JUDGE SCHEINDLIN

UNITED DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

06 CV 13422

---X EASTMAN KODAK COMPANY, Plaintiff, -v.- FILMLIGHT U.K.; FILMLIGHT DIGITAL FILM TECHNOLOGY, INC., Defendants. ---X	**Case No.** **COMPLAINT FOR PATENT INFRINGEMENT OF U.S. PATENT NOS. 6,924,911 AND 6,380,539** **DEMAND FOR JURY TRIAL**

Plaintiff EASTMAN KODAK COMPANY ("KODAK") hereby complains as follows against Defendants FILMLIGHT U.K. and FILMLIGHT DIGITAL FILM TECHNOLOGY, INC.

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CASHIERS

PARTIES

1. KODAK is a corporation organized and existing under the laws of the State of New Jersey, with its principal place of business in Rochester, New York. KODAK is a leading supplier of digital technology to the worldwide motion picture industry.

2. On information and belief, Defendant FILMLIGHT U.K. is a corporation organized and existing under the laws of the United Kingdom, with its principal place of business in London, England.

3. On information and belief, Defendant FILMLIGHT DIGITAL FILM TECHNOLOGY INC. is a corporation organized and existing under the laws of California, with its principal place of business in Universal City, California. FILMLIGHT U.K. and FILMLIGHT DIGITAL FILM TECHNOLOGY, INC. are hereinafter collectively referred to as "Defendants."

JURISDICTION AND VENUE

4. This is an action for patent infringement arising under the Patent Laws of the United States, Title 35, United States Code. This Court has subject matter jurisdiction under 28 U.S.C. §§ 1331 and 1338(a).

5. This Court has personal jurisdiction over Defendants because they regularly and continuously transact business throughout the United States and within this Judicial District by selling and offering for sale, *inter alia,* digital film mastering scanners.

6. Venue is proper before this Court pursuant to 28 U.S. C. § 1391 and § 1400(b).

CLAIM FOR PATENT INFRINGEMENT

7. KODAK is the owner by assignment of the entire right, title and interest in and to United States Patent No. 6,924,911 ("the '911 Patent") entitled "Method and System for Multi-Sensor Signal Detection" (attached hereto as Exhibit A), which was duly and legally issued by the United States Patent and Trademark Office on August 2, 2005.

8. KODAK is the owner by assignment of the entire right, title and interest in and to United States Patent No. 6,380,539 ("the '539 Patent") entitled "Four Color Trilinear CCD Scanning" (attached hereto as Exhibit B), which was duly and legally issued by the United States Patent and Trademark Office on April 30, 2002.

9. Upon information and belief, Defendants have been and still are infringing one or more of the claims of the '911 Patent, and the '539 Patent by making, using, selling and/or offering for sale, *inter alia*, digital film mastering scanners, including but not limited to the Northlight 2 film scanner and retrofitted Northlight film scanners (collectively referred to herein as the "FilmLight Products"), and/or by contributorily infringing and/or actively inducing others to infringe the '911 Patent, and the '539 Patent in this district and elsewhere in the United States.

10. Upon information and belief, Defendant's acts of direct infringement, contributory infringement and inducement have caused others to directly infringe the '911 Patent, and the '539 Patent.

11. Unless enjoined by this Court, Defendants will continue their acts of contributory infringement and/or inducement to the substantial and irreparable damage of KODAK.

COUNT I - (Infringement of the '911 Patent)

12. KODAK incorporates by reference each and every allegation contained in paragraphs 1 through 11 inclusive of this Complaint as though fully set forth herein.

13. Upon information and belief, Defendants are and has been directly infringing the '911 Patent by making, using, selling, and/or offering for sale the FilmLight Products which embody the claimed subject matter of the '911 Patent.

14. Upon information and belief, Defendants are and have been infringing the '911 Patent in violation of 35 U.S.C. §271(c) by selling, and/or offering to sell the FilmLight Products for use as digital film mastering scanners, which constitute a material part of the claimed subject matter of the '911 Patent, knowing the same to be made for infringing uses and not a staple article or commodity of commerce suitable for substantial non-infringing use. Defendants' conduct described in this paragraph, has contributed to the direct infringement of the '911 Patent by others.

15. Upon information and belief, Defendants have infringed and are presently infringing the '911 Patent in violation of 35 U.S.C. §271(b) by actively inducing others to infringe the '911 Patent and will continue to do so unless enjoined by this Court, by engaging in conduct that includes, but is not limited to, marketing, promoting, offering for sale, and manufacturing the FilmLight Products. As a result of Defendants' acts of inducement, others have directly infringed the '911 Patent.

16. Upon information and belief, Defendants' acts of infringement have been and continue to be committed with knowledge of KODAK's rights in the '911 Patent and in willful and wanton disregard of KODAK's rights, rendering this an exceptional case under 35 U.S.C. § 285.

17. Unless enjoined by the court, Defendants will continue their acts of infringement to the substantial and irreparable damage of KODAK.

COUNT II - (Infringement of the '539 Patent)

18. KODAK incorporates by reference each and every allegation contained in paragraphs 1 through 11 inclusive of this Complaint as though fully set forth herein.

19. Upon information and belief, Defendants are and has been directly infringing the '539 Patent by making, using, selling and/or offering for sale the FilmLight Products which embody the claimed subject matter of the '539 Patent.

20. Upon information and belief, Defendants are and have been infringing the '539 Patent in violation of 35 U.S.C §271 (c) by selling, and/or offering to sell the FilmLight Products for use as

digital film mastering scanners, which constitute a material part of the claimed subject matter of the '539 Patent, knowing the same to be made for infringing uses and not a commodity of commerce suitable for substantial non-infringing use. Defendants' conduct described in this paragraph, has contributed to the direct infringement of the '539 Patent by others.

21. Upon information and belief, Defendants have infringed and are presently infringing the '539 Patent in violation of U.S.C. §271(b) by actively inducing others to infringe the '539 Patent, and will continue to do so unless enjoined by this Court, by engaging in conduct that includes, but is not limited to, marketing, promoting, offering for sale, and manufacturing the FilmLight Products. As a result of Defendant's acts of inducement, others have directly infringed the '539 Patent.

22. Upon information and belief, Defendant's acts of infringement have been and continue to be committed with knowledge of KODAK's rights in the '539 Patent and in willful and wanton disregard of KODAK's rights, rendering this an exceptional case under 35 U.S.C. § 285.

23. Unless enjoined by the court, Defendants will continue their acts of infringement to the substantial and irreparable damage of KODAK.

PRAYER FOR RELIEF

WHEREFORE, Plaintiff demands judgment against Defendants and in favor of Plaintiff:

1. For an order preliminarily and permanently enjoining and restraining Defendants, their officers, directors, agents, servants, employees, attorneys, licensees and assignees, and all others acting in privity or in concert with them, from further infringement of the '539 Patent, and the '911 Patent;

2. Compensatory damages attributable to Defendant's infringement of the '539 Patent, and the '911 Patent;

3. Trebling Plaintiff's damages;

4. For costs of suit and attorneys fees;

5. For pre-judgment interest; and

6. Granting such other and further relief as the Court may deem just and proper.

DEMAND FOR JURY TRIAL

Plaintiff EASTMAN KODAK COMPANY hereby demands a trial by jury on all issues triable of right by a jury that are raised for determination by this Complaint or that may be raised by any counterclaim to be filed herein.

DATED: November 21, 2006

Respectfully submitted,

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EASTMAN KODAK COMPANY

EXHIBIT A

US006924911B1

(12) United States Patent
Ford et al.

(10) **Patent No.: US 6,924,911 B1**
(45) **Date of Patent: Aug. 2, 2005**

(54) **METHOD AND SYSTEM FOR MULTI-SENSOR SIGNAL DETECTION**

(75) Inventors: **Gordon D. Ford**, Round Rock, TX (US); **Thomas A. Dundon**, Austin, TX (US); **Albert D. Edgar**, Austin, TX (US); **Martin Potucek**, Austin, TX (US); **Raymond S. Lee**, Austin, TX (US)

(73) Assignee: **Eastman Kodak Company**, Rochester, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 838 days.

(21) Appl. No.: **09/686,336**

(22) Filed: **Oct. 11, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/159,073, filed on Oct. 12, 1999.

(51) **Int. Cl.**^{7} **H04N 1/04**

(52) **U.S. Cl.** **358/506**; 358/505; 358/504; 358/475; 358/509

(58) **Field of Search** 358/506, 505, 358/504, 487, 475, 509, 496, 497

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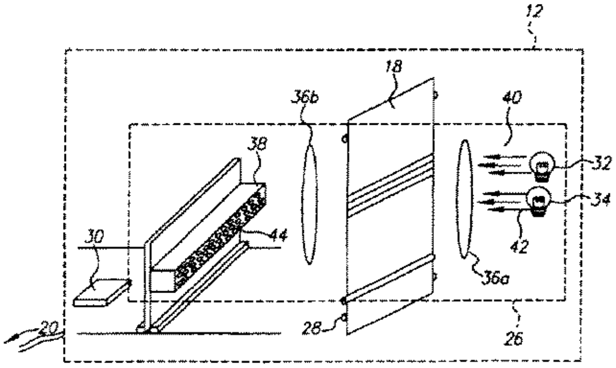
Primary Examiner—Kimberly Williams
Assistant Examiner—Negussie Worku
(74) *Attorney, Agent, or Firm*—Raymond M. Galasso

(57) **ABSTRACT**

A method and apparatus for defect detection through color-filter channels is provided. The present invention includes an electronic scanner or similar device having a multilinear imager, a computer, and software that implements all the color channels of the multilinear imager to collect IR information in order to detect defects on a physical medium. The present invention implements methods to increase IR gathering speed and/or increase the clarity of captured images on multilinear-imager devices. These improvements are accomplished by capturing infrared (IR) light through each color-filter channel such that image defects such as dust and scratches are removed. In one embodiment of the present invention, IR information is collected from each color channel at different scan positions in either a one-pass or a two-pass scanning system. In another embodiment of the present invention, each RGB color channel is used to collect both image and detect information at every scan line, again, either a one-pass or a two-pass scanning system.

21 Claims, 8 Drawing Sheets



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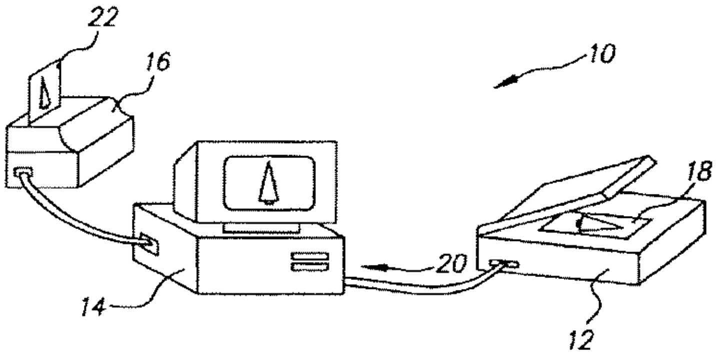

FIG. 1

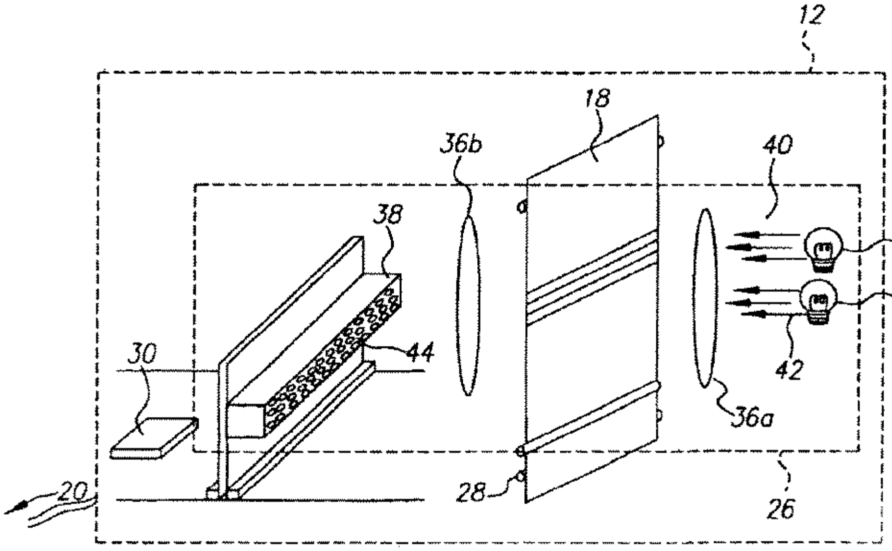

FIG. 2a

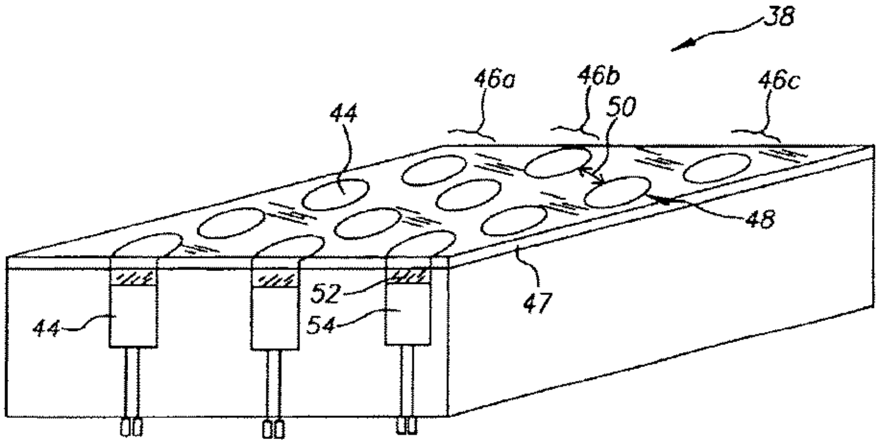

FIG. 2b

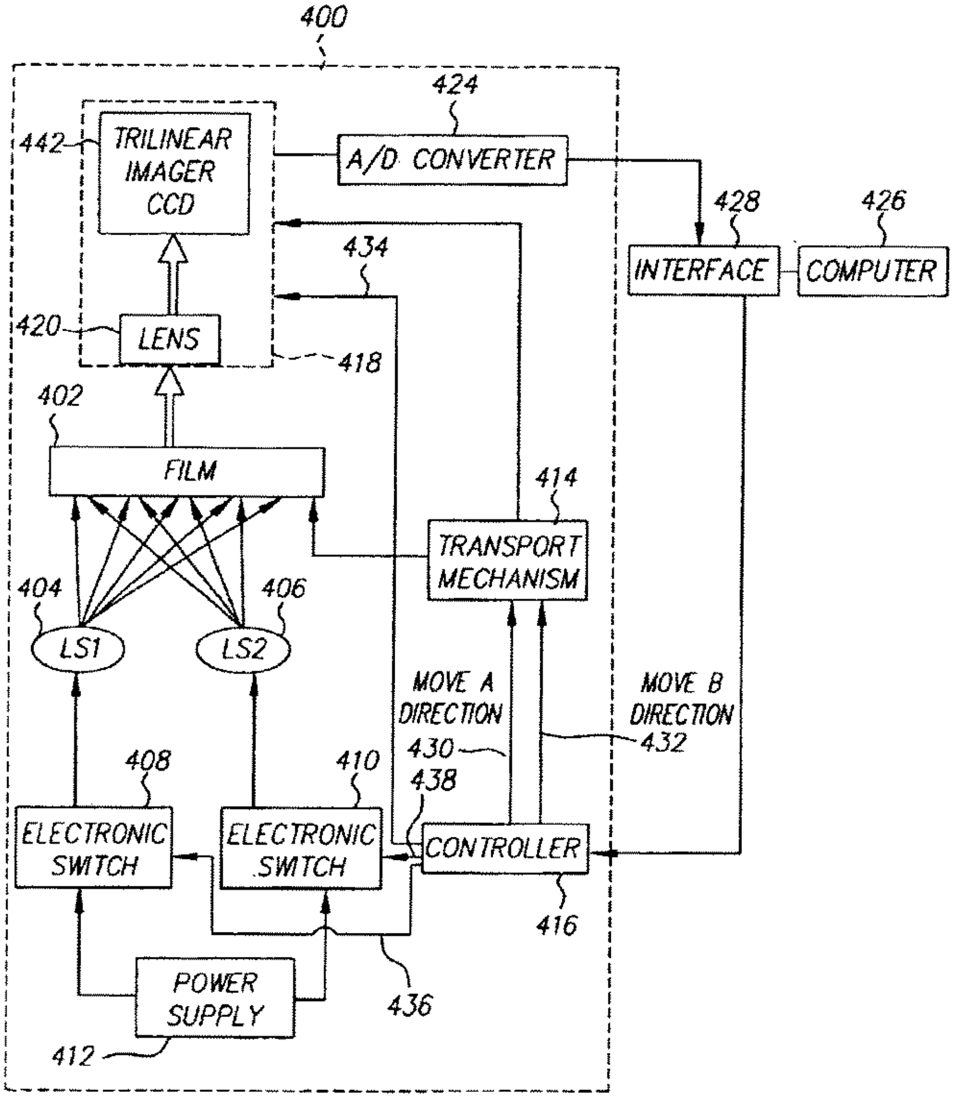
400
424
442
TRILINEAR IMAGER CCD
A/D CONVERTER
428
426
INTERFACE
COMPUTER
434
420
LENS
418
402
FILM
414
TRANSPORT MECHANISM
404
406
LS1
LS2
MOVE A DIRECTION
430
438
MOVE B DIRECTION
432
408
410
ELECTRONIC SWITCH
ELECTRONIC SWITCH
CONTROLLER
416
POWER SUPPLY
436
412

FIG. 3

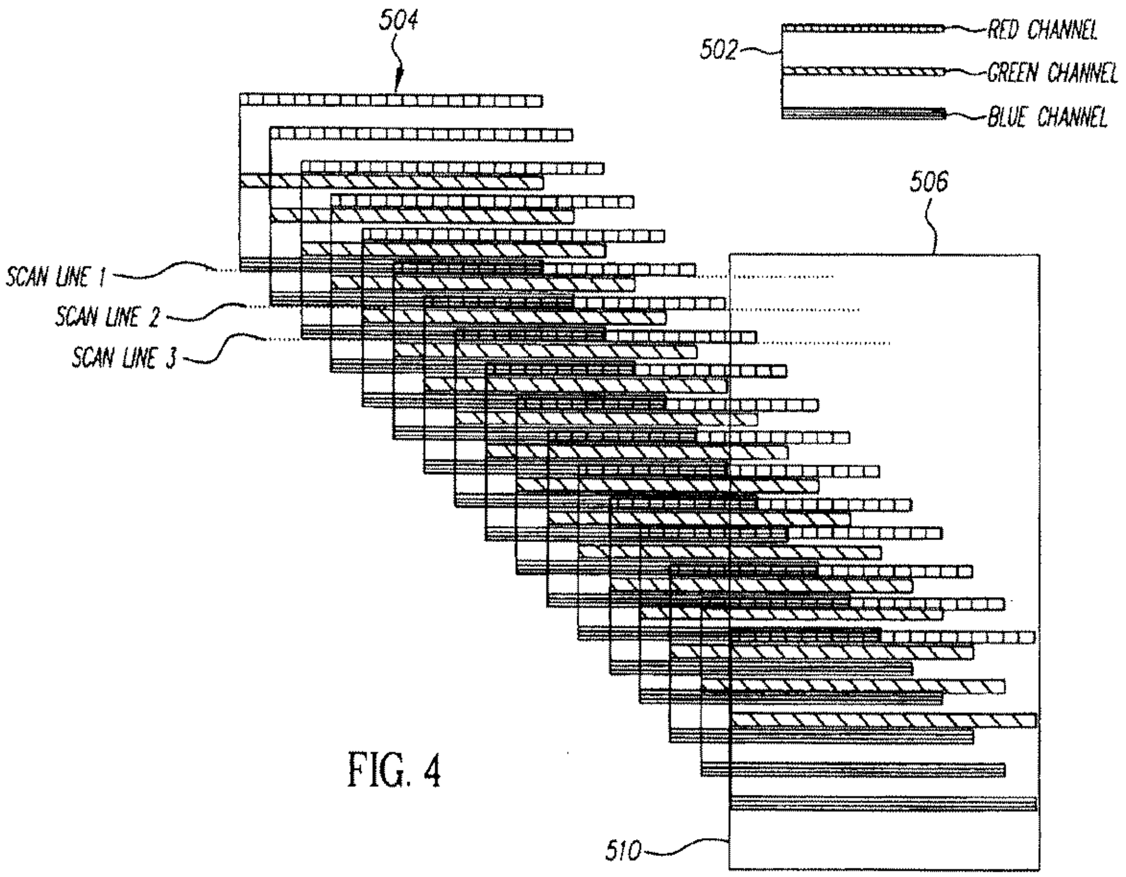
504
502
RED CHANNEL
GREEN CHANNEL
BLUE CHANNEL
506
SCAN LINE 1
SCAN LINE 2
SCAN LINE 3
510

FIG. 4

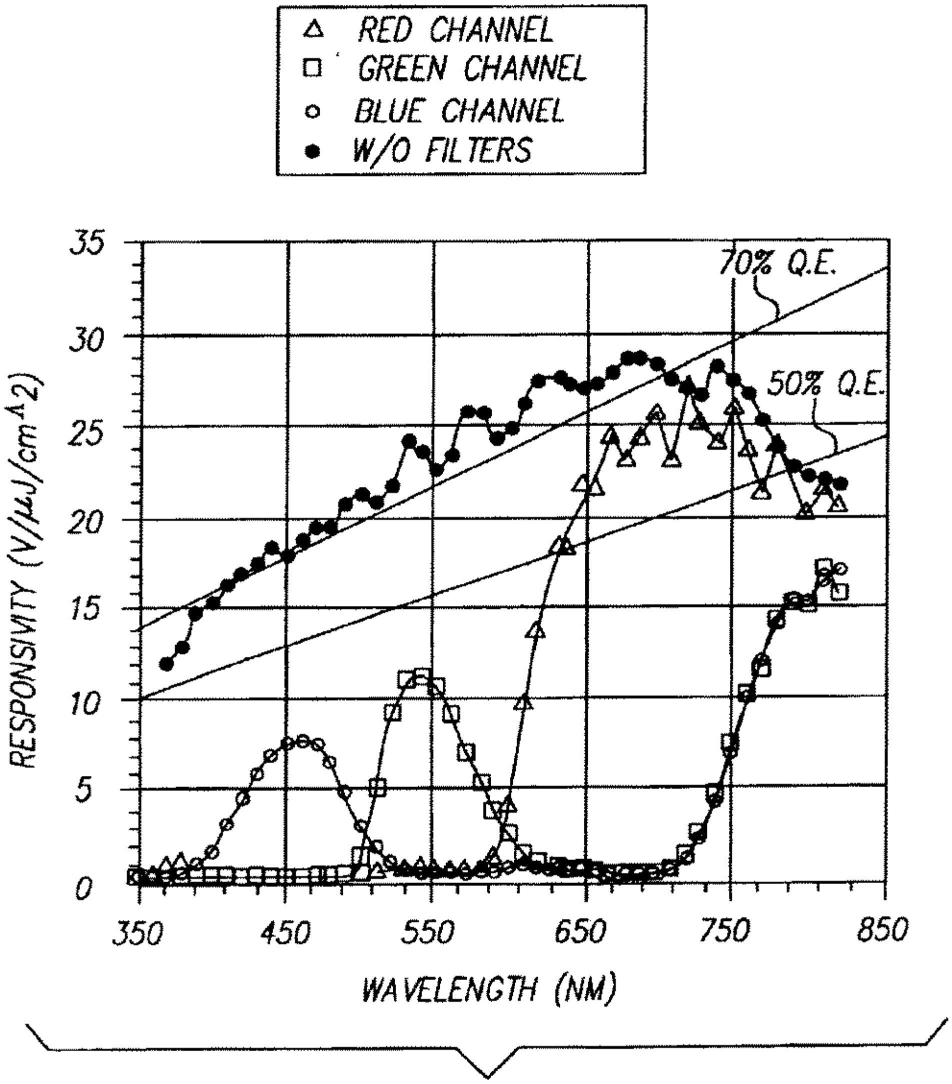
△ RED CHANNEL
□ GREEN CHANNEL
○ BLUE CHANNEL
● W/O FILTERS
70% Q.E.
50% Q.E.
RESPONSIVITY (V/μJ/cm^2)
0
5
10
15
20
25
30
35
350
450
550
650
750
850
WAVELENGTH (NM)

FIG. 5

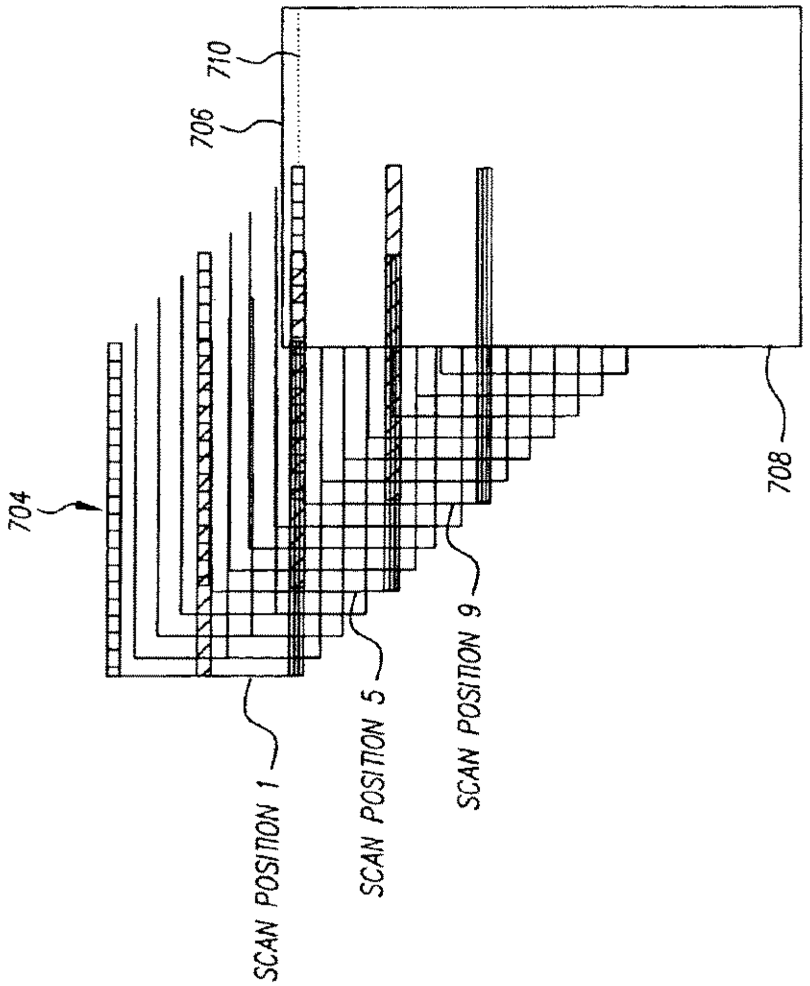
710
706
704
708
SCAN POSITION 1
SCAN POSITION 5
SCAN POSITION 9

FIG. 6

SCAN LINE	1	2	3	4	5	6	7	8	9	10
SCAN POSITION THAT RECORDS IR THROUGH BLUE CHANNEL	①	2	3	④	5	6	⑦	8	9	⑩
SCAN POSITION THAT RECORDS IR THROUGH GREEN CHANNEL	5	6	⑦	8	9	⑩	11	12	⑬	14
SCAN POSITION THAT RECORDS IR THROUGH RED CHANNEL	9	⑩	11	12	⑬	14	15	⑯	17	18

FIG. 7

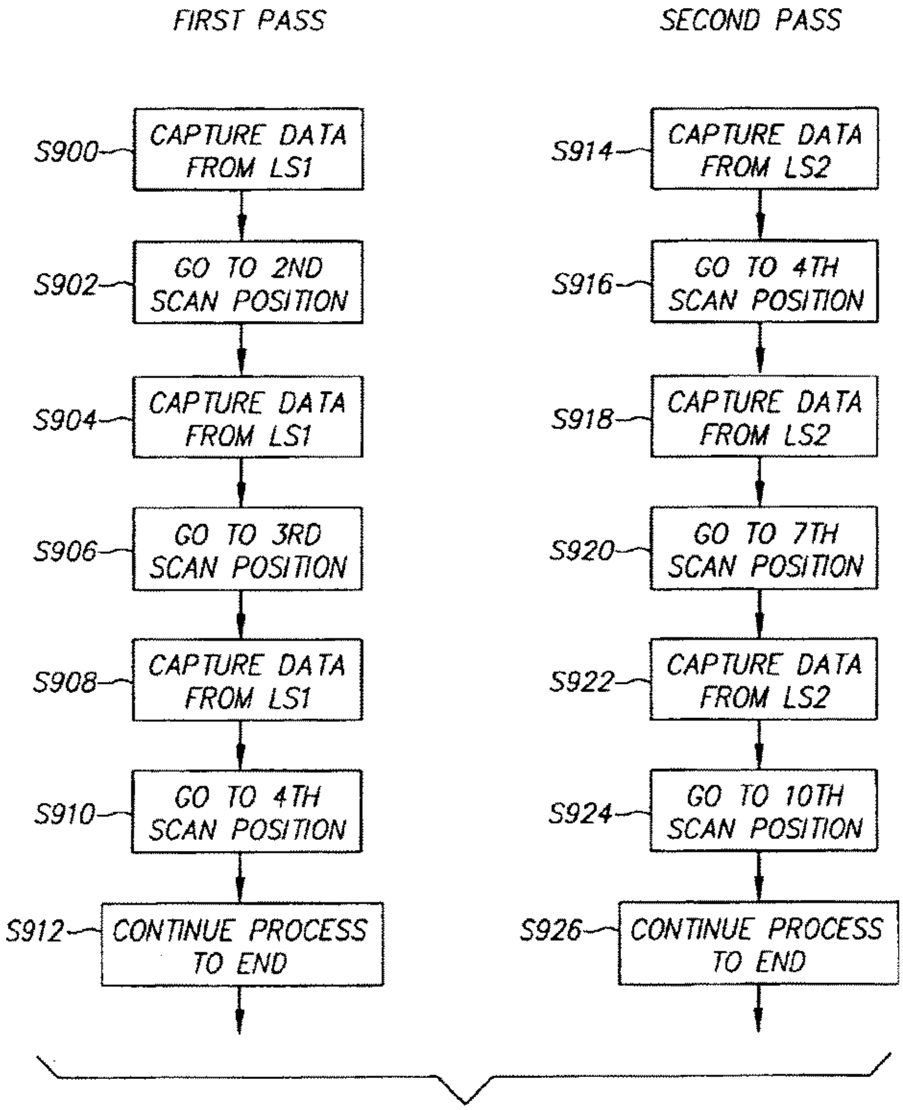
FIRST PASS
SECOND PASS
S900
CAPTURE DATA FROM LS1
S902
GO TO 2ND SCAN POSITION
S904
CAPTURE DATA FROM LS1
S906
GO TO 3RD SCAN POSITION
S908
CAPTURE DATA FROM LS1
S910
GO TO 4TH SCAN POSITION
S912
CONTINUE PROCESS TO END
S914
CAPTURE DATA FROM LS2
S916
GO TO 4TH SCAN POSITION
S918
CAPTURE DATA FROM LS2
S920
GO TO 7TH SCAN POSITION
S922
CAPTURE DATA FROM LS2
S924
GO TO 10TH SCAN POSITION
S926
CONTINUE PROCESS TO END

FIG. 8

METHOD AND SYSTEM FOR MULTI-SENSOR SIGNAL DETECTION

This application claims benefit to U.S. Provisional Application 60/159,073 filed on Oct. 12, 1999.

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to imaging systems, and more particularly to a method and system for multi-sensor signal detection.

BACKGROUND OF THE INVENTION

Imaging systems, such as digital cameras, satellites, and image scanners, operate by converting electromagnetic energy from a source image to an electronic, i.e., digital, representation, of an image. The source image could be an actual view, such as a landscape, satellite image, and the like, or embodied in a physical form, such as a photograph, film, picture, document, and the like. In many applications, the electromagnetic energy used to convert the image into a digitized image is visible light, however, infrared, microwave, and other suitable types of electromagnetic energy are also be used to create the digitized image.

Imaging systems generally include a number of optic sensors. The sensors measure the intensity of electromagnetic energy within a specific bandwidth of the electromagnetic spectrum. Each sensor generally comprises a color filter and a photodetector, such as a charge-coupled device, phototransistor, photoresistor, and the like. The photodetector produces an electrical signal that is proportional to the intensity of electromagnetic energy striking the photodetector. The color filter blocks all wavelengths of light in the visible electromagnetic spectrum except a specific bandwidth. For example, in a red sensor a red filter blocks all other wavelengths of light in the visible spectrum except for the wavelengths of light associated with the color red. Accordingly, only the red bandwidth of light from the source image is measured by the red sensor.

The sensors are generally geometrically positioned in arrays such that the electromagnetic energy striking each sensor corresponds to a distinct location in the source image. Accordingly, each distinct location of the source image corresponds to a distinct location, or pixel, in the digitized image. In color applications, the electronic imager comprises an array of color optic sensors relating to one of the three primary colors—red, green, and blue. The intensity of red, green, and blue electromagnetic energy associated with each discrete location of the source image is measured and recorded.

In electronic scanner applications, the scanner records the color intensity for each color optic sensor in a sequence of scan positions until the entire image is scanned. The spacing between scan positions is referred to as the scan line pitch. The scan line pitch is generally the same as the pixel pitch, i.e., width of the line of detectors, but may vary depending on the desired image resolution. The color data relating to each pixel is then correlated to produce the digitized image.

The digitized image often includes imperfections that are not present in the source image. One cause of such defects is the optical components of the imaging system. For example, in the case of a electronic imagers, the scanning surface or "platen" in the electronic imager may contain scratches and other optical path obstructions. Dust, fingerprints, and other such debris also causes optical path obstructions. These optical path obstructions are digitized along with the real image and appear as imperfections in the digitized image.

Another cause of imperfections is defects within the physical medium of the source image. For example, a photograph, film, or other physical medium having an image thereon may be scratched, distressed, or deformed despite careful handling. In addition, imperfections may arise from foreign matter, such as a hair, dust, and the like being deposited on the physical medium while the image is digitized. Thus, even though an image is replicated exactly as contained in the physical medium, imperfections may still be present in the digitized image.

One method of removing imperfections from transparent physical mediums, such as film, is to transmit infrared (IR) light through the transparent medium to produce a defect image. Conventional electronic imagers use the red filtered photodetector or a dedicated infrared photodetector for detecting and measuring the infrared light. As a result, conventional electronic imagers require two complete scans of the source image. The first scan uses conventional light to create a color digitized image. The second scan uses infrared light to create a digitized defect image that is used to correct the defects in the digitized image. A disadvantage of conventional methods is that the infrared scan takes the same length of time to complete as the color scan. Accordingly, this method for defect correction doubles the duration of the scanning process.

SUMMARY OF THE INVENTION

Accordingly, a need has arisen for an improved imaging system. The present invention provides a method and system for multi-sensor signal detection that substantially reduces or eliminates problems associated with prior systems and methods.

In accordance with one embodiment of the present invention, an improved imaging system for digitizing an object is provided. In this embodiment, the imaging system comprises an optical sensor array, a visible light source, and an infrared light source. The optical sensor array includes at least multiple sets of color sensors that detect different colors of visible light. In addition, at least two sets of color sensors operate to measure the intensity of infrared light.

The present invention can be implemented with many different methods for employing the three color channels in a trilinear imager to collect the IR defect data. One such method collects IR information from each color channel at every third scan position of the image. This method also enables defect data to be collected at every scan line. In this manner the IR information gathering time is three times faster than in a system using only one color channel for gathering IR information. One-pass and two-pass scanning methods can be used in this embodiment of the present invention.

In another embodiment of the present invention, a method for simultaneously collecting IR information from each scan line using each color channel (red-green-blue) is disclosed. Because this embodiment collects IR information from all three color channels for each scan line, three times more defect information about the image is captured as opposed to using only one color channel. The additional information can be used to increase the clarity of the captured image because it improves the signal/noise ratio.

Other technical advantages will be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings, wherein like referenced numerals represent like parts, in which:

FIG. 1 is a perspective drawing illustrating a computer imaging system in accordance with the present invention;

FIG. 2 is a perspective drawing illustrating an imaging system in accordance with the present invention;

FIG. 3 is a block diagram of a scanner using a trilinear imager for scanning images and capturing defects according to the present invention;

FIG. 4 is a diagram illustrating how a trilinear imager uses a scan pattern with red, green, and blue channels in a series of scan positions to capture information for all three colors for each scan line in an image according to the present invention;

FIG. 5 is a graph showing the spectral response of each filter in a trilinear imager according to the present invention;

FIG. 6 is a diagram illustrating how a trilinear imager uses three different scan positions to capture the three colors for one scan line according to the present invention;

FIG. 7 is a table illustrating scan positions that record IR information for different color channels for each scan line according to the present invention; and

FIG. 8 is a flow chart for a two-pass system according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1 through 8 illustrate an imaging system according to the present invention. As described in greater detail below, the imaging system allows an infrared defect scans to be performed at a faster rate than conventional systems. In particular, the present invention utilizes all of the color sensors in a tri-linear sensor system to obtain the infrared defect information.

FIG. 1 illustrates computer imaging system **10** in accordance with one embodiment of the present invention. The computer imaging system **10** comprises an electronic scanner **12**, a computer system **14**, and optional output device **16**. Although the computer imaging system **10** is illustrated with separate and distinct components, it will be understood that the computer imaging system **10** can be integrated into a single system, such as a kiosk imaging center.

As described in greater detail below, the computer imaging system **10** operates to digitize a source image **18** to produce a digital image **20** that electronically represents the source image **18**. The source image **18** may be a scene image, photograph, document, or any other suitable object that reflects or attenuates electromagnetic energy, i.e., light. The digital image **20** is output from the electronic scanner **12** to the computer system **14**. The digital image **20** is generally in the form of an electronic data stream or an electronic file having four numeric values that correspond to each pixel in the digital image **20**. The four numeric values describe the measured intensity of the red, green, blue, and infrared light for each discrete location of the source image **18**. The infrared value allows defects to be corrected as shown in the U.S. patent application No. 08/999,421, entitled Defect Channel Nulling, having a priority date of Jan. 6, 1997; and U.S. Pat. No. 6,498,867 entitled Method and Apparatus for Differential-Illumination Image Capturing and Defect Handling, filed Oct. 8, 1999, each of which is hereby incorporated by reference.

The computer system **14** may be any suitable computer, such as a personal computer using a Pentium microprocessor; a workstation; server; mainframe embedded system; discrete logic, and the like. The computer system **14** generally includes memory and a graphical user interface that allows the digital image to be viewed, saved, edited, electronically mailed, combined with other digital images, or any other suitable use according to the needs of a user. An optional output device **16** may be coupled to the computer system **14**. A typical output device **16** is a printer that allows a digital print image **22** to be produced.

FIG. 2A is a perspective drawing of the electronic scanner **12** shown in FIG. 1. The electronic scanner **12** is illustrated as an transmissive electronic scanner, such as a film, slide, or negative scanner. It will be understood, that the electronic scanner **12** may comprise any suitable color imaging device operable to digitize the source image **12**. For example, the electronic scanner **12** may comprise a reflective electronic scanner, such as a flatbed scanner; a drum type scanner; a copy machine; and a facsimile.

In the embodiment illustrated, the electronic scanner **12** comprises an optical imager **26**, a transport system **28**, and a processor **30**. As described in greater detail below, the optical imager **26** operates to illuminate the source image **18** with visible and infrared light and measure the intensity of visible colors and infrared for each discrete location of the source image **18**.

The transport system **28** operates to move the source image **18** relative to the optical imager **26**. Various embodiment of the transport system **28** may be implemented. For example, in one embodiment, the optical imager **26** is stationary and the source image **18** moves, or scans, across the optical imager **26**. In another embodiment, the source image **18** is stationary and the optical imager **26** scans across the source image **18**. In yet another embodiment, the source image **18** is stationary and the optical imager **26** is rastered across the source image **18**.

The processor **30** receives electronic data signals from the optical image **26** that are used to construct the digital image **20**. The processor **30** generally includes an analog-to digital (A/D) converter as well as a signal processor and/or preprocessor. The A/D converter converts the electronic data signal to digital signals that can be easily processed by the signal processor prior to being output as the digital image **20** to the computer system **14**. In many applications, the digital image **20** is actually constructed within the computer system **14**. In these applications, the digital image **20** output to the computer system **14** is an electronic data stream that is used by the computer system **14** to construct the complete digital image **20**.

Referring to FIG. 2A, the optical imager **26** includes a visible light source **32**, an infrared light source **34**, optics **36***a* and **36***b*, and a sensor system **38**. The visible light source **32** produces visible light **40**. i.e., white light, having a broad electromagnetic frequency band. In many applications, the visible light source **32** comprises a flourescent light that varies between low intensity and high intensity. The flourescent light source **32** is generally not turned off as the bulb takes time to warm-up to operating temperatures. The visible light source **32** may also comprise other suitable types of white light sources, such as halogen, LED's, incandescent, direct gas discharge lamps (xenon).

The infrared light source **34** operates a produce infrared light **42**. The infrared light source **34** is generally a white light source with a infrared filter that is transmissive to infrared light. In some applications the infrared light source **34** will incorporate a infrared filter with the same light bulb as the visible light source **32**. The infrared light source **34** may also comprise other suitable types of light sources, such as an LED, or direct gas discharge lamp.

The visible and infrared light, **40** and **42** respectively, are focused with optics **28***a* onto the source image **18**. The optics **28***a* may include mirrored surfaces and various lenses for directing the light onto the source image **18**. In the case of a transmissive electronic scanner **12**, the light passes through the source image **18** and is attenuated by the colors and defects in the source image **18**. The light from the source image **18** is then collected and focused by optics **28***b* onto the sensor system **38**. The optics **28***b* generally include precision focusing lenses for maintaining the spacial orientation of the light from the source image **18**. Spacial orientation allows the sensor system **38** to detect the light from discrete locations of the source image **18**.

The sensor system **38** generally comprises a trilinear array of sensors **44**. As described in greater detail below, the sensor system **38** measures the intensity of light associated with each color of light from the source image **18**. As a simple example, assume the color slide of a red kite in a blue sky. The red kit portion of the color slide will allow red light to pass through the slide, but will block substantially all of the blue and green light. The intensity of the red light is measured by the sensor system **38**. Accordingly, the sensor system **38** will measure a high red intensity but a low green and blue intensity. Similarly, the blue sky portion of the color slide will allow a substantial portion of the blue light and a small portion of the green light to pass through the slide, but will block substantially all of the green and red light. Accordingly, the sensor system **38** will measure a high blue intensity, a relatively low green intensity, and a low red intensity. The red, green, and blue intensities vary depending upon the color of that portion of the source image **18**.

FIG. 2B is a perspective cutaway view of the trilinear sensor system **38** of FIG. 2A. The sensor system **38** comprises a number of sensors **44** arranged in a set of three lines **46***a*/*b*/*c* with a glass cover **47** covering the sensors **44**. The horizontal spacing between consecutive lines **46** is known as a pixel pitch **48**. A pixel refers both to a position and to the information gathered at that position by the sensor **44**. The vertical spacing between sensor lines is known as a sensor line pitch **50** and is typically an integer multiple of the pixel pitch **48**. Each line **46** is associated with detecting a different color, such as red, green and blue. One example of a trilinear imager that is currently available is the Sony ILX724K.

Each sensor **44** generally comprises a color filter **52** and a photodetector **54**. The color filter **52** is transmissive to a certain color of visible light and also infrared light. For example, the blue line **46***a* has a blue color filter **52** that allows blue light to pass through the color filter **52**. The photodetector **54** measures the intensity of blue light striking the photodetector **54**. The photodetector **54** is generally a charge coupled device (CCD). However, other types of photodetectors **54** may be used, such as photoresistors, phototransistors, and the like. The color filter **52** is also transparent to infrared light. Accordingly, the infrared light **42** transmitted through the source image **18** is measured by each of the sensors **44**.

FIG. **3** is a functional block diagram of an embodiment of the present invention for capturing defect data. FIG. **3** illustrates a film scanner **400** that uses a trilinear imager **422** to capture the defect data from a transmissive medium, such as film **402** containing an image thereon.

Scanner **400** includes coupled elements including a first light source (LS1) **404** that produces visible light, and a second light source (LS2) **406** that produces IR light.

Scanner **400** also includes electronic switches **408** and **410**, a power supply **412**, a transport mechanism **414**, a controller **416**, a sensor unit **418**, and an analog to digital (A/D) converter **424**. Sensor unit **418** further includes lens **420** and the trilinear imager charge-coupled device (CCD) **422**. Within sensor unit **418**, lens **420** focuses light transmitted through film **402** such that the trilinear imager **422** can detect and capture image data.

Images and defects are captured when light generated by first and second light sources **404** and **406** is transmitted through film **402** to the sensor unit **418**. Sensor unit **418** outputs the captured image and defect information to an A/D converter **424**, which converts to digital image and defect data. The digital data is then transferred through interface **328** to be processed by a computer **326**.

First and second light sources **404** and **406** are preferably arranged for separate operation such that, during scanning, light from first light source **404** is used to capture an image (including defects), while the light from the second light source **406** is used to capture the defects on the image. In other words, when light from first (visible) light source **404** illuminates film **402**, the light transmitted through film **402** and received by sensor unit **418** will contain image information, including information on any defects that may be present on the surface of film **402**. When light from the second (IR) light source **406** illuminates film **402**, the light transmitted through film **402** and received by sensor unit **418** will contain information of defects on film **402**.

The first light source **404** generates light when power is applied from the power supply **412** via a first electronic switch **408**. The second light source **406** generates light when power is applied from the power supply **412** via a second electronic switch **410**. Electronic switches **408** and **410**, which may include transistors and/or relays, are regulated by the controller **416** via control lines **436** and **438**.

In addition to controlling electronic switches **408** and **410**, controller **416** is also coupled to transport mechanism **414** via control lines **430** and **432**. This allows controller **416** to send signals to transport mechanism **414** to control the positioning to system **400** components during separate operations for capturing image and/or defect information. Controller **416** is further coupled to sensor unit **418** via control line **434**. Controller **416** can comprise, for example, a programmable microcontroller such as an MC68HC05 made by Motorola.

Transport mechanism **414** preferably responds to commands from controller **416** by aligning system **400** components for separate operations for capturing image and/or defect information. More specifically, a first alignment will preferably provide for conventional image capturing, and a second alignment will preferably provide for capturing defects, as will be discussed in more detail hereinafter.

Operationally, controller **416** provides control signals for two separate scan cycles. During an “image scan” cycle, image data (including any defects) is captured, and during a separate “defect scan” cycle, defect data is captured. During a one-pass scan, for example, controller **416** preferably sends first alignment control signals **430** to transport mechanism **414** to align sensor unit **418** in a conventional one-pass manner. During a two-pass scan, sensor unit **418** is moved in response to first control signals **430** to a first alignment position. Then, during a defect scan cycle, sensor unit **418** is moved in response to second control signals **432** (a reverse scan cycle order can also be used). Although a one-pass scan is preferred for expediency, multiple scans can also be used.

In addition to controlling the alignment of the system **400** components, the controller **416** can also be used for controlling other components of the present invention. For example, first and second control signals **430** and **432** can be sent in conjunction with first and second control signals **436** and **438** to control electronic switches **408** and **410**, respectively. Controller **416** can also send additional control signals (not shown) such that, consistent with conventional image scanning, when light is supplied, a sensor is activated, and sensed light is captured during a given scan cycle. Alternatively, multiple controllers, CPU's, digital signal processors ("DSP's") and/or other data processing components can also be used in accordance with the present invention.

It will be apparent to those skilled in the art that other embodiments of the present invention are also possible. For example, the computer **426** could be replaced with dedicated hardware, and a wide variety of different light source could be used for the first light source **404**.

FIG. **4** illustrates how a trilinear imager **422** in FIG. **3** scans an image **506** on a page **510**. When the visible light source (LSI) **404** pulses, the trilinear imager **422** gathers information in a scan pattern **502** simultaneously capturing information for three separate scan lines across the image's page through each of the red, green, and blue channels. The imager **422** continues capturing information in a series of scan positions **504** as the visible light source pulses until each scan line of the image has been scanned for all three colors. The imager **422** gathers the scanned information for the image starting at the first scan line (scan line **1**). The scanner loads the image starting from scan line **1** because the first line of pixels covers all three color channels. Thereafter, each subsequent line, such as scan line **2** and scan line **3**, are loaded into the scanner. In the example provided above, it is assumed that the line spacing between each color channel of the scan pattern **502** is 4 lines. In other words, when the red channel is positioned on line **1**, the corresponding green and blue channels are positioned on lines **5** and **9**, respectively.

FIG. **5** is a graph showing the spectral response of each filter in a trilinear imager according to the present invention. As shown, the spectral response (y-axis) of each filter in the trilinear imager reaches a peak at a wavelength (x-axis) that is associated with a particular color. Each filter is also capable of blocking out wavelengths associated with certain colors. In addition, each filter used in the present invention is capable of responding to wavelengths associated with IR light. Therefore, the present invention can use multiple color-filter channels to capture defect information in response to IR light.

FIG. **6** illustrates how the trilinear imager **422** in FIG. **3** uses three different scan positions to capture information of all three colors for one scan line **710**, i.e. scan line **1**, of an image **706** on a page **708**, according to the preferred method of the present invention. For scan line **710**, the information from blue channel is captured during the first scan position (position **1**), the information from the green channel is captured during the fifth scan position (position **5**), and the information from the red channel is captured during the ninth scan position (position **9**). Thus, information for all three color channels are captured at different scan positions.

In the first embodiment of the present invention, a method for collecting IR information through at least one color channel for each scan line is disclosed. In this embodiment, defect data can be collected at every third scan position to capture information about every scan line. Using this method, the IR gathering time is at least three times faster than using a conventional scanner having only one color channel for detecting IR information. Preferably, the present method can be implemented with a scanner having components (hardware and settings) such that the sensor line pitch is not a factor of three times the scan line pitch.

The first embodiment of the present invention can be implemented with either a one-pass system or a two-pass system. In the one-pass system, the visible light source pulses during the first scan position, and the trilinear imager simultaneously captures three separate scan lines of image information across the image's page, one line for the red, green, and blue channels. Then, before moving the scanner to the second scan position, the IR light source pulses through all three color channels, thus allowing the trilinear imager to capture three separate scan lines of defect information across the page. When the scanner is in the second scan position, only the visible light is allowed to pulse, and the trilinear imager captures only the image information for three separate scan lines. At the third scan, again only the visible light is allowed to pulse and only image information is captured. The fourth scan position is similar to the first scan position where the visible light and IR light sources are pulsed in the order set forth above, and both image and defect information is captured. At the fifth and sixth scan positions, only image information is captured. At the seventh position, both image and defect information is captured. The process continues, pulsing the visible light for each scan position and further pulsing the IR light every third scan position, until all scan positions for the image have been captured.

FIG. **7** is a table illustrating scan positions that record IR information for different color channels for each scan line in accordance with the present invention. By using all three color channels to capture IR information, the scanner only needs to pulse the IR light at every third scan position, for example at scan positions **1**, **4**, **7**, **10**, **13**, **16**, and so on, to capture every scan line in an image. For example, for the first scan line, the trilinear imager records the IR information through the blue channel at the first scan position. For the second scan line, it records the IR information through the red channel at the tenth scan position. For the third line, it records the IR information through the green channel at the seventh scan position, and so on. At each of these scan positions (**1**, **4**, **7**, **10**, **13**, **16**, etc), the trilinear imager simultaneously records the IR information through all three color channels. At the tenth scan position, for example, it records through the red channel for scan line **2**, through the green channel for line **6**, and through the blue channel for line **10**.

Next, in a two-pass system of the first embodiment of the present invention, a visible light source is used to record color information for all the scan lines of the image during the first pass. Then an IR light source is used to capture defects during a second pass of the image while scanning the image either forward or backward. In the second pass, the system moves directly to every third scan position in the series and captures defect data, until all the scan lines for the image are covered. For example, the system moves to the first scan position, the fourth, the seventh, and so on. As in the one-pass system of the first embodiment, the trilinear imager records the IR information through all three color channels simultaneously to eventually gather correct information from every scan line in the image. But, unlike the one-pass system where the IR information is gathered when the IR light source pulses every third scan position during the first pass, the two-pass system captures the IR information every third scan position only during the second pass.

In more detail, FIG. **8** illustrates a flow chart of a two-pass system in accordance with the first embodiment of the present invention. The scanner pulses a visible light for the first scan position in **S900**, and the trilinear imager records image information. Then the scanner moves to the second scan position in **S902**, and so on until it captures the color for the entire image. On the second pass, scanning forward, the scanner pulses an IR light for the first scan position in **S914**, and the trilinear imager records defect information through all three color channels. Then the scanner moves to the fourth scan position in **S916**, and the trilinear imager records defect data. This process continues at every third position, at the 7th, 10th, 13th, 16th, and so on. Alternately, the second pass could scan backward at every third scan position.

An alternate method of the first embodiment is to use each color channel simultaneously to record IR information at every scan position, but reducing the gathering time by one third at each scan position. Thus, the gathering time is three times faster than if the scanning was performed at every scan position using the full gathering time. Since this alternative method employs three channels to simultaneously gather IR information, it gathers the same amount of defect information as the system using the full gathering time. After the IR information has been recorded from all three channels, this method systematically adds together the recorded values to accurately reflect and identify defects.

Another method of the first embodiment, also not restricted by the sensor line pitch, is to alternatively turn on the visible light and the IR light at every nth scan line, where n is the number of scan lines that fit into one sensor light pitch. For the next 2n scan lines, the scanner only turns on the visible light, and this pattern is repeated for the remainder of the page. For example, if the pixel pitch is 800 dpi ($1/800$ inch) and the sensor line pitch is 8 pixels ($8/800$ inch) and the scanner is scanning at 400 dpi ($1/400$ inch), then n is equal to 4 ($8/800$ divided by $1/400$). In this example, the scanner would alternate turning on the visible light and the IR light for the next 4 scan lines. For the next 8 scan lines, the scanner would turn on only the visible light. For the next 4 scan lines thereafter, the visible and IR lights would alternate. For the next 8 scan lines, the scanner would again turn on only the visible light. The same process would continue until the end of the page.

A second embodiment of the present invention uses each RGB color channel simultaneously in a multilinear-imager to collect IR information from every scan line. Since this embodiment collects IR information from all three channels for every scan line, three times as much defect information is captured. The additional information available from these three samples can be used to increase the clarity of the captured defect image since it improves the signal/noise ratio.

In a one-pass system in accordance with the second embodiment, the scanner pulses a visible light source for the first scan position, and the trilinear imager captures image information. Then the scanner pulses an IR light source in the first scan position, and the trilinear imager captures defect information. The scanner then moves on to the second scan position and again pulses the visible light source to capture image information and then pulses IR light source to capture defect information. This process continues until all scan positions for the image have been recorded.

In a two-pass system in accordance with the second embodiment, the scanner pulses a visible light source to record image information at each scan position until the entire image is covered. Then the scanner makes a second pass over the image, scanning information.

Once the present invention has captured defect information, users can employ a wide variety of methods to remove the defects from the scanned image, as is known by those skilled in the art.

Although the present invention has been described in several embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present invention encompass such changes and modifications that fall within the scope of the appended claims.

What is claimed is:

1. A method for capturing image and defect information from an image scanned from a medium, comprising the steps of:

capturing image and defect information by a sensor unit during every scan position while transmitting visible light from a first light source through the medium; and

capturing defect information by the sensor unit during every third scan position while transmitting infrared light from a second light source through the medium.

2. A method according to claim **1**, further comprising the steps of:

aligning the sensor unit and/or the medium in a first alignment during transmission of visible light; and

aligning the sensor and/or the medium in a second alignment during transmission of infrared light.

3. A method according to claim **1**, wherein visible light and infrared light are not transmitted simultaneously through the medium.

4. A method according to claim **1**, wherein the medium comprises one of a film, a document, and a photograph.

5. A method according to claim **1**, wherein the steps of transmitting visible light and infrared light through the medium occur during a first pass.

6. A method according to claim **1**, wherein the step of transmitting visible light occurs during a first pass and the step of transmitting infrared light occurs during a second pass.

7. A method according to claim **1**, wherein every scan position comprises three separate scan lines, each scan line associated with either a red, green, and blue channel of the sensor unit.

8. A method for capturing image and defect information from an image scanned from a medium, comprising the step of:

(1) alternatively transmitting visible light and infrared light through the medium for each scan line up to n lines in conjunction with capturing image and defect information during visible light transmission and capturing defect information during infrared light transmission;

(2) transmitting only visible light through the medium at each scan line for the next 2n scan lines in conjunction with capturing image information during visible light transmission after performing step (1); and

(3) repeating steps (1) and (2) until all image and defect information is captured for the medium.

9. A method according to claim **8**, wherein n equals a pixel pitch multiplied by a sensor line pitch divided by a scanning rate.

10. A method for capturing image and defect information from an image scanned from a medium, comprising the steps of:

transmitting visible light from a first light source through the medium to capture image and defect information by a sensor unit during every scan position with the sensor unit and/or the medium in a first alignment; and transmitting infrared light from a second light source through the medium to capture defect information by the sensor unit during every scan position after moving the sensor and/or the medium to a second alignment different than the first alignment.

11. A method according to claim **10**, wherein visible light is transmitted through the medium before the infrared light is transmitted.

12. A method according to claim **10**, wherein the medium comprises one of a film, a document, and a photograph.

13. A method according to claim **10**, wherein the steps of transmitting visible light and infrared light through the medium occur during a first pass.

14. A method according to claim **10**, wherein the step of transmitting visible light occurs during a first pass and the step of transmitting infrared light occurs during a second pass.

15. A method according to claim **10**, wherein every scan position comprises three separate scan lines, each scan line associated with either a red, green, and blue channel of the sensor unit.

16. A scanner used for capturing image and defect data from a surface of a medium containing an image thereon, comprising:

a first light source and a second light source;

a first switch coupled to the first light source and a second switch coupled to the second light source;

a power supply coupled to the first and second light switches;

a sensor unit having a multi-linear imager and optical lens, the optical lens adapted to focus light transmitted through the surface of the medium to the multi-linear imager, thereby capturing image and defect information;

an analog to digital converter adapted to convert the image and defect information to digital image and defect data;

a transport mechanism adapted to align the sensor unit and/or the medium for capturing the image and defect information, wherein the transport mechanism is configured for aligning the sensor unit and/or the medium in a first alignment for capturing image information and for moving the sensor unit and/or the medium to a second alignment different than the first alignment for capturing defect information; and

a controller adapted to control the first switch, the second switch, the transport mechanism, and the sensor unit.

17. An apparatus according to claim **16**, wherein the first light source generates visible light, and the second light source generates infrared light.

18. An apparatus according to claim **16**, wherein the first light source is used to capture image and defect information and the second light source is used to capture defect information.

19. An apparatus according to claim **16**, wherein the first light source and the second light source do not generate light simultaneously.

20. An apparatus according to claim **16**, wherein the medium comprises one of a film, a document, and a photograph.

21. A method of digitizing a source image, comprising:

collecting visible light data and infrared light data simultaneously on at least two color sensor channels at a first increment of scan positions; and

collecting visible light data during a second increment of scan positions greater than the first increment of scan positions on at least one of said color sensor channels.

* * * * *

EXHIBIT B

US006380539B1

(12) United States Patent
Edgar

(10) **Patent No.: US 6,380,539 B1**
(45) **Date of Patent: Apr. 30, 2002**

(54) **FOUR COLOR TRILINEAR CCD SCANNING**

(75) Inventor: **Albert D. Edgar**, Austin, TX (US)

(73) Assignee: **Applied Science Fiction, Inc.**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/012,255**

(22) Filed: **Jan. 23, 1998**

Related U.S. Application Data

(60) Provisional application No. 60/036,655, filed on Jan. 30, 1997.

(51) **Int. Cl.**^{7} **G01N 21/88**
(52) **U.S. Cl.** **250/339.05**; 250/341.1
(58) **Field of Search** 250/339.05, 339.06, 250/339.11, 340, 341.1, 208.1, 226, 330; 282/254; 348/274

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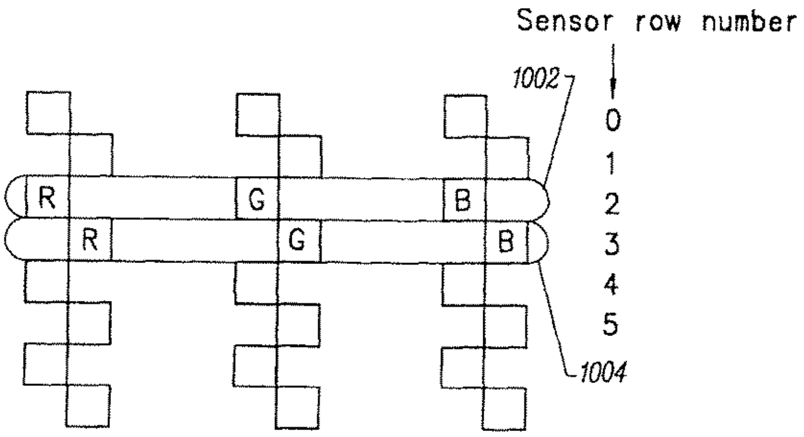
(57) **ABSTRACT**

A single pass scanner having a trilinear array, a source of white light, filters of the three primary colors and a separate source of infrared light is used in various methods of removing medium-based defects from a scanned film image. The method generates an infrared channel in addition to the common visible channels by covering the parallel rows of sensors in the trilinear array respectively with a red, green and blue filter to create the three color channels. Normally, each of the three color filters also passes infrared light, which is removed by filters external to the sensors. In a specific embodiment, interstitial in time between two visible light scans, the sensor is exposed to infrared light for a single scan. As the trilinear array sweeps across an image in time and spatial synchronization with the exposing lights, at least two visible channels and an infrared channel are generated.

50 Claims, 9 Drawing Sheets



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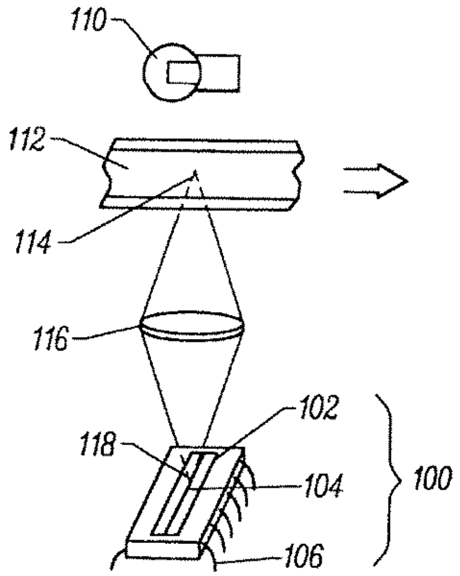
110
112
114
116
118
102
104
106
100

FIG. 1

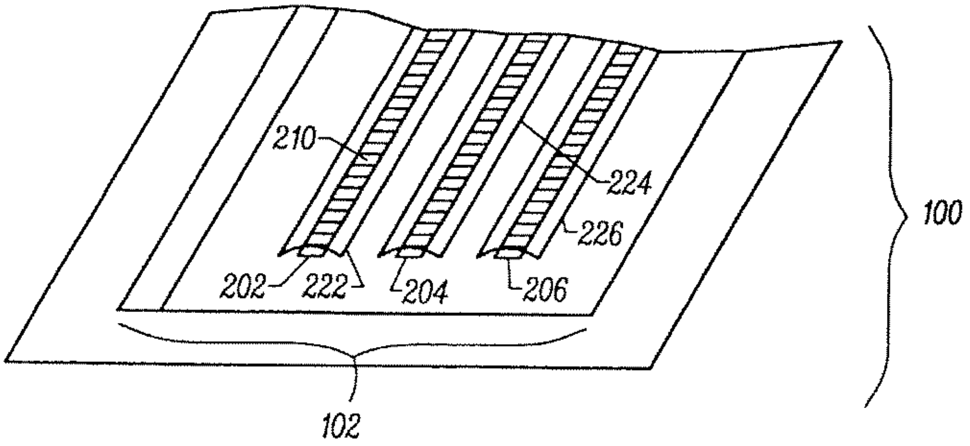
210
224
226
202
222
204
206
100
102

FIG. 2

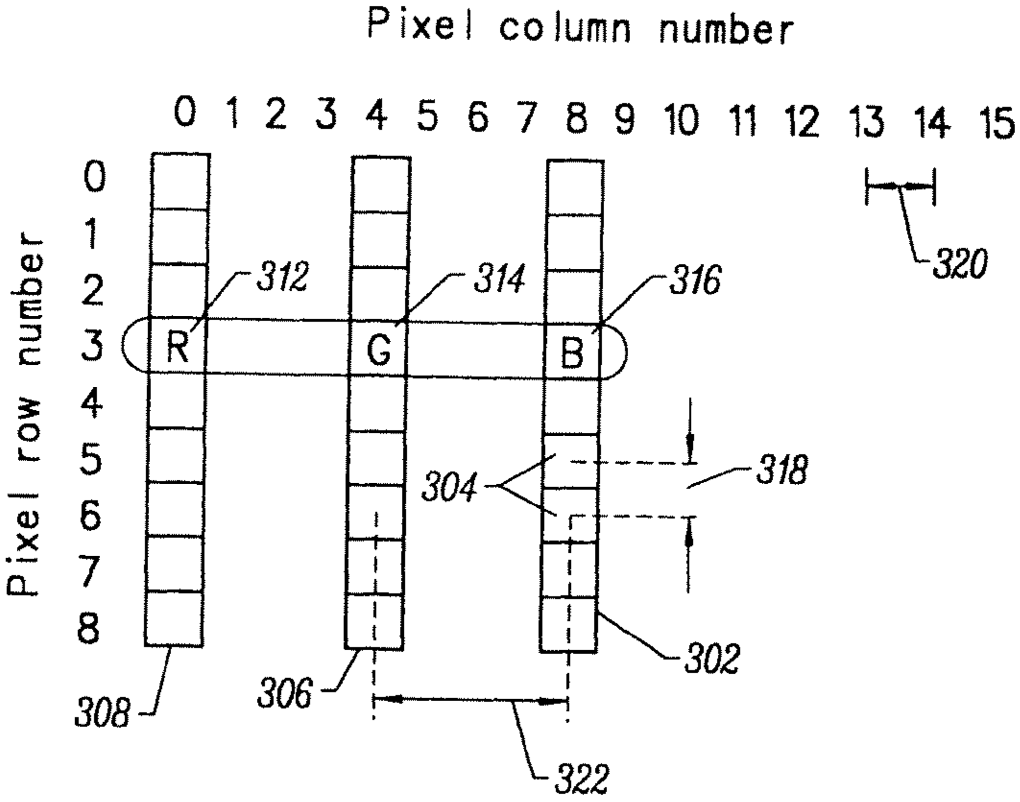
Pixel column number
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Pixel row number
0
1
2
3
4
5
6
7
8
R
G
B
312
314
316
320
318
304
302
306
308
322

FIG. 3

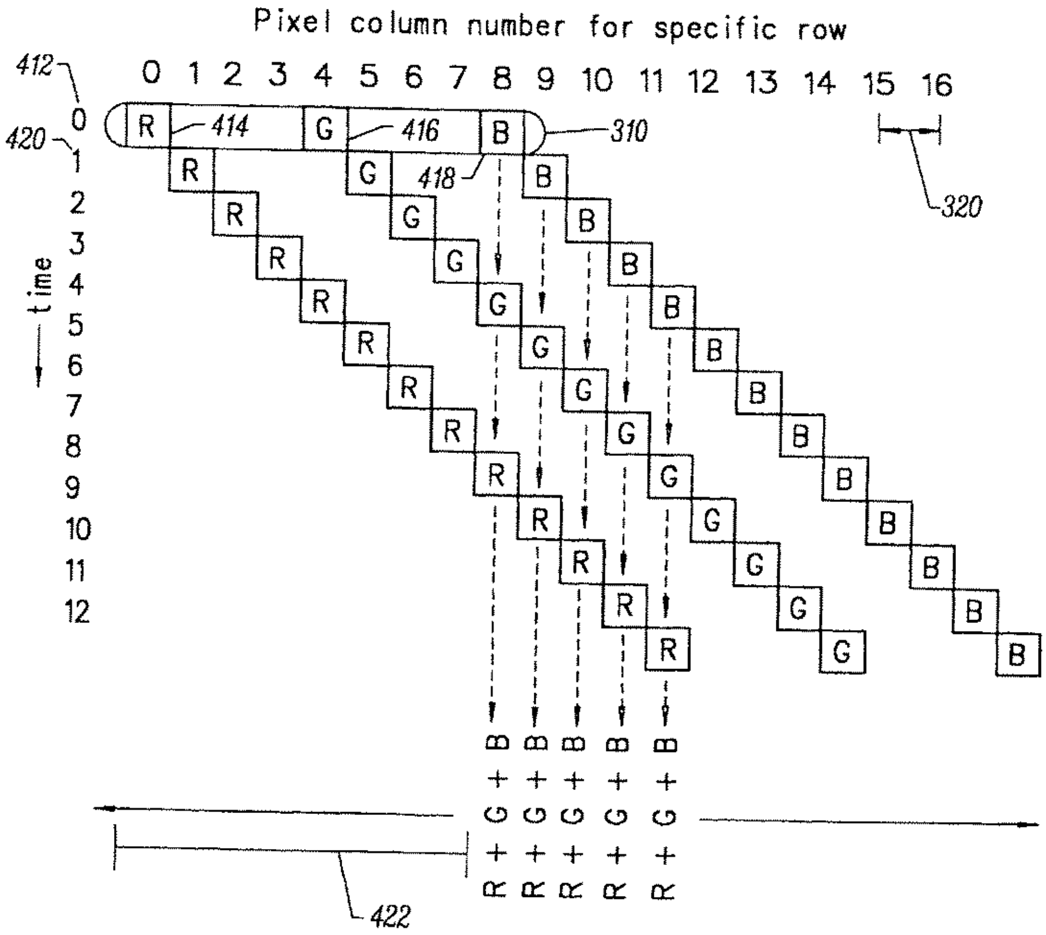
Pixel column number for specific row
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
412
420
time
0 1 2 3 4 5 6 7 8 9 10 11 12
R
G
B
414
416
418
310
320
R+G+B
422

FIG. 4

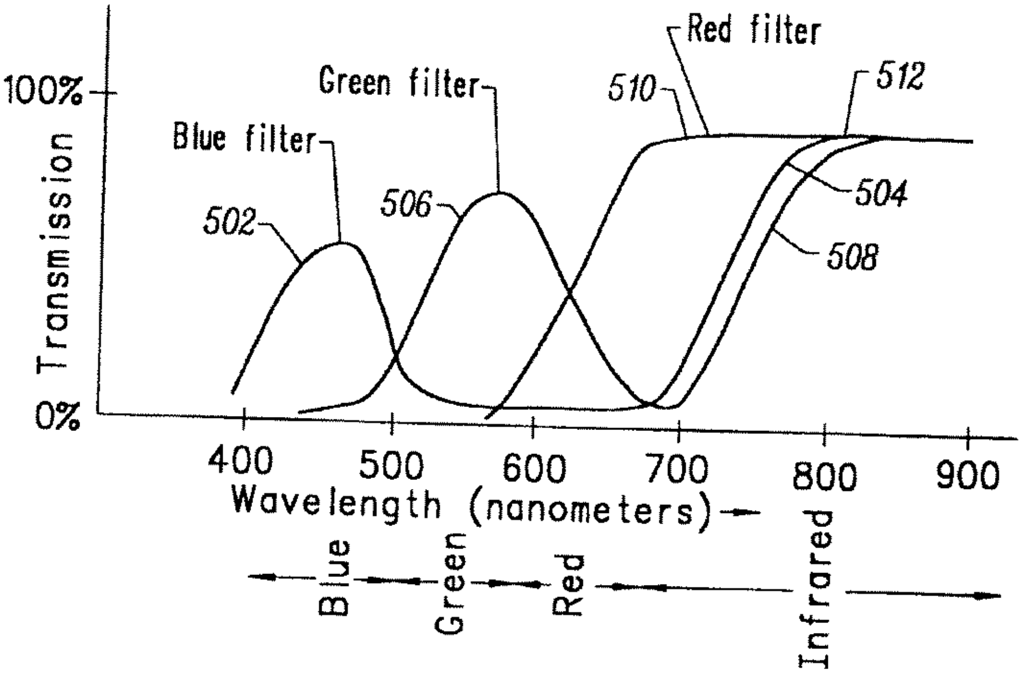
Red filter
512
510
Green filter
100%
Blue filter
506
502
504
508
Transmission
0%
400
500
600
700
800
900
Wavelength (nanometers)
Blue
Green
Red
Infrared

FIG. 5

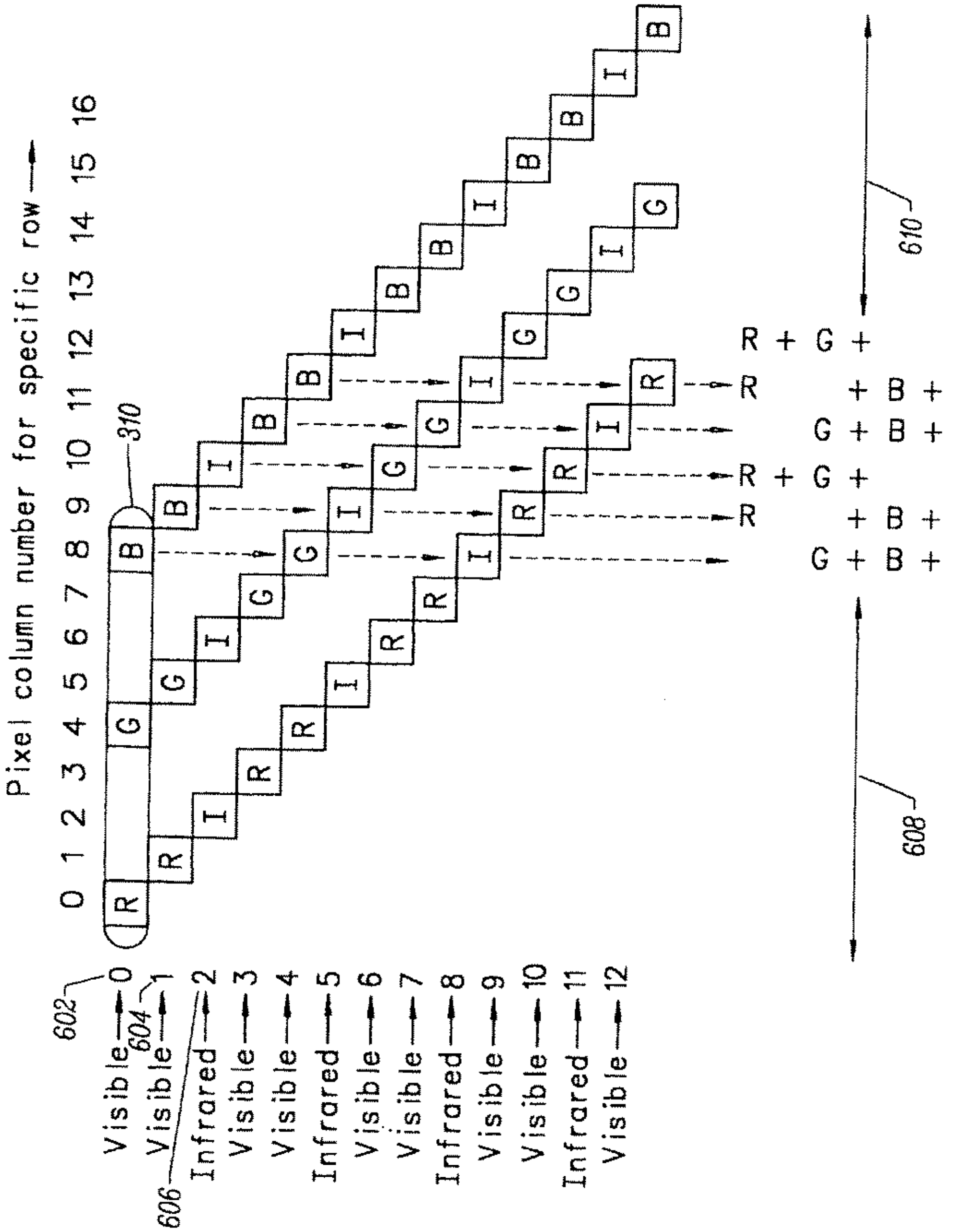
Pixel column number for specific row
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
602
604
606
310
Visible 0
Visible 1
Infrared 2
Visible 3
Visible 4
Infrared 5
Visible 6
Visible 7
Infrared 8
Visible 9
Visible 10
Infrared 11
Visible 12
R G B
R I R R I R R I R
G I G G I G G I G
B I B B I B B I B
R + G + I
R + B + I
G + B + I
R + G + I
R + B + I
G + B + I
608
610

FIG. 6

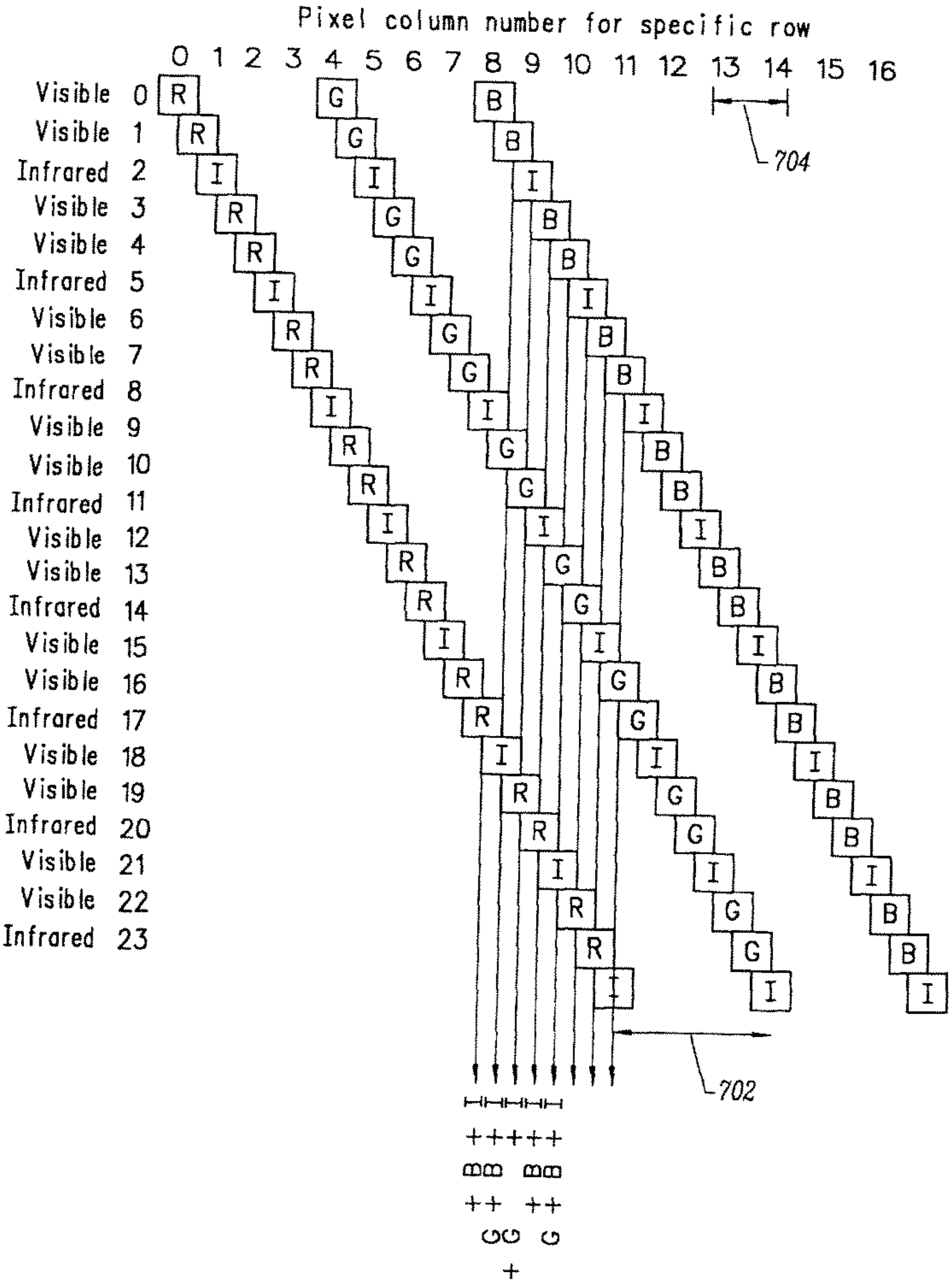
Pixel column number for specific row
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Visible 0
Visible 1
Infrared 2
Visible 3
Visible 4
Infrared 5
Visible 6
Visible 7
Infrared 8
Visible 9
Visible 10
Infrared 11
Visible 12
Visible 13
Infrared 14
Visible 15
Visible 16
Infrared 17
Visible 18
Visible 19
Infrared 20
Visible 21
Visible 22
Infrared 23
R
G
B
I
704
702

FIG 7

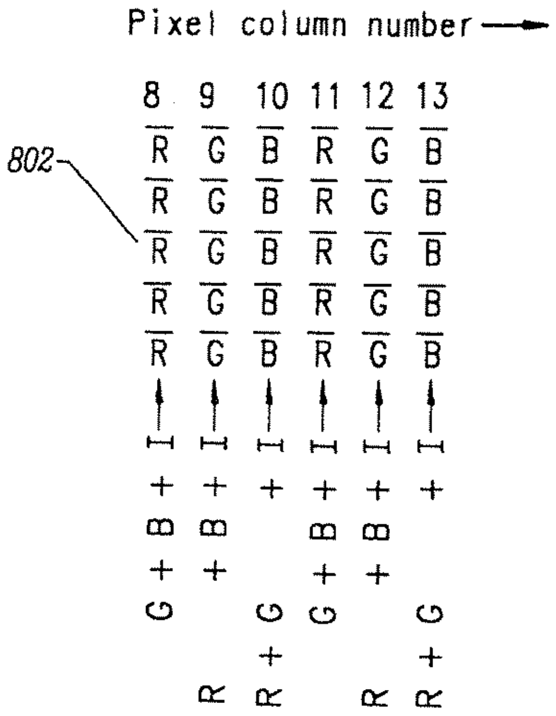
Pixel column number
8
9
10
11
12
13
802
R G B R G B
R G B R G B
R G B R G B
R G B R G B
R G B R G B
G+B+I
R+B+I
R+G+I
G+B+I
R+B+I
R+G+I

FIG. 8

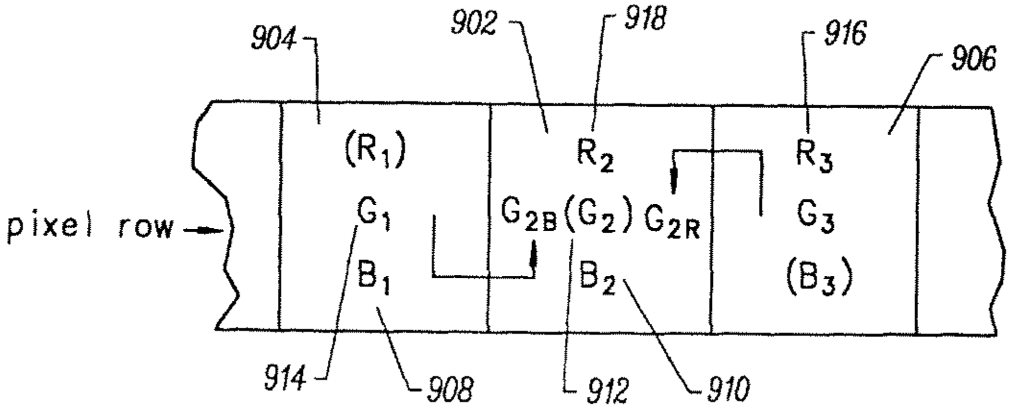
904
902
918
916
906
pixel row
(R1)
G1
B1
R2
G2B (G2) G2R
B2
R3
G3
(B3)
914
908
912
910

FIG. 9

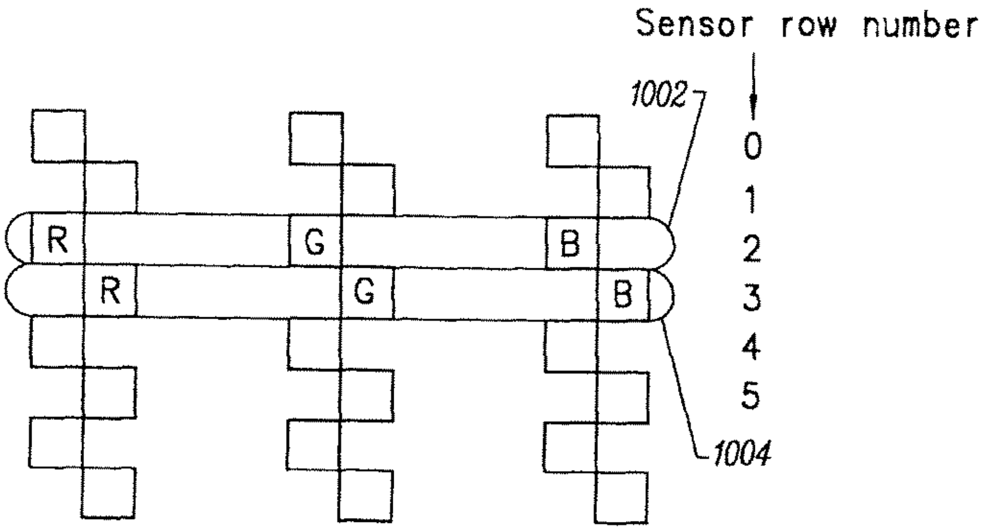

FIG. 10

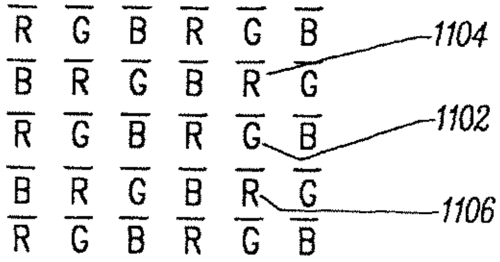

FIG. 11

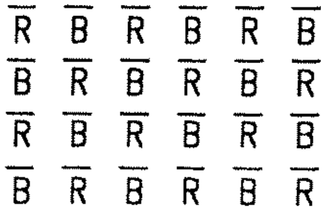

FIG. 12

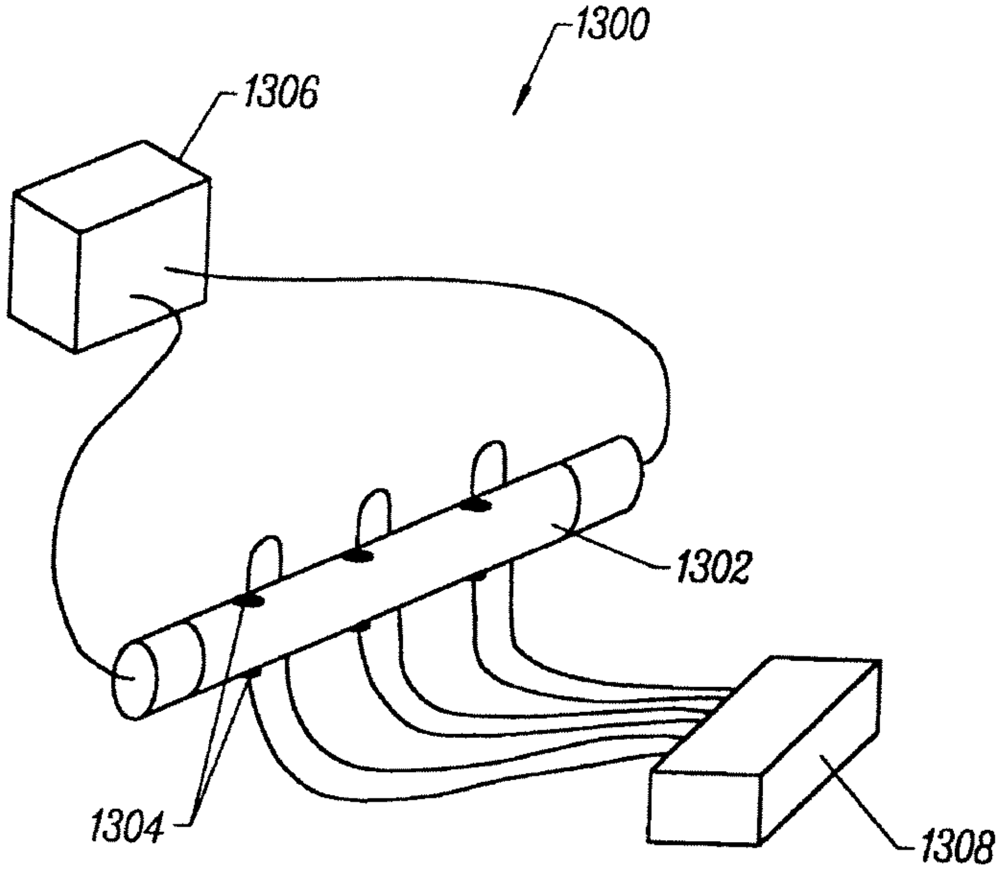

FIG. 13

FOUR COLOR TRILINEAR CCD SCANNING

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/036,655, filed Jan. 30, 1997.

FIELD OF THE INVENTION

This invention relates to image enhancement and recovery, and more particularly to a method and apparatus for scanning color image data.

BACKGROUND OF THE INVENTION

Ever since the first image of an object was captured on film, a serious problem was apparent which has continued to plague the field of image capture and reproduction to the present day, namely imperfections in the recording medium itself which distort and obscure the original image sought to be captured. These imperfections occur in innumerable forms including dust, scratches, fingerprints, smudges and the like. Archival polypropylene sleeves employed to protect negatives even contribute to the problem by leaving hairline surface scratches as the negatives are pulled out of and replaced into the sleeves.

One method of approaching the problem of defective images is described by the present inventor in U.S. Pat. No. 5,266,805 issued to Edgar. In that system, image data is stored on a recording medium or substrate containing non-image imperfections such as film having surface scratches, wave smudges, bubbles, or the like, which give rise to undesirable artifacts in images subsequently retrieved from the medium or substrate. Means are provided for deriving from the medium separate images in the red, green, blue and infrared portions of the electromagnetic spectrum corresponding to the image stored. The infrared image is used as an indicator or map of the spatial position of the non-image imperfections on and in the medium so the defects can be reduced or eliminated. In this way, the desired underlying image is recovered.

The fundamentals of scanner technology for scanning and storing images in digital form are well developed and available in commercial products. Scanners receive an optical image, and divide it into many points, called pixels. The scanner measures light at each of these points to give each pixel a numerical value. Software associated with the scanner can then manipulate and store the pixel data. A color scanner measures several numerical values for each point, one for each primary color of red, green and blue. For example, a scanner may measure a pink pixel to have 80% red, 40% green, and 40% blue. All numbers representing one of the primary colors are grouped by the software into a channel, or single color image. Some scanners measure only one primary color at a time, then back up, change either the light source or a color filter to a second color, and measure only that second color on a second pass of the image. These are called multipass scanners. An example of a multipass scanner is the RFS 3570 made by Eastman Kodak Company.

Other scanners make a single pass, and collect all color information in that one pass. One type of single pass color scanner uses a linear array, or line of sensors. This array is moved, or scanned, perpendicularly across the image to scan all points on the image line by line. During this scan a light source is rapidly switched between the various colors to be sensed. One complete cycle of the colored light sources occurs for each line of pixels in the image. Thus a single point on the image is seen by a single sensor in the array first

by one color, then by another color, and typically also by a third or fourth color, before that sensor moves on to another line of pixels on the image. Software is used to store the color-specific numerical information for each pixel into the appropriate channel so that at the end of the scan, multiple channels are available (one for each color). An example of a single pass scanner is the LS 1000 made by Nikon Corporation.

Another type of single pass scanner illuminates the image being scanned with light containing all visible colors, but places tiny color filters over the sensor elements so at any point in time there are sensors receiving each different color. One such method positions three linear arrays side by side to form a "trilinear array." One of the three arrays is placed under a red filter, one under a green filter, and the third under a blue filter. Typically these colored filters pass infrared light in addition to the color they are intended to pass, and for this reason the infrared light must be removed from the optical path by a separate filter elsewhere in the scanner, or the scanner must use a light source containing no infrared light. An example of a scanner employing a trilinear array is the SprintScan 35 made by Polaroid Corporation.

A problem arises when applying media surface defect correction to single pass scanners using trilinear arrays. The filters on standard trilinear arrays distinguish red, green, and blue light, but not the fourth "color" of infrared light necessary to practice surface defect correction. Further, to be compatible with existing color dyes that pass infrared light, infrared light is often removed from the optical path prior to reaching the sensor, precluding addition of a fourth line of sensors sensitive to infrared light.

The three sensor lines of a trilinear array typically are spaced by an integer multiple of the separation distance between pixels in the image. If the spacing integer is eight, then a specific point on the image may be sensed in red, and exactly eight steps later it may be sensed in green, and eight steps after that it may be sensed in blue. Thus, the same pixel is scanned at three different times. The software then realigns the color channels by moving each a multiple of eight steps so as to group together all of the pixels sensed in the same color. The spacing between sensor lines of the array is usually a power of two (such as 2, 4, 8, 16, 32, etc.) multiplied by the pixel spacing distance to allow the designer the option to choose submultiple resolutions. For example, if the spacing were 1/250th of an inch, the scanner could operate at 2,000; 1,000; 500; or 250 dots per inch, while retaining alignment between the colors with the appropriate offset.

Trilinear array scanners operate at very high speed because three lines of an image are scanned simultaneously. In addition, they provide very good color registration because of the single pass and in spite of generally low cost transport mechanics. Thus, there is no need to halt movement of the image at each scan line, and this further increases the speed of the scan. However, the market needs an image scanner with the speed and cost advantages of a single pass trilinear array which also includes surface defect correction capabilities.

Yet another type of single pass scanner uses an area array to cover a two dimensional region of the image at once rather than mechanically scanning with a linear array to cover the region. One such scanner called a color filter matrix further incorporates tiny color filters over each element in the area array. In a specific implementation used in a Kodak digital camera, half the sensor elements lie under tiny green filters incorporated on the sensor array in a checkerboard pattern. The other half of the sensor elements in the checkerboard are behind alternating red and blue filters. Thus, a quarter of the sensors respond to red light, half respond to green light and a quarter respond to blue light. In another implementation in a Polaroid digital camera, an entire column of sensors is behind tiny red filters, the adjacent column of sensors is behind tiny green filters, and the next column of sensors is behind tiny blue filters. This pattern repeats in additional columns. In yet another implementation common in video cameras, the colored filters on even rows are green and magenta, and the filters on odd rows are cyan and yellow. Because the array is not mechanically scanned, each pixel in the image is measured with only one of the three colors, as opposed to the other scanners discussed so far that measure each pixel of the image with three colors. As with the trilinear array discussed above, all the colored filters pass infrared light, and therefore infrared light must be removed by a separate filter elsewhere in the optical path.

Another important consideration for image scanners is data compression due to the rather large amount of pixel data which may be detected by image scanners. Scanners that only sense a single specific color from each specific pixel, such as those employing a color filter matrix, produce only one-third as much raw data as a scanner that senses all three colors from each pixel, and therefore such scanners employ a form of data compression. For a purely black and white image, detail can be resolved at the full pixel resolution of the scanner because for a black and white image, it does not matter whether a pixel senses in red, green, or blue light. On the other hand, problems may occur in the details of a color image where a point of white light aligns with a red sensor and so appears red, or with a blue sensor and so appears blue. It is known that this aliasing problem can be reduced by controlled blurring of the image so that a point of light will always cover several color sensors; however, this anti-alias blurring has the disadvantage of reducing image sharpness.

Another form of data compression of colored images adds the three primary colors to form a black and white image, called a Y channel image, that is stored at full resolution. Red and blue channel images are then individually differenced with this Y channel image. Typically the red channel minus the Y channel is called the U channel and the blue channel minus the Y channel is called the V channel. The U and V channel images are stored at lower resolutions than the Y channel image. In a specific implementation, alternating pixels store both Y and U records, and the next pixel stores both Y and V records, two numbers per pixel rather than three numbers needed to store all three primary colors. However, the disadvantage with using so called YUV color space is that 75% of the state space is wasted; that is, if Y, U, and V numbers were generated randomly within the full range appropriate to each, 75% of the generated numbers would produce invalid colors, or colors outside the range of real world colors.

Single chip color area sensors, commonly used in almost all consumer electronic imaging products, place color filters over each sensor in a single two dimensional array of sensors. Thus each pixel represents a single color, and this may be thought of as a data compression scheme in which two of the three primary colors are discarded for each pixel. Several patterns of colors are available in the art, such as the Bayer array that assigns half the pixels to green in a checkerboard; the striped color array such as that used in a Polaroid digital camera in which entire columns cycle between red, green, and blue; and a technique commonly used in video cameras that uses cyan, magenta, yellow, and green in a repeating square. All of these techniques have been previously described above.

It is, therefore, an object of this invention to provide an improved method and apparatus for scanning images with a variety of sensor arrangements.

It is yet another object of the present invention to scan images so that the image data may be compressed for easier storage and manipulation.

It is still another object of the present invention to provide an improved method and apparatus for scanning images which decreases the time it takes to scan the image.

It is another object of the present invention to provide a method and apparatus for recovering a scanned color image.

It is another object of the present invention to provide a method and apparatus for scanning images with infrared light in a single pass using a color filter matrix.

It is another object of the present invention to provide a method and apparatus for scanning images with infrared light in a single pass using an existing color filter matrix.

It is another object of this invention to provide a method and apparatus for scanning images under visible and infrared light so that surface defects in the scanned images are reduced or eliminated.

To achieve these and other objects which will become readily apparent upon reading the attached disclosure and appended claims, an improved method and apparatus for scanning an image is provided. Additional objects, advantages, and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

The present invention provides an improved method and apparatus for scanning an image. A plurality of sensors is arranged in groups. The first group of sensors is behind a filter material selective to both a first color and infrared light. A second group is behind a second filter material which is selective to a second different color and infrared light. An image at a first scan time is illuminated with light functionally free of infrared which is sensed with the first group of sensors to generate a first color image, and with the second group of sensors to generate a second color image. The image is then illuminated by a second light source containing infrared at a second scan time and sensed by at least one of the first or second group of sensors to generate an infrared image. From the first color image, the second color image, and the infrared image, a corrected color image is generated which is substantially free of media-based defects.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a prior art trilinear array component as used in a typical image scanning application;

FIG. **2** is a magnified view of part of the trilinear array component shown in FIG. 1;

FIG. **3** is a graphical representation of a trilinear array component;

FIG. **4** is a graphical representation of the scanning of a single row of pixels shown in FIG. 3;

FIG. **5** is a graph of visible and infrared light transmissivity;

FIG. **6** is a graphical representation of a scan of a single row of pixels by a trilinear array component with alternating visible and infrared light sources;

FIG. **7** is a graphical representation of a single row infrared scan at an increased resolution;

FIG. **8** illustrates an alternative representation of the information shown in FIG. **6** and indicates the color component not present;

FIG. **9** is a graphical representation of three pixels used in conjunction with a method for recovering missing color components;

FIG. **10** illustrates an alternate embodiment of a trilinear array;

FIG. **11** is a graphical representation of the color pattern generated by the trilinear array of FIG. **10**;

FIG. **12** is a graphical representation of a color pattern produced by a scanner in which no pixel lacks green; and

FIG. **13** is a perspective view of an illuminating light source.

DETAILED DESCRIPTION

A suitable apparatus for practicing the present invention may be constructed by modifying the design of a typical single pass image scanner utilizing a trilinear array and a gas discharge tube that diffuses white light. About ten light emitting diodes ("LEDs") may be attached around the gas discharge tube in a pattern that does not directly interfere with the light path between the tube and the film substrate being illuminated. A suitable LED is an aluminum gallium arsenide LED manufactured by Cleairex Technology, Inc. of Plano, Tex. These LEDs may be pulsed in sync with every third scan of the scanner by an external computer programmed to monitor the operation of the scanner. Overall illumination of the substrate may need to be attenuated to avoid saturation. The attenuation may be accomplished by adding a 64% passing neutral density filter, such as a Kodak ND 0.3, to the optical path. After scanning the image, the processes described below are applied to the pixel data generated by the scanner to separate out the infrared channel, to reconstruct missing colors, and to apply surface defect correction. To reduce the amount of data to be processed, a simple data compression scheme may be used for color images that avoids the previously described inefficiencies of YUV color space while still providing less aliasing than the single color per pixel method common in color area array sensors.

Considering this embodiment of the invention in more detail, FIG. **1** shows a typical trilinear array component **100** used in a single pass scanner. A long rectangular window **102** in the component **100** exposes a line of sensor elements **104**, typically laid in parallel with a CCD shift register (not shown) to receive the charges from the sensor elements **104** and shift those charges to an amplifier (not shown). The amplifier is typically etched into the same silicon die as component **100**, which outputs the amplified signal through pin connectors **106** for further processing. In this type of scanner application, light from a lamp **110**, which may be a gas discharge tube, illuminates an image on a film substrate **112**. A specific point **114** on this image is focused with lens **116** onto a specific sensor element **118** within line **104** of the trilinear array **100**. Typically the film substrate **112** is moved perpendicularly to the direction of the line **104** (as shown by the arrow) to complete a two dimensional scan of the image.

FIG. **2** shows a magnified view of the trilinear array component **100** of FIG. **1**. As seen in FIG. **2**, the rectangular window **102** contains three separate sensor lines **202**, **204**, and **206**, each of which consists of many individual sensing elements **210**. The sensor lines **202**, **204**, and **206** may each lie behind colored filters **222**, **224** and **226**, respectively, so that any illuminating light must pass through, and be affected by, these filters. Filter **222** over sensor line **202** passes both red and infrared light, filter **224** over line **204** passes green and infrared light, and filter **226** over line **206** passes blue and infrared light. The specific order and color of the colored filters **222**, **224** and **226** can be rearranged as desired.

In FIG. **3**, the layout of the sensors in the trilinear array **100** of FIG. **2** is represented graphically. The sensor line **302** under the blue selecting filter, called the blue column, consists of individual pixel sensors **304**. The spacing of these sensors **304** is referred to as the sensor row pitch **318**, and is usually the same as the pixel column pitch **320**. Similarly, there is a green column **306** and a red column **308**. The spacing of these columns is known as the sensor column pitch **322**. Typically, the sensor column pitch **322** is a power of two (such as 2, 4, 8, 16, 32, etc.) times the sensor row pitch **318** to allow easy reduction to scans at resolutions reduced from the highest resolution by powers of two. In a typical application, the ratio of sensor column pitch **322** to sensor row pitch **318** is 32, although a ratio of 4 is used in FIG. **3** for simplicity. In the representative trilinear array of FIG. **3**, a single sensor row **310** consists of a single red sensor **312**, a single green sensor **314**, and a single blue sensor **316**, each separated by the sensor column pitch **322**. In actual use, the image being scanned and the trilinear array move relative to each other in a direction perpendicular to the sensor lines. Individual scans of the image are made at increments of the pixel column pitch **320**, thereby producing a scanned image with image pixels spaced according to both the pixel column pitch **320** and the pixel row pitch **318**. This process creates scanned image information in a two-dimensional array of pixels wherein any specific pixel may be referenced by a column and row designation.

FIG. **4** illustrates the movement of and image data collection from a single sensor row **310** (originally shown in FIG. **3**) of a trilinear array. For purposes of illustration, the vertical axis in FIG. **4** represents the passage of time during a scan performed by sensor row **310**. At a first scan time **412**, the red sensor **414** aligns with pixel column 0 of the image, the green sensor **416** aligns with pixel column 4, and the blue sensor **418** aligns with pixel column 8. At the next scan time **420**, each of these sensors **414**, **416**, and **418** has moved to the right a distance equal to the pixel column pitch **320**. As is evident in FIG. **4**, pixel column 8 is the first column to be sensed by all three colored sensors. In order to complete the image scan, at some later point in time the trilinear array must reposition over the image to allow scanning of columns 0 through 7 by the green and blue sensors **416** and **418**. The first few columns which are not scanned by all the sensors before repositioning the sensor array define a distance referred to as the preamble **422**. After the scanning process has repeated a fixed number of times to fill the preamble **422**, each pixel column will have been sensed by all three colored sensors. Specifically, note that at pixel column 8, the red sensor **414** made a pass at time 8, the green sensor **416** made a pass at time 4, and the blue sensor **418** made a pass at time 0. In this way, a trilinear array can sense the red, green, and blue components of every pixel of an image even though the individual colored sensor columns do not lie directly on top of each other.

FIG. **5** illustrates a characteristic of almost all colored filters to pass infrared light to the sensors **414**, **416** or **418** of

FIG. 4. In particular, the thin colored filters used in typical trilinear arrays pass not only the colored light for which they were designed to be specific, but also any infrared light present at the time of the scan. The graph in FIG. 5 shows the transmissivity of light through blue, green and red filters versus the wavelength of the light. The blue filter transmits visible light at wavelengths between 400–500 nanometers as shown by curve **502**, and also transmits infrared light having wavelengths beyond 750 nanometers as shown at **504**. Curve **506** shows that a green filter transmits visible light at wavelengths between 500–600 nanometers, and also transmits infrared light as evidenced at **508**. Curve **510** illustrates that a red filter transmits visible light at wavelengths between 600–700 nanometers, and also transmits infrared light at **512**. To generate a scan in color, normally the infrared light must be removed from the illuminating light source. Alternatively, the light source may be functionally free of infrared light. This occurs when the amount of infrared light in the light source is known, such as 10%, and so may be mathematically removed from the scanned pixel information. For purposes of this disclosure, a light source which is functionally free of infrared light includes complete or partial elimination of infrared light from the light source. If the illuminating light source contains only infrared light, then all three sensors will transmit it. Thus, the scanner becomes an infrared scanner in which each pixel is scanned three times, once with each sensor line of the trilinear array.

FIG. **6** illustrates movement and data collection of a single sensor row **310** when the illuminating light source is alternately switched during the scan between a light source containing red, green, and blue (R, G, B), but no infrared light; and a light containing only infrared (I) light. Specifically, the visible light source is on for scans at times 0 and 1 (**602** and **604**, respectively). The illumination source then switches to infrared light for the scan at time 2 at **606**, and the cycle is repeated. As seen in FIG. **6**, this results in each pixel between the preamble **608** and postamble **610** being sensed in infrared light and in two of the three colors (red, green and blue). In particular, column 8 is sensed in infrared light and all colors except red, column 9 in infrared light and all colors except green, and column 10 in infrared light and all colors except blue. This sequence repeats across the image.

The scanning method shown in FIG. **6** uses a single pass scanner with a trilinear color sensor and a physically modified illuminating light source to generate a scan in which each pixel has an infrared record. This infrared record can be used to remove the effects of surface defects by dividing the visible records by the corresponding infrared records. More details on this method of surface defect correction may be found in U.S. Pat. No. 5,266,805 issued to the present inventor. Following surface defect correction, a relatively defect-free image remains in which each pixel is deficient in one of the three color components. However, these missing color components may be approximated from the adjacent color components which were detected by the corresponding color sensor.

The missing color components may potentially lower the quality of the scanned image. In practice, however, it has been found that negligible quality is actually lost if the missing color is estimated using methods disclosed below. This is because the important luminance resolution of a black and white image remains unaltered by discarding one of the three color components. The resolution reduction is confined entirely to the chrominance channel; however, as in television and JPEG compression, the color resolution can be significantly reduced relative to the luminance resolution.

Discarding one of the three color components provides true data compression that reduces the data size of an image while potentially losing negligible quality. In the case of a scanner, this type of data compression permits the addition of infrared-responsive surface defect correction without mandating the scan time penalty of making a fourth scan. With the method of FIG. **6**, the scanner proceeds at the same speed as in the non-infrared sensing method shown in FIG. **4**.

In situations where no data loss can be tolerated, the pixel column pitch can be reduced to produce a higher resolution scan. An interesting case results when the pixel column pitch is reduced to ⅔ of the pixel row pitch, so the loss of one of the three color components at each pixel is compensated with 3/2 the number of pixels. After this higher resolution scan, the image can be sized down so the resized pixel column pitch again matches the pixel row pitch. Of course, the increase in resolution does not need to be 3/2, but may be any convenient number. FIG. **7** illustrates the case where the resolution is doubled. In fact, it cannot normally be increased to 3/2. This may be explained as follows. If the ratio of the sensor column pitch **702** to the pixel column pitch **704** is "N," then in order for individual scans to align, "N" must be an integer. Furthermore, in order to distribute the infrared pixel information evenly, "N" must not be a multiple of three. If "N" were simply multiplied by 3/2 as a result of increasing resolution, then if "N" were still an integer, the product would have three as a factor. In practice, when "N" is a multiple of three, the resulting scan produces a cycle of two columns with red, green, and blue but no infrared pixel information, followed by a column with infrared information sensed three times. In the case illustrated in FIG. **6** where "N" is 4, "N" could be increased to 5, 7, or even 8 (as illustrated in FIG. **7**) but not to 6 or 9 if this problem is to be avoided.

FIG. **8** illustrates the topology of FIG. **6** in an alternative representation. The missing red color component in pixel column 8 of FIG. **6** is shown as $\bar{R}$ ("R bar" or "not R") at **802**. The missing colors in the other rows are analogously shown under a bar. FIG. **9** portrays a method for decompressing pixel data to recover missing color information when the illuminating light source is switched between visible and infrared light during image scanning (as previously described in conjunction with FIG. **6**). For purposes of illustration, the method is described for recovering green from a pixel missing green **902**, which lies between a pixel missing red **904** and a pixel missing blue **906**. Missing pixel color information is indicated in FIG. **9** by the first letter of the missing color in parentheses. This general method applies to any color combination by substituting the corresponding names for the missing colors. The simplest method of estimating the missing green pixel value G2 of the center pixel **902** is to average the green pixel values of the immediately adjacent pixels **904** and **906**.

An alternative embodiment for recovering the missing green pixel value of center pixel **902** is to use the known color pixel values of the surrounding pixels and their corresponding rates of change. Most images are primarily monochromatic, so red, green, and blue colors within a small region of the image tend to change with similar degree. In the example shown in FIG. **9**, the blue values B1 **908** and B2 **910** for the left and center pixels are known. The difference B2–B1 specifies how fast detail in the image is causing blue to change when moving from the left pixel **904** to the center pixel **902**. If it is assumed that the color green is changing across these same two pixels at about the same speed as the color blue changes, then the value of the green estimate of

G2 **912** originally obtained by averaging the green values of the adjacent pixels may be improved by adding the change in blue to G1 **914**, the left pixel, to give a new value of green for the center pixel G2B. Similarly, the estimate of G2 **912** may be improved by using the change in red between the right pixel R3 **916** and the center pixel R2 **918** to give an estimate of the change in green G2R based on the change in red. Averaging the two new estimates G2B and G2R gives an estimate for G2 **912** that is theoretically perfect for a monochrome image, and very good for real world images.

Additional variations on the data compression method described above are possible. For example, the difference in pixel color values may be calculated in the logarithmic domain which has the effect of multiplying G1 **914** by the ratio of B2 **910** over B1 **908** to produce the estimate G2B. This causes the estimate of green for the center pixel **902** to track the percentage change of blue when moving from the left pixel **904** to the center pixel **902** rather than using just the absolute difference. This variation gives a good prediction for any image that is constantly colored, but may introduce noise in the missing primary of saturated colors. Yet another mathematical variation on the method uses the square root domain. The square root domain provides a compromise between the linear and logarithmic cases, and most images are stored in computer memory in this mode. The use of the word "subtraction" in the previously described methods is generally meant to include all such differencing operations described above. A further refinement of the method of FIG. **9** acknowledges that the colors, on average, do not all change exactly the same. This is done by multiplying the change in blue B2–B1 and in red R2–R3 by a factor close to, but less than unity, for example 0.9. The value for the factor can be calculated based on the correlation between the colors in an adjacent region around the missing color element.

Often in a data compression method, it is not desirable to treat all pixel data in a given column of an image exactly alike. FIG. **10** shows an alternate topology of a trilinear array in which pixels of the even sensor rows, such as row 2 at **1002**, are offset by one pixel spacing from the odd sensor rows, such as row 3 at **1004**. This array produces the missing color pattern illustrated in FIG. **11**. Recovery of the missing colors could proceed using any of the methods described in conjunction with FIG. **9**. Furthermore, recovery could also use the differences from pixels above and below, rather than just to the left and right of each pixel, because the pixels above and below are missing a color different from the one being calculated. For example, to estimate the missing green information of pixel **1102**, one can add the change in blue from pixel **1104** to **1102** to the green of pixel **1104** to give a top green estimate; add the change in blue from pixel **1106** to pixel **1102** to the green of pixel **1106** to provide a bottom green estimate, and average these with the left and right estimates as previously described to give an improved estimate of the missing green data of pixel **1102**.

Other trilinear array topologies are possible. For example, in the sensor of FIG. **10**, row 0 and 1 can remain as shown, but row 2 may be offset two pixel columns to the right of row 0. This pattern may be repeated so row 3 is again aligned with row 0, row 4 is offset one pixel to the right, and row 5 is offset two pixels to the right. This produces a sensor pattern in which the missing color of the pixel directly above a given pixel is different than the missing color of the pixel directly below that given pixel. Still other sensor offsets are possible with the intent of more randomly dispersing the missing colors throughout the image. Such an offset helps reduce or prevent a sequence of vertical lines in the scanned image which would be likely to create a moire effect.

FIG. **12** portrays a pattern of missing pixels in which no pixel lacks green, but in which red and blue are each missing throughout the scanned image in a complementary checkerboard pattern. All color differences are calculated relative to green in estimating the red and blue missing colors. Such a green priority pattern provides the data compression described herein with less image quality loss.

In general, the reconstruction of missing colors can be performed on the image as it is scanned. Then, after reconstruction of each color, including the reconstructed color, is divided by the associated infrared information to perform surface defect correction. Alternately, each color can be divided by the associated infrared data to perform surface defect correction as soon as it is scanned, and then after surface defect correction the reconstruction of missing colors performed on the defect corrected scanned colors.

As previously described, there is a need for illuminating light sources which are switched between infrared and visible in order to practice this invention. Typical switchable visible light sources include a pure gas discharge tube, such as xenon, or light emitting diodes. In a more typical scenario the illuminating light contains a visible source that cannot be rapidly switched. Visible light sources such as incandescent lights glow with heat for several milliseconds after the power is removed. Visible light sources such as mercury vapor discharge tubes glow for several milliseconds after the power is removed because of the phosphor used to convert the ultraviolet light of mercury into visible light. Thus, even though the ultraviolet and mercury frequency band components turn off rapidly, the phosphor continues to glow with visible light for some time.

FIG. **13** illustrates an illuminating light source **1300** consisting of a mercury discharge tube **1302** surrounded by infrared light emitting diodes **1304**. The tube power source/controller **1306** operates the discharge tube **1302** while the LED power source/controller **1308** manages the operation of the LEDs. By surrounding the tube **1302** with the diode light sources **1304**, the milky white phosphor in the tube tends to diffuse the infrared light emitted by the diodes **1304** so the infrared and visible light appear to radiate from the same directions. This uniformity in source light emission is important to accurate surface defect correction. The illuminator can be driven by leaving the visible light source **1302** on for all scans and switching the infrared source **1304** on for every third scan, as has been previously described herein. When this is done, the infrared record will also contain visible light data corresponding to the "missing" color because that is the color of the filter over the sensor making the infrared scan. The overall illumination must be adjusted so the visible light plus the infrared light will not saturate the sensor. To reduce the amount of visible light contamination, the sensitivity of the array may be decreased. This can be accomplished by shortening the integration time and/or by increasing the infrared illumination.

When using the illuminator **1300** disclosed in FIG. **13** with the visible light source **1302** constantly on, the following steps will ensure proper scanning and surface defect correction. First, the "missing" color for each pixel is calculated from the adjacent pixels as before. The estimated value for that color is then subtracted from the sensed value which includes measurements of the "missing" color in addition to the infrared information. After the subtraction, this yields recovered infrared-only information for the pixel. The final step in the process is to divide the three colors for each pixel, including the two measured colors and one estimated color, by the recovered infrared information to perform surface defect correction.

In an alternate embodiment, the gas discharge lamp **1302** can be switched off during the infrared scan. This would attenuate, but not eliminate, the contamination of the infrared measurement by visible light. The mercury bands and different phosphor components each have different persistence, so each of the three color components red, green, and blue, decays to a different degree. Typically blue light will decay fastest, and hence exhibit the least contamination, while red light decays the slowest. When using such a switched illuminator, the estimated value for the "missing" color is calculated as previously explained; however, before being subtracted from the infrared record, it is first multiplied by a constant known by measurement to represent the amount of that color remaining after the visible light source is extinguished. Typical values for the constant would be 0.2 for blue, 0.5 for green, and 0.6 for red. By switching the visible light source off during the infrared scan, there is less contamination, and therefore less to be subtracted. This also helps to reduce noise and saturation problems.

Although the present embodiment has been described with a fluorescent visible source and an LED infrared source, there are many choices for visible and infrared sources. An alternate embodiment contemplates an unswitched incandescent lamp behind a rotating filter wheel that removes infrared with a filter for two scans, and passes only infrared with a second filter for the third scan. In this embodiment, the filter wheel must be synchronized with the sensor. In another version, a visible fluorescent source can be supplemented with an incandescent source behind a filter passing only infrared light, and further behind a rotating wheel or shutter that passes the infrared light only for the infrared scan. There are many combinations of visible sources, infrared sources, filter wheels :and shutters, and these are meant only to illustrate some of the many ways to provide the required light source in which infrared light is switched on alternating with, or in addition to, visible light.

The present invention has been described with a trilinear CCD array having a pulsed infrared source to generate the infrared image. However, high speed scanners such as the Tamron Fotvix utilize an area array to avoid the time required for mechanical movement of a linear array. These area array scanners typically employ a matrix of tiny color filters over each element of the area array to sense the color image. Typically, all of the filters pass infrared light. Because the image presented to the sensor array of the present embodiment must be free of infrared light, the infrared component is removed by a filter in the light path. To use a single chip area array, two scans are performed: a conventional visible scan containing no infrared light, and a second infrared scan containing infrared light. Because all colored filters typically pass infrared light, the second scanned image has an infrared value for each pixel of the image. By dividing the visible values sensed for each pixel by the infrared values sensed for each pixel, surface defect correction may be practiced. The surface defect corrected image under the color matrix is then processed conventionally to recover the full color image.

In another embodiment using an area array, the visible light source is extinguished for the infrared scan, and the infrared light source is extinguished for the visible scan. This may be done with two light sources which are alternately excited. The infrared source can be a group of infrared LEDs, and the visible source can be a xenon discharge lamp although many other sources known in the art can be substituted to produce visible and infrared light. Alternatively, the light sources could be placed behind shutters to obviate switching each source itself. In still another alternate embodiment, a single source containing both visible and infrared light such as an incandescent lamp could be placed behind a filter wheel to alternately pass only visible light and only infrared light. In such an embodiment, the visible value sensed for each pixel is then divided by the infrared value sensed for that pixel. Finally, the resulting color matrix is decoded into full color.

In an alternate version of the present invention using an area array, the visible light is not extinguished during the infrared scan so the infrared scan also contains some visible light. The visible light contained in the value sensed for each pixel during the infrared scan is canceled by subtracting the visible value sensed for that pixel in the visible scan to leave a value representing pure infrared. By dividing the visible value by the pure infrared value, surface defect correction may be implemented.

While this invention has been described with an emphasis upon certain preferred embodiments, variations in the preferred composition and method may be used and the embodiments may be practiced otherwise than as specifically described herein. Accordingly, the invention as defined by the following claims includes all modifications encompassed within the spirit and scope thereof.

What is claimed is:

1. A method for scanning an image on a substrate containing defects which uses a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, said method comprising:

illuminating the image at a first scan time with a first light source functionally free of infrared light;

sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image;

illuminating the image at a second scan time with a second light source containing infrared light;

sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

2. The method of claim **1** wherein the second light source substantially excludes light in the visible range.

3. The method of claim **2** wherein the first light source is a first switchable lamp, and the second light source is a second switchable lamp.

4. The method of claim **1** wherein the second light source emits light from a light emitting diode.

5. A method for scanning an image on a substrate containing defects which uses a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, said method comprising:

illuminating the image at a first scan time with a first light source functionally free of infrared light;

sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image, wherein the first group and second group of sensors are arranged in first and second parallel rows separated by an offset;

illuminating the image at a second scan time with a second light source containing infrared light;

sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

6. The method of claim **5** wherein the first scan time is one of a first sequence of scan times with light functionally free of infrared light and the second scan time is one of a second sequence of scan times in which the image is illuminated with a light source containing infrared light.

7. The method of claim **6** wherein the first sequence of scan times includes a first series of individual scan times spaced between a second series of individual scan times of the second sequence.

8. The method of claim **7** wherein the first and second series of individual scan times each comprises two individual scan times.

9. The method of claim **7** wherein the first and second series of individual scan times each comprises three individual scan times.

10. The method of claim **9** further comprising moving the parallel rows of sensors by an incremental amount in a direction perpendicular to the parallel rows between the individual scan times of the first sequence.

11. The method of claim **7** further comprising moving the parallel rows of sensors by an incremental amount in a direction perpendicular to the parallel rows between the individual scan times of the first and second sequences.

12. The method of claim **11** further comprising conducting individual scans of the second sequence based on the incremental amount so as to spatially overlay an individual scan of the first sequence.

13. The method of claim **12** wherein an individual scan of the second sequence overlays two individual scans of the first sequence.

14. The method of claim **13** further comprising

conducting a first group of individual scans selective to infrared, green, and blue light at a first pixel row site;

conducting a second group of individual scans selective to infrared, red, and blue light at a second pixel row site adjacent to the first pixel row site; and

conducting a third group of individual scans selective to infrared, red, and green light at a third pixel row site adjacent to the second pixel row site.

15. The method of claim **14** wherein a value for green is calculated for a pixel at the second pixel row site.

16. The method of claim **14** wherein a value for red is calculated for a pixel at the first pixel row site, a value for green is calculated for a pixel at the second pixel row site, and a value for blue is calculated for a pixel at the third pixel row site.

17. The method of claim **15** wherein the calculation for a value of green in the second pixel row site includes the step of averaging the value for green in adjacent pixels in the first and third pixel row sites.

18. The method of claim **17** wherein the calculation further comprises calculating the change of red value in adjacent pixels between the first and second pixel row sites.

19. The method of claim **17** wherein the calculation further comprises calculating the change of red value in adjacent pixels between the first and second pixel row sites, and the change in blue value in adjacent pixels between the third and second pixel row sites.

20. A method for scanning an image on a substrate containing defects which uses a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, said method comprising:

illuminating the image at a first scan time with a first light source functionally free of infrared light;

sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image, wherein the first group of sensors is arranged in a two dimensional grid;

illuminating the image at a second scan time with a second light source containing infrared light;

sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

21. A method for scanning an image on a substrate containing defects which uses a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, said method comprising:

illuminating the image at a first scan time with a first light source functionally free of infrared light;

sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image, wherein the first color is red, the second color is green, and further comprising a third group of sensors behind a third filter material selective to blue light and infrared light;

illuminating the image at a second scan time with a second light source containing infrared light;

sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

22. A method for scanning an image on a substrate containing defects which uses a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, said method comprising:

illuminating the image at a first scan time with a first light source functionally free of infrared light;

sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image;

illuminating the image at a second scan time with a second light source containing infrared light, wherein the second light source also comprises visible light;

sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

23. The method of claim **22** wherein the first light source is a first lamp emitting visible light, and the second light source emits a mixture of light from the first lamp and light from a switchable infrared lamp.

24. The method of claim **23** wherein the switchable infrared lamp is a light emitting diode.

25. The method of claim **23** wherein the light from the switchable infrared lamp is calculated as a difference between the second light source and the first light source.

26. An apparatus for scanning an image on a substrate containing defects comprising:

a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light;

means for illuminating the image at a first scan time with a first light source functionally free of infrared light;

means for sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image;

means for illuminating the image at a second scan time with a second light source containing infrared light;

means for sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

means for generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

27. The apparatus of claim **26** wherein the second light source substantially excludes light in the visible range.

28. The apparatus of claim **27** wherein the first light source is a first switchable lamp, and the second light source is a second switchable lamp.

29. The apparatus of claim **26** wherein the second light source emits light from a light emitting diode.

30. An apparatus for scanning an image on a substrate containing defects comprising:

a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, wherein the first group and second group of sensors are arranged in first and second parallel rows separated by an offset;

means for illuminating the image at a first scan time with a first light source functionally free of infrared light;

means for sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image;

means for illuminating the image at a second scan time with a second light source containing infrared light;

means for sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

means for generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

31. The apparatus of claim **30** wherein the first scan time is one of a first sequence of scan times with light functionally free of infrared light, and the second scan time is one of a second sequence of scan times in which the image is illuminated with a light source containing infrared light.

32. The apparatus of claim **31** wherein the first sequence of scan times includes a first series of individual scan times spaced between a second series of individual scan times of the second sequence.

33. The apparatus of claim **32** wherein the first and second series of individual scan times each comprises two individual scan times.

34. The apparatus of claim **32** wherein the first and second series of individual scan times each comprises three individual scan times.

35. The apparatus of claim **31** wherein the parallel rows of sensors are moved by an incremental amount in a direction perpendicular to the parallel rows between the individual scan times of the first sequence.

36. The apparatus of claim **31** wherein the parallel rows of sensors are moved by an incremental amount in a direction perpendicular to the parallel rows between the individual scan times of the first and second sequences.

37. The apparatus of claim **36** wherein the incremental amount enables, in conjunction with the offset between parallel rows of sensors, individual scans of the second sequence to spatially overlay individual scans of the first sequence.

38. The apparatus of claim **37** wherein the incremental amount enables an individual scan of the second sequence to overlay two individual scans of the first sequence.

39. The apparatus of claim **38** wherein sites of overlay are pixel row sites, and wherein a first pixel row site includes individual scans selective to infrared, green, and blue light; a second pixel row site adjacent to the first pixel row site includes individual scans selective to infrared, red, and blue light; and a third pixel row site adjacent to the second pixel row site includes individual scans selective to infrared, red, and green light.

40. The apparatus of claim **39** further comprising means for calculating a value for green for a pixel at the second pixel row site.

41. The apparatus of claim **39** further comprising means for calculating a value for red for a pixel at the first pixel row site, a value for green for a pixel at the second pixel row site, and a value for blue for a pixel at the third pixel row site.

42. The apparatus of claim **40** wherein the means for calculating a value of green in the second pixel row site further comprises means for averaging the value for green in adjacent pixels in the first and third pixel row sites.

43. The apparatus of claim **42** wherein the means for calculating further comprises means for calculating the change of red value in adjacent pixels between the first and second pixel row sites.

44. The apparatus of claim **42** wherein the means for calculating further comprises means for calculating the change of red value in adjacent pixels between the first and second pixel row sites, and the change in blue value in adjacent pixels between the third and second pixel row sites.

45. An apparatus for scanning an image on a substrate containing defects comprising:

a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light, wherein the first color is red, the second color is green, and further comprising a third group of sensors behind a third filter material selective to blue light and infrared light;

means for illuminating the image at a first scan time with a first light source functionally free of infrared light;

means for sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image;

means for illuminating the image at a second scan time with a second light source containing infrared light;

means for sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

means for generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

46. An apparatus for scanning an image on a substrate containing defects comprising:

a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light;

means for illuminating the image at a first scan time with a first light source functionally free of infrared light;

means for sensing light of the first color with the first group of sensors to generate a first color image, and light of the second color with the second group of sensors to generate a second color image;

means for illuminating the image at a second scan time with a second light source containing infrared light, wherein the second light source emits visible light;

means for sensing infrared light with at least one of the first or second group of sensors to generate an infrared image; and

means for generating from the first color image, second color image, and infrared image, a corrected color image substantially free of the defects.

47. The apparatus of claim **46** wherein the first light source is a first lamp emitting visible light, and the second light source emits a mixture of light from the first lamp and light from a switchable infrared lamp.

48. The apparatus of claim **47** wherein the switchable infrared lamp is a light emitting diode.

49. The apparatus of claim **48** wherein the light from the switchable infrared lamp is calculated as a difference between the second light source and the first light source.

50. An apparatus for scanning an image on a substrate containing defects comprising:

a plurality of sensors arranged in groups, wherein a first group is behind a first filter material selective to a first color of light and infrared light, and a second group is behind a second filter material selective to a second different color of light and infrared light;

a first light source configured to illuminate an image at a first scan time with light functionally free of infrared light, wherein the first group of sensors sense the first color of the light to generate a first color image and the second group of sensors sense the second color of the light to generate a second color image;

a second light source configured to illuminate the image at a second scan time with infrared light, wherein at least one of the first or second group of sensors sense the infrared light to generate an infrared image; and

at least one computing device configured to generate a corrected color image from the first color image, the second color image, and the infrared image.

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