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(54) A method for sensing temperature changes

Verfahren zur Detektierung von Temperaturänderungen

Procédé pour capter un changement de température

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method and system for measuring temperature changes in an environment, such as the interior of the body.

BACKGROUND OF THE INVENTION

[0002] In many circumstances it is important to measure the temperature inside a material body. Such circumstances may occur during industrial processes or exploration and analysis processes, such as in geophysical probing or in medical diagnostics and treatment of internal parts of the body.

[0003] Conventional thermometry and absolute thermometry are known methods for measuring temperature.

[0004] Conventional thermometry is based upon the temperature coefficient of properties of materials, such as resistance or mechanical expansion.

[0005] Absolute thermometry is a method which directly measures thermal energy of a sensor resistance. This method is based upon the known physical phenomenon of spontaneous thermal noise arising from the Brownian motion of ionized molecules within a resistance.

[0006] Thermal noise, which can be discussed in terms of thermal current, provides a direct measurement of temperature on a thermodynamic scale, thus the Boltzmann constant defines the temperature. The phenomenon of thermal noise is derived, for example, in the book: *CCD arrays cameras and displays* by Holst G.C., p. 128, 2nd edition, SPIE Press, 1998. The formula used to define thermal current is:

$$\langle i_n^2 \rangle = k\,T\,C$$

where *k* is the Boltzmann constant, T is the temperature of a sensor, and C is the capacitance of the sensor. Thus the magnitude of the signals produced by the thermal current is directly proportional to the square root of the temperature of the sensor. Experiments have indicated that the signal doubles with the increase of 7°C (degrees Centigrade), which means that a resolution better than 0.1°C is achieved.

[0007] In image sensors, the thermal current produced in an operating photodetector device, when no optical radiation impinges on the detector, is called "dark current". In CCD cameras dark current is basically charge which accumulates in the CCD pixels due to thermal noise. The effect of dark current is to produce an additive quantity to the electron count in each pixel.

[0008] US 3,937,086 to von Thuna, US 5,354,130 to Seppa et al. and US 5,098,197 to Shepard et al. all describe devices for measuring the absolute temperature of a body material by receiving and analyzing the thermal noise of the body material.

[0009] US 4,246,784 to Bowen describes a method for noninvasive temperature measurement of the interior of a body using the acoustic thermal noise spectrum of the measured body.

[0010] US 6,607,301 to Glukhovsky describes measuring temperature by sensing the dark current noise of an image sensing module of an in vivo device.

[0011] US 6, 148, 152 describes a system for thermal compensation of the optical performance of a lens system in a digital camera by using the dark current from the photosensor to measure the temperature of the lens system. The temperature information is used to correct for aberrations in the lens system caused by changes in temperature and to position the lens for optimum focus.

SUMMARY OF THE INVENTION

[0012] Embodiments of the present invention provide a method and system for sensing temperature changes in an environment, such as inside a body. According to one embodiment temperature changes are measured by calculating the temperature of an image sensor in the environment and deducing the environment's temperature from the image sensor's calculated temperature for one sample and then comparing the environment's temperature in one sample to the environment temperature of a previous sample. The temperature of the image sensor may be calculated by measuring its generated dark current noise.

[0013] The method and system of the present invention have the advantage of utilizing an image sensor, in which thermal noise is easily detectable, for deducing the temperature of a material body. Furthermore, according to embodiments of the invention, a single sensor may be utilized for obtaining visual data and data relating to the temperature of the environment. Thus, diverse information about an environment can be obtained utilizing a single sensing device.

[0014] There is thus provided according to embodiments of the present invention a method for sensing temperature changes in an environment comprising the steps of introducing into an environment an image sensor having an image sensing module, for one sample sensing the dark current noise of the image sensor, calculating the temperature of the image sensor, calculating the temperature of the environment and comparing the temperature of the environment of one sample to that of another, possibly consecutively taken sample. Optionally the calculated environment temperature and/or changes or fluctuations sensed in the environment temperature may by displayed.

[0015] It will be appreciated that the term "environment" in the present invention relates to a space enclosed within walls in which it is desired to measure the temperature of the space and/or of the walls.

[0016] The temperature of the image sensor is indicative of the temperature of it's immediate surroundings

and, relying on known factors such as heat distribution, distance from the image sensor, etc., the temperature of further areas can also be calculated.

[0017] The image sensors utilized in the invention can be digital cameras or video cameras such as vidiocon , CCD cameras or CMOS cameras.

[0018] Embodiments of the present invention further provide a system for sensing the temperature of an environment. According to one embodiment the system comprises an image sensor having an image sensing module in communication with an integrating unit for detecting the dark current of the image sensor image sensing module and optionally for calculating the temperature of the image sensor. The integrating unit may further calculate the temperature of the environment or the temperature of the environment may be calculated, based on data from the integrating unit, by a separate unit that is in communication with the integrating unit. Also included is a change detector for comparing data between different samples.

[0019] The integrating unit may have an amplifying function for amplifying signals received from the image sensor.

[0020] The communication between the image sensor and integrating unit can be optionally controlled according to the illumination conditions, optionally through a switch which enables communication only during periods in which the sensor is not illuminated.

BRIEF DESCRIPTION OF THE FIGURES

[0021] The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the figures in which:

Figure 1 is a block diagram representing an embodiment of the method according to the invention;

Figure 2 is a schematic illustration of an embodiment of the system according to the invention;

Figure 3 is a schematic illustration of a functional block layout of the image sensor according to the invention; and

Figure 4 is a schematic illustration of a medical device comprising the system according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0022] Analytical and diagnostic processes which utilize image sensors to monitor environments could benefit from obtaining information relating to the temperature of the environment, as a local change of temperature can indicate an irregular event.

[0023] For example, US 5,604,531, which is assigned to the common assignees of the present application, describes a swallowable capsule that can pass through the entire digestive tract and operate as an autonomous video endoscope. The swallowable capsule includes a) a camera system, b) an optical system for imaging an area of interest onto the camera system and c) a transmitter which transmits the video output of the camera system. Visual data obtained by the swallowable capsule can indicate, inter alia, the location of pathologies in the gastrointestinal tract. Also a local change of temperature in the gastrointestinal tract can be indicative of a pathology. Thus, the information obtained by visual means can be complemented and focussed by information relating to local temperature in the gastrointestinal tract.

[0024] The method according to embodiments of the present invention enables contemporary visual monitoring and temperature fluctuation sensing.

[0025] According to some embodiments an image sensor, such as in the above mentioned swallowable capsule, may be inserted into an environment, such as the gastrointestinal tract.

[0026] Illumination may be provided intermittently, either by elements connected to the image sensor itself or by external sources. When illumination is provided only visual data is obtained and displayed. A process for obtaining and displaying visual data is described, for example, in the above mentioned US 5,604,531.

[0027] In an intermittent dark period an integrating unit may be activated to obtain dark current data from the image sensor, though it is not imperative to shut off illumination in order to obtain data relating to dark current noise.

[0028] The integrating unit may be a processor capable of amplifying the obtained data, if necessary, and calculating the image sensor temperature using the known equations derived for thermal noise. It will be appreciated that these equations are an approximation of a complex phenomenon and that calibration should be employed in order to deduce the actual calculations that will be applied. According to some embodiments, for example, as schematically illustrated in Fig. 1, the image sensor temperature and/or the environment temperature need not be calculated. Rather, a difference in dark current measurements (which are typically indicative of temperature changes) may be determined. According to an embodiment of the invention a dark current data sample may be obtained (501), for example, according to a predetermined schedule or by any other appropriate method (for example, as discussed below). Each dark current data sample may be compared, for example by using a change detector, to a previous dark current sample (502). A difference between two samples can indicate a temperature change. According to some embodiments a sample may be compared to an average or other manipulation of several previous samples. Thus, the actual temperature of the image sensor and/or of the body lumen environment need not be calculated.

[0029] According to some embodiments a change in dark current data may be displayed (503). According to other embodiments only a change which is above a predetermined threshold may displayed. According to yet further embodiments a change which is over a predeter-

mined threshold may be used as a trigger for changing the activity of other elements of the system. For example, a swallowable capsule, such as described in the above mentioned US 5,604,531, may include an integrating unit which may be capable of detecting a change in dark current data, as described above. The integrating unit may be in communication with other elements of the capsule, such as the power supply or the illumination system or transmitter (29) of the capsule, and an ON or OFF signal may be generated, typically by the integrating unit, to any of these elements in accordance with detected dark current changes. Thus, the operational mode or settings of an in vivo sensor can be altered or activated in response to in vivo temperature. According to certain embodiments, a swallowable capsule may include a controller for activating or altering the operational mode or settings of the capsule in response to signals from the integrating unit. Such an embodiment may be useful in some case for example, for saving energy. According to one embodiment after a capsule is swallowed the patient is made to ingest a volume of cold or hot water at regular intervals. According to one embodiment the patient ingests cold or hot water over a period of a few hours, for example, a period in which the capsule has most probably left the stomach. While the capsule is in the stomach an ingested volume of cold or hot water may cause a change of temperature in the stomach environment. Once in the small intestine, the effect of a cold or hot drink is no longer felt. According to one embodiment of the invention a change of temperature may be checked at predetermined intervals. While a temperature change (typically above a predetermined threshold) is detected the capsule may be kept inactive. If a temperature change is not sensed the capsule may be triggered to activate the capsule. Thus, the capsule begins collecting data only when it is close to the large intestine thereby saving energy and allowing effective and complete action of the capsule in the large intestine.

[0030] Calculations of the environment temperature are based on the existence of thermal equilibrium between the image sensor and environment. These calculations take into account energy dissipation from the image sensor. Local temperature or the average temperature within the environment may be calculated, depending on specific requirements. The calculated temperature or temperature differences may then be displayed.

[0031] It will be appreciated that the various calculations and/or detections are carried out by software or software means executable on computing means such as a computer or similar data processors, microprocessors, embedded processors, microcomputers, microcontrollers etc.

[0032] The integrating unit may comprise separate processors, which need not all be physically connected. Some of the functions carried out by integrating unit, such as calculating the image sensor temperature and calculating the environment temperature, can be carried out in processors that are external to the environment and that are fed with data from the integrating unit by communication such as by IR or radio. Indeed, if an operator is to note the temperature of the environment, at least the function of displaying the calculated temperature must be performed externally to the environment.

[0033] Integrating unit may be in communication with other units to further process and use the data obtained by it. For example, a swallowable capsule, such as described in US 5,604,531, may comprise a sample chamber for collecting samples from the environment of the digestive tract. The process of collecting a sample can be controlled by integrating unit, such that samples are collected only in locations along the digestive tract in which a predetermined temperature is prevalent or in which a certain temperature change has been detected.

[0034] Reference is now made to Fig. 2, which is a schematic illustration of the system according to an embodiment of the invention. The system comprises an image sensor 20 having an image sensing module which includes a pixel array (as demonstrated in Fig. 3) in communication with an integrating unit 22. Communication is enabled by temperature sense switch 24 which is controlled by illumination indicator 26, such that communication is enabled only during dark periods.

[0035] When communication between the image sensor 20 and integrating unit 22 is established, integrating unit 22 receives dark current data from image sensor 20.

[0036] In an alternate embodiment a switch and/or illumination indicator need not be used. According to some embodiments dark current data may be received from the image sensor 20 continuously or according to a predetermined time schedule. For example, a system in which 25 ms light flashes are followed by 475 ms dark periods, may be programmed to sample dark current data once every dark period. In an alternate embodiment a system may include a dark frame once every so often, e.g., one frame in every 256 frames is not illuminated. According to some embodiments a system may be programmed to sample dark current data during a dark frame.

[0037] As will be discussed below, it is possible to calculate the image sensor's 20 temperature based on dark current data obtained from a single pixel of the image sensor pixel array, though data obtained from a higher number of pixels will achieve more accurate results. It is therefore possible to keep a portion of the image sensor's 20 pixels of the pixel array, constantly unexposed to illumination, and obtain dark current data from the unexposed pixels, without having to shut off the illumination.

[0038] Thus, dark current data can be obtained also during constant illumination by either covering a portion of the pixels of the pixel array or by having a portion of the pixel array pixels outside of the image field, e.g. the pixels in the periphery of the pixel array.

[0039] The integrating unit 22 is a processor capable of amplifying the dark current signal and calculating the image sensor temperature from the dark current signal. It is further capable of calculating the environment tem-

perature from the image sensor temperature and is capable of displaying the calculated environment temperature 21. Integrating unit 22 may control different temperature sensitive units 28, such as the sample chamber described above, in correspondence with predetermined temperatures.

[0040] The system may also include a change detector 222 (typically in communication with the integrating unit 22) and a controller 225 for activating or altering the operational mode or settings of the capsule in response to signals from the integrating unit. The system includes a transmitter 29.

[0041] Reference is now made to Fig. 3 which is a schematic illustration of a functional block layout of the image sensor according to the invention. The image sensor comprises a single chip 40 having an image sensing module 42 and a control circuits area 44. The image sensing module 42 includes a pixel array 48 for capturing an image. The control circuits area 44 includes the timing and logic circuitry 47 and A/D circuitry 46.

[0042] Signals can be received from all the pixels of the pixel array 48. Dark current is received from pixels that are not illuminated or from pixels during a dark period whereas current signals received from an illuminated pixel are the summation of the dark current and light current of the pixel. The accumulation of signals from all the pixels is converted to data which is communicated through a transmitter to the integrating unit for decoding and for displaying a visual representation and /or the temperature derived from the data.

[0043] The system of the invention will be further described and demonstrated by Fig. 4 which is a schematic illustration of a medical device comprising a system according to the invention.

[0044] The medical device illustrated in Fig 4 is a swallowable capsule, generally referenced 30, such as that described in the above mentioned US 5,604,531. Swallowable capsule 30 comprises a CMOS camera 32, that is in communication with integrating unit 34. The swallowable capsule 30 further comprises illuminating elements 36 that are in communication with illumination indicator 33. The swallowable capsule 30 further comprises a transmitter 29. The gastrointestinal tract walls 31 are illuminated by illuminating elements 36, in intermittent pulses, capturing consecutive images of the gastrointestinal tract walls 31 by camera 32, enabling an operator to view the gastrointestinal tract walls. Communication between camera 32 and integrating unit 34 is enabled in between illumination pulses when illumination indicator 33, sensing the lack of illumination, activates the temperature sense switch (not shown) to an ON position.

[0045] Alternatively, the illumination indicator 33 may be activated by the operator to simultaneously turn off the illumination elements 36 and switch the temperature sense switch to an ON position.

[0046] Once communication is established between camera 32 and integrating unit 34 dark current signals generated from camera 32 are received and processed, as described above, by integrating unit 34. The calculated gastrointestinal temperature is displayed on a display unit external to the gastrointestinal tract.

[0047] Swallowable capsule 30 further comprises a sample chamber 35 for collecting samples from the gastrointestinal tract environment. The collected sample may be cells from the gastrointestinal tract walls or a liquid sample from the gastrointestinal tract environment. The mechanism for collecting samples, which can be any suitable mechanism known in the art, is controlled by integrating unit 34, such that it is activated in accordance with the gastrointestinal tract environment calculated temperature. Alternatively, the mechanism can be controlled by the operator based on the displayed temperature.

[0048] It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow:

Claims

1. A method for sensing a temperature change in an environment comprising the steps of:

   introducing into the environment an image sensor (20) having an image sensing module (42)
   sensing the dark current noise of the image sensing module, thereby obtaining a dark current data sample;
   comparing a dark current data sample to a previous sample; and
   calculating a change sensed in the environment temperature, based on said comparison.

2. The method according to claim 1 comprising the step of triggering a change in activity of elements of the image sensor.

3. The method according to claim 2 wherein triggering a change is in accordance with a change detected in the comparing step.

4. A system for sensing a temperature change in an environment comprising

   an image sensor (20),
   an integrating unit (22), and
   a change detector (222),
   said image sensor being adapted to be introduced into an environment; and
   said integrating unit receiving dark current noise samples from the image sensor, and said change detector detecting changes between dark current noise samples, thereby detecting a change in the environment temperature.

5. The system according to claim 4 wherein the image sensor comprises one or more elements selected from the group consisting of: an image sensing module, an illumination system, a transmitter and a power supply.

6. The system according to claim 5 wherein the integrating unit is in communication with one or more elements of the image sensor.

Patentansprüche

1. Verfahren zum Detektieren einer Temperaturänderung in einer Umgebung umfassend die Schritte:

einführen eines Bildsensors (20) aufweisend ein Bilderfassungsmodul (42) in die Umgebung
detektieren des Dunkelstromrauschens des Bilderfassungsmoduls, um dadurch eine Dunkelstromdatenprobe zu erhalten;
vergleichen einer Dunkelstromdatenprobe mit einer vorhergehenden Probe; und
berechnen einer Veränderung detektiert in der Umgebungstemperatur, basierend auf dem genannten Vergleich.

2. Verfahren nach Anspruch 1, umfassend den Schritt des Auslösens einer Veränderung bezüglich der Aktivität von Elementen des Bildsensors.

3. Verfahren gemäss Anspruch 2, wobei das Auslösen einer Veränderung im Zusammenhang mit einer Veränderung steht, die im Schritt des Vergleichs ermittelt wurde.

4. Ein System zum Detektieren einer Temperaturänderung in einer Umgebung umfassend

einen Bildsensor (20),
eine Integrationseinheit (22), und
einen Veränderungsdetektor (222),

wobei der genannte Bildsensor ausgestaltet ist zum Einführen in die Umgebung; und
wobei die genannte Integrationseinheit Dunkelstromrauschproben vom Bildsensor erhält, und wobei der genannte Veränderungsdetektor Veränderungen zwischen den Dunkelstromrauschproben detektiert, um derart eine Veränderung in der Umgebungstemperatur zu detektieren.

5. System gemäss Anspruch 4, wobei der Bildsensor eine oder mehrere Elemente umfasst ausgewählt aus der Gruppe besteht aus: ein Bilderfassungsmodul, ein Beleuchtungssystem, ein Übertragungsgerät und eine Stromversorgung.

6. System gemäss Anspruch 5, wobei die Integrationseinheit in Verbindung steht mit einem oder mehreren Elementen des Bildsensors.

Revendications

1. Procédé de détection d'un changement de température dans un environnement, comprenant les étapes consistant à :

introduire, dans l'environnement, un capteur d'image (20) possédant un module de captage ou d'exploration d'image (42) ;
détecter ou capter le bruit de courant d'obscurité du module de captation d'image, obtenant ainsi un échantillon de données de courant d'obscurité ;
comparer un échantillon de données de courant d'obscurité avec un échantillon précédent ; et
calculer un changement détecté dans la température de l'environnement, à partir de ladite comparaison.

2. Procédé selon la revendication 1, comprenant l'étape consistant à déclencher un changement dans l'activité des éléments du capteur d'image.

3. Procédé selon la revendication 2, dans lequel le déclenchement d'un changement s'accomplit en fonction d'un changement détecté au cours de l'étape de comparaison.

4. Système pour détecter un changement de température dans un environnement, comprenant :

un capteur d'image (20) ;
un intégrateur (22) ;
un détecteur de changement (222) ;
ledit capteur d'image étant apte à être introduit dans un environnement ; et
ledit intégrateur recevant des échantillons de données de courant d'obscurité de la part du capteur d'image, et ledit détecteur de changement détectant des changements entre échantillons de données de courant d'obscurité, détectant ainsi un changement dans la température de l'environnement.

5. Système selon la revendication 4, dans lequel le capteur d'image comprend un ou plusieurs éléments, sélectionnés dans le groupe comprenant : un module de captation ou d'exploration d'image, un système d'illumination, un émetteur ou transmetteur et une alimentation électrique.

6. Système selon la revendication 5, dans lequel l'intégrateur est en communication avec un ou plusieurs

éléments du capteur d'image.

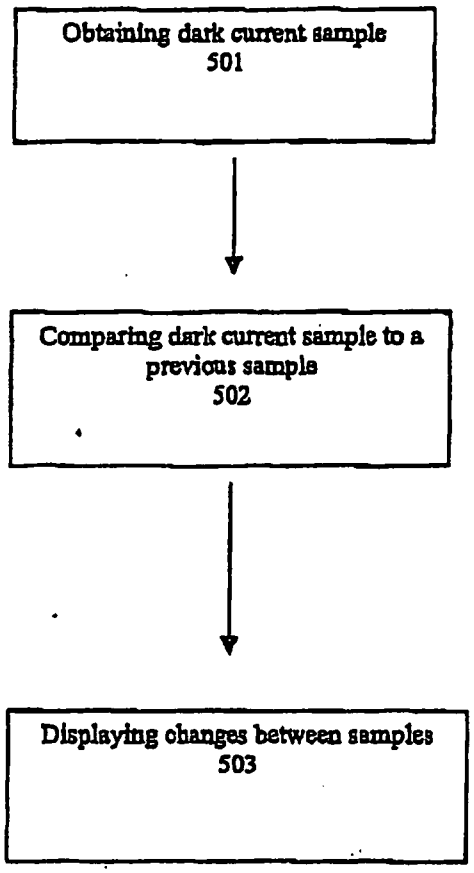
Obtaining dark current sample
501
Comparing dark current sample to a previous sample
502
Displaying changes between samples
503

FIG. 1

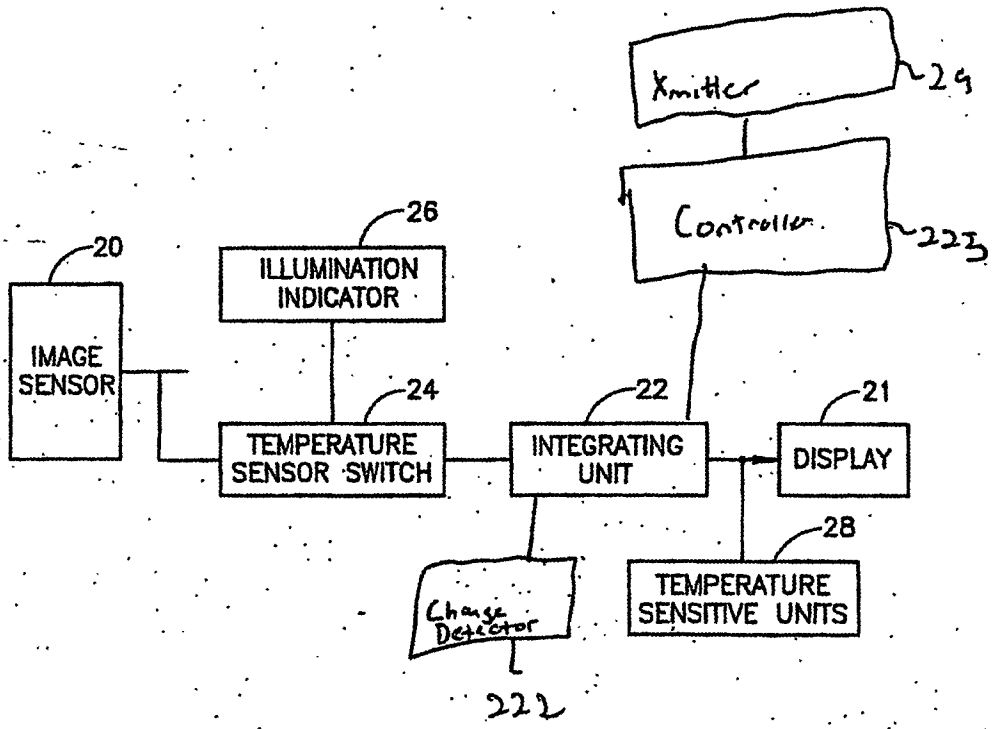
Xmitter
29
Controller
223
26
ILLUMINATION INDICATOR
20
IMAGE SENSOR
24
TEMPERATURE SENSOR SWITCH
22
INTEGRATING UNIT
21
DISPLAY
28
TEMPERATURE SENSITIVE UNITS
Charge Detector
222

FIG.2

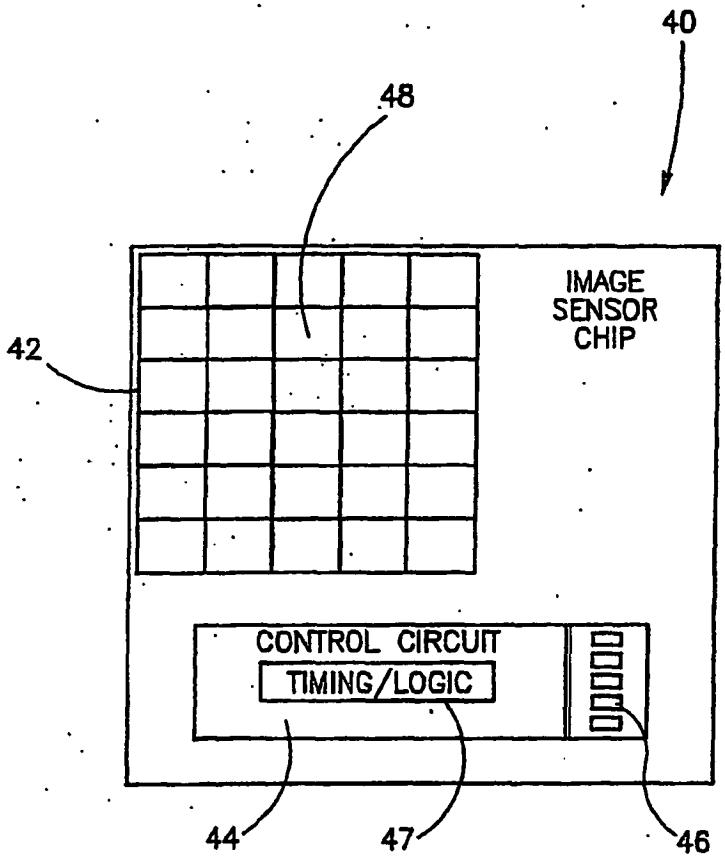
40
48
42
IMAGE
SENSOR
CHIP
CONTROL CIRCUIT
TIMING/LOGIC
44
47
46

FIG.3

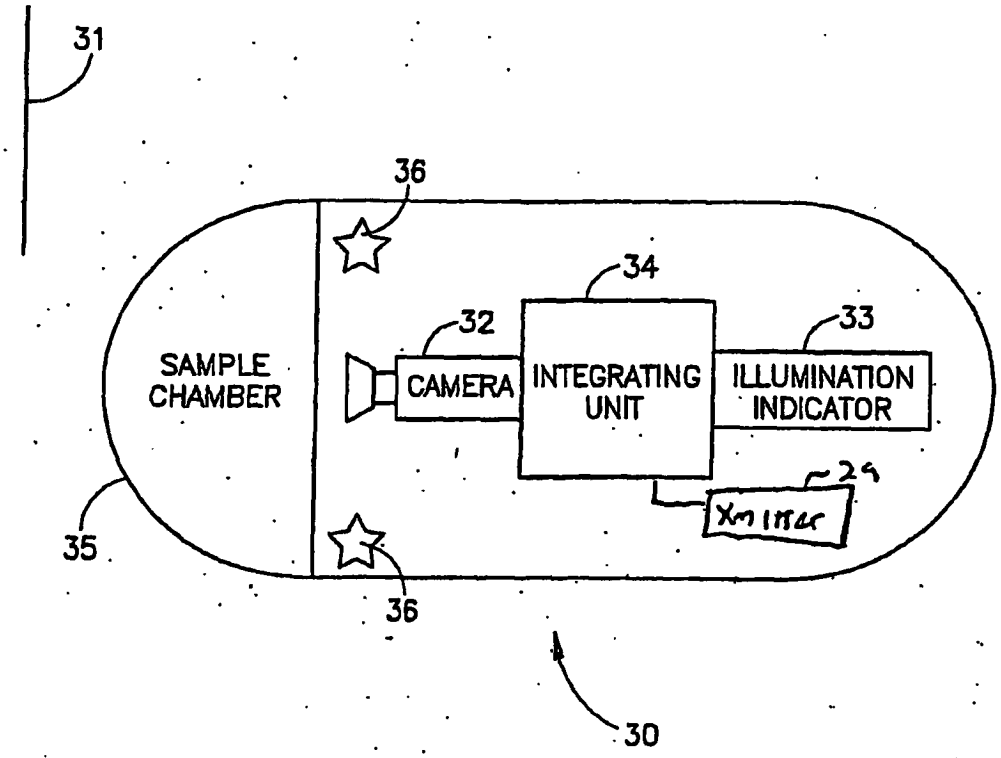
31
36
34
32
33
SAMPLE CHAMBER
CAMERA
INTEGRATING UNIT
ILLUMINATION INDICATOR
29
Xmitter
35
36
30

FIG.4

REFERENCES CITED IN THE DESCRIPTION

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- US 6607301 B **[0010]**
- US 6148152 A **[0011]**
- US 5604531 A **[0023] [0026] [0029] [0033] [0044]**

专利名称(译)	一种用于感测温度变化的方法		
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申请(专利权)人(译)	基文影像有限公司.		
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摘要(译)

本发明提供了一种用于感测环境中的温度变化的方法和系统。通过计算环境中图像传感器的温度并从图像传感器的一个样品的计算温度推导环境温度，然后将一个样品中的环境温度与先前样品的环境温度进行比较来测量温度变化。该方法和系统可以结合到医疗设备中。