Comp. Appl. Arch. 13, 1985.

SOME FURTHER DEVELOPMENTS IN HARDWARE AND SOFTWARE FOR THE AUTOMATIC CAPTURE OF ARTEFACT SHAPES BY TELEVISION CAMERA

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Abstract

A television camera interface constructed by the authors was first reported in 1982. This paper describes developments from this prototype system to include higher resolution, false colour displays and more sophisticated analysis software on several different microcomputers. Other developments in archaeological graphics are also considered. There are some thoughts for the future on the archival qualities of various media: in particular videodisks, their potential, use for interactive graphics and drawbacks.

Introduction

The capture of a television picture by computer is of course not new, although it is only recently that costs have fallen sufficiently to make artefact shape capture by this method an economic possibility for archaeologists. There have been many industrial applications of this technique, notably TV camera vision for production line robots, which have to recognise the type and orientation of engineering parts picked up from a conveyor belt for assembly. Slow-scan cameras with picture comparison to detect changes have been used for security surveillance. In the late 1970s Computer Portraits Ltd., of London, used a similar system to capture portraits of the public, printing the images on tee-shirts using line printer-overprinting characters to achieve a crude approximation to grey levels.

The techniques of picture processing are well-known (Rosenfeld 1976), but because of the large memory requirements for picture storage and the need for fast processing speed, the computers used have in general been mini if not mainframe computers. Scollar (1977), for example, developed a multi-processor PDP11 system for aerial photograph and map processing. Instead of a TV camera this used an Optronics P1000 scanner but it did use TV raster displays for picture monitoring using grey sale and colour look-up tables.

The adaptation to mirocomputers of this technique was demonstrated by the authors in 1982 (Wilcock & Coombes 1982). Further developments to higher resolution, false colour displays and more sophisticated analytical software are reported in this paper for several different microomputers. A similar development was reported by Howard in 1982.

Since 1982 several commercial hardware attachments for microcomputers have become available, ranging from rather crude photosensitive semicondutor bodies, the equivalent of the retina of the eye, to sophisticated and expensive frame grabbers which capture a whole TV camera frame in 1/25sec. The hardware described in this paper, developed at North Staffordshire Polytechnic, costs little and the circuitry is available from the authors on request. The method described takes several seconds to capture a frame, but as the artefacts are static while being scanned this is of no significance and it cuts the cost considerably.

The TV camera

A standard TV camera has been used in this study. This is designed to produce a raster scan with 625 lines. To avoid flicker detection by the human eye, the picture must be refreshed at least 25 times/sec. Thus the frame period is set at 25Hz (40ms). It is found that a more pleasing picture with markedly reduced flicker is produced if two rasters, one using the odd lines and the other the even lines, are interlaced. The picture is then made up from the two interlaced fields each with a field period of 50Hz (20ms). Each of the 625 lines together with its flyback period occupies 64 msec (625 x 64msec = 40ms), an effective line frequency of 15,625Hz. Finally, an external synchronisation pulse can be used to trigger the scan. This enables custom-built electronic circuitry to direct the acquisition of brightness data from known parts of the picture. Figure 1 shows typical brightness waveforms obtained from the camera when it is viewing a simple scene, a vertical black band on a white background.

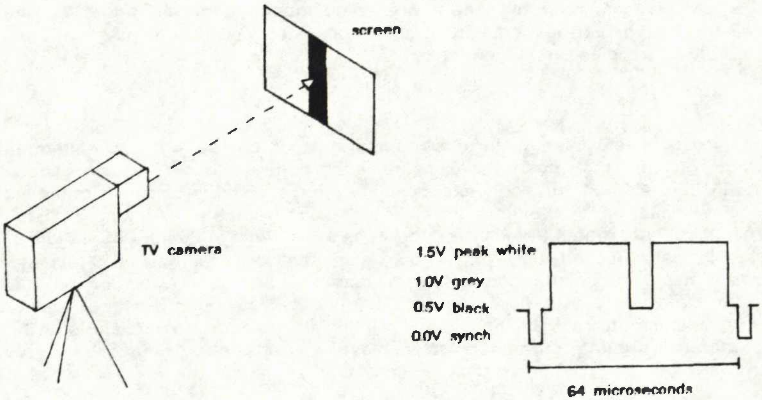

Figure 1: Brightness waveforms for a simple scene.

The inter-face

The timing circuitry and interface were designed and constructed by Coombes. It was decided to digitise the brightness of every line of the raster scan using a successive-approximation analogue-to-digital convertor (ADC) available on a single chip (ZN427E-B) and providing an 8-bit digital output. This resolution is much higher than is needed. Most microcomputers allow for the simultaneous display of not more than about 16 different grey scales. It was demonstrated in 1859 by Fechner that as the brightness stimulus increases in geometrical progression, the resulting sensation increases in arithmetical progression. Thus the relative brightness changes which can be detected by the human eye increase in size as the absolute brightness increases. That is, the perception of change in grey scale depends on the background illumination. A change at the dark end of the scale is much easier to detect than a change of the same magnitude at the bright end. Also the brightnesses of a succession of grey scales which are perceived to increase linearly in equal brightness steps actually have absolute brightnesses which increase logarithmically.

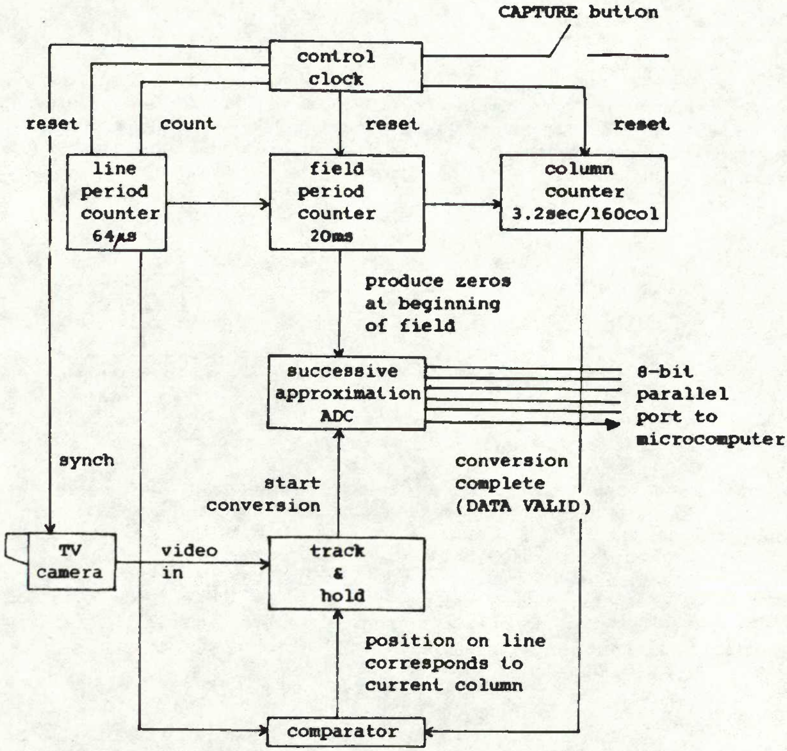

Figure 2: Simplified circuit diagram for the interface

The circuitry of the interface is summarised in Figure 2. The time for conversion of each sample is about 15msec. It was therefore decided to sample each raster line once only, at a time determined by a column counter. Thus a whole vertical column of 312 samples is taken before the next column is commenced by incrementing the column counter. The whole column is digitised in 20ms. The slight vertical displacement of the successive interlaced fields is ignored, as this is not detectable at the resolution used.

The number of columns captured may also vary. The usual TV aspect ratio of 4:3 suggests that 256 columns (256 x 20ms = 5.12sec to capture) would be suitable.

A track and hold circuit is used to hold the sampled video input voltage steady while the ADC works. The control clock is started by the manual capture button. This triggers the TV camera, and resets then begins to increment a counter divided into the line period counter (least significant bits, period 64msec), the field period counter (middle bits, period 20ms) and the column counter (most significant bits, with a timing range up to the number of columns x 20ms, 3.2s for 160 columns, or 5.12s for 256 columns, etc.). The field period counter, when at zero arranges for zero bytes to be passed by the ADC to the parallel port, allowing the software to identify the beginning of a column. The line period counter and the column counter contents are compared. When the counts are equal the raster line has reached a position across the screen corresponding to the current column position, and a sample is taken. Finally a DATA VALID signal is generated by the ADC at the completion of the conversion. This is used as an interrupt signal to the microcomputer hardware or may be passed as a data bit via the parallel port for indentification by the software.

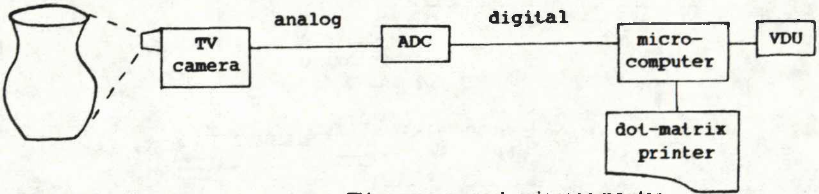

Figure 3: Picture capture by a TV camera and microcomputer.

Hardware: TV camera, analog-to-digital convertor, timing circuits, micro-computer, visual display unit and dot-matrix printer.

Software: machine code to detect DATA VALID signals from the timing circuits, to accept digitised brightnesses and compress the brightness information by look-up tables, to store data in the form required by the graphics memory and to generate the corresponding dot patterns for dot-matrix printing of the grey scales.

Interface: parallel user port with digital brightness signals and the DATA VALID signal.

Software

A typical hardware arrangement is shown in Figure 3. The software was written by Wilcock. For reasons of time machine code is required for the capture, grey scale translation, graphics memory assembly and dot-matrix pattern selection, when dot-density display is in use. The capture routine is time-critical and may require several experiments before the sequence of machine code instructions matches the raster scan and capture electronics. The algorithm employed is:

wait for 4 zero samples = top of column
ignore several lines, if required select a more central part of the picture
read data values continuously: wait for DATA VALID to be false
read data values continuously: wait for DATA VALID to be true
sample current data value
translate to corresponding grey scale using a look-up table
calculate storage address in display memory
pack grey scale codes into pixel
ignore one or several lines of raster scan, if <312 lines are to be sampled per column to get lower resolution
repeat until column is complete
repeat until all columns are complete
reorganise display memory if required: display picture
translate grey scales to dot-density patterns or false colours if required

Display methods available for the captured frame are:

monochrome dot-density screen, software controlled

about 16 grey scales which is the maximum the eye can perceive, hardware controlled

a limited number of false olour shades, perhaps selected from a much larger palette depending on the microompuler in use, hard and software controlled

In principle these facilities can be achieved on any microcomputer where there is diret access to the memory-mapped video controller. In practice there is a trade-off between resolution and number of colours. The higher the resolution or the more bits allocated per pixel, 4 bits allows 2^4=16 colours, the more memory is taken up. For a fixed memory allocation, the higher the resolution, the greater the number of pixels; the smaller the number of colours, the smaller the number of pixels. In some extreme cases part of the visible screen may have to be taken for temporary storage. For example, in the BBC model B, which has only 32K bytes of memory, the screen is used to store both memory-mapped display and software.

As mentioned above, machine code programming is required for time-sensitive parts of the capture, but high-level languages can be employed subsequently for picture processing. Typical operations are:

manipulation of brightness levels for discrimination, producing a silhouette of the artefact

windowing to ignore irrelevant parts of the picture

calculation of the centre line of the silhouette by multiple regression, assuming lateral symmetry

digitising the profile of the silhouette

rotating the image until the centre line is vertical

calculating statistics:

- area
- volume, assuming cylindrical symmetry
- profile code
- height
- maximum width
- height of maximum width
- width/height ratios at given heights, etc.

calculation of similarity coefficients between current artefact and others held on file

The picture-capture eqipment has been made to work on a variety of microcomputers at North Staffordshire Polytechnic including North Star Horizon, Research Machines 380Z and the BBC model B.

The future

It is appropriate at this stage to consider what developments should be achievable in archaeological graphics during the next few years. The obvious development to consider is the videodisk. Of course this technology is in its early stages at present and is not yet standardised. There are at least three commercial systems: the RCA capacitance electronic disk; the Philips laser vision disk; and Thorn-EMI video high density disk; plus several Japanese models. The most useful systems allow: fast or random frame search; speeded-up or backward replay; slow motion; freeze frame; two sound tracks for stereo or two separate commentaries for different audiences or in different languages; and full remote control. The potential is clearly shown in Figure 4 which illustrates

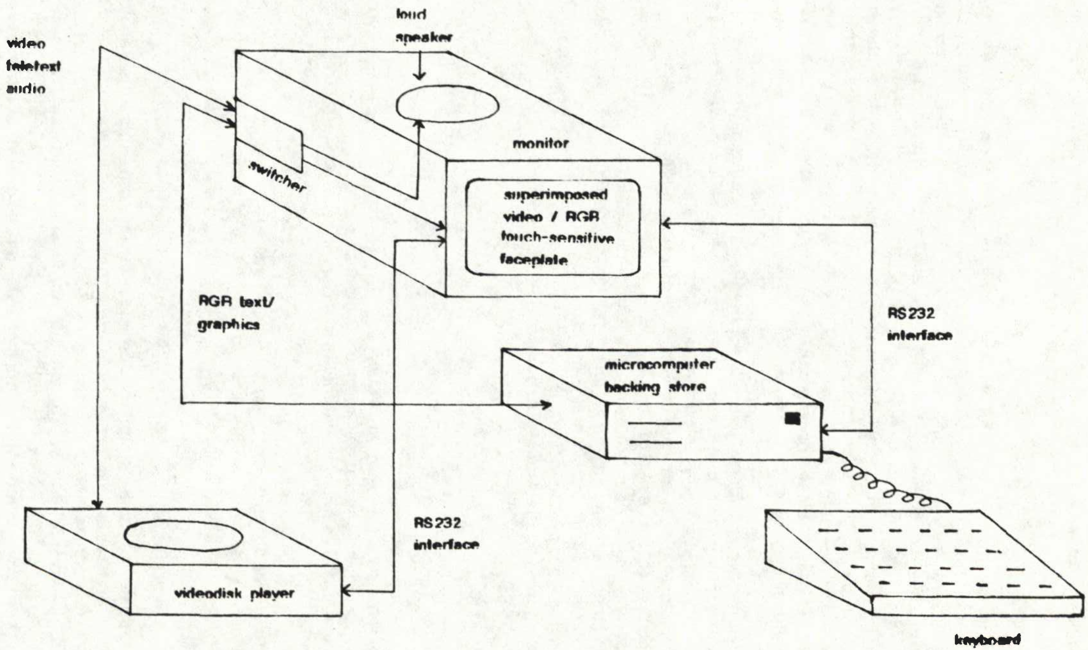

Figure 4: Control of a videodisk player by a microcomputer and touch-sensitive faceplate.
The figures for this paper have been redrawn

control of a video disk player by a microcomputer and touch-sensitive faceplate. This allows random selection of a single frame, a short video sequence or longer films. Complete museum collections, document archives and films of archaeological excavations could thus be available on videodisk for consultation, together with audio commentary and overlaid computer text and graphics for man-machine interaction. For example, positional control using the touch-sensitive screen could select a particular area of a map. Information relevant to that area could then be displayed.

However, there are some drawbacks. The relative archival qualities* of paper documentation, conventional photographs, photographic films and slides, microfilm, magnetic tapes, floppy disks, microfiche and videodisks should be considered. Almost none of these media are of archival quality, that is of indefinite life. While long-term life, about 100 years, applies to only a few. The best material for archival life is still roll microfilm. Paper has a life of only 10-100 years. Only acid-free paper is of archival quality. Magnetic tape needs to be refreshed or re-recorded every 12-18 months and must be kept in institutions where this can be automatically carried out. Updating to new hardware may also be necessary. Floppy disks are very unstable and susceptible to mechanical damage. They must be backed-up and re-recorded frequently. Film is not good archival material but its life can be prolonged by cold storage.

It might be hoped that videodisks would be an improvement on these other recording media but this is unfortunately not true. Manufacturers suggest a maximum life of 10 years for videodisks but the preferred life is only 2-3 years. Despite a capacity of >50,000 frames/side, the poor resolution obtainable at present means that a high-resolution A4 page of text needs 5 or 6 frames storage. In the worst case only about 8,000 A4 pages can therefore be stored. Data compression plus use of medium resolution and monochrome only gives a best performance of <50,000 pages/disk. Any use of colour or grey scale shades will of course reduce the resolution or increase the number of frames required per page. We must hope that these qualities will improve.

The future holds some exciting prospects. For example, the Domesday Project, promoted by the BBC, is intended to give a picture of life in Britain in 1986 based on demographic information available from all areas. It is intended as an an Information Technology equivalent, using videodisks, of Domesday Book. Regrettably it will not have the archival durability of the original. The disk will be accompanied by software suitable for the BBC micro. Clearly videodisks have great potential for archaeological storage and retrieval.

References

HOWARD, P. 1982 Camera interface for a microcomputer. Wireless World February: 30-36.

ROSENFELD, A. 1976 Digital picture analysis. Springer Verlag, Berlin.

SCOLLAR, I. HUANG, T.S. WEIDNER, B. & TANG, G. 1977 An installation for interactive transfer of information from oblique aerial photos to maps. Computer Applications in Archaeology 5: 105-118.

WILCOCK, J.D. & COOMBES, T. 1982 A television camera interface for the automatic capture of artefact shapes by microcomputer. Proceedings Microcomputer Jamboree, XXII International Archaeometry Symposium, Bradford, 27-33.