

IMAGE PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an image processing apparatus used in association with image detecting apparatus such as X-ray image detecting apparatus, for medical and industrial use.

The latest type of X-ray image detecting apparatus is provided with a one-dimensional sensor array which includes a plurality of image detectors of semiconductor. The sensor array is scanned perpendicular thereto so as to obtain a two-dimensional image. In addition, a memory is provided for storing the two-dimensional image by arranging pixel data output by the image detectors in a predetermined pattern.

This type of image detecting apparatus has a problem in that if the sensor array includes a defective image detector having a reduced sensitivity, the image produced by the defective detector is spoiled by a line noise.

If the defective image detector amounts to be more than one, or alternatively, if the extent of unequal sensitivity depends upon temperature, it is difficult to adjust all the image detectors so as to have equal sensitivity.

SUMMARY OF THE INVENTION

The present invention is to provide an image processing apparatus usable in association with image detecting apparatus in order to remove a line noise likely to occur because of unequal sensitivity between image detectors which constitute the sensor array.

According to the present invention, there is provided an apparatus for processing a two-dimensional image obtained by scanning a sensor array of image detectors in a direction perpendicular to the array, the apparatus comprising an image memory for storing the two-dimensional image formed by pixel data output from the image detectors of the sensor array, a first read-out



means for reading the stored pixel data resulting from a particular detector of the array, a second read-out means for reading the stored pixel data resulting from a neighbouring detector or detectors, a first arithmetic means for measuring the magnitude of the difference in sensitivity between the detector whose pixel data is read by the first read-out means and the detector(s) whose pixel data is read by the second read-out means, and a second arithmetic means for compensating for any deficiency of sensitivity in the particular detector on the basis of the output of the first arithmetic means.

Pixel data output by the image detectors is linearly arranged and stored in the memory, and the first read-out means reads the pixel data wholly or partially from the memory. Then the second read-out memory reads another pixel data in the neighbourhood of the first-mentioned pixel data read by the first read-out means. The first arithmetic means measures the magnitude of a difference in the sensitivity between a particular image detector and the other image detectors.

If all the image detectors have a uniform sensitivity, and the resulting image is sufficiently even with no dark or bright spots, the mean value per pixel obtained from all the pixel data output by the particular image detector must be in agreement with that obtained from all the pixel data output by the other image detectors in the neighbourhood of the particular image detector. This means that the difference in sensitivity is 0 (zero). If there is a difference between the mean values, the difference indicates that there is a difference in sensitivity. By using this difference, the second arithmetic means compensates for the deficient pixel data output by the particular detector on the basis of the output by the first arithmetic means. In this way, according to the present invention, a line noise can be removed with the original resolution of image maintained.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram diagrammatically showing the entire structure of the image processing apparatus embodying the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The exemplary apparatus 1 is provided with m rows of pixels each row having n pixels corresponding to the image detectors in the sensor array, which will hereinafter be referred to merely as "detector". The sensor array is scanned perpendicular thereto so as to obtain a two-dimensional image which consists of $(n \times m)$ pixels. Now, suppose that the (i) th detector i outputs pixel data V_{ij} ($j=1$ to m), a mean value per pixel obtained will be:

$$S_i = \sum_{j=1}^m V_{ij}/m$$

If all the detectors have equal sensitivity and the resulting image is safe from any noise, the value S_i ought to be equal to the means value S' , obtained from pixels derived from a detector situated near to the detector i .

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If the detector i has a low sensitivity, the mean values will be as follows:

$$S_i < S'_i$$

This unequal relationship will be visually observed as a dark line (alternatively, an excessively bright line) formed by the outputs from the detector i . In order to remove this line noise, the difference Δ between S_i and S'_i should be added to the data V_{ij} ($j = 1$ to m). The exemplary apparatus 1 shown in Figure 1 is based on this principle.

The exemplary apparatus 1 includes two memories 2 and 11, a first counter 3 and a second counter 4, data buses 5, 6, 7, and 20, a first arithmetic unit 8, a second arithmetic unit 9, and a third arithmetic unit 10.

The memory 2 stores an image which consists of $(n \times m)$ pieces of pixels obtained by scanning sensor arrays (not shown) each having n pieces of detectors. The first counter 3 indicates the position of pixel along the array to which it belongs, and the second counter 4 indicates the position of pixels in the scanning direction of the array.

The data buses 5, 6, and 7 are led from the memory 2. The data bus 5 outputs data V_{ij} from the counters 3 and 4, and the data buses 6 and 7 output data about pixel h , that is, $(V_{(i-h)j} \sim V_{(i-1)j})$ and $(V_{(i+1)j} \sim V_{(i+h)j})$. The data bus 20 is also connected to the memory 2 so as to change the pixel data V_{ij} about the positions of pixels indicated by the counters 3 and 4 therethrough.

The arithmetic units 8 and 9 receive inputs delivered thereto through the data buses 6 and 7, respectively. The third arithmetic unit 10 receives outputs from the arithmetic units 8 and 9, and the pixel



data V_{ij} through the data bus 5.

The arithmetic units 8 and 9 calculate a median (alternatively, a mean value) of data about the pixel h input thereto, and generate outputs ℓ_{mj} and r_{mj} , respectively.

The third arithmetic unit 10 houses four resistors ℓ , r , c , and k (neither shown), and if the value $|\ell_{mj} - r_{mj}|$ is smaller than a predetermined value ϵ , the resistor ℓ increases its value by ℓ_{mj} . Likewise, the resistor r increases its value by r_{mj} , the resistor c increases its value by V_{ij} , and the resistor k increases its value by 1. These increments are made for j ($= 1$ to m). When j becomes equal to m , the third arithmetic unit 10 calculate the value $\Delta_i = [(\ell + r)/2 - c]/k$. The resulting value Δ_i is stored in the (i) th of the memory 11 as a compensating value. When j becomes equal to 1, each resistor in the third arithmetic unit 10 is reset to 0 (zero), and thereafter, the increment is performed.

In the above-mentioned process, the data $|\ell_{mj} - r_{mj}| > \epsilon$ is ignored. A large difference in sensitivity between adjacent points indicates that an image obtained is about an out-of-focus condition of the edge portion of the object. From this, the out-of-focus can be realized and remedied. The value ϵ , which is a parameter obtainable through experiments, is determined according to the magnitude to which a line noise due to different sensitivities between the detectors is removed.

When the compensating value Δ_i for each detector is calculated, the counters 3 and 4 are reset to their initial values, and the value $(V_{ij} + \Delta_i)$ is calculated by the calculator 12 while the value j of the second counter 4 is increased for the value i of each first counter 3. The resulting value is put into a predetermined place in the memory



2 through the data bus 20.

If a detector i in a particular array has a different sensitivity from that of the others, the magnitude of the difference can be expressed as a difference Δ_i between the mean value of all the pixel data output by the faulty detector i and the mean value of all the pixel data output by a detector in the neighborhood of the faulty detector i . By adding this difference Δ_i to the pixel data V_{ij} , that is, $V_{ij} + \Delta_i$, the deficient sensitivity can be easily compensated.

In the illustrated embodiment the compensating value for the detector i is obtained on the basis of $[(\ell + r)/2 - c]/k$ and each pixel is compensated by adding the difference Δ_i to the faulty value V_{ij} ($j = 1$ to m). The compensation is not limited to this method but it is also possible to use the following formula as a compensating value:

$$\Delta_i = (\ell + r)/(2c)$$

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CLAIMS:

1. An apparatus for processing a two-dimensional image obtained by scanning a sensor array of image detectors in a direction perpendicular to the array, the apparatus comprising an image memory for storing the two-dimensional image formed by pixel data output from the image detectors of the sensor array, a first read-out means for reading the stored pixel data resulting from a particular detector of the array, a second read-out means for reading the stored pixel data resulting from a neighbouring detector or detectors, a first arithmetic means for measuring the magnitude of the difference in sensitivity between the detector whose pixel data is read by the first read-out means and the detector(s) whose pixel data is read by the second read-out means, and a second arithmetic means for compensating for any deficiency of sensitivity in the particular detector on the basis of the output of the first arithmetic means.

2. The apparatus according to claim 1, further comprising a first counter and a second counter both connected to the image memory, wherein the first counter indicates the position of the pixels along the array to which they belong and the second counter indicates the position of the pixels in a direction in which the arrays are scanned.

3. The apparatus according to claim 1, further comprising a second memory interposed between the first arithmetic means and the second arithmetic means, the second memory storing the magnitude of difference in sensitivity measured by the first arithmetic means as a compensating value for the less sensitive detector.

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4. The apparatus according to claim 1, wherein the second read-out means comprises a pair of data buses through which data about adjacent pixels located on each side of the pixel whose data is read by the first read-out means, and wherein the first arithmetic means and second arithmetic means calculate a median or a mean value of data about the pixels read by the data buses and generate outputs corresponding to the calculated median or mean value to a third arithmetic means.

5. The apparatus according to claim 2, wherein the second read-out means comprises a pair of data buses through which data about adjacent pixels located on each side of the pixel whose data is read by the first read-out means, and wherein the first arithmetic means and second arithmetic means calculate a median or a mean value of data about the pixels read by the data buses and generate outputs corresponding to the calculated median or mean value to a third arithmetic means.

6. The apparatus according to claim 5, wherein the third arithmetic means comprises a first resistor, a second resistor, a third resistor, and a fourth resistor arranged in such a manner that if the absolute value of a difference between the medians or mean values is below a reference value, the first resistor is caused to increase its value by the median or mean value output by the first arithmetic means, the second resistor is caused to increase its value by the median or mean value output by the second arithmetic means, the third resistor is caused to increase its value by the pixel data read by the first read-out means, and the fourth resistor is caused to increase its value by 1 (one).

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