United States Patent [19]
Sezaki et al.

[11] **3,869,602**
[45] **Mar. 4, 1975**

[54] APPARATUS FOR AUTOMATIC COMPUTATION OF CARDIOTHORACIC RATIO

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[22] Filed: **Aug. 29, 1972**

[21] Appl. No.: **284,558**

[30] **Foreign Application Priority Data**

Sept. 3, 1971 Japan 46-68426

[52] **U.S. Cl.**...... **235/151.3,** 128/2.05 R, 178/DIG. 5
[51] **Int. Cl.** **G06f 15/42**
[58] **Field of Search**..................... 235/151.3; 444/1; 128/2.05 R, 2.06 R, 2.06 B, 2.6 G, 2.1 R, 419 R, DIG. 3; 178/DIG. 5, DIG. 22; 250/320, 321, 322, 323, 401

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Primary Examiner—Joseph F. Ruggiero
Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[57] **ABSTRACT**

An apparatus for automatically measuring the cardiothoracic ratios speedily and with a sufficiently high accuracy, characterized in that the profiles of the thorax and heart are first inferred by processing information on brightness from an X-ray image and then an error in the inference of the profiles is corrected by contextual data processing, so that the cardiothoracic ratio may be computed on the basis of the corrected data.

6 Claims, 16 Drawing Figures

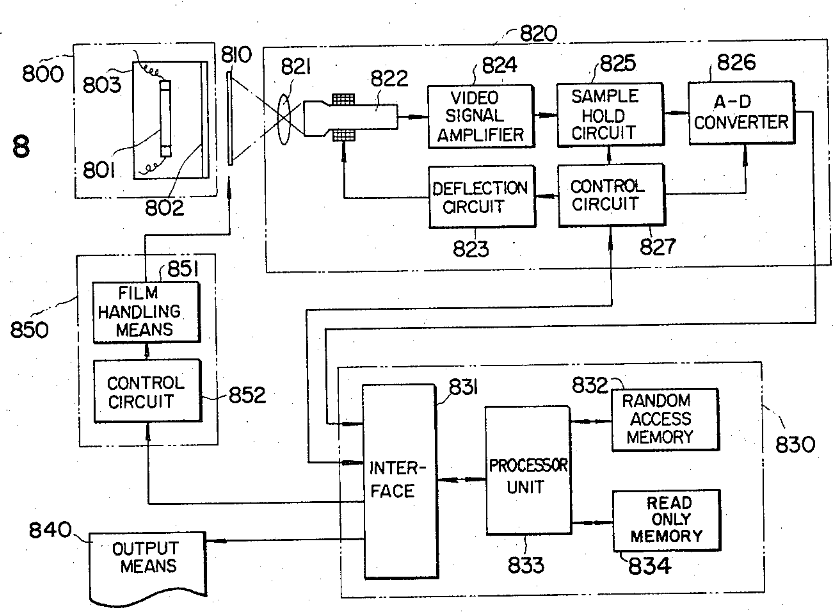


FIG. 1

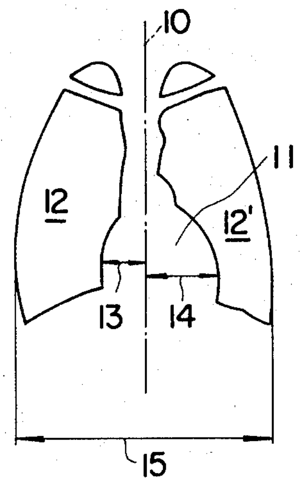

10
11
12
12'
13
14
15

FIG. 2

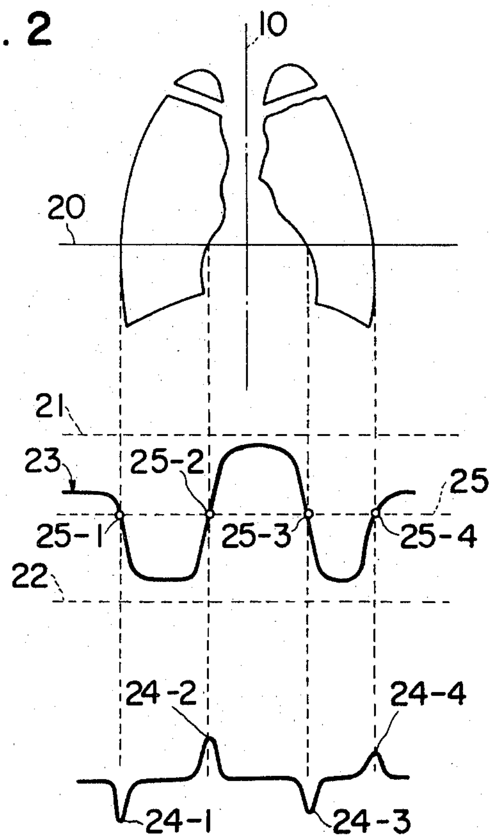

10
20
21
23
25-2
25
25-1
25-3
25-4
22
24-2
24-4
24-1
24-3

FIG. 3

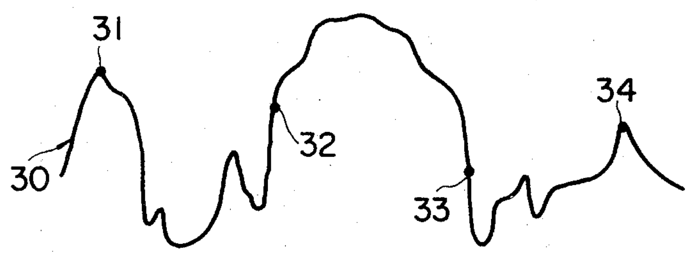


FIG. 4

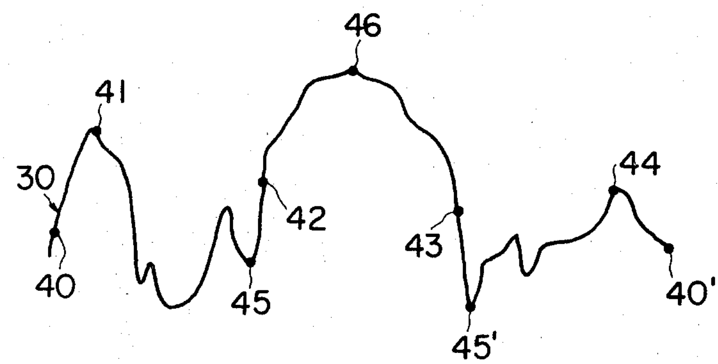


FIG. 6

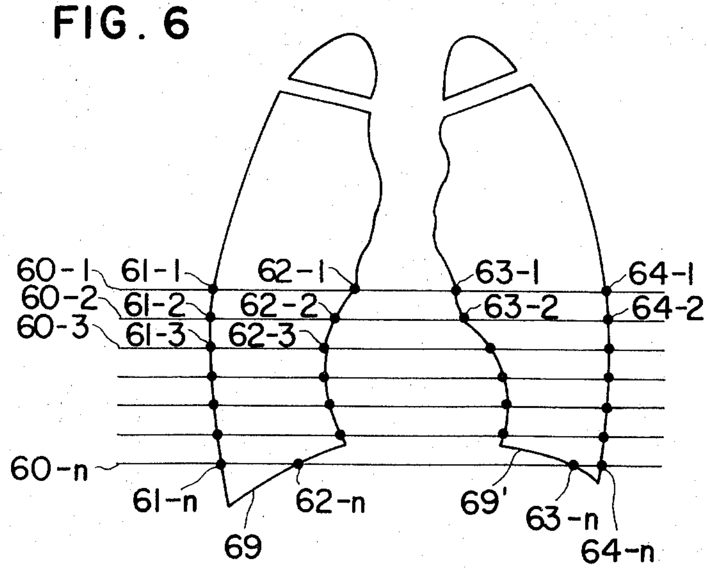


FIG. 5

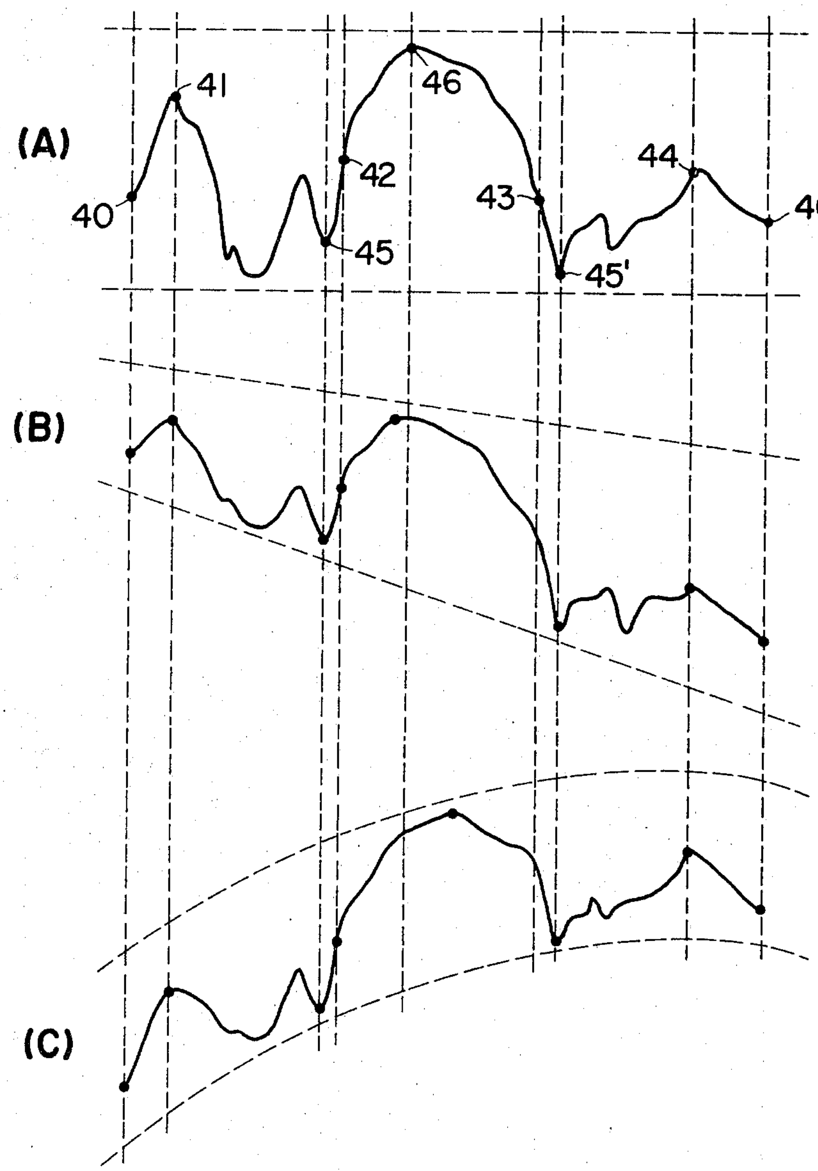


FIG. 7A

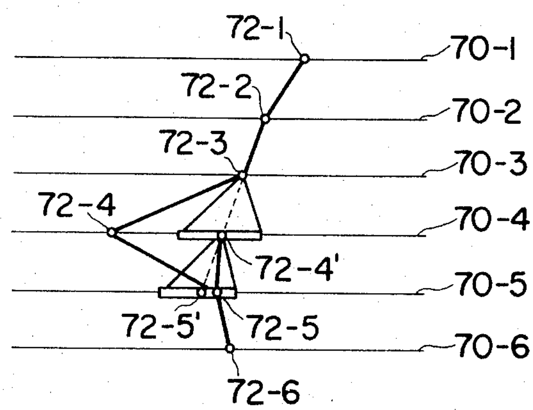
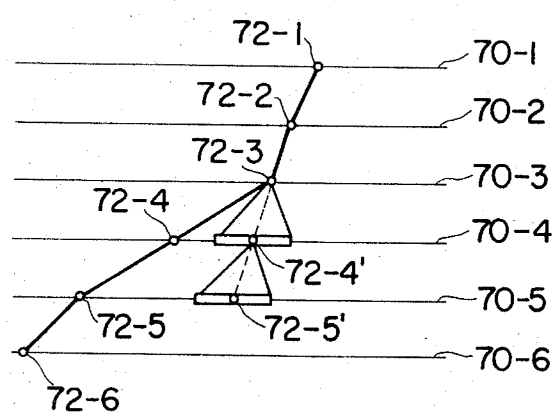

72-1
72-2
72-3
72-4
72-4'
72-5'
72-5
72-6
70-1
70-2
70-3
70-4
70-5
70-6

FIG. 7B


72-1
72-2
72-3
72-4
72-4'
72-5
72-5'
72-6
70-1
70-2
70-3
70-4
70-5
70-6

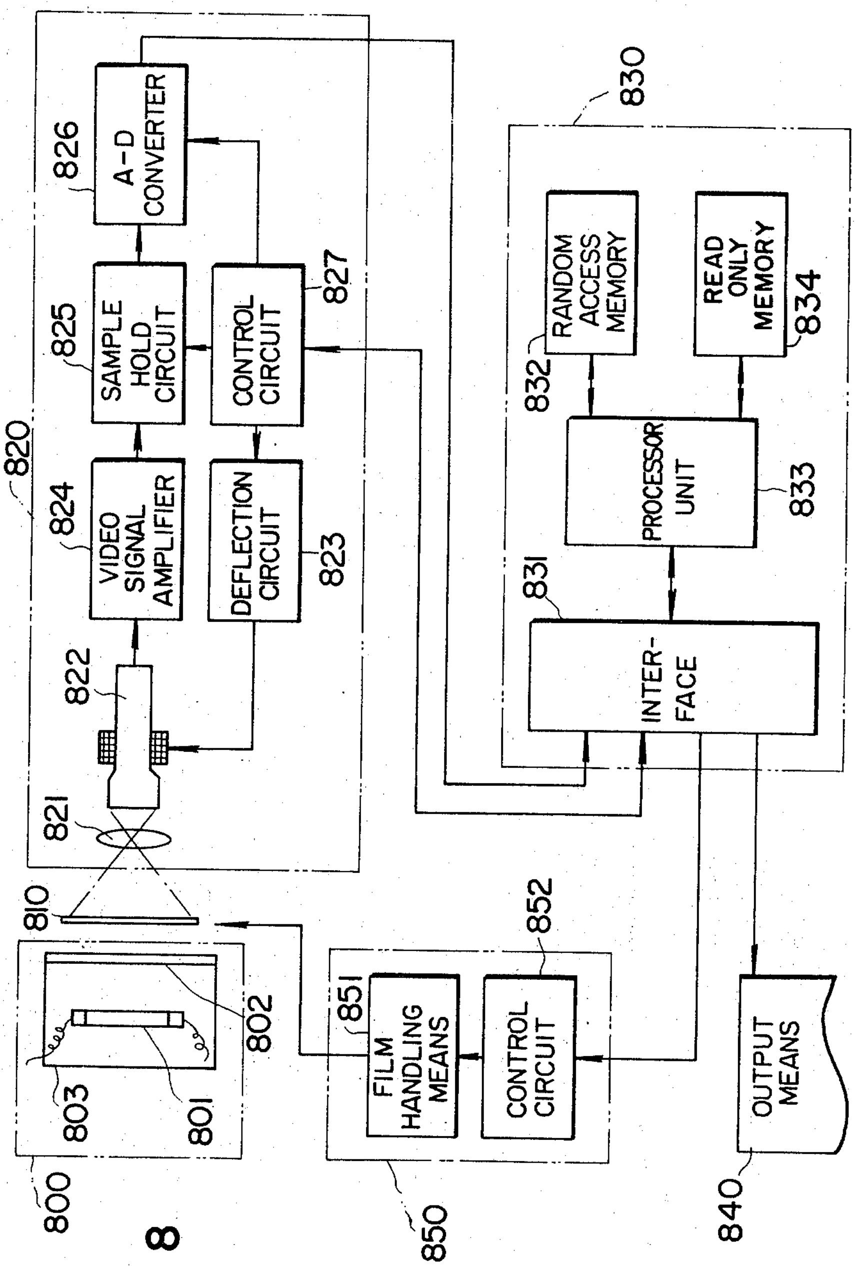

A-D CONVERTER
826
SAMPLE HOLD CIRCUIT
825
CONTROL CIRCUIT
827
VIDEO SIGNAL AMPLIFIER
824
DEFLECTION CIRCUIT
823
820
822
821
810
802
803
801
800
FILM HANDLING MEANS
851
CONTROL CIRCUIT
852
850
830
RANDOM ACCESS MEMORY
832
READ ONLY MEMORY
834
PROCESSOR UNIT
833
INTER-FACE
831
OUTPUT MEANS
840

FIG. 8

FIG. 9

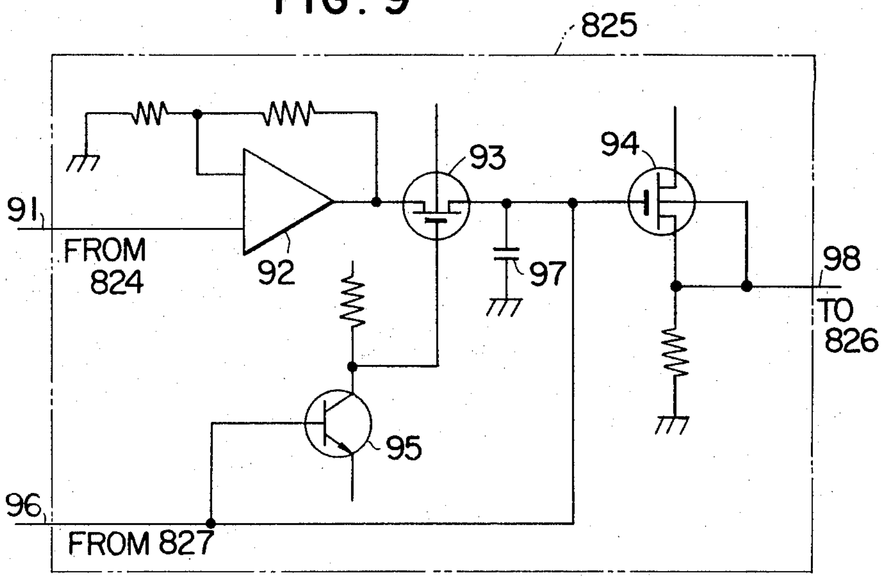

825
91
FROM
824
92
93
94
97
98
TO
826
95
96
FROM 827

FIG. 11

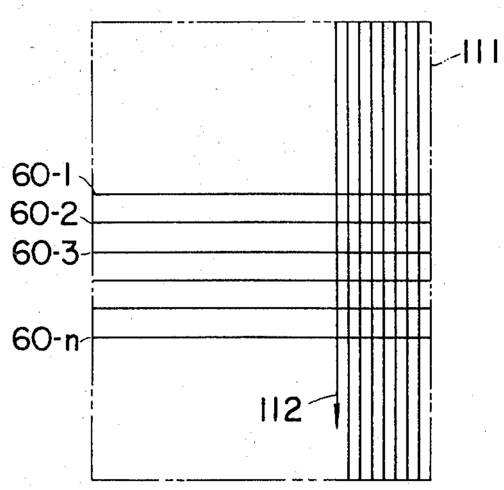
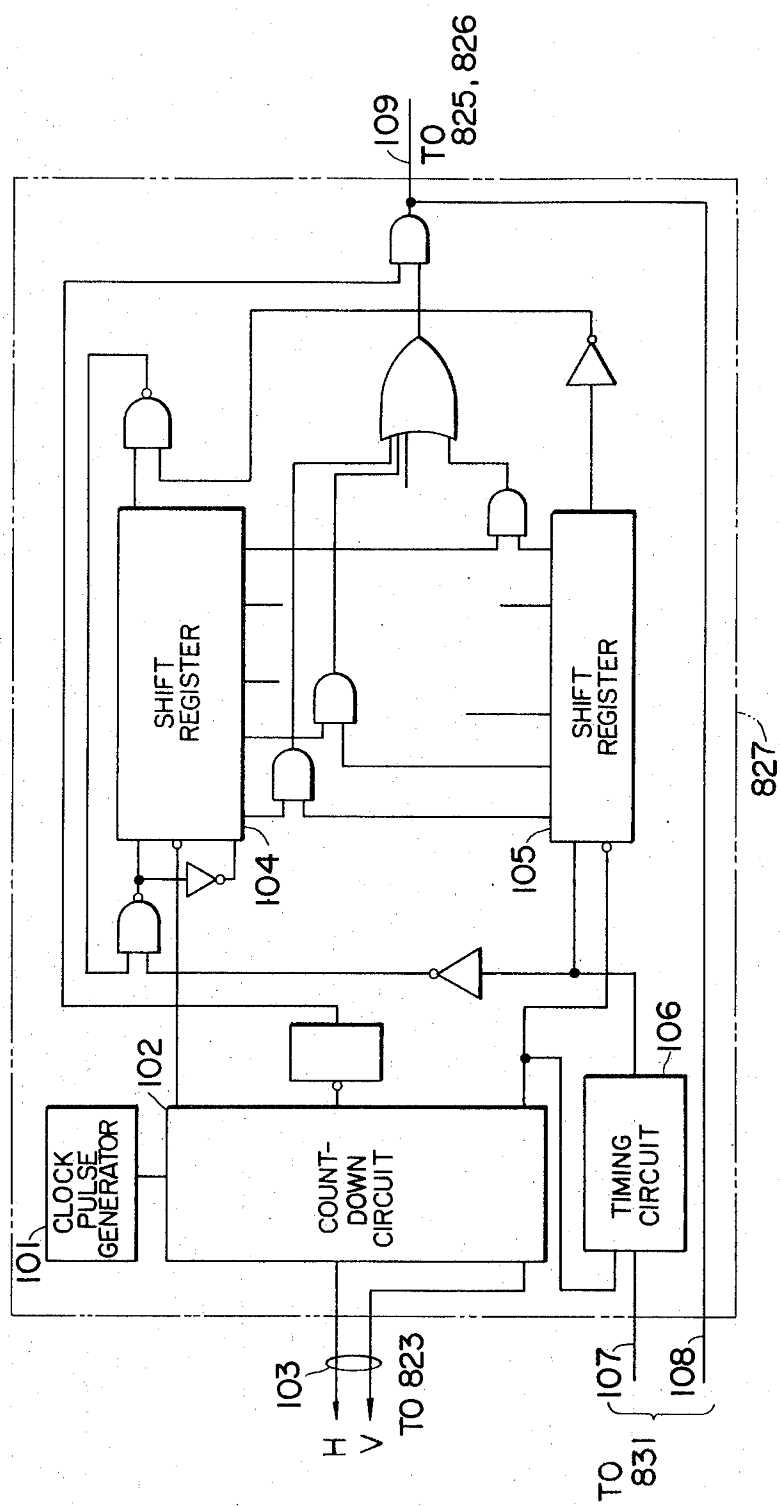

111
60-1
60-2
60-3
60-n
112

FIG. 10


109
TO
825, 826
SHIFT
REGISTER
SHIFT
REGISTER
104
105
827
CLOCK
PULSE
GENERATOR
101
102
COUNT-
DOWN
CIRCUIT
TIMING
CIRCUIT
106
103
H
V
TO 823
107
108
TO
831

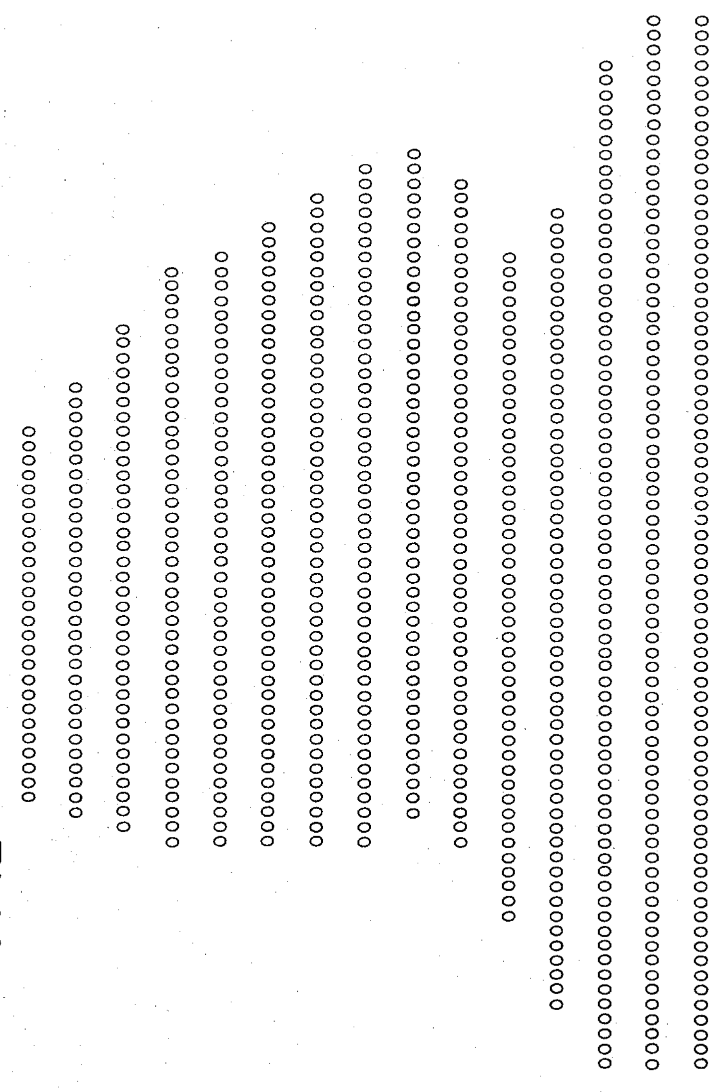


FIG. 12

FIG. 13

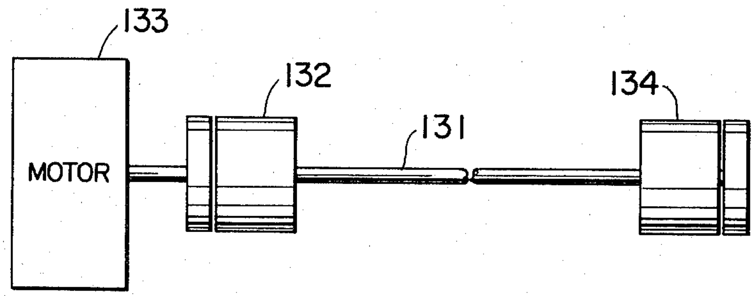


FIG. 14

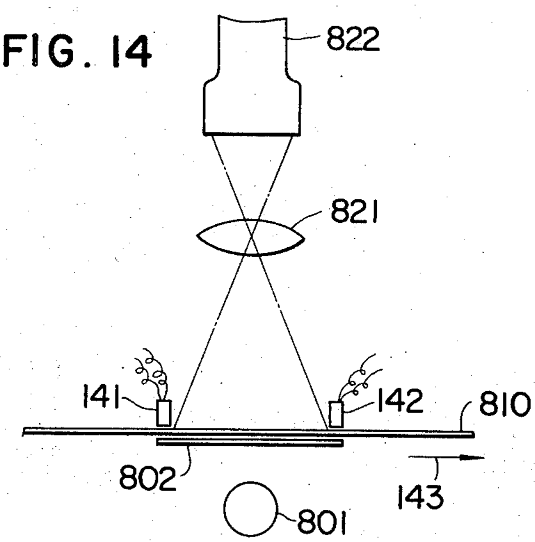
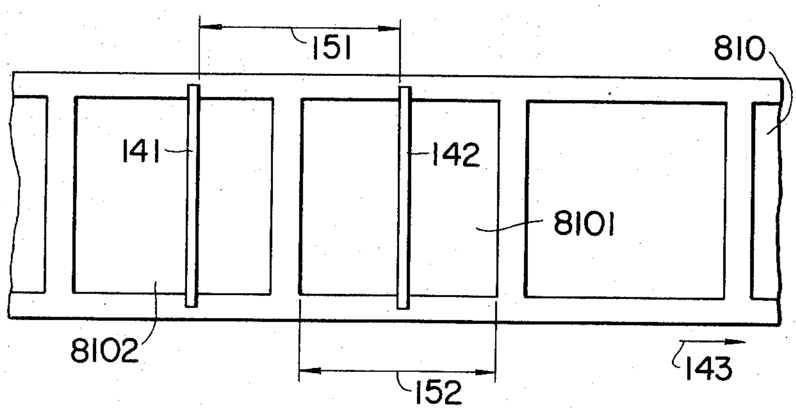


FIG. 15



APPARATUS FOR AUTOMATIC COMPUTATION OF CARDIOTHORACIC RATIO

The present invention relates to an apparatus for automatically computing the cardiothoracic ratio especially on the basis of an X-ray photograph.

The recent years have seen a great increase in the number of persons in the advanced nations who have died of cancer or malignant tumor, heart diseases and other adult diseases, raising the need for improved preventive medicine. A reinforcement of the present system of mass examination may be an answer. One object of the mass examination is to find and pick up out of examinees those diseased persons who have no subjective symptoms. The achievement of this purpose requires the processing of a large volume of medical data collected. This job which is known as a "screening," even though very monotonous, must be endorsed by a deep knowledge as well as a wealth of experience in the field of medicine, demanding a great time and labor of a doctor involved. Nevertheless, the shortage of the number of doctors poses a serious problem which cannot be solved in the near future.

It is common that a heart disease is accompanied by an abnormal enlargement of the heart, and the universally adopted method of measurement thereof is by the cardiothoracic ratio advocated by C. S. Danzer, which is defined as a ratio in percentage of the transverse diameter of the heart to the maximal transverse internal diameter of the thorax. (See, for example, the Japanese Medical Journal No. 2433, PP. 130 and No. 2,422, PP. 134 to PP. 135). In other words, since the cardiac enlargement is a helpful overall indicator of a heart disease, the CTR is a valuable clinical parameter for the screening process.

The CTR is usually determined with a rule or similar means applied to an X-ray or equivalent image of the chest. Even though various devices have been devised in an effort to facilitate the measurement, no substantial progress has been made in the direction of greatly saving the labor for the measurement.

It is easily imagined that the computation of the CTR will be made easily by a hypothetical method in which the brightness of an image is converted into an electrical signal by means of an appropriate photoelectric converter and portions of the signal with a large gradient are located by differentiating them or points are determined where the signal crosses a predetermined leve, in order to obtain the profiles of the thorax and heart. The past attempts made in this direction, however, did not necessarily agree with the actual results of measurements, thereby preventing the widespread use of this method. H. P. Meyers et al reported in 1964 that the cardiothoracic ratio automatically computed with a flying spot scanner and a digital computer almost agreed with the actual measurements (H. P. Meyers et al. "Automated Computer Analysis of Radiographic Images," Radiology Vol. 83, PP, 1,029 to 1,034, Dec. 1964). But their algorithm is based on a principle different from the one mentioned above and is entirely empiric. Anyway, the amount of information contained in a sheet of X-ray film is so great that its complete processing requires either very expensive hardware or greatly prolonged time.

An object of the present invention is to provide an apparatus for determining the cardiothoracic ratio both speedly and with a sufficiently high accuracy without human labor.

The principal operations or operating principle of the apparatus according to the present invention consist of the first step of processing brightness information included in an X-ray image by an improved method to infer the profiles of the thorax and heart, the second step of correcting an error, if any, in the inference by contextual data processing and the third step of computing the cardiothoracic ratio on the basis of the corrected data.

Another object of the present invention is to provide an automatic cardiothoracic ratio measuring apparatus with a high performance at a reasonable cost.

Still another object of the invention is to automate the screening operation either by recording or displaying the results of measurements of the cardiothoracic ratios of many examinees which have been obtained as a result of automatically and successively processing the X-ray images of their chests, or by identifying for recording or display purposes the serial numbers of the examinees' chest images with a cardiothoracic ratio amost equal to or higher than a reference or producing an alarm signal when their cardiothoracic ratios are almost equal to or greater than a predetermined reference, thereby to save the labor of a doctor and eliminate not only the differences in the results of measurements, which otherwise might occur for individual doctors, but their exhaustion for improved objectivity, reliability and repeatability of the measurements.

The above and other objects, features and advantages will be made apparent by the detailed description taken in conjunction with the accompanying drawings, in which:

FIG. **1**, is a diagram for explaining what is the cardiothoracic ratio;

FIG. **2** is a diagram showing an electrical signal generated by photo-electric conversion of an X-ray chest image along a straight line at right angles to the median line;

FIg. **3** is a diagram showing a typical electrical signal obtained from an actual X-ray chest image;

FIG. **4** is a diagram for explaning the manner in which the peripheral points are determined in a typical electrical signal;

FIG. **5** is a diagram similar to FIG. **4** for explaining the manner in which the peripheral points are determined in a distorted electrical signal;

FIG. **6** is a diagram for explaining the manner in which the transverse diameter of the heart and the maximal transverse internal diameter of the thorax are determined;

FIGS. 7A and 7B are diagrams for explaining the manner in which data obtained are corrected;

FIG. **8** is a block diagram showing an embodiment of the present invention;

FIGS. **9** and **10** are diagrams showing in detail a part of the embodiment of FIG. **8**;

FIG. **11** shows a scanning locus;

FIG. **12** is a diagram showing a silhouette of the heart;

FIG. **13** is a plan showing a film driving system;

FIG. **14** is a plan showing a frame detecting system; and

FIG. **15** an enlarged plan showing a part of the frame detecting system of FIG. **14.**

First, preliminary explanation will be made of an

X-ray image of the chest and the cardiothoracic ratio.

Referring to FIG. 1 drawn for explaining what is the cardiothoracic ratio, the reference numeral **10** shows a reference called the median line, numeral **11** the heart and numerals **12** and **12'** lungs. The numerals **13** and **14** show lines drawn perpendicular to the median line on the left and right sides thereof respectively at such points where the heart is projected most to the left and right. If the lengths of the two lines are expressed as $\overline{13}$ and $\overline{14}$ respectively, $\overline{13} + \overline{14}$ represents the maximal transverse diameter of the heart. The numeral **15** shows the maximal transverse internal diameter of the thorax the length of which is expressed as $\overline{15}$. Therefore, the cardiothoracic ratio is given as $[(\overline{13}+\overline{14})/\overline{15} \times 100$ percent.

In FIG. **2**, an electrical signal **23** obtained by photoelectric conversion of an X-ray image of the chest along a given straight line **20** at right angles to the median line **10** is shown in a simplified form, the numerals **21** and **22** respectively showing the white and black levels. Although FIG. **2** is concerned with an ordinary image with a dark lung field, its brightness may be reversed.

It is assumed in all the descriptions below that the lung field is shown dark and the white and black levels are positioned at upper and lower sides respectively. It should be noted, however, that these assumptions do not adversely affect the possibility of general application of the invention.

The conventional straightward method of determining the peripheral points of the heart and thorax consisted in differentiating the electrical signal **23** to obtain points **24-1, 24-2, 24-3** and **24-4** with great gradients or finding the points including **25-1, 25-2, 25-3** and **25-4** on the signal curve where it crosses a predetermined level of line. The data thus obtained was used to obtain $\overline{13}$, $\overline{14}$ and $\overline{15}$ and then to compute the cardiothoracic ratio.

Actually, however, partly because an X-ray image of the chest contains complicated intermediate tones with irregular variations in shade and partly because the images of ribs and blood vessels overlap each other in the lung field, the electrical signal **23** of FIG. **2** usually takes a more complex form as shown in FIG. **3.** The curve of FIG. **3** shows an example of a typical electrical signal on which numerals **31, 32, 33** and **34** indicate the peripheral points corresponding to those on the straight line **20** as determined by the observation of a person with a wealth of medical knowledge and experience. The points **31, 32, 33** and **34** are considered to be true peripheral points. If the first one of the conventional methods explained with reference to FIG. **2** in which an electrical signal is differentiated to find points with the greatest gradients is applied to curve **30** of FIG. **3** it is possible to detect the points on the curve of FIG. **3** corresponding to the points **24-1, 24-2, 24-3** and **24-4** on the curve of FIG. **2** but additional points which are almost indistinguishable from the true peripheral points are unnecessarily detected. On the other hand, the application to the curve **30** of the second conventional method in which points where the signal crosses a preset reference level are located has the disadvantage of the difficulty in presetting the reference level and often leads to the result that the detected peripheral points are highly variable when the shade gradient is gentle, resulting in the failure to detect the true peripheral points depending upon the shape of the curve **30** and the reference level-setting process.

The peripheral points detected by the conventional methods do not agree with the correct peripheral points in many cases, sometimes even with an error for beyond the practically allowable limit. This is the very reason why, in spite of the simple engineering processes involved, the conventional methods have not been successfully commercialized.

The operating principle of the present invention will be now explained. Referring first to the first step of the operation, the manner is described below in which the peripheral points are determined with reference to the curve **30** of FIG. **4** showing a typical electrical signal.

Points **40** and **40'** show the ends of the curve **30.** Numeral **46** shows the maximum point on the gentle part of the curve almost at the center thereof. This maximum point **46** of the curve **30** which is corresponding to the straight line **20** is found in every ordinary X-ray image of the chest.

When the curve **30** is followed starting at the end point **40,** the first point **41** is reached where the gradient is negative. This point **41** corresponds to the point **31** of FIG. **3.** Following the curve **30** further toward the point **46,** a minimum point **45** is reached before point **46.** Intermediate between point **45** and point **46,** there always exists a point with the maximum gradient which corresponds to point **32** of FIG. **3** and may be expressed as point **42.** In like manner, points **43** and **44** corresponding to points **33** and **34** respectively on the curve of FIG. **3** are determined by following the curve **30** from the other end point **40'.**

The points **41, 42, 43** and **44** thus determined agree with the true peripheral points very well. Further, the process of determining the points is stable and simple, and a measurement error is sufficiently within the limit of commercial applications excepting the cases mentioned later. A qualitative analysis of this advantage is shown in FIGS. **5**(A), **5**(B) and **5**(C), FIG. **5**(A) being quite identical with FIG. **4.** FIGS. **5**(B) and **5**(C) show how the peripheral points **41, 42, 43** and **44** determined according to the invention are almost free from influences of any distortions of an electrical signal. According to the conventional methods, by contrast, even if satisfactory results may be obtained from the signal of the waveform shown in FIG. **5**(A), distortions of the signal as shown in FIGS. **5**(B) and **5**(C) will result in an increased error or make it impossible to detect the peripheral points. Photo-electric converters now commonly used include the flying spot scanner and the vidicon camera, although a mechanical scanning means is also available. Regardless of which means is employed, however, it is well known that the distortions as shown in FIG. **5** are a frequent phenomenon due to various causes. It is also expected that an X-ray image itself carries such distortions. Further, although not referred to in the explanation of FIG. **5,** it is evident that the peripheral points determined by the method of the invention are affected very little by variations in the amplitude and DC level of an electrical signal resulting from the variations in the contrast of the X-ray image or the gain of an amplifier.

A set of peripheral points thus determined will assume different co-ordinates by moving the line **20** in the direction of the median line. The resulting series of peripheral points which provide the profiles of the thorax and heart are shown in FIG. **6.** In this figure, the numerals **60-1, 60-2, 60-3, ... 60-n** show equidistant straight lines at right angles to the median line which are equivalent to the straight line **20** moved up and down. The distance between the straight lines which is determined taking into consideration the required accuracy and economy may be much longer than in the television raster. The peripheral points **61-1, 62-1, 63-1** and **64-1; 61-2, 62-2, 63-2** and **64-2; 61-3, 62-3, ...; 61-n, 62-n, 63-n** and **64-n** determined by the above-mentioned method are the series of data providing the profiles of the thorax and the heart.

Before going to the second step, explanation will be made now of the third step of operation with reference to FIG. **6** for convenience of illustration.

In order to compute the cardiothoracic ratio, it is necessary first of all to determine $\overline{13}$, $\overline{14}$ and $\overline{15}$ as explained above with reference to FIg. **1.** Assuming that $\overline{62\text{-}1}, \overline{62\text{-}2}, \overline{62\text{-}3}, \ldots, \overline{62\text{-}n}$ show the length of the lines perpendicular to the median line and passing the points **62-1, 62-2, 62-3, ... 62-n** respectively and that $\overline{62\text{-}1}$ is the longest of them, the length $\overline{62\text{-}1}$ corresponds to the length $\overline{13}$ shown in FIG. **1.** In this particular illustration, however, since the point **62-n** on the straight line **60-n** is known to be a peripheral point of the diaphragm **69** but not the peripheral point between the lungs and the heart, the line **62-n** will be disregarded, as mentioned in detail later with reference to the second step of operation, in determining the length $\overline{62\text{-}1}$. Similarly, assuming that $\overline{63\text{-}1}, \overline{63\text{-}2}, \overline{63\text{-}3}, \ldots . \overline{63\text{-}n}$ show the length of lines perpendicular to the median line and passing through the points **63-1, 63-2, ... 63-n** respectively, the maximum length $\overline{63\text{-}J}$ corresponding to **14** in FIG. **1** is determined without regard to $\overline{63\text{-}n}$. Furthermore, if the distance between the points **61-1** and **64-1** is expressed as $\overline{65\text{-}1}$, the distance between points **61-2** and **64-2** as $\overline{65\text{-}2}$ and so on, the maximum distance $\overline{65\text{-}K}$ is determined which corresponds to $\overline{15}$ in FIG. **1.**

Accordingly, the cardiothoracic ratio is computed from the length $\overline{62\text{-}1}$, $\overline{63\text{-}J}$ and $\overline{65\text{-}K}$ as $\overline{62\text{-}1} + \overline{63\text{-}J}/\overline{65\text{-}K} \times 100$ percent. Actually, however, the cardiothoracic ratio is obtained only after the correction of the profile at the second step of the operation which will be explained below.

It was already explained that the peripheral points **41, 42, 43** and **44** determined in FIGS. **4** and **5** according to the first step of operation agree well with the true peripheral points and that the results obtained are very stable. Even in this case, however, an error sometimes occurs which exceeds an allowable limit. This is mainly attributable to the fact that as mentioned above the shades of the ribs and blood vessels are indistinguishable from that of the lung field or the heart. The result is an electrical signal representing false information indicating an erroneous peripheral point. As far as the observation is one-dimensional, this error is inevitable, and it is easily expected that even an observer with a wealth of medical knowledge and experience will make a similar mistake if he is to observe an X-ray image of the chest through the slits perpendicular to the median line. Nevertheless he is usually able to infer the profiles of the thorax and the heart accurately, this is not only due to his knowledge and experience but to his ability to correct the superficial results of the one-dimensional observation by making reference to all the factors involved, thereby effectively inferring the original two dimensional picture. Along this line, a contextual data processing step was followed in correcting an erroneous determination of the profile according to the present invention. The operation of the present invention is based on the principle of the prediction method as shown in FIGS. **7A** and **7B** to correct an error and identify the diaphragm.

The straight lines **70-1, 70-2, ... 70-6** in FIG. **7A** correspond to the straight line **20.** Let us assume that the peripheral points **72-1, 72-2, ... 72-6** were determined by following the first step of operation, the point **72-4** being a false peripheral point determined as mentioned above. Also, assume that the co-ordinates representing the points **72-1, 72-2, ... 72-6** are $D_{(1)}$, $D_{(2)}$, ... $D_{(6)}$ respectively. It In a given series of data, it is generally known how to predict the probable value of $D_{(i)}$ on the basis of $D_{(i\text{-}2)}$ and $D_{(i\text{-}1)}$. The simplest method of such a prediction is the linear prediction method in which the predicted value of D(i) is given as $P_{(i)} \pm \Delta$, if $D_{(i\text{-}2)}$ and $D_{(i\text{-}1)}$ are known where $P_{(i)} = 2 \times D_{(i\text{-}1)} - D_{(i\text{-}2)}$ and the symbol Δ shows an allowable limit which will depend on the standard shape of the heart and the spaces between the straight lines **70-1, 70-2, ...** and **70-6,** for example.

In the example of FIG. 7A, if $D_{(4)}$ departs from the range predicted on the basis of $D_{(2)}$ and $D_{(3)}$, $D_{(4)}$ is provisionally disregarded and $P_{(4)}$ is substituted therefor, and then it is examined whether $D_{(5)}$ actually exists within the range of $P_{(5)} \pm \Delta$ estimated on the basis of $D_{(3)}$ and $P_{(4)}$. If so, the preceding provisional substitution is deemed reasonable and a further procedure is followed, after completing the correction of $D_{(4)}$. The point **72-4'** on the straight line **70-4** shows the result thus corrected, the thick portion of the straight line indicating the range covering $\pm \Delta$. The point **72-5'** is provided for the purpose of the above-mentioned examination and meaningless once the presence of point **72-5** within the range of $\pm \Delta$ is verified.

FIG. 7B shows the case in which $D_{(5)}$ does not actually exist within the range of $P_{(5)} \pm \Delta$ estimated on the basis of $D_{(3)}$ and $P_{(4)}$. In this case, the provisional substitution is not deemed reasonable and $D_{(4)}$ is again employed for a further procedure disregarding $P_{(4)}$. Such a case occurs in the neighborhood of the diaphragms **69** and **69'** in FIG. **6.** The data series tend to depart from the median line sharply in the neighborhood of the diaphragm, and it is known that points **72-4, 72-5,** 72-6, ... correspond to the diaphragm, so that these data may be eliminated in the process of determining the maximal transverse diameter of the heart. FIGS. 7A and 7B are primarily concerned with the determination of the profile of the heart, but a similar correcting process is applied to the determination of the profile of the thorax. Incidentally, the method of correction explained with reference to FIGS. 7A and 7B is only an example of many possible methods, and does not preclude the use of a combination of more complex techniques of prediction. The important thing is to verify the co-relation with points in the neighborhood.

Although the above explanation of the operating principle of the present invention was with reference to the automatic measurement of the cardiothoracic ratio, the present invention may be also effectively applied to the automatic measurements of not only the size of various internal organs but the area occupied thereby as its image is projected in a certain direction, as well as the volume of the internal organ through the combination of the above data and the ratio between them on the basis of radiographs.

It will be understood from above that it is possible to embody the present invention in various forms, one of which will be explained below in detail with reference to FIG. **8.**

In this figure, the reference numeral **800** shows a light source including a lamp **801,** a light diffusion plate **802** and a box **803** serving simultaneously as a reflector. The light source **800** which is so designed that almost uniform brightness is obtained over the whole area of the light diffusion plate **802** is identical with the one used by a doctor for the observation of an X-ray film. The X-ray film **810** is disposed near the light diffusion plate **802.** Numeral **820** shows a photo-electric conversion system including a lens **821,** vidicon tube **822,** deflection circuit **823,** video signal amplifier **824,** sample and hold circuit **825,** A-D converter **826** and control circuit **827.** The lens **821,** vidicon tube **822,** deflection circuit **823** and video signal amplifier **824** or a part thereof are equivalent to and may be replaced by a standard type of television camera with **525** scanning lines. The lens **821,** however, should preferably be provided with an automatic iris control regulated by, say, a CdS sensor in the neighborhood of the lens. The iris of the lens is automatically adjusted to maintain the good operating conditions of the vidicon tube and the video signal amplifier even if the average shade of the film image varies with the photographing and developing conditions or an object.

The output of the video signal amplifier **824** is applied through the sample and hold circuit **825** to the A–D converter **826** where parallel digital outputs are produced. The number of levels into which the shade is quantized in the digital data processing of an image depends upon the object of the data processing, but 7 bits that is **128** levels or 8 bits that is **256** levels meet the requirements of the present invention. In other words, one datum is contained in one byte. The detail in this connection is shown in FIG. **9.** In this figure, the output of the video signal amplifier **824** is applied to the lead wire **91.** The reference numeral **92** shows an operational amplifier, numerals **93** and **94** MOS FET's, numeral **95** a drive circuit for supplying a sampling signal to the gate of the MOS FET **93.** A timing signal for the sampling operation is introduced from the control circuit **827** and applied to the lead wire **96.** A high input imedpance of the gate of the MOS FET **94** and capacitor **97** constitute a hold circuit, a signal held by which is taken out of the source of the MOS FET and applied through the lead wire **98** to the A-D converter **826.** No explanation will be made of the A-D converter **826** which is well known. The control circuit **827** acts to control not only the sample and hold circuit **825** and A-D converter **826** but the deflection circuit **823** and is shown in detail in FIG. **10.** In this figure, the numeral **101** shows a clock pulse generator, numeral **102** a countdown circuit, numeral **103** a lead wire for supplying horizontal and vertical synchronizing pulses to the deflection circuit **823** of the vidicon tube **822,** and numeral **104** a dynamic shift register for a circulating storage with a circulation time equal to a horizontal scanning period, which is provided with output terminals for designating the positions of the parallel straight lines **60-1, 60-2, 60-3, ... 60-**n in FIG. **6.** Numeral **105** shows a shift register for determining the number of the parallel straight lines **60-1, 60-2, 60-3, ... 60-**n in FIG. **6,** numeral **106** a timing circuit, numeral **107** a lead wire for introducing a data read start instruction signal through the interface **831** as explained later, numeral **108** a lead wire for introducing a data read end alarm signal, and numeral **109** a lead wire for supplying a timing signal to the sample and hold circuit **825** and A-D converter **826.**

Explanation will be made now to make more clear how the sample and hold circuit **825,** A-D converter **826** and the deflection circuit **823** of the vidicon tube **822** are controlled by the control circuit **827.** Referring to FIG. **11,** the reference numeral **111** shows the range of image pick-up within which the vidicon tube operates, and numeral **112** a locus of the electron beam scanning. To make it easier to understand the relationship with FIG. **6,** the locus in FIG. **11** is shown rotated by 90°, even though actually its aspect ratio is **3** to **4** and agrees with a standard television system as already explained. The interlaced scanning ratio of 2 to 1 in the standard television system is not employed in this embodiment as will be clear from FIG. **10,** partly because a resolution of about **128** lines is sufficient for the purpose of the present invention, and partly because it is desired that the control circuit **827** should not unnecessarily be complicated. More in detail, the clock pulse generator **101** produces an output at the frequency of 1 MHz, while the horizontal and vertical synchronizing signals produced from the count-down circuit **102** have the period of 64μ sec or the frequency of 15.625 KHz and 16.384 m sec or 61.035 Hz respectively. Strictly speaking, therefore, they are different from the standard system but it is needless to say that this small difference in frequency does not affect the normal operation of the standard type of camera or monitor. This merit, however, is not an important element of the present invention. The parallel straight lines **60-1, 60-2,** 60-3, ... 60-n, as shown perpendicular to the horizontal scanning lines **112** in FIG. **11,** are a locus of points where the signals are sampled and converted from analog into digital under the control of the control circuit **827,** being so controlled as to recover a line of data for each field. These parallel straight lines correspond to the parallel straight lines **60-1, 60-2, 60-3, ... 60-**n in FIG. **6.** Hereinafter these parallel lines are called virtual scanning lines.

The above-mentioned method of obtaining the virtual scanning lines by the standard type of scanning and the controlling of timing of the sampling operation is only one of the possible methods. Another method of achieving the object of the present invention is to deflect the electron beam along the above-mentioned vertical scanning lines. In other words, what is important is to convert the brightness of an image into an electrical signal along such loci. Back to FIG. **8,** the digital signal thus obtained is processed on the aforementioned principle by the data processing means **830** which comprises an interface **831,** random access memory **832,** processor unit **833** and read only memory **834.** The capacity of the random access memory **832** is primarily determined by the total number of data sampled along the loci corresponding to the parallel straight lines **60-1, 60-2, 60-3, ... 60-**n in FIG. **6.** In this embodiment are needed about 2,000 bytes including 1,920 bytes — the tentative number of the vertical scanning lines or **15** multiplied by the number of data contained in a line or **128** — and an additional small amount of working storage. The capacity of the read only memory **834** is determined by the number of steps of the program for carrying out the data processing on the afore-mentioned principle, and in this embodiment it must be about 2,000 bytes.

The data processing means **830** should preferably be provided with an interrupt function, whereby the processing time can be shortened. This data processing means may be replaced by a small digital computer which is generally called a minicomputer, in which case the program may be written not in the read only memory **834** but in the random access memory **832** with a capacity of approximately 4,000 bytes or words. The numeral **840** in FIG. **8** shows an output means for producing the computation results of the cardiothoracic ratio. Such an output means is typically represented by an input-output typewriter such as Teletype ASR33 of Teletype corporation or a CRT display terminal. In any case, the profile of the heart and therefore the silhouette thereof as shown in FIG. **12** which is an interim result of the data processing operation is easily printed or otherwise displayed as desired by a doctor involved. The availability of this option is very important as it helps the doctor, if he so desires, diagnose a heart disease especially when the cardiothoracic ratio is abnormally high.

The reference numeral **850** in FIG. **8** shows a film handling system including a film handling mechanism **851** and a control circuit **852.** The types of film handled are roughly divided into a sheet and a roll. A film handling system for a sheet is similar in construction to an OCR system called a document reader, while a roll film handling system is like an OCR system generally called a journal tape reader. In this case of a sheet film handling system, sheet films in an input hopper are fed one by one to automatically measure the cardiothoracic ratio following the above-mentioned operating steps, while this system is so arranged that on completion of a processing the processed films are housed in a stacker to make ready for the next film processing. In the case of a roll film handling system, on the other hand, a roll of film is fed from one spool to the other by means of a pinch roller, and it is desirable that the film is maintained stationary at least during the period of time in which a frame of film is being processed or when the film is being scanned to derive information. Accordingly, as shown in FIG. **13,** the shaft **131** of the pinch roller is connected to the shaft of the motor **133** through the electromagnetic clutch **132** or the shaft of the electromagnetic clutch/brake **134** through the electromagnetic clutch **132.** The time when the film should be stopped occurs when the center of a frame of film to be processed reaches the optical axis of the lens **821,** as detected by photo-electric sensors. The vidicon **822,** lens **821,** film **810,** light diffusion plate **802** and lamp **801** in FIG. **14** are identical to those shown in FIG. **8,** the numerals **141** and **142** showing the photo-electric sensors. The numeral **810** shows a roll film which is fed in the direction of arrow **143.**

The relationship between a series of frames of the film **810** and the photo-electric sensors **141** and **142** as seen from the lens is shown in FIG. **15.** In this figure, the distance **151** between the two photo-electric sensors **141** and **142** is equal to the length **152** of a frame of the recorded roll film **810.** On completion of the processing one frame **8101,** either the control circuit **852** is energized by a signal from the data processing means **830,** or the operator in response to an alarm from the displayer indicating the completion of the processing depresses a button for feed instructions, thereby to restart the feed of the roll film **810** in the direction of arrow **143,** but it is not until the next frame **8102** reaches the mid-point between the sensors **141** and **142** that the outputs of both the sensors **141** and **142** change to the white level. The output of the sensors is shaped and, after an AND operation thereof, the control circuit **852** is energized, whereupon the film **810** is stopped by the electromagnetic clutch/brake **134.**

The film handling system **850** may be replaced by a manual system in which the film is fed by hand sheet by sheet or frame by frame, as the occasion may be.

Also, it is needless to say that instead of the digital system of data processing employed in the embodiment, an analog or appropriate hybrid system may be used to carry out the operating principles explained in FIGS. **1** to **7.**

Furthermore, in place of a transparent image aimed at in the embodiment of FIG. **8,** it is possible to construct the apparatus according to the present invention in such a manner as to handle an opaque image by slight modification of the light source **800** and the photo-electric conversion system **820.**

What is claimed is:

1. A system for automatically measuring the cardiothoracic ratios comprising photo-electric conversion means (**820**) for effectively scanning a chest X-ray image (**810**) along a plurality of parallel lines perpendicular to the median line of said chest X-ray image and converting the brightness of said X-ray image into a corresponding electrical signal, data processing means (**830**) for processing data obtained from said photo-electric conversion means, and means (**840**) for recording or displaying the value of the cardiothoracic ratio obtained from said data processing means, said data processing means (**830**) inferring intersections between the boundary lines of the thorax and the heart and said plurality of parallel lines on the basis of data obtained along each of said parallel lines, said data processing means (**830**) correcting erroneous data which may be contained in four series of data corresponding to the boundary lines of the thorax and the heart, whereby the cardiothoracic ratio is determined on the basis of said four series of data.

2. A system for automatically measuring the cardiothoracic ratios according to claim **1,** in which said film handling means is manually operated.

3. A system for automatically measuring the cardiothoracic ratios according to claim **1,** in which said photo-electric conversion means comprises a standard type of television image pickup device or an equivalent film camera.

4. A system for automatically measuring the cardiothoracic ratios according to claim **1,** in which said data processing means is replaced by a general-purpose digital computer.

5. A system for automatically measuring the cardiothoracic ratios according to claim **1,** in which data are processed in such a manner as to display or record the profiles of the heart and/or the thorax or the silhouettes thereof as well as the cardiothoracic ratios.

6. A system for automatically measuring the cardiothoracic ratios according to claim **1,** further comprising film handling means for automatically feeding the film carrying said chest X-ray image.

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