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Proposed Project:

AN IMPROVED FORM OF X-RADIOGRAPHY

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RESEARCH LABORATORIES

Electric & Musical Industries Ltd
Hayes · Middlesex

1967

RESEARCH LABORATORIES OF ELECTRIC & MUSICAL INDUSTRIES, LTD.,
HAYES, MIDDLESEX.

PROPOSED PROJECT: AN IMPROVED FORM OF X-RADIOGRAPHY

1. INTRODUCTION

The purpose of the study is to investigate the employment of a computer to make better use of the information obtained when an object is examined by gamma rays or X-rays.

It is well known that when an X-ray picture is taken through an object the three dimensional interior must be shown as a two dimentional picture. Hence all details from front to rear appear superimposed one upon another and a confused picture results; indeed, any 'submerged' object usually has to be comparatively thick to be seen at all. As an illustration, if the object to be studied was one such as a book, normal methods of X-ray pictures would reveal little of the content, because the information on, say, a middle page could not be extracted from the confusion caused by all the other pages in front of and behind it. However, it is hoped that the system under investigation would be capable of extracting the information from one page (or slice) only, thus presenting a map of all the information contained in that slice only, irrespective of that on the pages on either side of it. This concept is illustrated in Figures 1 and 2 on page .

In Figure 1 the normal X-ray technique is shown producing a confused and fuzzy picture of all the objects in the path of the X-ray beam AB, whereas in Figure 2 the proposed system produces a clear outline of all submerged objects within the body.

If the slice is divided into a 'mesh' of say 20 thousand 1 mm cubes.

2. DESCRIPTION OF THE SYSTEM

Figure 3 illustrates the scanning system. The object to be examined would be scanned in one plane only by a very narrow beam of gamma rays* emitted by source A not only linearly across the plane in a direction X, but at all angles as illustrated by the 2nd, 3rd, etc. scans.

The gamma rays* which penetrate the object would be detected by an accurately aligned collimator and sensing device, B, which would always be pointing towards the source of the gamma rays. The readings from the detector taken "round the edge" of the object would be digitised and fed to a computer for processing. If sufficient scans and angles of scan are made there should be enough information from the 'edge' readings in the detector to produce sufficient equations to calculate by computer the value of transmission of each cubic millimetre of material within the slice (i.e. there would be more equations than variables). A crude picture could, therefore, be built up in matrix form of the absorption of the material within the 'slice'.

* or any other rays used for diagnosis.

3. ADVANTAGES OVER THE CONVENTIONAL X-RAY EQUIPMENT IN THE MEDICAL FIELD

The principal application would be for detecting tumours and suchlike tissues which are likely to vary from a minimum of 1 cubic centimetre to a maximum of 60 cubic centimetres in volume. A high definition would therefore not be called for and it is accordingly possible to concentrate on accurate absorption readings.

The importance of this new system lies in the fact that the calculated absorption values are 100% due to the material constituting the tumour, whereas in the conventional X-ray picture they represent the mean absorption of all the material along the line of the penetrating rays (line AB in Figure 1) of which only a very small percentage will be due to the tumour. This is very important since tumours may only absorb 5% more gamma rays or X-rays than the normal healthy tissue round them, and therefore higher accuracies of detection are very much in demand.

~~Further~~ advantages of such a system would be:

(1) In general the system makes better use of available information which is presented in the form of ~~more~~ accurate absorption readings, and an ~~increased number~~ of pictures for the same dose of radiation to the patient. The tones and detail of the picture would not be obscured as in normal X-ray pictures by other confusing information being printed on top (equivalent to, say, 40 superimposed pictures).

(2) Absolute values of absorption could be plotted accurately for each cubic centimetre of material within the slice (if necessary these could be plotted as numbers for comparison with each other). The 'contrast' of the picture could be arranged so that the full black to white range represents a window of very small ranges of absorption.

4. COMPARISON WITH TOMOGRAPHY

The following paragraphs describe how a simple comparison can be drawn between the proposed system and tomography, and indicate that it must be possible to obtain more information and better accuracy, for a given dosage, by means of the system proposed.

Figure 4A illustrates the usual movement of the plate and source in tomography. The line A B is on a row of elements through the slice to be viewed, which would be perpendicular to the paper. The shadow of these elements would be kept stationary on the photographic plate whereas areas at O and P would move and blur; and information concerning these areas is therefore lost. For convenience, the beam from the X-ray source is shown as a multiplicity of beams 1 cm in diameter and the elements to be measured 1 cm^3. If the body is 40 cm thick, then 1 cm^3 of material in the slice would influence only a small proportion of the X-rays arriving at the plate - approximately 3%; the rest of the rays arriving produce fogging or blurred images superimposed upon the picture.

It is possible to replace the plate with a series of detectors (at a, b, c ...) approximately 1 cm apart and to take readings at a number of angles (representing say 1 cm of movement of the source) as the source is rotated around the body. The sum of the readings on each detector during one partial rotation of the source would then produce a tomograph of AB equivalent to the normal method, and with no extra radiation required. The two systems are therefore comparable. However, it can be seen in Fig. 4A that there is a whole series of lines above and below the line AB, e.g. CD and EF, which, if the readings from the detectors are chosen in a certain order and added, would produce a different section through the body. The whole body therefore can be covered by a series of calculated tomograms with the dose required only for one tomogram produced in the normal way. A possible method of removing blur might be as follows -

(a) Produce tomogram of line AB.

(b) Calculate the blurring of this tomogram from the information contained in all the other tomograms on either side of it, i.e. areas O and P.

(c) Subtract (b) ~~and~~ from (a).

This method of producing a more accurate tomogram is however impractical. It only serves to show in a simple way that information is avalable for obtaining:-

(1) Considerably more pictures for the same dose.

(2) More accurate absorption readings with "blurring" and "fogging" removed.

In practice, it is easier and more accurate to calculate the picture from the readings as described in paragraph 2 above , as it can be seen that Fig. 4A is only a special case of Fig. 3, the scan in the latter being shown as parallel lines rotated through 180° whereas the former scans over approximately 90° with slightly converging lines. The proposed system is therefore a method of producing an idealised type of tomogram.

Note

Methods of producing a number of pictures at the same time in tomography by using more than one plate must result in an overall reduction of information on each plate as the available photons must be shared by the plates.

5. TECHNICAL CONSIDERATIONS

The method described at the beginning of this paper illustrates a simple system. A study has been made of the practical problems of this system and the following conclusions have been drawn.

5.1 Choice of Source

(1) Low energy gamma sources (such as Americium 60 keV) produce an ideal single line spectrum at the correct energy level, but have insufficient intensity of radiation. It would take many hours to produce a picture from these sources.

(2) Higher energy sources (such as Caesium 137 - 600 keV) are a considerable improvement; the production of a picture would take less than one hour but the separation and detection of the various tissues of the body is not as good as the low energy X-rays or gamma rays.

(3) X-rays. There is theoretically sufficient intensity to produce a series of 40 pictures in less than one minute, but to handle this rate of information a special array of linear detectors would have to be developed (described later). However, using a bank of 10 scintillation counters at present obtainable, a useful picture could be obtained in 3 minutes. A picture with the maximum possible information would take 1 hour. or using a linear detector 3 minutes.

It is well known that X-ray sources have considerable spread over the energy spectrum and this could complicate the computer program. It may be possible that the source would have to be calibrated by means of a "phantom" wedge and the results fed into the computer for reference. Experiments would have to be conducted to deduce the limits of accuracy of such a system.

5.2 Detectors

For most laboratory and prototype machines scintillation counters would be adequate. However, their use is restricted by an upper limit of the rate of counting; they are costly and the number used per equipment must therefore be restricted. Both these factors must increase the time taken to obtain a picture. It can be shown that the accuracy of the detector need be no greater than 1 part in 1000 to produce approximately 2% accuracy of absorption reading on the picture. The range of accuracy need cover only 1/3 of the full range of the detector. It may be possible therefore in the future to use analogue methods of proportional detection from a bank of semiconductors*(see Fig. 4B). The output of each detector could be integrated and electronically scanned sequentially to reduce the complexity of equipment (variations of d.c. levels and gain could be corrected by the computer).

One half rotation of 180° would be required (Fig. 4B) to produce 40 "slices" in considerably less than 1 minute. Such a device must be considered as a possible future solution to the problem of excessive time to obtain a picture.

Picture time approx 3 min.

* As an interim measure one scintillator and photomultiplier could be used in a linear mode of operation but later semiconductors may be developed to fit this application.

5.3 Definition

If a one centimetre wide beam is chosen, a resolution better than 1 cm could be obtained; for example, if the shape of the cross-section of the beam is known, at least three extra values may be computed from this information. Hence it may be possible to build up a picture with a 120 x 120 matrix instead of 40 x 40. However, the most accurate readings would only be produced in areas greater than 1 cm^2.

5.4 Compton Scatter

Compton scatter presents no problem with a simple system using a single detector and collimator. However, should multiple detectors be used (above 10) it would be necessary to correct for this effect, and a system to achieve this has been worked out.

6. RESEARCH PROPOSALS

A simple test jig could be made in which the object is rotated in front of a fixed radioactive source and collimator, and detected by a fixed scintillation counter and collimator. Blocks of material of known absorption could be arranged in various patterns within the beam and readings taken through them at known angles. These could be compared with the calculated values of absorption and accuracy assessed of the picture that would have been obtained. If the assessments are favourable, readings could be fed into a paper tape punch. A program for accepting the information and reconstructing the picture could be written and used on the 1905 computer. This being only a practical experiment, the time taken to form a picture would be very much slower than would be the case in normal use. Phantoms of tumours of varying size and density could be presented to the machine and the pictures produced compared with normal X-ray photographs and tomograms of the same phantom.

A theoretical study to overcome the computing problems associated with the broad spectrum produced by an X-ray tube could also be included.

7. APPLICATIONS

There are two main applications for the equipment:

(1) In Hospitals, Clinics and Medical Centres for the early detection of tumours when symptoms indicate that such may be present.

(2) For fitting in static and mobile Mass Radiography Units used for "screening". In this case a bank of detectors used side by side so that many picture slices may be taken through the patient at the same time would be essential. The digital information presented is in a form such as can be compared in a computer with other pictures by pattern recognition techniques, and by this means it could deal with the large amount of information that would come from Mass Radiography Units of this type.

8. CONCLUSIONS

The theoretical studies conducted so far have indicated that present methods of tomography do not use the majority of information available to the detector (film). It is theoretically possible to improve the accuracy of detection of absorption within the body by at least an order. At the same time at least 20 times as many pictures for the same amount of radiation through the body could be obtained.

Although scintillation counters are very time consuming they would be quite suitable for accurate systems where the 'rate' of taking a picture is of low importance. They could also be used in cases where a minimum radiation dose is necessary, when a smaller number of counts would be taken for each reading (which would also increase the picture rate). This would reduce the accuracy of detection but it could still be kept as good as a conventional tomogram. However, scintillation counters are not suitable for faster systems in which 40 "slices" would be required in one minute. In this case it is hoped that in the future a bank of linear detectors could be developed to fit this requirement.

At the moment it is necessary to prove that the theory works in practice with currently available components, irrespective of how long it takes to produce a picture.

If the proposed system can be proved successfully, it would be a very considerable incentive for the component manufacturers to produce components capable of speeding up the process.

9. ESTIMATED COST

It is estimated that £10,000 would be required to cover the work involved in proving the system.

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APPENDIX Table of Comparisons between existing Systems and Proposed System of Radiography

	Normal X-Ray Picture	Tomography	Proposed System
Accuracy of absorption reading 1 cu cm of material	High accuracies of detection impossible. 1 cubic cm of material controls only 3% of radiation received through the body. A random distribution of material in line with it varying ±1% could obliterate all possibility of detection.	Picture obscurred by "blurring" and fog, e.g. if readings through the body vary randomly by 5% then the "blurring" produced by this would allow the tumour to be detected to an accuracy of 30%.	Accuracy of detection is theoretically better than 1%. The accuracy of these readings is practically independent of the nature of the material which surrounds a given element.
Definition minimum size of picture elements.	Better than 0.1 mm	Approx. 1 sq. cm.	1 sq. cm detected accurately. 1/9th sq. cm would be defined less accurately. Picture matrix 120 x 120
Ability to deduce absolute values of absorption.	Impossible to deduce absolute values.	Vague comparison of absorption with the mean value of the rest of the body.	Absolute values of absorption can be plotted for each cubic cm of material.
Number of pictures produced for a given radiation dose.	One	One (or 3 less accurate pictures).	Theoretically between 20 and 40 pictures.

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NORMAL X-RAY TECHNIQUE.

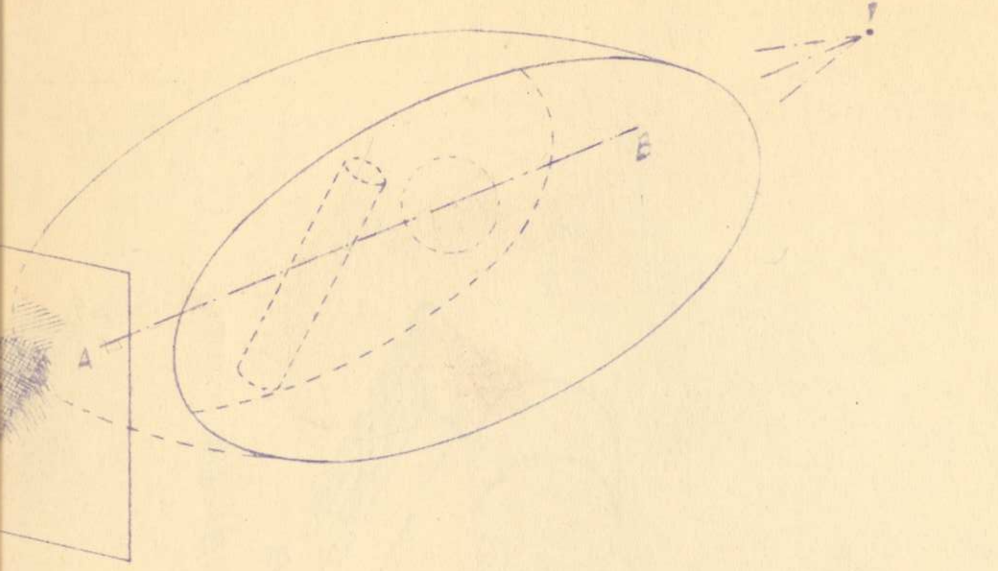


FIG. 1.

~~PROPOSED~~ SYSTEM

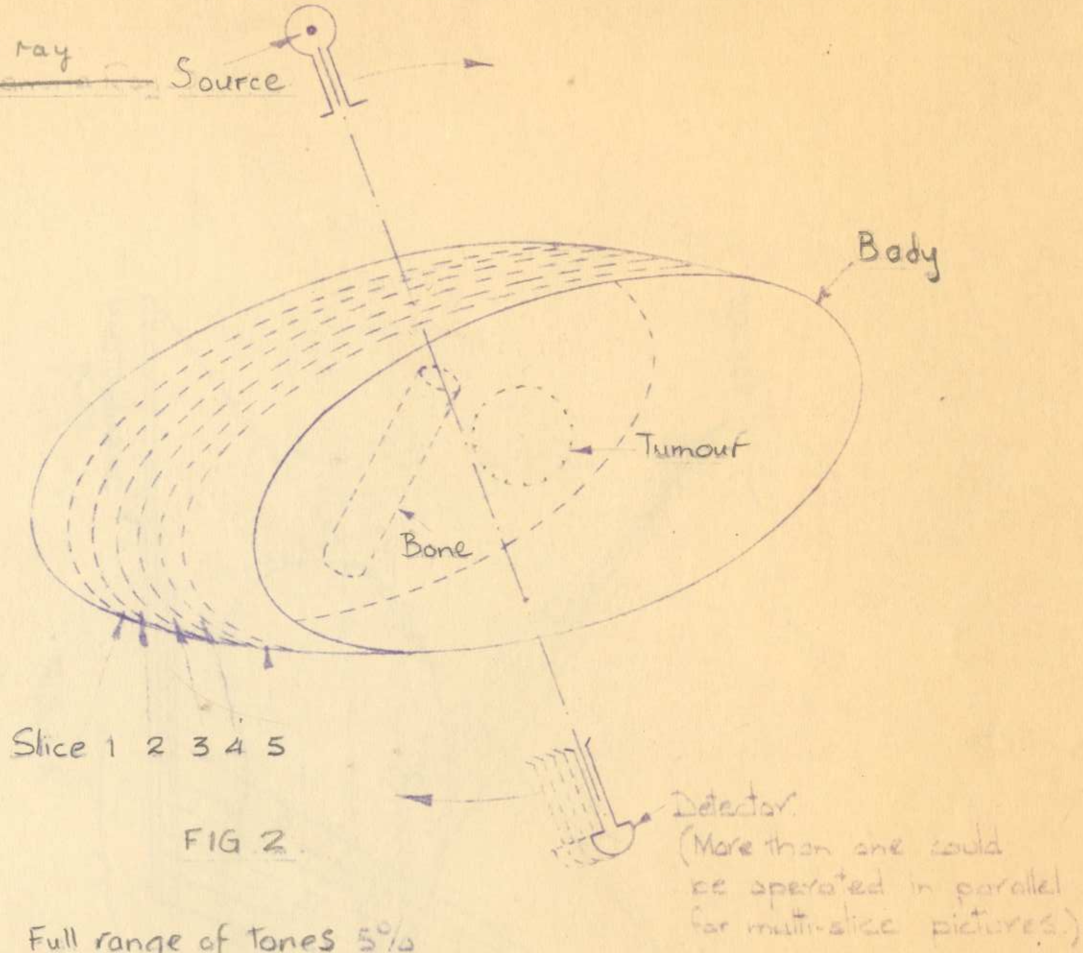
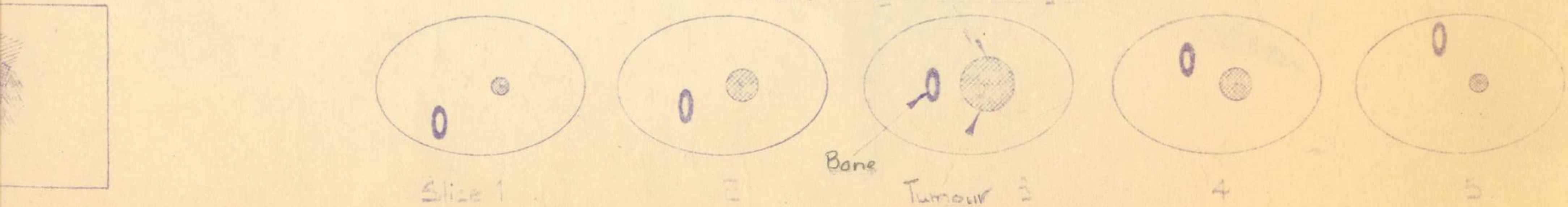


FIG 2.

Full range of tones 5% of total range of readings



Pictures reconstructed by ~~proposed~~ system.

...ICTURE

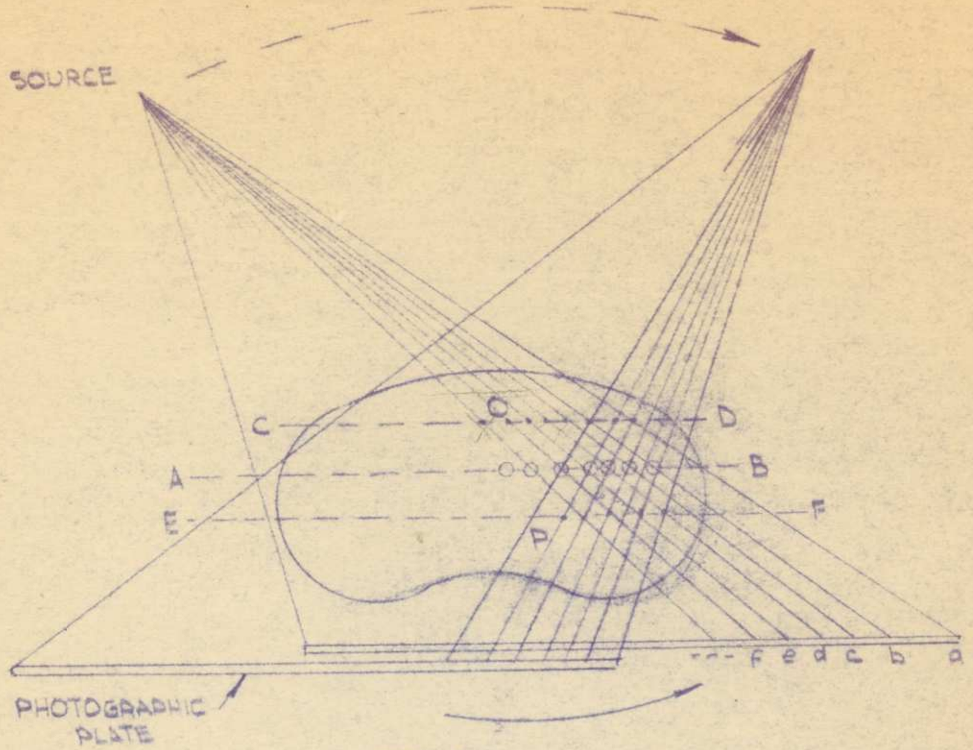

SOURCE
C
O
D
A
B
E
F
P
f e d c b a
PHOTOGRAPHIC PLATE

FIG.4A

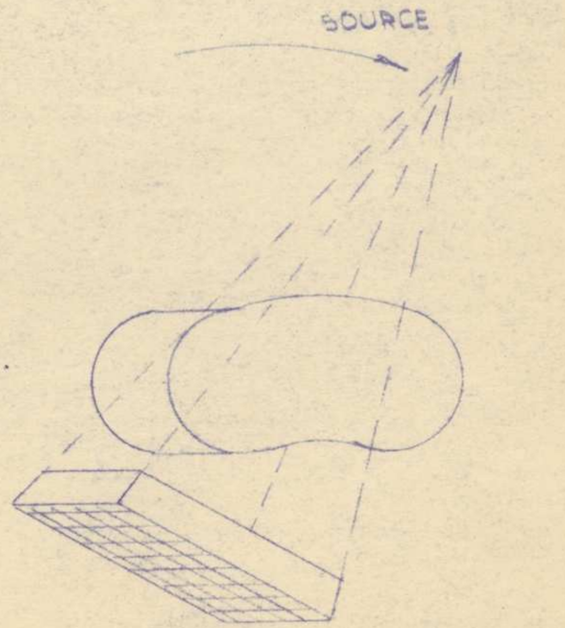

SOURCE
BANK OF DETECTORS

FIG.4B