A display controller for the interactive analysis of scintigrams with a PDP-8 computer

Eine Sichtgerät-Steuerung für die interaktive Auswertung von Szintigrammen mit einem PDP-8-Rechner

Walter Ebenritter, Karl-Heinz Höhne Deutsches Elektronen-Synchrotron (DESY), Hamburg

1. Introduction

A collaboration between the Deutsches Elektronen-Synchrotron (DESY) and the University Hospital Hamburg-Eppendorf exists for electronic data processing in medicine. The fields covered so far are data processing in clinical chemistry [1, 2] and the evaluation of data from image devices in nuclear medicine [3, 4]. The base for these activities is the DESY on-line system, consisting of 21 satellite computers (mostly PDP-8's) and two central computers (IBM 360/75, 360/65) [5, 6]. In the nuclear medicine project two-dimensional projections of the radiation distribution in a human organ (scintigrams) are recorded. The advantage of computer processing of scintigrams lies in better presentation and quantitative analysis [7]. This analysis is most effective when it is done in the form of a dialogue of the physician with the computer ("interactive"), since in this way the capabilities of computer and man are combined to give an optimum result.

Physicians may interact with the system mainly through pictorial information. For rapid presentation (reaction time approximately 1 second) and interactive manipulation of these pictures (see Fig. 2), only cathode ray tube (CRT) devices are suitable, since no other device is fast enough. The only question is what technique should be used (e.g., refreshing display from computer memory, separate display processor, TV display, storage display). We decided to use a refreshing display driven by the computer memory. The reason is that in our system the small computers are considered as data acquisition devices rather than as computing devices, so the satellite computers may comfortably spend a large part of their time driving the display. Hence the display controller may be relatively simple and cheap. Nevertheless, no commercial system meeting our requirements could be found. General purpose graphic displays are too expensive and, in general, do not incorporate a gray-tone feature.

This paper describes a simple display controller which is operating successfully in routine use. The controller operates in two modes, the "dot mode" and the "area mode". Dot mode allows the display of discrete items such as lines and dots, whereas the area mode provides for the presentation of pictures with contrasting areas. This paper is mainly concerned with the area contrast mode of the display.

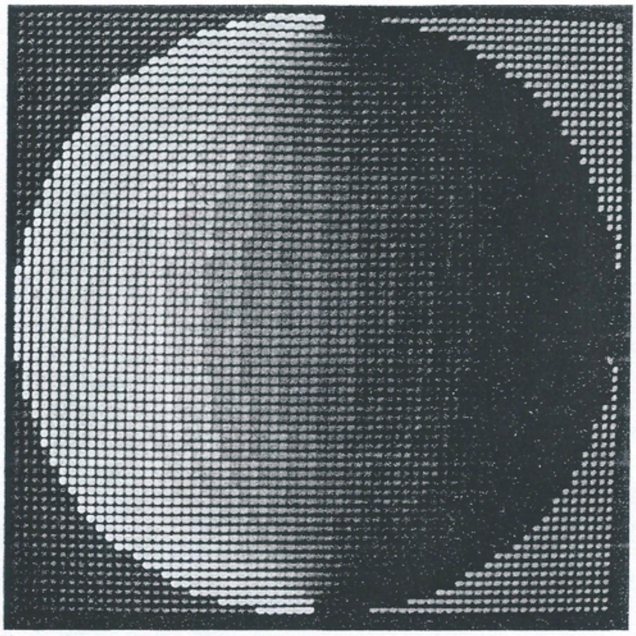


Fig. 1: CRT image of a test pattern

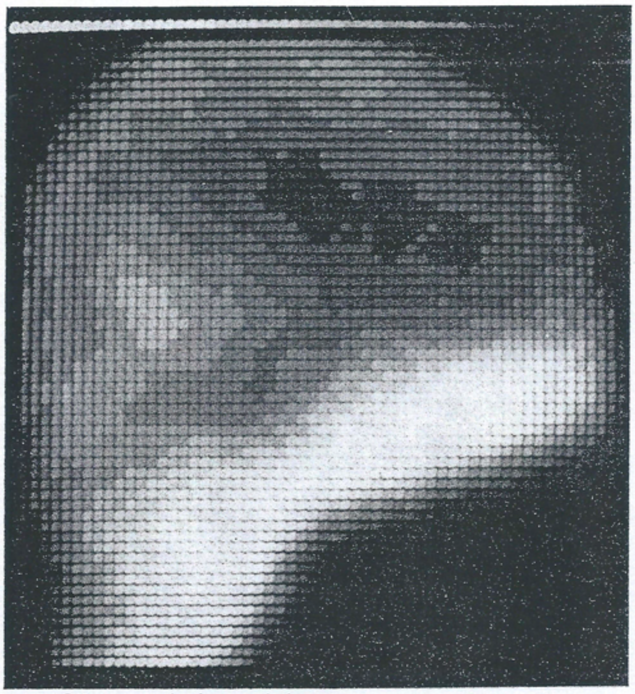


Fig. 2: CRT image of a brain scintigram

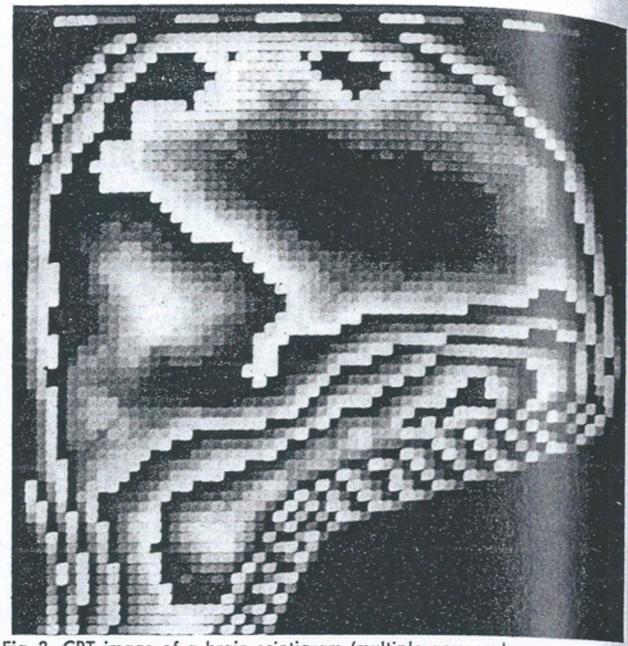


Fig. 3: CRT image of a brain scintigram (multiple gray-scale presentation)

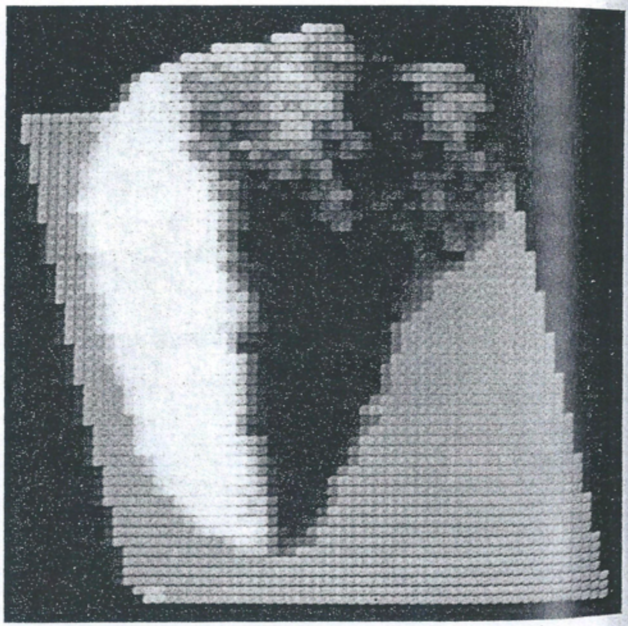


Fig. 4: CRT image of a liver scintigram (perspective presentation)

2. Properties

2.1. Matrix size

In our system the digitized scintigrams are stored in a matrix of 128 × 128 points equivalent to 16 *K* storage locations in a PDP-8/e computer. Since the detector is circular and the organs to be displayed in many cases do not fill the sensitive region of the detector, not more than half the matrix is covered. Thus, nearly in all cases an area of 64 × 64 covers the region of interest (see, e.g., Fig. 2). Hence we decided to display only a 64 × 64 matrix.

As a result the region of interest of the picture may be presented in full resolution as well as the entire picture with reduced resolution. The main advantage of this decision is the reduction of the refreshing store against the original picture field.

2.2. Presentation of gray tones

Experience shows that a decisive advantage of scintigram processing by computer is the possibility to interact with the picture and to apply quantitative procedures. A reproduction of a scintigram with continuously changing intensity is not of primary importance. It is important, however, that the impression of brightness shows some proportionality to the quantity to be displayed. Consequently the 16 possible gray tones may be adjusted individually, allowing a calibration according to the properties of the human observer. Fig. 1 shows a test pattern. Note that the linearity of the impression is lost in the photograph. Fig. 3 shows the same scintigram as Fig. 2, but in a presentation in which the count density range is covered by a multiple of the gray scale. Fig. 4 shows a perspective presentation of a liver scintigram.

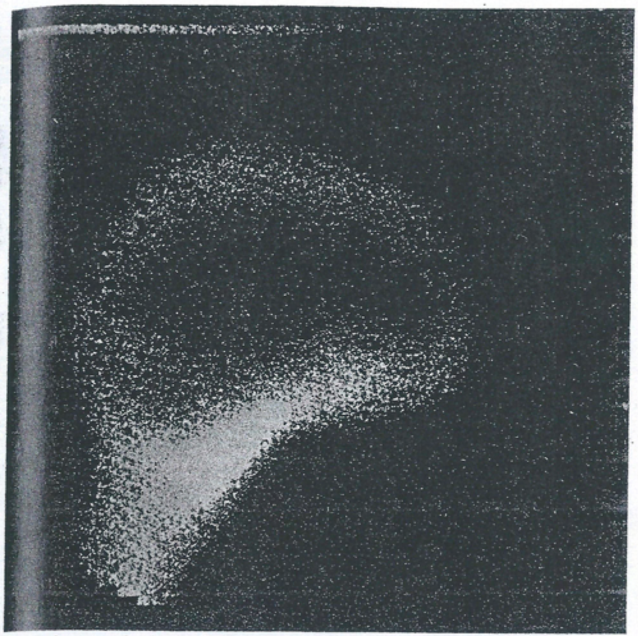


Fig. 5: Image of a brain scintigram on the storage CRT

2.3. *CRT displays*

Commercially available x, y-displays are usually designed for the presentation of pictures consisting of lines rather than for gray tone pictures, so their brightness is limited to avoid destructive burning of the screen. Nevertheless, we decided to use a Hewlett-Packard 1300 A display; but we removed this disadvantage by a modification of the grid voltage supply. This display has the advantage that the light beam may be defocussed to a quadratic shape. Thus the impression of continuity of the pictures in produced in a very simple way, even if the resolution is poor as in our case.

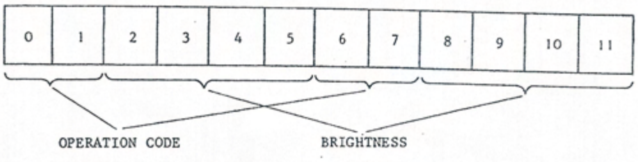
In our application hard copies of the pictures are required in many cases. It seemed to us that the hard copy output via a Tektronix Hard Copy Unit coupled to a Tektronix 611 Storage Oscilloscope was the fastest and cheapest solution compared to plotters, lineprinters etc. Thus the hardware has been designed to drive a storage oscilloscope alternatively to the HP 1300 A. A storage display picture is shown in Fig. 5.

2.4. *Display modes*

During the interactive treatment of pictures the most frequent action in the labelling of points or parts of the picture. An example is the labelling of regions of interest for quantitative comparision of the count densities by the program. In our case this is done by a DEC 370 light pen. The labels may be made visible by blinking elements, by blank elements in a bright environment or vice versa. The function of blink, blank (zero intensity) and unblank (full intensity) are performed in hardware via an operation code attached to the brightness data, without destruction of the original brightness information in the refreshing store. This feature saves a great deal of program and buffer space.

2.5. *Data format and programming*

The 64×64 picture matrix is represented by 2048 computer words, each containing the information for two adjacent picture elements in the way shown in Fig. 6. Each element is characterized by a 2 bit operation field and a 4 bit brightness field. Operation code 0 means that the element remains blank independent of the content of the brightness field. If the operation code is 1 the element is presented with an intensity specified by the brightness field. Operation code 2 is the same as 1, but the element is blinking with a frequency of 2 s^{-1}. Operation code 3 specifies full unblanking independent of the content of the brightness field.



CODE	OPERATION
0	blank
1	'brighness'
2	blink
3	unblank

Fig. 6: Interpretation of the display data

load x
load y
intensify
select „area mode"
select „dot mode"
clear light pen flag
skip on light pen flag
enable light pen
disable light pen
select HP display
select storage display
skip on end-of-frame flag
clear end-of-frame flag

Fig. 7: List of Commands to the controller

In order to produce an area display the program must contain the following steps: load the data to be displayed into the leading 2 K words of a predetermined memory field, select the device, select the display mode and start the display. The display now loops independent of the current program. A list of commands to the controller is found in Fig. 7.

2.6. *Display calibration*

The dependence of the intensity of the light spot on the electron beam current producing it is non-linear. The dependence of the spot intensity on the visual impression is also non-linear. Furthermore, the visual impression is strongly influenced by the brightness of the environment. If, nevertheless, the user wants to have a picture the brightness of which is proportional to the detected radiation distribution in a scintigram, the gray scale has to be calibrated. Since in the case of the HP 1300 A display (with a P7 phosphor) the different gray levels are produced by different life times of the spot at a certain position we get a relation for the life time of the spot as a function of the perceived brightness which may be expressed in the following form:

$$T_N = 0{,}06 \exp \frac{(\log T_{max} - \log 0{,}06)\, N}{15}$$

where T_N is the duration of the light spot intensification in µs, N is the intensity step number (range 0 ... 15), T_{max} is the time spent for the highest intensity in µs. This relation has been gained by the evaluation of a 16 step gray scale, which has been set up empirically. T_0 has been set exactly to zero. In the case of the Tektronix 611 Oscilloscope the above method is not applicable. The problem can be solved if one represents a picture element by a dot pattern with variable dot numbers. Here also the number of dots/elements is not a linear function of the brightness recognized by the user but it shows a similar behaviour as in the case described above. The distribution of dots per element has been defined by a random number generator. Fig. 5 shows a scintigram of a brain presented on a storage oscilloscope.

2.7. *Hardware concept*

A block diagram of the hardware is shown in Fig. 8. The first block on the left represents the light spot position logic. It is fed by two sources alternatively. In "dot mode" the position information (10 bits/coordinate) comes from the buffered accumulator bus (BAC) which is fed by the program and allows random access to the screen. In "area mode" the beam is positioned by the x, y generator which automatically generates a grid of 64×64 positions. The coordinates of the current dot position are held in the x and y registers which are connected to the deflection inputs of the CRT via digital to analog converters and amplifiers. The selection of the display mode depends on the status of the mode flip-flop.

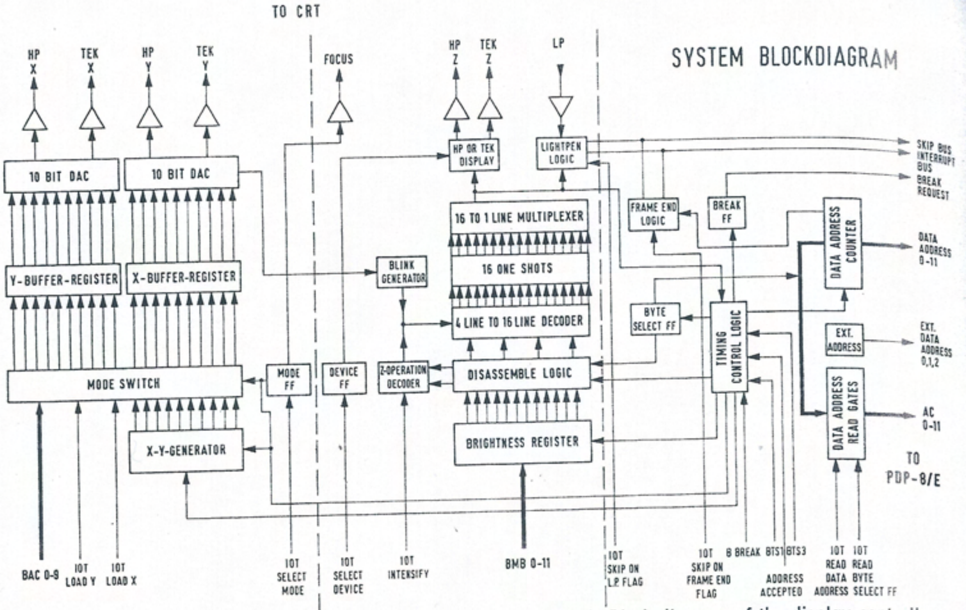


Fig. 8: Block diagram of the display controller

In "dot mode" no intensity variation is possible, in "area mode" 16 levels of intensity are produced by the intensity logic shown in the centre of Fig. 8. In this mode the intensity to be displayed is drawn from the direct memory access channel output (BMB) and interpreted as shown in Fig. 6. For this purpose the word is held in a brightness register, is disassembled into two bytes and the operation code is decoded. A4 to 16 lines decoder drives one of 16 one shots whose outputpulse length depends on the required intensity. Then the 16 outputs are ored together to give the z signal for the CRTs. In "area mode" the use of the storage CRT is not meaningful. In the "dot mode" time course is given by the program. In the "area mode" it is done by hardware in the control logic. An address counter presents the address of the word to be read from the computer memory, transfers the word into the brightness register, the operation decoder and the disassembly unit. The control logic works in an asynchronous way. This means that immediately after the unblanking signal which is varying in time the next byte is fetched from the brightness register. If the brightness register contains two bytes specifying zero brightness the logic immediately gets the next word from the memory.

For light pen operation the address counter may be read into the accumulator as well as the content of the byte selection flip-flop which points to the current byte of the brightness register.

Table: Summary of features

Feature	"Area Mode"	"Dot Mode"
data transmission	direct memory access	programmed
access to CRT	sequential	random
image format	64×64 elements	1024×1024
refreshing store	2048 words permanent	arbitrary
speed	≧ 50 images/sec (depending on picture content)	7,2 µs/dot
gray levels	16	1
light pen support	yes	yes
CRT's	x-y display with writing speed ≧ 40 cm/µs	x-y display and/or storage display

The controller is built in TTL logic. Detailed circuit diagrams may be requested from the authors.

3. Conclusions

The controller has now been in routine use for 1 year. Experience shows that it is very well suited for the interactive treatment of scintigrams since it allows

a) a true gray-tone reproduction of the radiation distribution,

b) the immediate interaction with the picture.

Furthermore, it is cheap compared to commercial general purpose graphic display units. A summary of the features is given in the Table.

We should like to thank Mr. G. Pfeiffer who has developped the various display programs. We are grateful to the group F58 of DESY which supplied several hardware components. We are indebted to Prof. Dr. C. Schneider and Drs. R. Montz, D. Novak and K. Reichstein for many useful discussions.

(Received on 28. 5. 1973)

References

[1] Dahlmann, K., K.-H. Höhne: LABMAT – Data Acquisition and Retrieval in a Clinical Laboratory Using the DESY on-Line System. DESY Report DV-71/3 (1971)

[2] Höhne, K.-H., K. Dahlmann, W.-R. Dix: Anwendung einer dezentralisierten Rechnerstruktur in der medizinischen Datenverarbeitung. Fachtagung Methoden der Informatik in der medizinischen Datenverarbeitung, Hannover 1972.

[3] Lipps, H., K.-H. Höhne, G.Pfeiffer, H.-E. Niekrens, C. Schneider, D. Novak: Ein System zur interaktiven graphischen Auswertung von Szintigrammen. Fachtagung Methoden der Informatik in der medizinischen Datenverarbeitung, Hannover 1972.

[4] Höhne, K.-H., H. Lipps, H.-E. Niekrens, G. Pfeiffer, W. Ebenritter: ISAAC, Interactive Acquisition and Analysis of Scintigrams with a Computer System. DESY Report DV-73/1 (1973)

[5] Akolk,F., H. Dilcher, H. Frese, G. Hochweller, P. Kuhlmann, E. Raubold; DESY On-Line System. Computer Physics Comm. 4 (1972) 275

[6] Kuhlmann, P. E.: PDA-Manual. Interner Bericht DESY R1-71/2 (1971)

[7] Proceedings of the Symposium on Medical Radioisotope Scintigraphy, IAEA-SM/164, Monte Carlo 1972