodachrome 64, giving maximum sharpness (between 63 and 100 lines per millimetre - LPM) coupled with some exposure latitude in case of bad weather conditionsThe film stock used for slides was Kodachrome 64, giving maximum sharpness (between 63 and 100 lines per millimetre - LPM) coupled with some exposure latitude in case of bad weather conditions which in this project were not a problem. While the KY-F30B video rostrum camera (high budget) resolved about 400 horizontal TV lines the usable portion of a 35mm slide can resolve >2016 lines horizontally (32mm x 63LPM) so its spatial resolution is >5 times better than the KY-F30B. In spite of these considerations soon after image capture commenced it became apparent that for some subjects, particularly those viewed through a microscope, a different benchmark from the slide might have been more appropriate.

Although spatial resolution was excellent, light levels for Kodachrome 64 had to be accurate to less than + or - half a stop for correct exposure coupled with optimal contrast range. It is worth considering these conditions in comparison with Kodak Ektar 100 negative stock used for negatives and prints. This film inherently has greater contrast range and an exposure latitude between -1 and +3 full stops either side of correct exposure, within which parameters an acceptable colour print can be obtained. To produce each photographic image a standard Nikon F3 35mm camera was used with appropriate Nikon lens plus Wratten filter where necessary for the particular subject. Exposure was kept between f5.6 and f8 to maximise lens sharpness, with exposure time calculated automatically. This was possible because all the subjects were static and a tripod was used throughout.

Central resource equipment

Rostrum camera.

A major piece of equipment for the Central Resource Model was a vertically mounted JVC KY-F30B 3 chip video Rostrum Camera channel with a JVC HZ-714B 7-98mm/f1.4 (14-1) zoom lens with macro facility. Using an additional 6 diopter close up attachment it was possible to fill the frame with a single frame of 16mm film or any size of image larger than that by using the lens in its zoom and macro modes with or without the close up attachment. This camera package comes with automatic black and white balance, and +9 or +18db of extra light sensitivity allowing it to operate down to 20lux at f1.4 with consequent resolution loss.

There is provision for capturing positive or negative images, although the negative option is not as useful as at first might appear. In spite of the potential gains of working from negative film (greatly improved contrast ratio and exposure latitude), this does not mean that a rostrum camera with a negative switch can be simply used for this purpose. The colour dyes used in negative film have been perfected to provide optimum quality when printing hard copy. Electronic transfer of negative images causes negative colours to fight with each other, exhibiting 'cross talk' (interference), and an elaborate system of filtering, known as 'masking' is necessary to cope with different spectral sensitivities between media to capitalise on potential gains. A colour paint box will not adequately replace masking arrangements and by itself is not a comprehensive solution. The negative switch on a rostrum camera, without additional masking, will correctly replace blacks with whites and vice versa, but other colours will not turn out so well.

A feed of 100% colour bars, and enhanced edge sharpness through the use of a high-resolution shutter or contour correction are also facilities on this camera head. Controls for operating and adjusting enhancement devices are strongly built for intensive use and are a major reason for budgeting a high outlay on this single piece of professional quality equipment. While enhancement may be performed after digitisation faithful colour rendition is better achieved before transfer if possible. Spatial resolution problems (presented for instance by thin lines on maps and drawings) are also better optimised before digitisation if possible.

Output from the camera can be either Composite (1 volt peak to peak, 75 ohm), Y/C or S-Video (1.0 + 0.3 volts peak to peak, 75 ohm) or RGB (3 x 0.7 volts peak to peak, 75 ohm). Standard broadcasting line-up procedure is followed by closing down the iris fully and black-balancing the camera with a single push button control. The iris is then opened up and white balancing is carried out by pointing the lens at a piece of white paper illuminated by the light source of choice or, in the case of transmitted light, by switching on the light box and white balancing against its back-lit opalescent glass. White balance is then carried out using the same push button control; the principle being that if a camera will transmit white correctly it will do the same with the full range of colours. This automatic line-up procedure is sufficient to ensure high quality colour and spatial resolution when used on all reversal images (slides, prints and artefacts), provided the camera does not develop a fault. As with all quality automatic line-up cameras today, if a fault does develop it can be difficult to access it for maintenance.

The KY-F30B camera operates routinely with the lens at about f5.6 - f8 with the Anglepoises plus 60 watt opalescent domestic bulbs.

Video capture board

A Screen Machine II board was chosen for Central Resource operation. This equipment can accept either a Composite video signal (output 1.0 volt) or a Y/C signal (1.3 volts in total). The Y/C signal, being more powerful, provides better spatial resolution, but the Composite signal is adequate for many applications. Images can be captured at full screen, half screen or quarter screen size with this board. Full screen capture (736 x 560 pixels) was preferred on the basis that unless there was a known image size required for output, it was best to start with as much information in store as possible. During processing, file sizes would be shrunk downstream, but with less digital information than eventually needed for display, quality would be lost by trying to insert it later. Preferred capture was to Targa file at 736 x 560 pixels in millions of colours via Photoshop to optical disc, which at that stage meant a file size of about 1.2 megabytes for a full colour photographic image. The Targa file format was selected because Iterated SystemsÆ fractal compression (which we intend to assess in the future) was designed to work with Targa files.

To compare other methods of capture meaningfully (e.g. via scanner) standardisation on 736 x 560 pixels was maintained as specified for the Screen Machine II board. Colour and resolution control settings were standardised on the capture board to allow realistic comparison of the output of the different image capture devices.

Scanner

The Central Resource scanner was a Hewlett Packard Scanjet IIC with associated Deskscan II software. In common with most scanners today, the Scanjet was TWAIN compliant for use with a photo-retouching package like Photoshop or Picture Publisher. Colour control within the scannerÆs own software was not sophisticated and more subtle results were achieved in Photoshop prior to eventual storage on optical disc. To optimise screen display quality the recommended resolution of 75 dots per inch was selected. Higher resolution was unnecessary in the absence of a requirement for hard copy prints.

Low budget equipment

Rostrum camera

Our choice for a low budget camera was a JVC TK-1280E single CCD channel with Computar 18-108mm/f2.5 (6-1) zoom lens with macro facility. This was a camera capable of giving very acceptable colour and spatial resolution quality for its price. Its design provides for two pre-set colour positions plus a manual adjustment position accessing two colour vectors, green - magenta and blue - red, on screw controls. While this camera can deliver good colour quality it does need adjustment to achieve it, possibly for each individual image, and the controls are not really designed strongly enough to stand up to sustained manipulation on a regular basis. This is a camera which will work best if it is set up and then can deliver without too much adjustment. Used for image capture it is likely to have to cope with images of varying quality in many formats, and its two pre-sets and adjustment provision may soon wear out with use. Its final drawback is a white balance sensor which adjusts continuously to whatever image is presented to it in the automatic adjustment mode. This sensor can only be disabled by switching to one of the pre-set positions. In spite of its drawbacks, the camera does represent value for the amount of money that is spent on it.

Video capture board

The low budget board used was a videologic captivator board which retails for around £300. No particular losses of quality were detected because of it, but it did not have the adjustment possiblities standard on the Screen Machine II board.

Scanner

The low budget scanner was a Logitech Scanman Colour handheld model which was TWAIN compliant for use with Photoshop or a similar photo-retouching package. Scanning was achieved, depending on the size of the original image, by moving the scanner across it in a number of parallel passes to be stitched together more or less seamlessly in the software. This stitching operation is automatic, but can be undertaken manually in the event of the software not being able to find enough common reference points.

PhotoCD

In addition to the observations on use of PhotoCD images in 3.1 and 4.3, the following is a technical description of the PhotoCD process from a Kodak Fact File.

> "PhotoCD images are created though the scanning of photographic film - either positive or negative - to create a photographic quality digital image. The image file is compressed from its original file size (18Mb to 72Mb depending on film size, i.e. 35mm to 4x5 inches) down to approximately 5Mb to 18Mb, depending on film size, through a visually lossless compression routine. The resulting image file is converted to the Image Pac format where it is represented in five or six resolutions:-

Base/16 (thumbnail resolution)	128x128 pixels
Base/4	256x384 pixels
Base (TV resolution)	512x768 pixels (in reality 480x640 pixels)
BaseX4 (HDTV)	1024x1536 pixels
Basex16 (photographic)	2048x3072 pixels
Basex64 (photographic)	4096x6144 pixels (Pro Master PhotoCD only)"