

The Role of the Physician-Computer Interaction in the Acquisition and Interpretation of Scintigraphic Data

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It is well known that the application of computers in scintigraphy largely improves the diagnostic value of scintigrams. The speed for finding the diagnosis and its reliability may be further enhanced by interactive data analysis, i.e. when different modes of data presentation and quantitative evaluation are offered to the physician without noticeable delay. As an example of the advantages of the interactive method some features of the system ISAAC (*Interactive Scintigram Acquisition and Analysis with a Computer*) are demonstrated.

Key-Words: Scintigraphy, Interactive Systems, Man-Machine Communication, Image Processing

DIE ROLLE DER ARZT-COMPUTER-INTERAKTION BEI DER ERFASSUNG UND INTERPRETATION SZINTIGRAPHISCHER DATEN

Es ist bekannt, daß die Anwendung von Rechnern in der Szintigraphie den diagnostischen Wert von Szintigrammen wesentlich erhöht. Die Geschwindigkeit der Diagnosefindung sowie die Sicherheit der Diagnose kann jedoch durch interaktive Datenauswertung erhöht werden, d.h. wenn verschiedene Arten der Darstellung und quantitativen Auswertung der Daten dem Arzt ohne merkwürdige Verzögerung angeboten werden. Als Beispiel für die Vorzüge der interaktiven Methode werden einige Eigenschaften des Systems ISAAC (*Interaktive Szintigramm-Aufnahme und -Auswertung mit einem Computer*) gezeigt.

Schlüssel-Wörter: Szintigraphie, interaktive Systeme, Mensch-Maschine-Kommunikation, Bildbearbeitung

Introduction

It is now many years since computers have been applied for the improvement of the diagnostic value of scintigraphic data [2—4, 13—17]. The treatment of the data may be divided into two groups:

- 1.) Improvement of the data (e.g., non-uniformity corrections, digital filters, extraction of the time development) and
- 2.) the improvement of the presentation of the data to the physician (imaging of the data as gray-tone-pictures, isointensity curves etc.).

Concerning the presentation of the data it seems that many authors use static images of the data to interpret them. Clearly, an image is still the best tool to present a quantity which is distributed in a twodimensional space, but generally it does not represent all aspects of the underlying data. Therefore one should proceed in examining scintigraphic data in the same manner as one would examine any other unknown object, e.g., looking at it from different angles, changing the illumination, turning it around, changing the magnification, feeling it with one's fingers, comparing it with known objects and, when the structure is clear, measuring the interesting parts. Ultimately a picture which, as a result of the procedure, gives an optimum image of the structure may be taken for documentation purposes. In the case of scintigrams the gathered data are considered as the object to be examined in the form of different images gained by such manipulations as variation of thresholds, change of presentation mode (gray-tone, isointensity curves etc.) and quantitative output of count rates or the time course for user-selected areas. In this way, one may not only examine the previously recorded data but also influence its production by feeding back the results of the examination of a picture.

This interactive way of exploration of an object is in our opinion by far more helpful to the physician than the improvements of static pictures (e.g., the improvement of the dynamic range of the pictures), since the perception of a picture by a person shows a complicated dependency on factors such as environment, physiological properties and experience [11]. Thus, besides the exhaustive extraction of the information content of the data, the interactive method largely eliminates ambiguities of perception and device-dependent inaccuracies. Furthermore it meets the practice of the physician who does not usually trust a finding which is the outcome of a single observation.

The interactive method, however, can only be realized if a computer system is available which can produce different presentations of the data within seconds after the acquisition of the data (for other interactive systems see e.g. [14]).

This paper describes the experience gained in the interactive processing of scintigrams during a one year period, using a computer system called ISAAC [9, 12] (*Interactive Scintigram Acquisition and Analysis with a Computer*) which has been set up in collaboration between the Deutsches Elektronen-Synchrotron DESY and the Department of Radiology of the University Hospital Hamburg-Eppendorf (UKE).

Some Features of the System ISAAC

ISAAC is an operational system which is designed to be employed by physicians in the daily work of the hospital. No special training is required for its utilization. A block diagram of the system ISAAC is shown in Fig. 1. It is a part of the DESY on-line system, a computer system consisting of two large central computers (IBM/360-75, /360-65) and some 18 small computers on-line to the central facility [1]. Two of them are installed on the site

of the UKE. One is utilized in the Clinical Laboratory (System LABMAT [5, 6, 8, 10]), the other, a PDP-8/e serves for the on-line acquisition and processing of γ -camera data within the system ISAAC.

allows the presentation of 64×64 matrices only, experience shows that this is no serious restriction, because the region of interest in nearly all cases does not cover more than a quarter of the original matrix.

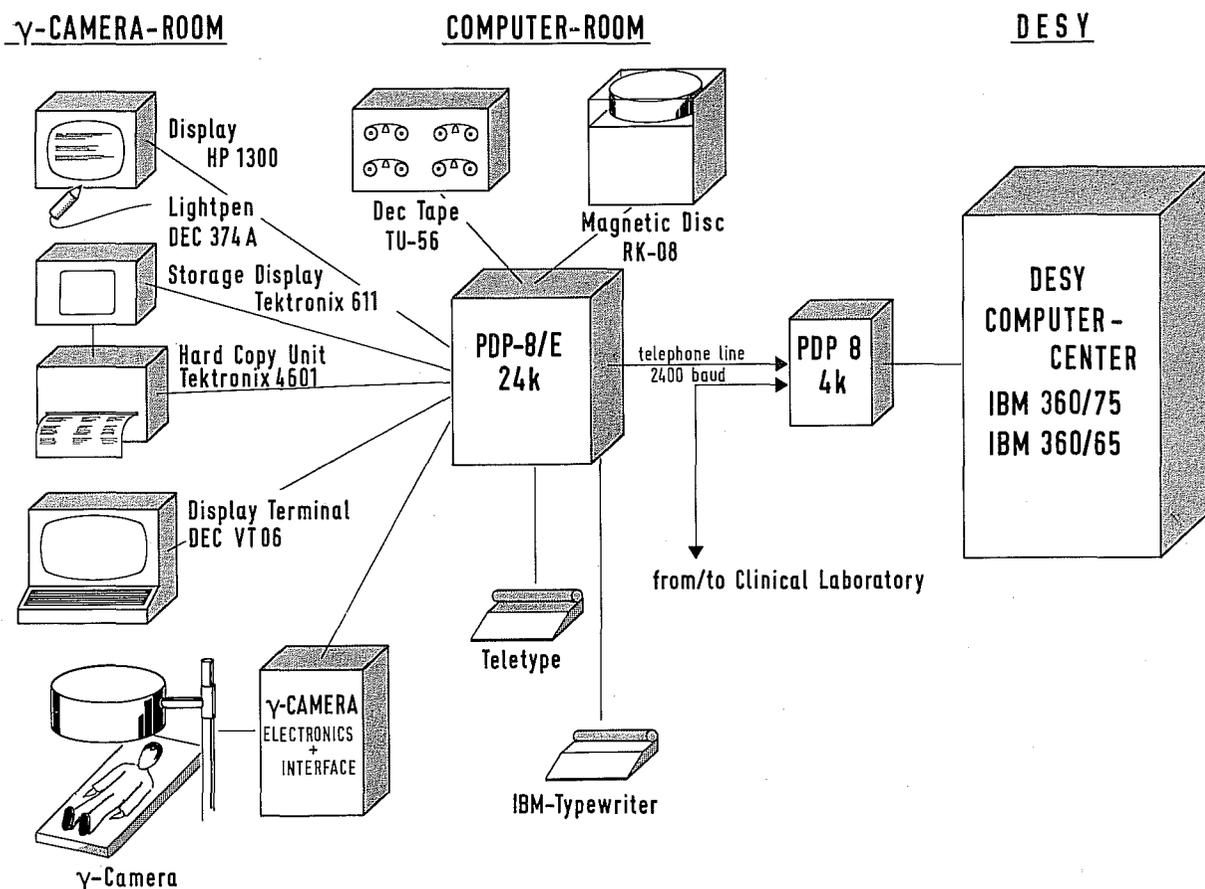


Fig. 1: Block Diagram of the System ISAAC

Peripheral devices consist of an 800 k word disc store for program and intermediate data storage, four DECtape units serving in the current version for long time data storage, a typewriter for bookkeeping purposes and a graphic input-output assembly consisting of

- 1) a HP 1300 A refreshing display unit with light pen,
- 2) a Tektronix 611 storage display,
- 3) a Tektronix 4601 hard copy unit,
- 4) an alphanumeric display terminal VT 06.

This assembly represents the man-computer link during data taking and assessment. The alphanumeric display terminal accepts the commands to the computer and feeds back alphanumeric results. The refreshing display unit [7] displays the pictures as 64×64 matrices with 16 gray levels, and offers the possibility of fast interaction via a light pen. The storage display may be used as a secondary display and serves together with the hard copy unit for the immediate production of hard copies. The interaction with the system is by keyboard and/or light pen. Although ISAAC is connected to a large central computer facility, the features described here are performed merely by the small and relatively cheap computer.

The data are taken as 128×128 matrices or sequentially event by event. Although the display unit

In routine use of the system a fixed time schedule is followed: During the morning the responsible physician together with the operator takes the data from the patients (about 30 to 40 exposures per day). The data are immediately available as smoothed and corrected pictures, which may be processed by the system. Thus, already in the data acquisition phase the physician can use the computer in an interactive way for his decision on how to proceed in data taking, and hence he can optimize the acquisition. In the afternoon, the display assembly is moved to the conference room, where the collected scintigrams which are stored on the magnetic disk are examined by a team of physicians as described in the following chapter.

The Interactive Treatment of the Data

The system allows a variety of presentations and manipulations of the data. When examining e.g. a brain scintigram, the physician starts the assessment procedure by considering its *gray tone presentation* (Fig. 2a; reaction time 1s). The region of interest is now chosen and magnified to full resolution (Fig. 2b; reaction time 3s). Generally non-interesting parts of the picture cover a large part of the luminance range. Thus, the interesting effects may not show sufficient contrast. Contrast is enhanced

when an *upper and/or lower threshold* is subtracted and the remaining portion is expanded to the full luminance range (Fig. 2c; reaction time 100 ms/step of 1/16 of maximum). Since the amount of background subtraction

is acquainted with the system, immediately recognizes that e.g. the count density in the region marked by an arrow is three times higher than it is in the environment.

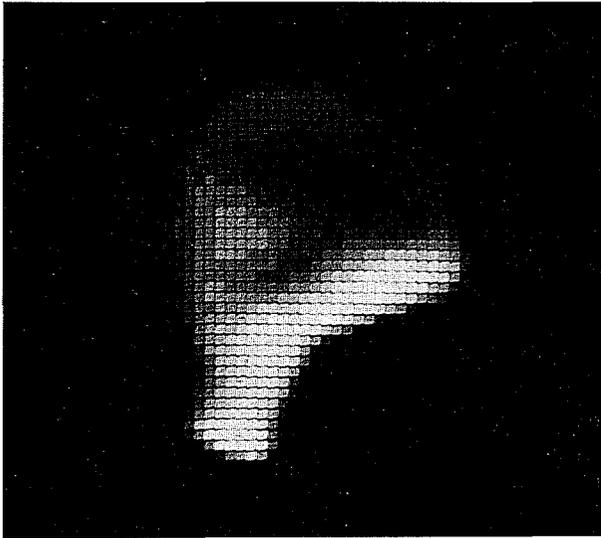


Fig. 2a. Gray tone presentation of a brain scintigram (total)

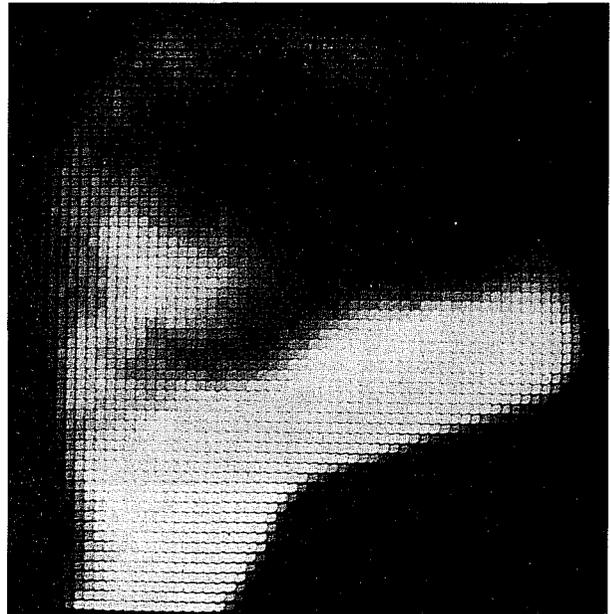


Fig. 2c. Gray tone presentation of a brain scintigram with upper and lower threshold subtraction

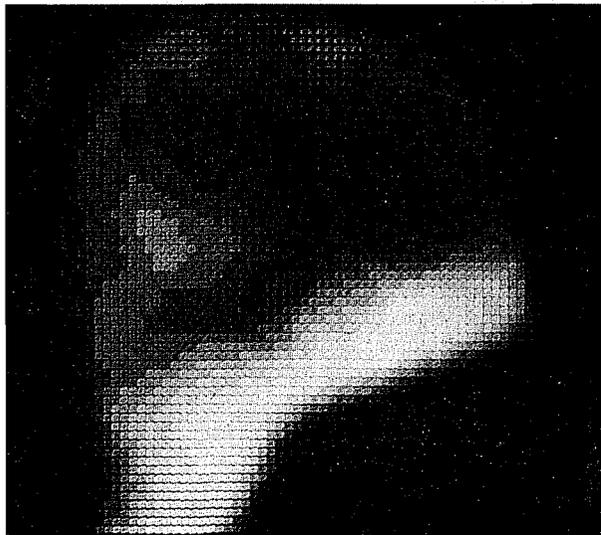


Fig. 2b. Gray tone presentation of a brain scintigram (magnified)

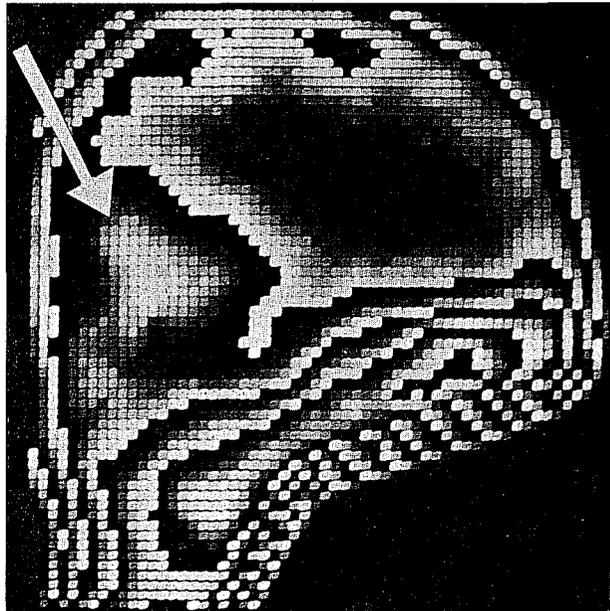


Fig. 2d. Multiple gray scale presentation of a brain scintigram

depends on many factors, the interactive method is superior to an automatic way. The upper threshold subtraction is convenient in cases, where the effects to be made visible have low count density compared to the environment. Although the gray scale on the screen of the CRT display is adjusted empirically by hardware to an impression of brightness, which is »proportional« to the count density, a quantitative evaluation is not yet possible. A semiquantitative assessment is immediately achieved when the physician requests a *multiple gray scale presentation* (Fig. 2d; multiplicity = 5, reaction time 50 ms independent of multiplicity). The multiplicity to give an optimum presentation strongly depends on the structure of the scintigram and thus can only be explored in the interactive way. Once it is found, a physician who

In most cases the assessment procedure, which has taken some 30 seconds per view of the organ, is terminated because the finding is proved or because the case is normal. Otherwise, or if the physician wants more detailed information, he may apply further procedures. If more detailed information on the shape of the radioactivity distributions is required, the *activity distribution* over user selected rows or columns may be plotted (reaction time 200 ms, output on storage CRT 15s). In the installation described here the user has the possibility to view the

scintigrams and the distributions simultaneously on the two different displays.

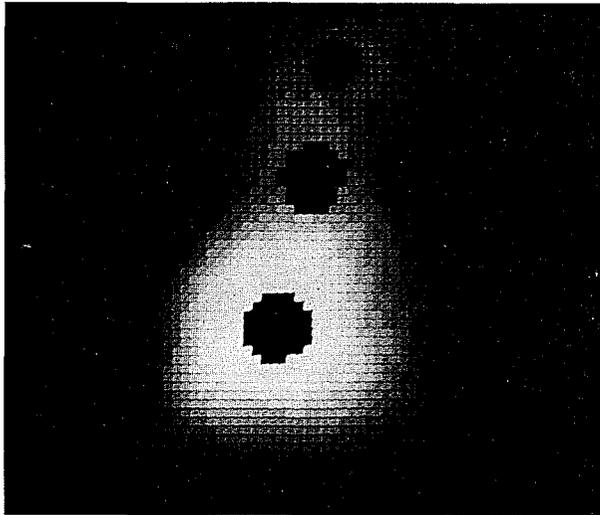
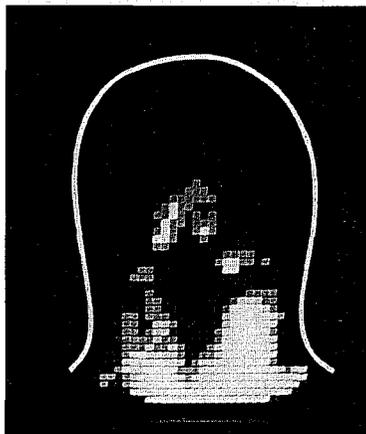


Fig. 3a. Lung scintigram with 3 labelled regions of interest

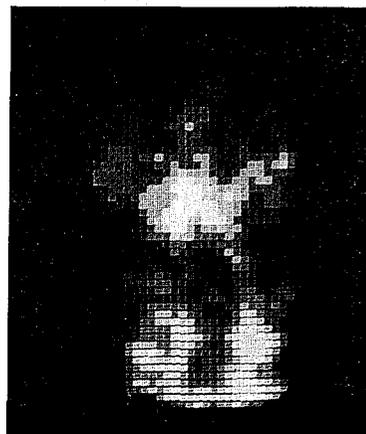
Most efficient use of the direct interaction of the user with the system is made for the *quantitative comparison of regions of interest*. Regions of any shape marked on the CRT with a light pen may be compared by the computer. Fig. 3a shows a lung perfusion scintigram with 3 labelled regions. Fig. 3b shows the results of the comparison as a typewriter output.

REGION 1			
TOTAL	= 1887.0	MAXIMUM	= 65
ELEMENTS	= 31	MINIMUM	= 53
MEAN	= 60.9		
REGION 2			
TOTAL	= 3224.0	MAXIMUM	= 101
ELEMENTS	= 39	MINIMUM	= 71
MEAN	= 82.7	DEVIATION	= 35.8%
REGION 3			
TOTAL	= 5906.0	MAXIMUM	= 170
ELEMENTS	= 36	MINIMUM	= 155
MEAN	= 164.1	DEVIATION	= 169.5%

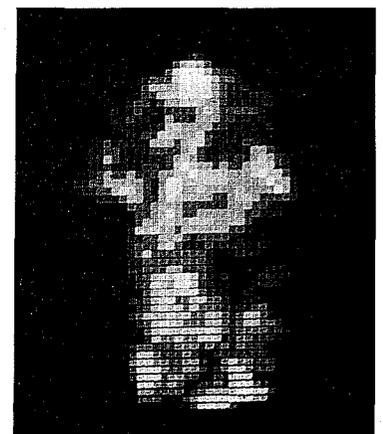
Fig. 3b. Result of the comparison of the regions of interest shown in Fig. 3a



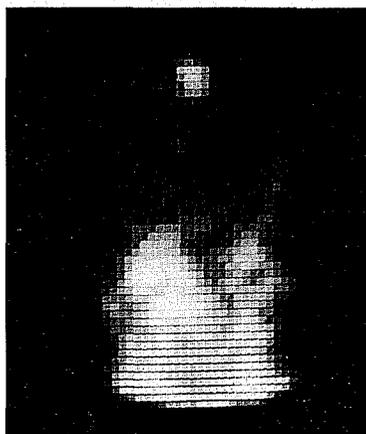
a



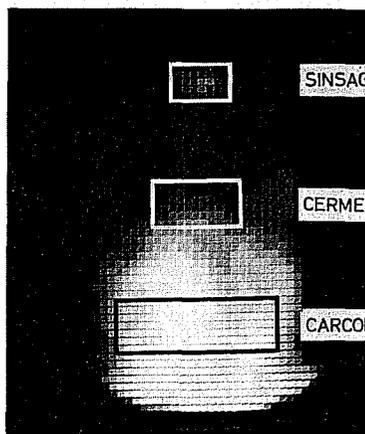
b



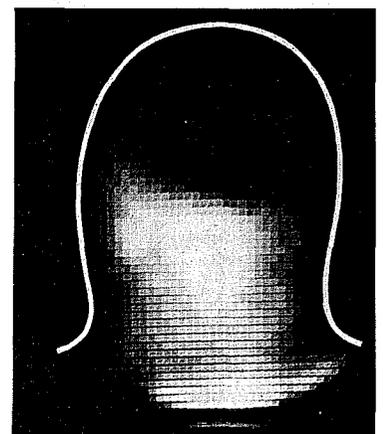
c



d



e



f

Fig. 4a—4d. Brain scintigrams of a normal patient for the time interval from 6—27 seconds after injection
 Fig. 4e. Brain scintigram of a normal patient for the time interval from 0—200 seconds after injection with 3 labelled regions of interest
 Fig. 4f. Brain scintigram of a patient with confirmed cerebral death for the time interval from 0—200 seconds after injection

The above examples show the helpfulness of the method in the exploration of the spatial structure of a scintigram. The method is even more effective in the evaluation of the *time course of the gathered data*, since the integral scintigram does not give any hint to the observer on what time intervals are the significant ones. In our system the physician may select by light pen a region of interest for which the computer plots a curve of the time course. From this curve he may derive the interesting time intervals and then examine snapshots of the data within these intervals. The inspection of the snapshots may in turn lead to a more precise definition of the region of interest for which the time course may be plotted again to give a more accurate result. Figs. 4a—4d show as an example a series of snapshots of a brain scintigram. Fig. 4e shows the integral scintigram of a normal patient, and Fig. 4f the integral scintigram of a patient with confirmed cerebral death. Figs. 5a + b show the time

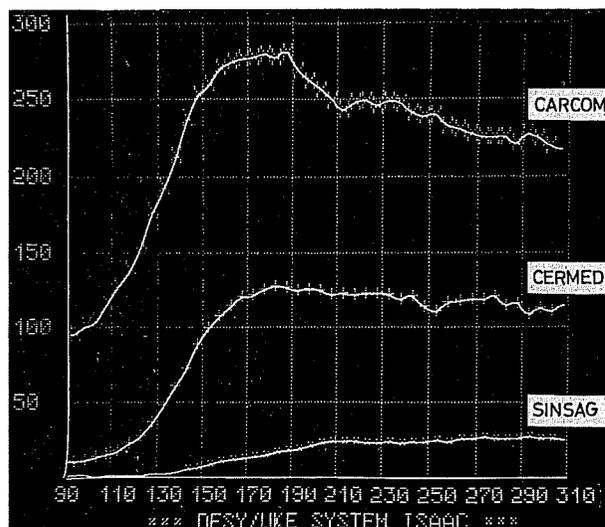
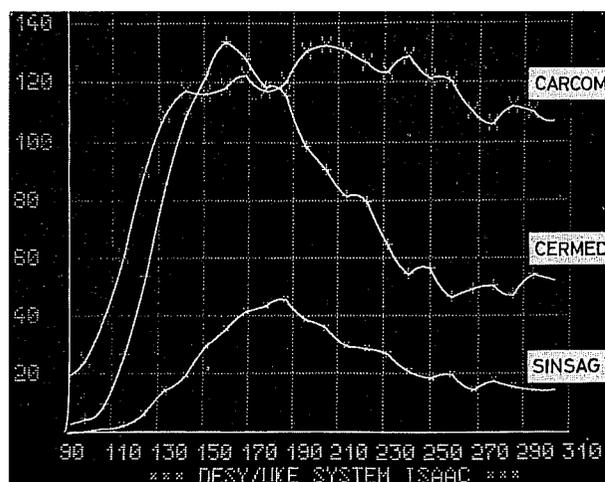


Fig. 5a. Time course for the regions of interest shown in Fig. 4e for the normal patient

Fig. 5b. Time course for the regions of interest shown in Fig. 4e for the patient with confirmed cerebral death

course for three selected areas as indicated in Fig. 4e for the two cases. With any of the manipulation described above, the physician can, at the end of the procedure, find a presentation which shows his findings in the best possible

way. In our system the physician ultimately makes a paper copy on the Tektronix hard copy unit (reaction time 15s). In almost every case this presentation is not the one he has chosen at the beginning, but rather it is the one which shows the product of what he has learnt about the object during the procedure. Just this difference represents the improvement introduced by the interactive method.

Conclusions

As completely automatical methods for the diagnosis of abnormalities in scintigrams are still far from practical application, the experience shows that the interactive evaluation in the present state of computer science and nuclear medicine is the best way to extract a maximum amount of information from the data. This is because the ability of man to recognize and classify complicated structures is combined with the property of the computer to do computations with large amounts of data in a short time. This cooperation is very effective when both the physician and the computer work at comparable speeds, as it is the case when working with the system ISAAC.

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