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(54) Apparatus and method for thermal image recording

Gerät und Verfahren für thermische Bildaufzeichnung

Appareil et méthode d'enregistrement d'images thermique

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- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 502 (M-1676), 20 September 1994 & JP 06 171134 A (MATSUSHITA ELECTRIC IND CO LTD), 21 June 1994,**
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Description

[0001] This invention relates to a thermal image recording apparatus according to the preambe of claim 1. It is used to form a recording corresponding to image data on a thermal recording material (hereunder referred to as a "thermal material") using a thermal head. The invention also relates to a thermal recording method according to the preamble of claim 5 for application of that apparatus. More specifically, the invention relates to a thermal image recording apparatus and method which are capable of forming recordings at high speed without uneven densities. An apparatus and a method of the above type are known from JP 6 171 134 A.

[0002] Thermal materials comprising a thermal recording layer on a substrate such as a paper or film are commonly used to record the images produced in diagnosis by ultrasonic scanning. This recording method, commonly referred to as thermal image recording, eliminates the need for wet processing and offers several advantages including convenience in handling. Hence, the use of the thermal image recording system is not limited to small-scale applications such as diagnosis by ultrasonic scanning, and an extension to those areas of medical diagnoses such as CT, MRI and X-ray photography where large and high-quality images are required, is under review.

[0003] As is well known, the thermal image recording apparatus uses a thermal head having a glaze in which heat generating resistors corresponding to the number of pixels of one line are arranged in one direction and, with the glaze slightly pressed against the thermal recording layer of the thermal material, the two members are moved relative to each other in a direction approximately perpendicular to the direction in which the heat generating resistors are arranged, and the respective heat generating resistors of the glaze are heated in accordance with the image to be recorded to heat the thermal recording layer imagewise, thereby accomplishing image reproduction.

[0004] A typical method of heating the individual heat generating resistors is by applying an electric current to such resistors for specified time periods that correspond to the image data of the individual pixels in the image to be recorded. However, the temperatures of the heat generating resistors to be energized vary from each other depending on the history of heat generation up to the previous line and, therefore, even if the heat generating resistors corresponding to the pixels having the same image data in the present line are energized for the same time period, temperature differences will occur between the heated resistors, thereby producing unevenness in the recording density.

[0005] In order to solve this problem of uneven recording densities, the image data must be compensated for temperature such that the heat generating temperature for the image data are corrected for each heat generating resistor on the basis of that image data and the history of heat generation up to the previous line.

[0006] Unexamined Published Japanese Patent Application 59-98878 & EP110675A teaches a thermal recording apparatus capable of outputting images at consistent density during high-speed recording. This apparatus performs thermal transfer recording using an ink ribbon and comprises memory means for storing the quantity of energy stored in each of the heat generating resistors, first computing means by which the electric energy to be applied to each of the heat generating resistors is calculated on the basis of the output data from said memory means and the input image data, second computing means by which the quantity of energy stored in each of the heat generating resistors is calculated on the basis or the output data from the memory means and the input image data, and control means by which the quantity of the electric energy to be applied to each of the heat generating resistors is controlled in accordance with the output of the first computing means.

[0007] In the above thermal recording apparatus, the electric energy to be applied at the present time is calculated on the basis of the image data to each of the heat generating resistors and the quantity of the heat stored up to the present time, namely, the past image data weighted to have a progressively smaller value back into the past; therefore, according to that patent, the calculated results reflect the changes in the temperatures of the individual heat generating resistors more correctly and, compared to the conventional system, the apparatus can provide more uniform recording densities, which is an advantage particularly salient in a high-speed recording mode.

[0008] In fact, however, the apparatus is designed to be such that the electric energy to be applied to the heat generating resistor corresponding to each one of the pixels is calculated for the entire surface of one screen, so that quite a lot of time is required to calculate the electric energy of interest. Therefore, if the size of one screen increases or if the number of recording pixels is increased in order to meet the demand for producing images of higher quality, it becomes difficult to achieve high-speed recording with this apparatus. If a capability for high-speed calculation is needed, the system configuration must be made complex enough which increases the manufacturing cost.

SUMMARY OF THE INVENTION

[0009] The present invention has been accomplished under these circumstances and has as an object to provide a thermal image recording apparatus that has a compact and low-cost system configuration and which yet is capable of forming recordings of high image quality without uneven densities.

[0010] Another object of the invention is to provide a recording method applicable to that apparatus.

[0011] These objects are achieved by the features of claim 1 and claim 5, respectively. Preferred embodiments are

set forth in the dependent claims.

[0012] The invention provides a thermal image recording apparatus with which an image to be recorded corresponding to image data is formed on a thermal recording material using a thermal head, said apparatus having an image processing unit which comprises:

means by which the image to be recorded on one screen is divided into a specified number of regions each having a specified number of pixels and which calculates for each of said regions a representative value of the image data within that region;
means for calculating a predicted value of temperature for each of said regions from said representative value of the image data within that region and an initial value of temperature as detected with a specified number of thermistors;
means for calculating a value of temperature correction for each of said regions from said predicted value of temperature for that region; and
means by which the values of temperature correction for said regions are interpolated to calculate a value of temperature correction for each of the pixels in said image to be recorded on one screen and by which the image data of each of said pixels are compensated for temperature.

[0013] The invention also provides a thermal image recording method for forming an image to be recorded corresponding to image data on a thermal recording material using a thermal head, said method comprising the steps of:

dividing the image to be recorded on one screen into a specified number of regions each having a specified number of pixels and calculating for each of said regions a representative value of the image data within that region;
calculating a predicted value of temperature for each of said regions from said representative value of the image data within that region and an initial value of temperature as detected with a specified number of thermistors;
calculating a value of temperature correction for each of said regions from said predicted value of temperature for that region;
interpolating the values of temperature correction for said regions to calculate a value of temperature correction for each of the pixels in said image to be recorded on one screen; and then
performing temperature compensation on the image data of each of said pixels.

[0014] It is preferred that said representative value of the image data within each of said regions is either the image data corresponding to a specified pixel within that region or an average value of the image data corresponding to a specified number of pixels within that region or an average value of the image data corresponding to all pixels within that region.

[0015] It is also preferred that said specified number of thermistors are disposed in specified positions on said thermal head and are adapted to be such that if either one of thermistors fails, an initial value of temperature to be detected with the failing thermistor is replaced by either an initial value of temperature as detected with a nearby thermistor or a value obtained by interpolating initial values of temperature as detected with the thermistors on the two adjoining sides of the failing thermistor.

[0016] It is further preferred that the predicted value of temperature for each of said regions is calculated on the basis of an electrically equivalent CR circuit model (hereunder referred to as CR model) of the thermal head.

[0017] The thermal image recording apparatus and method of the invention are characterized by the following: the image to be recorded on one screen is divided into a specified number of regions each having a specified number of pixels; the value of temperature correction is calculated for each of these regions; and the values of temperature correction for the respective regions are interpolated to calculate the value of temperature correction for each of the pixels in the image to be recorded on one screen.

[0018] Therefore, using the thermal image recording apparatus and method of the invention, one can not only produce records without uneven image densities but also form recorded images of high quality at high speed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1 is a diagram showing the concept of an example of the thermal image recording apparatus of the invention;
Fig. 2 is a diagram showing the concept of an example of the recording section of the thermal image recording apparatus of the invention;
Fig. 3 is a block diagram of an exemplary system for processing image data to the thermal image recording apparatus of the invention;

Fig. 4 is a flowchart for the steps that are performed in an example of the image processing unit of the system for processing image data to the thermal image recording apparatus of the invention;

Fig. 5 is a diagram showing the concept of an example of the image to be recorded by the thermal image recording method of the invention which has been divided into a specified number of regions each having a specified number of pixels;

Fig. 6 is a perspective view of an exemplary thermal head for use in the thermal image recording apparatus of the invention;

Fig. 7 is a cross section of the thermal head shown in Fig. 6;

Fig. 8 shows a circuit diagram of an example of the electrically equivalent CR model for a cross section of the thermal head in the thermal image recording apparatus of the invention;

Fig. 9 shows a partial circuit diagram of an example of the electrically equivalent CR model for the entire portion of the same thermal head; and

Fig. 10 is a diagram showing an exemplary method of calculating the value of temperature correction for each pixel in the thermal image recording apparatus of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] The thermal image recording apparatus and method of the invention will now be described in detail with reference to the preferred embodiments shown in the accompanying drawings.

[0021] Fig. 1 shows schematically an example of the thermal image recording apparatus of the invention. The thermal image recording apparatus generally indicated by 10 in Fig. 1 and which is hereunder simply referred to as a "recording apparatus" performs thermal image recording on thermal recording materials of a given size, say, B4 (namely, thermal recording materials in the form of cut sheets). The apparatus comprises a loading section 14 where a magazine 24 containing thermal films A is loaded, a feed/transport section 16, a recording section 20 performing thermal image recording on thermal films A by means of the thermal head 66, and an ejecting section 22.

[0022] The thermal films A comprise respectively a substrate consisting of a transparent film such as a transparent polyethylene terephthalate (PET) film, which is overlaid with a thermal recording layer.

[0023] Typically, such thermal films A are stacked in a specified number, say, 100 to form a bundle, which is either wrapped in a bag or bound with a band to provide a package. As shown, the specified number of thermal films A bundled together with the thermal recording layer side facing down are accommodated in the magazine 24 of the recording apparatus 10, and they are taken out of the magazine 24 one by one to be used for thermal image recording.

[0024] The loading section 14 has an inlet 30 formed in the housing 28 of the recording apparatus 10, a guide plate 32, guide rolls 34 and a stop member 36.

[0025] The magazine 24 is a case having a cover 26 which can be freely opened, and is inserted into the recording apparatus 10 via the inlet 30 of the loading section 14 in such a way that the portion fitted with the cover 26 is inserted first; thereafter, the magazine 24 as it is guided by the guide plate 32 and the guide rolls 34, is pushed until it contacts the stop member 36, whereupon it is loaded at a specified position in the recording apparatus 10.

[0026] The feed/transport section 16 has the sheet feeding mechanism using the sucker 40 for grabbing the thermal film A by application of suction, transport means 42, a transport guide 44 and a regulating roller pair 52 located in the outlet of the transport guide 44. The thermal films A are taken out of the magazine 24 in the loading section 14 and transported to the recording section 20.

[0027] The transport means 42 is composed of a transport roller 46, a pulley 47a coaxial with the roller 46, a pulley 47b coupled to a rotating drive source, a tension pulley 47c, an endless belt 48 stretched between the three pulleys 47a, 47b and 47c, and a nip roller 50 that is to be pressed onto the transport roller 46.

[0028] When a signal for the start of recording is issued, the cover 26 is opened by the OPEN/CLOSE mechanism (not shown) in the recording apparatus 10. Then, the sheet feeding mechanism using the sucker 40 picks up one sheet of thermal film A from the magazine 24 and feeds the forward end of the sheet to the transport means 42 (to be nipped between rollers 46 and 50).

[0029] At the point of time when the thermal film A has been pinched between the transport roller 46 and the nip roller 50, the sucker 40 releases the film, and the thus fed thermal film A is supplied along the transport guide 44.

[0030] At the point of time when the thermal film A to be used in recording has been completely ejected from the magazine 24, the OPEN/CLOSE mechanism closes the cover 26. The distance between the transport means 42 and the regulating roller pair 52 which is defined by the transport guide 44 is set to be somewhat shorter than the length of the thermal film A in the direction of its transport. The advancing end or the thermal film A first reaches the regulating roller pair 52 by the transport means 42. The regulating roller pair 52 are normally at rest. The advancing end of the thermal film A stops here.

[0031] When the advancing end of the thermal film A reaches the regulating roller pair 52, the temperature of the thermal head 66 is checked and if it is at a specified level, the regulating roller pair 52 start to transport the thermal

film A, which is transported to the recording section 20.

[0032] Fig. 2 shows schematically the recording section 20. As shown, the recording section 20 has the thermal head 66, a platen roller 60, a roller pair 56 (56a and 56b), a guide 58, a fan 76 for cooling the thermal head 66 (see Fig. 1, not shown in Fig. 2), a guide 62, and a transport roller pair 63.

[0033] As shown, the thermal head 66 is capable of thermal recording at a recording (pixel) density of, say, about 300 dpi. The head comprises a ceramic substrate 66b having a glaze 66a in which the heat generating resistors performing one line thermal recording on the thermal film A are arranged in one direction (perpendicular to the paper of Fig. 2), and a heat sink 66c fixed to the ceramic substrate 66b. The thermal head 66 is supported on a support member 68 that can pivot about a fulcrum 68a either in the direction of arrow a or in the reverse direction.

[0034] The platen roller 60 rotates at a specified image recording speed while holding the thermal film A in a specified position, and transports the thermal film A in the direction (direction of arrow b in Fig. 2) approximately perpendicular to the direction in which the glaze 66a extends.

[0035] Before the thermal film A is transported to the recording section 20, the support member 68 has pivoted to the UP position (in the direction opposite to the direction of arrow a) so that the glaze 66a of the thermal head 66 is not in contact with the platen roller 60.

[0036] When the transport of the thermal film A by the regulating roller pair 52 starts, said film A is subsequently pinched between the rollers 56 and transported as it is guided by the guide 58.

[0037] When the advancing end of the thermal film A has reached the record START position (i.e., corresponding to the glaze 66a), the support member 68 pivots in the direction of arrow a and the thermal film A becomes pinched between the glaze 66a on the thermal head 66 and the platen roller 60 such that the glaze 66a is pressed onto the recording layer while the thermal film A is transported in the direction of arrow b by means of the platen roller 60, the regulating roller pair 52 and the transport roller pair 63 as it is held in a specified position by the platen roller 60.

[0038] During this transport, the individual heat generating resistors on the glaze 66a are actuated imagewise to perform thermal image recording on the thermal film A. After the end of thermal image recording, the thermal film A as it is guided by the guide 62 is transported by the platen roller 60 and the transport roller pair 63 to be ejected into a tray 72 in the ejecting section 22. The tray 72 projects exterior to the recording apparatus 10 via the outlet 74 formed in the housing 28 and the thermal film A carrying the recorded image is ejected via the outlet 74 for takeout by the operator.

[0039] We now describe the method for performing thermal image recording with the above-described apparatus of the invention.

[0040] Fig. 3 is a block diagram of an exemplary system for processing image data to the thermal image recording apparatus of the invention.

[0041] As shown, the image data supplied to an image processing unit 80 are subjected to temperature correction and various other image processing jobs on the basis of thermistors 67a, 67b, 67c, 67d and 67e, as well as thermistors (not shown) for detecting the temperature of the heat sink and the ambient temperature and the thus processed image data are stored in an image memory 82. On the basis of the stored image data, a recording control unit 84 controls the heat generation by the individual heat generating resistors on the glaze 66a of the thermal head 66.

[0042] Fig. 4 is a flowchart for the steps that are performed in an example of the image processing unit 80. As shown in the Figure, prior to the image recording with the thermal head 66, the image to be recorded on one screen is divided into a specified number of regions each having a specified number of pixels and the image data within each region are subsampled to calculate a representative value for that image data. The representative value for the image data within each region may be the image data corresponding to a specified pixel in that region, or the average of the image data corresponding to a specified number of pixels in that region, or the average of the image data corresponding to all pixels in that region.

[0043] Consider, for example, the case where the image to be recorded on one screen consists of 3072 pixels in the horizontal direction and 4224 pixels in the vertical direction and said image is divided into a grid pattern of 25 $\times$ 133 regions each consisting of 128 $\times$ 32 pixels, as shown in Fig. 5. It should be noted that this is just one example and the number of pixels in the image to be recorded on one screen and the number of pixels in each of the regions into which said image is divided or the number of such regions are not limited to any particular values. It should also be understood that regions which do not have 128 $\times$ 32 pixels may be present along the edges of the screen as in the case shown in Fig. 5.

[0044] If the image data corresponding to one pixel in each of the regions into which the image to be recorded on one screen has been divided is to be taken as a representative value for the image data within that region, said representative value M(i,j) may be calculated in the illustrated case by the following formula:

$$M(i,j) = D(i \times 128, j \times 32)$$

where i and j are the coefficients representing the region numbers in the horizontal and vertical directions, respectively, such that i is an integer satisfying the relation $0 \leq i \leq 24$ and that j is an integer satisfying the relation $0 \leq j \leq 132$; D represents the image data corresponding to the pixels in the image to be recorded on one screen and, in the illustrated case, it is within the range of from D(0,0) to D(3071,4223).

[0045] If the average of the image data corresponding to a certain number of pixels, say, four pixels in each region is taken as a representative value for the image data in that region, said representative value M(i,j) for the image data D may be calculated by the following formula:

$$M(i,j) = \{D(i\times128-32, j\times32-8) + D(i\times128-32, j\times32+8) + D(i\times128+32, j\times32-8) + D(i\times128+32, j\times32+8)\}/4$$

[0046] If the average of the image data corresponding to all pixels in each region, namely, 128×32 pixels is taken as a representative value for the image data in that region, said representative value M(i,j) for the image data D may be calculated by averaging the image data D for the region surrounded by the following points:

D(i×128-64, j×32-16)
D(i×128-64, j×32+15)
D(i×128+63, j×32-16)
D(i×128+63, j×32+15)

[0047] In the illustrated case, the image data D for one screen are within the range from D(0,0) to D(3071,4223), so if the image data D in either one of the formulae set forth above are outside the stated range, the representative value for the image D in each region may be calculated on the assumption that D = 0 for example. Needless to say, the precision of the correction is best improved if the average of the image data D corresponding to all pixels in each region is used as the representative value for that image data D.

[0048] In the next step, the image processing unit 80 calculates a predicted value of temperature $V_g(i,j)$ for each region on the basis of both the representative value M(i,j) for the image data D within that region and the initial value of temperature which is detected with, for example, thermistors 67a, 67b, 67c, 67d and 67e provided in specified positions on the thermal head 66 and thermistors (not shown) for detecting the temperature T_h of heat sink 66c and the ambient temperature T_a.

[0049] Before describing a specific example of the method of calculating the predicted value of temperature for each region, let us briefly discuss the basic construction of the thermal head used in the thermal image recording apparatus of the invention.

[0050] Figs. 6 and 7 are a perspective view and a cross section, respectively, of an exemplary thermal head. The thermal head generally indicated by 66 comprises the ceramic substrate 66b with the glaze 66a, a base 66e which is a metallic (e.g. aluminum) plate superposed on the ceramic substrate 66b on the side remote from the glaze 66a, and the heat sink 66c that is superposed on the opposite side of the base 66e and which has a plurality of heat dissipating fins 66d.

[0051] In the illustrated thermal head 66, the heat dissipating fins 66d of the heat sink 66c have five cutouts 66f formed in specified positions, and thermistors 67a, 67b, 67c, 67d and 67e for detecting the temperature of the thermal head 66 (see Fig. 3) are installed within the respective cutouts 66f. The heat generating resistors are formed at the tip of the glaze 66a and, as Fig. 7 shows, the heat generated by the resistors is transmitted through the glaze 66a, ceramic substrate 66b and base 66e in that order until it is dissipated from the fins 66d of the heat sink 66c.

[0052] This is the basic construction of the thermal head 66 for use in the thermal image recording apparatus of the invention. Needless to say, this is just one example of the thermal head design and will in no way limit the thermal image recording apparatus of the invention.

[0053] The method of calculating the predicted value of temperature for each of the regions into which the image to be recorded on one screen has been divided will now be described assuming that the heat transmission system of the thermal head 66 is likened to an electric equivalent circuit of a CR model consisting of a capacitance component C and a resistance component R. In the equivalent circuit discussed below, the quantity of the heat generated by the heat transmission system per unit time, the temperature, the heat capacity and the heat resistance are replaced by the current, voltage, capacitance and resistance of an equivalent electric system.

[0054] Fig. 8 shows a circuit diagram of an example of the electrically equivalent CR model for a cross section of the thermal head. The equivalent circuit generally indicated by 86 includes a constant-current source 88 and a constant-voltage source (dry cell) 90 such that the quantity of the heat generated by each heat generating resistor is assumed to be constant and likened to the generation of a constant current I by the constant-current source 88 whereas the ambient temperature T_a is assumed to be constant and likened to the generation of a constant voltage V_a by the constant voltage source 90; in addition to these elements, the capacitance component C and resistor component R

associated with the glaze 66a, base 66e and heat sink 66c are used to represent by a CR model the cross-sectional structure of one of the heat generating resistors in the thermal head 66 shown in Fig. 7.

[0055] In the illustrated equivalent circuit 86, the capacitance components of the glaze 66a, base 66e and heat sink 66c are designated by C_g, C_b and C_h, respectively and, similarly, the resistance components between glaze/base, base/heat sink and heat sink/ambient air are designated by R_{gb}, R_{bh} and R_{ha}, respectively. The voltages at the glaze 66a, base 66e, heat sink 66c and in the ambient air are designated by V_g, V_b, V_h and V_a, respectively.

[0056] As already mentioned, the heat generated by the heat generating resistors is transmitted from the glaze 66a through base 66e and heat sink 66c to the ambient air after the lapse of a certain time. This may be likened to the following phenomenon in the equivalent circuit 86: the current I generated by the constant-current source 88 is delayed by a specified time corresponding to the CR time constant which is determined by the capacitance component C_g of the glaze 66a and the resistance component R_{gb} between the glaze 66a and the base 66e and, thereafter, the current I flows out of the constant-current source 88 past the glaze 66a to reach the base 66e, from which it flows through the heat sink 66c to reach the ambient air in the same manner as in the actual thermal head.

[0057] Fig. 9 shows a circuit diagram for a CR model of the entire design of the thermal head 66 (see Fig. 6) that is constructed using the equivalent circuit 86 shown in Fig. 8. In the equivalent circuit generally indicated by 92 in Fig. 9, the resistance component between the glazes 66a of adjacent heat generating resistors is designated as R_g and, similarly, the resistance component between bases 66e is designated as R_b and the resistance component between heat sinks 66c as R_h. The voltages at the individual glaze 66a, base 66e and heat sink 66c are designated as $V_g(i,j)$, $V_b(i,j)$ and $V_h(i,j)$, respectively.

[0058] Assuming that the image to be recorded on one screen is divided into 25×133 regions as shown in Fig. 5, we now describe the method of calculating the predicted value of temperature $V_g(i,j)$ of each region using the equivalent circuit 92 as a CR model of the thermal head.

[0059] First, the initial values of temperature T_1, T_2, T_3, T_4 and T_5 to be detected by thermistors 67a, 67b, 67c, 67d and 67e are set as the initial values of the voltage V_g at the glaze 66a and the voltage V_b at the base 66e; in addition, the initial value of temperature T_h of heat sink 66c is set as the initial value of the voltage V_h at the heat sink 66c. As for the voltage V_a in the ambient air, the ambient air temperature T_a is set at a fixed value. The initial values of V_g at the glaze 66a, V_b at the base 66e and V_h at the heat sink 66c, as well as the voltage V_a in the ambient air may be calculated by the following formulae:

$$V_g(i,0) = V_b(i,0)$$

$$= T_1 \text{ (when } i = 3)$$

$$= T_2 \text{ (when } i = 7)$$

$$= T_3 \text{ (when } i = 12)$$

$$= T_4 \text{ (when } i = 17)$$

$$= T_5 \text{ (when } i = 21)$$

$$V_h(i,0) = T_h \ (0 \leq i \leq 24)$$

$$V_a = T_a$$

[0060] If i takes on the values other than those indicated above, the initial values of V_g at the glaze 66a and V_b at the base 66e are calculated and set by linear interpolation of the initial values of temperature T_1, T_2, T_3, T_4 and T_5 which have been detected with the thermistors 67a, 67b, 67c, 67d and 67e, respectively. In the case under discussion where the thermal head 66 has a plurality of thermistors, if one of them fails, the initial value of the temperature as detected by a nearby thermistor may be substituted or the initial values of the temperature as detected by the thermistors on the two adjoining sides of the failing thermistor may be subjected to linear interpolation to calculate the initial value of the temperature which is to be detected with the failing thermistor.

[0061] Then, the predicted value of temperature $V_g(i,j)$ for each region may be calculated by the following formulae:

$$V_g(i, j+1) = V_g(i,j) + (kI+V_{g1}+V_{g2})/C_g$$

$$V_{g1} = \{V_g(i+1, j) - 2V_g(i,j) + V_g(i-1, j)\}/R_g$$

$$V_{g2} = \{V_b(i,j) - V_g(i,j)\}/R_{gb}$$

$$V_b(i, j+1) = V_b(i,j) + (V_{b1}+V_{b2}+V_{b3})/C_b$$

$$V_{b1} = \{V_b(i+1, j) - 2V_b(i,j) + V_b(i-1, j)\}/R_b$$

$$V_{b2} = \{V_g(i,j) - V_b(i,j)\}/R_{gb}$$

$$V_{b3} = \{V_h(i,j) - V_b(i,j)\}/R_{bh}$$

$$V_h(i, j+1) = V_h(i,j) + (V_{h1}+V_{h2}+V_{h3})/C_h$$

$$V_{h1} = \{(V_h(i+1, j) - 2V_h(i,j) + V_h(i-1, j)\}/R_h$$

$$V_{h2} = \{V_b(i,j) - V_h(i,j)\}/R_{bh}$$

$$V_{h3} = \{V_a-V_h(i,j)\}/R_{ha}$$

[0062] In the calculation formulae set forth above, k is a proportionality constant, i is an integer satisfying the relation $0 \leq i \leq 24$ and j is an integer satisfying $0 \leq j \leq 131$, provided that i - 1 = 0 if i = 0 and that i + 1 = 24 if i = 24, and I is the current generated from the constant-current source, namely, the quantity of the heat generated by an individual heat generating resistor and, specifically, the representative value M(i,j) of the image data D within each region is substituted into I.

[0063] The foregoing is an example of the method for calculating the predicted value of temperature $V_g(i,j)$ in the image processing unit 80.

[0064] In the next step, the image processing unit 80 calculates the value of temperature correction K(i,j) for each region from the thus calculated predicted value of temperature $V_g(i,j)$ of that region. An exemplary formula for making this calculation is:

$$K(i,j) = 1 - K_m\{V_g(i,j) - V_s\}$$

where K_m and V_s are both proportionality constants, with K_m typically taking a real number on the order of 0.001 - 0.03.

[0065] Finally, the image processing unit 80 interpolates the values of temperature correction K(i,j) for the respective regions of interest such as to calculate the value of temperature correction K_p for each of the pixels in the image to be recorded on one screen. Consider, for example, the case shown in Fig. 10 which assumes the following four regions for which the value of the temperature correction K(i,j) has been calculated:

$$K_a = K(i,j)$$

$$K_b = K(i+1, j)$$

$$K_c = K(i, j+1)$$

$$K_d = K(i+1, j+1)$$

If $\Delta ca = (K_c - K_a)/32$ and $\Delta db = (K_d - K_b)/32$, the value of temperature correction K_p for the pixel located at the point distant from K_a by (x,y) may be calculated by the following formula:

$$K_p(i\times 128+x, j\times 32+y) = (K_a+\Delta db\times y) + \{(K_b+\Delta db\times y) - (K_a+\Delta ca\times y)\} \times x/128$$

[0066] Hence, the temperature corrected image data D' can be calculated by the following formula:

$$D'(i\times 128+x, j\times 32+y) = K_p(i\times 128+x, j\times 32+y) \times D(i\times 128+x, j\times 32+y)$$

[0067] Thus, the image processing unit 80 calculates the value of temperature correction K_m for each of the pixels in the image to be recorded on one screen, calculates the image data as temperature corrected by K_m, and writes the corrected data into the image memory 82. Thereafter, the recording control unit 84 uses the temperature corrected image data to control the heat generation by the individual heat generating resistors in the glaze 66a on the thermal head 66. This is the way an image is recorded on one screen by means of the thermal head 66.

[0068] The thermal image recording apparatus and method of the invention have the basic design and operational features described above.

[0069] While the specific design of the image processing unit 80 is not limited in any particular way, the value of temperature correction for each of the pixels in the image to be recorded on one screen may be calculated by either a software or hardware based method. The foregoing description is directed to the case of using a CR model to calculate the values of temperature correction but this is not the sole case of the invention. It should also be noted that even in the case of employing a CR model, the model need not be applied to each of the glaze, base and heat sink taken separately but various modifications may of course be effected according to the design of the thermal head to be used or the desired precision in correction.

[0070] As described above in detail, the thermal image recording apparatus and method of the invention are characterized in that the image to be recorded on one screen is divided into a specified number of regions each consisting of a specified number of pixels, the value of temperature correction is calculated for each of said regions and, subsequently, the values of temperature correction for the respective regions are interpolated to calculate the value of temperature correction for each of the pixels of interest. As a result, the values of temperature correction for the pixels in the image to be recorded can be calculated at a sufficiently high speed to ensure that images of high quality without uneven densities can be recorded at high speed. In addition to this obvious advantage, the present invention is capable of providing a low-cost and compact recording apparatus that can be easily adapted to the image recording in the future which requires even higher image quality and a huge amount of data storage.

Claims

1. A thermal image recording apparatus (10) with which an image to be recorded corresponding to image data is formed on a thermal recording material (A) using a thermal head (66), said apparatus (10) having an image processing unit (80) which comprises:

   means by which the image to be recorded on one screen is divided into a specified number of regions each having a specified number of pixels and which calculates for each of said regions a representative value of the image data within that region;
   characterized by:
   means for calculating a predicted value of temperature for each of said regions from said representative value of the image data within that region and an initial value of temperature as detected with a specified number of thermistors (67a - 67e);
   means for calculating a value of temperature correction for each of said regions from said predicted value of temperature for that region; and

means by which the values of temperature correction for said regions are interpolated to calculate a value of temperature correction for each of the pixels in said image to be recorded on one screen and by which the image data of each of said pixels are compensated for temperature.

2. A thermal image recording apparatus (10) according to claim 1, wherein said representative value of the image data within each of said regions is either the image data corresponding to a specified pixel within that region or an average value of the image data corresponding to a specified number value of pixels within that region or an average value of the image data corresponding to all pixels within that region.

3. A thermal image recording apparatus (10) according to claim 1, wherein said specified number of thermistors (67a - 67e) are disposed in specified positions on said thermal head (66) and are adapted to be such that if either one of the thermistors (67a - 67e) fails, an initial value of temperature to be detected with the failing thermistor is replaced by either an initial value of temperature as detected with a nearby thermistor or a value obtained by interpolating initial values of temperature as detected with the thermistors on the two adjoining sides of the failing thermistor.

4. A thermal image recording apparatus (10) according to claim 1, wherein the predicted value of temperature for each of said regions is calculated on the basis of an electrically equivalent CR circuit model (92) of the thermal head (66).

5. A thermal image recording method for forming an image to be recorded corresponding to image data on a thermal recording material (A) using a thermal head (66), said method comprising the steps of:

dividing the image to be recorded on one screen into a specified number of regions each having a specified number of pixels and calculating for each of said regions a representative value of the image data within that region;
characterised by:
calculating a predicted value of temperature for each of said regions from said representative value of the image data within that region and an initial value of temperature as detected with a specified number of thermistors (67a - 67e);
calculating a value of temperature correction for each of said regions from said predicted value of temperature for that region;
interpolating the values of temperature correction for said regions to calculate a value of temperature correction for each of the pixels in said image to be recorded on one screen; and then
performing temperature compensation on the image data of each of said pixels.

6. A thermal image recording method according to claim 5, wherein said representative value of the image data within each of said regions is either the image data corresponding to a specified pixel within that region or an average value of the image data corresponding to a specified number of pixels within that region or an average value of the image data corresponding to all pixels within that region.

7. A thermal image recording method according to claim 5, wherein said specified number of thermistors (67a - 67e) are disposed in specified positions on said thermal head (66) and are adapted to be such that if either one of thermistors (67a - 67e) fails, an initial value of temperature to be detected with the failing thermistor is replaced by either an initial value of temperature as detected with a nearby thermistor or a value obtained by interpolating initial values of temperature as detected with the thermistors on the two adjoining sides of the failing thermistor.

8. A thermal image recording method according to claim 5, wherein the predicted value of temperature for each of said regions is calculated on the basis of an electrically equivalent CR circuit model (92) of the thermal head (66).

Patentansprüche

1. Thermobildaufzeichnungsvorrichtung (10), mit der ein Bilddaten entsprechendes, aufzuzeichnendes Bild auf einem Thermoaufzeichnungsmaterial (A) mit Hilfe eines Thermokopfs (66) erzeugt wird, wobei die Vorrichtung (10) eine Bildverarbeitungseinheit (80) besitzt, welche aufweist:

eine Einrichtung, mit der das aufzuzeichnende Bild auf einem Bildschirm in eine spezifizierte Anzahl von Zonen

unterteilt wird, die jeweils eine spezifizierte Anzahl von Pixeln aufweisen, und die für jede der Zonen einen repräsentativen Wert der Bilddaten innerhalb dieser Zone berechnet,
gekennzeichnet durch:

eine Einrichtung zum Berechnen eines Temperaturvorhersagewerts für jede der Zonen aus dem repräsentativen Wert der Bilddaten innerhalb dieser Zone, sowie eines Temperaturanfangswerts, wie er durch eine spezifizierte Anzahl von Thermistoren (67a - 67e) erfaßt wird;

eine Einrichtung zum Berechnen eines Korrekturtemperaturwerts für jede der Zonen aus dem Temperaturvorhersagewert für diese Zone; und

eine Einrichtung, mit der die Temperaturkorrekturwerte für die Zonen interpoliert werden, um einen Temperaturkorrekturwert für jedes der Pixel in dem aufzuzeichnenden Bild auf dem Bildschirm zu berechnen, und mit der die Bilddaten jedes der Pixel temperaturkompensiert werden.

2. Vorrichtung (10) nach Anspruch 1, bei der der repräsentative Wert der Bilddaten innerhalb jeder der Zonen entweder den einem spezifizierten Pixel innerhalb dieser Zone entsprechenden Bilddaten selbst entspricht oder einem Mittelwert der Bilddaten, die einer spezifizierten Anzahl von Pixeln innerhalb dieser Zone entsprechen, oder einem Mittelwert der Bilddaten entsprechend sämtlichen Pixeln innerhalb dieser Zone.

3. Vorrichtung (10) nach Anspruch 1, bei der die spezifizierte Anzahl von Thermistoren (67a - 67e) in spezifizierten Positionen an dem Thermokopf (66) angeordnet und dazu ausgebildet ist, daß, wenn irgendeiner der Thermistoren (67a - 67e) ausfällt, ein Temperaturanfangswert, der von dem ausgefallenen Thermistor erfaßt werden müßte, ersetzt wird durch entweder einen Temperaturanfangswert, wie er von einem in der Nähe befindlichen Thermistor erfaßt wird, oder durch einen Wert, den man erhält durch Interpolieren von Temperaturanfangswerten, wie sie mit Hilfe der Thermistoren an zwei benachbarten Seiten des ausgefallenen Thermistors erfaßt werden.

4. Vorrichtung (10) nach Anspruch 1, bei der der Temperaturvorhersagewert für jede der Zonen auf der Grundlage einer elektrischen CR-Ersatzschaltung (92) des Thermokopfs (66) berechnet wird.

5. Thermobildaufzeichnungsverfahren zum Erzeugen eines Bilddaten entsprechenden, aufzuzeichnenden Bildes auf einem Thermoaufzeichnungsmaterial (A) mit Hilfe eines Thermokopfs (66), umfassend die Schritte:

Unterteilen des aufzeichnenden Bildes auf einem Bildschirm in eine spezifizierte Anzahl von Zonen, die jeweils eine spezifische Anzahl von Pixeln aufweisen, und Berechnen eines repräsentativen Wertes von Bilddaten innerhalb der Zone für jede der Zonen;
gekennzeichnet durch:

Berechnen eines Temperaturvorhersagewerts für jede der Zonen aus dem repräsentativen Wert der Bilddaten innerhalb dieser Zone und einem Temperaturanfangswert, wie er von einer spezifizierten Anzahl von Thermistoren (67a - 67e) erfaßt wird;

Berechnen eines Temperaturkorrekturwerts für jede der Zonen aus dem Temperaturvorhersagewert für diese Zone;

Interpolieren der Temperaturkorrekturwerte für die Zonen, um einen Temperaturkorrekturwert für jedes der Pixel in dem auf einem Bildschirm aufzuzeichnenden Bild zu berechnen; und - anschließend -

Durchführen einer Temperaturkompensation der Bilddaten für jedes der Pixel.

6. Verfahren nach Anspruch 5, bei dem der repräsentative Wert der Bilddaten innerhalb jeder der Zonen entweder die Bilddaten entsprechend einem spezifizierten Pixel innerhalb dieser Zone selbst sind, oder ein Mittelwert der Bilddaten entsprechend einer spezifizierten Anzahl von Pixeln innerhalb dieser Zone, oder ein Mittelwert der sämtlichen Pixeln innerhalb der Zone entsprechenden Bilddaten.

7. Verfahren nach Anspruch 5, bei dem die spezifizierte Anzahl von Thermistoren (67a - 67e) in spezifizierten Positionen an dem Thermokopf (66) angeordnet und dazu ausgebildet ist, daß, wenn einer der Thermistoren (67a - 67e) ausfällt, ein Temperaturanfangswert, der von dem ausgefallenen Thermistor hätte erfaßt werden sollen, er-

setzt wird durch entweder einen Temperaturanfangswert, der von einem in der Nähe befindlichen Thermistor erfaßt wird, oder durch einen Wert, den man erhält durch Interpolieren von Temperaturanfangswerten, wie sie mit Hilfe der Thermistoren auf den beiden benachbarten Seiten des ausgefallenen Thermistors erfaßt werden.

8. Verfahren nach Anspruch 5, bei dem der Temperaturvorhersagewert für jede der Zonen auf der Grundlage einer elektrischen CR-Ersatzschaltung (92) des Thermokopfs (66) berechnet wird.

Revendications

1. Dispositif d'enregistrement thermique d'image (10) avec lequel une image à enregistrer correspondant à des données d'image est formée sur un matériau d'enregistrement thermique (A) en utilisant une tête thermique (66), ledit dispositif (10) comportant une unité de traitement d'image (80) qui comprend :

un moyen grâce auquel l'image à enregistrer sur un écran est divisée en un nombre spécifié de régions présentant chacune un nombre spécifié de pixels et qui calcule pour chacune desdites régions une valeur représentative des données d'image à l'intérieur de cette région,
caractérisé par :
un moyen destiné à calculer une valeur prédite de température pour chacune desdites régions à partir de ladite valeur représentative des données d'image à l'intérieur de cette région et d'une valeur initiale de température, telle qu'elle est détectée avec un nombre spécifié de thermistances(67a à 67e),
un moyen destiné à calculer une valeur de correction de température pour chacune desdites régions à partir de ladite valeur prédite de température pour cette région, et
un moyen grâce auquel les valeurs de correction de température pour lesdites régions sont interpolées afin de calculer une valeur de correction de température pour chacun des pixels de ladite image à enregistrer sur un écran et grâce auquel les données d'image de chacun desdits pixels sont compensées en température.

2. Dispositif d'enregistrement thermique d'image (10) selon la revendication 1, dans lequel ladite valeur représentative des données d'image à l'intérieur de chacune desdites régions représente soit les données d'image correspondant à un pixel spécifié à l'intérieur de cette région, soit une valeur moyenne des données d'image correspondant à une valeur d'un nombre spécifié de pixels à l'intérieur de cette région, soit une valeur moyenne des données d'image correspondant à tous les pixels à l'intérieur de cette région.

3. Dispositif d'enregistrement thermique d'image (10) selon la revendication 1, dans lequel lesdites thermistances en nombre spécifié (67a à 67e) sont disposées à des positions spécifiées sur ladite tête thermique (66) et sont conçues pour être telles que si l'une ou l'autre des thermistances (67a à 67e) est défaillante, une valeur initiale de température à détecter avec la thermistance défaillante est remplacée soit par une valeur initiale de température telle qu'elle est détectée par une thermistance proche, soit par une valeur obtenue en interpolant des valeurs initiales de température telles qu'elles sont détectées avec les thermistances sur les deux côtés adjacents de la thermistance défaillante.

4. Dispositif d'enregistrement thermique d'image (10) selon la revendication 1, dans lequel la valeur prédite de température pour chacune desdites régions est calculée sur la base d'un modèle de circuit CR électriquement équivalent (92) de la tête thermique (66).

5. Procédé d'enregistrement thermique d'image destiné à former une image à enregistrer, correspondant à des données d'image sur un matériau d'enregistrement thermique (A) en utilisant une tête thermique (66), ledit procédé comprenant les étapes consistant à :

diviser l'image à enregistrer sur un écran en un nombre spécifié de régions présentant chacune un nombre spécifié de pixels et calculer pour chacune desdites régions une valeur représentative des données d'image à l'intérieur de cette région,
caractérisé par :
le calcul d'une valeur prédite de température pour chacune desdites régions à partir de ladite valeur représentative des données d'image à l'intérieur de cette région et d'une valeur initiale de température telle qu'elle est détectée avec un nombre spécifié de thermistances (67a à 67e),
le calcul d'une valeur de correction de température pour chacune desdites régions à partir de ladite valeur prédite de température pour cette région,

l'interpolation des valeurs de correction de température pour lesdites régions afin de calculer une valeur de correction de température pour chacun des pixels de ladite image à enregistrer sur un écran, et ensuite l'exécution de la compensation de température sur les données d'image de chacun desdits pixels.

6. Procédé d'enregistrement thermique d'image selon la revendication 5, dans lequel ladite valeur représentative des données d'image à l'intérieur de chacune desdites régions représente soit les données d'image correspondant à un pixel spécifié à l'intérieur de cette région, soit une valeur moyenne des données d'image correspondant à un nombre spécifié de pixels à l'intérieur de cette région, soit une valeur moyenne des données d'image correspondant à tous les pixels à l'intérieur de cette région.

7. Procédé d'enregistrement thermique d'image selon la revendication 5, dans lequel lesdites thermistances en nombre spécifié (67a à 67e) sont disposées à des positions spécifiées sur ladite tête thermique (66) et sont conçues pour être telles que si l'une ou l'autre des thermistances (67a à 67e) est défaillante, une valeur initiale de température à détecter avec la thermistance défaillante est remplacée soit par une valeur initiale de température telle qu'elle est détectée avec une thermistance proche, soit par une valeur obtenue en interpolant des valeurs initiales de température telles qu'elles sont détectées avec les thermistances sur les deux côtés adjacents de la thermistance défaillante.

8. Procédé d'enregistrement thermique d'image selon la revendication 5, dans lequel la valeur prédite de température pour chacune desdites régions est calculée sur la base d'un modèle de circuit CR électriquement équivalent (92) de la tête thermique (66).

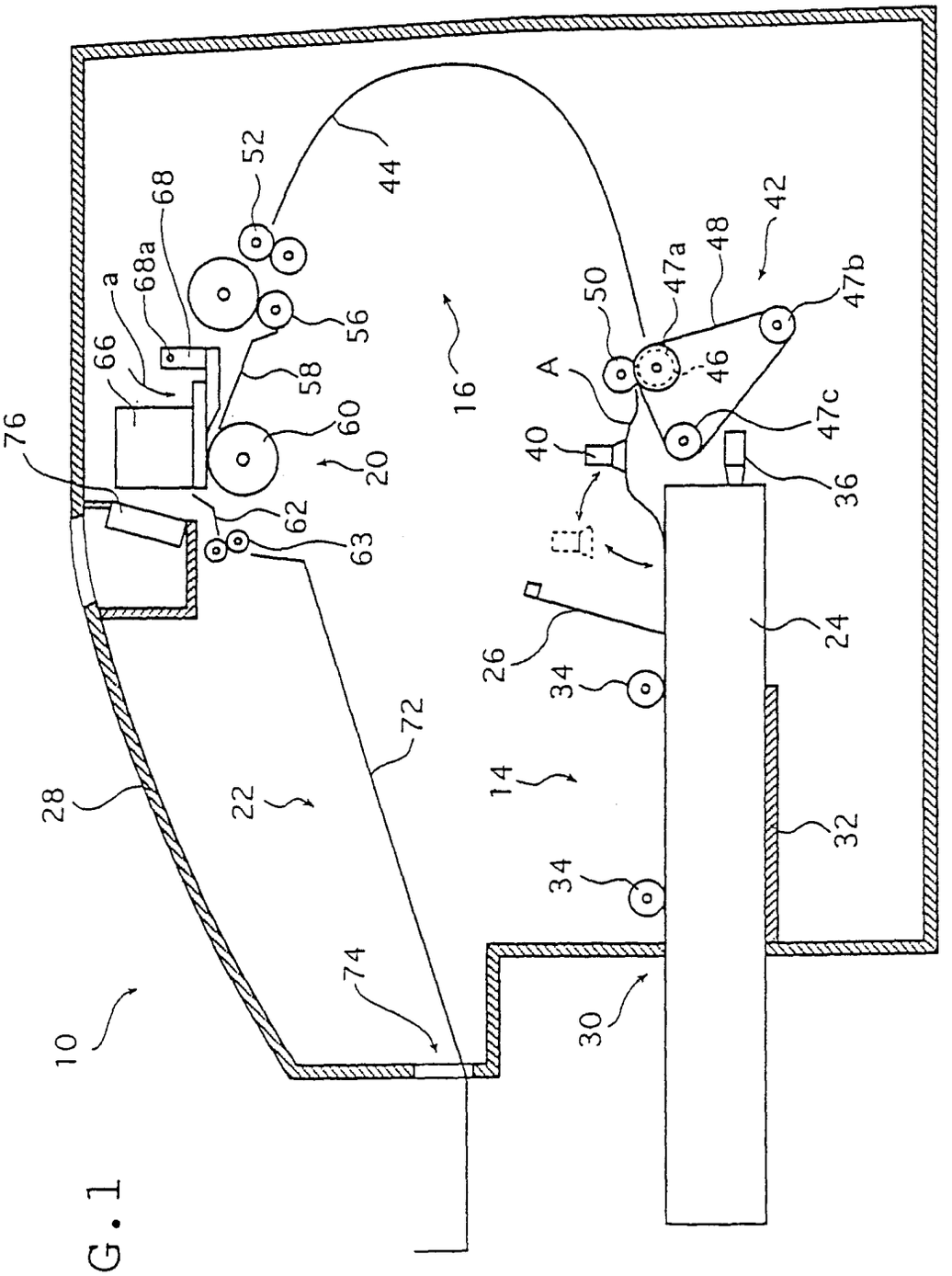

10
14
16
20
22
24
26
28
30
32
34
34
36
40
42
44
46
47a
47b
47c
48
50
52
56
58
60
62
63
66
68
68a
72
74
76
A
a

FIG. 1

FIG.2

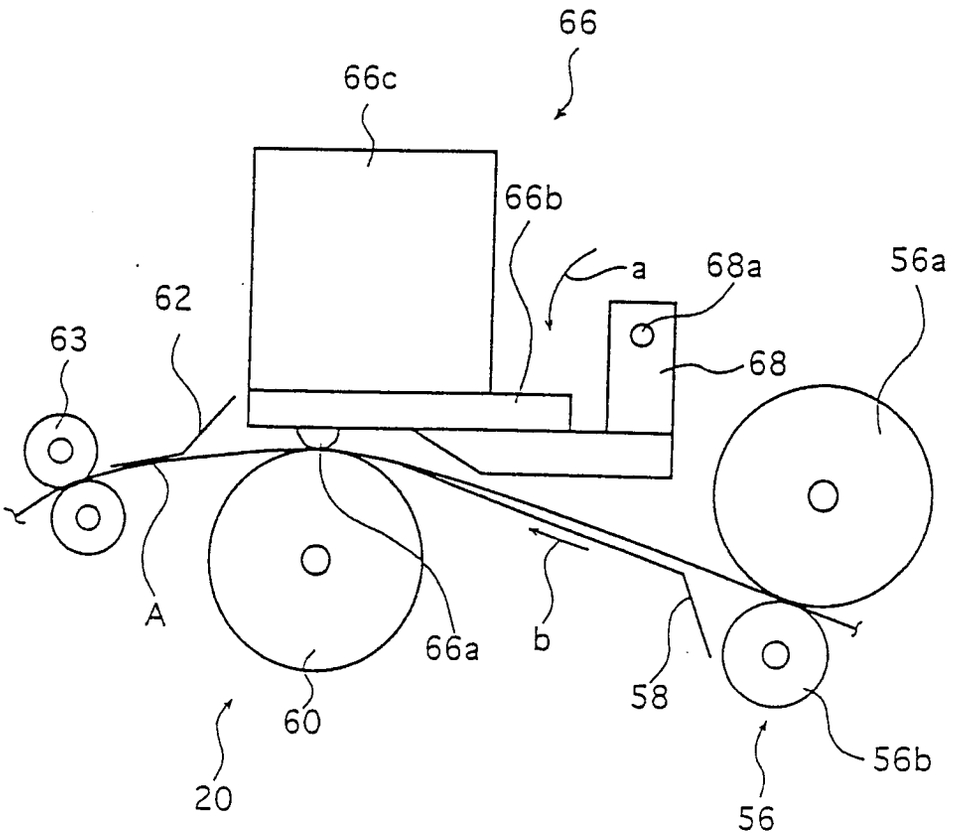


FIG.3

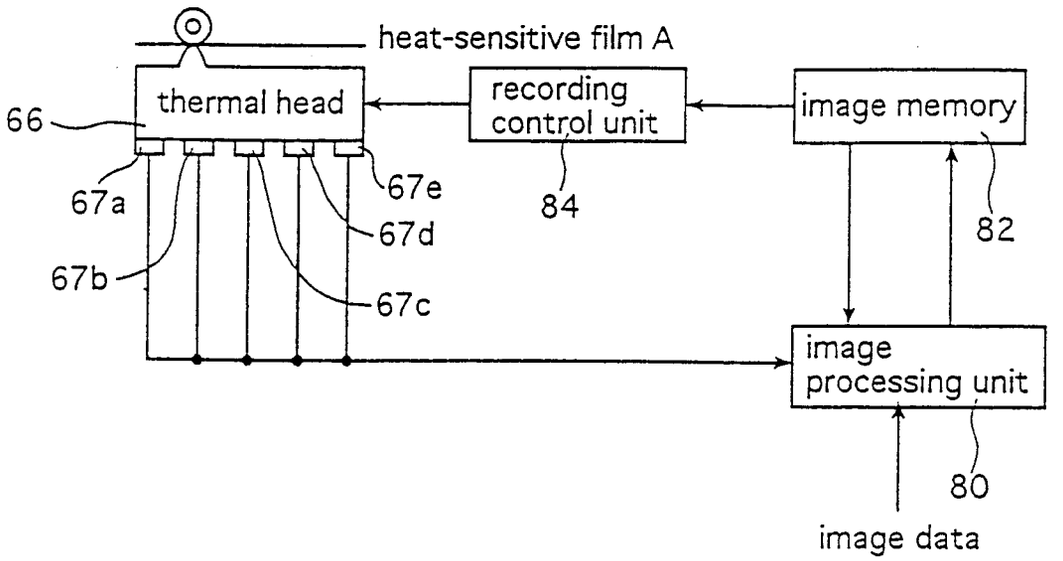

heat-sensitive film A
thermal head
recording control unit
image memory
66
67a
67b
67c
67d
67e
84
82
image processing unit
80
image data

FIG.5

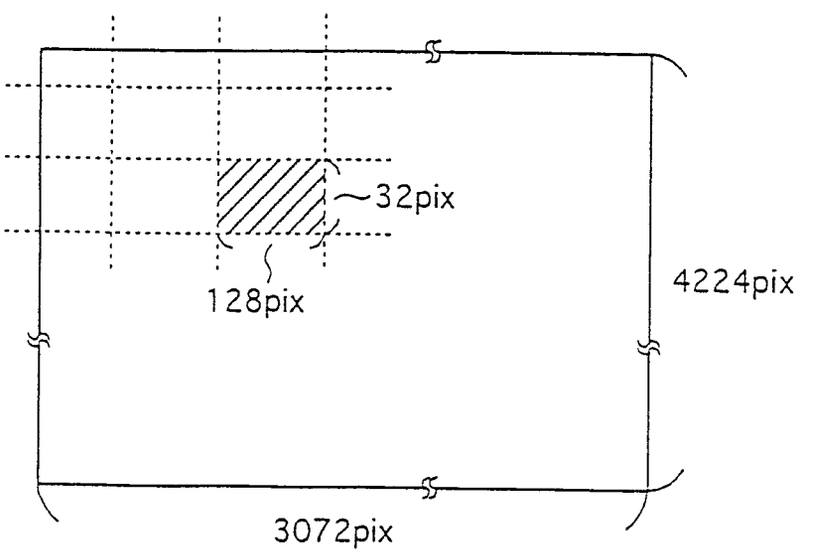

32pix
128pix
4224pix
3072pix

FIG. 4

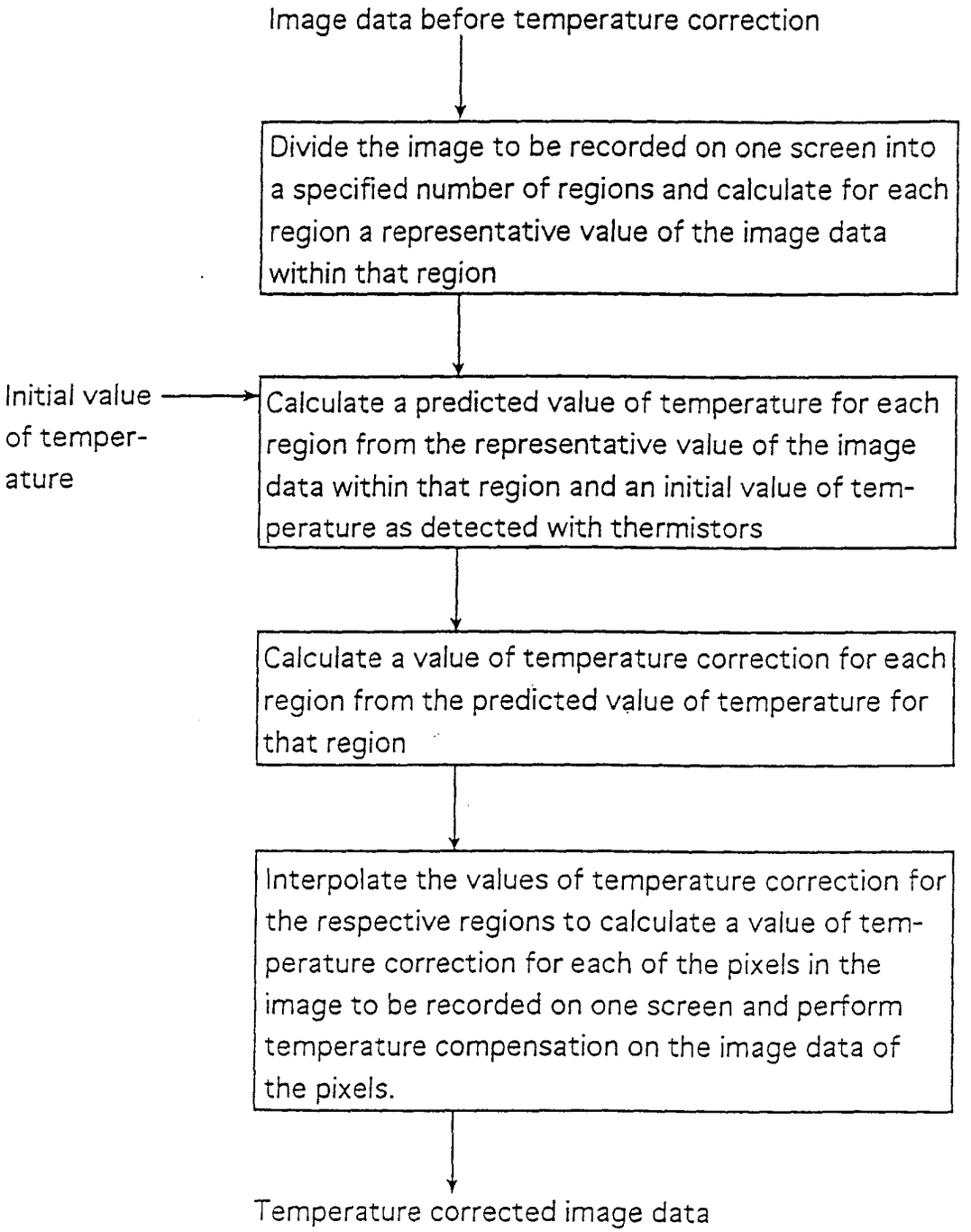


Image data before temperature correction
Divide the image to be recorded on one screen into a specified number of regions and calculate for each region a representative value of the image data within that region
Initial value of temperature
Calculate a predicted value of temperature for each region from the representative value of the image data within that region and an initial value of temperature as detected with thermistors
Calculate a value of temperature correction for each region from the predicted value of temperature for that region
Interpolate the values of temperature correction for the respective regions to calculate a value of temperature correction for each of the pixels in the image to be recorded on one screen and perform temperature compensation on the image data of the pixels.
Temperature corrected image data

FIG.6

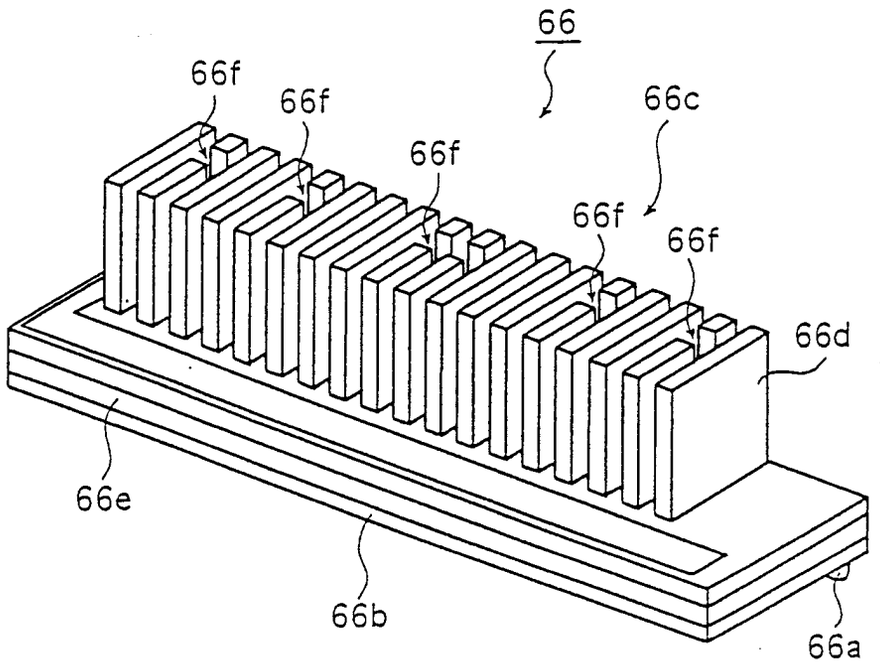

66
66f
66f
66f
66f
66f
66c
66d
66e
66b
66a

FIG.7

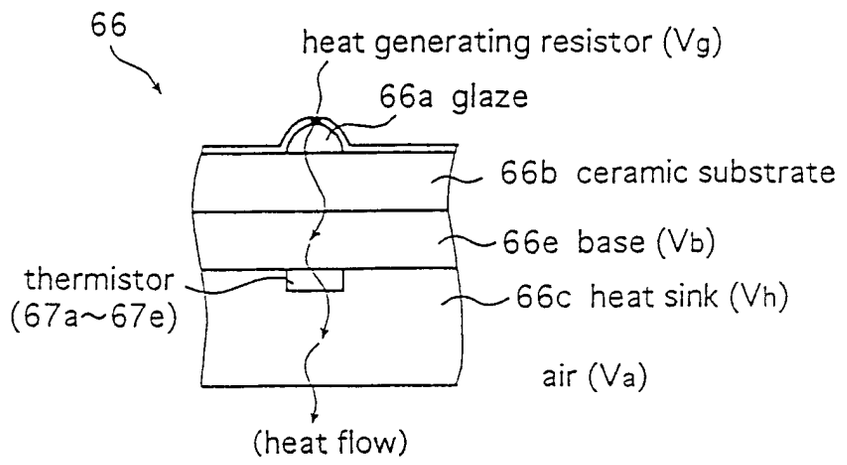

66
heat generating resistor (Vg)
66a glaze
66b ceramic substrate
66e base (Vb)
thermistor
(67a~67e)
66c heat sink (Vh)
air (Va)
(heat flow)

FIG.8

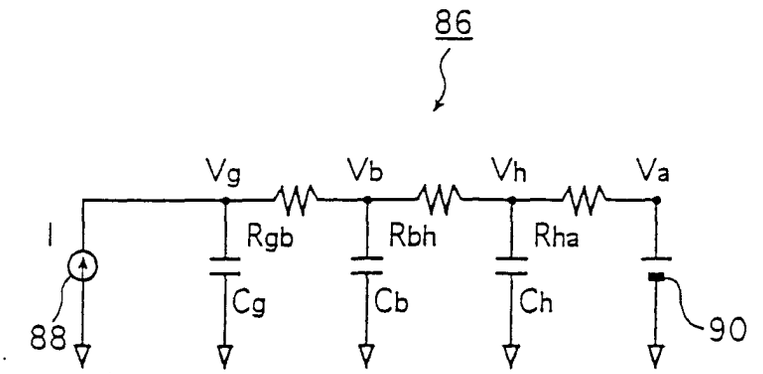

86
Vg
Vb
Vh
Va
I
Rgb
Rbh
Rha
Cg
Cb
Ch
88
90

FIG.9

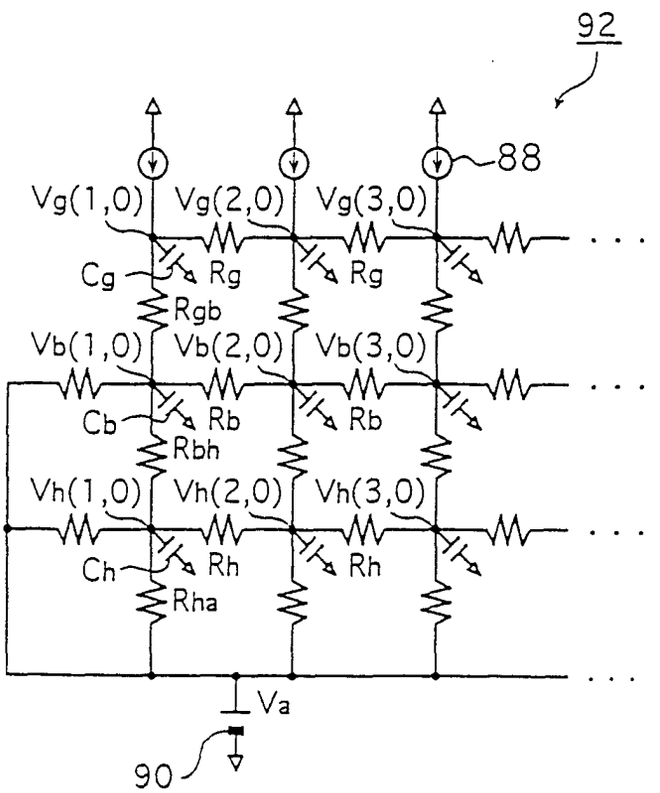
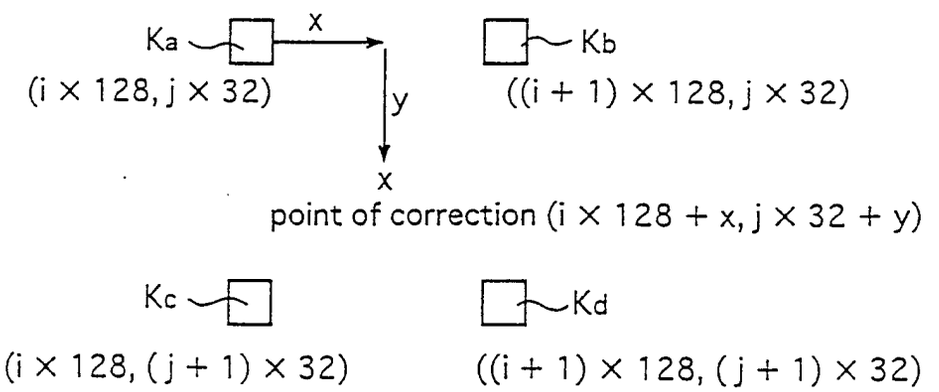

92
88
Vg(1,0)
Vg(2,0)
Vg(3,0)
Cg
Rg
Rgb
Vb(1,0)
Vb(2,0)
Vb(3,0)
Cb
Rb
Rbh
Vh(1,0)
Vh(2,0)
Vh(3,0)
Ch
Rh
Rha
Va
90

FIG.10


Ka
x
Kb
(i × 128, j × 32)
y
((i + 1) × 128, j × 32)
x
point of correction (i × 128 + x, j × 32 + y)
Kc
Kd
(i × 128, (j + 1) × 32)
((i + 1) × 128, (j + 1) × 32)