US006757828B1

(12) **United States Patent**
Jaffe et al.

(10) **Patent No.: US 6,757,828 B1**
(45) **Date of Patent: Jun. 29, 2004**

(54) **INDIGENOUS AUTHENTICATION FOR SENSOR-RECORDERS AND OTHER INFORMATION CAPTURE DEVICES**

(76) Inventors: **Jonathan E. Jaffe**, 1003 Bradford Blvd., Gallatin, TN (US) 37066; **Joel D. Goldhar**, 720 Foxdale Ave., Winnetka, IL (US) 60093; **Michael A. Warot**, 532 Florence, Hammond, IN (US) 46324

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 706 days.

(21) Appl. No.: **09/626,044**

(22) Filed: **Jul. 27, 2000**

(51) **Int. Cl.**[7] **H04L 9/00**
(52) **U.S. Cl.** **713/176**; 380/200; 380/258
(58) **Field of Search** 713/176, 168, 713/161, 200; 380/258, 229, 200, 54, 46; 348/207.99; 382/276, 312–313

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,499,294 A * 3/1996 Friedman 713/179
5,504,518 A * 4/1996 Ellis et al. 725/22
5,764,770 A * 6/1998 Schipper et al. 713/176
6,253,337 B1 * 6/2001 Maloney et al. 714/38
6,269,446 B1 * 7/2001 Schumacher et al. 713/176

* cited by examiner

Primary Examiner—Kim Vu
Assistant Examiner—Hosuk Song
(74) *Attorney, Agent, or Firm*—Welsh & Katz, Ltd.

(57) **ABSTRACT**

A method and system of authentication for sensor-recorders and other information capture devices is disclosed. In accordance with aspects of the current invention, a digital sample of the environment is obtained. From this sample and at least one parameter representative of at least one condition under which the sample was generated, a digital signature is created. This signature is stored in memory with the sample to be checked at a later time for authenticity. The file is checked for authenticity by generating a second signature from the file and comparing that signature to the original signature. If the two signatures are identical, the sample is considered authentic and if the two signatures are different, the sample cannot be authenticated.

6 Claims, 21 Drawing Sheets

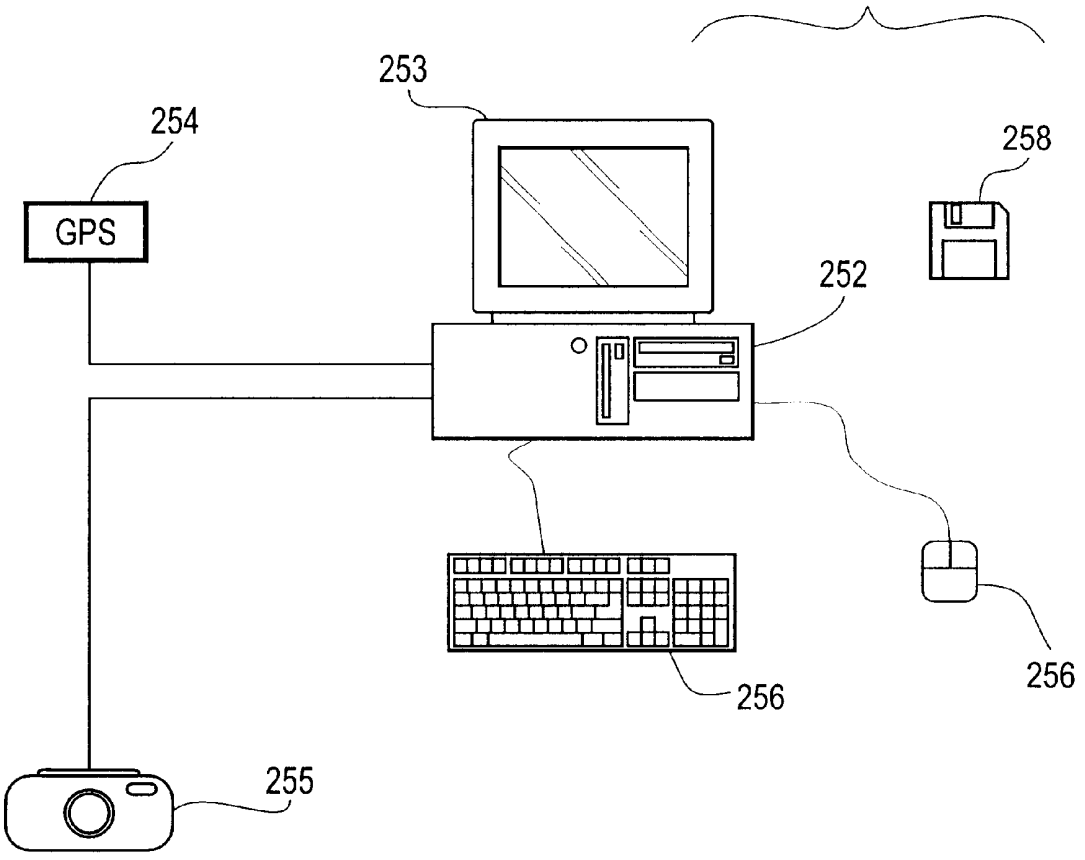


FIG. 1

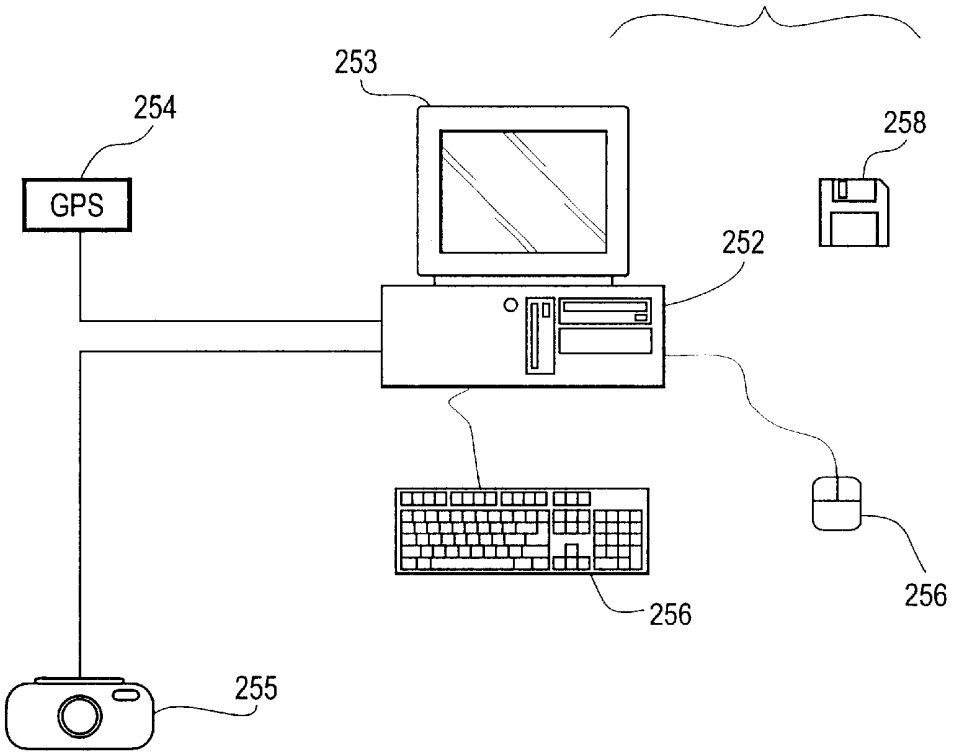


FIG. 2

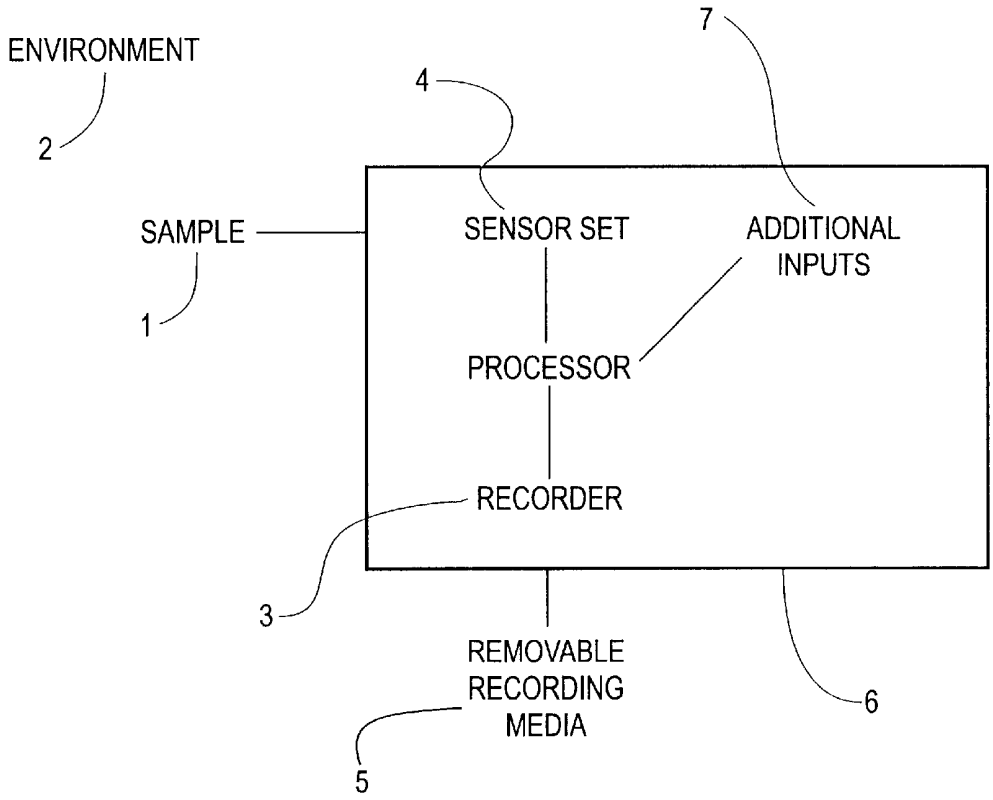
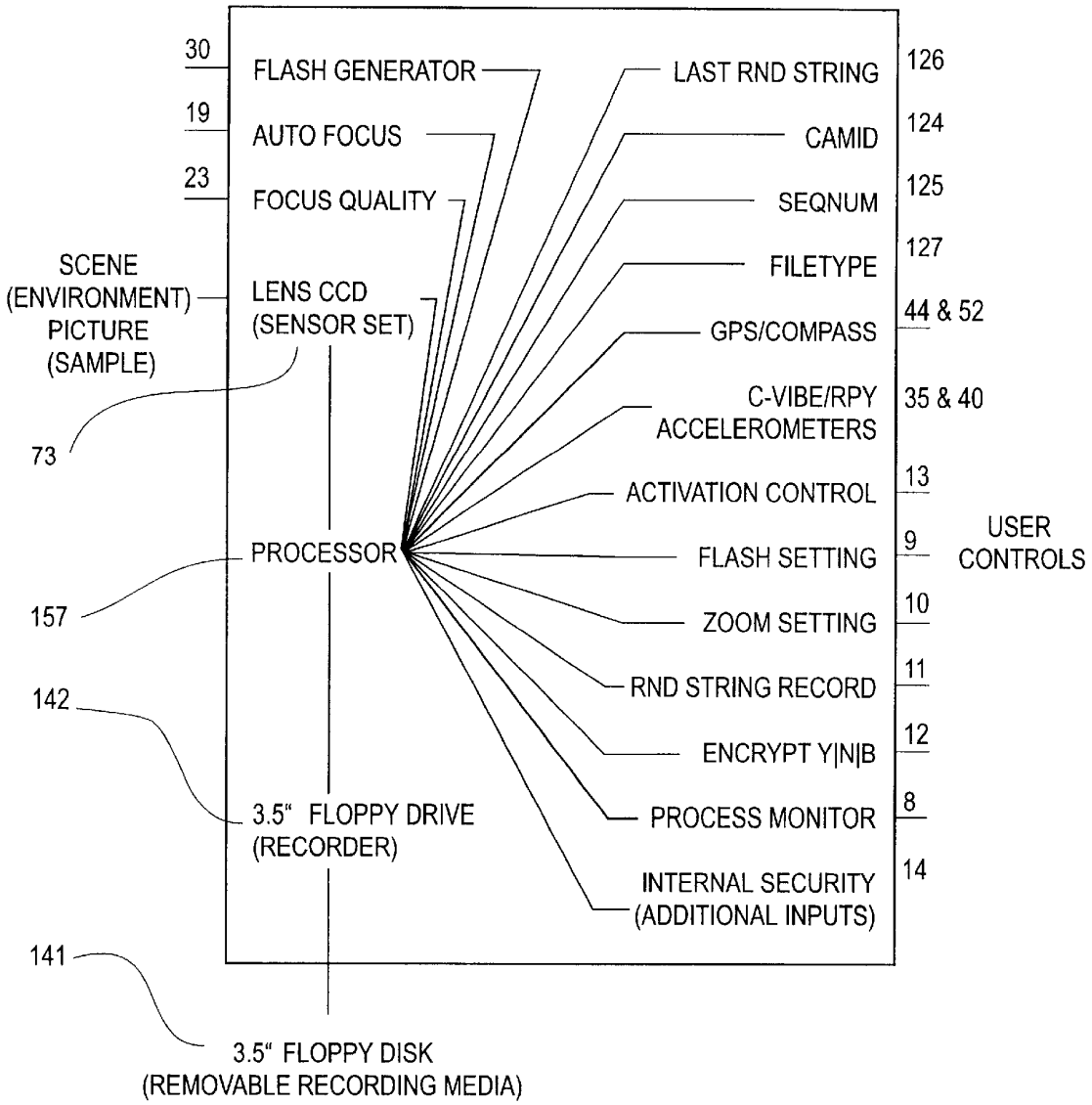

ENVIRONMENT
2
4
7
SAMPLE
1
SENSOR SET
ADDITIONAL INPUTS
PROCESSOR
RECORDER
3
REMOVABLE RECORDING MEDIA
5
6

FIG. 2A



GPS IS GEOPOSITIONING SYSTEM
C-VIBE IS THE COUNTER VIBRATION UNIT
RPY IS ROLL-PITCH YAW DETECTION
CAMID IS CAMERA IDENTIFICATION
SEQNUM IS SEQUENCE NUMBER

FIG. 3

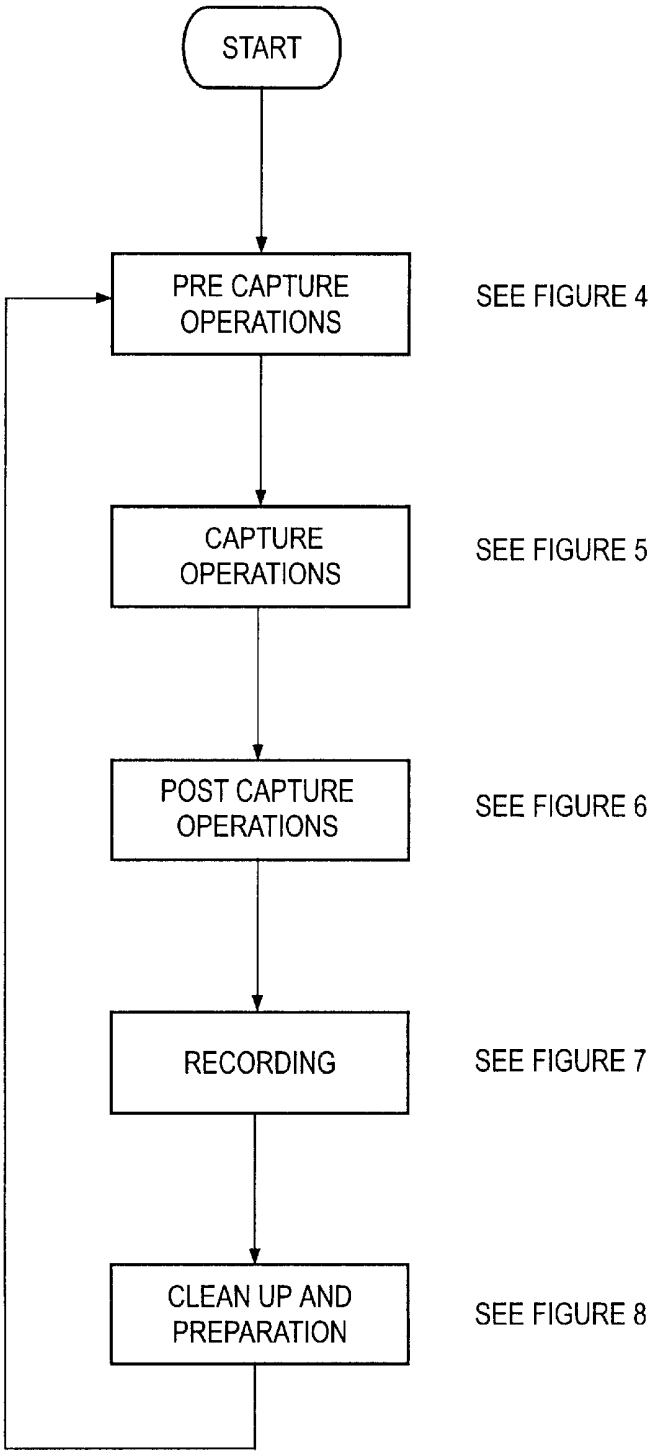
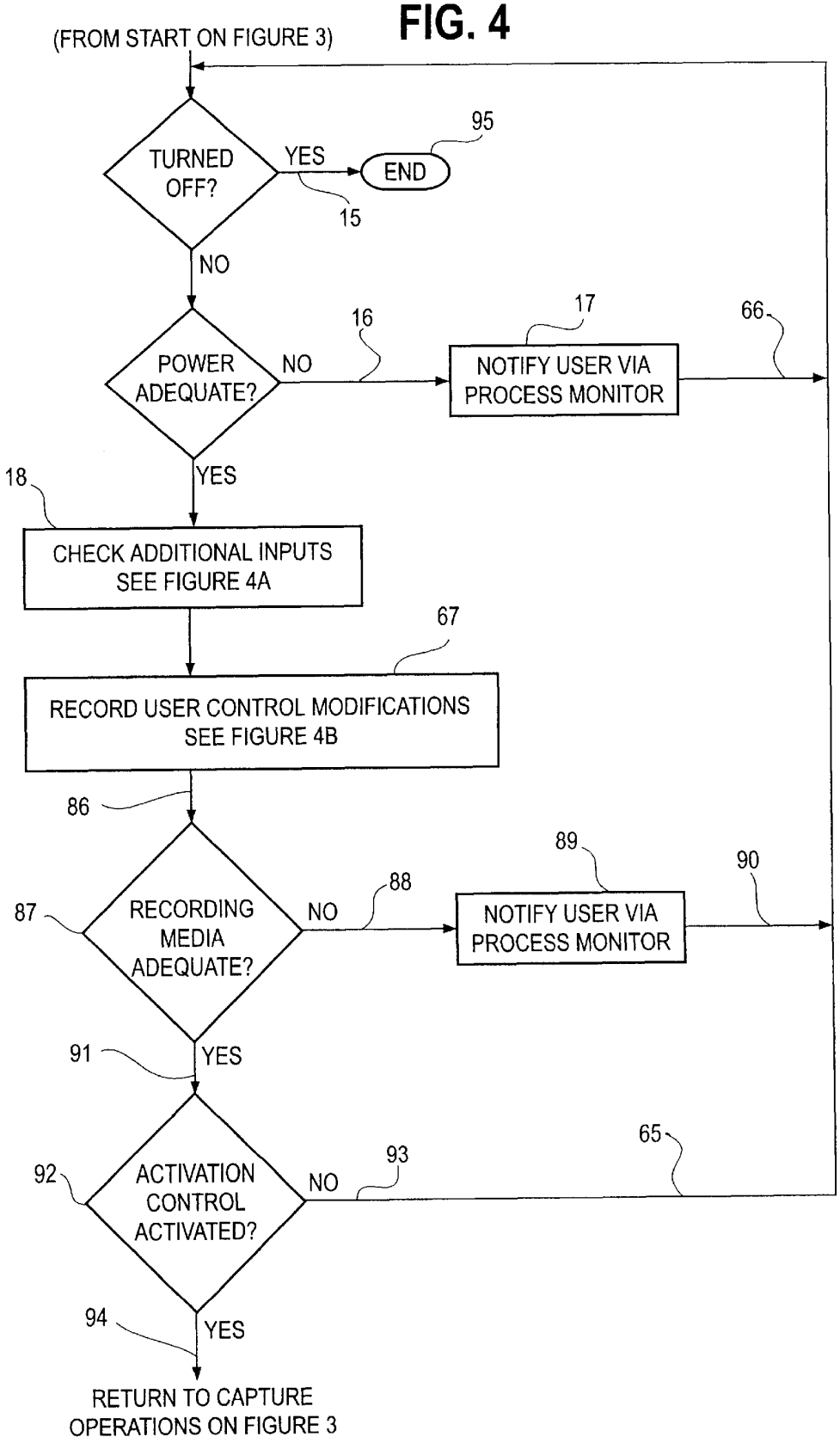
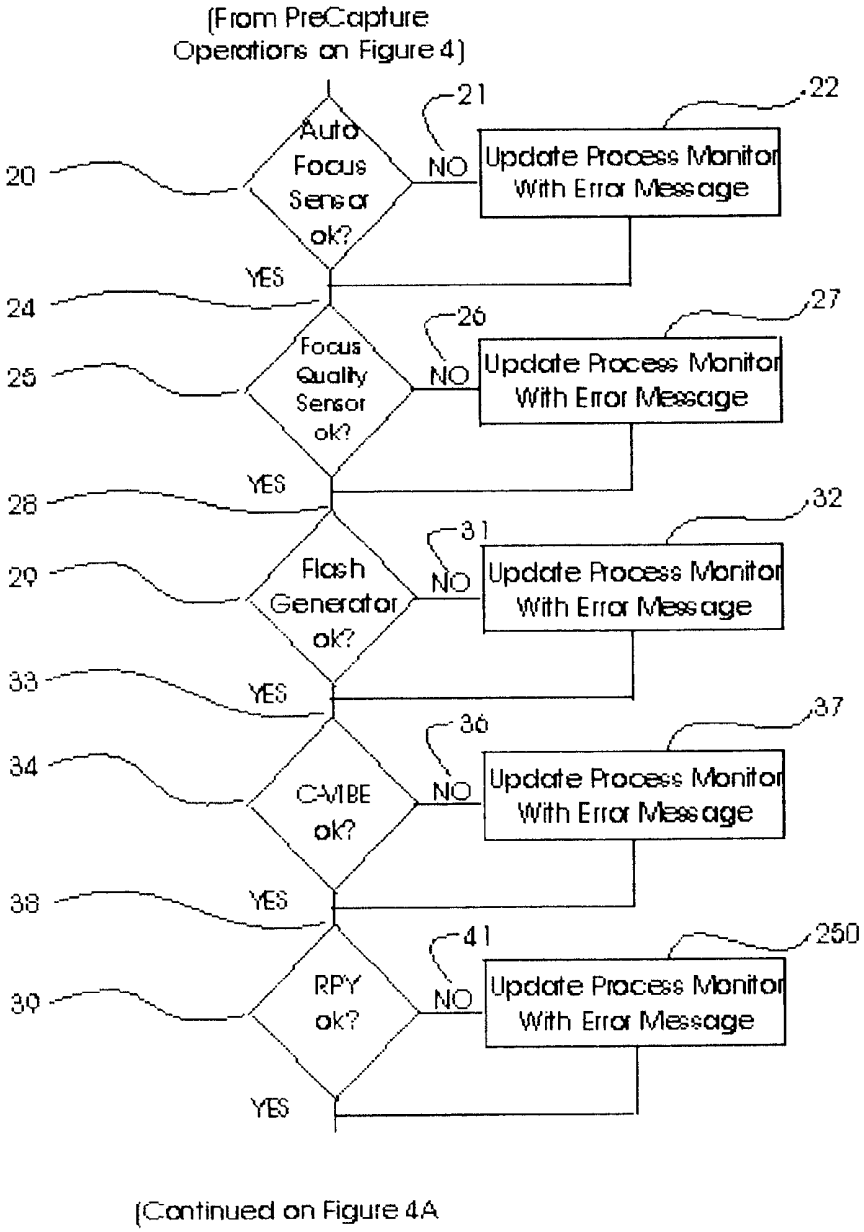

START
PRE CAPTURE OPERATIONS
SEE FIGURE 4
CAPTURE OPERATIONS
SEE FIGURE 5
POST CAPTURE OPERATIONS
SEE FIGURE 6
RECORDING
SEE FIGURE 7
CLEAN UP AND PREPARATION
SEE FIGURE 8

FIG. 4


(FROM START ON FIGURE 3)
TURNED OFF?
YES
END
95
15
NO
POWER ADEQUATE?
NO
16
17
NOTIFY USER VIA PROCESS MONITOR
66
YES
18
CHECK ADDITIONAL INPUTS SEE FIGURE 4A
67
RECORD USER CONTROL MODIFICATIONS SEE FIGURE 4B
86
RECORDING MEDIA ADEQUATE?
87
NO
88
89
NOTIFY USER VIA PROCESS MONITOR
90
91
YES
ACTIVATION CONTROL ACTIVATED?
92
NO
93
65
94
YES
RETURN TO CAPTURE OPERATIONS ON FIGURE 3



(Continued on Figure 4A

FIGURE 4A

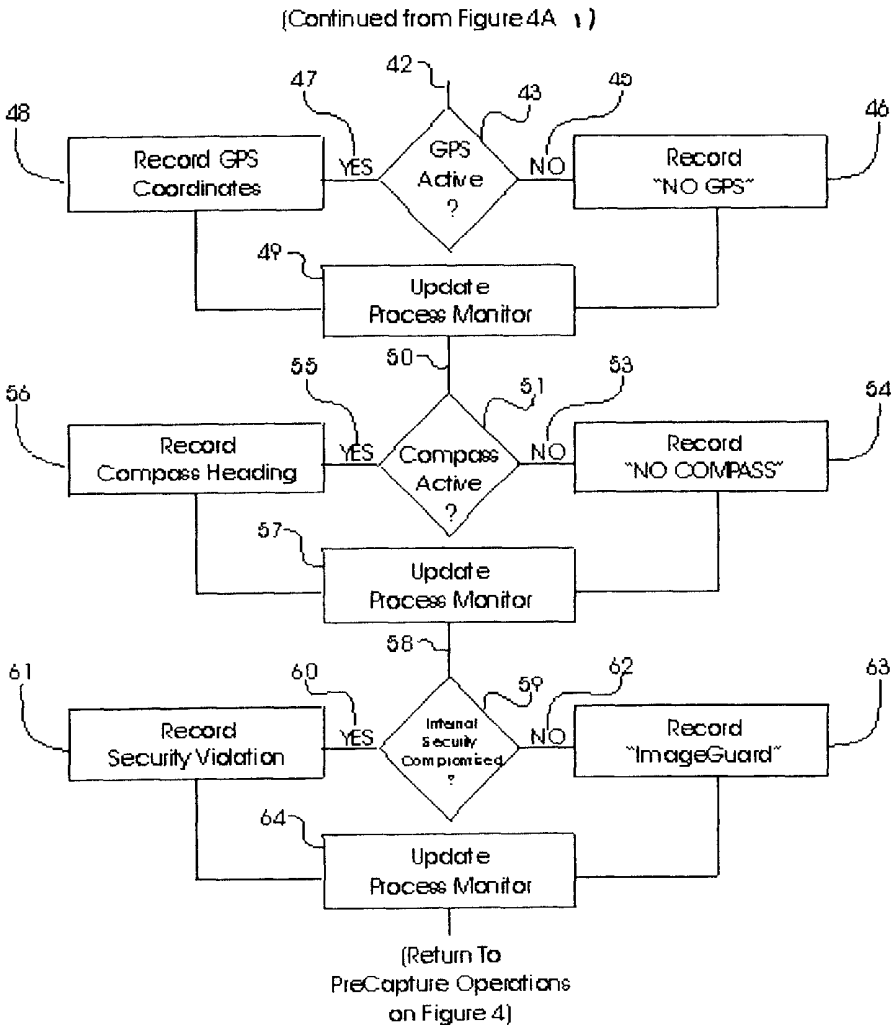

(Continued from Figure 4A 1)
42
47
43
45
48
46
Record GPS Coordinates
YES
GPS Active ?
NO
Record "NO GPS"
49
Update Process Monitor
50
55
51
53
56
54
Record Compass Heading
YES
Compass Active ?
NO
Record "NO COMPASS"
57
Update Process Monitor
58
61
60
59
62
63
Record Security Violation
YES
Internal Security Compromised ?
NO
Record "ImageGuard"
64
Update Process Monitor
(Return To PreCapture Operations on Figure 4)

FIGURE 4A2

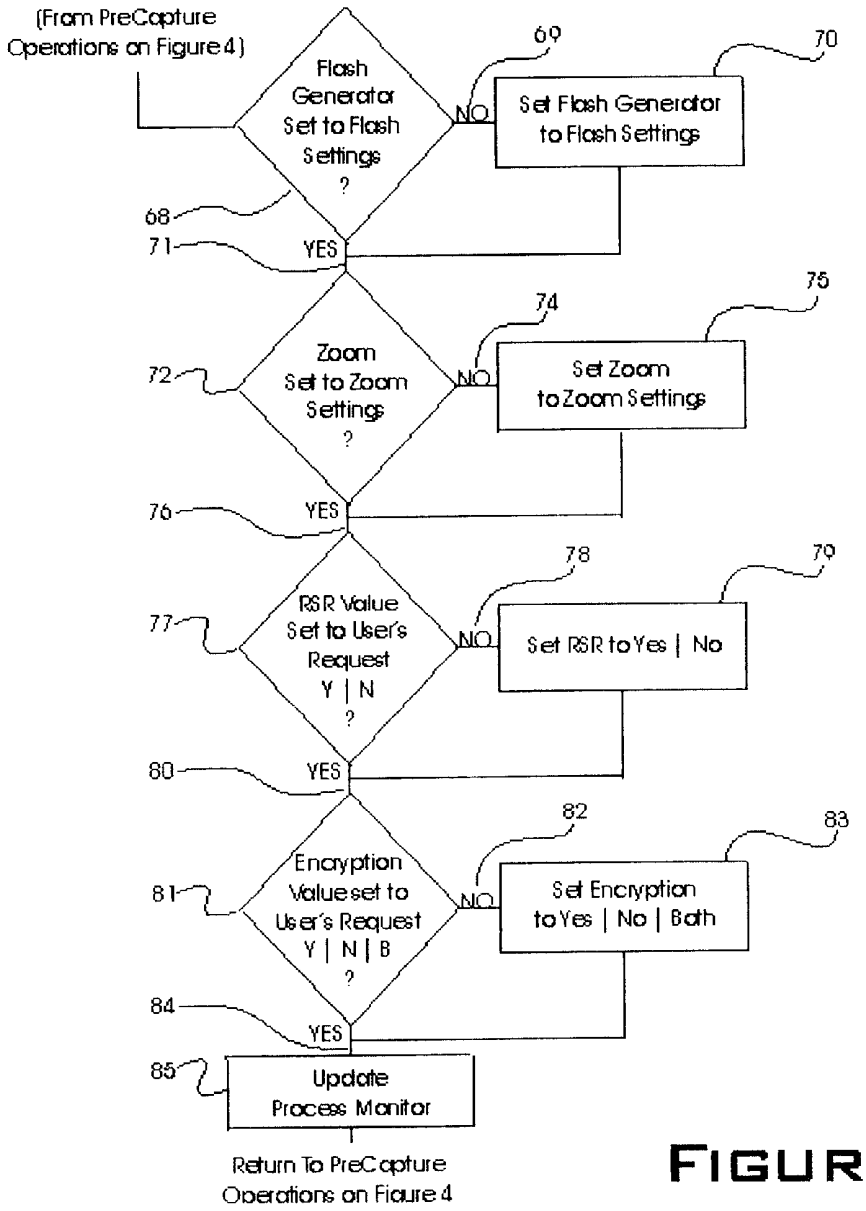

(From PreCapture Operations on Figure 4)
Flash Generator Set to Flash Settings ?
NO
69
Set Flash Generator to Flash Settings
70
68
YES
71
Zoom Set to Zoom Settings ?
72
NO
74
Set Zoom to Zoom Settings
75
YES
76
RSR Value Set to User's Request Y | N ?
77
NO
78
Set RSR to Yes | No
79
YES
80
Encryption Value set to User's Request Y | N | B ?
81
NO
82
Set Encryption to Yes | No | Both
83
YES
84
Update Process Monitor
85
Return To PreCapture Operations on Figure 4

FIGURE 4B

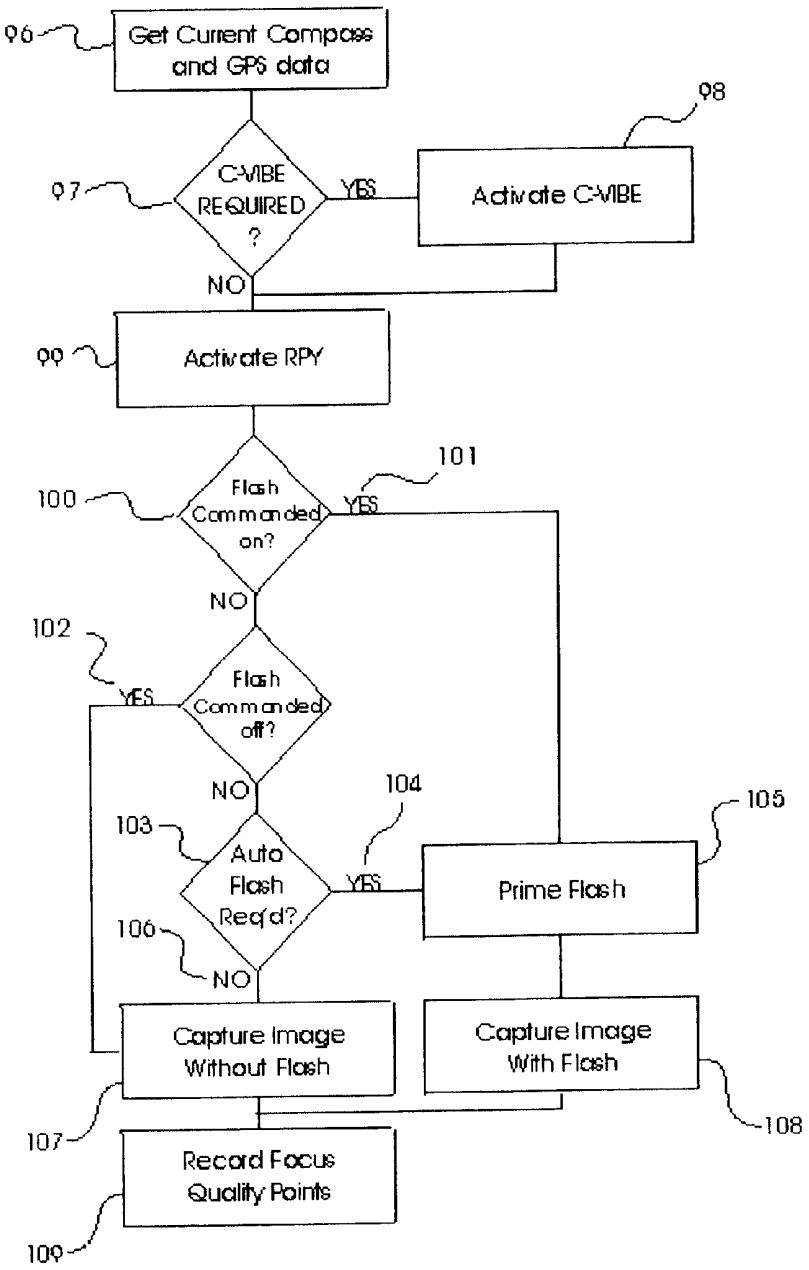
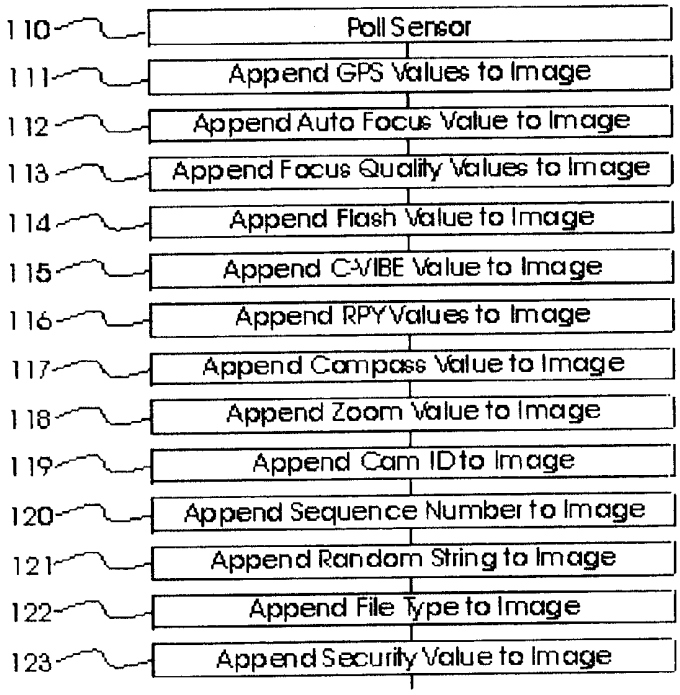

96
Get Current Compass and GPS data
98
97
C-VIBE REQUIRED ?
YES
Activate C-VIBE
NO
99
Activate RPY
100
Flash Commanded on?
101
YES
NO
102
YES
Flash Commanded off?
NO
104
103
Auto Flash Req'd?
YES
105
Prime Flash
106
NO
Capture Image Without Flash
Capture Image With Flash
108
107
Record Focus Quality Points
109

FIGURE 5



(Continued on Figure 6 B)

FIGURE 6

FIG. 6B

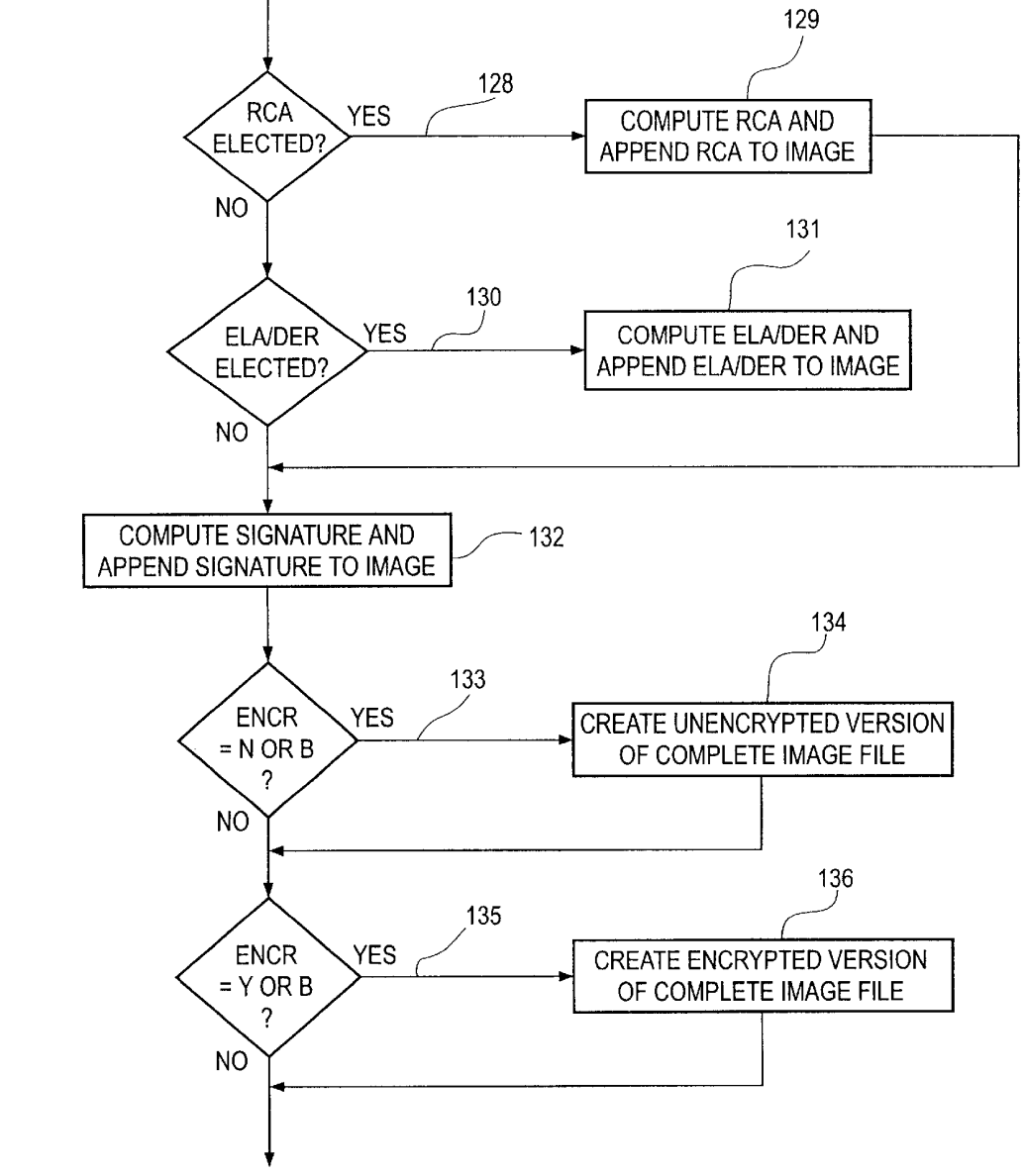

RCA ELECTED?
YES
128
129
COMPUTE RCA AND APPEND RCA TO IMAGE
NO
ELA/DER ELECTED?
YES
130
131
COMPUTE ELA/DER AND APPEND ELA/DER TO IMAGE
NO
COMPUTE SIGNATURE AND APPEND SIGNATURE TO IMAGE
132
ENCR = N OR B ?
YES
133
134
CREATE UNENCRYPTED VERSION OF COMPLETE IMAGE FILE
NO
ENCR = Y OR B ?
YES
135
136
CREATE ENCRYPTED VERSION OF COMPLETE IMAGE FILE
NO
END OF POST CAPTURE OPERATIONS

FIG. 7

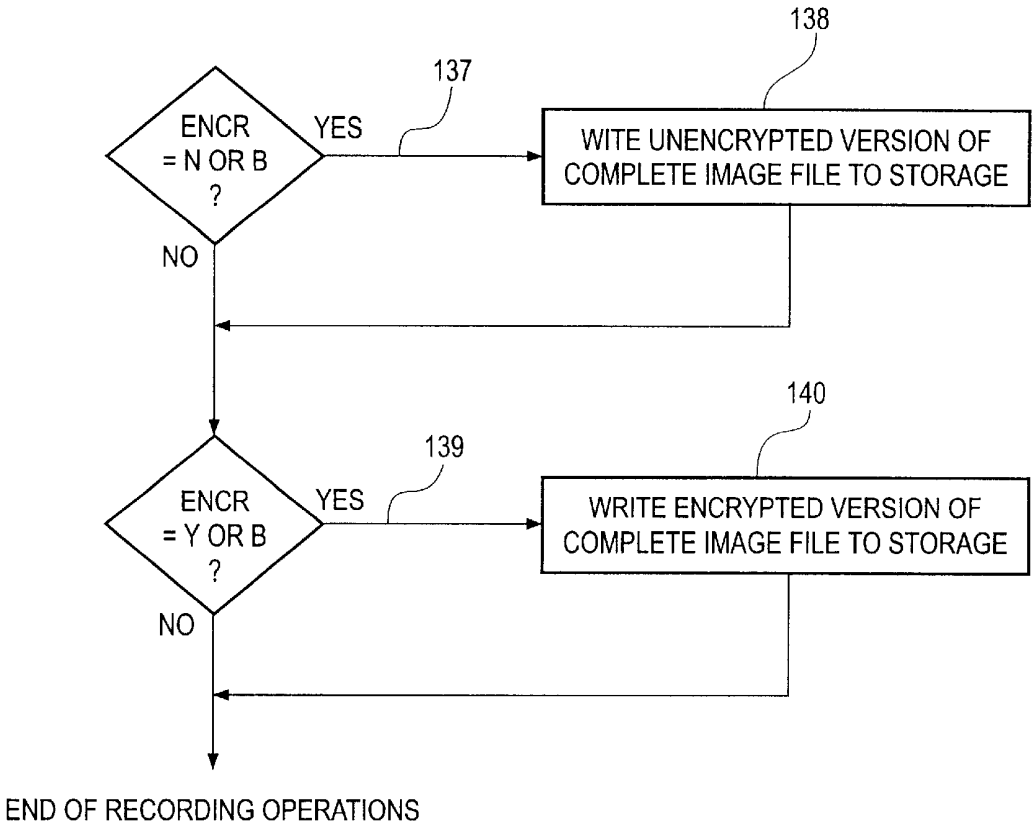
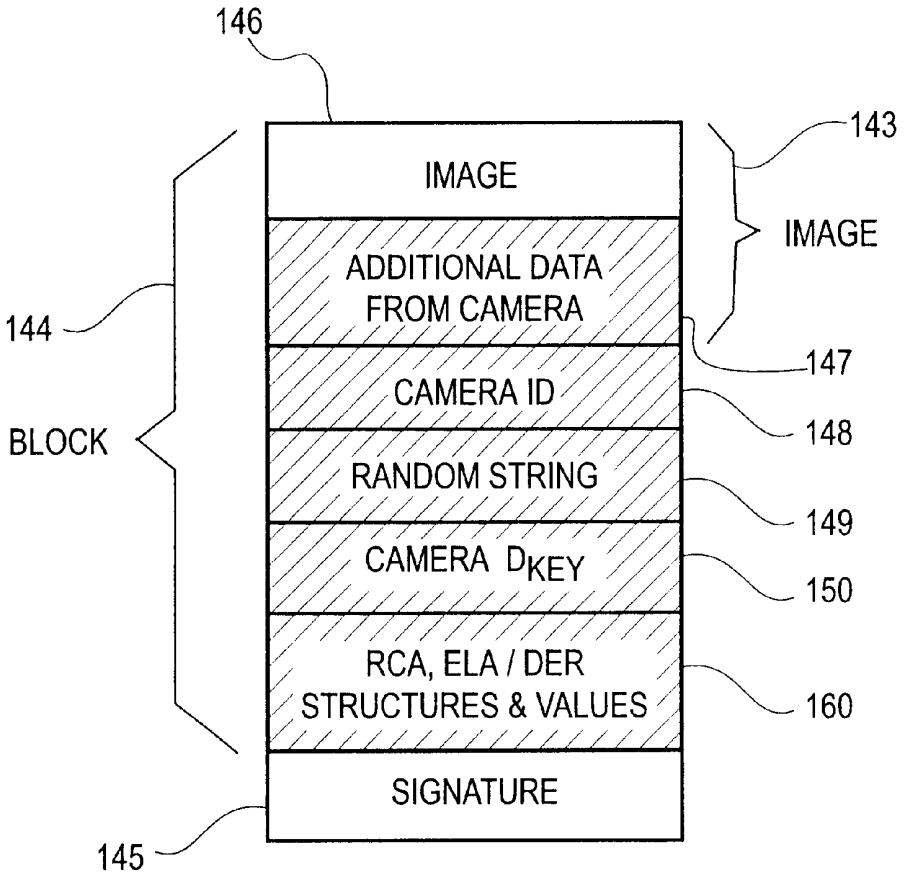

138
137
ENCR
= N OR B
?
YES
WITE UNENCRYPTED VERSION OF
COMPLETE IMAGE FILE TO STORAGE
NO
140
139
ENCR
= Y OR B
?
YES
WRITE ENCRYPTED VERSION OF
COMPLETE IMAGE FILE TO STORAGE
NO
END OF RECORDING OPERATIONS

FIG. 7A


146
143
IMAGE
IMAGE
ADDITIONAL DATA FROM CAMERA
144
147
CAMERA ID
148
BLOCK
RANDOM STRING
149
CAMERA D_{KEY}
150
RCA, ELA / DER STRUCTURES & VALUES
160
SIGNATURE
145

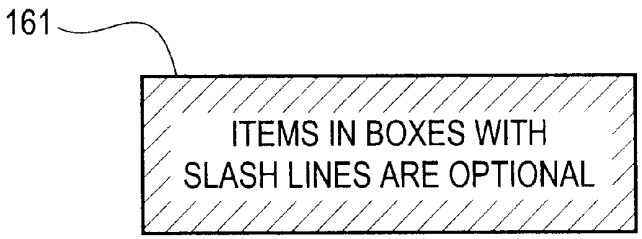

161
ITEMS IN BOXES WITH SLASH LINES ARE OPTIONAL

FIG. 8

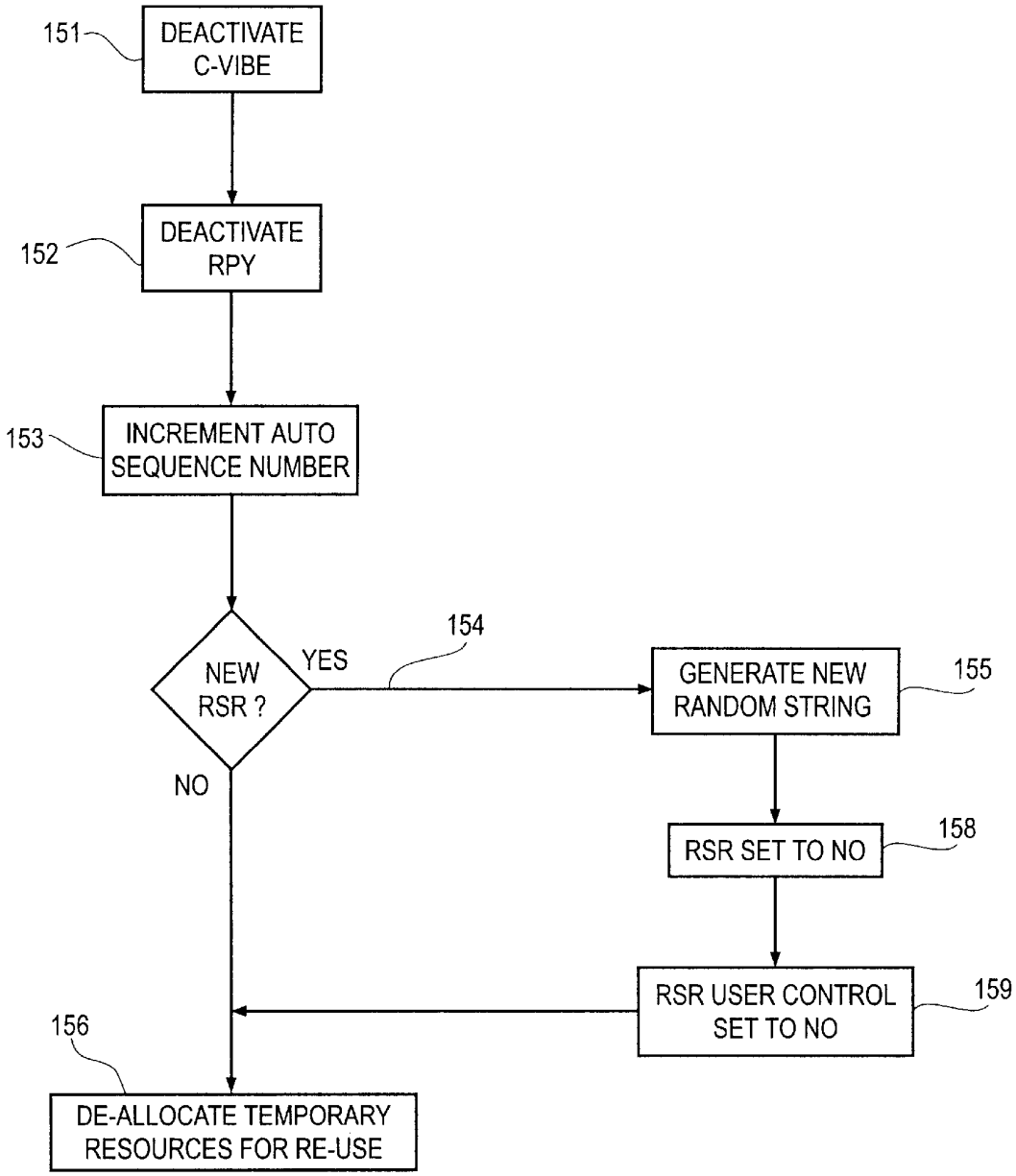
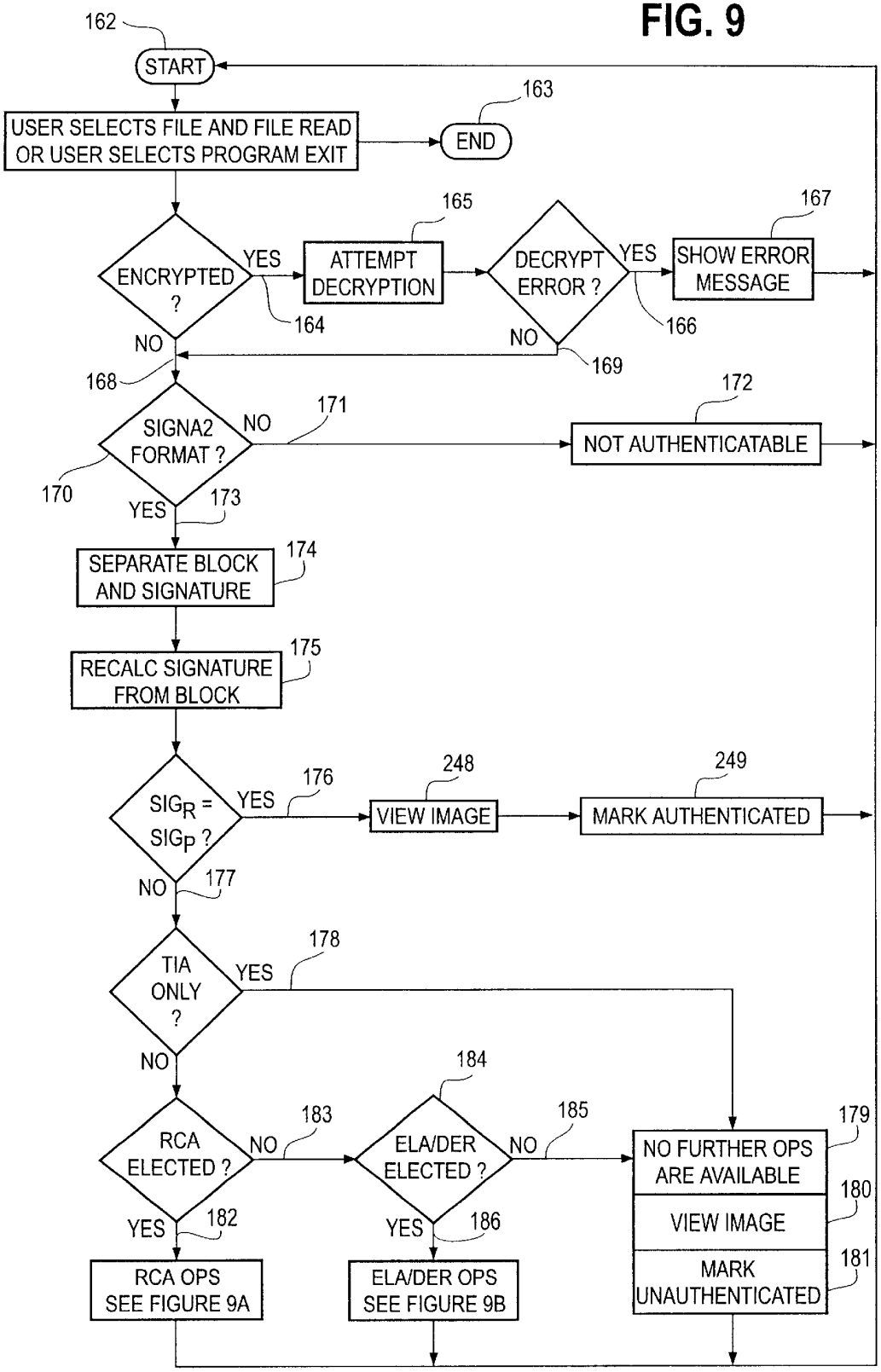

151
DEACTIVATE C-VIBE
152
DEACTIVATE RPY
153
INCREMENT AUTO SEQUENCE NUMBER
NEW RSR ?
YES
154
NO
GENERATE NEW RANDOM STRING
155
RSR SET TO NO
158
RSR USER CONTROL SET TO NO
159
156
DE-ALLOCATE TEMPORARY RESOURCES FOR RE-USE

FIG. 9


162
START
USER SELECTS FILE AND FILE READ OR USER SELECTS PROGRAM EXIT
163
END
ENCRYPTED ?
YES
165
ATTEMPT DECRYPTION
DECRYPT ERROR ?
YES
167
SHOW ERROR MESSAGE
164
166
NO
NO
169
168
SIGNA2 FORMAT ?
NO
171
172
NOT AUTHENTICATABLE
170
YES
173
SEPARATE BLOCK AND SIGNATURE
174
RECALC SIGNATURE FROM BLOCK
175
SIGR = SIGP ?
YES
176
248
VIEW IMAGE
249
MARK AUTHENTICATED
NO
177
TIA ONLY ?
178
YES
NO
184
RCA ELECTED ?
NO
183
ELA/DER ELECTED ?
NO
185
179
NO FURTHER OPS ARE AVAILABLE
180
VIEW IMAGE
181
MARK UNAUTHENTICATED
YES
182
YES
186
RCA OPS SEE FIGURE 9A
ELA/DER OPS SEE FIGURE 9B

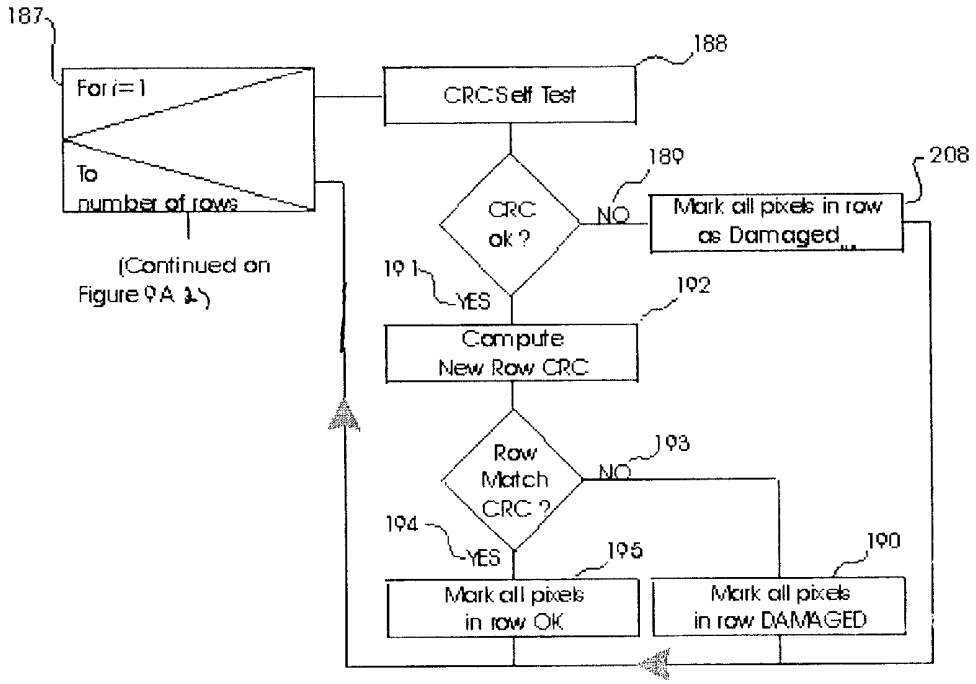

187
For i=1
To
number of rows
(Continued on
Figure 9A)
188
CRC Self Test
189
CRC
ok ?
NO
208
Mark all pixels in row
as Damaged
191
YES
192
Compute
New Row CRC
193
Row
Match
CRC ?
NO
194
YES
195
Mark all pixels
in row OK
190
Mark all pixels
in row DAMAGED

FIGURE 9A

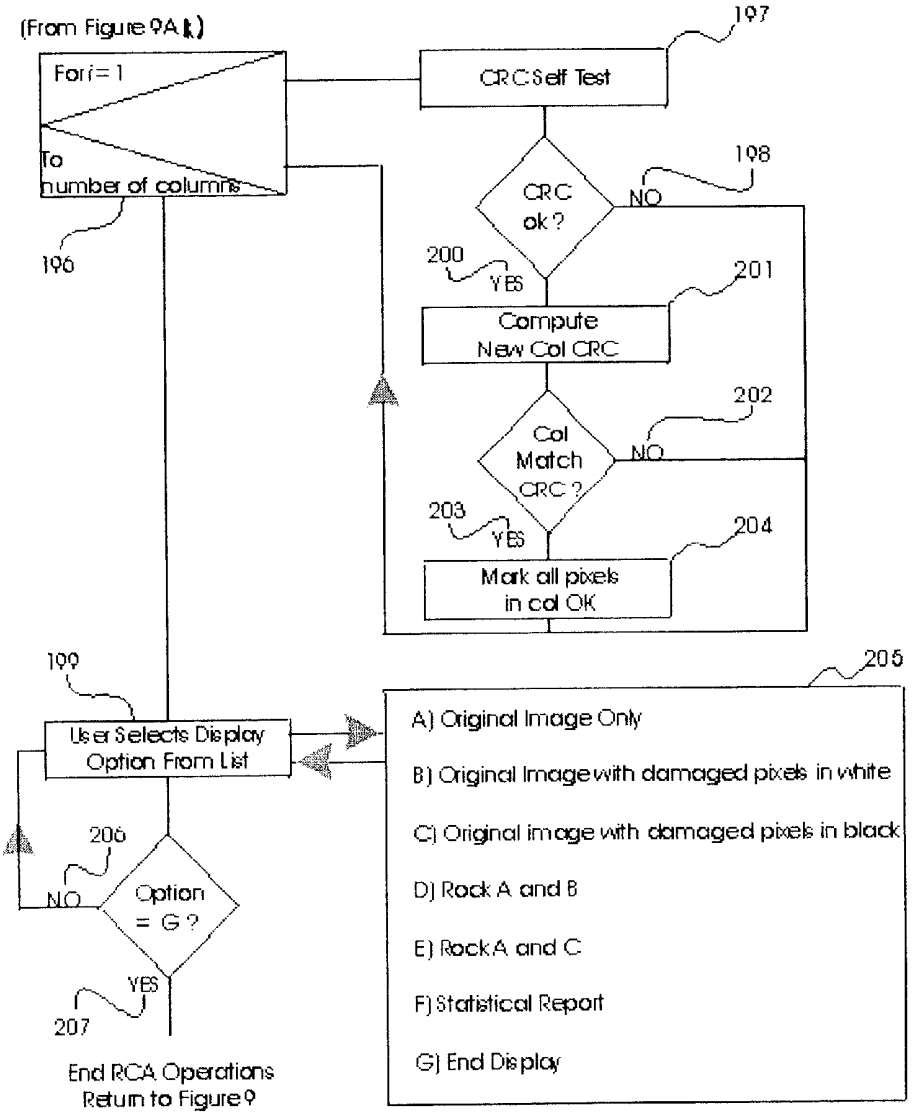

(From Figure 9A1)
For i = 1
To number of columns
196
CRC Self Test
197
CRC ok?
198
NO
200
YES
Compute New Col CRC
201
Col Match CRC?
202
NO
203
YES
Mark all pixels in col OK
204
199
User Selects Display Option From List
205
A) Original Image Only
B) Original Image with damaged pixels in white
C) Original image with damaged pixels in black
D) Rock A and B
E) Rock A and C
F) Statistical Report
G) End Display
206
NO
Option = G?
YES
207
End RCA Operations
Return to Figure 9

FIGURE 9A2

FIG. 9B-1

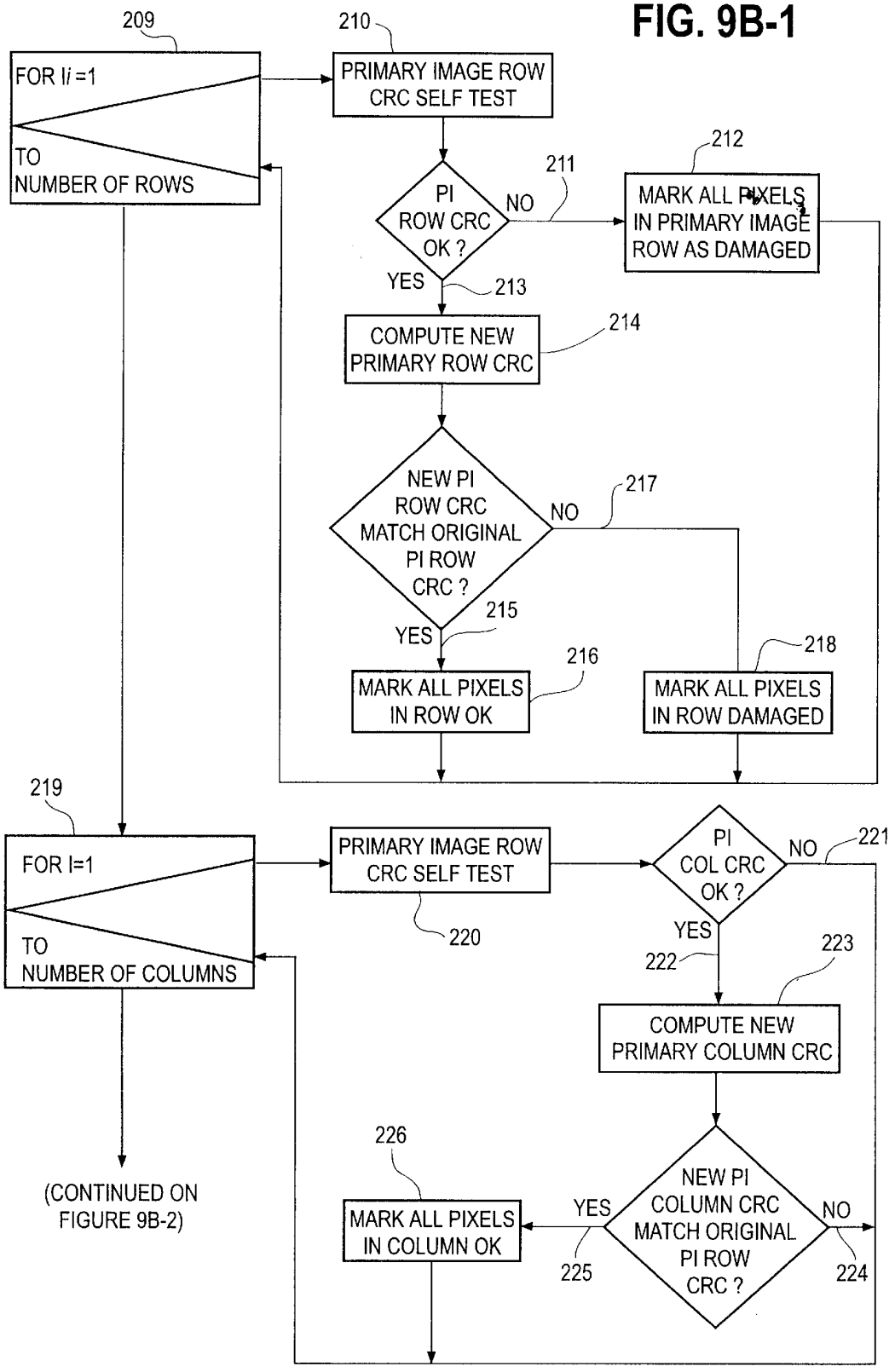
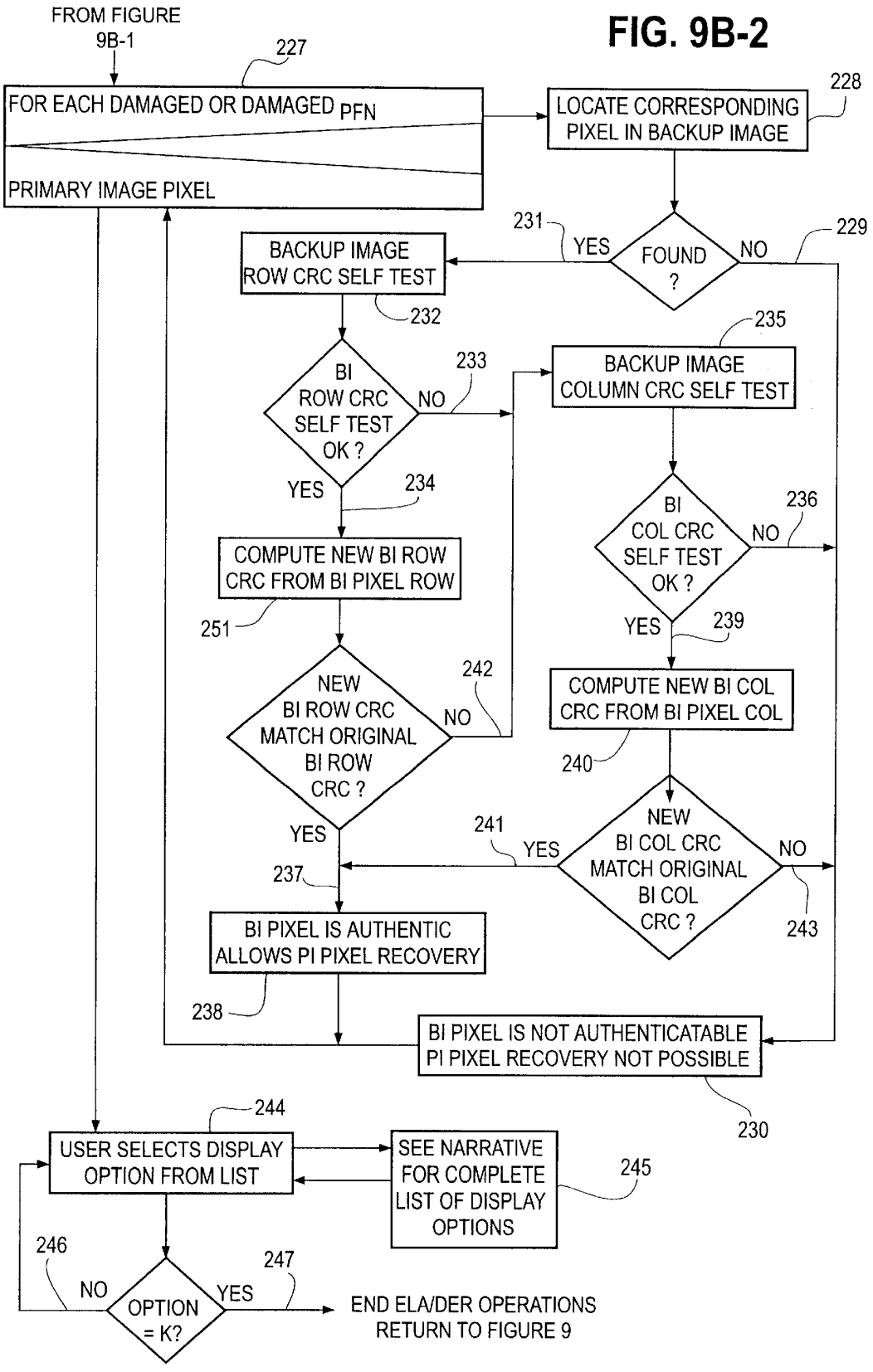

209
FOR I/ =1
TO
NUMBER OF ROWS
210
PRIMARY IMAGE ROW
CRC SELF TEST
PI
ROW CRC
OK ?
NO
211
212
MARK ALL PIXELS
IN PRIMARY IMAGE
ROW AS DAMAGED
YES
213
COMPUTE NEW
PRIMARY ROW CRC
214
NEW PI
ROW CRC
MATCH ORIGINAL
PI ROW
CRC ?
NO
217
YES
215
MARK ALL PIXELS
IN ROW OK
216
MARK ALL PIXELS
IN ROW DAMAGED
218
219
FOR I=1
TO
NUMBER OF COLUMNS
PRIMARY IMAGE ROW
CRC SELF TEST
220
PI
COL CRC
OK ?
NO
221
YES
222
223
COMPUTE NEW
PRIMARY COLUMN CRC
226
MARK ALL PIXELS
IN COLUMN OK
YES
225
NEW PI
COLUMN CRC
MATCH ORIGINAL
PI ROW
CRC ?
NO
224
(CONTINUED ON
FIGURE 9B-2)

FIG. 9B-2


FROM FIGURE 9B-1
227
FOR EACH DAMAGED OR DAMAGED PFN
PRIMARY IMAGE PIXEL
228
LOCATE CORRESPONDING PIXEL IN BACKUP IMAGE
231
YES
FOUND ?
NO
229
BACKUP IMAGE ROW CRC SELF TEST
232
235
BACKUP IMAGE COLUMN CRC SELF TEST
233
BI ROW CRC SELF TEST OK ?
NO
YES
234
COMPUTE NEW BI ROW CRC FROM BI PIXEL ROW
251
BI COL CRC SELF TEST OK ?
236
NO
YES
239
COMPUTE NEW BI COL CRC FROM BI PIXEL COL
240
NEW BI ROW CRC MATCH ORIGINAL BI ROW CRC ?
242
NO
YES
241
NEW BI COL CRC MATCH ORIGINAL BI COL CRC ?
YES
NO
243
237
BI PIXEL IS AUTHENTIC ALLOWS PI PIXEL RECOVERY
238
BI PIXEL IS NOT AUTHENTICATABLE PI PIXEL RECOVERY NOT POSSIBLE
230
244
USER SELECTS DISPLAY OPTION FROM LIST
SEE NARRATIVE FOR COMPLETE LIST OF DISPLAY OPTIONS
245
246
247
NO
OPTION = K?
YES
END ELA/DER OPERATIONS RETURN TO FIGURE 9

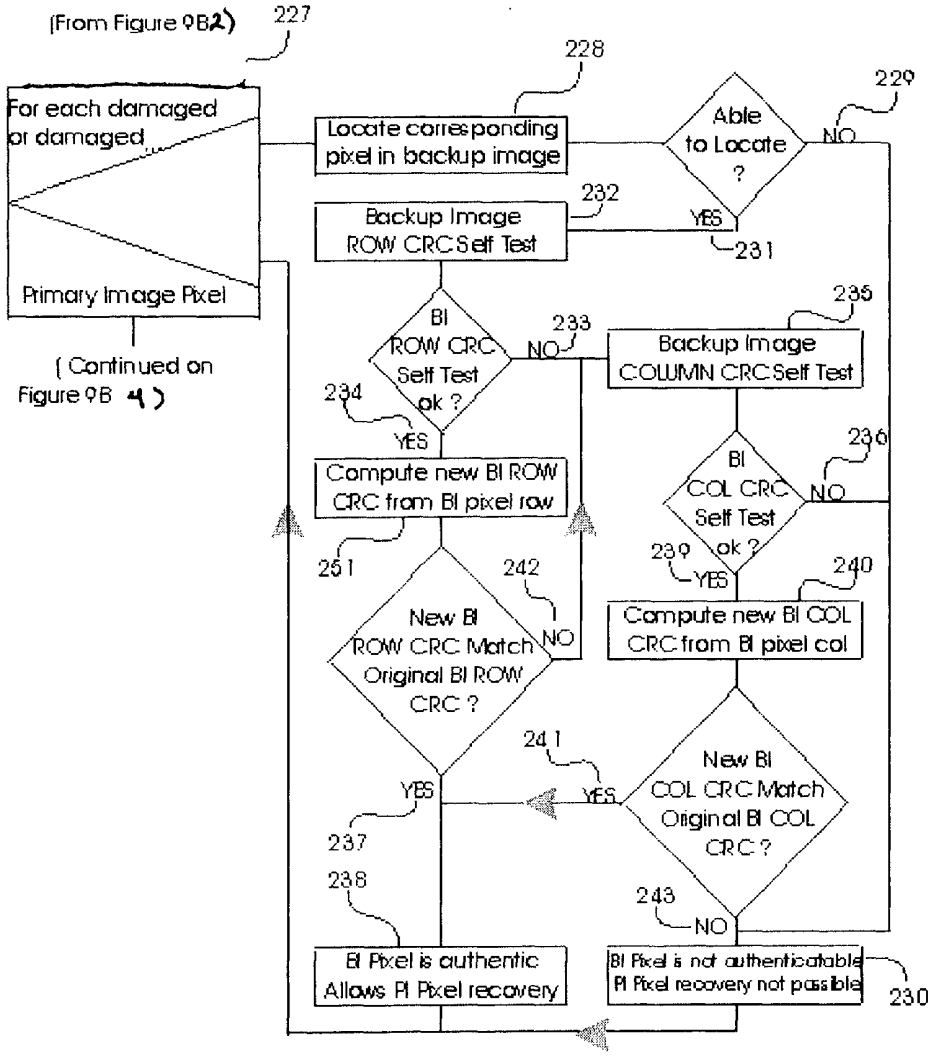

(From Figure 9B2)
227
For each damaged or damaged
Primary Image Pixel
(Continued on Figure 9B 4)
228
Locate corresponding pixel in backup image
229
Able to Locate ?
NO
YES
231
232
Backup Image ROW CRC Self Test
BI ROW CRC Self Test ok ?
233
NO
234
YES
235
Backup Image COLUMN CRC Self Test
BI COL CRC Self Test ok ?
236
NO
239
YES
240
Compute new BI COL CRC from BI pixel col
Compute new BI ROW CRC from BI pixel row
251
242
New BI ROW CRC Match Original BI ROW CRC ?
NO
241
YES
New BI COL CRC Match Original BI COL CRC ?
243
NO
YES
237
238
BI Pixel is authentic Allows PI Pixel recovery
BI Pixel is not authenticatable PI Pixel recovery not possible
230

FIGURE 9B3

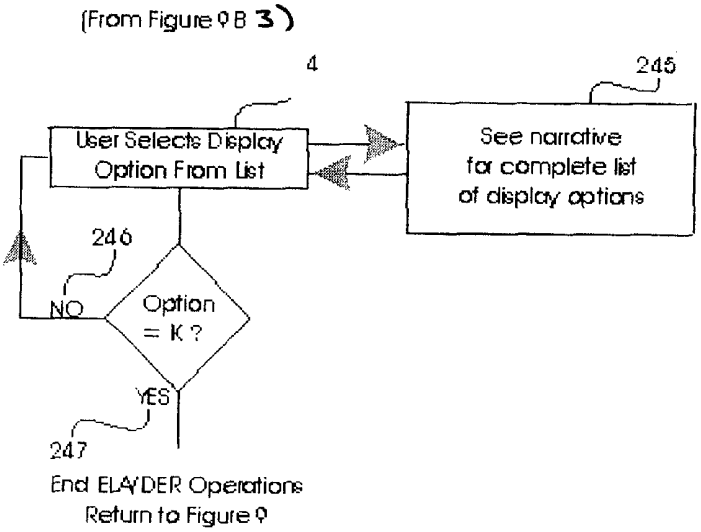

(From Figure 9B 3)
4
245
User Selects Display Option From List
See narrative for complete list of display options
246
NO
Option = K ?
YES
247
End ELAYDER Operations Return to Figure 9

FIGURE 9B4

INDIGENOUS AUTHENTICATION FOR SENSOR-RECORDERS AND OTHER INFORMATION CAPTURE DEVICES

FIELD OF THE INVENTION

The present invention generally relates to a method and apparatus for acquiring and recording a sample of an environment and, more particularly, to a method and apparatus that allows the stored recording to be verified as an authentic, unaltered sample of the environment.

BACKGROUND OF THE INVENTION

One purpose of the present invention is to provide a solution to the problem of either deliberate or inadvertent alteration of recordings. In this context, "recordings" refers to all recordings, including digital images, data files, and the more common audio recording.

Photographs, movies and printed materials have historically been regarded as media that can be trusted to be authentic copies of the original. Early attempts at alteration of photographs for the purposes of revisionist history were almost comically detectable with five people sitting at a table, but six pairs of legs underneath. Hand written, permanently bound, notebooks are used in research laboratories for their resistance against attempts at alteration. Recent technological advances have brought the ability to alter images to the neophyte level. When a master employs the advanced technology the alterations are almost completely undetectable. For this reason digital photography is seldom used in situations when "chain of custody" requirements exist to protect the authenticity of a recording be it photographic, written or auditory. For example, the picture of an accident scene could be altered to show bottles of alcoholic beverages around the driver, even if those bottles hadn't really been there when the picture was taken, but were a post accident embellishment.

A digital camera with apparatus for authentication of images produced from an image file is disclosed in U.S. Pat. No. 5,499,294. Referring to FIG. **3**A of U.S. Pat. No. 5,499,294, a block diagram of a system including a digital camera is shown that produces a file image with a digital signature. A device specific decryption key is required to allow a file image to be authenticated. Furthermore, in order to determine whether a file image is authentic, the person performing the authentication must know which camera took the picture; due to the fact that each camera includes a unique private encryption key.

SUMMARY OF THE INVENTION

It is desirable to provide an improved method and system for determining the authenticity of a sample of an environment. A digital signature is created that is a function of both the sample of the environment itself, as well as at least one parameter that is representative of at least one condition under which the digital sample was acquired. The sample is stored in memory together with the at least one parameter and the digital signature. Authenticity of the stored image is determined by creating a new signature from the stored image and at least one parameter, and then comparing the two signatures to determine if they are the same.

Such a method and apparatus is advantageous for several reasons. First, one aspect of the present invention is that it is not necessary to know what device sampled the environment because it only is necessary to have the stored sample, parameters, and signature. Second, encryption is not required for authentication purposes, thereby allowing information storage devices to be manufactured in a more cost effective manner.

Other features and advantages of the present invention will become apparent from the following description.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of one embodiment of the present invention showing a digital camera, a personal computer, and an external GPS unit;

FIG. **2** is a schematic diagram of a self-contained digital camera that incorporates certain aspects of the present invention;

FIG. **2**A is a detailed schematic diagram of a self-contained digital camera that incorporates certain aspects of the present invention.;

FIG. **3** is a flow chart of an operational sequence according to a first embodiment of the present invention;

FIG. **4** is a flow chart of the Pre Capture Operations from FIG. **3**;

FIG. **4**A1 is a flow chart of the Check Additional Inputs for Pre Capture Operations in FIG. **4**;

FIG. **4**A2 is a continuation of the flow chart from FIG. **4**A1;

FIG. **4**B is a flow chart for recording the user controls during the Pre Capture Operation;

FIG. **5** is a flow chart of the Capture Operations from FIG. **3**;.

FIG. **6** is a flow chart of the Post Capture Operations from FIG. **3**;

FIG. **6**B is the continuation of the flow chart from FIG. **6**;

FIG. **7** is a flow chart of the Recording operation from FIG. **3**;

FIG. **7**A is a diagram of a file format for a signed digital image.

FIG. **8** is a flow chart of the Clean up and Preparation from FIG. **3**;

FIG. **9** is a flow chart of the Authentication Sequence;

FIG. **9**A1 is a flow chart of the RCA Operations from FIG. **9**;

FIG. **9**A2 is a continuation of the flow chart from FIG. **9**A1;

FIG. **9**B1 is a flow chart of the ELA/DER Operations from FIG. **9**;

FIG. **9**B2 is a continuation of the flow chart from FIG. **9**B1;

FIG. **9**B3 is a continuation of the flow chart from FIG. **9**B2;

FIG. **9**B4 is a continuation of the flow chart from FIG. **9**B3;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One aspect of the present invention is the concept and method of indigenous authentication. That is, a family of devices to create recordings with material to validate its authenticity. One embodiment of the present invention relates to digital photography where an image is authenticated as a whole. An intermediate version allows the authentication of less than the whole. An advanced version allows for recovery of damaged (altered from its original state) elements. Additional inputs including, but not limited to,

date, time, latitude, longitude, altitude, roll, pitch, yaw, and compass heading can be made part of the image as well as the status of camera elements including camera identification, image sequence number, flash status, lens zoom factor, counter vibration status, focus status and focus quality. This additional information becomes part of the recording and can also be authenticated.

The present invention is applicable to information capture scenarios other than digital cameras such as self-authenticating identification documents, an extension of the notary public system, or electronic laboratory notebooks to replace the handwritten ones mentioned above. Once established as a trustworthy source; the indigenous authentication concept can be extended further for recording quality control, legal requirements and financial instruments.

A key to verifiable authenticity is to insure that the authentication information generation is tightly coupled to the sensor set and recorder. There can be nothing that can possibly alter the recording before the authentication information is generated. Authentication using this method requires neither comparison files, nor conventional or reverse encryption. The strength of authentication is increased by using one-time random elements and by the use of a random string, regenerated under user control. Although not required for basic operation, the resulting recording can be optionally encrypted to conceal the information. The absence of required conventional encryption or reverse encryption eliminates the need for a public registrar or record keeping relating to the management of decryption keys. As the authentication is indigenous there is no requirement to identify which recorder was used.

Referring to FIG. **2**, an environment **2** can be sampled **1** in a variety of formats. In recording a single sample of a visual environment, a single frame optical recorder, generally known as a camera, is used. The sample taken, known as a "photograph," has been recorded on positive transparency films (slides); negative transparency films (negatives); opaque or translucent prints; and more recently as digital files.

In recording a continuous sample of a visual environment, a continuous optical recorder such as a video camera, movie film camera or a digital movie camera is used. These samples, generically called "movies," have been recorded on transparency film, videotape and more recently as digital files

In recording a sample of an auditory environment, a continuous audio recorder such as a tape recorder or a digital recorder is used. These samples, generally called "recordings," have been recorded on a wide variety of wire, tape and digital files.

With the development of sensors and recorders, the recording of samples of taste, touch and smell can be accommodated in the same generic model. Also, samples are not limited to the five human senses. The method for authentication and verification disclosed in the present application can be used on samples taken from any sensor set including, but not limited to, the full range of physical, chemical, and spectral phenomena.

To ensure authentication, additional inputs **7** other than the sensor set **4** are not accessible to the user without detection as shown in FIG. **2**. To accomplish this the additional inputs are shown inside the device physical boundary Analog recorders may also be incorporated into this system through the use of analog to digital converters.

One use of the present invention is to create an image or data file that is considered "trustworthy" in any situation where proof of authenticity is necessary. This includes, but is not limited to, legal evidence, insurance claims, project management, scientific research, invention, quality control, identification, intelligence gathering, purchasing, command and control, law enforcement, document and image transmission.

The increasingly rapid transition to digital capture, analysis, storage, transmission, distribution and use of information, using increasingly sophisticated hardware and software for creation and capture tools, makes it increasingly difficult to accept any image or data file as authentic on its face.

With the continued growth of personal computers in society and the increasing use of the internet, electronic miscreance including deliberate fraud and inadvertent changes caused by transmission or storage errors are on the rise. The need for authentication parallels that rise to counter proliferation of altered files. The need for authentication also increases with the potential damage an altered file might cause. For example, contracts, purchase orders, legal decisions, electronic bill payments, electronic invoices, quality control information, blue prints, designs: all of these could cause great harm if an altered version were believed to be authentic. It is not unreasonable to presume that indigenous authentication might become the norm, in an attempt to prevent or derail any possible malicious acts by miscreants.

One aspect of the present invention allows generally complete mitigation of the threat of undetected image alteration and subsequent use of the altered image for purposes of deliberate or unknowing deception. Thus, a framework is provided for future devices to accomplish similar ends and provide a solution to an ever more troubling social and economic problem, namely the eroding credibility of photographic images, especially in law enforcement where the images may become evidence in a legal proceeding.

Referring to FIG. **1**, a schematic diagram of one embodiment of the present invention showing a digital camera, a personal computer, and an external GPS unit is shown. A general purpose microcomputer **252** is used to simulate the processor **157** and its programming. The mouse **256** and keyboard **257** are used to simulate the user's setting of controls (See FIGS. **2**A, **9 10 11 12 13**). The microcomputer's monitor **253** is analogous to the process monitor **8** shown in FIG. **2**A. An external geographic positioning system **254** (GPS) is used instead of an internal **44** one. An externally connected digital camera **255** simulates the lens sensor set **73** auto focus **19** and flash generator **30**. The microcomputer's **252** floppy drive (not shown) performs the function of the recorder **142** and the 3.5" floppy disk **259** is the removable storage media **141**.

Referring to FIG. **2**A, a device model for a single frame optical recorder, more commonly known as a camera, is shown. FIG. **2**A does not show the externally supplied source or internal batteries that must power this device. In this camera, the user may access the process monitor **8**. For approximate aiming, access may be gained through a shaft, parallel to the axis of the lens. Access to the process monitor **8** may also be gained through a processor **157** controlled recreation of the current scene. Indicators appear on the process monitor indicating flash status, zoom status, etc.

Operators may aim the device, activate the device, and set user controls, including but not limited to, flash **9** zoom **10** random string recording (RSR) **11** or optional encryption **12**. During the operation of the camera, internal security **14** is monitored to detect the integrity of the tight coupling of the sensor set and the recorder **6**.

Referring to FIG. **3**, when the processor **157** receives an activation signal, the multi phase operating cycle proceeds through the pre capture, capture, post capture, recording, clean up and preparation operations before returning to the pre capture phase. To reduce the time within each phase, parallel processing and other engineering techniques are used.

Referring to FIG. **4**, the pre capture sequence is the most common operating phase of the unit. The device cycles in the pre capture operation **65** until activated by user control **13** or turned off **15** in preparation for normal termination **95**. If the device is turned on and inadequate **16** power is present to complete the operating cycle, the user activation will have no effect. An indication **17** is given to the user through the process monitor and no further processing is completed **66**.

If sufficient power is present to complete the operating cycle, the additional inputs and components are checked. Referring to FIG. **4**A **1** the auto focus **19** sensor and processor are then checked **20**. If a malfunction **21** is present the process monitor **8** will be updated with an error message **22** to inform the user.

Independent of the auto focus's status, processing continues checking the focus quality sensor **23** the flash generator **30** counter vibration unit (C-VIBE) **35** and the roll, pitch, yaw (RPY) unit **40**. These tests are performed in order (**20**, **25**, **29**, **34** and **39**) independent of resulting status. At each stage, if a malfunction is present, the process monitor is updated with an error message to inform the user (**27**, **32**, **37** and **250**).

Referring to FIG. **4**A**2** the status processing continues **42** with a check **43** of the global position system (GPS) unit **44**. If there is a malfunction **45** the value "NO GPS" is recorded **46**. If no malfunctions **47** are present, the current GPS coordinates and other GPS information are recorded **48** and the process monitor **8** is updated **49** with an error message or the current coordinates.

Independent of the GPS status, processing continues **50** with a check **51** of the internal compass **52** If a malfunction **53** is present, the value "NO COMPASS" is recorded **54**. Otherwise **55** the current compass heading is recorded **56** and the process monitor **8** is updated **57** with an error message or the current heading.

Independent of the compass status, processing continues **58** with a check **59** of the internal security system **14**. If there is a breach of security **60** the violation is recorded **61**. Otherwise **62** the value "ImageGuard" is recorded **63** and the process monitor **8** is updated **64** with the violation or "ImageGuard"

Referring to FIG. **4**, after the additional inputs and components are checked **18** the user control modifications are recorded **67**. Referring to FIG. **4**B, the current setting for the flash generator **30** is checked **68** against the flash settings **9** provided by the user. If not identical **69** the setting for the flash generator **30** is set **70** to that provided by the user.

The user's zoom setting **10** is then checked **72** against the zoom setting of the lens **73**. If not identical **74** the setting for zoom **73** is set **75** to that provided by the user. The current random string record (RSR) value is then checked **77** against the setting **11** provided by the user. If not identical **78** the RSR value is set **79** to that provided by the user. The two possible values are "Y" for "Yes, record a new random string with the next image" and "N" for "No, don't record a new random string with the next image."

The current encryption value is then checked **81** against the encryption value **12** provided by the user. If not identical **82** the current encryption value is set **83** to that provided by the user. The three possible values are "Y" for "Yes, produce an encrypted image only", "N" for "No, don't produce an encrypted image, produce an unencrypted image only" and "B" for "Produce both an encrypted image and an unencrypted image." During this process the process monitor. **8** is updated **85** to reflect any changes made.

Referring to FIG. **4**, once the user control modifications are recorded **67** processing continues **86** with a test **87** for adequate recording media. If there is inadequate recording media **88** the process monitor **8** is updated **89** with an error message and no further processing is completed **90** past this point.

After the test dealing with adequate recording media is completed **91** all pre capture operations are complete. A test **92** is made for the status of the activation control **13**. If the control is not active **93** processing is cycled **65** and if active, processing continues **94** with capture operations.

Referring to FIG. **5**, once the user activation control **13** is active, processing moves from pre capture operations (see FIG. **4**) to capture operations.:(see FIG. **5**) Current values are acquired **96** from the GPS and:Compass system. If the GPS is not, active **45** the "NO GPS" value **46** is recorded. If the GPS is active **47** the GPS coordinates **48** are recorded as is the current date and time. If the Compass, is active **55** the current heading is recorded and if not active **51**, the "NO COMPASS" value **54** is acquired.

At this point, if required **97** the counter vibration unit (C-VIBE) is activated **98** to counter vibration. The roll, pitch and yaw (RPY) sensors are activated **99** and the need to prime **105** the flash unit is determined. A test is made for the user commanding the flash on or off **100**. If the flash is commanded on **101** or auto flash detects **103** the requirement **104** for a flash, the flash is primed **105** and the image is captured with flash **108**. Otherwise the image is captured without a flash **107**.

Focus quality points are detected **109** by accessing the focus quality additional input **23**. The number of focus quality points is selected, and the maximum range and minimum range are recorded. Here the camera uses either sound ranging, or another technology to measure depth of field. This procedure is required for auto focus and would detect the reproduction of a picture. This procedure also reports the number of points with differing ranges as well as the closest and farthest focus quality points from the camera. For example, "10 p 1 m Inf" would mean 10 points of differing depth, the nearest being one meter, the farthest is infinity.

Referring to FIG. **6**, once the image has been captured (see FIG. **5**) processing moves to post capture operations. First the CCD (or other sensor) is polled **110** to gather the image and pre pare it for recording. The GPS values for latitude, longitude, altitude, date, time, and satellites used for the positioning; that were previously acquired **96** are then appended **111** to the image. If the GPS was not functional **45** the "NO GPS" value **46** is appended **111** to the image. The AutoFocus status; number of focus quality points **109**; maximum range and minimum range; flash value (commanded on, commanded off, auto-flash required, or auto-flash not required); counter vibration value (active **98** or not); roll, pitch and yaw (RPY) values; recorded compass heading **96**; lens **73** zoom setting; camera identifier (CamID **124** set by the factory and unalterable by the user); current image sequence number **125**; current random string **126**; and file type (**127** set by the factory and unalterable by the user) are all appended to the image. If internal security is compromised **60** a security violation **61** is appended **123** to the image. Otherwise the "ImageGuard" value is appended **123** to the image.

Referring to FIG. **6**B, there are three levels of authentication and damaged element recovery. The initial level is total image authentication (TIA). At this level only the entire image is authenticated or not. The second level is row/column authentication (RCA) where each row and column of the picture elements (pixels) can be authenticated independently. Under RCA, less than the whole image can be authenticated. The third level is elemental level authentication (ELA) and damaged element recovery (DER).

Under the ELA structure, each and every single pixel can be authenticated independently. If a single pixel fails authentication (damaged) there are structures added to the image in the post capture operation which provide multiple methods of determining the original value of the damaged pixel. This is called damaged element recovery (DER). Initially the level of authentication and damaged element recovery is to be set at the factory so that no affiliated user control (**9**, **10**, **11**, **12** and **13**) is shown. There can be only one level of authentication (TIA, RCA, ELA/DER) active per use. (See FIG. **9** "Authentication Sequence" and more on authentication.)

If RCA is elected **128** the RCA structures and values are computed and appended **129** to the image. If ELA/DER is elected **130** the ELA/DER structures and values are computed and appended **131** to the image. The signature protocol used in - this device is the commercially available MD5 but the signature protocol is not limited to the MD5. The digital signature **132** which is a function of the signature protocol (SP) being used and the block, is computed and made part of the file. (SIGNA=ƒ (SP (Block))) The Block **144** is the digital data composed of the image and optionally: additional information, the camera id, the random string, the camera decryption key, and the RCA and ELA/DER structures and values.

If the user has elected **133** no encryption, or both encrypted and unencrypted, as set by the user control **12** and evidenced by the encryption value **83** then an unencrypted version of the complete image file is created **134**. If the user has elected **135** encryption, or both encrypted and unencrypted, as set by the user control **12** and evidenced by the encryption value **83** then an encrypted version of the complete image file is created **136**.

Referring to FIG. **7**, if the user has elected **137** no encryption, or both encrypted and unencrypted, as set by the user control **12** and evidenced by the encryption value **83** then an unencrypted version of the complete image file is written **138** by the recorder **142** on the recording media **141**. If the user has elected **139** encryption, or both encrypted and unencrypted, as set by the user control **12** and evidenced by the encryption value **83** then an encrypted version of the complete image file is written **140** by the recorder **142** on the recording media **141**.

Referring to FIG. **2**A, a 3.5" floppy drive **142** and removable 3.5" floppy diskette **141** is shown as the recorder and recording media. Other available recording options include flash RAM with removable memory modules, and storage not internal to the device via infra red, serial, Ethernet, Token Ring, parallel, universal serial bus (USB), firewire or other communication mode to either a single computer or a network of computers.

Referring to FIG. **7**A, the files created by the Signa**2** process are in a format generally accepted by the industry. Most specifically, the Signa**2** files are not proprietary. Additional information is contained within the file, but the addition of the information is in compliance with the standards for the format.

There are two braces in the figure. The first titled "Image" indicates the two elements that are viewable by programs compliant with generally accepted industry formats. Elements outside this brace are not viewable by programs compliant with generally accepted industry formats. The second **144** titled "Block" indicates the elements covered by the signature **145**. Everything inside the "Block" is what is signed.

Elements shaded in gray **161** are optional and not required to fulfill the basic purpose of Signa**2** devices. A tightly coupled image **146** and signature **145** are the minimum required elements for the Signa**2** process. The sensor set **73** acquires the image **146** which is the minimum viewable information. Additional data from the camera **147**, viewable by the user, include: Global Positioning System (GPS) information **111**; zoom settings; AutoFocus status; the results of the focus quality sampling; roll, pitch and yaw (RPY) values; the compass heading; flash status; File Type; CamID; Seq **120**; and Security Value.

The GPS information **111** may include **48** latitude, longitude, altitude, date, time, satellites used in the determination or "NO GPS" **46** if there is a fault **45** with the system. The zoom setting **75** information includes the setting used by the lens **73** for capturing the image expressed either in millimeters with 50 mm being "eye-normal", or in X where 1X is 50 mm. The compass heading **117** includes information on which way the camera was pointing at the time the image was captured.

The flash status **114** information includes the commands, Commanded ON, Commanded OFF, Auto ON or Auto OFF. In the flash status, the first two refer to settings forced by the user and the latter two refer to the user allowing the camera to decide to flash or not and whether it did or not. There may be other options.

The CamId **119** or camera identification code, is set at the factory and part of each image. Examples are SHEP0001 or MOLL0454. Although not required for authentication it does provide a means of determining, at least initial ownership of the device.

Seq **120** is the sequence number for unique image identification, automatically incremented. When used with CamId above BECK5102-98312 uniquely identifies the camera and the picture.

The two Security Values **123** are ImageGuard and NONVERIFIED. ImageGuard appears if no internal errors are detected and the security is not compromised. NONVERIFIED (or other indication of compromise) appears if security is compromised within the system.

Other segments within the File Structure include Camera ID **148**; Random String **149**; Camera Decryption Key **150**; RCA and ELA/DER structures and values **160**; and the digital signature **145**. The Camera ID **148** is the unique camera identification, the same as above, but in a section of the file not viewable by the user. The Random String **149** is the current random string and is made part of the file. The Camera Decryption Key **150** is a camera specific decryption key that stays in the camera.

Referring to FIG. **8**, this figure illustrates the process for clean up and preparation. In this portion of the process, functions not useful in pre capture operations (see FIG. **4**) are deactivated and preparations are made for subsequent image capture. The counter vibration, and the roll, pitch, yaw are deactivated **151**, **152** and the image sequence number is incremented **153**.

If the "Random String Recording" has been set **79** to YES by the user control **11** the image itself and other information

(Referring to FIG. 7A) are used to generate **155** a new random string that replaces the previous random string. The "Random String Recording" **79** is then reset **158** to NO and the user control **11** is set **159** to NO. Temporary resources used by the processor **157** are then deallocated **156** to prepare them for re-use.

It is important to note that the previous random string is used for the image just created. Therefore, frequent resetting of the random string will deter pattern recognition and increase security. This is discussed in the "Role of the random string in increasing the strength of the digital signature" below.

Referring to FIG. **9**, authentication starts with a file believed to contain an image and the additional items (see FIG. 7A) to make the file authenticatable as a Signa**2** image. The authentication program must be easily and freely available from a secure public source. Otherwise someone seeking to deceive could provide a faux-authentication program to generate a forced-negative or forced-positive authentication.

The program starts **162** with a self diagnostic to insure that the authentication program itself has not been damaged or corrupted. This self diagnostic is repeated each time processing reaches this **162** point to guard against alterations made after the program has been loaded. Should the self diagnostic fail the program immediately ends with an error message. This self diagnostic procedure and the possibility of a failure are not shown on FIG. **9**.

Once the authentication program has been loaded the user is presented with an opportunity to select a file or elect program exit. If the user elects program exit the authentication program ends **163**. If an encrypted file is selected **164** an attempt **165** is made to decrypt the file This may require a decryption key obtained from the user or taken from-the file **150**. If a decryption error **166** occurs, an error message **167** is displayed and the program cycles back to start **162**

If the file was not **168** encrypted or was decrypted without error **169** a test **170** is made to confirm that the file is in the Signa**2** format. If the file is not **171** in Signa**2** format, the file is not authenticatable **172** and the program cycles back to start **162**

If the file is **173** in Signa**2** format ,the block **144** is separated **174** from the signature **145** and the signature is recalculated **175** from the original block **144**. If the recalculated signature (SIG_R) matches **176** the provided signature (SIG_P), the image may be viewed **248** and is marked authenticated **249** as a valid image using total image authentication (TIA). The program then cycles back to start **162**.

If the two signatures do not match, and the authenticator program has been acquired from a trusted source and is free from alteration; then the image file has been damaged or altered. This is a true-negative, an image properly determined not to be authentic. With an uncompromised authenticator program, a Signa**2** image file using TIA level authentication cannot generate false-negatives. The image and the signature are in a single file and altering the file, either intentionally or accidentally; constitutes invalidation and a proper negative authentication.

If the recalculated signature (SIG_R) does not **177** match the provided signature (SIG_P), a series of tests are made for one of three authentication levels. If only total image authentication (TIA) is available **178** then no further operations are available **179**. The image is viewed **180** and marked unauthenticated **181**. The program then cycles back to start **162**.

Referring to FIG. **9**, if row/column authentication (RCA) is **182** elected, processing continues with RCA Operations and the program cycles back to start **162**. If row/column authentication (RCA) has not **183** been elected, a **184** test for elemental level authentication/damaged element recovery (ELA/DER) is made.

Referring to FIG. **9B1** if ELA/DER has **186** been elected, processing continues with ELA/DER Operations and the program cycles back to start **162**. If ELA/DER has not been elected **185** there is an error condition as one of the three levels of authentication (TIA, RCA, ELA/DER) should be available. This error condition is handled by reporting no further operations are available **179**. The image is viewed **180** marked unauthenticated **181** and the program cycles back to start **162**.

Referring to FIG. **9**, row/column authentication (RCA) is elected **182** when a file in a Signa**2** format **173** has a signature failure **177**. The signature used in comparison **145** is a single signature for the entire file. RCA structures and values **160** provide for a method of detecting errors, not at the whole file level, but at a level for each row and column. Checking each row and column provides two opportunities to detect an error for each pixel.

Cyclic Redundancy Check (CRC) is the method used to describe this form of error detection. There are several varieties of CRC as well as other algorithms for error detection of this type. Although CRC is used here for description purposes, other error detection codes (or error correction codes such as Hamming and Reed-Soloman) may be implemented to augment or replace the CRC error detection code.

Referring to FIG. **9A1** a digital image consists of picture elements, known as pixels, arranged in a matrix of rows and columns. RCA Operations commence by stepping **187** through each row of the image testing **188** the CRC for internal integrity. Although CRCs do not contain an inherent internal integrity test, part of the RCA structures include additional values to test the CRC. If the CRC fails **189** this self test, all pixels in that row are marked as damaged, but potentially false negatives (PFN) **208**.

If the CRC itself is ok **191** the entire row of pixels is used to compute **192** a new CRC for the row. This new CRC is compared to the original CRC. If they do not **193** match, all of the pixels in the row are marked as damaged **190**. If the new CRC does **194** match the original CRC, all of the pixels in the row are marked **195** ok.

Referring to FIG. **9A2** RCA operations continue by stepping **196** through each column of the image and testing **197** the CRC of each column for internal integrity. If the CRC fails **198** this test, no further operations are conducted on the column of pixels. If the CRC itself is ok **200** the entire column of pixels is used to compute **201** a new CRC for the column. If the new CRC does not **202** match the original CRC, no further operations are conducted on this column. If the new CRC does **203** match the original CRC, all of the pixels in the column are marked **204** ok.

A pixel may be marked in one of six ways: Ok—ok from row CRC **195** and column CRC **204**; Damaged—ok from row CRC **190** and column CRC **204**; $Damaged_{PFN}$—ok from row CRC failure **189** **208** and column CRC **204**; Ok—null from row CRC **195**; Damaged—null from row CRC **190**; and $Damaged_{PFN}$—null from row CRC failure **208**. There is no second status because of column CRC failure **202**.

The nature of the two operations (row and column) generate a matrix where some rows of pixels may be marked as damaged in the row operations and some of those pixels changed from damaged to ok by the column operations. This

is because an entire row is marked damaged or ok. If a column is marked ok, the pixels that may have been marked damaged as part of a whole row were not in fact damaged and are changed to being ok. As an example, a single damaged pixel would cause a whole row to be marked as damaged in row operations. Column operations would mark every column ok except the column that had the damaged pixel. The end result is an image with a single pixel marked damaged.

Once the image has been authenticated the user selects **199** from a list of presented display options **205**. The display options are: Option A—Display only the original image without any modification; Option B—Display the original image with damaged pixels forced to white; Option C—Display the original image with damaged pixels forced to black; Option D—Rock A and B; Option E—Rock A and C; Option F —Statistical Report; and Option G—End display options. "Rocking" refers to rapidly displaying two alternating images.

The statistical report under Option F contains the following elements: F**1** contains the total number of pixels in the image. F**2** contains the total number of pixels marked ok—ok, Damaged—ok, Damaged$_{PFN}$—ok and ok—null, expressed as a number, and as a relative percent of the total number of pixels (F**2**/F**1**)*100 known as the "Undamaged Percentage."

Ok—ok pixels passed both row **194** and column **203** CRC test. Ok—null pixels passed the row **194** CRC test, but the column CRC was damaged **198** and provided no additional information. Damaged—ok pixels were not actually damaged. The pixels were marked damaged because the new row CRC did not match **193** the original row CRC, and the whole row was marked **190** damaged even though the pixels passed **203** the column CRC test Darnaged$_{PFN}$—ok also contains pixels that were not actually damaged. The pixels were marked damaged due to the row CRC failure **189** that caused the entire row to be marked Damaged$_{PFN}$ even though the pixels passed **203** the column CRC test.

F**3** contains the total number of pixels marked Damaged—null expressed as a number, and as a relative percent of the total number of pixels in the image (F**3**/F**1**) *100 known as the "True Negative Percentage." The pixels were marked Damaged-null because the new row CRC did not match the original row CRC test **193**. There is no second status because of column CRC failure **202**.

F**4** contains the total number of pixels marked Damaged$_{PFN}$—null expressed as a number, and as a relative percent of the total number of pixels in the image (F**4**/F**1**) *100 known as the "Potential False Negative Percentage." The pixels were marked Damaged$_{PFN}$—null because the row CRC failed **189** **208** the self test and the pixel could not be authenticated as ok due to column CRC failure **202**. The sum of the relative percents of F**2** F**3** and F**4** should equal 100%, and the sum of F**2** F**3** and F**4** should equal F**1**.

The user may continue to select **206** alternate display options until they elect to end display options **207**. At that point RCA operations are concluded.

Referring to FIG. **9B1**, ELA/DER Operations occur when a file in Signa**2** format **173** has a signature failure **177** and both element level authentication (ELA) and damaged element recovery (DER) authentication are elected **186**. The signature used in comparison **145** is a single signature for the entire file. ELA/DER structures and values **160** provide for a method of determining authentication, not at the whole file level, but at a level for each element.

The ELA/DER structure includes a complete duplicate of the image, compressed and encoded. It is this duplicate image that allows for elemental level authentication and damaged element recovery. In the description below the original version of the image, the one the user can see, is referred to as the "Primary Image", abbreviated PI. The compressed and encoded version of the image is referred to as the "Backup Image", abbreviated BI. Both the Primary Image and the Backup Image have row and column CRCs, or other error detection protocols.

Referring to FIG. **9B1** initially each row **209** of the primary image (PI) is stepped through and a self test **210** is performed on each primary image row CRC. If the CRC fails **211**the self test, all of the pixels in the primary image row are marked **212** Damaged$_{PFN}$ as potential false negative damaged pixels. If the primary image row CRC passes **213** the self test, a new primary row CRC is computed **214** from the pixels in the primary image row. If the new primary image row CRC matches **215** the original primary row CRC, all the pixels in the row are marked **216** as ok (undamaged). If the new primary image row CRC does not **217** match the original primary row CRC, all the pixels in the row are marked **218** as damaged.

Referring to FIG. **9B2**, once the row-wise process is complete, each column **219** of the primary image is stepped through with a self test **220** performed on the primary image column CRC. If the CRC fails the self test **221** no further operations are conducted on this column. If the primary image column CRC passes **222** the self test, a new primary column CRC is computed **223** from the pixels in the primary image column. If the new primary image column CRC matches **225** the original primary image column CRC, all of the pixels in that column are marked **226** ok. If the new primary image column CRC does not **224** match the original primary image column CRC, no further operations are conducted on this column.

Each pixel may be marked in one of six ways: Ok—ok from row CRC **216** and column CRC **226**; Damaged—ok from,row CRC **218** and column CRC **226**; Damaged$_{PFN}$—ok from row CRC failure **212** and column CRC **226**; Ok—null from row CRC **216**; Damaged—null from row CRC **218**; and Damaged$_{PFN}$—null from row CRC failure **212**. There is no second status because of column CRC failure **221**

Referring to FIG. **9B3** authentication then starts on each damaged or damaged$_{PFN}$ pixel with attempts to recover the original value of that element. Additional processing efforts are not made to distinguish between true negatives and false negatives due to the fact that the same damaged element recovery (DER) procedures are used on each.

To recover the value of a damaged primary image pixel the corresponding backup image pixel must first be located and validated. Validation of the corresponding backup image pixel can occur under either of the two scenarios. In the first scenario, the backup image ROW CRC for the corresponding backup image pixel is undamaged and the computed backup image ROW CRC matches the original backup image ROW CRC. In the second scenario, the backup image COLUMN CRC for the corresponding backup image pixel is undamaged and the computed backup image COLUMN CRC matches the original backup image COLUMN CRC.

Stepping **227** through each damaged or damaged$_{PFN}$ pixel in the primary image is done to locate **228** the corresponding pixel in the backup image. The backup-image will require decompression first. If the corresponding backup image pixel cannot **229** be located, it cannot be authenticated and it is not possible to recover the value of the primary image pixel **230**. Once the corresponding backup image pixel is **231** located, a self test **232** is performed on the backup image ROW CRC.

If the backup image ROW CRC self test fails **233** the backup image ROW CRC is damaged and is unusable for authentication. The backup image COLUMN CRC for the corresponding backup image pixel is then used for authentication and a self test **235** of the backup image COLUMN CRC is performed.

If the backup image COLUMN CRC for the corresponding backup image pixel fails **236** the self test, the corresponding backup image pixel cannot be authenticated and it is not possible to recover the value of the primary image pixel **230**. If the backup image COLUMN CRC for the corresponding backup image pixel passes **239** the self test then a new backup image COLUMN CRC is computed **240**.

If the new backup image COLUMN CRC matches **241** the original backup image COLUMN CRC **238** the corresponding backup image pixel is authentic and can be used to recover the value of the damaged or damaged$_{PFN}$ primary image pixel. If the new backup image COLUMN CRC does not match **243** the original backup image COLUMN CRC, the corresponding backup image pixel cannot be authenticated and it is not possible to recover the value of the primary image pixel **230**.

If the backup image ROW CRC self test succeeds **234** a new backup image ROW CRC is computed **251**. If the new backup image ROW CRC matches **237** the original backup image ROW CRC then **238** the corresponding backup image pixel is authentic and can be used to recover the value of the damaged or damaged$_{PFN}$ primary image pixel. If the new backup image ROW CRC does not **242** match the original backup image ROW CRC, one or more of the backup image pixels in that row is damaged and the backup image column must be tested for authentication.

A self test **235** of the backup image COLUMN CRC is performed. If the backup image COLUMN CRC for the corresponding backup image pixel fails **236** the self test, the corresponding backup image pixel cannot be authenticated and it is not possible to recover the value of the primary image pixel **230**. If the backup image COLUMN CRC for the corresponding backup image pixel passes **239** the self test then a new backup image COLUMN CRC is computed **240**.

If the new backup image COLUMN CRC matches **241** the original backup image COLUMN CRC **238** the corresponding backup image pixel is authentic and can be used to recover the value of the damaged or damaged$_{PFN}$ primary image pixel.

If the new backup image COLUMN CRC does not match **243** the original backup image COLUMN CRC then the corresponding backup image pixel cannot be authenticated and it is not possible to recover the value of the primary image pixel **230**.

Each pixel may then be marked in one of eight ways: Ok—ok, from row CRC **216** and column CRC **226**; Damaged—ok, from row CRC **218** and column CRC **226**; Damaged$_{PFN}$—ok, from row CRC failure **212** and column CRC **226**; Ok—null, from row CRC **216**; Damaged—null—recovered, from row CRC **218** (The original value of the pixel was recovered **238**); Damaged—null—not recovered, from row CRC **218** (the original value of the pixel was not **230** recovered); Damaged$_{PFN}$—null—recovered, from row CRC failure **212** (the original value of the pixel was recovered **238**); and Damaged$_{PFN}$—null—not recovered, from row CRC failure **212** (the original value of the pixel was not **230** recovered). Damaged—null and Damaged$_{PFN}$—null are replaced with the results of the recovery efforts

Referring to FIG. **9B4** once the authentication and recovery operations are completed the user is presented **244** with a list of eleven presented display options **245**. Option A display only the original image without any modification Option B display the original image with damaged and damaged$_{PFN}$ pixels forced to white. Option C display the original image with damaged and damaged$_{PFN}$ pixels forced to black. Option D display the original image with damaged and damaged$_{PFN}$ pixels replaced with recovered pixels. Unrecovered damaged and damaged$_{PFN}$ pixels are forced to white. Option E display the original image with damaged and dam aged$_{PFN}$ pixels replaced with recovered pixels. Unrecovered damaged and damaged$_{PFN}$ pixels are forced to black.

Rapidly displaying two alternating images is known as "rocking." Option F rocks between A and B. Option G rocks between A and C. Option H rocks between A and D. Option I rocks between A and E.

Option J displays the Statistical Report containing the various elements. This option displays the total number of pixels in the image **J1**. It also displays the total number of pixels marked ok—ok, Damaged—ok, Damaged$_{PFN}$—ok and ok—null, expressed as a number, and as a relative percent of the total number of pixels **(J2/J1)*100** known as the "Undamaged Percentage" **J2**. Ok—ok pixels are those that passed both row **216** and column **226** CRC test. Ok—null pixels are those that passed the row **216** CRC test, but the column CRC was damaged **221** and provided no additional information. Damaged—ok pixels are those that were not actually damaged. The pixels were marked damaged because the new row CRC did not match **217** the original row CRC and the whole row was marked **218** damaged. These pixels passed **225** the column CRC test. Damaged$_{PFN}$—ok pixels were those that were not actually damaged. The pixels were marked damaged$_{PFN}$ because of row CRC failure **211** caused the entire row to be marked **212** Damaged$_{PFN}$. The pixels passed **225** the column CRC test.

Option J also displays the total number of damaged—null—recovered pixels as a number, and as a relative percent of the total number of pixels **(J3/J1)*100** known as the "Damaged and Recovered Percentage" **J3**. The total number of damaged —null—not recovered pixels are also displayed as a number and as a relative percent of the total number of pixels **(J4/J1)*100** known as the "Damaged and Not Recovered Pecentage" **J4**.

Option J displays the total number of damaged$_{PFN}$—null—recovered pixels as a number and as a relative percent of the total number of pixels **(J5/J1)*100** known as the "Damaged$_{PFN}$ and Recovered Pecentage" **J5**. It also displays the total number of damaged$_{PFN}$—null—not recovered pixels as a number and as a relative percent of the total number of pixels **(J6/J1)*100** known as the "Damaged$_{PFN}$ and Not Recovered Pecentage" **J6**. The sum of **J2 J3 J4 J5** and **J6** should equal **J1**, and the sum of the relative percents of **J2 J3 J4 J5** and **J6** should equal 100%.

The final option that may be selected is Option K to end display options. The user may continue to select **246** alternate display options until they elect to end display options **247**. At that point ELA/DER operations are concluded.

The following is information on True Negatives, False Negatives and False. Positives using row/column authentication (RCA) given that an authenticator program has been acquired from a trusted source and is free from alteration.

If a pixel is damaged (altered from its original state) and this damage is detected by the RCA operations then the pixel is a true-negative, part of an image properly determined not to be authentic. Using RCA it is possible to generate a false negative, that is where a pixel is in fact authentic, but is being marked as damaged.

There are eight possible cases of pixel authenticity/damage, row CRC authenticity/damage, and column CRC authenticity/damage.

Case	A	B	C	D	E	F	G	H
Pixel Damaged	N	Y	N	N	Y	Y	N	Y
Row CRC Damaged	N	N	Y	N	Y	N	Y	Y
Col CRC Damaged	N	N	N	Y	N	Y	Y	Y

Y = damaged
N = not damaged or ok

The number of possibilities can be expressed as

$$\frac{\text{(The number of elements)!}}{\text{(Number of identical elements)!}}$$

There are three elements in all cases. Case A is the case in which none of the three items are damaged. There is the single case with zero Y and three N. (3!/3!=1) Cases B through D are the cases in which a single item of the three are damaged. There are three cases with one Y and two N. (3!/2!=3.) Cases E through G are the cases in which two of the three items are damaged. There are three cases with two Y and one N.(3!2!=3.) Case H is the case in which three of the three items are damaged.; There is one case with three Y and zero N **(3!/3!=1.)**

Only in case G where both the row CRC and column CRC are damaged, and the pixel is not damaged, would a false negative be generated. Failure **189** of the row CRC self test would cause all the pixels in the row to be marked damaged$_{PFN}$ **190**. The column. CRC would also fail **198** the column CRC self test and the pixel would remain marked as damaged$_{PFN}$. In case H, both the row CRC and column CRC are damaged and would appear to mimic case. G, except that this is not a false negative because the pixel is also damaged.

Using the same table it can be shown that a false positive (a damaged pixel being improperly authenticated as undamaged) is not a possible condition. Cases B, E, F, and H have damaged pixels. In case B, the row CRC is undamaged and the newly computed **192** row CRC would not **193** match the original row CRC. Thus all pixels in the row would be marked **190** as damaged. In case B the column CRC is also undamaged. The computed new column CRC **201** would not **202** match the original CRC and the pixels in the column marked as damaged would remain marked as damaged. Only if the new column CRC matches the original column CRC **203** would all the pixels in the column, including the damaged one, be marked **204** as ok.

In case E, the row CRC is damaged and it would fail **189** the row CRC self test **188** causing all pixels in the row to be marked **208** as damaged$_{PFN}$. The column CRC is undamaged and would pass **200** the column CRC self test. The new column CRC would not **202** match the original CRC and the pixels in the column marked as damaged$_{PFN}$ would remain marked as damaged due to the fact that when a row CRC is damaged, the row of pixels is marked as "damaged potential false negative" or damaged$_{PFN}$. Only if the new column CRC matches the original column CRC **203** would all the pixels in the column, including the damaged one, be marked **204** as ok.

In case F, the row CRC is undamaged and would pass **191** the row CRC self test **188**. The newly computed row CRC **192** would not match **193** the original row CRC causing all of the pixels in the row to be marked **190** damaged. In case F, the column CRC is damaged and it would not **198** pass the CRC self test and the pixels in the column marked as damaged would remain marked as damaged.

In case H, the row CRC is damaged and would fail **189** the row CRC self test **188** causing all pixels in the row to be marked **208** as damaged$_{PFN}$. In case H, the column CRC is damaged and would not **198** pass the CRC self test. The pixels in the column marked as damaged$_{PFN}$ would remain marked as damaged$_{PFN}$ due to the fact that when a row CRC is damaged, the row of pixels is marked as "damaged potential false negative" or damaged$_{PFN}$.

Under RCA, false positives, a damaged, pixel being improperly authenticated as undamaged, cannot occur if the authenticator program has been acquired from a trusted source and is free from alteration

The following is information on True Negatives, False Negatives and False Positives using element level authentication (ELA) with damaged element recovery (DER). If a pixel is damaged (altered from its original state) and the damage is detected by the ELA operations then the pixel is a true-negative, part of an image properly determined not to be authentic. Using ELA it is possible to generate a false-negative, that is where a pixel is in fact authentic, but is being marked as damaged.

There are sixty-four (64) possible cases of primary image pixel authenticity/damage, backup image pixel authenticity/damage, primary row CRC authenticity/damage, backup row CRC authenticity/damage, primary column authenticity/damage, and backup column CRC authenticity/damage.

In table form these cases are

Y=damaged N=not damaged or ok

Group 1 Primary Image pixel is authentic and Backup Image pixel is authentic

Case	A1	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1	O1	P1
Primary Image Pixel	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Backup Image Pixel	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Primary-Row CRC	N	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	Y
Backup-Row CRC	N	N	Y	N	N	Y	N	N	Y	Y	N	Y	Y	N	Y	Y
Primary-Column CRC	N	N	N	Y	N	N	Y	N	Y	N	Y	Y	N	Y	Y	Y
Backup-Column CRC	N	N	N	N	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y

-continued

Group 2 Primary Image pixel is damaged and Backup Image pixel is authentic															
Case	A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2	L2	M2	N2	O2	P2
Primary Image Pixel	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Backup Image Pixel	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Primary-Row CRC	N	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	Y
Backup-Row CRC	N	N	Y	N	N	Y	N	N	Y	Y	N	Y	Y	N	Y	Y
Primary-Column CRC	N	N	N	Y	N	N	Y	N	Y	N	Y	Y	N	Y	Y	Y
Backup-Column CRC	N	N	N	N	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y

Group 3 Primary Image pixel is authentic and Backup Image pixel is damaged																
Case	A3	B3	C3	D3	E3	F3	G3	H3	I3	J3	K3	L3	M3	N3	O3	P3
Primary Image Pixel	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Backup Image Pixel	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Primary-Row CRC	N	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	Y
Backup-Row CRC	N	N	Y	N	N	Y	N	N	Y	Y	N	Y	Y	N	Y	Y
Primary-Column CRC	N	N	N	Y	N	N	Y	N	Y	N	Y	Y	N	Y	Y	Y
Backup-Column CRC	N	N	N	N	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y

Group 4 Primary Image pixel is damaged and Backup Image pixel is damaged																
Case	A4	B4	C4	D4	E4	F4	G4	H4	I4	J4	K4	L4	M4	N4	O4	P4
Primary Image Pixel	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Backup Image Pixel	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Primary-Row CRC	N	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	Y
Backup-Row CRC	N	N	Y	N	N	Y	N	N	Y	Y	N	Y	Y	N	Y	Y
Primary-Column CRC	N	N	N	Y	N	N	Y	N	Y	N	Y	Y	N	Y	Y	Y
Backup-Column CRC	N	N	N	N	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y

In order to be a false negative: (1) the primary image pixel must be, in fact, undamaged (N); (2) initial operations must improperly indicate that the primary image pixel is damaged; and (3) all subsequent operations must fail to correct that improper indication.

The factor that in a false negative the primary image pixel must be, in fact, undamaged (N) limits the results to Group 1 and Group 3. The primary row CRC must be damaged (Y) to initially mark a row of PI pixels as damaged$_{PFN}$. If the ROW CRC is undamaged and the row of pixels is undamaged, then pixel will be marked ok. This is not a negative, false or otherwise and limits the results to cases B, F, G, H, L, M, N and P in Group 1 and Group 3.

The primary column CRC must be damaged (Y) to preclude the correction of a pixel marked damaged by a damaged row CRC. In cases B, F, H, and M, the primary column CRC is undamaged (N) which would correct the improper identification of the pixel as damaged$_{PFN}$ limiting the results to cases G, L, N and P in Group 1 and Group 3.

The backup row CRC must be damaged (Y) to preclude correction. In cases G and N, the backup row CRC is undamaged (N) and would correct the improper identification of the pixel as damaged limiting the results to case L and P in Group 1 and Group 3.

The backup column CRC must be damaged (Y) to preclude correction. In case L, the backup column CRC is not damaged (N) and would correct the improper identification of the pixel as damaged$_{PFN}$. In case P1 the backup image pixel is also authentic, but because of the damage to all of the error detection structures (primary crow CRC, primary column CRC, backup row CRC and backup column CRC) it cannot be validated as authentic. Only in cases P1 and P3 could an authentic pixel be marked damaged without the possibility of correction.

Using the same tables it can be shown that a false positive (a damaged pixel being improperly authenticated as undamaged) is not a possible condition. Group 2 and, Group 4 both contain damaged primary image pixels. If the primary row CRC is damaged, all pixels in the, row are marked damaged. If the primary row CRC is undamaged, the new row CRC will not match the provided row CRC and all pixels in the row will be marked damaged. For the purposes of isolating a case of false positive, it does not matter if the primary row CRC is damaged (Y) or not (N). The pixel will

be marked as damaged or damaged$_{PFN}$. Again, the primary image ROW CRC alone guarantees that a damaged pixel will be marked damaged or, damaged$_{PFN}$.

To be a false positive all detective and corrective mechanisms must fail in a mode to change the primary row CRC determination that the pixel is damaged or darnmaged$_{PFN}$. If the primary column CRC is damaged **221** it will not change the determination that a pixel is damaged. If the primary column CRC is undamaged **222** the new PI COLUMN CRC will not match the original PI COLUMN CRC. Thus, it will not change the determination that a damaged pixel is damaged. For the purposes of isolating a case of false positive it does not matter if the primary column CRC is damaged (Y) or not (N). The damage pixel will remain marked as damaged.

Backup row and column CRCs are used for damaged element recovery, not element level authentication. Thus, for the purposes of isolating a case of false positive it does not matter if the backup row CRC is damaged (Y) or not (N), and it does not matter if the backup column CRC is damaged (Y) or not (N). The damaged pixel will remain marked as damaged.

This eliminates all cases in Group 2 and Group 4 as possible sources of a false positive condition. As no other cases remain for consideration, false positives are not possible if the authentication program is free from unauthorized alteration.

Using the same tables we can determine if a damaged pixel can or cannot be recovered from the damaged element recovery structures. To be considered for recovery a primary image pixel must be either, in fact damaged or a false-negative (a pixel marked damaged that is, in fact, undamaged). This limits consideration to damaged pixels in Groups 2 and 4 and cases P1 and P3 for the two possible false-negative situations.

The backup image pixel must be, in fact, undamaged. All Group 4 cases where the BI pixel is damaged are not recoverable due to the fact that all false positives are not possible. The backup image control structures must authenticate it the BI pixel as undamaged. The backup row CRC can be damaged which would lead to the backup image pixel being improperly considered damaged. If the backup column CRC were undamaged, it would correct the improper designation of the backup image pixel as damaged.

An undamaged backup row CRC would indicate that the backup image pixel is undamaged. A damaged backup column CRC would not change the determination of the backup row CRC that the backup image pixel is undamaged. Thus, as long as either the backup image row CRC or backup image column CRC are undamaged, an undamaged backup image pixel can be authenticated and used to recover the damaged primary image pixel. Only in cases J2 M2, O2 and P2 are both the backup image CRC structures damaged and unable to authenticate the undamaged backup image as undamaged.

In the false positive cases of P1 and P3 both of the backup CRC structures are damaged and unable to authenticate the undamaged backup image as undamaged. Therefore, in all 16 cases of Group 4 cases J2 M2, O2 and P2,a damaged primary image pixel cannot be recovered. If P1 or P3 generates a false negative, the improperly identified damaged primary image pixel cannot be recovered.

The following is information on the role of the random string in increasing the strength of the digital signature. A series of examples and explanations shows how the use of one time and random elements increase the resistance of a digital signature to successful fraudulent impersonation.

Starting with a blank image and a constant signature algorithm, any true image could be altered to blank and the signature from a truly blank image could be added. The resulting altered image would be improperly validated as authentic with little effort. Clearly this is a weaker situation and an undesirable outcome as the same image generates the same signature.

In the adaptive signature, a signature is generated from the contents of the image. In the case of a blank image, the same signature would be generated. An image could be manipulated to blank and the signature duplicated from a properly signed blank image. This would allow the improper validation as authentic in a manner similar to the preceding with the same undesirable outcome.

An example of an adaptive signature is one that contains a one-time element. The addition of a one-time element allows for differing signatures even if the image itself is blank. One-time elements are never repeated such as date-time or image sequence number. Some convolution or manipulation of these one-time elements is desirable to preclude their easy forgery. This is a stronger solution as the same image generates differing signatures.

An adaptive signature may also be a signature that contains one-time elements and random elements. A "random string" is a sequence of characters generated from many variables including selected values from a previous image. The algorithm to create the random string is a trade secret and may differ from device to device even among the same production run of otherwise identical devices. The algorithm used may also vary from use to use of the same device. Two blank images captured a second apart with the same device can generate two widely different signatures. Two blank images captured at the exact same moment by two different devices can generate two widely different signatures. This creates a stronger solution than the adaptive signature containing only a one-time element.

Another variation is an adaptive signature with a one-time element and a one-time random element. The user has control over how often a new random string is created. If the random string were created anew after each image was captured, then pattern recognition of the resulting signature from the image is not possible as random elements are, by definition, not patterned. Unless the signature generation protocol and the random string generation algorithm were known or reverse engineered, the ability to sign a properly constituted Signa2 image resides solely inside the Signa2 devices. By varying the random string generation protocol between devices, varying between protocols between use to use of the same device, and regenerating the random string frequently, analysis of the results to determine the process (a form of reverse engineering) is an almost fruitless exercise.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is considered as illustrative and not restrictive in character, it being understood that all changes and modification that come within the spirit of the invention are desired to be protected.

What is claimed is

1. A method for authenticating a data stream stored in a data file in memory, said method comprising the steps of:

storing a data stream in a data file in a memory;

utilizing a sensor, which is tightly coupled to said memory, to generate at least one internal and unique parameter;

monitoring the integrity of the tight coupling between said memory and said sensor when said at least one internal and unique parameter is generated, and, if said integrity

is compromised, then also providing an indication of said compromised integrity;

utilizing a signature protocol to generate a first signature based on said data stream and said at least one parameter, said first signature being generated without altering said data stream and being appended to said data file in said memory;

utilizing said signature protocol to generate a second signature based on said image;

comparing said first signature to said second signature,

if said first and second signatures are not the same, then generating an error signal that is displayed to a user to indicate that said stored data stream is not authentic, and

if said first and second signatures are the same, then generating an ok signal that is displayed to a user to indicate that said stored data stream is authentic.

2. The method of claim **1**, wherein said memory form a part of a digital camera.

3. The method of claim **1**, wherein said at least one parameter comprises a random number.

4. The method of claim **1**, further comprising the step of appending at least one additional parameter to said data file in said memory, said at least one additional parameter being generally representative of a condition under which said data stream was generated.

5. The method of claim **4**, wherein said at least one additional parameter is selected from a group consisting of: GPS coordinates, zoom settings, AutoFocus status, focus quality sampling, roll, pitch and yaw values, compass headings, flash status, CamID, Seq, and a Security Value.

6. The method of claim **1** wherein said data stream is a digit sample of an environment.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 6,757,828 B1
APPLICATION NO.	: 09/626044
DATED	: June 29, 2004
INVENTOR(S)	: Jonathan E. Jaffe, Joel D. Goldhar and Michael A. Warot

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 21, Lines 8-9, should read:
"utilizing said signature protocol to generate a second signature based on said data stream"

Signed and Sealed this
Seventeenth Day of August, 2021

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office