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NISHIMURA et al.

(54) **MEDICAL IMAGE PROCESSING APPARATUS, LUMINAL IMAGE PROCESSING APPARATUS, LUMINAL IMAGE PROCESSING METHOD, AND PROGRAMS FOR THE SAME**

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(73) Assignee: **OLYMPUS CORPORATION**, TOKYO (JP)

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Related U.S. Application Data

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(30) **Foreign Application Priority Data**

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Feb. 15, 2005 (JP) 2005-038117

Publication Classification

(51) **Int. Cl.**
G06K 9/46 (2006.01)

(52) **U.S. Cl.** **382/128**

(57) **ABSTRACT**

There is provided a medical image processing apparatus including an image-extracting section extracting a frame image from in vivo motion picture data picked up by an in vivo image pickup device or a plurality of consecutively picked-up still image data, and an image analysis section analyzing the frame image extracted by the image-extracting section to output an image analysis result. The image analysis section includes a first biological-feature detection section detecting a first biological feature, a second biological-feature detection section detecting, based on a detection result obtained by the first biological feature detection section, a second biological feature in a frame image picked up temporally before or after the image used for detection by the first biological feature detection section; and a condition determination section making a determination for a biological condition based on a detection result obtained by the second biological feature detection section to output the determination.

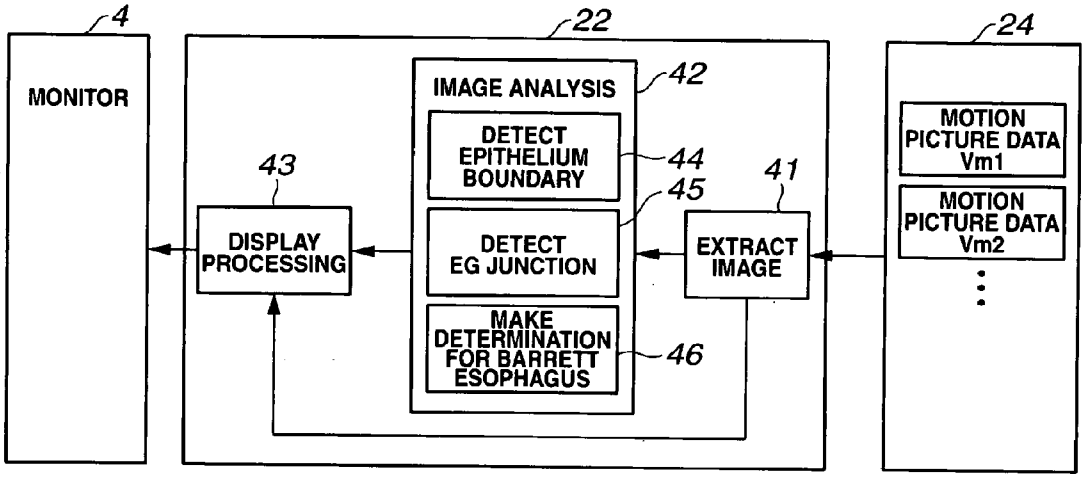


FIG.1

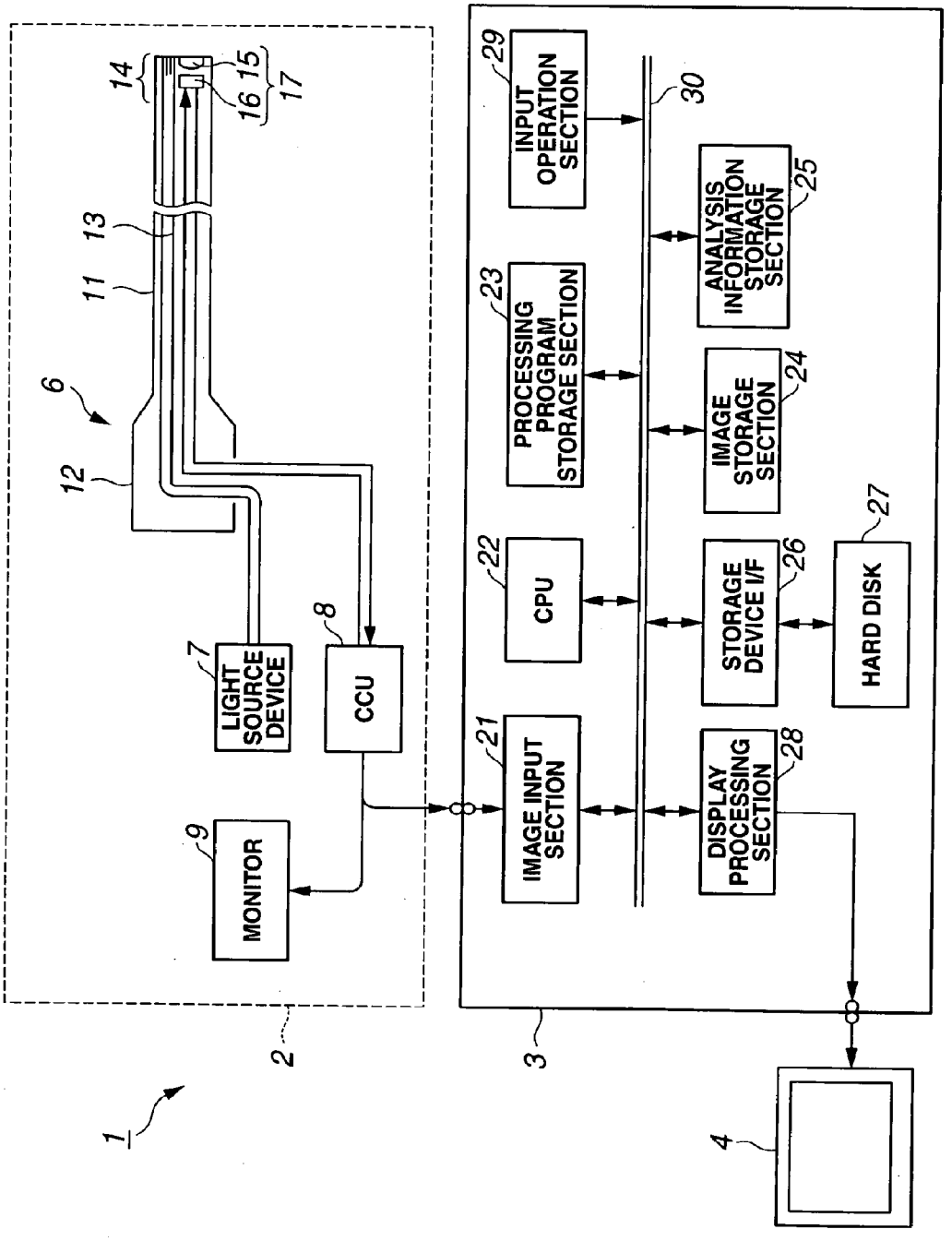

1
2
3
4
6
7
LIGHT SOURCE DEVICE
8
CCU
9
MONITOR
11
12
13
14
15
16
17
21
IMAGE INPUT SECTION
22
CPU
23
PROCESSING PROGRAM STORAGE SECTION
24
IMAGE STORAGE SECTION
25
ANALYSIS INFORMATION STORAGE SECTION
26
STORAGE DEVICE I/F
27
HARD DISK
28
DISPLAY PROCESSING SECTION
29
INPUT OPERATION SECTION
30

FIG.2

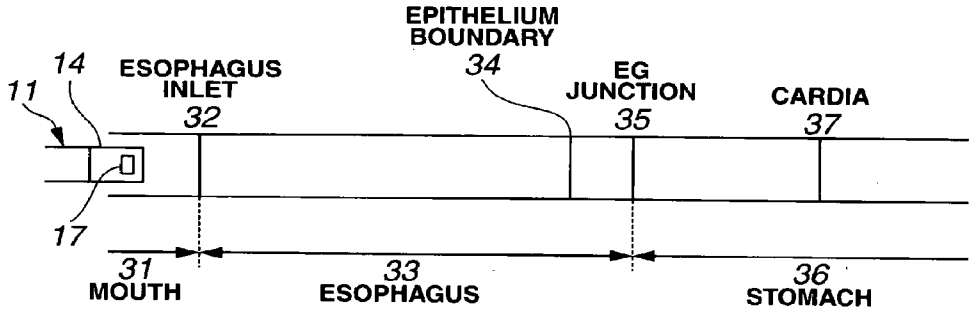


FIG.3

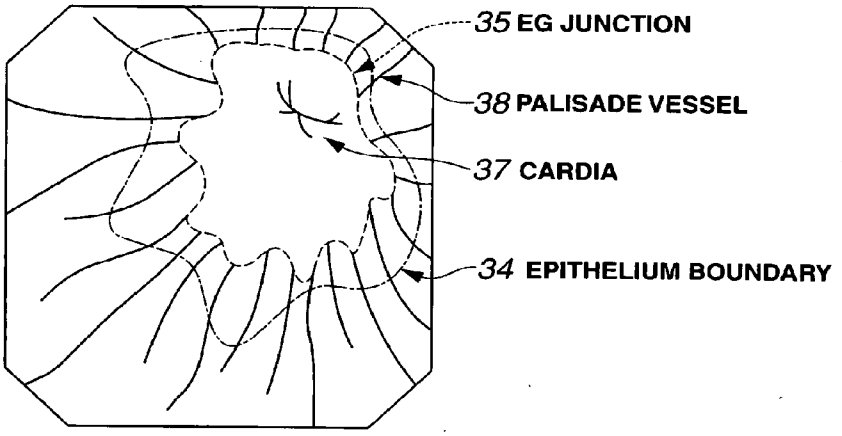


FIG.4

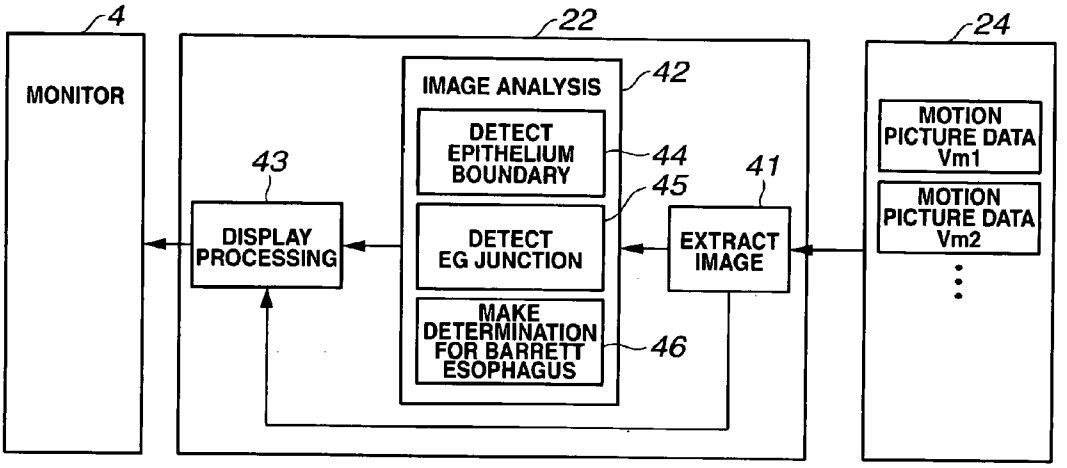


FIG.5

FRAME NUMBER	STILL IMAGE DATA	FRAME TIME
0	Vs0	00:00:00.000
1	Vs1	00:00:00.033
⋮		
MAX_COUNT	VsM	00:00:10.000

FIG.6A

FRAME NUMBER	ANALYSIS RESULT
27	SUSPECTED BARRETT ESOPHAGUS
28	SUSPECTED BARRETT ESOPHAGUS
⋮	

FIG.6B

MAX_COUNT
MAX_N
ANALYSIS RESULT
ACQUISITION INTERVAL N
DETERMINATION REFERENCE VALUE

FIG.7

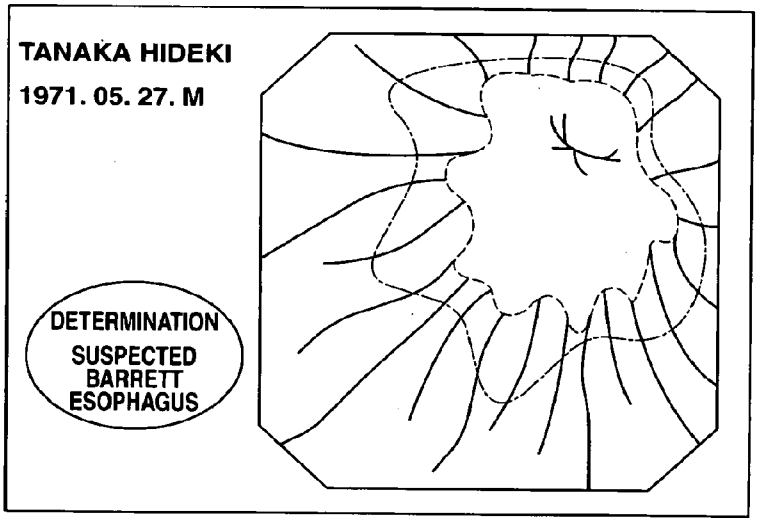


FIG.8

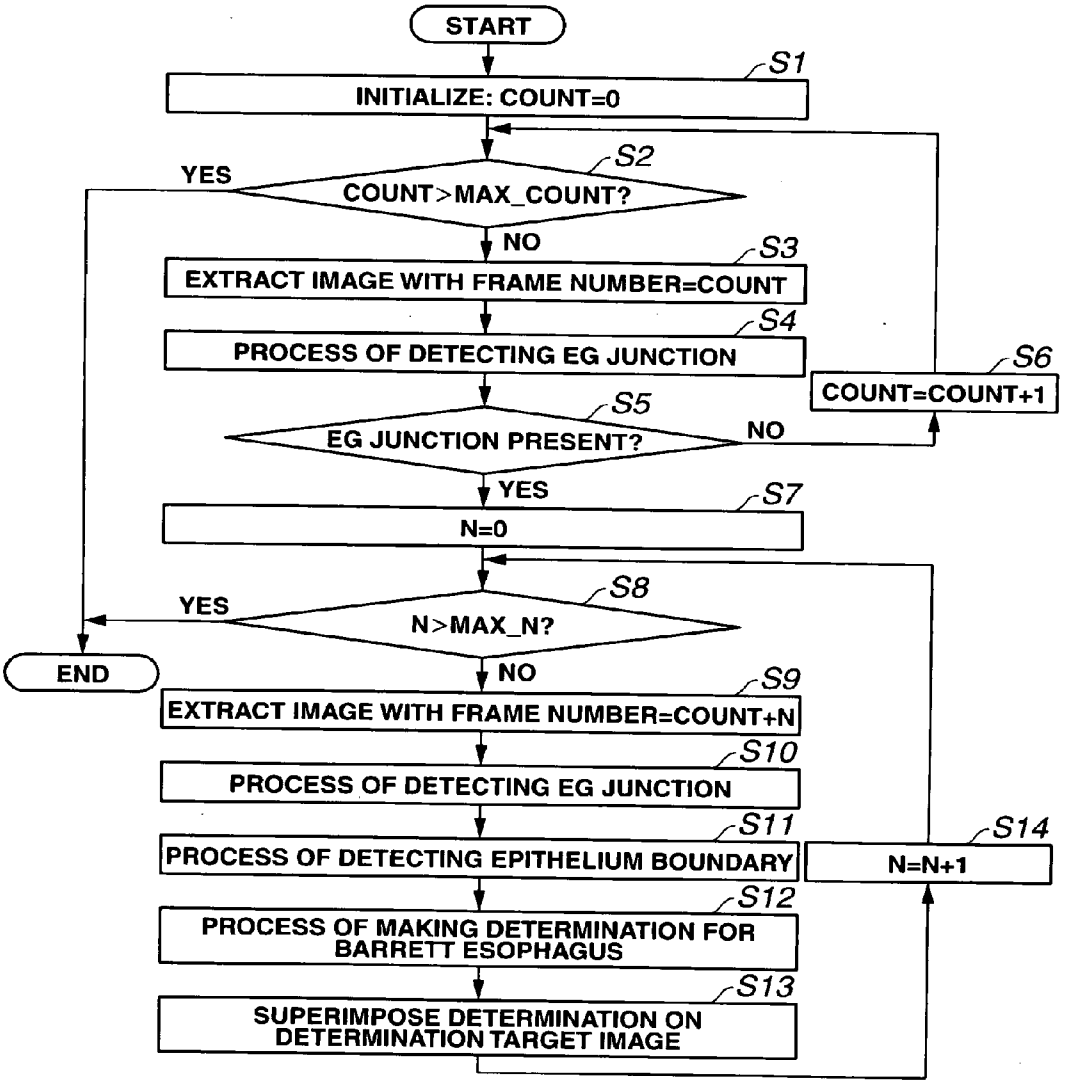

START
S1
INITIALIZE: COUNT=0
S2
YES
COUNT>MAX_COUNT?
NO
S3
EXTRACT IMAGE WITH FRAME NUMBER=COUNT
S4
PROCESS OF DETECTING EG JUNCTION
S6
COUNT=COUNT+1
S5
EG JUNCTION PRESENT?
NO
YES
S7
N=0
S8
YES
N>MAX_N?
END
NO
S9
EXTRACT IMAGE WITH FRAME NUMBER=COUNT+N
S10
PROCESS OF DETECTING EG JUNCTION
S11
PROCESS OF DETECTING EPITHELIUM BOUNDARY
S14
N=N+1
S12
PROCESS OF MAKING DETERMINATION FOR BARRETT ESOPHAGUS
S13
SUPERIMPOSE DETERMINATION ON DETERMINATION TARGET IMAGE

FIG.9

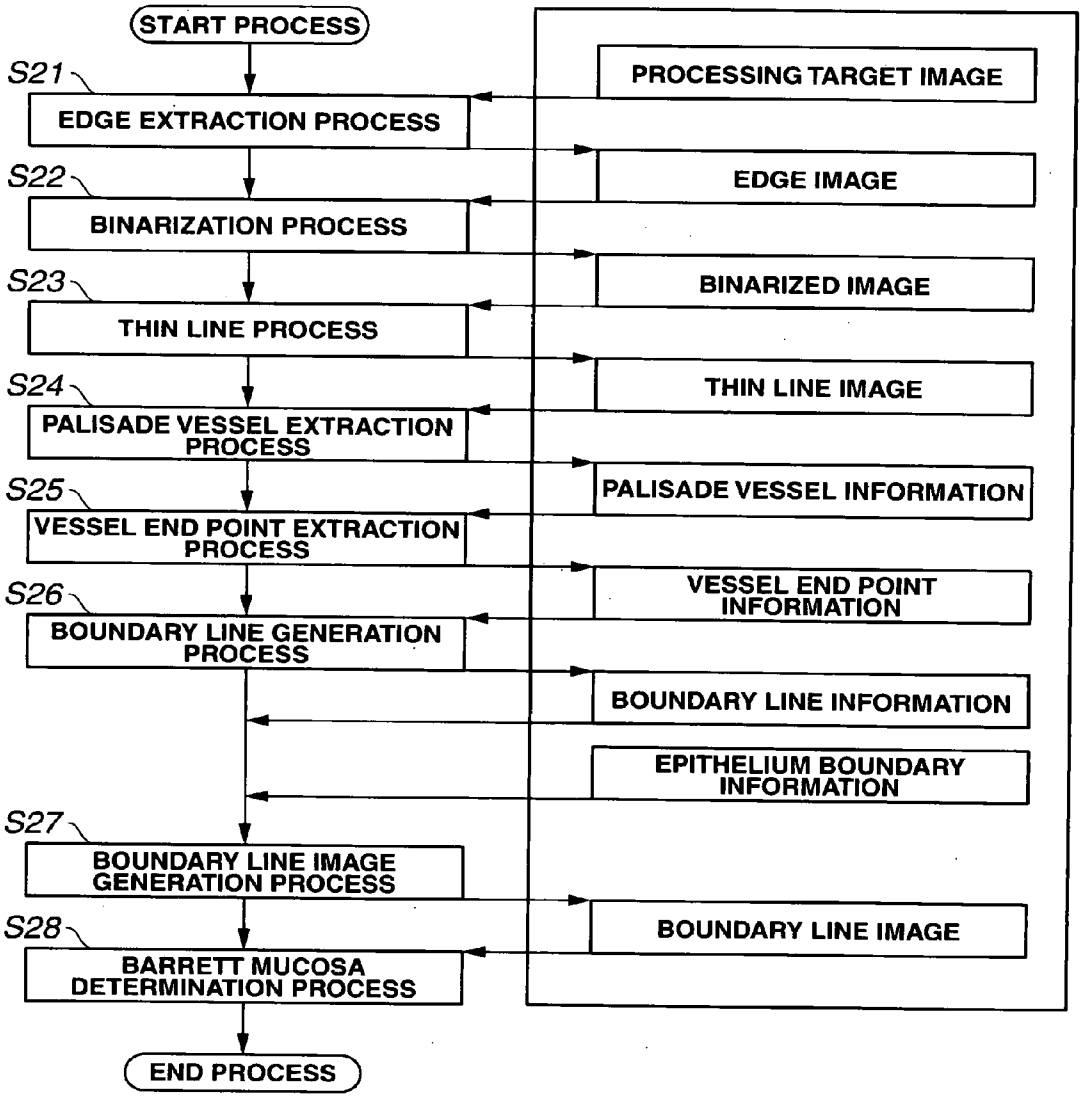

START PROCESS
S21
EDGE EXTRACTION PROCESS
S22
BINARIZATION PROCESS
S23
THIN LINE PROCESS
S24
PALISADE VESSEL EXTRACTION PROCESS
S25
VESSEL END POINT EXTRACTION PROCESS
S26
BOUNDARY LINE GENERATION PROCESS
S27
BOUNDARY LINE IMAGE GENERATION PROCESS
S28
BARRETT MUCOSA DETERMINATION PROCESS
END PROCESS
PROCESSING TARGET IMAGE
EDGE IMAGE
BINARIZED IMAGE
THIN LINE IMAGE
PALISADE VESSEL INFORMATION
VESSEL END POINT INFORMATION
BOUNDARY LINE INFORMATION
EPITHELIUM BOUNDARY INFORMATION
BOUNDARY LINE IMAGE

FIG.10A

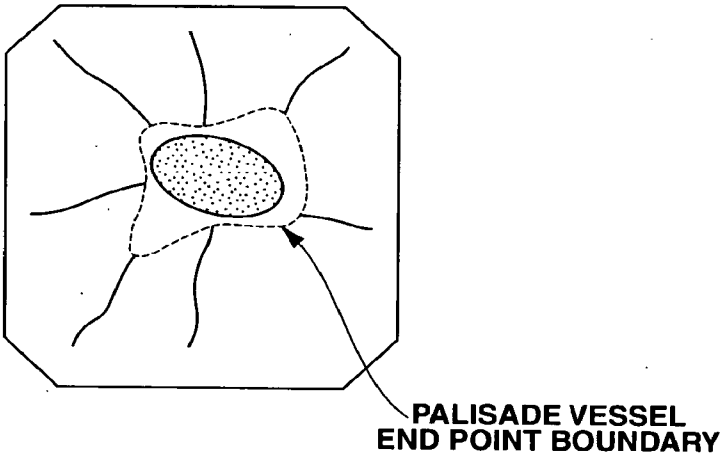


FIG.10B

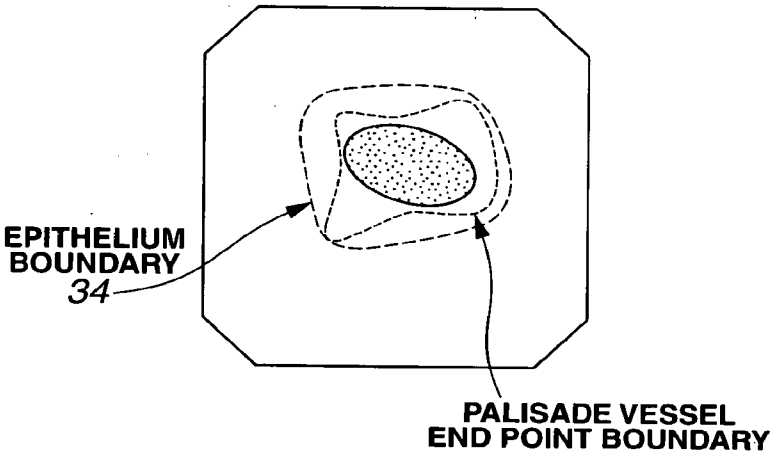


FIG.10C

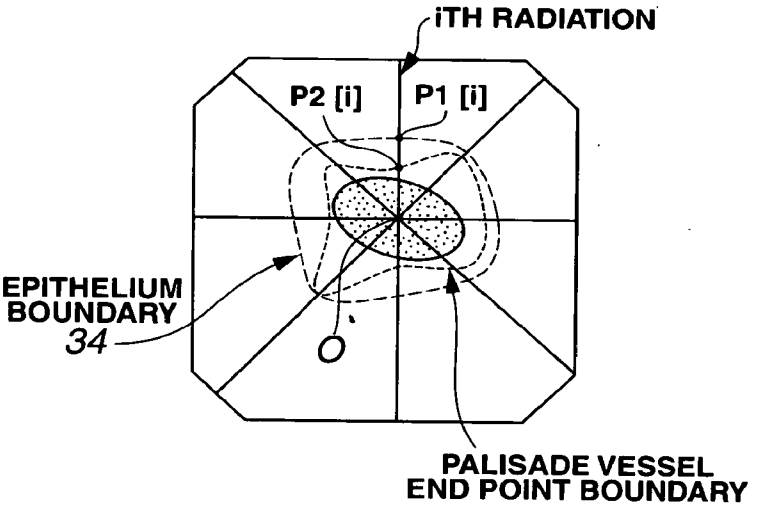


FIG.11

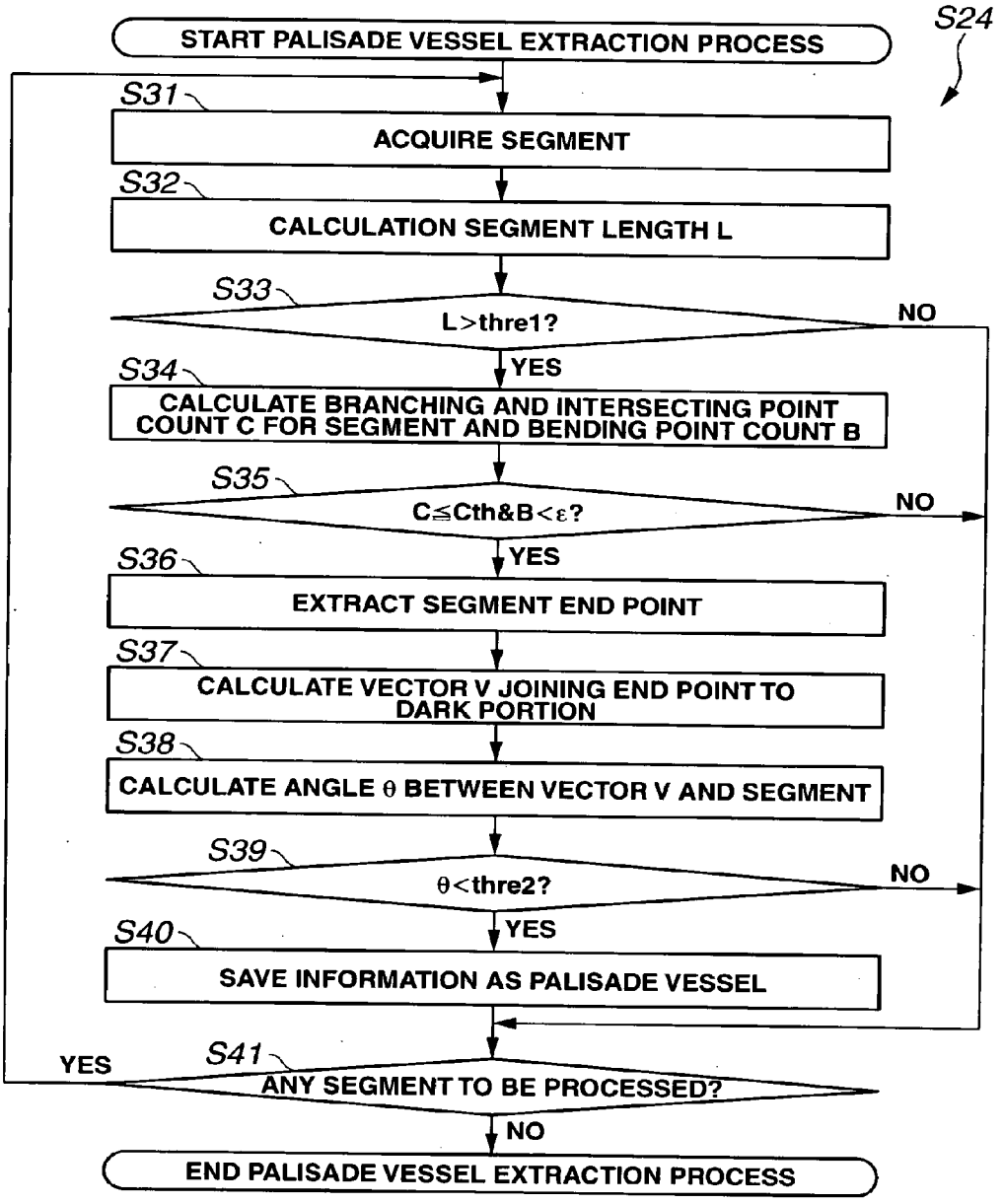

S24
START PALISADE VESSEL EXTRACTION PROCESS
S31
ACQUIRE SEGMENT
S32
CALCULATION SEGMENT LENGTH L
S33
L>thre1?
NO
YES
S34
CALCULATE BRANCHING AND INTERSECTING POINT COUNT C FOR SEGMENT AND BENDING POINT COUNT B
S35
C≦Cth&B<ε?
NO
YES
S36
EXTRACT SEGMENT END POINT
S37
CALCULATE VECTOR V JOINING END POINT TO DARK PORTION
S38
CALCULATE ANGLE θ BETWEEN VECTOR V AND SEGMENT
S39
θ<thre2?
NO
YES
S40
SAVE INFORMATION AS PALISADE VESSEL
S41
YES
ANY SEGMENT TO BE PROCESSED?
NO
END PALISADE VESSEL EXTRACTION PROCESS

FIG.12A

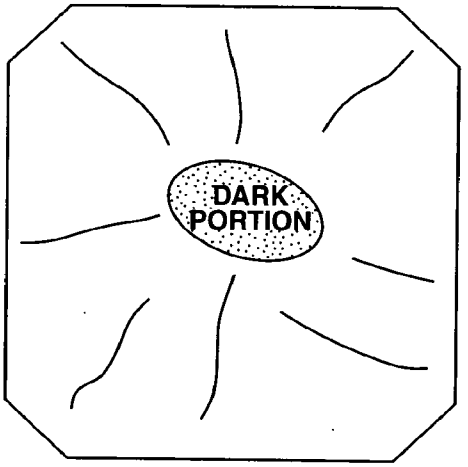


FIG.12B

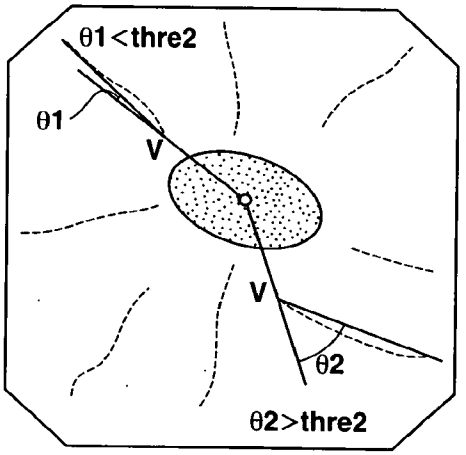


FIG.12C

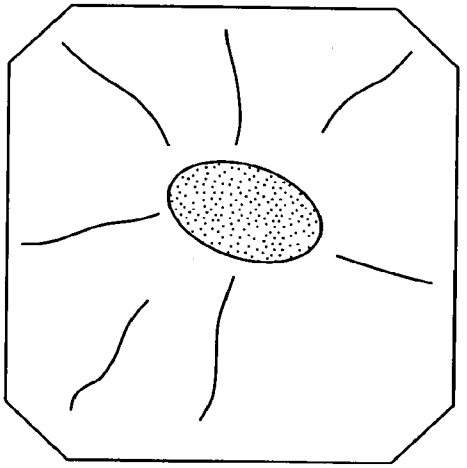


FIG.13

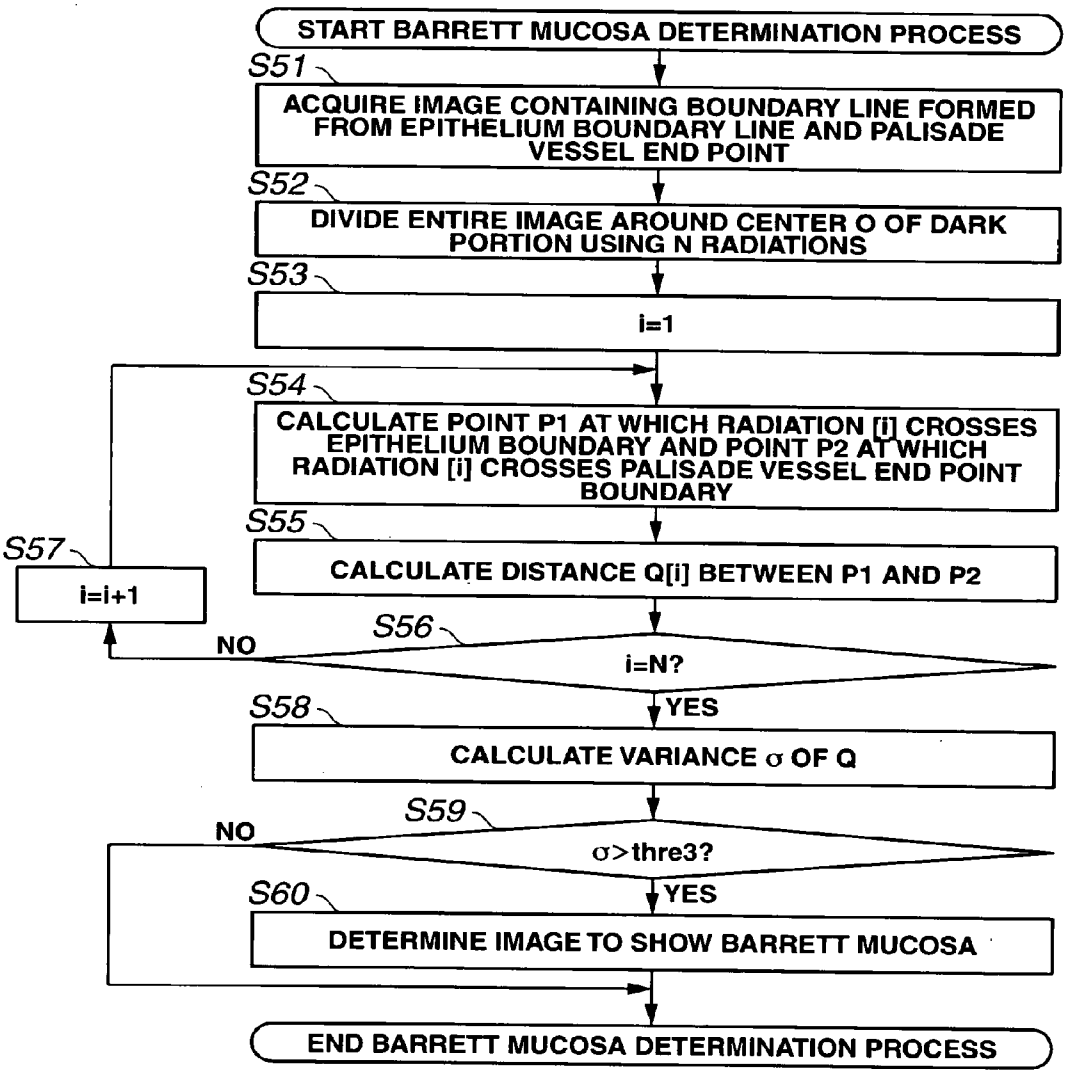

START BARRETT MUCOSA DETERMINATION PROCESS
S51
ACQUIRE IMAGE CONTAINING BOUNDARY LINE FORMED FROM EPITHELIUM BOUNDARY LINE AND PALISADE VESSEL END POINT
S52
DIVIDE ENTIRE IMAGE AROUND CENTER O OF DARK PORTION USING N RADIATIONS
S53
i=1
S54
CALCULATE POINT P1 AT WHICH RADIATION [i] CROSSES EPITHELIUM BOUNDARY AND POINT P2 AT WHICH RADIATION [i] CROSSES PALISADE VESSEL END POINT BOUNDARY
S55
CALCULATE DISTANCE Q[i] BETWEEN P1 AND P2
S56
i=N?
NO
YES
S57
i=i+1
S58
CALCULATE VARIANCE σ OF Q
S59
σ>thre3?
NO
YES
S60
DETERMINE IMAGE TO SHOW BARRETT MUCOSA
END BARRETT MUCOSA DETERMINATION PROCESS

FIG.14

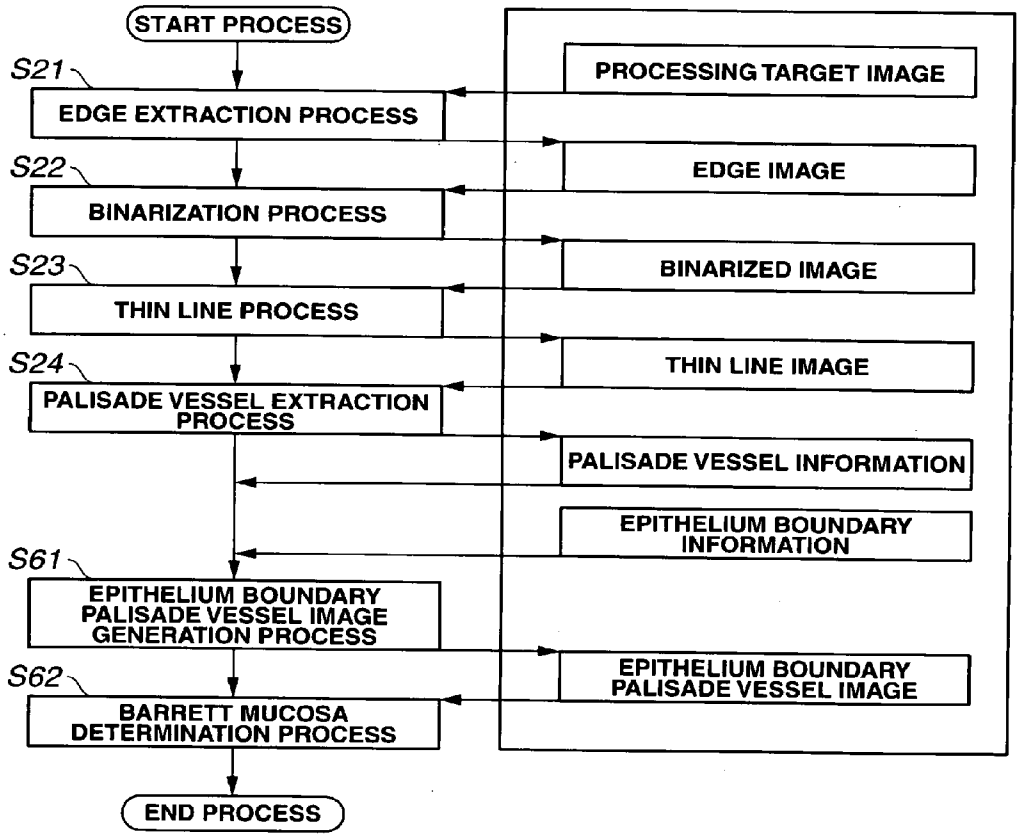

START PROCESS
S21
EDGE EXTRACTION PROCESS
S22
BINARIZATION PROCESS
S23
THIN LINE PROCESS
S24
PALISADE VESSEL EXTRACTION PROCESS
S61
EPITHELIUM BOUNDARY PALISADE VESSEL IMAGE GENERATION PROCESS
S62
BARRETT MUCOSA DETERMINATION PROCESS
END PROCESS
PROCESSING TARGET IMAGE
EDGE IMAGE
BINARIZED IMAGE
THIN LINE IMAGE
PALISADE VESSEL INFORMATION
EPITHELIUM BOUNDARY INFORMATION
EPITHELIUM BOUNDARY PALISADE VESSEL IMAGE

FIG.15A

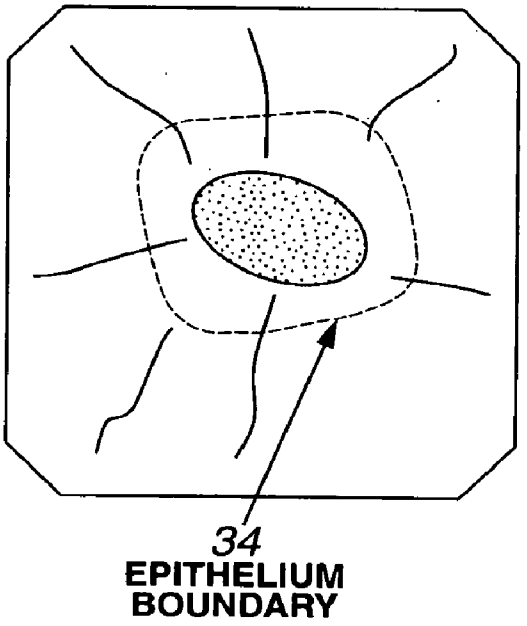


FIG.15B

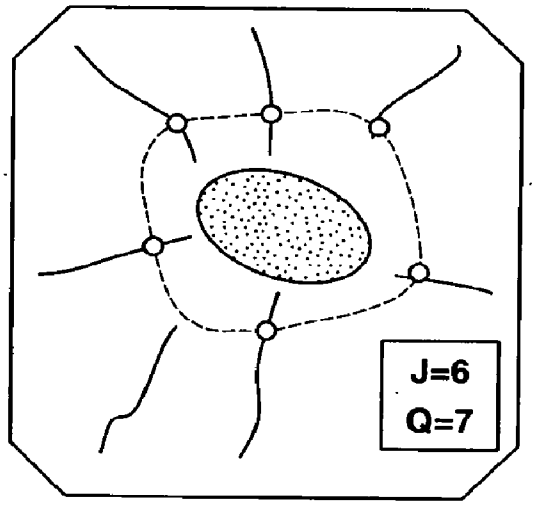


FIG.16

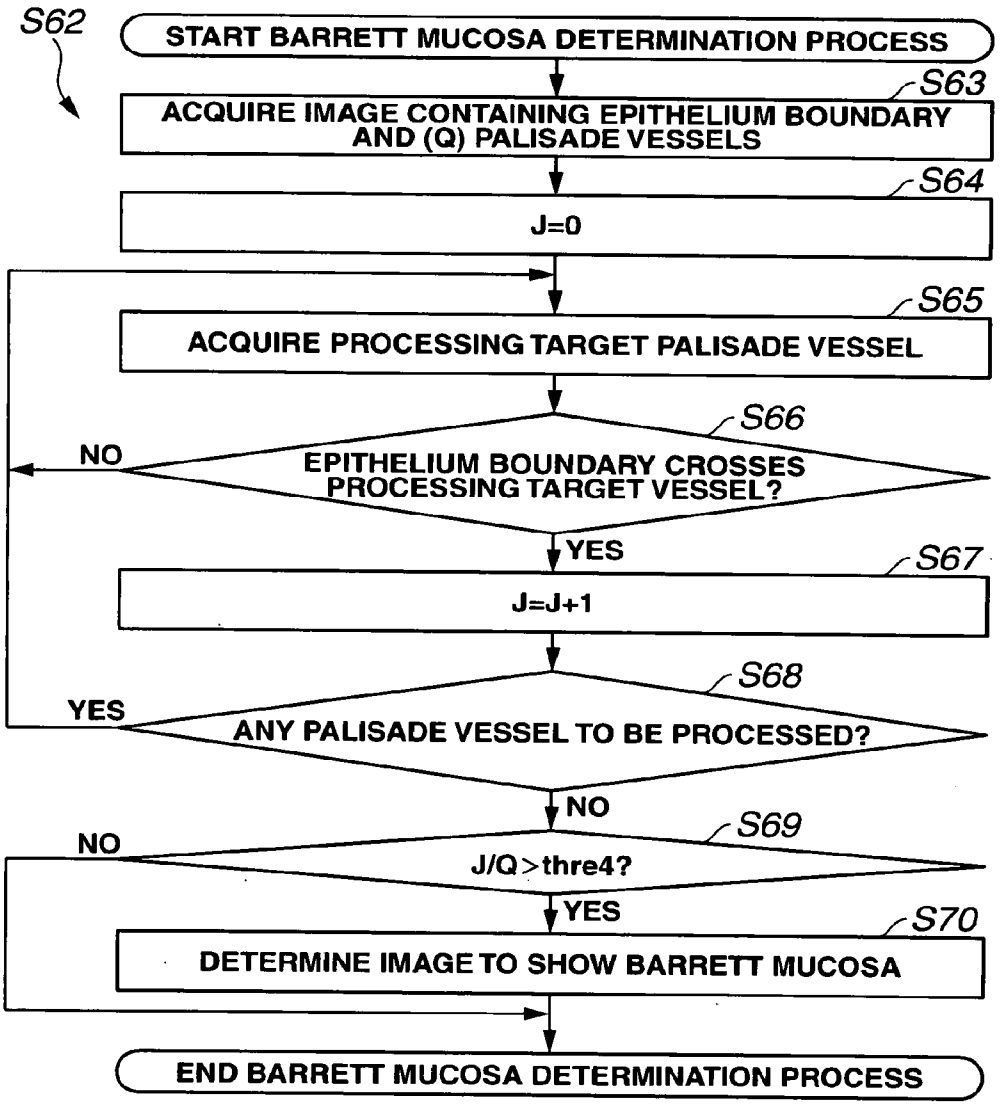

S62
START BARRETT MUCOSA DETERMINATION PROCESS
S63
ACQUIRE IMAGE CONTAINING EPITHELIUM BOUNDARY AND (Q) PALISADE VESSELS
S64
J=0
S65
ACQUIRE PROCESSING TARGET PALISADE VESSEL
S66
EPITHELIUM BOUNDARY CROSSES PROCESSING TARGET VESSEL?
NO
YES
S67
J=J+1
S68
ANY PALISADE VESSEL TO BE PROCESSED?
YES
NO
S69
J/Q>thre4?
NO
YES
S70
DETERMINE IMAGE TO SHOW BARRETT MUCOSA
END BARRETT MUCOSA DETERMINATION PROCESS

FIG.17

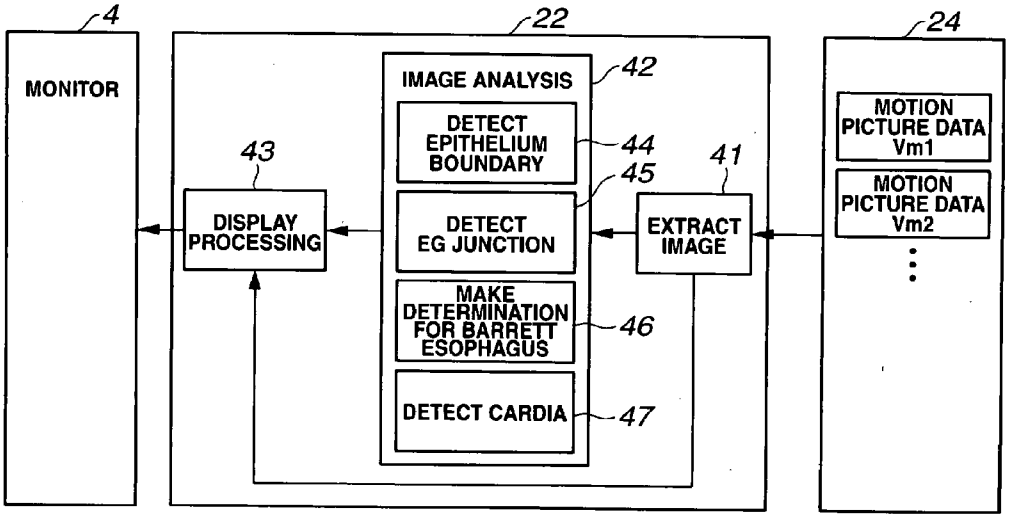

4
MONITOR
22
IMAGE ANALYSIS
42
DETECT EPITHELIUM BOUNDARY
44
45
DETECT EG JUNCTION
MAKE DETERMINATION FOR BARRETT ESOPHAGUS
46
DETECT CARDIA
47
43
DISPLAY PROCESSING
41
EXTRACT IMAGE
24
MOTION PICTURE DATA Vm1
MOTION PICTURE DATA Vm2

FIG.18

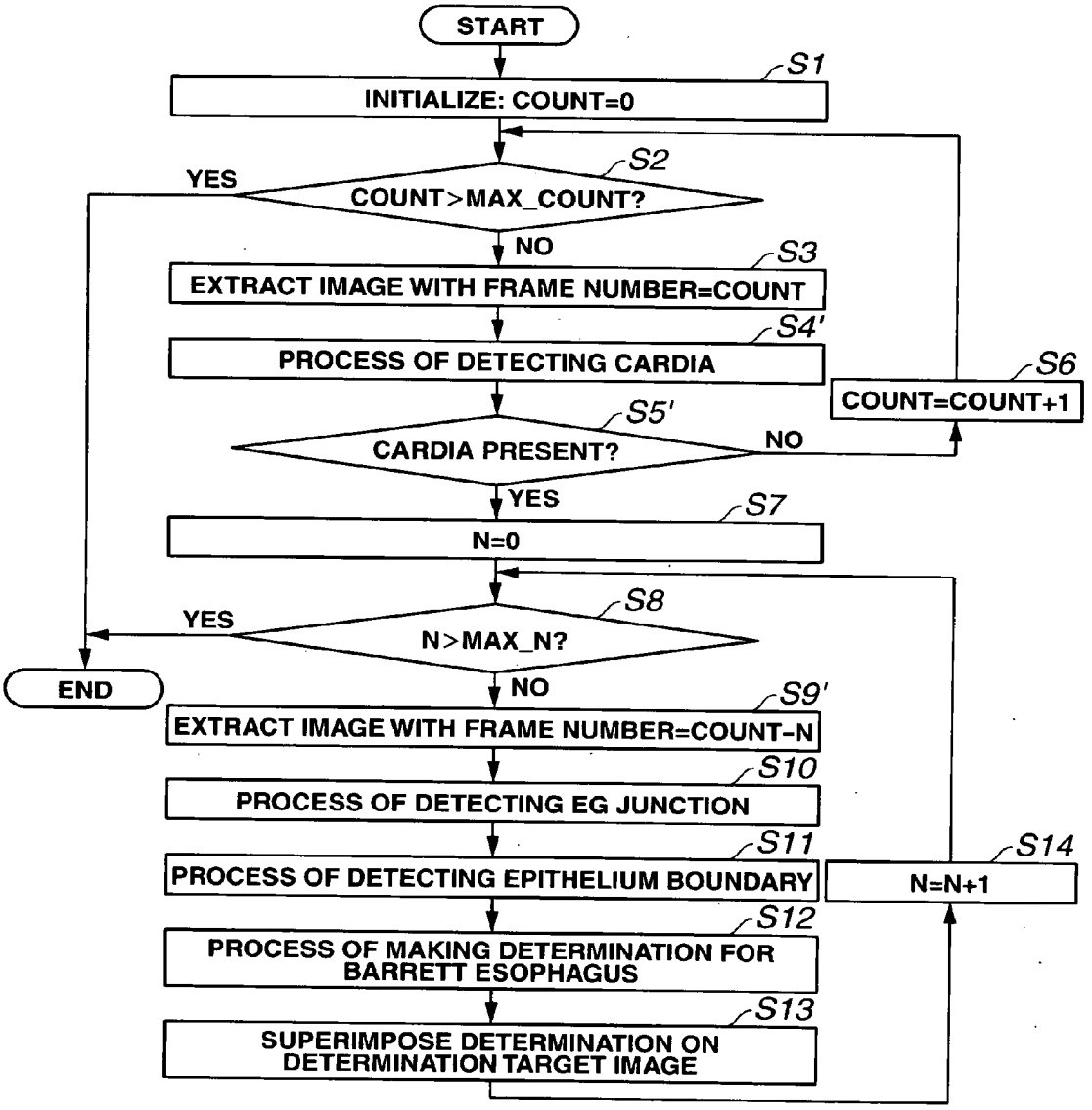

START
S1
INITIALIZE: COUNT=0
S2
YES
COUNT>MAX_COUNT?
NO
S3
EXTRACT IMAGE WITH FRAME NUMBER=COUNT
S4'
PROCESS OF DETECTING CARDIA
S6
COUNT=COUNT+1
S5'
CARDIA PRESENT?
NO
YES
S7
N=0
S8
YES
N>MAX_N?
END
NO
S9'
EXTRACT IMAGE WITH FRAME NUMBER=COUNT-N
S10
PROCESS OF DETECTING EG JUNCTION
S11
PROCESS OF DETECTING EPITHELIUM BOUNDARY
S14
N=N+1
S12
PROCESS OF MAKING DETERMINATION FOR BARRETT ESOPHAGUS
S13
SUPERIMPOSE DETERMINATION ON DETERMINATION TARGET IMAGE

FIG.19

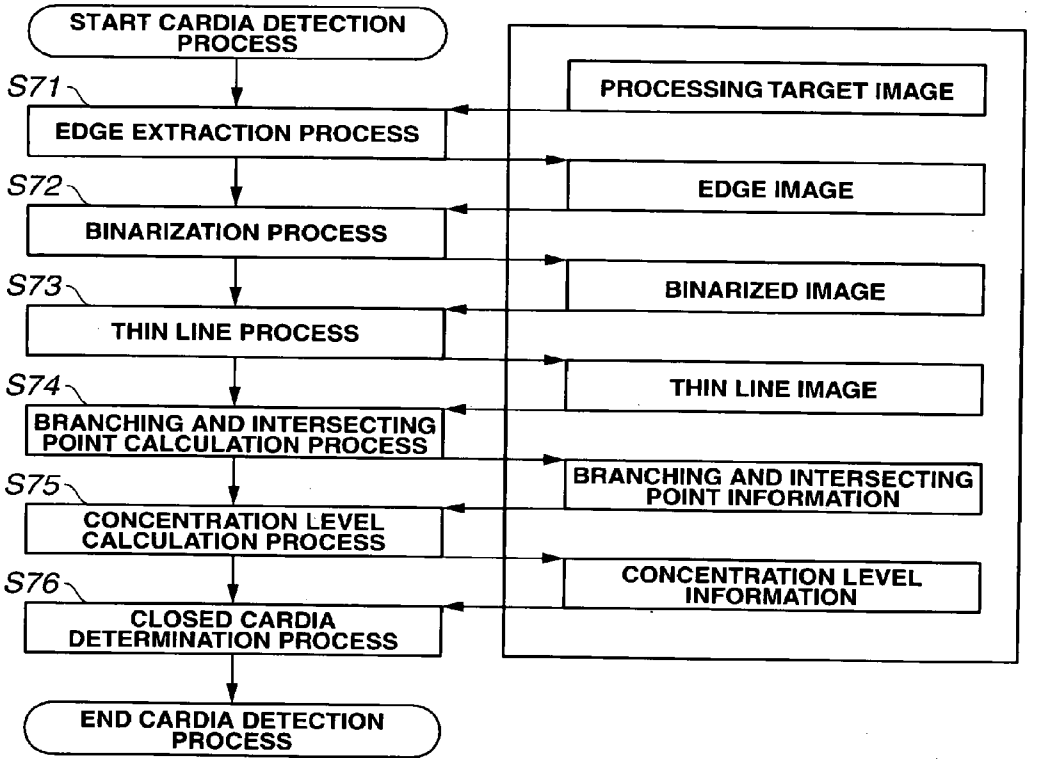


FIG.20A

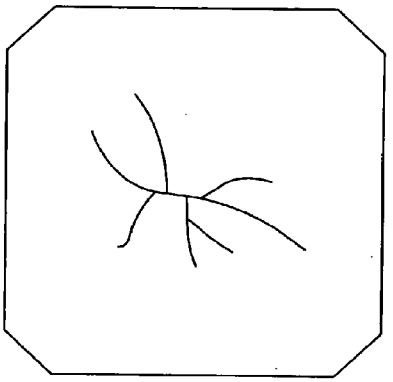


FIG.20B

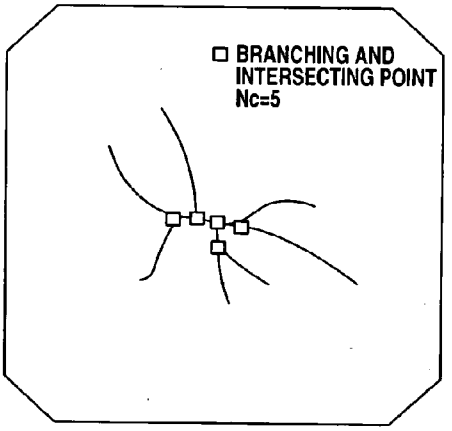


FIG.21

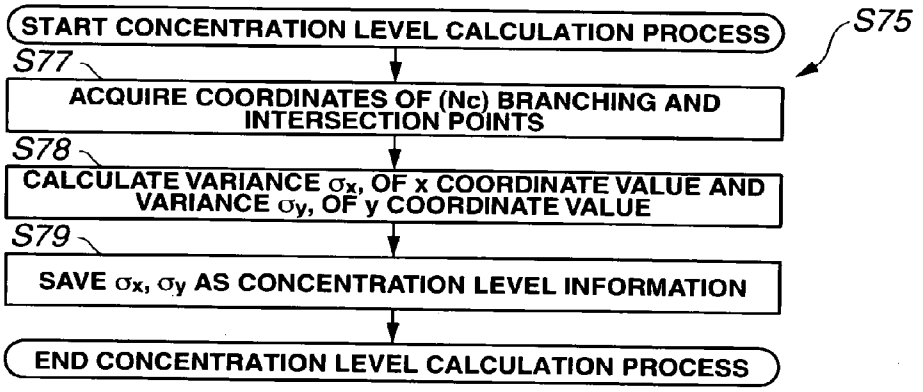


FIG.22

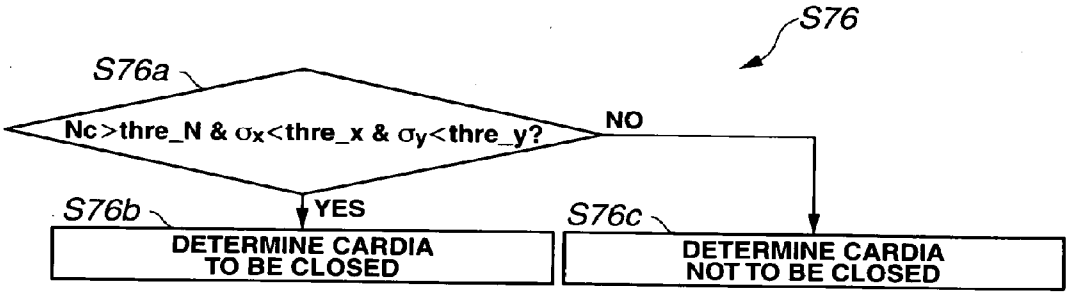


FIG.23

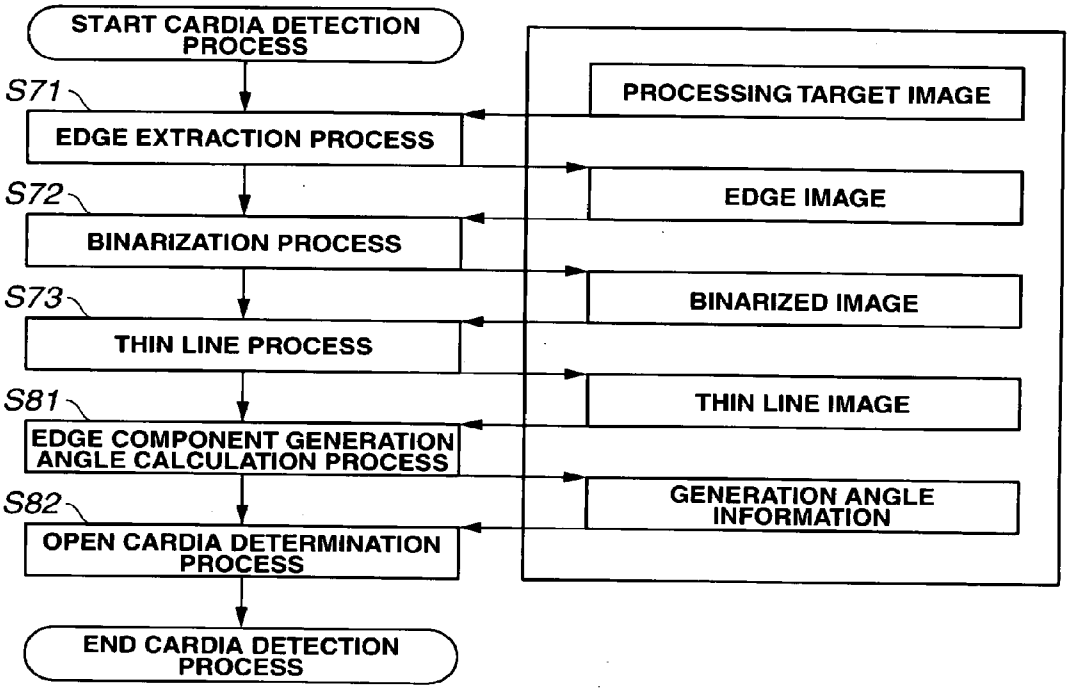


FIG.24A

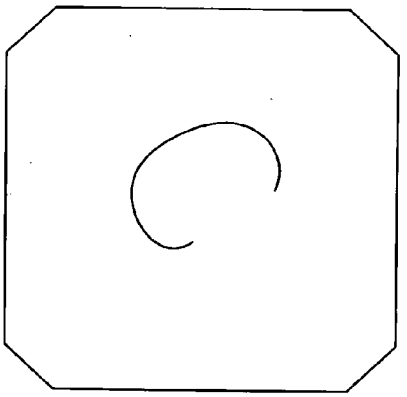


FIG.24B

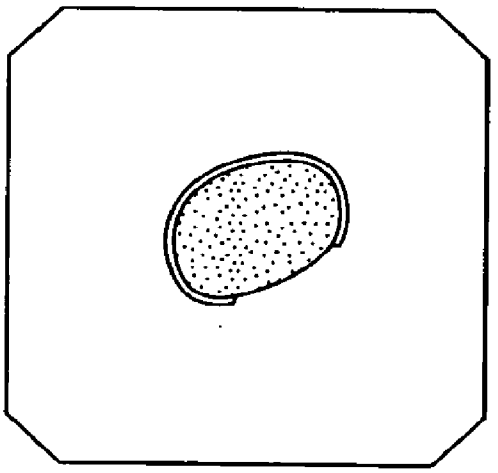


FIG.24C

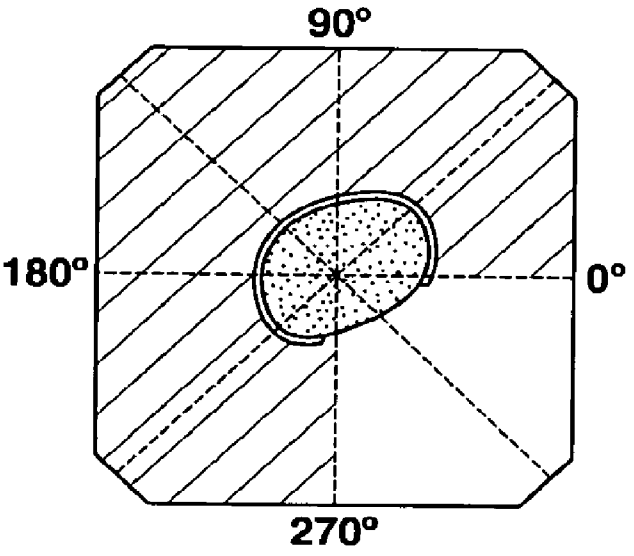


FIG.25

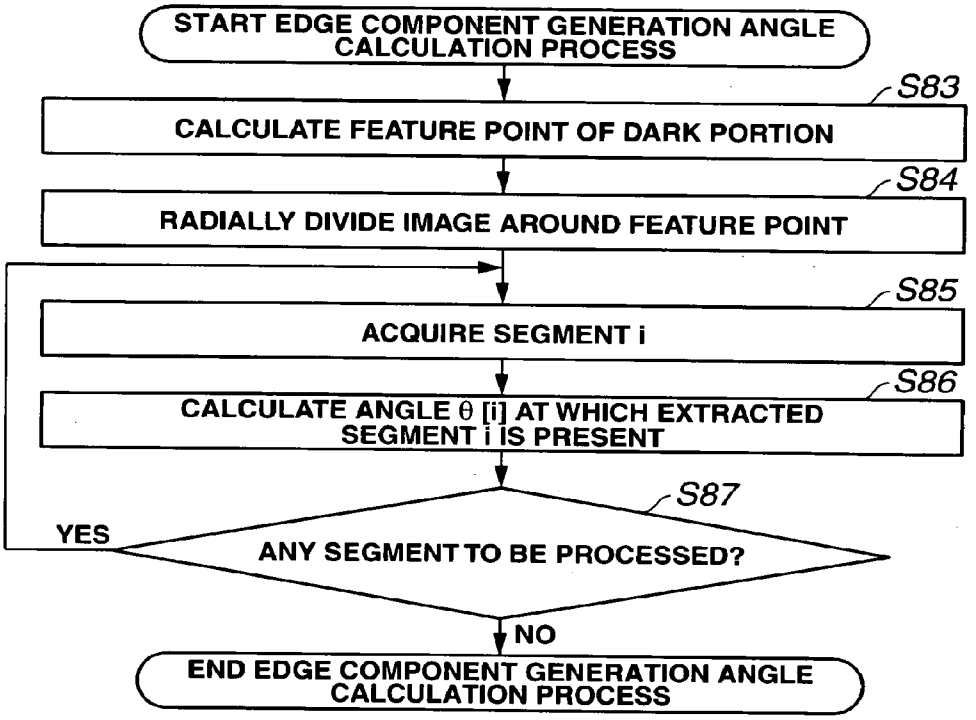

START EDGE COMPONENT GENERATION ANGLE CALCULATION PROCESS
S83
CALCULATE FEATURE POINT OF DARK PORTION
S84
RADIALLY DIVIDE IMAGE AROUND FEATURE POINT
S85
ACQUIRE SEGMENT i
S86
CALCULATE ANGLE θ [i] AT WHICH EXTRACTED SEGMENT i IS PRESENT
S87
ANY SEGMENT TO BE PROCESSED?
YES
NO
END EDGE COMPONENT GENERATION ANGLE CALCULATION PROCESS

FIG.26

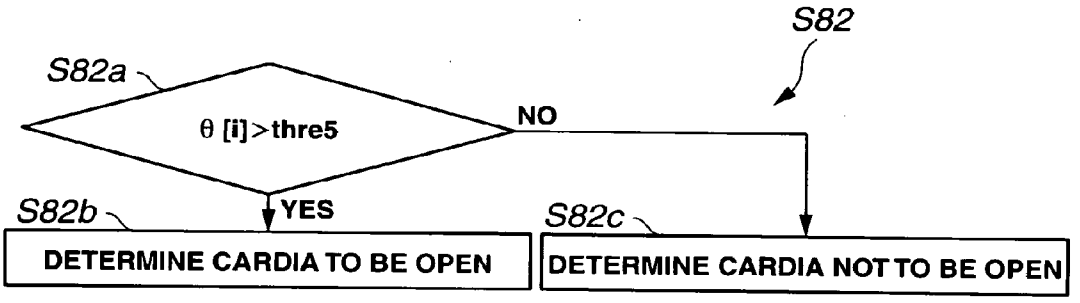

S82
S82a
θ [i]>thre5
NO
YES
S82b
DETERMINE CARDIA TO BE OPEN
S82c
DETERMINE CARDIA NOT TO BE OPEN

FIG.27

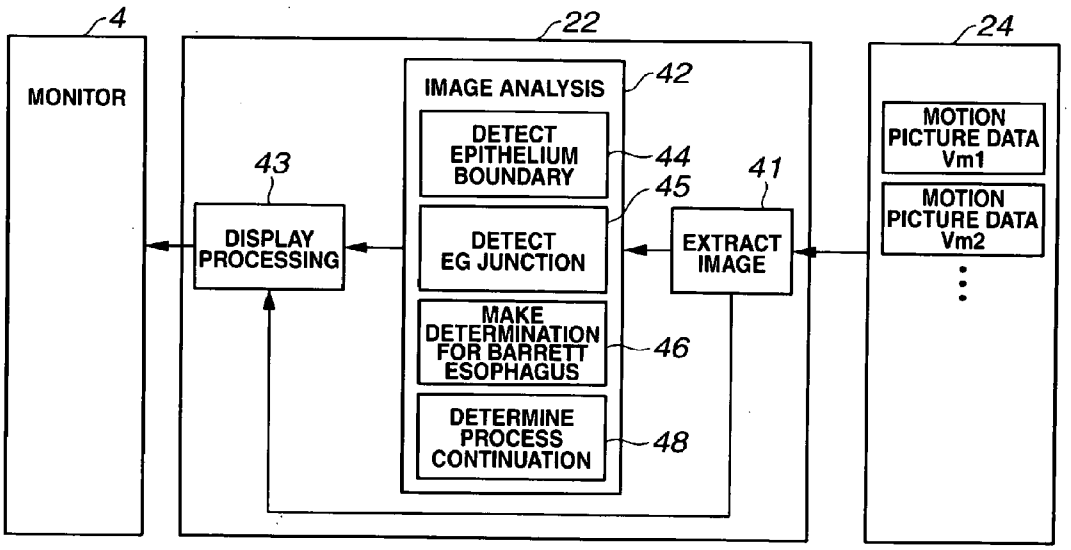

4
MONITOR
22
IMAGE ANALYSIS
42
DETECT EPITHELIUM BOUNDARY
44
45
DETECT EG JUNCTION
MAKE DETERMINATION FOR BARRETT ESOPHAGUS
46
DETERMINE PROCESS CONTINUATION
48
43
DISPLAY PROCESSING
41
EXTRACT IMAGE
24
MOTION PICTURE DATA Vm1
MOTION PICTURE DATA Vm2

FIG.28

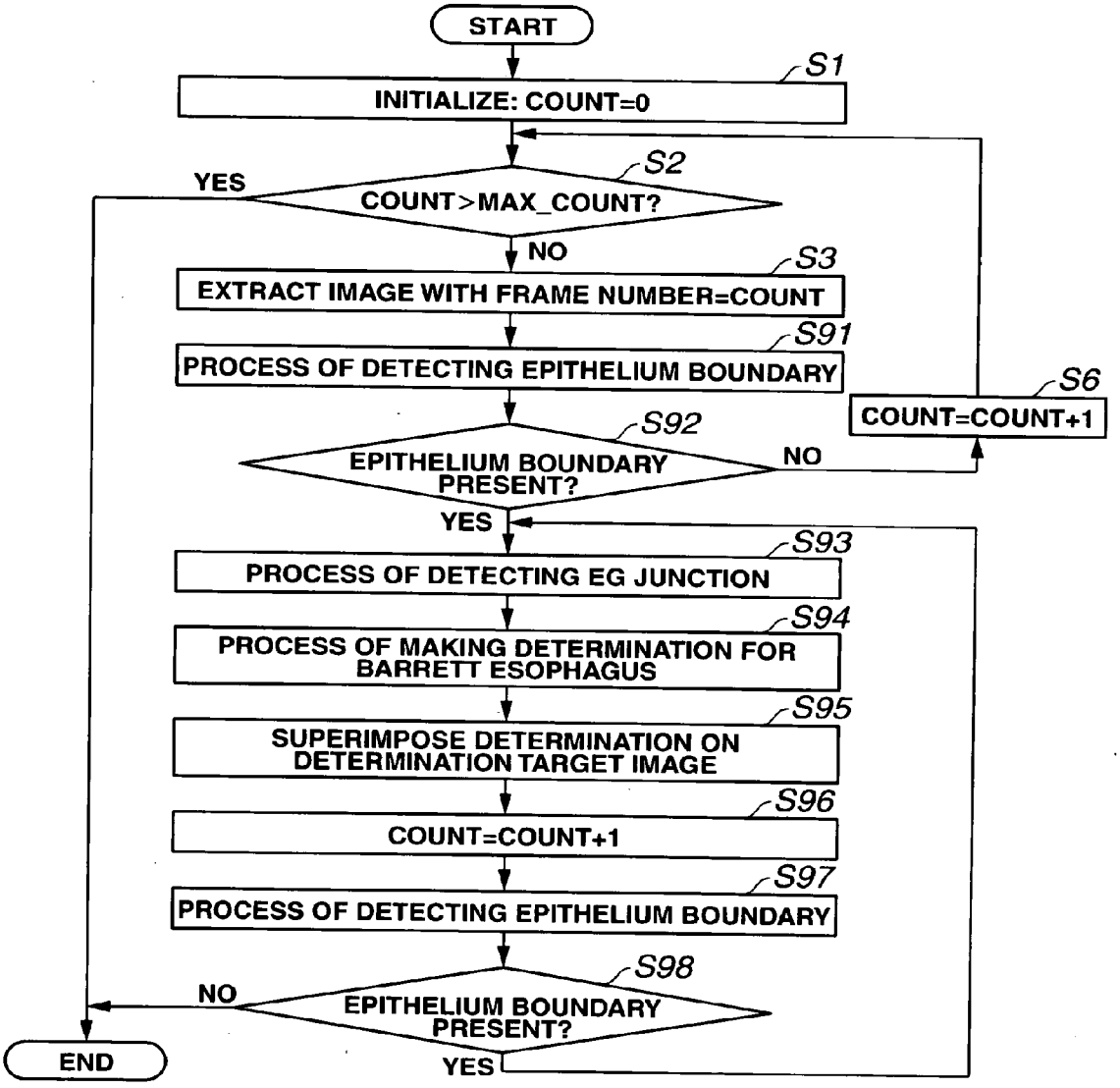

START
S1
INITIALIZE: COUNT=0
S2
YES
COUNT>MAX_COUNT?
NO
S3
EXTRACT IMAGE WITH FRAME NUMBER=COUNT
S91
PROCESS OF DETECTING EPITHELIUM BOUNDARY
S92
EPITHELIUM BOUNDARY PRESENT?
NO
S6
COUNT=COUNT+1
YES
S93
PROCESS OF DETECTING EG JUNCTION
S94
PROCESS OF MAKING DETERMINATION FOR BARRETT ESOPHAGUS
S95
SUPERIMPOSE DETERMINATION ON DETERMINATION TARGET IMAGE
S96
COUNT=COUNT+1
S97
PROCESS OF DETECTING EPITHELIUM BOUNDARY
S98
NO
EPITHELIUM BOUNDARY PRESENT?
END
YES

FIG.29

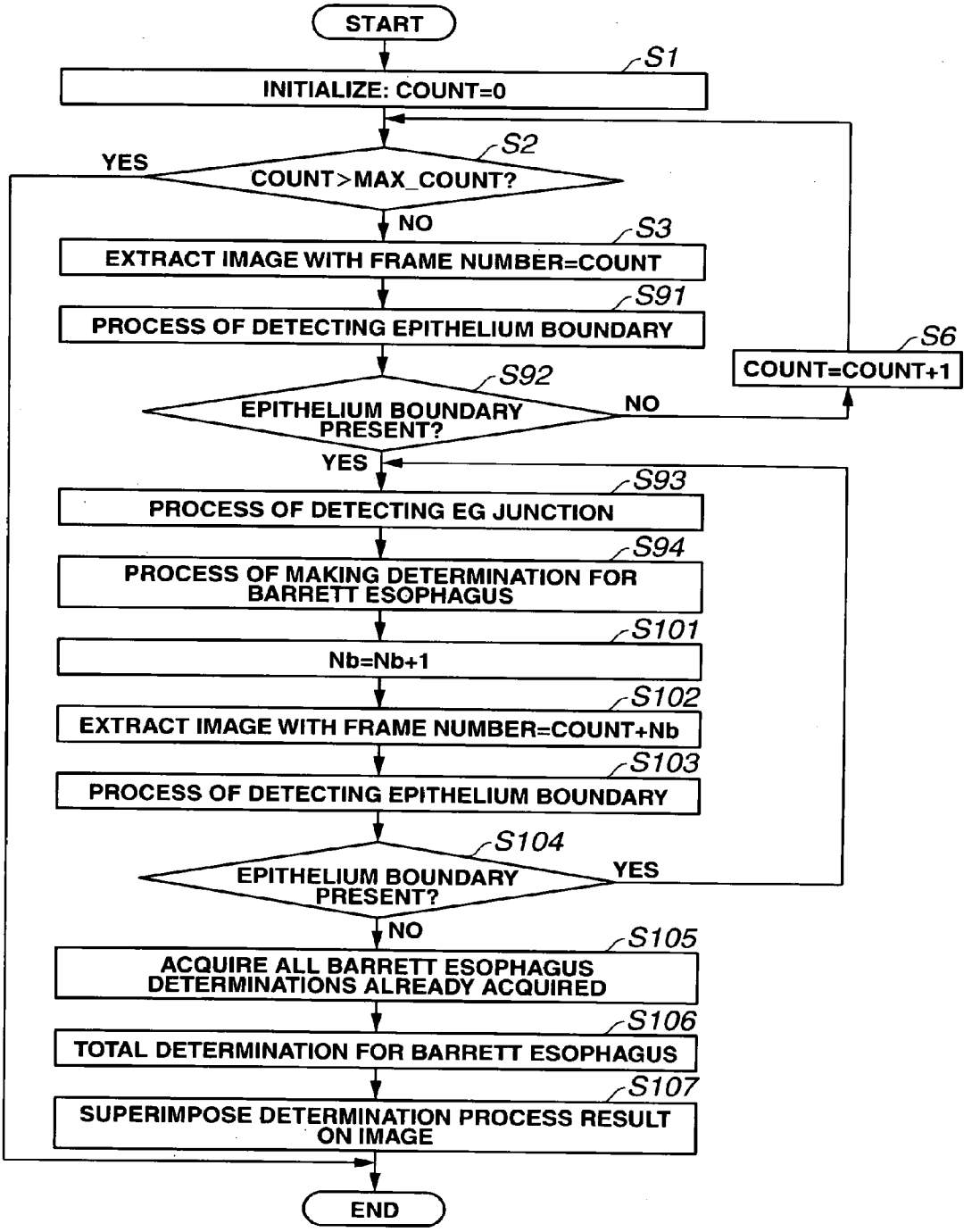

START
S1
INITIALIZE: COUNT=0
S2
YES
COUNT>MAX_COUNT?
NO
S3
EXTRACT IMAGE WITH FRAME NUMBER=COUNT
S91
PROCESS OF DETECTING EPITHELIUM BOUNDARY
S92
EPITHELIUM BOUNDARY PRESENT?
NO
S6
COUNT=COUNT+1
YES
S93
PROCESS OF DETECTING EG JUNCTION
S94
PROCESS OF MAKING DETERMINATION FOR BARRETT ESOPHAGUS
S101
Nb=Nb+1
S102
EXTRACT IMAGE WITH FRAME NUMBER=COUNT+Nb
S103
PROCESS OF DETECTING EPITHELIUM BOUNDARY
S104
EPITHELIUM BOUNDARY PRESENT?
YES
NO
S105
ACQUIRE ALL BARRETT ESOPHAGUS DETERMINATIONS ALREADY ACQUIRED
S106
TOTAL DETERMINATION FOR BARRETT ESOPHAGUS
S107
SUPERIMPOSE DETERMINATION PROCESS RESULT ON IMAGE
END

FIG.30A

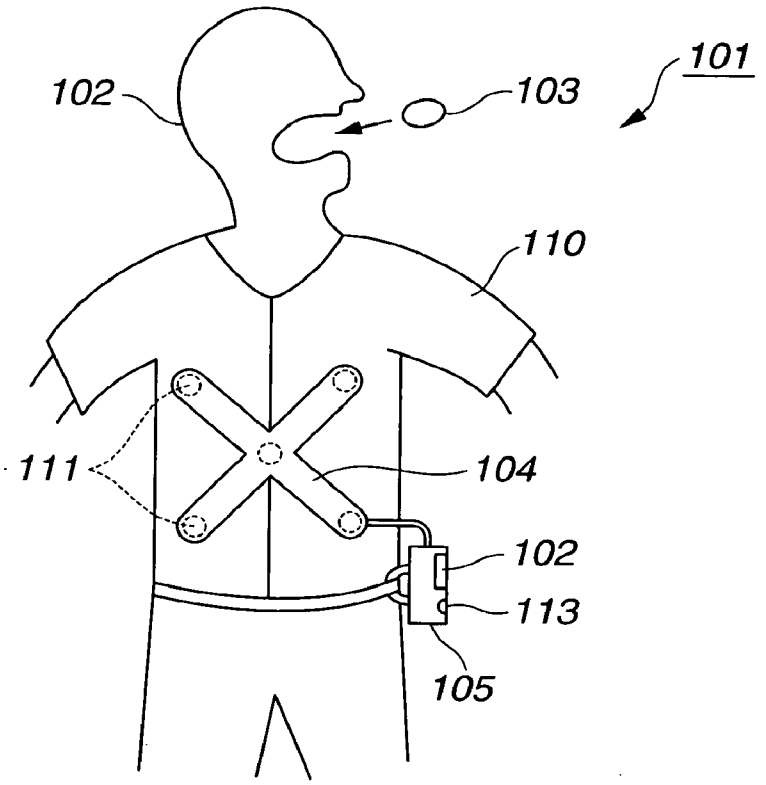


FIG.30B

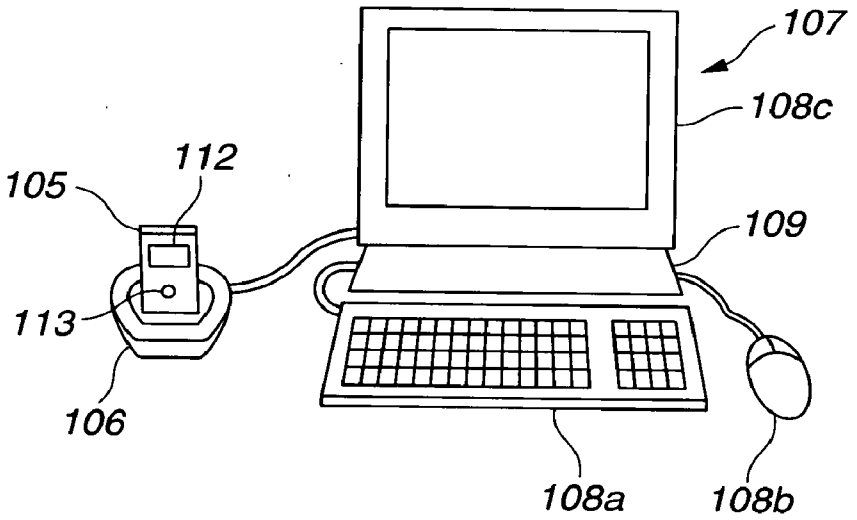


FIG.31

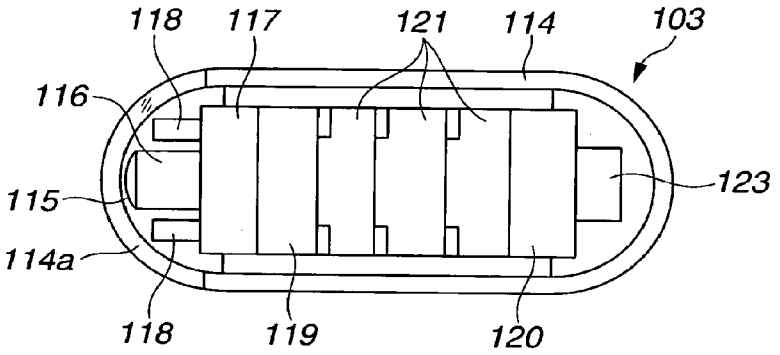

118
117
121
114
103
116
115
123
114a
118
119
120

FIG.32

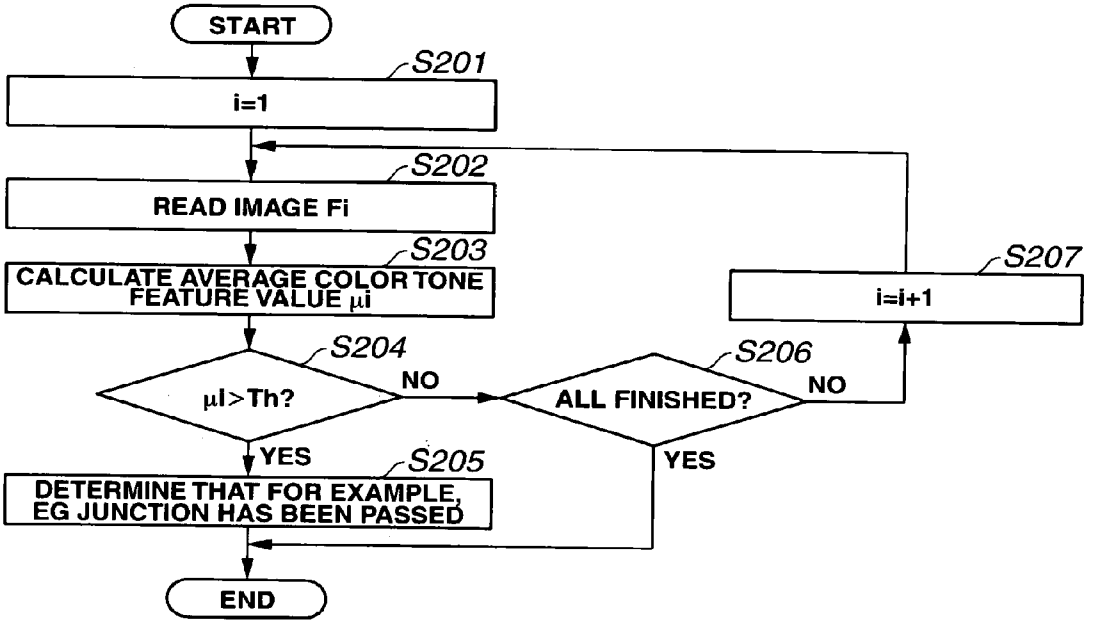

START
S201
i=1
S202
READ IMAGE Fi
S203
CALCULATE AVERAGE COLOR TONE FEATURE VALUE μi
S204
μI>Th?
NO
YES
S205
DETERMINE THAT FOR EXAMPLE, EG JUNCTION HAS BEEN PASSED
S206
ALL FINISHED?
NO
YES
S207
i=i+1
END

FIG.33

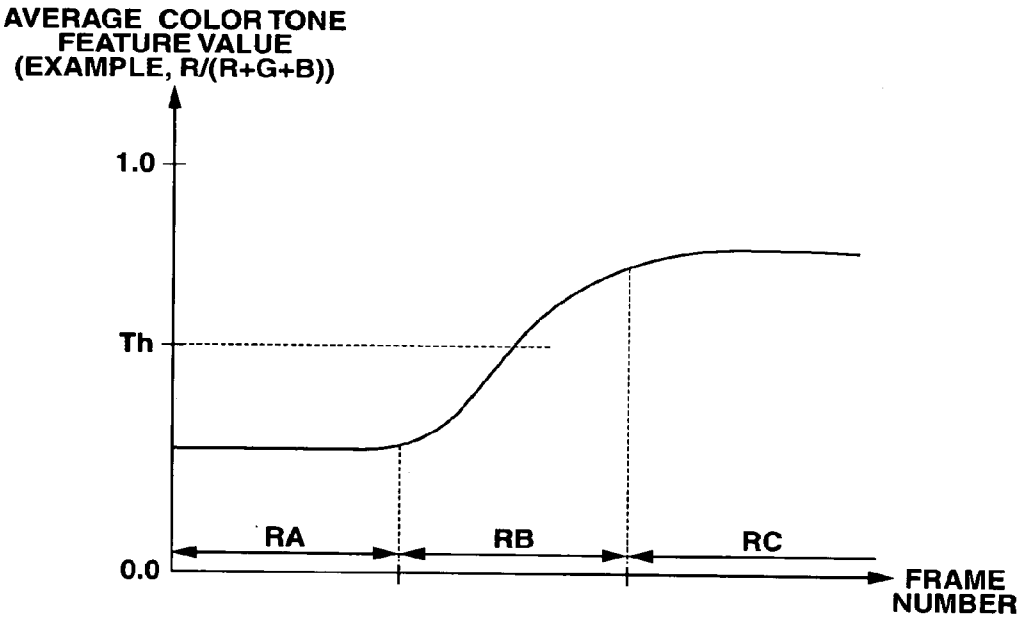

AVERAGE COLOR TONE FEATURE VALUE (EXAMPLE, R/(R+G+B))
1.0
Th
0.0
RA
RB
RC
FRAME NUMBER

FIG.34

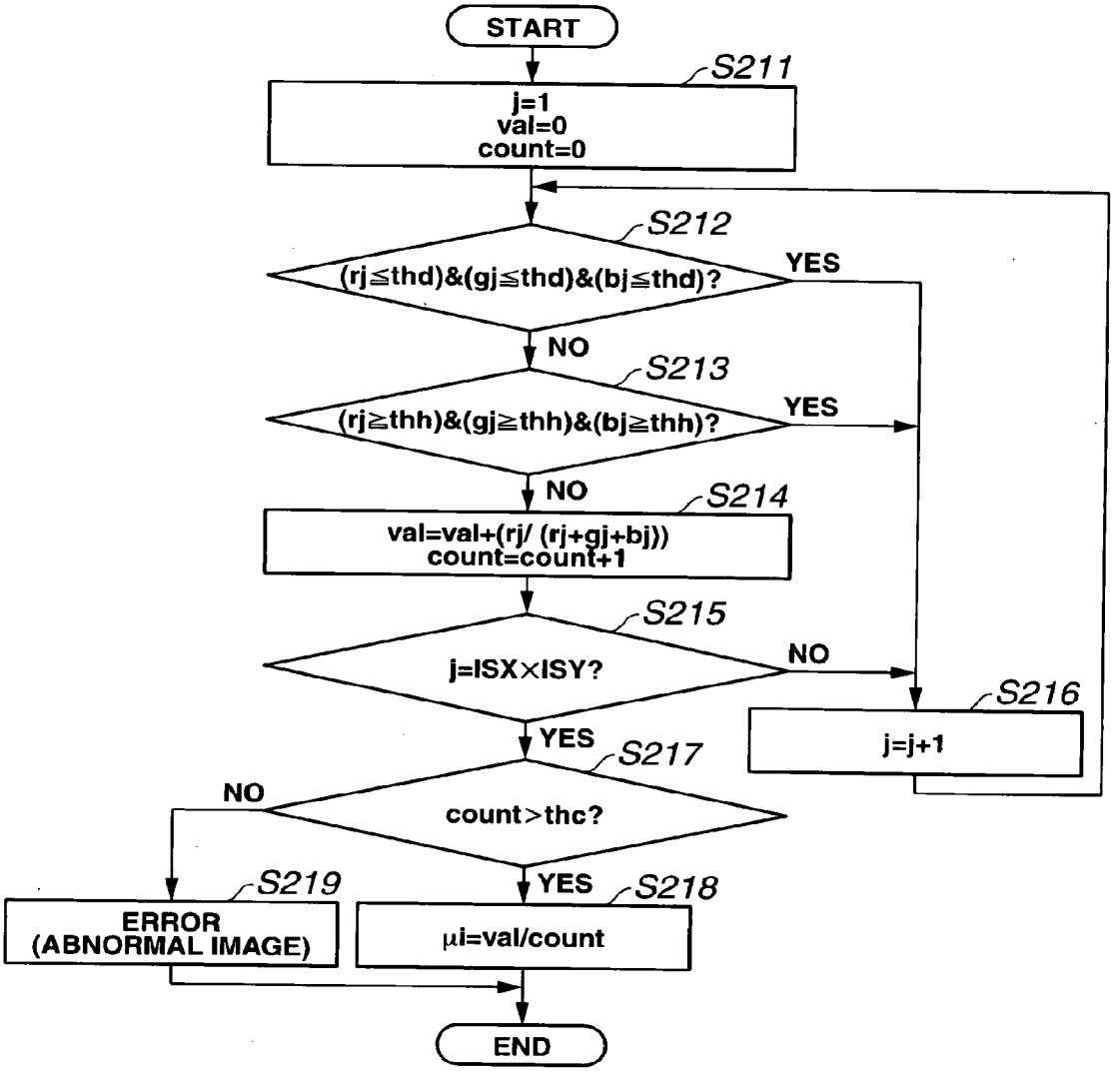

START
S211
j=1
val=0
count=0
S212
(rj≦thd)&(gj≦thd)&(bj≦thd)?
YES
NO
S213
(rj≧thh)&(gj≧thh)&(bj≧thh)?
YES
NO
S214
val=val+(rj/ (rj+gj+bj))
count=count+1
S215
j=ISX×ISY?
NO
S216
j=j+1
YES
S217
count>thc?
NO
YES
S218
μi=val/count
S219
ERROR
(ABNORMAL IMAGE)
END

FIG.35

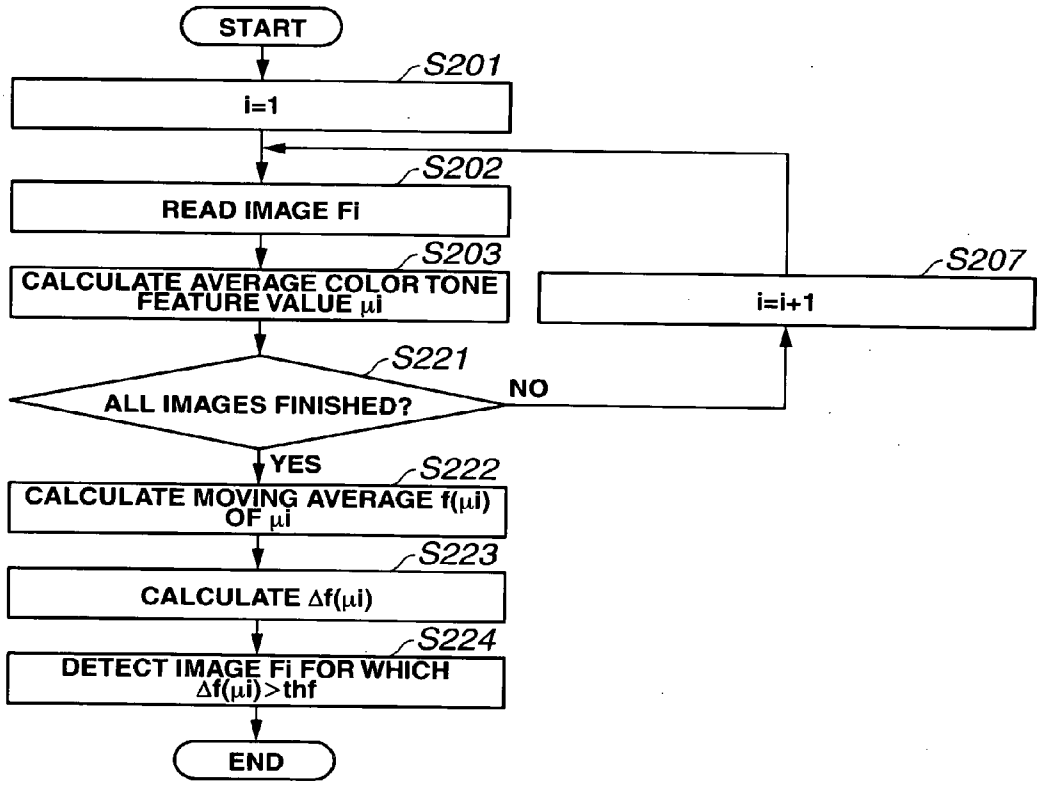

START
S201
i=1
S202
READ IMAGE Fi
S203
CALCULATE AVERAGE COLOR TONE FEATURE VALUE μi
S221
ALL IMAGES FINISHED?
NO
YES
S207
i=i+1
S222
CALCULATE MOVING AVERAGE f(μi) OF μi
S223
CALCULATE Δf(μi)
S224
DETECT IMAGE Fi FOR WHICH Δf(μi)>thf
END

FIG.36

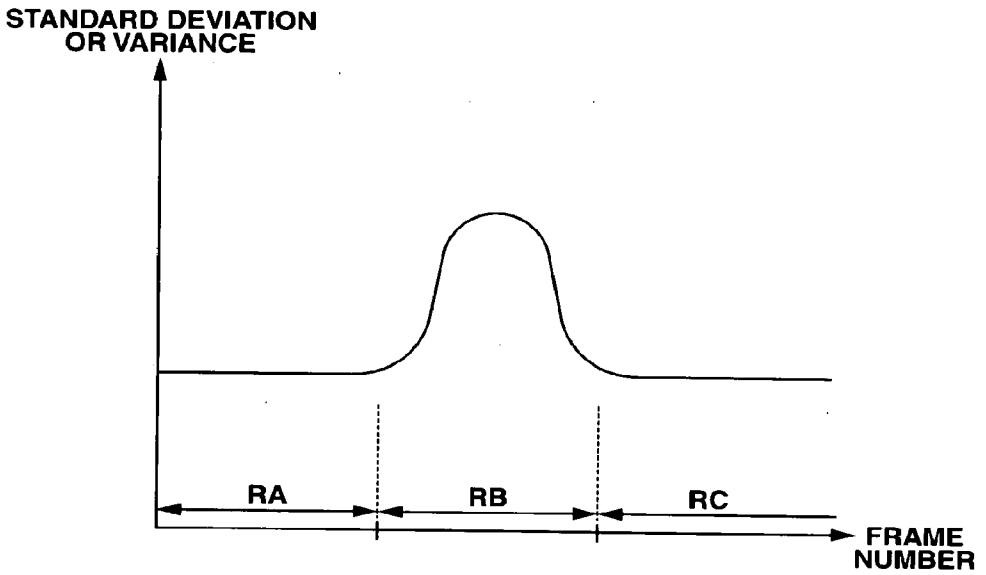

STANDARD DEVIATION
OR VARIANCE
RA
RB
RC
FRAME
NUMBER

FIG.37

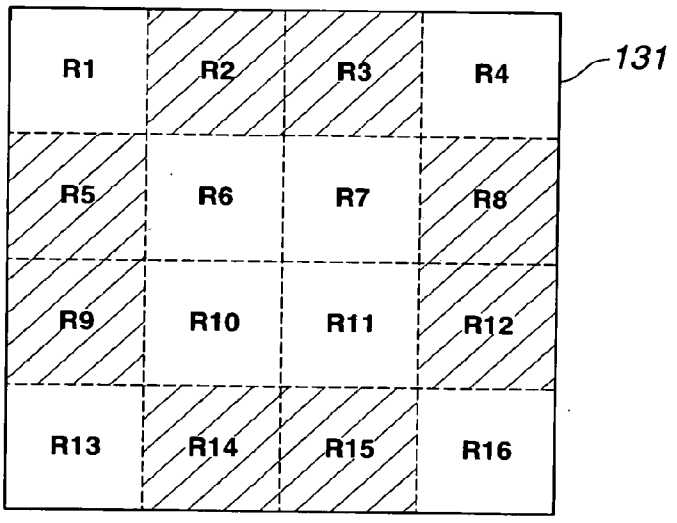

R1
R2
R3
R4
131
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16

FIG.38

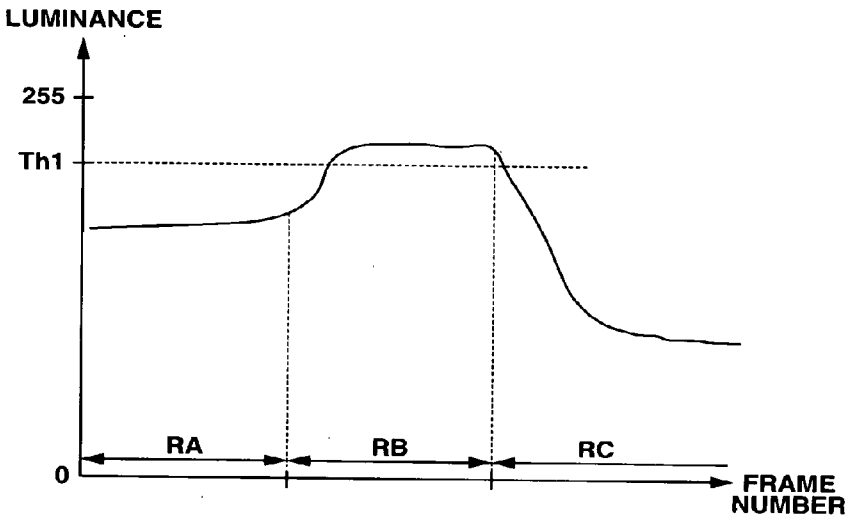

LUMINANCE
255
Th1
0
RA
RB
RC
FRAME NUMBER

FIG.39

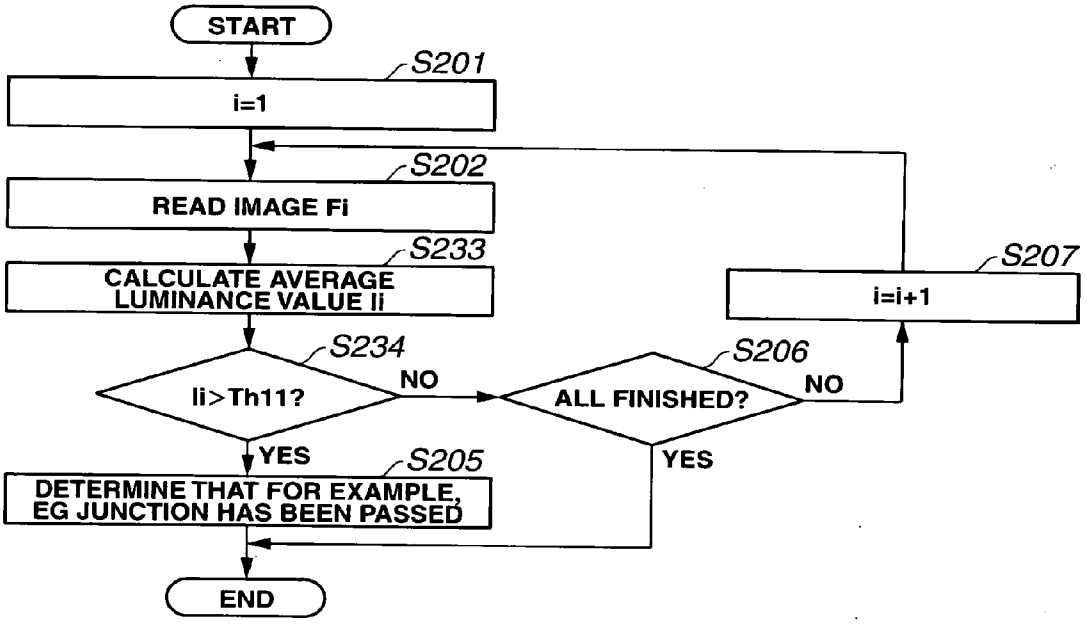

START
S201
i=1
S202
READ IMAGE Fi
S233
CALCULATE AVERAGE LUMINANCE VALUE Ii
S234
Ii>Th11?
NO
YES
S205
DETERMINE THAT FOR EXAMPLE, EG JUNCTION HAS BEEN PASSED
END
S206
ALL FINISHED?
NO
YES
S207
i=i+1

FIG.40

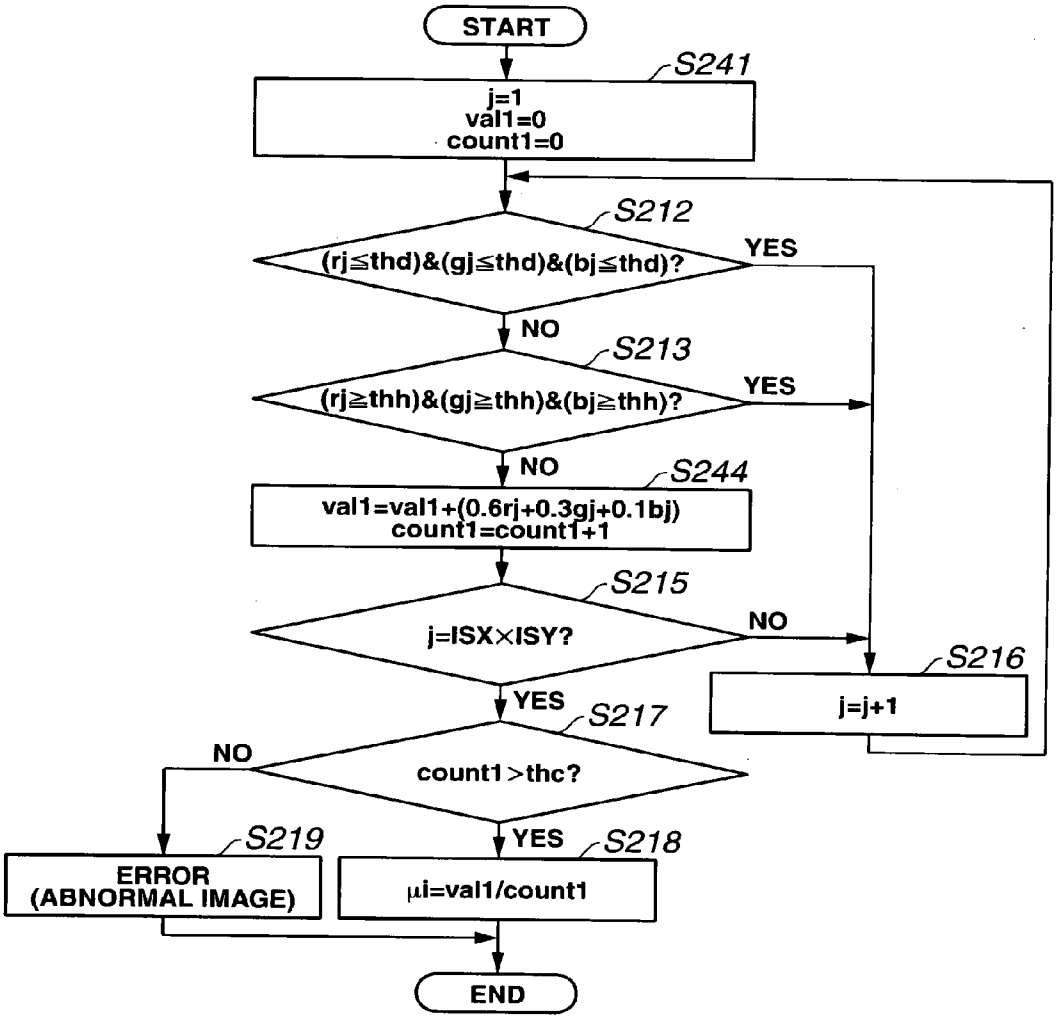

START
S241
j=1
val1=0
count1=0
S212
(rj≦thd)&(gj≦thd)&(bj≦thd)?
YES
NO
S213
(rj≧thh)&(gj≧thh)&(bj≧thh)?
YES
NO
S244
val1=val1+(0.6rj+0.3gj+0.1bj)
count1=count1+1
S215
j=ISX×ISY?
NO
S216
j=j+1
YES
S217
count1>thc?
NO
YES
S219
ERROR
(ABNORMAL IMAGE)
S218
μi=val1/count1
END

FIG.41

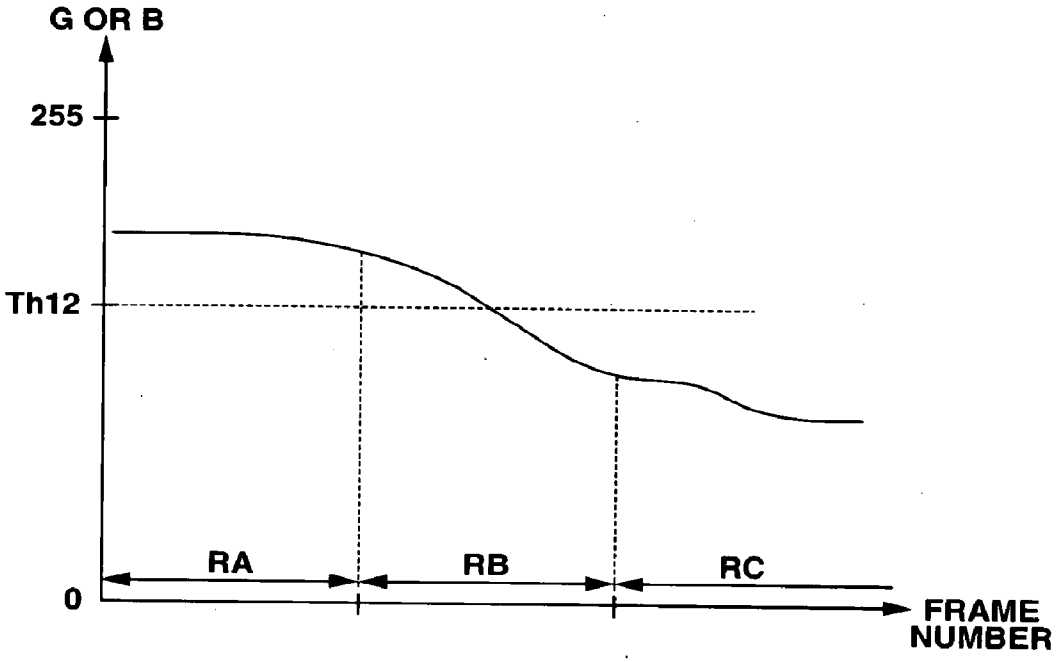


FIG.42

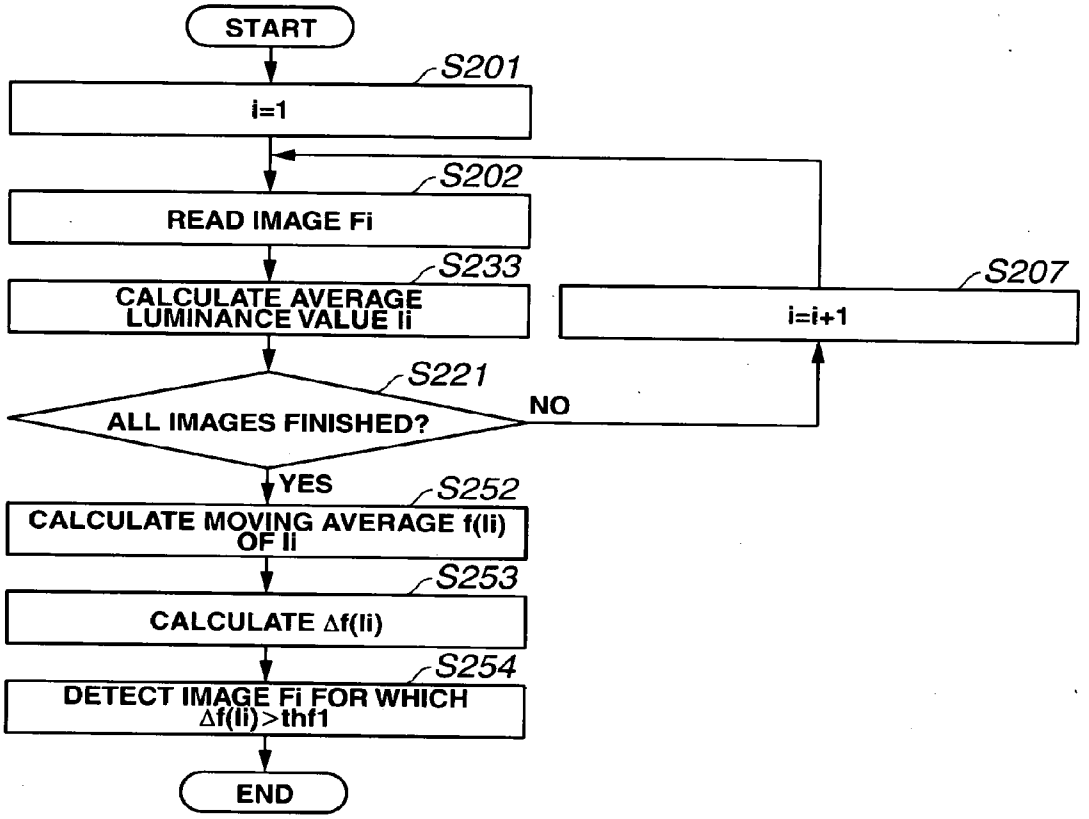

START
S201
i=1
S202
READ IMAGE Fi
S233
CALCULATE AVERAGE LUMINANCE VALUE Ii
S221
ALL IMAGES FINISHED?
NO
YES
S207
i=i+1
S252
CALCULATE MOVING AVERAGE f(Ii) OF Ii
S253
CALCULATE Δf(Ii)
S254
DETECT IMAGE Fi FOR WHICH Δf(Ii)>thf1
END

FIG.43

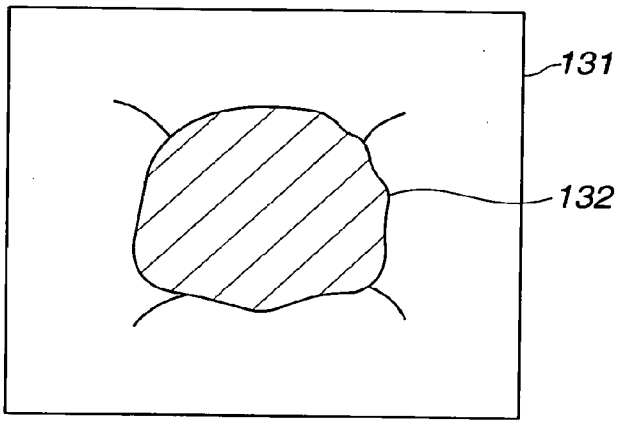

131
132

FIG.44

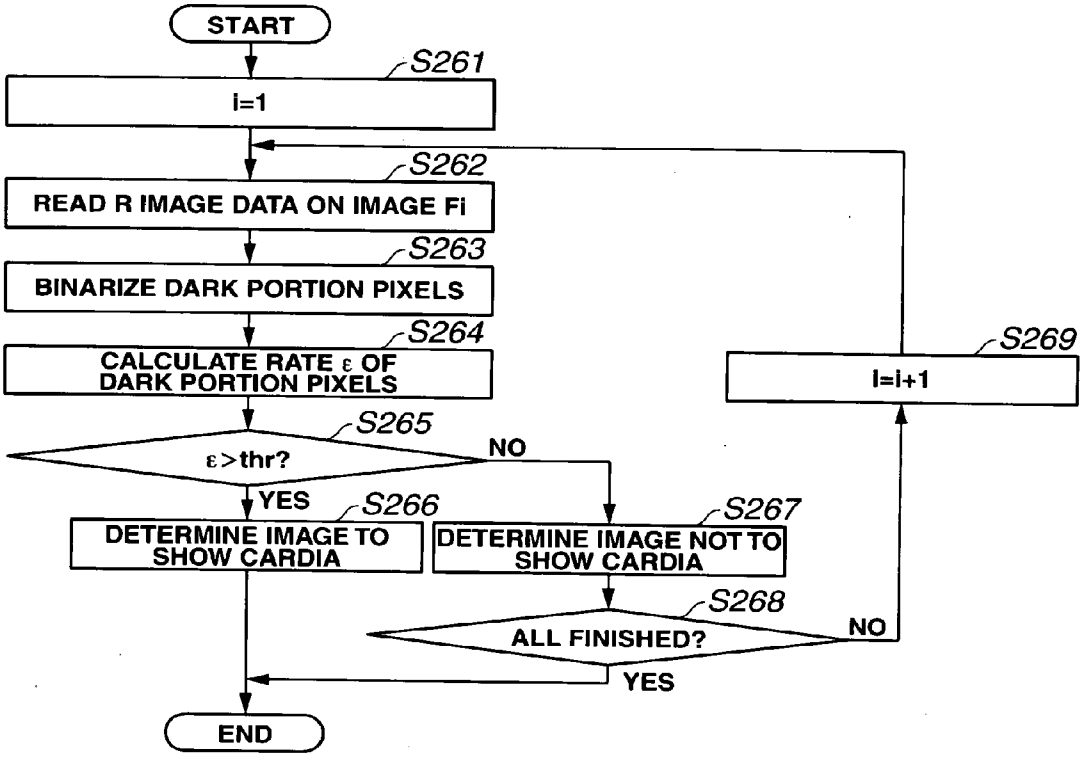

START
S261
i=1
S262
READ R IMAGE DATA ON IMAGE Fi
S263
BINARIZE DARK PORTION PIXELS
S264
CALCULATE RATE ε OF DARK PORTION PIXELS
S265
ε>thr?
NO
YES
S266
DETERMINE IMAGE TO SHOW CARDIA
S267
DETERMINE IMAGE NOT TO SHOW CARDIA
S268
ALL FINISHED?
NO
YES
S269
i=i+1
END

FIG.45

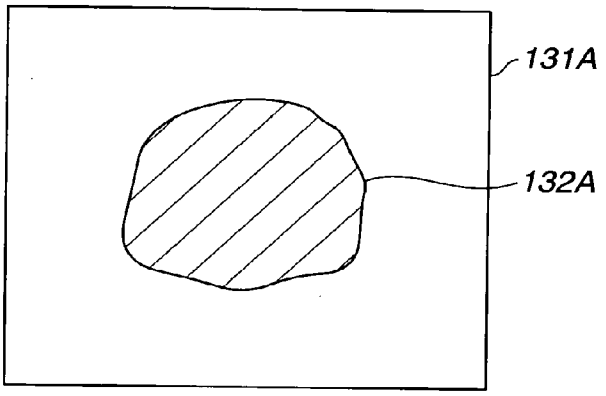

131A
132A

FIG.46

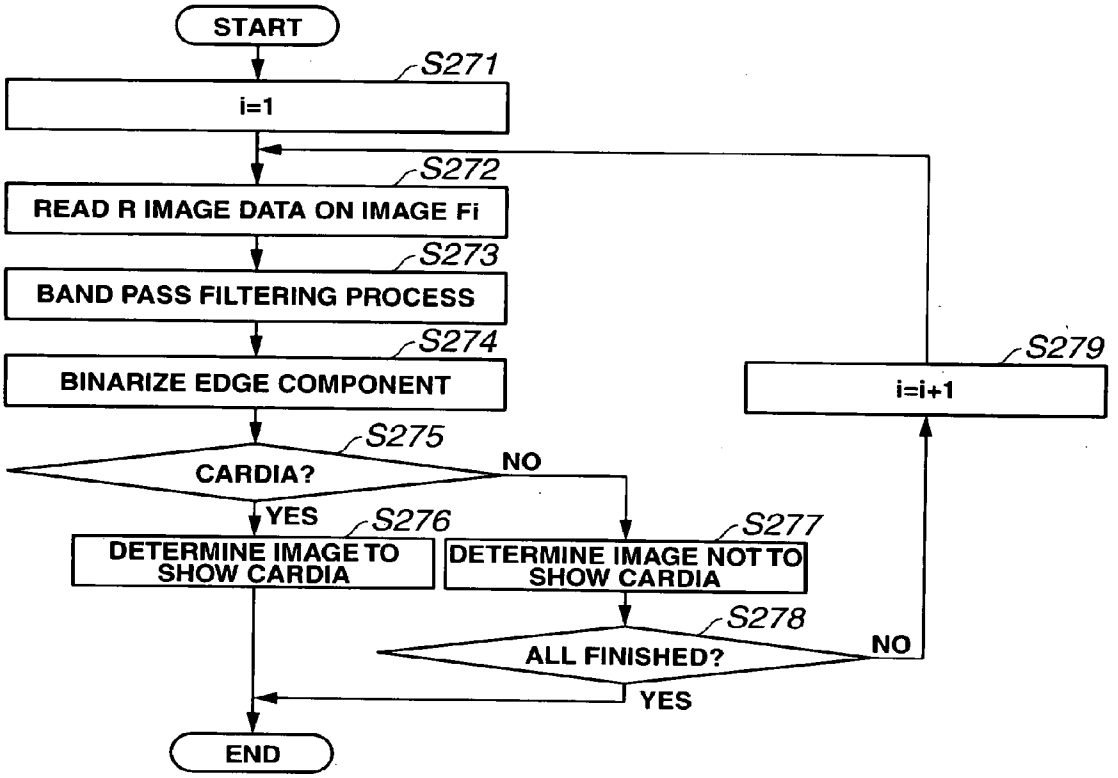

START
S271
i=1
S272
READ R IMAGE DATA ON IMAGE Fi
S273
BAND PASS FILTERING PROCESS
S274
BINARIZE EDGE COMPONENT
S275
CARDIA?
NO
YES
S276
DETERMINE IMAGE TO SHOW CARDIA
S277
DETERMINE IMAGE NOT TO SHOW CARDIA
S278
ALL FINISHED?
NO
YES
S279
i=i+1
END

FIG.47

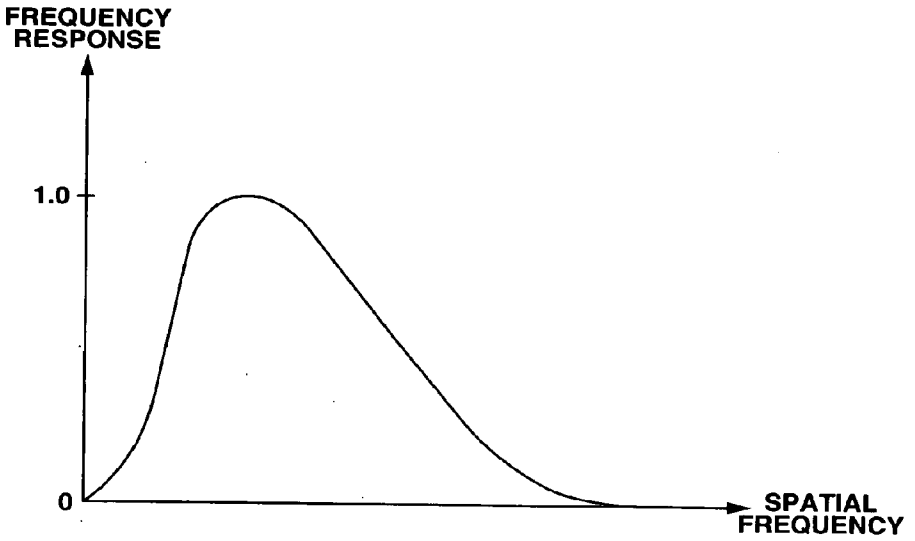

FREQUENCY RESPONSE
1.0
0
SPATIAL FREQUENCY

FIG.48

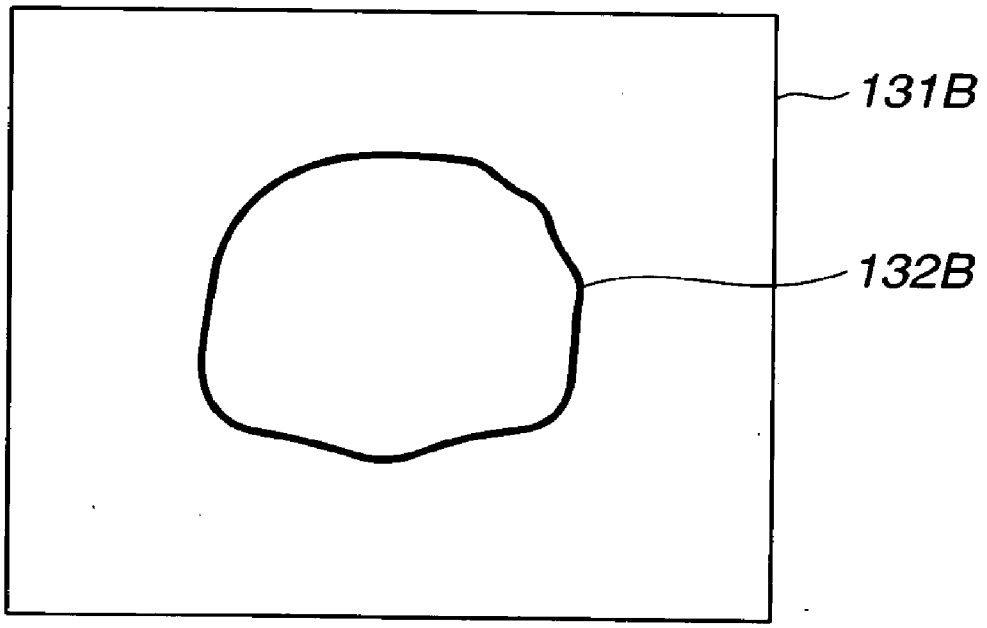


FIG.49

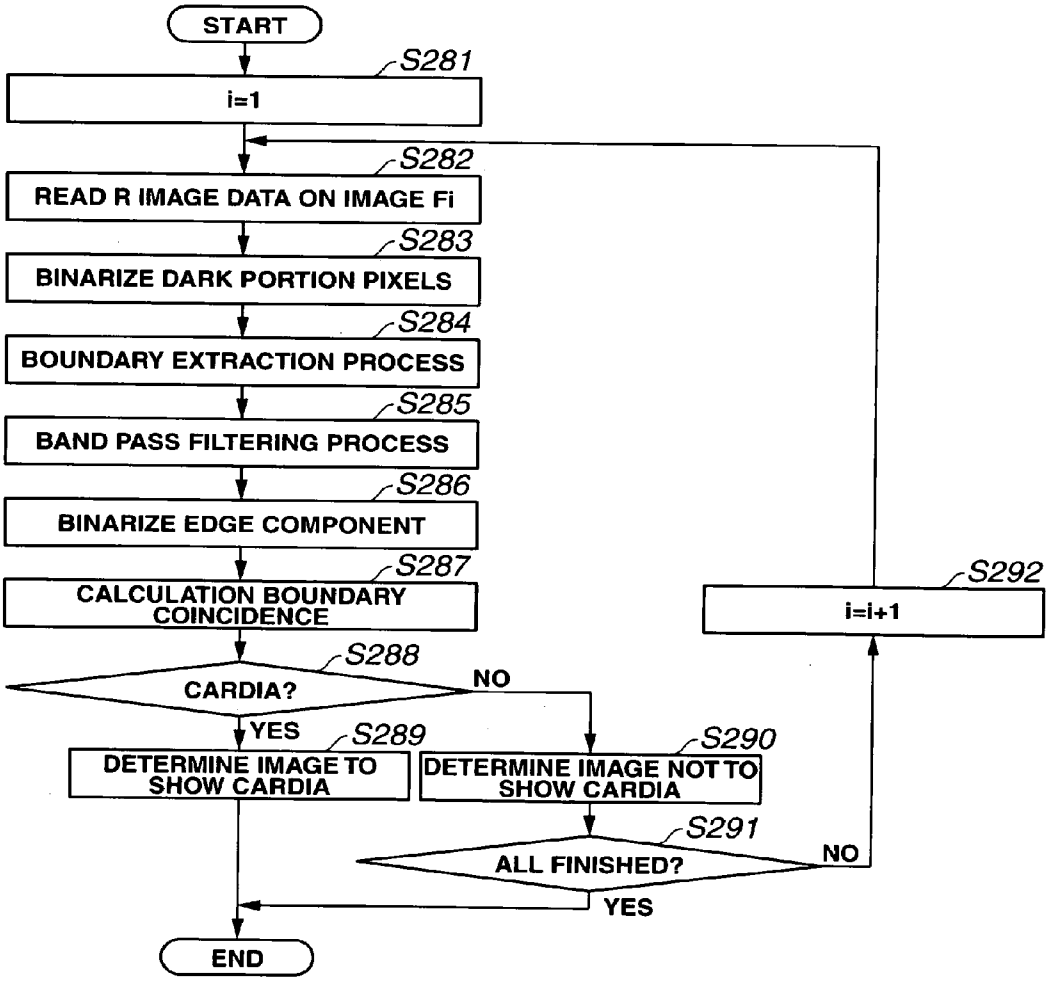

START
S281
i=1
S282
READ R IMAGE DATA ON IMAGE Fi
S283
BINARIZE DARK PORTION PIXELS
S284
BOUNDARY EXTRACTION PROCESS
S285
BAND PASS FILTERING PROCESS
S286
BINARIZE EDGE COMPONENT
S287
CALCULATION BOUNDARY COINCIDENCE
S288
CARDIA?
NO
YES
S289
DETERMINE IMAGE TO SHOW CARDIA
S290
DETERMINE IMAGE NOT TO SHOW CARDIA
S291
ALL FINISHED?
NO
YES
S292
i=i+1
END

FIG.50

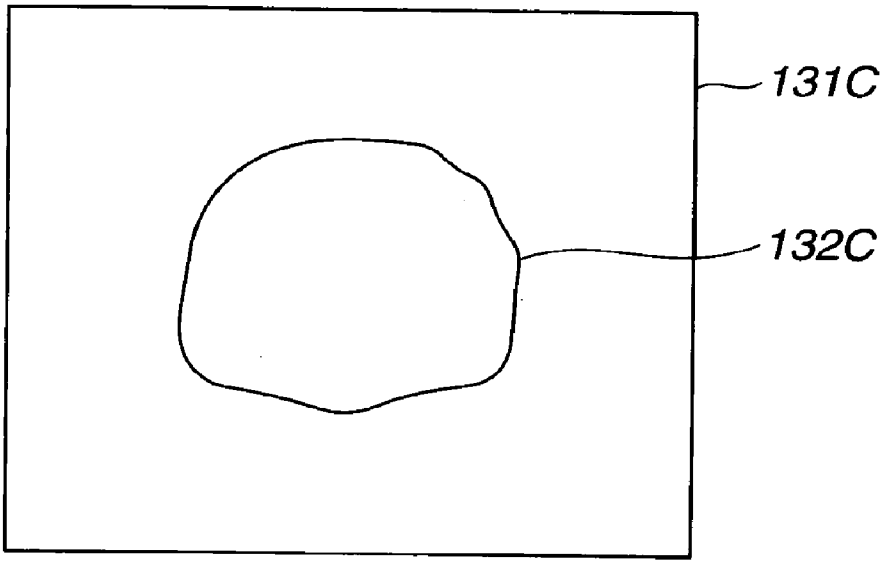


FIG.51

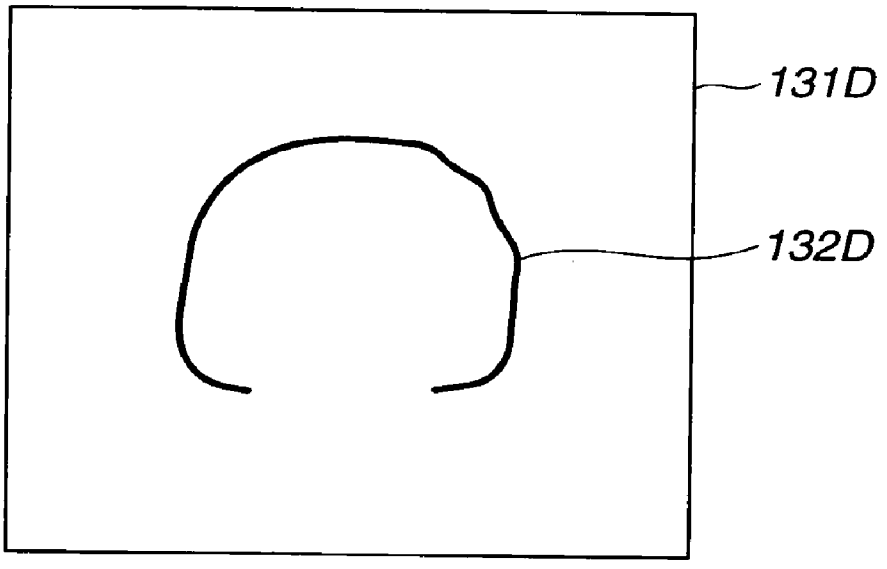


FIG.52

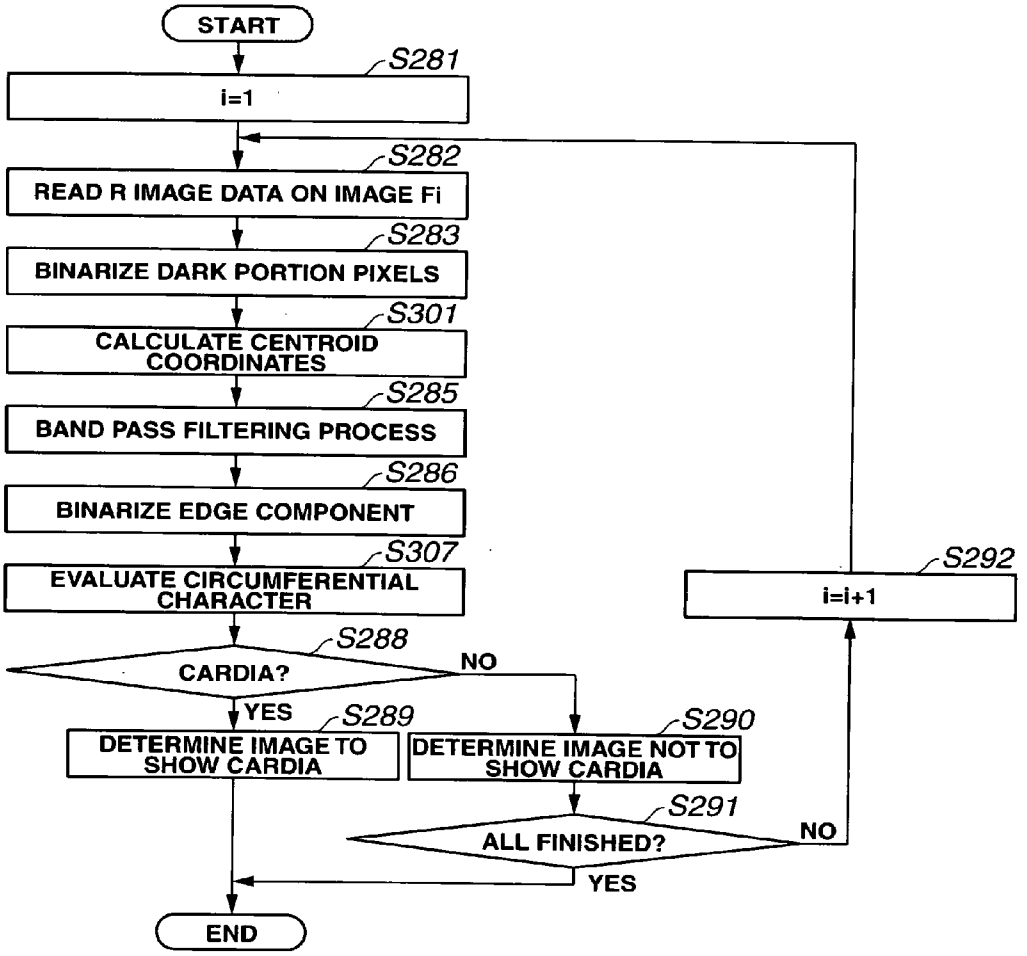

START
S281
i=1
S282
READ R IMAGE DATA ON IMAGE Fi
S283
BINARIZE DARK PORTION PIXELS
S301
CALCULATE CENTROID COORDINATES
S285
BAND PASS FILTERING PROCESS
S286
BINARIZE EDGE COMPONENT
S307
EVALUATE CIRCUMFERENTIAL CHARACTER
S288
CARDIA?
NO
YES
S289
DETERMINE IMAGE TO SHOW CARDIA
S290
DETERMINE IMAGE NOT TO SHOW CARDIA
S291
ALL FINISHED?
NO
YES
S292
i=i+1
END

FIG.53

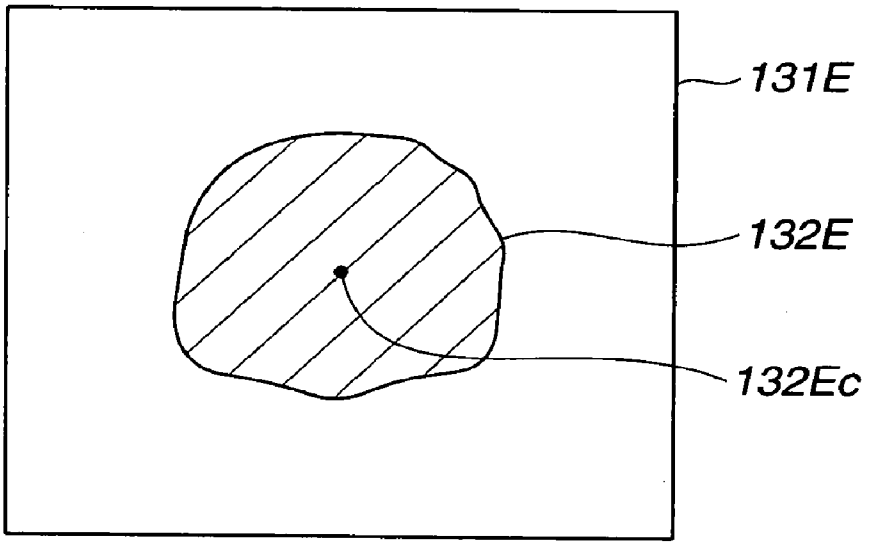


FIG.54

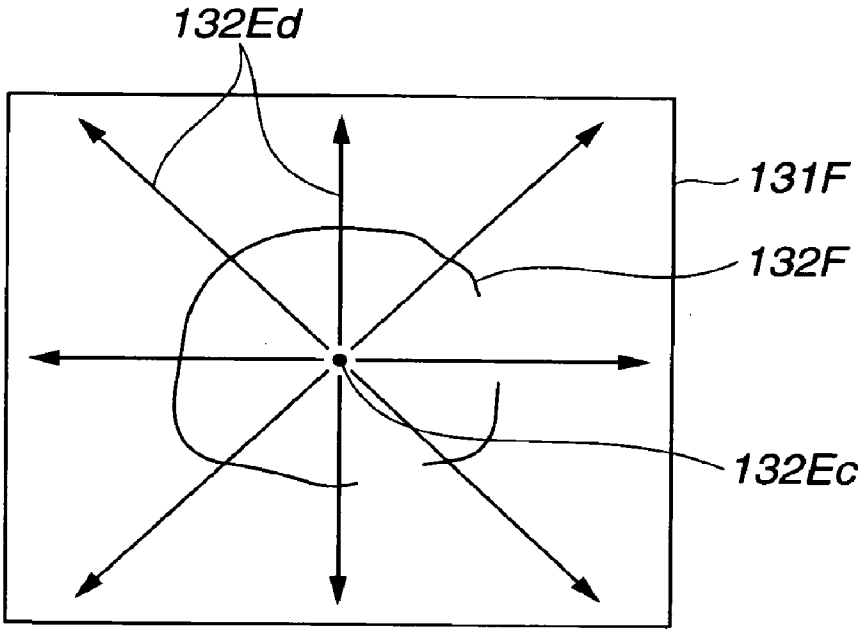


FIG.55

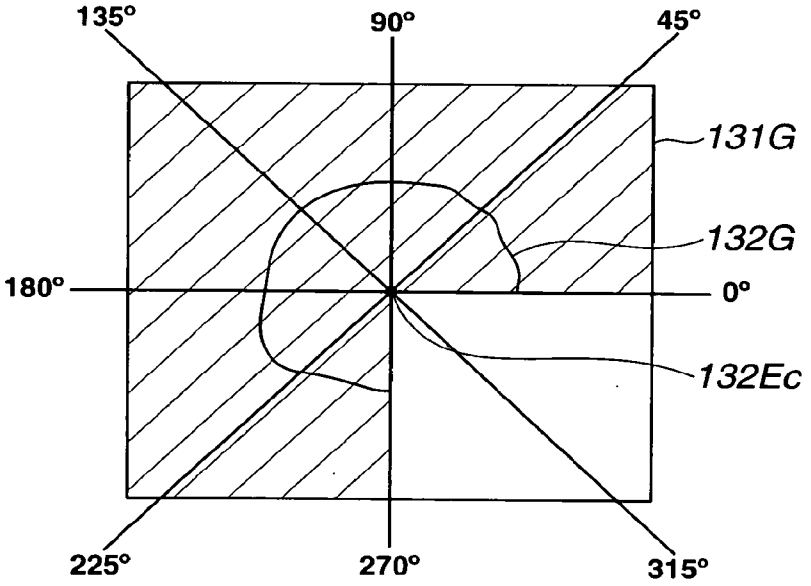


FIG.56

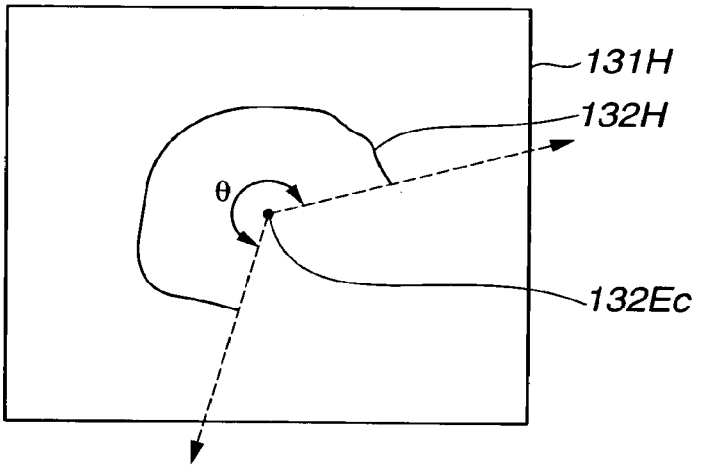


FIG.57

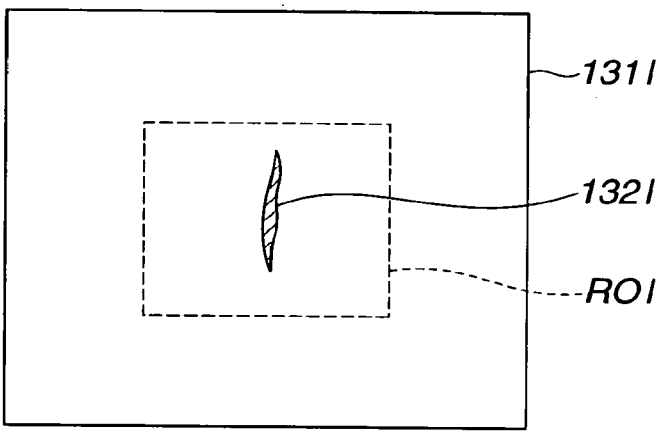


FIG.58

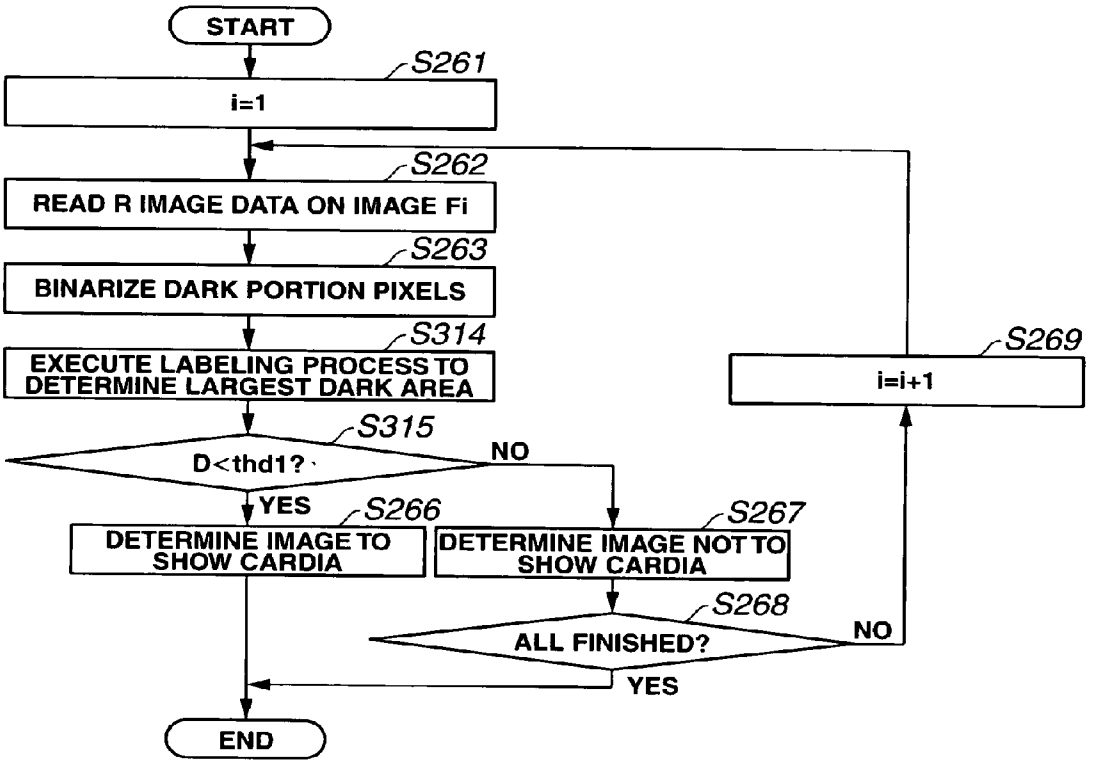

START
S261
i=1
S262
READ R IMAGE DATA ON IMAGE Fi
S263
BINARIZE DARK PORTION PIXELS
S314
EXECUTE LABELING PROCESS TO DETERMINE LARGEST DARK AREA
S315
D<thd1?
NO
YES
S266
DETERMINE IMAGE TO SHOW CARDIA
S267
DETERMINE IMAGE NOT TO SHOW CARDIA
S268
ALL FINISHED?
NO
YES
S269
i=i+1
END

FIG.59

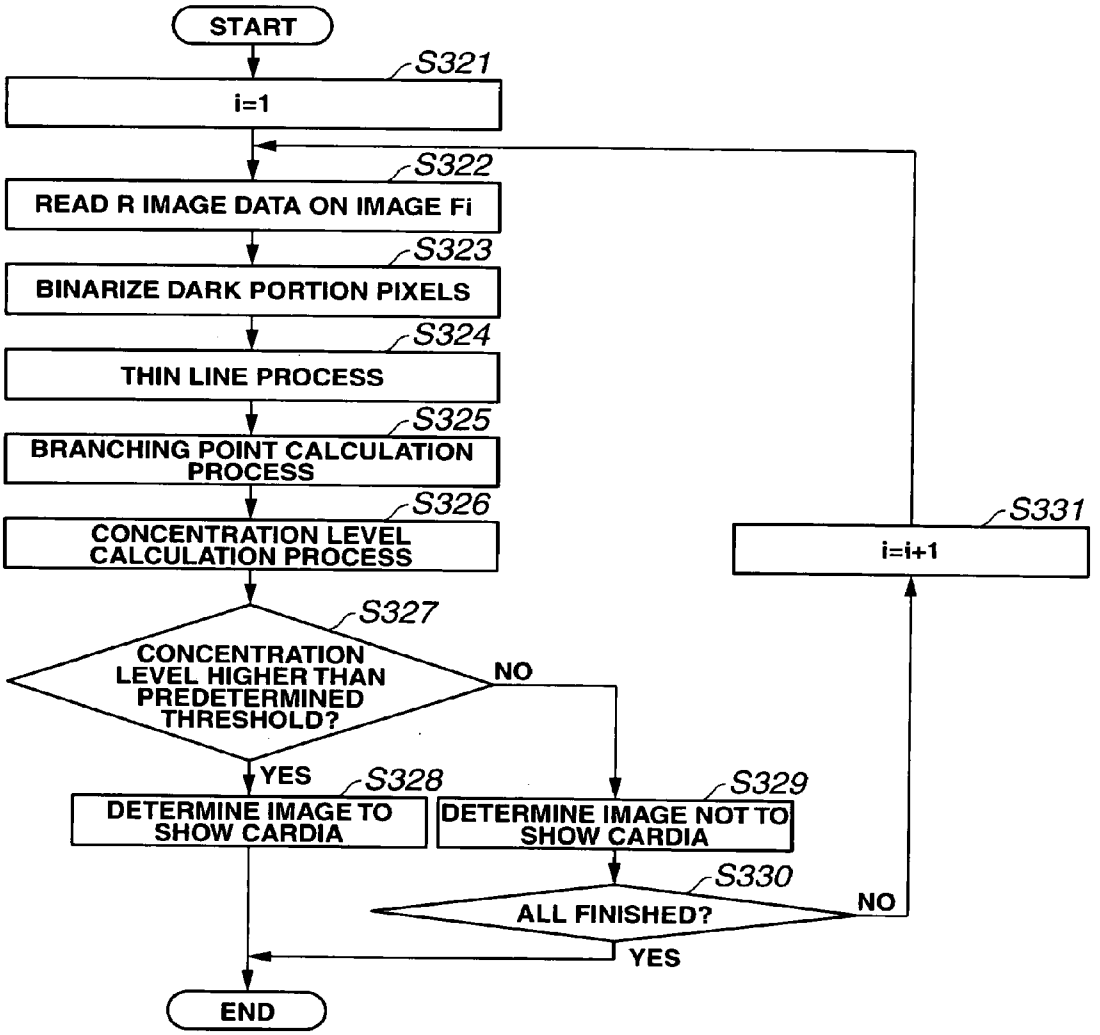

START
S321
i=1
S322
READ R IMAGE DATA ON IMAGE Fi
S323
BINARIZE DARK PORTION PIXELS
S324
THIN LINE PROCESS
S325
BRANCHING POINT CALCULATION PROCESS
S326
CONCENTRATION LEVEL CALCULATION PROCESS
S327
CONCENTRATION LEVEL HIGHER THAN PREDETERMINED THRESHOLD?
NO
YES
S328
DETERMINE IMAGE TO SHOW CARDIA
S329
DETERMINE IMAGE NOT TO SHOW CARDIA
S330
ALL FINISHED?
NO
YES
S331
i=i+1
END

FIG.60

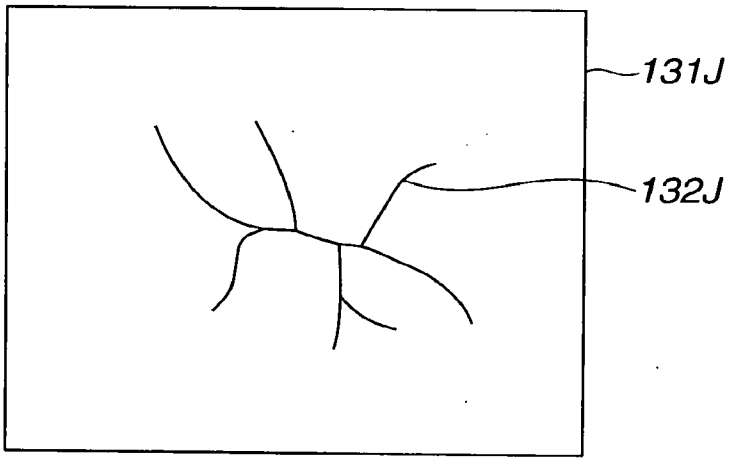


FIG.61

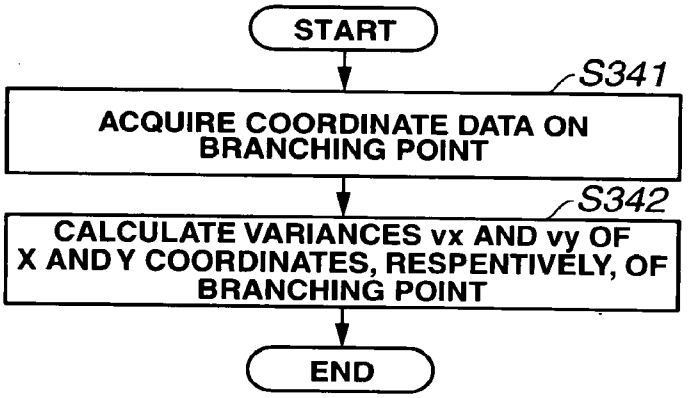
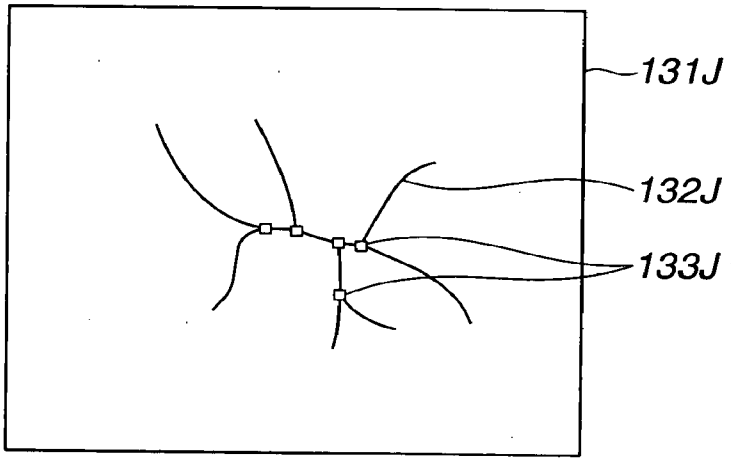


FIG.62



MEDICAL IMAGE PROCESSING APPARATUS, LUMINAL IMAGE PROCESSING APPARATUS, LUMINAL IMAGE PROCESSING METHOD, AND PROGRAMS FOR THE SAME

[0001] This application is a divisional application of U.S. application Ser. No. 11/884,515 filed on Aug. 15, 2007, which claims benefit of Japanese Patent Application No. 2005-038116 filed on Feb. 15, 2005, and No. 2005-038117 filed on Feb. 15, 2005, the contents of which are incorporated by reference.

TECHNICAL FIELD

[0002] The present invention relates to a medical image processing apparatus that efficiently determines a condition of interest on the basis of a large amount of biological image data, a luminal image processing and a luminal image processing method which detect the cardia on the basis of images of the interior of the lumen, and programs for the apparatuses and method.

BACKGROUND ART

[0003] In general, in conventional endoscopic examinations using an endoscope, in vivo image data picked up by an endoscopic apparatus or an endoscopic observation apparatus are immediately displayed on a display device such as a CRT and externally stored as motion picture data. A physician views the motion pictures or views frame images in the motion pictures as still images, during or after examinations for diagnosis.

[0004] Further, in recent years, swallowable capsule endoscopes have been used.

[0005] For example, as disclosed in Japanese Patent Laid-Open No. 2004-645, image data picked up in vivo with an in-capsule endoscope is sequentially externally accumulated as motion picture data by radio communication. The physician views the motion pictures or views frame images in motion pictures as still images for diagnosis.

[0006] Furthermore, Japanese Patent Laid-Open No. 2004-188026 discloses an apparatus that applies an image analysis process on still images to display the results of the analysis on endoscopic images or in another display area.

[0007] The image analysis results allow the physician to make diagnosis on the basis of image analysis values for IHb, vessel analysis, and the like, which are objective determination criteria, without recourse of the physician's subjective.

[0008] However, when the physician views motion pictures after endoscopic examinations or views motion pictures picked up by an in-capsule endoscope, the enormous number of frame images contained in the motion pictures results in the need to make much effort in finding a point on the motion pictures at which a suspected lesion is shown, extracting each frame image showing the lesion and apply an image analysis process to the image, and making diagnosis on the basis of each image analysis result.

[0009] To solve this problem, a system can be implemented which uses the above image analysis apparatus for still images to apply the same image analysis process to all the frame images contained in the motion pictures and to then store the results.

[0010] However, the application of the same image analysis process to all the frame images increases processing time, resulting in the need to wait a long time until processing results are obtained. Further, a long time is required until appropriate processing results are obtained even if the image analysis process is applied with parameters changed. Another disadvantage is that this method increases the amount of data needing to be stored until appropriate processing results are obtained.

[0011] Furthermore, screening in examinations with an endoscopic apparatus determines whether or not the Barrett mucosa or the Barrett esophagus is present. The Barrett mucosa is developed when at the junction between the stomach and the esophagus (EG junction), the squamous epithelium forming the esophagus is replaced with the mucosa of the stomach under the effect of the reflux esophagitis or the like. The Barrett mucosa is also called the cylindrical epithelium. If the Barrett mucosa extends at least 3 cm from the mucosal boundary all along the circumference of a cross section of the lumen of the esophagus, the patient is diagnosed to have a disease called the Barrett esophagus.

[0012] The incidence of the Barrett esophagus has been increasing particularly among Americans and Europeans. The Barrett esophagus is very likely to develop into the adenocarcinoma and thus has been a major problem. Consequently, it is very important to discover the Barrett mucosa early.

[0013] Thus, medical image processing apparatus are desired to objectively determine biological feature values for the Barrett esophagus, the Barrett mucosa, or the like and to provide determinations to the operator.

[0014] Further, as described above, in the medical field, observation and diagnosis of the organs in the body cavity are widely performed using medical equipment having an image pickup function.

[0015] For example, in the diagnosis of the esophageal disease, in the case of the disease diagnosis of the Barrett esophagus near the EG junction (junction between the stomach and the esophagus) in the upper part of the cardia, which corresponds to the boundary between the stomach and the esophagus, endoscopic examinations are important for the diagnosis of the esophagus because the Barrett esophagus may develop into the adenocarcinoma as described above. An endoscope is inserted into a patient's mouth, and the physician makes the diagnosis of the esophageal disease while viewing endoscopic images displayed on a monitor screen.

[0016] Further, as described above, in recent years, capsule-like endoscopes have been developed which allow the physician to make the diagnosis of the esophageal disease while viewing images obtained with the capsule-like endoscope. A system has been proposed which detects the disease on the basis of biological images obtained with a capsule-like endoscope (see, for example, WO 02/073507 A2).

[0017] However, even the above proposed system does not disclose the detection of the cardia or the vicinity of the cardia boundary based on images showing an area extending from the esophagus to the stomach.

[0018] For example, enabling the cardia or the boundary of the cardia to be detected allows the physician to observe biological tissue images of the detected cardia or cardia boundary in detail. This enables the disease such as the Barrett esophagus to be quickly diagnosed.

OBJECT OF THE INVENTION

[0019] The present invention has been made in view of the above problems. An object of the present invention is to

provide a medical image processing apparatus that can efficiently determine a condition of interest on the basis of a large amount of image data.

[0020] Another object of the present invention is to provide a luminal image processing apparatus that can detect the cardia on the basis of intraluminal images.

DISCLOSURE OF INVENTION

Means for Solving the Problem

[0021] A medical image processing apparatus in accordance with a first aspect of the present invention comprises an image extracting section that extracts a frame image from in vivo motion picture data picked up by an in vivo image pickup device or a plurality of consecutively picked-up still image data, and an image analysis section that analyzes the frame image extracted by the image extracting section to output an image analysis result. The image analysis section comprises a first biological feature detection section that detects a first biological feature, a second biological feature detection section that detects, on the basis of a detection result obtained by the first biological feature detection section, a second biological feature in a frame image picked up temporally before or after the image used for detection by the first biological feature detection section, and a condition determination section that determines a biological condition on the basis of a detection result obtained by the second biological feature detection section to output the determination.

[0022] A medical image processing method in accordance with a second aspect of the present invention comprises a step of extracting a frame image from in vivo motion picture data picked up by an in vivo image pickup device or a plurality of consecutively picked-up still image data, a step of analyzing the extracted frame image to detect a first biological feature, a step of detecting, on the basis of a result of the detection of the first biological feature, a second biological feature in a frame image picked up temporally before or after the image used for detection by the first biological feature detection section, and a step of making a determination for a biological condition on the basis of a result of the detection of the second biological feature to output the determination.

[0023] A program in accordance with a third aspect of the present invention allows a computer to execute a function of extracting a frame image from in vivo motion picture data picked up by an in vivo image pickup device or a plurality of consecutively picked-up still image data, a function of analyzing the extracted frame image to detect a first biological feature, a function of detecting, on the basis of a result of the detection of the first biological feature, a second biological feature in a frame image picked up temporally before or after the image used for detection by the first biological feature detection section, and a function of making a determination for a biological condition on the basis of a result of the detection of the second biological feature to output the determination.

[0024] A luminal image processing apparatus in accordance with a fourth aspect of the present invention comprises a feature value calculating section that calculates a predetermined feature value by executing image processing on one or a plurality of intraluminal images obtained by picking up an image of the gastrointestinal tract and a boundary detection section that detects a boundary of the gastrointestinal tract on the basis of the calculated feature value.

[0025] A luminal image processing method in accordance with the fourth aspect of the present invention comprises a step of calculating a predetermined feature value by executing image processing on one or a plurality of intraluminal images obtained by picking up an image of the gastrointestinal tract and a step of detecting a boundary of the gastrointestinal tract on the basis of the calculated feature value.

[0026] A program in accordance with the fourth aspect of the present invention allows a computer to execute a function of calculating a predetermined feature value from one or a plurality of intraluminal images obtained by picking up an image of the gastrointestinal tract and a function of detecting a boundary of the gastrointestinal tract on the basis of the calculated feature value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. **1** is a block diagram showing the entire configuration of an endoscope system comprising a first embodiment;

[0028] FIG. **2** is a diagram schematically showing the parts of the upper gastrointestinal tract endoscopically examined by orally inserting an endoscope;

[0029] FIG. **3** is a diagram showing an example of an endoscopic image of the vicinity of the boundary between the esophagus and the stomach;

[0030] FIG. **4** is a diagram showing the functional configuration of essential sections of the image processing apparatus;

[0031] FIG. **5** is a diagram showing that motion picture data stored in an image storage section is stored as sets of still image data;

[0032] FIG. **6**A is a diagram showing analysis results stored in an analysis information storage section;

[0033] FIG. **6**B is a diagram showing an example of information used for an analysis process or set by a processing program storage section **23**;

[0034] FIG. **7** is a diagram showing an example of a monitor display showing an analysis result together with an endoscopic image;

[0035] FIG. **8** is a flowchart of a process procedure for determining the Barrett esophagus condition;

[0036] FIG. **9** is a flowchart showing a process procedure of executing a process of detecting the EG junction, together with information such as images used or generated in the procedure;

[0037] FIG. **10**A is a diagram showing a palisade vessel end point boundary;

[0038] FIG. **10**B is a diagram showing the palisade vessel end point boundary and an epithelium boundary;

[0039] FIG. **10**C is a diagram showing that an image of the palisade vessel end point boundary or the like is divided by eight radial lines;

[0040] FIG. **11** is a flowchart showing the details of a palisade vessel extraction process shown in FIG. **9**;

[0041] FIG. **12**A is a diagram showing an example of an image illustrating an operation performed for the process shown in FIG. **11**;

[0042] FIG. **12**B is a diagram showing an example of an image illustrating an operation performed for the process shown in FIG. **11**;

[0043] FIG. **12**C is a diagram showing an example of an image illustrating an operation performed for the process shown in FIG. **11**;

[0044] FIG. **13** is a flowchart showing the details of a Barrett mucosa determination process shown in FIG. **10**;

[0045] FIG. **14** is a flowchart of a variation of the process shown in FIG. **9**;

[0046] FIG. **15**A is a diagram showing an example of an image illustrating an operation shown in FIG. **14** and the like;

[0047] FIG. **15**B is a diagram showing an example of an image illustrating the operation shown in FIG. **14** and the like;

[0048] FIG. **16** is a flowchart showing the details of the Barrett mucosa determination process shown in FIG. **14**;

[0049] FIG. **17** is a diagram showing the functional configuration of essential sections of an image processing apparatus in accordance with a second embodiment;

[0050] FIG. **18** is a flowchart of a process procedure of determining the Barrett esophagus condition in accordance with the second embodiment;

[0051] FIG. **19** is a flowchart showing a process procedure of executing a cardia detection process, together with information such as images which is used or generated in the procedure;

[0052] FIG. **20**A is a diagram illustrating an operation shown in FIG. **19**;

[0053] FIG. **20**B is a diagram illustrating an operation shown in FIG. **19**;

[0054] FIG. **21** is a flowchart showing the details of a concentration level calculation process shown in FIG. **19**;

[0055] FIG. **22** is a flowchart showing a closed cardia determination process shown in FIG. **19**;

[0056] FIG. **23** is a flowchart showing a process procedure of executing a cardia detection process in accordance with a variation, together with information such as images which is used or generated in the procedure;

[0057] FIG. **24**A is a diagram illustrating an operation shown in FIGS. **23** and **25**;

[0058] FIG. **24**B is a diagram illustrating the operation shown in FIGS. **23** and **25**;

[0059] FIG. **24**C is a diagram illustrating the operation shown in FIGS. **23** and **25**;

[0060] FIG. **25** is a flowchart showing the details of an edge component generation angle calculation process shown in FIG. **23**;

[0061] FIG. **26** is a flowchart showing an open cardia determination process shown in FIG. **23**;

[0062] FIG. **27** is a diagram showing the functional configuration of essential sections of an image processing apparatus in accordance with Example **2**;

[0063] FIG. **28** is a flowchart of a process procedure of determining the Barrett esophagus condition;

[0064] FIG. **29** is a flowchart of a process procedure of determining the Barrett esophagus condition in accordance with a variation;

[0065] FIG. **30**A is a block diagram showing the general configuration of a capsule endoscope apparatus in accordance with a fourth embodiment;

[0066] FIG. **30**B is a block diagram showing the general configuration of a terminal apparatus serving as a luminal image processing apparatus in accordance with the fourth embodiment;

[0067] FIG. **31** is a diagram illustrating the general structure of the capsule endoscope in accordance with the fourth embodiment;

[0068] FIG. **32** is a flowchart showing an example of the flow of a process of detecting the cardia by passing through the EG junction, the process being executed by the terminal apparatus;

[0069] FIG. **33** is a schematic graph illustrating a variation in the color tone in a series of endoscopic images obtained;

[0070] FIG. **34** is a flowchart showing an example of the flow of a process in step S**203** shown in FIG. **32**;

[0071] FIG. **35** is a flowchart showing an example of the flow of a process of detecting a variation in average color tone feature value by calculating a differential value for average color tone feature values;

[0072] FIG. **36** is a graph illustrating a variation in the standard deviation or variance of the color tone feature in a series of endoscopic images obtained in accordance with a seventh variation of the fourth embodiment;

[0073] FIG. **37** is a diagram showing an example of areas of a frame image which are subjected to image processing in accordance with the fourth embodiment and a variation thereof;

[0074] FIG. **38** is a schematic graph illustrating a variation in the brightness of a series of endoscopic images obtained, specifically, a variation in luminance, in accordance with a fifth embodiment;

[0075] FIG. **39** is a flowchart showing an example of the flow of a process of detecting the cardia upon passage through the EG junction, the process being executed by a terminal apparatus on the basis of the series of endoscopic images obtained in accordance with the fifth embodiment;

[0076] FIG. **40** is a flowchart showing an example of the flow of a process in step S**33** shown in FIG. **39**;

[0077] FIG. **41** is a schematic graph illustrating a variation in G or B pixel data in the series of endoscopic images, the G or B pixel data being used as brightness information on the images instead of the luminance calculated from the three pixel values for R, G, and B as described above;

[0078] FIG. **42** is a flowchart showing an example of the flow of a process of detecting a variation in brightness by calculating a differential value for average luminance values in accordance with the fifth embodiment;

[0079] FIG. **43** is a diagram showing an example of an image in which a capsule endoscope is located in front of the open cardia in accordance with a sixth embodiment;

[0080] FIG. **44** is a flowchart showing an example of the flow of a process of detecting the open cardia on the basis of a series of endoscopic images in accordance with the sixth embodiment;

[0081] FIG. **45** is a diagram showing an example of an image obtained when the capsule endoscope passes through the open cardia in accordance with a seventh embodiment;

[0082] FIG. **46** is a flowchart showing an example of a process of detecting the open cardia on the basis of a series of endoscopic images in accordance with the seventh embodiment;

[0083] FIG. **47** is a diagram showing a filter property observed during a bandpass filtering process in accordance with the seventh embodiment;

[0084] FIG. **48** is a diagram showing an example of an image resulting from the process of predetermined bandpass filtering and binarization executed on the image shown in FIG. **45**;

[0085] FIG. **49** is a flowchart showing an example of the flow of a process of detecting the cardia on the basis of a series of endoscopic images obtained in accordance with an eighth embodiment;

[0086] FIG. **50** is a diagram showing an image of an extracted boundary in accordance with the eighth embodiment;

[0087] FIG. **51** is a diagram showing an example of an image resulting from the process of predetermined bandpass filtering and binarization executed on a processing target image in accordance with the eighth embodiment;

[0088] FIG. **52** is a flowchart showing an example of the flow of a process of detecting the cardia on the basis of a series of endoscopic images obtained in accordance with a ninth embodiment;

[0089] FIG. **53** is a diagram showing the position of a centroid calculated by a dark area centroid coordinate calculation process in accordance with the ninth embodiment;

[0090] FIG. **54** is a diagram illustrating the evaluation of a circumferential character in accordance with the ninth embodiment;

[0091] FIG. **55** is a diagram illustrating that the evaluation of the circumferential character is based on area rate in accordance with a fourth variation of the ninth embodiment;

[0092] FIG. **56** is a diagram illustrating that the evaluation of the circumferential character is based on angular range in accordance with a fourth variation of a tenth embodiment;

[0093] FIG. **57** is a diagram showing an example of an image in which the capsule endoscope is located in front of the closed cardia in accordance with the tenth embodiment;

[0094] FIG. **58** is a flowchart showing an example of the flow of a process of detecting the cardia on the basis of a series of endoscopic images obtained in accordance with the tenth embodiment;

[0095] FIG. **59** is a flowchart showing an example of the flow of a process of detecting the cardia on the basis of a series of endoscopic images obtained in accordance with an eleventh embodiment;

[0096] FIG. **60** is a diagram showing an example of an image illustrating the cardia shape expressed with thin lines on the basis of the image of the closed cardia, in accordance with the eleventh embodiment;

[0097] FIG. **61** is a flowchart showing an example of the flow of a process of calculating the variance value, corresponding to the concentration level parameter, in accordance with the eleventh embodiment; and

[0098] FIG. **62** is a diagram showing an example of an image illustrating branching points in accordance with the eleventh embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

[0099] Embodiments of the present invention will be described with reference to the drawings.

First Embodiment

[0100] FIGS. **1** to **16** relate to a first embodiment. FIG. **1** shows the entire configuration of an endoscopic system comprising the present embodiment. FIG. **2** schematically shows the parts of the upper gastrointestinal tract endoscopically examined by orally inserting an endoscope. FIG. **3** shows an example of an endoscopic image of the vicinity of the boundary between the esophagus and the stomach. FIG. **4** shows the functional configuration of an image processing apparatus in accordance with the present embodiment. FIG. **5** shows that motion picture data stored in an image storage section is stored as sets of still image data.

[0101] FIGS. **6**A and **6**B show analysis results stored in an analysis information storage section, information stored in a processing program storage section, and the like. FIG. **7** shows an example of a monitor display showing an analysis result together with an endoscopic image. FIG. **8** is a flowchart of a process procedure for determining the Barrett esophagus condition in accordance with the present embodiment. FIG. **9** shows a process procedure of executing a process of detecting the EG junction, together with information such as images used or generated.

[0102] FIGS. **10**A to **10**C are diagrams showing the boundary of an end point of the palisade vessel. FIG. **11** is a flowchart of a palisade vessel extraction process shown in FIG. **9**. FIGS. **12**A to **12**C show an example of an image illustrating an operation performed for the process shown in FIG. **11**. FIG. **13** is a flowchart of a Barrett mucosa determination process shown in FIG. **10**. FIG. **14** is a flowchart of a variation of the process shown in FIG. **9**. FIGS. **15**A and **15**B show an example of an image illustrating an operation shown in FIG. **14** and the like. FIG. **16** is a flowchart of the Barrett mucosa determination process in FIG. **14**.

[0103] An endoscopic system **1** shown in FIG. **1** is composed of an endoscopic observation apparatus **2**, a medical image processing apparatus (hereinafter simply referred to as an image processing apparatus) **3** composed of a personal computer or the like to execute image processing on images obtained by the endoscopic observation apparatus **2**, and a monitor **4** that displays the images subjected to the image processing by the image processing apparatus **3**.

[0104] The endoscopic observation apparatus **2** has an endoscope **6** forming an in vivo image pickup device inserted into the lumen to pick up images of the interior of the body, a light source device **7** that supplies illumination light to the endoscope **6**, a camera control unit (hereinafter simply referred to as a CCU) **8** that executes signal processing for the image pickup means of the endoscope **6**, and a monitor **9** to which video signals outputted by the CCU **8** are inputted to display endoscopic images picked up by an image pickup device.

[0105] The endoscope **6** has an insertion portion **11** inserted in the body cavity and an operation portion **12** provided at a trailing end of the insertion portion **11**. Further, a light guide **13** is placed inside the insertion portion **11** to transmit illumination light.

[0106] A trailing end of the light guide **13** is connected to the light source device **7**. Illumination light supplied by the light source device **7** is transmitted by the light guide **13**. The (transmitted) illumination light is then emitted from a distal plane attached to an illumination window provided at a distal end **14** of the insertion portion **11** to illuminate a subject such as a diseased part.

[0107] An image pickup apparatus **17** is provided which comprises an objective lens **15** attached to an observation window located adjacent to the illumination window and for example, a charge coupled device (hereinafter referred to as a CCD) **16** located at a position where the objective lens **15** forms an image and serving as a solid-state image pickup device. An optical image formed on an image pickup surface of the CCD **16** is photoelectrically converted by the CCD **16**.

[0108] The CCD **16** is connected to the CCU **8** via a signal line to output the photoelectrically converted image signal in response to the application of a CCD driving signal from the CCU **8**. The image signal is subjected to signal processing by a video processing circuit in the CCU **8** and thus converted into a video signal. The video signal is outputted to the moni-

tor **9**, which thus displays the endoscopic image on a display surface thereof. The video signal is also inputted to the image processing apparatus **3**.

[0109] In the present embodiment, the endoscope **6** is used in the following case. The distal end **14** of the insertion portion **11** of the endoscope **6** is inserted through the mouth of the patient down to the vicinity of the boundary between the esophagus and the stomach to determine whether or not the Barrett mucosa is present near the boundary; the Barrett mucosa is the normal mucosa (specifically, the squamous epithelium) of the esophagus, the mucosa to be detected, modified to exhibit the condition of the mucosa part of the stomach.

[0110] In this case, a video signal corresponding to an endoscopic image obtained by picking up an image of the surface of the biological mucosa in the body is also inputted to the image processing apparatus **3**. An image processing method described below is executed on the video signal to detect (determine) whether or not the Barrett mucosa is present or the state of a disease called the Barrett esophagus has been reached.

[0111] The image processing apparatus **3** has an image input section **21** to which a video signal corresponding to the endoscopic image inputted by the endoscopic observation apparatus **2** is inputted, a CPU **22** serving as a central processing unit to execute image processing on image data inputted by the image input section **21**, and a processing program storage section **23** that stores a processing program (control program) that allows the CPU **22** to execute image processing.

[0112] Further, the image processing apparatus **3** has an image storage section **24** that stores image data and the like inputted by the image input section **21**, an analysis information storage section **25** that stores analysis information and the like processed by the CPU **22**, a hard disk **27** serving as a storage device that stores the image data, analysis information, and the like processed by the CPU **22**, via a storage device interface **26**, a display processing section **28** that executes a display process for displaying the image data and the like processed by the CPU **22**, and an input operation section **29** comprising a keyboard and the like and used by the user to input data such as image processing parameters and to perform instruction operations.

[0113] The video signal generated by the display processing section **28** is outputted to the display monitor **4** to display the processed image subjected to image processing, on the display surface of the display monitor **4**. The image input section **21**, the CPU **22**, the processing program storage section **23**, the image storage section **24**, the analysis information storage section **25**, the storage device interface **26**, the display processing section **28**, and the input operation section **29** are connected together via a data bus **30**.

[0114] In the present embodiment, an examination or diagnosis target site is the circumferential portion of the junction between the esophagus and the stomach. An image obtained by the endoscope **6** is subjected to image analysis to determine whether or not a suspected site of the Barrett esophagus is present, that is, to make a condition determination.

[0115] Thus, the insertion portion **11** of the endoscope **6** is inserted into the patient's mouth from the distal end of the insertion portion **11** to perform image pickup. FIG. **2** is a figure showing a luminal site in which the distal end of the endoscope is positioned when the endoscope **6** is orally inserted into the body cavity of the patient. The distal end **14** of the endoscope **6** is inserted into the mouth **31** and advances from the esophagus inlet **32** into the esophagus **33**. The distal end **14** of the endoscope **6** moves through the epithelium boundary **34** and the EG junction **35** to the stomach **36** and then via the cardia **37** to the interior of the stomach **36**.

[0116] The operation of inserting the endoscope **6** allows the acquisition of motion picture data picked up in the above order. The motion picture data thus acquired is stored in the image storage section **24**. Image analysis is executed on frame images of still images constituting the motion picture data.

[0117] FIG. **3** is a schematic diagram of an example of a picked-up endoscopic image of the vicinity of the boundary between the esophagus **33** and the stomach **36**. In the endoscopic image, the cardia **37** is an inlet to the interior of the stomach and is opened and closed.

[0118] The palisade vessels **38** substantially radially running outside the cardia **37** are present only in the esophagus **33** side. The palisade vessels **38** extend in the vertical direction along the lumen of the esophagus **33**.

[0119] Further, an area extending from the epithelium boundary **34** (shown by an alternate long and short dash line) corresponding to the boundary between the mucosal tissue in the esophagus **33** side and the mucosal tissue in the stomach **36** side to the cardia has a very reddish mucosal color tone (the epithelium in which this color tone is distributed is called the columnar epithelium). An area extending in the opposite direction has a whitish mucosal color tone (the epithelium in which this color tone is distributed is called the squamous epithelium). This enables the epithelium boundary to be determined by endoscopic observations.

[0120] A line (shown by a dashed line) joining the end points of the palisade vessels **38** together is a boundary line (in fact, the line is not present) that cannot be easily identified by endoscopic observations. The line is called the EG junction **35** and corresponds to the tissue boundary between the stomach **36** and the esophagus **33**.

[0121] The epithelium boundary **34** is normally located near the EG junction **35**. However, if the reflux esophagitis or the like replaces the squamous epithelium forming the esophagus **33** with the mucosa (columnar epithelium or Barrett mucosa) of the stomach **36**, the epithelium boundary **39** rises toward the esophagus **33**.

[0122] If the Barrett mucosa is formed at least 3 cm away from the normal mucosal boundary all along the circumference of the cross section of the esophagus lumen, the patient is diagnosed to have the Barrett esophagus.

[0123] FIG. **4** shows the functional configuration of essential sections of the image processing apparatus **3**.

[0124] Image data on motion pictures with its image picked up by the endoscope **6** and inputted to the image processing apparatus **3** is stored, as motion picture data Vm**1**, Vm**2**, . . . , in the image storage section **24**, serving as image storage (image recording) means.

[0125] In this case, the motion picture data Vm**1**, Vm**2**, . . . have a data structure in which still images are accumulated over time. Thus, when the motion picture data Vm**1**, Vm**2**, . . . are stored in the image storage section **24**, for example, as shown in FIG. **5**, frame numbers **0**, **1**, . . . , MAX_COUNT are assigned to the still image data, which are thus labeled as Vs**0**, Vs**1**, . . . , VsM (M=MAX_COUNT).

[0126] Further, frame time simultaneously stored in the image storage section **24** is stored. The still image data may be compressed in accordance with JPEG or the like before being stored.

[0127] When image processing is started, the CPU **22** and processing program allow an image extracting block **41** composed of software to extract and read the still image data within the range indicated by specified frame numbers from, for example, the motion picture data Vm**1** read from the image storage section **24**. The image extracting block **41** constitutes an image extracting section that extracts frame image data from in vivo motion picture data or data on a plurality of consecutively picked-up still images.

[0128] Extracted still image data are sequentially sent to an image analysis block **42** and a display processing block **43**.

[0129] The image analysis block **42** comprises an epithelium boundary detection block **44** that detects epithelium boundary, an EG junction detection block **45** that detects the EG junction, and a Barrett esophagus determination block **46** that determines whether or not the patient has the Barrett esophagus. The image analysis block **42** constitutes an image analysis section that analyzes the frame image extracted by the image extracting block **41** to output an image analysis result.

[0130] The epithelium boundary detection block **44**, for example, detects a variation in mucosa color tone in an image as an edge to detect an epithelium boundary line present in the image as a point sequence.

[0131] The EG junction detection block **45**, for example, detects a line joining the end points of the palisade vessels together as a point sequence (a method for detection will be described below in detail).

[0132] The Barrett esophagus determination block **46** calculates feature values such as the shape of the epithelium boundary, the striped residue of the squamous epithelium, the distance between the epithelium boundary and the EG junction, the standard deviation of the distance, and the maximum and minimum values of the distance to determine whether or not the target site with its image picked up indicates the Barrett esophagus.

[0133] Information on the determination made by the Barrett esophagus determination block **46** is stored in the analysis information storage section **25**, and sent to the display processing block **43**. The information on the determination based on the analysis executed by the image analysis block **42** is displayed in a still image shown on the monitor **4** via the image extracting block **41**.

[0134] FIG. **6**A shows an example of analysis results stored in the analysis information storage section **25**. FIG. **6**B shows an example of information used or set when the processing program storage section **23** executes an analysis process.

[0135] Further, FIG. **7** shows a display example in which information on a determination is displayed in an analyzed still image on the monitor **4**.

[0136] As described with reference to FIG. **8**, to make a condition determination of whether or not any still image data in the motion picture data contains the Barrett esophagus, the present embodiment determines whether or not an image of a reference site (in the present embodiment, the EG junction) comprising a first biological feature (value) was picked up temporally before or after (substantially simultaneously with) the pickup of an image of a determination target site to be subjected to a Barrett esophagus condition determination. The EG junction detection block **45** constitutes a first biological feature detection section that detects the first biological feature.

[0137] The present embodiment is characterized by executing such an image processing procedure as described below if the determination process determines that an image of the reference site has been picked up. A second biological feature (value) (in the present embodiment, a feature of the epithelium boundary) is detected in a still image in a frame following or preceding the frame of the reference site. Then, on the basis of the detection result of the second biological feature, a Barrett esophagus determination is made. This allows an efficient determination to be made for the Barrett esophagus condition, the condition determination target. The epithelium boundary detection block **44** constitutes a second biological feature detection section that detects the second biological feature in the frame image picked up temporally before or after the image used for the detection by the EG junction detection block **45**, on the basis of the detection result from the EG junction detection block **45**.

[0138] Such image analysis processing makes it possible to omit, for example, a process of detecting the second biological feature in images not comprising the first biological feature. This allows a condition determination to be efficiently made for the condition determination target in a short time. A large amount of image data can thus be appropriately processed.

[0139] Now, with reference to the flowchart in FIG. **8**, description will be given of the operation of the image processing apparatus **3** in accordance with the present embodiment.

[0140] When the user uses the input operation section **29** to specify a file name for motion picture data to the CPU **22**, which executes a process in accordance with a processing program, the CPU **22** reads the maximum number of frames for the specified motion picture data, from the image storage section **24**. As shown in FIG. **6**B, the maximum frame number is substituted into a parameter MAX-COUNT indicating the maximum frame number to start a process in accordance with the processing program.

[0141] In the first step S**1**, the CPU **22** initializes a frame number variable COUNT, that is, sets COUNT=0.

[0142] In the next step S**2**, the CPU **22** compares the frame number variable COUNT with MAX_COUNT. If COUNT>MAX_COUNT, the process is ended.

[0143] If step S**2** results in the opposite determination, that is, COUNT≦MAX_COUNT, the process proceeds to step S**3** where the image extracting block **41** extracts an image with a frame number=COUNT.

[0144] In the next step S**4**, the EG junction detection block **45** executes, in accordance with the present embodiment, a process of detecting the EG junction in the image with that frame number as a process of detecting the first biological feature (the biological feature is hereinafter simply referred to as the feature).

[0145] Depending on whether or not the detection result indicates a point sequence of a line indicating the EG junction **35**, the CPU **22** determines whether or not the EG junction **35** is present as shown in step S**5**.

[0146] If the CPU **22** determines in step S**5** that the EG junction **35** is not present, the CPU **22** suspends the process in steps S**3** and S**4** to proceed to the next step S**6**. The CPU **22** then increments the frame number variable COUNT by one and returns to step S**2** to repeat the process in steps S**2** to S**6**.

[0147] On the other hand, in step S**5**, if the CPU **22** determines that the EG junction **35** is present, the CPU **22** detects the second feature in step S**7**, and on the basis of the detection result, shifts to a condition determination process of determining whether or not the patient has the Barrett esophagus, the condition determination target.

[0148] In step S**7**, to start the Barrett esophagus determination process, the CPU **22** sets the variable N, specifically, sets the variable N at 0.

[0149] In the next step S**8**, the CPU **22** compares the variable N with a predetermined constant MAX_N, more specifically, the maximum frame number for which the process of determining whether or not the patient has the Barrett esophagus is to be executed. Then, if the comparison result indicates N>MAX_N, the CPU **22** ends the process. The present embodiment thus avoids determining whether or not the patient has the Barrett esophagus, for images with frame numbers following the preset maximum frame number.

[0150] On the other hand, if step S**8** results in the opposite comparison result, that is, N≦MAX_N, the process proceeds to step S**9**, where the image extracting block **41** extracts an image with a frame number=COUNT+N. That is, an image is extracted which is located temporally N frames after the image in which the EG junction **35** is detected (At this time, N is 0, that is, the initial value. Accordingly, the Barrett esophagus determination process is executed on the basis of the image in which the EG junction **35** has been detected. As is apparent from the subsequent process, whether or not the patient has the Barrett esophagus is sequentially executed on images picked up temporally after the one in which the EG junction **35** has been detected).

[0151] Then, in step S**10**, the EG junction detection block **45** executes a process of detecting the EG junction **35** in the image with that frame number.

[0152] In the next step S**11**, the epithelium boundary detection block **44** executes a process of detecting the epithelium boundary **34** in the image with that frame number as a process of detecting the second feature. The process of detecting the epithelium boundary **34** corresponds to, for example, the process from step S**1** to step S**4** shown in FIG. 4 of Japanese Patent Application No. 2004-360319. Specifically, since the squamous epithelium in the esophagus side has a color tone different from that of the columnar epithelium in the stomach side as described above, the coordinates of the epithelium boundary **34** can be calculated (detected) by executing an edge process and a thinning process on endoscopic image data and then joining a generated sequence of points for the boundary together to obtain a coordinate point sequence along the boundary.

[0153] In the next step S**12**, the Barrett esophagus determination block **46** uses the point sequence for the line indicating the EG junction **35** detected in step S**10** and the point sequence for the line indicating the epithelium boundary **34** detected in step S**11** to determine whether or not the condition determination target site in the picked-up image is the Barrett esophagus. The Barrett esophagus determination block **46** constitutes a condition determination section that make a determination for the condition of a living body on the basis of the detection result from the epithelium boundary detection section **44** to output a determination.

[0154] Specifically, a process described in connection with a Barrett esophagus determination process shown in FIG. **13** described below makes it possible to determine whether or not the patient has the Barrett esophagus.

[0155] In step S**13**, the Barrett esophagus determination block **46** passes the determination of whether or not the target site is the Barrett esophagus and the frame number to the display processing block **43**. The display processing block **43** extracts image data indicated by the specified frame number from an internal buffer (not shown) and superimposes the determination on the image data. The image data is sent to the monitor **4**, which displays the image together with the determination on the display screen.

[0156] For example, if the target site is determined to be the Barrett esophagus, then as shown in FIG. **6**B, for example, "suspected Barrett esophagus" is displayed in the determination target image.

[0157] In step S**14** subsequent to step S**13**, the variable N is incremented by one, and then the process returns to step S**8**. The process from step S**8** to step S**14** is then repeated. Thus, when the variable N exceeds the maximum value MAX_N, the process is ended.

[0158] According to the present embodiment configured as described above and executing the process described above, to analyze images to determine whether or not analysis target still image data constituting motion picture data on picked-up endoscopic images shows the Barrett esophagus, the process of detecting an image having the feature of the EG junction **35** is executed in order of picked-up images, the EG junction **35** constituting the end points of the palisade vessels, which are present around the periphery of the Barrett esophagus determination site. The process of detecting the feature of the epithelium boundary **34**, required to make a determination for the Barrett esophagus condition, is then executed on images following the one determined by the above process to have the feature of the EG junction **35**. Then, on the basis of the detection result, the positional relationship between the epithelium boundary **34** and the EG junction **35**, and the like, the apparatus determines whether or not the target site is the Barrett esophagus. This makes it possible to efficiently determine whether or not the target site is the Barrett esophagus.

[0159] Further, determinations can be made for the Barrett esophagus and the Barrett mucosa (Barrett epithelium), which is a pre-symptom of the Barrett esophagus disease as described below. This enables determinations suitable for early treatments.

[0160] Further, the present embodiment presets the maximum frame number for the condition determination of whether or not the target site is the Barrett esophagus to avoid the condition determination of whether or not the target site is the Barrett esophagus, for images with frame numbers following the maximum frame number. This makes it possible to prevent time from being spent on images that need not be subjected to the condition determination of whether or not the target site is the Barrett esophagus.

[0161] That is, if images of the interior of the esophagus **33** are sequentially picked up starting with the mouth **31** and ending with the interior of the stomach **36**, that is, the interior of the cardia **37**, as shown in FIG. **2**, then the image of the interior of the stomach need not be subjected to the condition determination of whether or not the target site is the Barrett esophagus. In this case, setting the frame number of the stomach image at MAX_N makes it possible to avoid the condition determination of whether or not the target site is the Barrett esophagus.

[0162] Now, the process of detecting the EG junction **35** will be described with reference to FIGS. **9** to **13**. Description will be given below of an image analysis process of detecting

the EG junction **35** and then detecting the epithelium boundary **34** and making a determination for the Barrett mucosa. The image analysis process is intended to provide an apparatus and method for appropriately determining whether or not the target site is the Barrett mucosa. The image analysis process makes it possible to appropriately determine whether or not the target site is the Barrett mucosa.

[0163] FIG. **9** shows the relevant process procedure, data generated, and the like. The left of FIG. **9** shows the contents of the process, and information such as images generated is shown inside a frame in the right of the figure.

[0164] When the image analysis process is started, in the first step S**21**, an edge extraction process is executed on a process target image. The edge extraction process generates an edge image by for example, applying a bandpass filter to a G color component image in an RGB image.

[0165] The edge extraction technique based on the bandpass filter is well known. An edge image may also be generated using a luminance component of the processing target image. If not only the edge of the vessel but also the edge of another shape (contour) is extracted, the vessel edge alone can be extracted by applying the bandpass filter to the R component of the processing target image to exclude the edge of the extracted shape.

[0166] Steps S**21** to S**26** in FIG. **9** are used for a processing section corresponding to the stomach/esophagus detection process in step S**4** in FIG. **8**.

[0167] In the next step S**22** in FIG. **9**, a binarization is executed on the edge image to generate a binarized image. The binarization in accordance with the present embodiment compares the pixel value of each pixel in the edge image with a specified threshold to determine the value of each pixel in the binarized image to be 0 or 1.

[0168] In the next step S**23**, a well-known thinning technique is applied to the binarized image to execute a thinning process to generate a thinned image.

[0169] In the next step S**24**, a palisade vessel extraction process of extracting the palisade vessels inherent in the esophagus **33** is executed on the thinned image. Extracted palisade vessel information is saved. A flowchart of this process is shown in FIG. **11** (this will be described below).

[0170] In the next step S**25**, the coordinates of the end points of the palisade vessels saved in the palisade vessel extraction process are acquired. In step S**26**, a boundary line generation process of connecting a sequence of end point coordinate points together with a segment is executed to generate (acquire) boundary line information. FIG. **10**A shows the boundary line information generated by the process, more specifically, the palisade vessel end point boundary.

[0171] Moreover, in step S**27**, a boundary line image is generated which contains the boundary line information (palisade vessel end point boundary) acquired by the boundary line image generation process, and a dark portion and the epithelium boundary **34**, which have already been acquired. This image is shown in FIG. **10**B.

[0172] In the next step S**28**, the Barrett esophagus determination process is executed, that is, whether or not the target site is the Barrett esophagus or the Barrett mucosa, on the basis of already acquired information on the positional relationship with the epithelium boundary **34** between the squamous epithelium and the columnar epithelium. This process will be described below in detail with reference to FIG. **13**.

[0173] As described above, determinations are made for the Barrett esophagus or the Barrett mucosa and displayed to finish the process.

[0174] Now, the palisade vessel extraction process in step S**24** in FIG. **9** will be described with reference to FIG. **11**.

[0175] When the palisade vessel extraction process is started, in the first step S**31**, unprocessed segments are acquired from the thinned image. An example of the corresponding image is shown in FIG. **12**A.

[0176] In the next step S**32**, the number of pixels in each segment is calculated to be a segment length L. In the next step S**33**, the calculated segment length L is compared with a predetermined threshold thre1 to determine whether the former is greater or smaller than the latter. In the determination process, if L>ther1, the process proceeds to the next step S**34**. If L≦ther1, that segment is determined not to be the palisade vessel. The process then shifts to step S**41**. In the present embodiment, for example, ther1=50.

[0177] In step S**34**, the number C of branching and intersecting points in each segment and the number B of bending points in each segment are calculated. In step S**35**, the numbers are compared with a predetermined threshold ϵ. When C≦Cth and B<ϵ, the process proceeds to the next step S**36**. When C>Cth or B≧ϵ, that segment is determined not to be the extraction target palisade vessel but a dendritic vessel. The process then shifts to step S**41**. In the present embodiment, Cth=0 and ϵ=3.

[0178] In step S**36**, one of the two end points of the segment which is closer to the already acquired image dark portion is acquired. In step S**37**, a vector v connecting the end point and the center of the dark portion together is calculated.

[0179] In the next step S**38**, the angle θ between the vector v and a straight line connecting the segment start point and the segment end point together is calculated. In the next step S**39**, the apparatus determines whether the calculated angle θ is greater or smaller than a threshold thre2.

[0180] If the determination in step S**39** indicates that θ<thre2 (for example, θ**1** in FIG. **12**B), the process proceeds to step S**40**. In contrast, if θ≧thre2 (for example, θ**2** in FIG. **12**B), that segment is determined not to be the palisade vessel. The process then shifts to step S**41**. In the present embodiment, thre2=45°.

[0181] In step S**40**, those of the segments extract in step S**31** which meet the determination conditions in step S**39** are determined to be the palisade vessels. The information (the segment length L, the branching and intersecting point count C of the segment, the bending point count B, the coordinate point sequence of the segment, the coordinates of the end point, and the angle θ) on those segments is saved as palisade vessel information. This enables the palisade vessels to be extracted as shown in FIG. **12**C.

[0182] As described above, the process from step S**31** to step S**35** constitutes a processing section in which the EG junction detection block **45** determines the segment to be the palisade vessel taking into account the branching point count, intersecting point count, and bending point count of the segment obtained by executing the thinning process on the frame image data. The process from step S**36** to step S**39** constitutes a processing section in which the EG junction detection block **45** determines the segment to be the palisade vessel taking into account the angle between the segment connecting the opposite ends of the segment obtained by executing the thinning process on the frame image data and the vector connect-

ing the dark portion center of the image dark portion of the frame image to one of the opposite ends which is closer to the image dark portion.

[0183] In step S**41**, the presence or absence of any unprocessed segment is determined If there remains any unprocessed segment, the process loops back to step S**31**. If all the segments have been processed, the process is ended.

[0184] In steps S**36** to S**39**, a matched filter may be used to extract only vessels extending toward the dark portion.

[0185] Now, the Barrett mucosa determination process in step S**28** in FIG. **9** will be described with reference to FIG. **13**. In step S**51**, the boundary line image generated by the above boundary line image generation process is acquired. This corresponds to FIG. **10**B.

[0186] In the next step S**52**, the entire image is divided by a predetermined number of, that is, N radial lines. FIG. **10**C shows that the image is divided with N set at, for example, 8.

[0187] In the next step S**53**, a variable i indicating the ith radial line [i] is set at an initial value of 1.

[0188] In the next step S**54**, a point P**1** at which the ith radial line [i] crosses the epithelium boundary **34** and a point P**2** at which the ith radial line [i] crosses the boundary formed are calculated. FIG. **10**C shows an image showing the calculated points P**1** and P**2**.

[0189] In the next step S**55**, the distance Q[i] between the points P**1** and P**2** is calculated.

[0190] In the next step S**56**, the apparatus determines whether all the radial lines have been processed. That is, the apparatus determines whether or not i is equal to the radial line count N. If i has not reached N, then in step S**57**, i is incremented by one. The process then returns to step S**54** to execute a process similar to that described above. If all the radial lines have been processed, the process proceeds to step S**58**.

[0191] Once the distance Q[i] between the points P**1** and P**2** is calculated for all the radial lines, that is, the N radial lines, the N distances Q[i] are used to calculate a variance σ in step S**58**.

[0192] In the next step S**59**, the apparatus determines whether the variance σ is greater or smaller than a predetermined threshold thre3. If σ>thre3, the process proceeds to step S**60**. In contrast, if σ≦thre3, the image is determined not to show the Barrett mucosa. The process is then ended. In the present embodiment, thre3=5.

[0193] In step S**60**, if the image acquired in step S**51** meets the determination condition in step S**59**, the image is determined to show the Barrett mucosa. The determination is, for example, displayed, announced, or saved, and the process is then ended.

[0194] Whether or not the target site is the Barrett mucosa (Barrett epithelium) can be accurately determined in accordance with the process shown in FIGS. **9** to **13**.

[0195] That is, the process detects each of the EG junction **35** and the epithelium boundary **34**, and on the basis of the detection results, determines whether or not the target site is the Barrett mucosa. This enables appropriate and accurate determinations.

[0196] The process shown in FIG. **13** may be partly changed as described below so that substantially quantitative determinations can be made for the Barrett mucosa and the Barrett esophagus by calculating (estimating) the radius (diameter) of the esophagus **33** in the image and using a known statistical value for the radius.

[0197] A process of calculating the distance (defined as R[i] for simplification) between the dark portion center O and the point P**1** (or between the dark portion center O and the point P**2**) is executed between, for example, steps S**55** and S**56** in FIG. **13**.

[0198] The determination process in step S**56** is executed, and not only the distance Q[i] between the points P**1** and P**2** but also the distance R[i] is calculated for all the radial lines [i]. Subsequently, instead of calculating the variance σ of the distances Q[i] in step S**58** in FIG. **13**, the average value Rav of the distances R[i] is calculated. The average value Rave is determined to be an evaluation value (estimation value) for the radius near the epithelium boundary **34** in the esophagus **33**.

[0199] A statistical radius value Rs (cm) for the esophagus **33** of a normal adult or a person having a body type similar to that of the patient is pre-stored in the memory or the like. The average value Rav and the radius value Rs are used to evaluate the average value of the distance Q[i] between the points P**1** and P**2**.

[0200] The apparatus then determines whether or not the average value of the distances Q[i] is at least 3.0 cm, and if the distance Q[i] is at least **3.0** cm, determines that the target site is the Barrett esophagus.

[0201] That is, the presence or absence of the Barrett esophagus is determined taking into account each distance between the dark portion center O as a predetermined point and the epithelium boundary crossing each of the plurality of radial lines radially extending from the dark portion center O or each distance between the EG junction and the dark portion center O.

[0202] Further, if the average value of the distances Q[i] is, for example, about 1.5 cm, this may be determined to indicate the substantial progress of the Barrett mucosa. Further, if the average value of the distances Q[i] is, for example, about 0.5 cm, this may be determined to be an initial symptom of the Barrett mucosa.

[0203] Thus, the present variation makes it possible to substantially quantitatively determine whether or not the target site is the Barrett esophagus, and in the case of the Barrett mucosa, to quantitatively determine the progress of symptoms. Then, early treatments can be achieved by for example, displaying the determination.

[0204] Alternatively, instead of the Barrett mucosa determination process shown in FIG. **9**, a process such as a variation shown in the flowchart in FIG. **14** may be executed.

[0205] The present variation differs from the process in the above flowchart in that as shown in FIG. **14**, an epithelium boundary palisade vessel image generation process in step S**61** is executed in place of the vessel end point extraction process in step S**25** in FIG. **9**, the boundary line generation process in step S**26** in FIG. **9**, and the boundary line image generation process in step S**27** in FIG. **9**. An epithelium boundary palisade vessel image generated by this process is used to execute a Barrett mucosa determination process in step S**62**.

[0206] In the epithelium boundary palisade vessel image generation process in step S**61**, an epithelium boundary palisade vessel image is generated as shown in FIG. **15**A, the image containing the palisade vessels acquired by the palisade vessel extraction process, and the dark portion and epithelium boundary already acquired.

[0207] In the next step **62**, the epithelium boundary palisade vessel image generated in the last step S**61** is used to

execute the Barrett mucosa determination process. FIG. **16** shows a flowchart of the Barrett mucosa determination process.

[0208] As shown in FIG. **16**, in the first step S**63**, an image containing the epithelium boundary **34** already acquired and the palisade vessels is acquired.

[0209] In the next step S**64**, the number J of palisade vessels crossing the epithelium boundary line is initialized, that is, J is set at 0.

[0210] In the next step S**65**, a processing target vessel is acquired from the Q palisade vessels. Moreover, in the next step S**66**, the apparatus determines whether or not the processing target vessel crosses the epithelium boundary **34**. If the processing target vessel crosses the epithelium boundary **34**, the process proceeds to the next step S**67** to add 1 to the palisade vessel count J. If the processing target vessel does not cross the epithelium boundary **34**, the process returns to step S**65** to acquire the next processing target vessel. Then, the same process as described above is repeated.

[0211] In step S**68** subsequent to step S**67**, the apparatus determines whether or not all the palisade vessels have been processed. If there remains any unprocessed palisade vessel, the process returns to step S**65** to repeat the same process as described above. In contrast, if all the palisade vessels have been processed, the process proceeds to the next step S**69**.

[0212] FIG. **15**B shows an example of an image for which the number J of palisade vessels crossing the epithelium boundary **34** is calculated. In FIG. **15**B, the number Q of palisade vessels is 7, and 6 (=J) of these palisade vessels cross the epithelium boundary **34**.

[0213] In step S**69**, the apparatus determines whether J/Q is larger or smaller than a predetermined threshold thre4. If J/Q>thre4, the process proceeds to step S**70**. In contrast, if J/Q≦thre4, the image is determined not to show the Barrett mucosa. The process is then ended. In the present embodiment, thre4=0.5.

[0214] In step S**70**, if the image acquired in step S**63** meets the determination conditions in steps S**66** and S**69**, the image is determined to show the Barrett mucosa. The determination is, for example, displayed on the monitor **4**, and the process is then ended.

[0215] The present variation makes it possible to determine whether or not the target site is the Barrett mucosa depending on how many palisade vessel end points are present inside the epithelium boundary **34**.

[0216] As described above, according to the present embodiment, to analyze a large amount of still image data constituting motion picture data on endoscopic images to determine whether or not the target site is the Barrett esophagus, a process is executed which involves detecting an image having the feature of the EG junction **35**, a first feature site present around the periphery of a Barrett esophagus determination target site and constituting the stomach-side end points of the palisade vessels. Then, for example, a process of detecting the epithelium boundary **34**, a second feature site, is executed on an image following the one detected by the above process, to determine whether or not the target site is the Barrett esophagus. This makes it possible to make an efficient condition determination, that is, to efficiently determine whether or not the target site is the Barrett esophagus. This is effective for reducing the effort required for manual extraction operations.

[0217] Further, the EG junction **35**, set to be the first feature site the feature of which is detected first as described above, is also utilized to make a determination for the Barrett esophagus condition. This enables the feature detection to be effectively utilized.

[0218] A determination can also be made for the Barrett mucosa (Barrett epithelium), a pre-symptom of the Barrett esophagus disease. This enables determinations suitable for early treatments and the like.

[0219] It is also possible to avoid the determination of whether or not the target site is the Barrett esophagus, for images that do not require the determination.

[0220] The present embodiment has been described in conjunction with motion picture data. However, the present invention may be applied to a plurality of consecutive still image data for one examination (this also applies to the other embodiments and the like).

Second Embodiment

[0221] Now, a second embodiment will be described with reference to FIGS. **17** to **26**. In the above first embodiment, to determine whether or not the target site is the Barrett esophagus, the process of detecting the EG junction **35** is first executed to detect an image containing the EG junction **35**.

[0222] The process of detecting the EG junction **35** imposes a heavy load, reducing processing speed. Accordingly, the processing speed or the detection speed needs to be improved. A cardia detection process is possible which can be executed more quickly than the detection of the EG junction **35** and which deals with the biological site expected to be accurately detected.

[0223] The present embodiment focuses on this to improve the processing speed and the like.

[0224] The configuration of the hardware of an image processing apparatus in accordance with the present embodiment is similar to that in accordance with the first embodiment; the configuration can be described with reference to FIG. **1**. FIG. **17** shows the functional configuration of the CPU **22** based on a processing program in accordance with the present embodiment. In the configuration shown in FIG. **17**, a cardia detection block **47** is further provided in the image analysis block **42**, included in the configuration shown in FIG. **4**. The cardia detection block **47** constitutes a first biological feature detection section that detects the first biological feature.

[0225] FIG. **18** shows a flowchart of a process in accordance with the present embodiment. In accordance with the flowchart, a Barrett esophagus determination is made, and for example, the determination is displayed.

[0226] The cardia detection block **47**, for example, detects a dark portion and thus detects the cardia **37** in the image data on the basis of the shape of the detected dark portion and the degree of rapidity of a change in lightness near the edge of the dark portion. This will be described below in detail with reference to FIG. **19**.

[0227] The process procedure shown in FIG. **18** is different from that shown in the flowchart in FIG. **8** in that a process of detecting the cardia **37** in step S**4'** is executed in place of the process of detecting the EG junction **35** in step S**4** and that a process of determining the presence of the cardia **37** in step S**5'** is executed in place of the process of determining the presence of the EG junction **35** in step S**5**, following step S**4**.

[0228] Further, instead of extracting the image with the frame number=COUNT+N in step S**9** of the process procedure in FIG. **8**, an image with a frame image=COUNT−N is extracted as shown in step S**9'** in FIG. **18**.

[0229] That is, in the first embodiment, the EG junction **35** is located around the periphery of the Barrett esophagus determination target site. Accordingly, an image obtained temporally after the site is detected in the original image is examined to obtain an image showing an area closer to the periphery of the site. This meets image pickup conditions for an image pickup operation performed while inserting the distal end **14** of the endoscope **6**.

[0230] In contrast, as seen in FIG. **2**, the cardia **37** is a site serving as an inlet to the stomach through which the endoscope enters the stomach after having passed through the EG junction **35** and the epithelium boundary **34**. Consequently, a frame image is extracted which is located temporally N frames before the image in which the cardia was detected. Images picked up before the above image are sequentially subjected to the determination of whether or not the image shows the Barrett esophagus.

[0231] According to the present embodiment, after the detection of the cardia **37**, which imposes a lighter processing load than the detection of the EG junction **35**, the Barrett esophagus determination process is executed on the basis of the image in which the cardia **37** has been detected. This enables the Barrett esophagus determination to be achieved in a shorter time.

[0232] This makes it possible to shift more efficiently to the Barrett esophagus determination process, allowing effects similar to those of the first embodiment to be exerted in a shorter time.

[0233] Now, the process of detecting the cardia **37** will be described with reference to FIGS. **19** to **22**. FIG. **19** shows a process flow in which the closed cardia is detected, as well as data used or generated during the process.

[0234] When the process of detecting the cardia **37** is started, an edge detection process is executed on a processing target image as shown in step S**71** to generate an edge image.

[0235] In the present embodiment, the edge extraction process generates an edge image by applying a bandpass filter to an R color component image.

[0236] The edge extraction technique based on the bandpass filter is well known. An edge image may also be generated using a luminance component of the processing target image.

[0237] In the next step S**72**, a binarization is executed on the edge image to generate a binarized image. The binarization in accordance with the present embodiment compares the pixel value of each pixel in the edge image with a specified threshold to determine the value of each pixel in the binarized image to be 0 or 1.

[0238] In the next step S**73**, a well-known thinning technique is applied to the binarized image to execute a thinning process to generate a thinned image. FIG. **20**A shows an example of a generated thinned image.

[0239] In the next step S**74**, a branching and intersecting point calculation process of calculating branching and intersecting points for all the thin lines in the thinned image. FIG. **20**B shows an example of branching and intersection points calculated for the thinned image in FIG. **20**A. FIG. **20**B shows that the number Nc of branching and intersecting points is 5.

[0240] The coordinates of the branching and intersecting points calculated by the branching and intersecting point calculating process in step S**74** are saved as branching and intersecting point information.

[0241] In the next step S**75**, a concentration level calculation process is executed for calculating the concentration level of the branching and intersecting points on the basis of the coordinate values of the branching and intersecting points. Thus, concentration level information is calculated.

[0242] The concentration level information will be described below with reference to the flowchart in FIG. **21**. In the first step S**77**, the coordinate values of the Nc branching and intersecting points are acquired. In the next step S**78**, calculation is made of the variance σx of the x coordinates of the Nc branching and intersecting points and the variance σy of the y coordinates of the Nc branching and intersecting points. In the next step S**79**, the variances σx and σy are saved as concentration level information. The process is then ended.

[0243] In the concentration level calculation process, instead of the variances, standard deviations, coefficients of variations, average values of the distances between each of the Nc branching and intersecting points and the centroid, or the like may be determined to obtain concentration level information.

[0244] Referring back to FIG. **19**, the concentration level information calculated by the concentration level calculation process in step S**75** is used to execute a closed cardia determination process in the next step S**76**.

[0245] As shown in step S**76***a* in FIG. **22**, the closed cardia determination process make a determination by comparing the branching and intersecting point count Nc with a predetermined threshold thre_N and compares the concentration level information (σx, σy) with thresholds thre_x and thre_y, respectively.

[0246] If the conditions $Nc>thre_N$, $\sigma x<thre_x$, and $\sigma y<thre_y$ in step S**76***a* are determined to be met, the target site is determined to be the closed cardia **37** as shown in step S**76***b*. On the other hand, the conditions in step S**76***a* are determined not to be met, that is, $Nc \leqq thre_N$, $\sigma x \geqq thre_x$, or $\sigma y \geqq thre_y$, the target site is determined to not to be the closed cardia **37** as shown in step S**76***c*.

[0247] The cardia determination process is thus executed, and the cardia detection process shown in FIG. **19** is then ended.

[0248] This enables the cardia **37** to be detected.

[0249] As described above, the present embodiment first executes the process of detecting the cardia **37**, and if the cardia **37** is detected, makes a determination for the Barrett esophagus, the determination target, for previously picked-up images. This enables the Barrett esophagus determination to be efficiently made even with a large amount of image data.

[0250] Further, if the Barrett esophagus determination process is executed as described in the first embodiment, the Barrett mucosa determination can also be made. This determination is effective for early treatments.

[0251] FIG. **23** shows a flowchart process of cardia detection in accordance with a variation.

[0252] The present variation executes an edge component generation angle calculation process in step S**81** which is intended to detect the open cardia, in place of the branching and intersecting point calculation process in step S**74** and the next concentration level calculation process in step S**75**, in the process flowchart shown in FIG. **19**. The present variation then executes an open cardia determination process of detecting (determining) the open cardia in step S**82** on the basis of generation angle information calculated by the edge component generation angle calculation process.

[0253] Steps S71 to S73 in the process shown in FIG. **23** are the same as those shown in FIG. **19**.

[0254] An edge extraction process is executed on a processing target image as shown in step S71 to generate an edge image. The binarization in step S72 is further executed on the edge image to generate a binarized image. The thinning process in step S73 is further executed to generate a thinned image shown in FIG. **24**A.

[0255] Then, an image containing a dark portion is provided which has been subjected to a dark portion binarization using a dark portion extraction threshold in order to allow the image dark portion to be extracted. The image is superimposed on the thinned image acquired by the thinning process to obtain an image shown in FIG. **24**B. The edge component generation angle calculation process in step S81 is then executed on the resulting image to calculate generation angle information on a high edge angle.

[0256] An open cardia determination process in step S82 is then executed to determine whether or not the target site is the open cardia.

[0257] FIG. **25** is a flowchart showing the details of the edge component generation angle calculation process in step S81 in FIG. **23**.

[0258] In the first step S83, one feature point in the dark portion in the image is selected. In the present embodiment, the feature point in the dark portion in the image selected for calculation is, for example, the centroid of the dark portion.

[0259] In the next step S84, the image is divided into a plurality of, for example, M pieces around the calculated feature point such as the centroid or center point in the circumferential direction, using radial lines.

[0260] In the next step S85, one of the thin lines in the thinned image shown in FIG. **24**A described above, that is, a segment i, is extracted (acquired).

[0261] In the next step S86, the angle θ[i] through which the extracted segment i is present is calculated. That is, the number Ni of areas in which the segment i is present is counted, and on the basis of the count, the angle θ[i] through which the extracted segment i is present is calculated by $\theta[i]=Ni\times(360/M)°$.

[0262] An example of the calculation is shown in FIG. **24**C. FIG. **24**C shows that the number Ni of areas in which the segment i is present is **6**, the range of areas being enclosed by a parting line of 0° and a parting line of 270°. That is, in FIG. **24**C, the area (shaded part) in which the edge is present spans 270°.

[0263] In the next step S87, the apparatus determines whether or not there remains any unprocessed segment. If there remains any unprocessed segment, the process returns to step S85 to acquire the unprocessed segment. Then, a process similar to that described above is executed.

[0264] On the other hand, if all the segments have been processed, the edge component generation angle calculation process is ended. Referring back to FIG. **23**, angle information on the angle θ[i] generated by the edge component generation angle calculation process in step S81 is used to execute the open cardia determination process in step S82 to determine whether or not the target site is the open cardia.

[0265] The open cardia determination process compares the angle θ[i] with a predetermined threshold thre5, for example, as shown in step S82*a* in FIG. **26**. That is, the apparatus determines whether a condition θ[i]>thre5 is met. If the condition θ[i]>thre5 is met, the apparatus determines that the edge corresponds to the open cardia as shown in step S82*b*. In contrast, if the condition is not met, the apparatus determines that the edge does not correspond to the open cardia. Thus, the process of detecting the cardia is ended.

[0266] This enables the open cardia to be detected.

[0267] Then, the process of detecting the Barrett esophagus is executed on the image in which the cardia has been detected. This enables an efficient Barrett esophagus determination.

Third Embodiment

[0268] Now, a third embodiment of the present invention will be described with reference to FIGS. **27** to **29**. The configuration of the hardware of an image processing apparatus in accordance with the present embodiment is similar to that in accordance with the first embodiment; the configuration can be described with reference to FIG. **1**. FIG. **27** shows the functional configuration of essential sections provided by the CPU **22** executing a processing program in accordance with the present embodiment. In the configuration shown in FIG. **27**, a processing continuation determination block **48** is further provided in the image analysis block **42**, included in the configuration shown in FIG. **4**. The processing continuation determination block **48** constitutes a biological feature detection section that detects the first biological feature.

[0269] The processing continuation determination block **48** determines whether or not a point sequence for the epithelium boundary line detected by the epithelium boundary detection block **44** is present. The processing continuation determination block **48** further controls the operation of the image analysis block **42** in accordance with the above determination.

[0270] FIG. **28** shows a flowchart of a process procedure in accordance with the present embodiment. In accordance with the flowchart, a Barrett esophagus determination is made, and for example, the determination is displayed.

[0271] The process method in accordance with the flowchart shown in FIG. **28** corresponds to the process procedure in accordance with the first embodiment shown in FIG. **8** and in which instead of the process of detecting the EG junction **35**, an easier process of detecting the epithelium boundary **34** is executed.

[0272] First, an image in which the epithelium boundary **34** is detected is retrieved. Once the image in which the epithelium boundary **34** is detected cab be retrieved, the Barrett esophagus determination process is executed.

[0273] The process procedure will be described with reference to the flowchart in FIG. **28**. The initial steps S1 to S3 are the same as those in the flowchart in FIG. **8** and will thus not be described.

[0274] In step S3, an image with the frame number COUNT is extracted, and in the next step S91, a process of detecting the epithelium boundary **34** is executed.

[0275] In the next step S92, for the epithelium boundary **34** subjected to the detection process, the processing continuation determination block **48** determines whether or not a point sequence for a line indicating the epithelium boundary **34** is obtained in step S91 to determine whether or not the epithelium boundary **34** is present.

[0276] If the apparatus determines in step S92 that the epithelium boundary **34** is not present, the process proceeds to step S6 to increment the frame number variable COUNT by one. The process then returns to step S2 to continue the process from step S2 to step S92, that is, the analysis operation of detecting the epithelium boundary **34**.

[0277] On the other hand, if the apparatus determines in step S**92** that the epithelium boundary **34** is present, the process shifts from the analysis operation of detecting the epithelium boundary **34** to step S**93**, that is, the analysis operation of making a determination for the Barrett esophagus.

[0278] In step S**93**, the EG junction detection block **45** executes the process of detecting the EG junction **35** starting with the image with that frame number.

[0279] After the process of detecting the EG junction **35**, in the next step S**94**, the Barrett esophagus determination block **46** uses the point sequence for the line indicating the EG junction **35** detected in step S**93**, and the point sequence for the line indicating the epithelium boundary **34** detected in step S**91**, to determine whether or not the target site in the picked-up image is the Barrett esophagus.

[0280] Upon determining that the target site is the Barrett esophagus, the Barrett esophagus determination block **46** passes the determination and the frame number to the display processing block **43** in step S**95**. The display processing block **43** extracts the image with the specified frame number from the buffer and superimposes the determination on the image data. For example, the display processing block **43** provides such a display as shown in FIG. **7**.

[0281] In the next step S**96**, the COUNT is incremented by one. In the next step S**97**, an image with the next frame number (=COUNT) is newly acquired. The process of detecting the epithelium boundary **34** is then executed on the image.

[0282] In the next step S**98**, the apparatus determines whether or not the epithelium boundary **34** is present on the basis of the preceding detection process.

[0283] In step S**98**, the processing continuation determination block **48** determines whether or nor the point sequence for the line indicating the epithelium boundary **34** is obtained in the preceding step S**97**, to determine whether or not the epithelium boundary **34** is present.

[0284] If the apparatus determines in step S**98** that the epithelium boundary **34** is not present, the process loop from step S**93** to step S**98** is stopped, that is, the analysis operation for the Barrett esophagus determination process is stopped to end the process.

[0285] On the other hand, if the epithelium boundary **34** is determined to be present, the process returns to step S**93** to execute the process of detecting the EG junction **35** to continue the Barrett esophagus determination process. In this manner, if the presence of the epithelium boundary **34** is detected, the process in the process loop is repeated. The process is ended when the presence of the epithelium boundary **34** fails to be detected again. That is, the biological condition determination is performed on frame images in which the epithelium boundary has been detected.

[0286] The present embodiment, operating as described above, first executes the process of detecting the epithelium boundary **34**, and when the epithelium boundary **34** is detected through the detection process, shifts to the process of determining the presence or absence of the Barrett esophagus. Then, when the presence of the epithelium boundary **34** fails to be detected again, the process is ended. This enables an efficient Barrett esophagus determination.

[0287] That is, the present embodiment provides the processing continuation determination section to perform the following control. Only the image of the periphery of the epithelium boundary **34** is detected, which is required to make a determination for the Barrett esophagus condition. Then, when the epithelium boundary **34** fails to be detected in the image again, the Barrett esophagus determination process is ended. This enables the image required for the Barrett esophagus determination process to be extracted to allow the Barrett esophagus determination process to be executed, without the need for much time and effort.

[0288] That is, the present embodiment allows the Barrett esophagus determination process to be executed in a shorter time and with less effort than the first embodiment.

[0289] In the present embodiment, after the epithelium boundary **34** is detected in a frame image, the next epithelium boundary detection target image is a frame image temporally and consecutively following the above frame image. However, the next detection target image to be acquired may be a temporally preceding frame image depending on, for example, the temporal direction in which images are picked up.

[0290] Alternatively, the next frame image to be acquired may be specified by defining the intervals at which consecutive frame images are acquired as N (N is a natural number of 1, 2, 3, . . .) and incrementing COUNT to COUNT+N in step S**97**.

[0291] Now, a variation of the present embodiment will be described. When the apparatus determines whether or not each image shows the Barrett esophagus, the picked-up image may be erroneously determined not to show the Barrett esophagus under the effect of noise, halation, a temporal variation in light quantity, shading, or the like contained in the image data, though the image actually shows the Barrett esophagus.

[0292] Thus, the present variation solves this problem by the process procedure shown in FIG. **29**. Steps S**1** to S**94** in the process procedure shown in the flowchart in FIG. **29** are the same as those in the process procedure shown in FIG. **28** (however, in FIG. **29**, a frame number variable Nb is additionally used and thus initialized to zero in step S**1**).

[0293] In FIG. **28**, the determination in step S**94** is displayed in step S**95**. However, in the present variation, after the determination process in step S**94**, the frame number is changed to the next one. Then, the process of detecting the epithelium boundary **34**, the process of detecting the EG junction **35**, and the like are executed to allow the Barrett esophagus determination process to be executed.

[0294] Then, when the current image is found not to contain the epithelium boundary **34**, the process totally determines whether or not the target site is the Barrett esophagus on the basis of all the determinations of whether or not the target site is the Barrett esophagus. The total determination is then displayed.

[0295] The process procedure will be described below with reference to FIG. **29**. Steps S**1** to S**94** in the process procedure are the same as those shown in FIG. **28** (however, as described above, in step S**1**, another frame number variable Nb is initialized to zero) and will not be described below.

[0296] In step S**94**, the apparatus determines whether or not the target site is the Barrett esophagus on the basis of the position at which the epithelium boundary **34** is present and which has been determined in step S**92** as well as the result of the process of detecting the EG junction **35** in step S**93**. The Barrett esophagus determination is temporality stored, and in the next step S**101**, the variable of the frame number Nb is incremented by one. In the next step S**102**, an image with the frame number Nb incremented by one, that is, the frame number COUNT+Nb, is extracted.

[0297] In the next step S**103**, the process of detecting the epithelium boundary **34** is executed. After the detection process, the apparatus determines in the next step S**104** whether or not the epithelium boundary **34** is present. If the epithelium boundary **34** is present, the process returns to step S**93** to execute the process of detecting the EG junction **35** to execute, for example, the process of determining whether or not the target site is the Barrett esophagus as described above.

[0298] On the other hand, upon determining that the epithelium boundary **34** is not present, the process shifts to step S**105** to acquire all the determinations for the Barrett esophagus made during the process from step S**93** to step S**104**.

[0299] In the next step S**106**, the process totally determines whether or not the target site is the Barrett esophagus on the basis of all the Barrett esophagus determinations. In the next step S **107**, the total determination is then displayed so as to be superimposed on the image. The process is then ended.

[0300] The Barrett esophagus determination block **46** totally determines in step S**106** whether or not the target site is the Barrett esophagus as follows.

[0301] For example, the Barrett esophagus determination block **46** calculates the ratio Na/Nb of the number Na of images determined to show the Barrett esophagus to the number Nb of images subjected to the determination of whether or not the target site is the Barrett esophagus. If the ratio Na/Nb is greater than **0.8**, the Barrett esophagus determination block **46** determines that the image pickup target is the Barrett esophagus. In step S**107**, the Barrett esophagus determination block **46** superimposes information "Suspected Barrett esophagus" on all the Nb images used for the Barrett esophagus determination.

[0302] The present variation, performing the process operation as described above, exerts effects similar to those of the third embodiment. The present variation further makes a total determination using information on the determination of whether or not each of a plurality of images shows the Barrett esophagus. This makes it possible to very reliably determine whether or not the target site is the Barrett esophagus.

[0303] In the above description, image processing is executed on endoscopic images picked up by inserting the endoscope **6** with the elongate insertion portion into the living body. However, the contents of the process in each of the above embodiments and variations are also applicable to endoscopic images picked up by a capsule endoscope that is swallowed through the mouth to pick up in vivo images.

[0304] The capsule endoscope is normally an in vivo image pickup apparatus that consecutively picks up still images at regular time intervals. In this case, after swallowed through the mouth, the capsule endoscope moves through the esophagus **33**, the stomach, the small intestine, and the large bowel, while picking up images thereof, while without moving backward. Each of the above embodiments and variations is also applicable to this case.

[0305] Further, the present invention includes embodiments each obtained by, for example, partly combining the above embodiments and the like together.

[0306] As described above, according to the above embodiments and variations, to determine the condition of the living body, it is possible to detect the first biological feature and then the second biological feature. This enables an efficient determination for the condition of interest such as the Barrett esophagus from a large amount of image data. That is, if the first biological feature fails to be detected, the detection of the second biological feature is omitted. This enables an efficient image analysis process. Therefore, even with a large amount of image data, an efficient determination can be made for the condition of interest such as the Barrett esophagus.

[0307] Now, a luminal image processing apparatus in accordance with an embodiment will be described with reference to the drawings.

Fourth Embodiment

[0308] First, with reference to the drawings, description will be given of a luminal image processing apparatus utilizing a capsule endoscope apparatus as well as a method for the luminal image processing in accordance with a fourth embodiment. First, with reference to FIGS. **30**A, **30**B and **31**, description will be given of the luminal image processing apparatus utilizing the capsule endoscope apparatus in accordance with the fourth embodiment. FIGS. **30**A and **30**B are block diagrams showing the general configuration of a capsule endoscope apparatus **101** and a terminal apparatus **107** serving as a luminal image processing apparatus in accordance with the present embodiment.

[0309] As shown in FIG. **30**A, the capsule endoscope apparatus **101** using an image processing method in accordance with the present embodiment comprises a capsule endoscope **103**, an antenna unit **104**, and an external device **105**. Although described below in detail, the capsule endoscope **103** is shaped so as to be swallowed through the mouth of a patient **102** that is a subject to advance through the esophagus and the gastrointestinal tract. The capsule endoscope **103** internally has an image pickup function of picking up images of the esophagus and the gastrointestinal tract to generate picked-up image information and a transmission function of transmitting the picked-up image information to the exterior of the living body. The antenna unit **104** has a plurality of reception antennas **111** installed on the body surface of the patient **102** to receive the picked-up image information transmitted by the capsule endoscope **103**. The external device **105** is externally shaped like a box and has functions of, for example, executing various processes on the picked-up image information received by the antenna unit **104**, recording the picked-up image information, and displaying the picked-up images on the basis of the picked-up image information. An armor of the external device **105** has a liquid crystal monitor **112** and an operation portion **113** on a surface thereof, the liquid crystal monitor **112** displaying the picked-up images, the operation portion **113** being used to give instructions on the operation of the various functions. Further, the external device **105** has an alarm display LED for the amount of power remaining in a battery serving as a driving power supply, and a power supply switch serving as the operation switch **113**.

[0310] The external device **105** is installed on the body of the patient **102**, and as shown in FIG. **30**B, is installed on a cradle **106** to connect to the terminal apparatus **107**. For example, a personal computer is used as the terminal apparatus **107**, which is a luminal image processing apparatus and serves as a cardia detection apparatus. The terminal apparatus **107** comprises a terminal main body **109** having functions of processing and storing various data, a keyboard **108***a* and a mouse **108***b* which are used to input various operations, and a display **108***c* that displays the results of processing results. The basic function of the terminal apparatus **107** is to load, via the cradle **106**, the picked-up image information recorded in the external device **105**, and to write and record the picked-up image information in a rewritable memory contained in the terminal main body **109** or a portable memory such as a

rewritable semiconductor memory that can be freely installed in and removed from the terminal main body **109**, and to execute image processing such that the recorded picked-up image information is displayed on the display **108***c*. Moreover, the terminal apparatus **107** executes a cardia detection process using an image processing method in accordance with an embodiment described below. The picked-up image information stored in the external device **105** may be loaded into the terminal apparatus **107** via a USB cable or the like instead of the cradle **106**. The cradle **106** and the like constitute an image input section via which images picked up by the capsule endoscope **3** are inputted.

[0311] Now, the external shape and internal structure of the capsule endoscope **103** will be described with reference to FIG. **31**. The capsule endoscope **103** is shaped like a capsule comprising an armor member **114** having a U-shaped cross section and a hemispherical cover member **114***a* installed at a distal open end of the armor member **114** in a water tight manner via an adhesive and formed of a transparent member.

[0312] In an internal hollow portion of the capsule shape, comprising the armor member **114** and the cover member **114***a* and inside a central portion of the arc of the hemisphere of the cover member **114***a*, an objective lens **115** is housed in a lens frame **116** to capture an image of an observation target which is incident via the cover member **114***a*. A charge coupled device (hereinafter referred to as a CCD) **117** that is an image pickup device is located at an image formation position of the objective lens **115**. Four white LEDs **118** are arranged on the same plane around the lens frame **116**, in which the objective lens **115** is housed, to emit and radiate illumination light (only two LEDs are shown in the figure). The following are arranged in the hollow portion of the armor member **114** and behind the CCD **117**: a processing circuit **119** that drivingly controls the CCD **117** to executes a process of generating a photoelectrically converted image pickup signal, an image pickup process of executing predetermined signal processing on the image pickup signal to generate a picked-up image signal, and a LED driving process of controlling an operation of illuminating and non-illuminating the LEDs **118**, a communication processing circuit **120** that converts the picked-up image signal generated by the image pickup process executed by the processing circuit **119** into a radio signal to transmit the radio signal, a transmission antenna **123** that transmits the radio signal from the communication processing circuit **120** to the exterior, and a plurality of button cells **121** that supply driving power to the processing circuit **119** and the communication processing circuit **120**. The CCD **117**, LED **118**, processing circuit **119**, communication processing circuit **120**, and transmission antenna **123** are arranged on circuit boards (not shown) that are connected together via flexible boards.

[0313] The capsule endoscope **103** picks up in vivo images at predetermined time intervals while moving through the body of the patient **102** and transmits the images to the external device **105**. The external device **105** records each of the received endoscopic images in a built-in storage device. The endoscopic image recorded in the external device **105** is transferred via the cradle **106** to the terminal apparatus **107**, where the image is stored in a storage device (not shown). The terminal apparatus **107** executes a cardia detection process on the basis of the transferred and stored endoscopic image. The cardia detection process is executed by image processing software, that is, a program, which executes image processing on image data on the endoscopic image. The image processing software is executed by a processing device such as the CPU in the terminal apparatus **107**.

[0314] Image processing described below is implemented by software and may be executed by any of the capsule endoscope **103**, the external device **105**, and the terminal apparatus **107**. The description below takes an example in which the image processing is executed by the terminal apparatus **107**, which uses the personal computer. In the description of the contents of the image processing, the size of one frame image corresponds to 3 planes of ISX×ISY (1≦ISX, ISY. For example, ISX=640, ISY=480) for red (R), green (G), and blue (B). Gray scales for the pixels in each plane correspond to 8 bits, that is, have a value of 0 to 255.

[0315] Further, the capsule endoscope **103** picks up 15 to 30 images per second (15 fps to 30 fps) to, for example, examine the esophagus. The image pickup function is controlled such that after passing through the esophagus, the capsule endoscope **103** performs a slower image pickup operation with the reduced number of images picked up per second. This is achieved by, for example, providing a timer circuit (not shown) and performing control such that when a timer count provided by the timer circuit indicates that a predetermined time has not passed yet, a faster image pickup operation is performed with the increased number of images picked up per second and such that after the predetermined time passes, a slower image pickup operation is performed with the reduced number of images picked up per second.

[0316] FIG. **32** is a flowchart showing an example of the flow of a process executed by the terminal apparatus **107** to detect the cardia by passing through the EG junction on the basis of a series of obtained endoscopic images. A series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. A process shown in FIG. **32** is executed on each of the frames. Image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **32** is executed.

[0317] To process the first frame of the series of images on which the process shown in FIG. **32** is to be executed, first, the frame number i is set at 1 (step S**201**). Reference character i denotes an integer from 1 to n.

[0318] Then, image data on an image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **107** (step S**202**). The image Fi comprises three planes for R, G, and B.

[0319] On the basis of the read image data on the image Fi, a predetermined feature value for the endoscopic image, that is, a color tone feature value, in this case, an average color tone feature value μi, is calculated (step S**203**). The average color tone feature value μi is the average value of the color tone feature values for all the pixels contained in each image. Step S**203** constitutes a feature value calculation step or a feature value calculation section which calculates the average color tone feature value, the color tone feature value for each image Fi based on the values for all the pixels.

[0320] Then, the apparatus determines whether or not the average color tone feature value pi exceeds a predetermined threshold Th (step S**204**). If a value R/(R+G+B) described below is used as the color tone feature value, the threshold Th is, for example, 0.5.

[0321] Adjusting the value of the threshold Th makes it possible to determine whether the read image Fi shows the vicinity of the EG junction, that is, the boundary of the gas-

trointestinal tract, the central portion of the EG junction, or the inlet of the stomach. This will be described below with reference to FIG. **33**.

[0322] If the determination in step S**204** is YES, that is, the average color tone feature value μi exceeds the predetermined threshold Th, the capsule endoscope **103** is about to enter the EG junction or is passing through the EG junction. Consequently, the apparatus determines that the read image Fi was picked up at that time (step S**205**). Steps S**204** and S**205** constitute a boundary detection section that detects the boundary of the gastrointestinal tract on the basis of the calculated average color tone feature value pi and a determination section that the intraluminal image shows an area extending from the esophagus to the cardia on the basis of the detection result of the EG junction, corresponding to the boundary.

[0323] If the determination in step S**204** is NO, that is, the average color tone feature value pi does not exceed the predetermined threshold Th, the apparatus determines whether or not the process shown in FIG. **32** has been finished on all of the series of images to be subjected to the process shown in FIG. **32** (step S**206**). Once the process is finished on all the images, the determination in step S**206** is YES and the process is ended. If the determination in step S**206** is NO, there remains an unprocessed image and a process of changing i to i+1 is thus executed (step S**207**). The process from step S**202** to step S**204** is repeated on the next image.

[0324] As described above, in step S**205**, when the average color tone feature value pi exceeds the predetermined threshold Th, the apparatus determines that the capsule endoscope **103** is passing through the EG junction or is about to enter the EG junction. In other words, the process can also determine that the capsule endoscope **103** will subsequently reach the cardia or the stomach. That is, the process can also determine that the cardia is being detected.

[0325] Now, description will be given of the color tone of the biological tissue extending from the esophagus to the stomach. FIG. **33** is a schematic graph illustrating a variation in color tone among a series of endoscopic images obtained. In FIG. **33**, the axis of abscissa indicates the image numbers (frame numbers), along the time series, of the endoscopic images picked up along a path from the esophagus squamous epithelium through the EG junction to the stomach. The axis of ordinate indicates the color tone feature value for the endoscopic image corresponding to each of the image numbers.

[0326] The color tone of images picked up by the capsule endoscope **103** swallowed through the subject's mouth varies as shown in FIG. **33**. That is, the color tone varies between the squamous epithelium RA of the esophagus and the stomach portion RC of the columnar epithelium. The color tone varies gradually step by step in the EG junction RB, located between the squamous epithelium RA and the stomach portion RC. In FIG. **33**, for example, with a color tone feature value R/(R+G+B) calculated from three pixel values for R, G, and B as described below, the esophagus squamous epithelium RA has a white color tone and thus a small color tone feature value. The stomach portion RC has a red color tone and thus a great color tone feature value. For the EG junction RB, located between the squamous epithelium RA and the stomach portion RC, the color tone feature value varies gradually from the white color tone to the red color tone.

[0327] Thus, when such a color tone feature value as shown in step S**204** in FIG. **32**, which varies gradually, exceeds the predetermined threshold Th (the color tone changes to red), the apparatus determines that the image was picked up when the capsule endoscope **103** was about to enter the EG junction or was passing through the EG junction. In other words, the cardia, the boundary of the gastrointestinal tract, is detected. That is, the cardia is detected on the basis of the difference in color tone between the esophagus mucosa and the stomach mucosa. Specifically, the average value of the color tone feature values or the like is utilized to make a reliable determination for the passage or the like.

[0328] Now, description will be given of a specific example of the average color tone feature value μi, described with reference to FIG. **32**.

[0329] FIG. **34** is a flowchart showing an example of the flow of the process in step S**203** in FIG. **32** which is executed on each frame image and in which R/(R+G+B), calculated from the three pixel values for R, G, and B, is used as the average color tone feature value μi. The process shown in FIG. **34** calculates a chromaticity rj/(rj+gj+bj) on the basis of three pixel values rj, gj, bj for R, G, and B for each of the pixels in one frame to determine the average color tone feature value μi. Reference character j denotes a number identifying a pixel in the image data on each frame.

[0330] First, j is set at 1, val is set at 0, and count is set at 0 (step S**211**). Here, val denotes a variable required to determine the sum of color tone feature values, and count denotes a variable required to determine the number of pixels used to calculate the average color tone feature value μi.

[0331] Then, the apparatus determines in step S**212** whether or not the jth pixel belongs to a dark portion. Specifically, the values of the jth pixel in each of an R image, a G image, and a B image are defined as rj, gj, and bj. Then, if rj≦thd, gj≦thd, and bj≦thd, that pixel is determined to belong to the dark portion. Here, thd denotes a threshold for each color which is used to determine whether or not the pixel belongs to the dark portion. In the present embodiment, thd is set at **10**. If the jth pixel is determined to belong to the dark portion, the process proceeds to step S**216**. If the jth pixel is determined not to belong to the dark portion, the process proceeds to step S**213**.

[0332] Then, the apparatus determines in step S**213** whether or not the jth pixel is extremely bright, that is, the jth pixel belongs to a halation portion. Specifically, if rj≧thh, gj≧thh, and bj≧thh, the pixel is determined to be a halation pixel. Here, thh denotes a threshold for each color which is used to determine whether or not the pixel is a halation pixel. In the present embodiment, Th is set at 200. If the jth pixel is determined to be a halation pixel, the process proceeds to step S**216**. If the jth pixel is determined not to be a halation pixel, the process proceeds to step S**214**.

[0333] In steps S**212** and S**213**, for the R image, G image, and B image, each of the thresholds thd and thh has the same value for rj, gj, and bj. However, for the biological mucosa, the R image generally tends to be brightest. Accordingly, the threshold may be set higher for rj than for gj and bj. Alternatively, the threshold may vary among rj, gj, and bj.

[0334] In step S**214**, val=val+rj/(rj+gj+bj)) and count=count+1 are calculated. To determine the sum of the color tone feature values, the color tone feature value rj/(rj+gj+bj) is added to a variable val and the variable count is incremented by one.

[0335] In step S**215**, the apparatus determines whether or not the process from step S**212** to step S**214** has been executed on all the pixels. Specifically, if j<ISX×ISY, then in step

S216, 1 is added to the number j identifying the pixel (j=j+1) and steps S212 to S214 are executed on the next pixel. If j=ISX×ISY, that is, the process from step S212 to step S214 has been executed on all the pixels, the apparatus determines whether or not count is greater than a threshold thc (step S217). The threshold thc is a value indicating the number of pixels insufficient for color tone evaluation; a value equal to or greater than the threshold thc means that a sufficient number of pixels are present which are effective for color tone evaluation. In step S217, if the determination is YES, that is, a sufficient number of pixels are present which are effective for color tone evaluation, the average color tone feature value μi is calculated by dividing the color tone feature value sum val by the number of pixels count used to calculate the average color tone feature value pi (step 218). Specifically, μi=val/count. As described above, the average color tone feature value pi is calculated for the pixels in the intraluminal image other than the dark portion pixels and the halation pixels.

[0336] If the determination is NO in step S217, that is, a sufficient number of pixels are not present which are effective for color tone evaluation, that frame image is considered to be an error, that is, an abnormal image (step S219). The average color tone feature value μi is determined to be, for example, 0 (zero). In step S204 in FIG. 32, the apparatus determines that the average color tone feature value pi does not exceed the threshold Th.

[0337] Now, variations of the present embodiment will be described.

[0338] In FIGS. 32 to 34, described above, the apparatus determines whether or not, for example, the capsule endoscope has passed through the EG junction or the cardia, on the basis of each frame image. However, as a first variation, the apparatus may determine that, for example, the capsule endoscope 103 has passed through the EG junction when the determination in step S4 is μi>Th for a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0339] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a second variation, the process shown in FIG. 32 may be executed on one particular image.

[0340] Moreover, as a third variation, the moving average of the average color tone feature value μi for a plurality of consecutive images may be calculated so that the apparatus can determine whether or not, for example, the capsule endoscope 103 has passed through the EG junction, depending on whether or not the moving average value exceeds a predetermined threshold. For example, when m=2, 3, 4, . . . , and i>=m+1 (this means that m consecutive images are obtained from n images and that (m+1) is equal to or smaller than i), the moving average value is calculated on the basis of the average color tone feature value pi for images F(i−m) to Fi obtained from the m consecutive images. The apparatus then determines whether or not the moving average exceeds a predetermined threshold. Even with a very reddish intraesophageal image or the like possibly resulting from a variation in illumination conditions caused by a variation in observation distance, angle, or the like, the use of such a moving average makes it possible to eliminate the adverse effect of a slight variation in average color tone feature value to more accurately determine that, for example, the capsule endoscope 103 has passed through the EG junction.

[0341] Further, as a fourth variation, in the above example, R/(R+G+B), the ratio of pixel values calculated from the three pixel values for R, G, and B, is used as a color tone feature value. The fourth variation may use another parameter. Another parameter for the color tone feature value may be, for example, G/(R+G+B) or IHb (=32 $\log_2$(R/G)), hue, or color saturation.

[0342] Moreover, as a fifth variation, a plurality of color tone feature values may be used. For example, in step S203 in FIG. 32, R/(R+G+B) and G/(R+G+B) may be used as the ratios of pixel values calculated from the three pixel values for R, G, and B, and calculation is made of the average values of these color tone feature values, that is, the average value μ1i of the color tone feature value (R/(R+G+B)) for all the pixels in each image and the average value μ2i of the color tone feature value (G/(R+G+B)) for all the pixels in the image. In step S204, the apparatus determines whether or not for the average values μ1i and μ2i, μ1i>Th1 and μ2i>Th2.

[0343] Further, as a sixth variation, the passage of the capsule endoscope 103 through the EG junction or the like may be detected on the basis of the amount of variation in average color tone feature value. That is, the apparatus may determine, instead of whether or not the average color tone feature value obtained from each of the series of consecutive images exceeds a predetermined threshold, whether or nor the amount of variation in the average color tone feature value for two images exceeds a predetermined threshold. That is, the average color tone feature value for each image is compared with that for the preceding or succeeding image. If the difference between the two average color tone feature values exceeds a predetermined threshold, the apparatus may determine that, for example, the capsule endoscope 103 has moved from the esophagus into the EG junction or from the EG junction into the stomach. The apparatus determines whether or not the differential value (μi−μ(i−m1)) between the average color tone feature values μ(i−m1) and μi for the images F(i−m1) and Fi has varied by a predetermined threshold or more. m1 is 1, 2, 3, . . .

[0344] The color tone of the mucosa may vary owing to individual differences in mucosa color, the presence of a lesion such as the Barrett esophagus, or a variation among image pickup systems. The sixth variation thus makes it possible to determine whether or not, for example, the capsule endoscope 103 has passed through the EG junction without undergoing the adverse effect of the individual differences or the like.

[0345] Moreover, in this case, a variation in average color tone feature value may be detected by calculating the differential value of the average color tone feature values.

[0346] FIG. 35 is a flowchart showing an example of the flow in which a variation in average color tone feature value is detected by calculating the differential value of the average color tone feature values.

[0347] Image data on each image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. 35 is executed, as described in conjunction with the process shown in FIG. 32. The processing from step S201 to step S203 is the same as the processing from step S201 to step S203 shown in FIG. 32. That is, to start the process with the first frame, first, the frame number i is set at 1 (step S201). Then, image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus 7 (step S202). The average color tone feature value pi is calculated on the basis of the read image data on the image Fi (step S203).

[0348] The apparatus determines whether or not the process has been executed on all the images, that is, the process has been finished on all the images (step S**221**). If the process has not been finished on all the images, the determination in step S**221** is NO. Then, a process of changing i to i+1 is executed (step S**207**), and the process shifts to step S**202**.

[0349] When the process has been finished on all the images, the determination in step **221** is YES, and for obtained plural average color tone feature value μi, a moving average value f(μi) is calculated over a predetermined range, that is, over a predetermined number of consecutive images for smoothing (step S**222**). A differential value Δf(μi) is calculated on the basis of a temporal variation in the moving average value f(μi) (step S**223**).

[0350] The image Fi is identified and detected which corresponds to the differential value Δf(μi) exceeding a predetermined threshold thf (step S**224**). Steps S**3** to S**24** constitute a detection section that detects the boundary of the gastrointestinal tract.

[0351] This enables the detection of a plurality of images for which the amount of variation in color tone exceeds the threshold. Even with individual differences in mucosa color or the like, the apparatus can determine whether or not, for example, the capsule endoscope **103** has passed through the EG junction without undergoing the adverse effects of the individual differences or the like.

[0352] Moreover, as a seventh variation, a standard deviation or a variance may be used in place of the average value of color tone feature values.

[0353] For example, FIG. **36** is a graph illustrating a variation in the standard deviation or variance of the color tone feature value for a series of endoscopic images obtained. In FIG. **36**, the axis of abscissa indicates the image numbers (frame numbers), along the time series, of endoscopic images of the area extending from the esophagus squamous epithelium through the EG junction to the stomach. The axis of ordinate indicates the standard deviation σi or variance vi of the color tone feature value for the endoscopic image corresponding to each of the image numbers.

[0354] The color tone of the images picked up by the capsule endoscope **103** swallowed through the subject's mouth varies as shown in FIG. **33**. However, the calculated standard deviation or variance of the color tone feature value R/(R+G+B) varies as shown in FIG. **36**. That is, in each of the images of the squamous epithelium RA of the esophagus and the stomach portion RC of the columnar epithelium, the color tone is uniform, and the standard deviation σi or variance vi of the color tone feature value R/(R+G+B) is thus small. However, for the EG junction RB, located between the squamous epithelium RA of the esophagus and the stomach portion RC of the columnar epithelium, a greater standard deviation σi or variance vi is observed.

[0355] Consequently, on the basis of the standard deviation σi or variance vi of the color tone feature value for each image, the apparatus can determine whether or not, for example, the capsule endoscope **103** is passing through the EG junction.

[0356] Moreover, instead of the standard deviation σi or variance vi of the color tone feature value, a variation coefficient for the standard deviation σi or variance vi (=standard deviation σi/average color tone feature value μi) may be used.

[0357] Moreover, the above examples use the image data on all the pixels in each frame image. However, as an eighth variation, instead of processing all the pixels, only the pixels in predetermined regions of each frame may be sampled for processing as shown in FIG. **37**. FIG. **37** shows an example of regions in each frame image **131** which are to be subjected to the image processing in accordance with the above present embodiment and variations.

[0358] Each frame image **131** is divided into predetermined regions. In FIG. **37**, each image **131** is divided into **16** rectangular regions. The above processing is executed only on predetermined ones (R**2**, R**3**, R**5**, R**8**, R**9**, R**12**, R**14**, and R**15**) of the resulting regions, that is, only on the regions of interest (ROI). In particular, since the esophagus is a luminal organ, the regions other than the one corresponding to the center of the visual field may be set to be the regions of interest (ROI) in order to more accurately calculate the color tone of the mucosa surface.

[0359] Accordingly, processing only the regions of interest (ROI) reduces the amount of calculation required, enabling an increase in processing speed.

[0360] Moreover, when only the regions of interest (ROI) are processed, the processing speed may further be increased by, instead of processing all the frames, processing only the pixels in the regions of interest (ROI) in every k (k=1, 2, 3, . . .) frames. In particular, a large number of images are picked up for the interior of the esophagus. Consequently, accurate determinations may be made in spite of minor decimations.

[0361] As described above, the present embodiment (including the variations) makes it possible to determine, on the basis of the color tone feature value for each luminal image, whether or not the image shows that the capsule endoscope is about to enter the EG junction or is passing through the EG junction.

[0362] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect whether or not each image shows that the capsule endoscope is about to enter the EG junction or is passing through the EG junction. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Fifth Embodiment

[0363] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with a fifth embodiment. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **101** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus is similar to that in the fourth embodiment and will not be described below.

[0364] The above fourth embodiment uses the color tone feature value. The cardia detection apparatus, a luminal image processing apparatus in accordance with the present embodiment, is different from the fourth embodiment in that the apparatus uses brightness information on each image to determine whether or not, for example, the image shows that the capsule endoscope is passing through the EG junction.

[0365] FIG. **38** is a schematic graph illustrating a variation in brightness among a series of endoscopic images obtained, specifically a variation in luminance among the images. In FIG. **38**, the axis of abscissa indicates the image numbers (frame numbers), along the time series, of endoscopic images

of the area extending from the esophagus squamous epithelium through the EG junction to the stomach. The axis of ordinate indicates the luminance of the endoscopic image corresponding to each of the image numbers.

[0366] The luminance of images picked up by the capsule endoscope **103** swallowed through the subject's mouth indicates the brightness of the images. The luminance varies as shown in FIG. **38**. That is, the luminance varies between the squamous epithelium RA of the esophagus and the stomach portion RC of the columnar epithelium. Further, the luminance for the EG junction RB, located between the squamous epithelium RA and the stomach portion RC, is different from those for the squamous epithelium RA and the stomach portion RC. As shown in FIG. **38**, for example, with the luminance calculated on the basis of the three pixel values for R, G, and B, the esophagus squamous epithelium RA exhibits a large average luminance value except for a dark portion and a halation portion of the image because the esophagus squamous epithelium RA is a relatively narrow luminal organ and lies close to the mucosa wall. The stomach portion RC exhibits a relatively low luminance. The EG junction RB, located between the esophagus squamous epithelium RA and the stomach portion RC, exhibits a larger luminance value than the esophagus squamous epithelium RA because the closed cardia is viewed from the front in the esophagus, composed of a lumen.

[0367] Thus, when the brightness information on the image, varying gradually, exceeds a predetermined threshold Th1, the apparatus determines that, for example, the endoscope is passing through the EG junction or is about to enter the EG junction. That is, on the basis of a variation in the brightness information on the picked-up image, the closed cardia is detected when the capsule endoscope **103** is about to enter the EG junction or is passing through the EG junction. Specifically, an average luminance value or the like is used as the brightness information in order to allow the passage or the like to be reliably determined

[0368] Like FIG. **32**, FIG. **39** is a flowchart showing an example of the flow of a process of detecting the cardia when the EG junction is passed; the process is executed by the terminal apparatus **107** on the basis of a series of endoscopic images obtained. The process shown in FIG. **39** is substantially similar to that shown in FIG. **32**. A series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **39** is executed on each frame. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **39** is executed. In FIG. **39**, steps similar to those shown in FIG. **32** are denoted by the same step numbers, and the description of these steps is simplified. Further, in the description below, the luminance value is used as brightness information. The case in which the G or B pixel data value is used brightness information will not be described because this case differs from the one in which the luminance value is used as brightness information only in threshold data used and in that the determination depends on whether or not the value of the pixel data is smaller than the threshold.

[0369] First, to start processing with the first one of a series of images to be subjected to the process shown in FIG. **39**, the frame number i is set at 1 (step S**201**). Then, the image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **107** (step S**202**).

[0370] An average luminance value Ii is calculated from the read image data on the image Fi (step S**233**). The average luminance value Ii is the average of the luminance values of all the pixels contained in each image. In this case, the luminance value I is a feature value indicating the brightness of the image as described above. For example, the luminance I is calculated by 0.6R+0.3G+0.1B. Step S**233** constitutes a feature value calculation step or a feature value calculation section which calculates the average luminance value based on the luminance values of all the pixels in each image Fi.

[0371] Then, the apparatus determines whether or not the average luminance value Ii exceeds a predetermined threshold Th11 (step S**234**).

[0372] Adjusting the threshold Th11 makes it possible to determine whether or not the read image Fi was picked up in the vicinity of the inlet to the EG junction or in the central portion of the EG junction.

[0373] If the determination in step S**234** is YES, that is, when the average luminance value Ii exceeds the predetermined threshold Th11, the apparatus determines that the image Fi was picked up when the capsule endoscope **103** was about to enter the EG junction or was passing through the EG junction (step S**205**). Steps **234** and **205** constitute a boundary detection section that detects the boundary of the gastrointestinal tract on the basis of the calculated average luminance value Ii and a determination section that determines that the intraluminal image shows the area between the esophagus and the cardia on the basis of the detection result for the EG junction, corresponding to the boundary.

[0374] If the determination in step S**234** is NO, that is, when the average luminance value Ii does not exceed the predetermined threshold Th11, the apparatus determines whether or not the process shown in FIG. **39** has been finished on the series of images to be subjected to the process shown in FIG. **39** (step S**206**). When the process has been finished on all the images, the determination in step S**206** is NO. The process is thus ended. If the determination in step S**206** is NO, there remains an unprocessed image. Accordingly, a process of changing i to i+1 is executed (step S**207**), and the process from step S**202** to step S**234** is subsequently repeated. Steps S**233** to S**205** constitute a detection section that detects the boundary of the gastrointestinal tract.

[0375] Also in the present embodiment, in step S**205**, when the average luminance value Ii, brightness information, exceeds the threshold Th11, the image Fi was picked up when the capsule endoscope **103** was about to enter the EG junction or was passing through the EG junction. In other words, the apparatus may also determine that the capsule endoscope **103** will subsequently pass through the closed cardia or reach the interior of the stomach. This allows the cardia to be detected.

[0376] Now, description will be given of a specific example of the average luminance value Ii, described with reference to FIG. **39**.

[0377] FIG. **40** is a flowchart showing an example of the flow of the process in step S**233** which uses, as the average luminance value Ii, (0.6R+0.3G+0.1B) calculated from the three pixel values for R, G, and B executed on each frame image. The process shown in FIG. **40** calculates the average luminance value Ii by calculating the luminance value (0.6R+0.3G+0.1B) from three pixel values rj, gj, bj for R, G, and B for each of the pixels in each frame.

[0378] FIG. **40** includes process steps similar to those shown in FIG. **34**. A similar process is denoted by the same

step numbers and will not be described below. Reference character j denotes a number identifying a pixel in the image data on each frame.

[0379] First, j is set at 1, val**1** is set at 0, and count**1** is set at 0 (step S**241**). Here, val**1** denotes a variable required to determine the sum of brightness feature values, and count**1** denotes a variable required to determine the number of pixels used to calculate the average luminance value Ii.

[0380] Then, the apparatus determines in step S**212** whether or not the jth pixel belongs to the dark portion. If the jth pixel is determined to belong to the dark portion, the process proceeds to step S**216**. If the jth pixel is determined not to belong to the dark portion, the process proceeds to step S**213**.

[0381] Then, the apparatus determines in step S**213** whether or not the jth pixel is extremely bright, that is, the jth pixel belongs to a halation portion. If the jth pixel is determined to be a halation pixel, the process proceeds to step S**216**. If the jth pixel is determined not to be a halation pixel, the process proceeds to step S**244**.

[0382] In steps S**212** and S**213**, for the R image, G image, and B image, each of the thresholds thd and thh has the same value for rj, gj, and bj. However, for the biological mucosa, the R image generally tends to be brightest. Accordingly, the threshold may be set higher for rj than for gj and bj. Alternatively, the threshold may vary among rj, gj, and bj.

[0383] In step S**244**, val**1**=val**1**+(0.6rj+0.3gj+0.1bj) and count**1**=count**1**+1 are calculated. To determine the sum of the brightness feature values, the luminance feature value (0.6rj+0.3gj+0.1bj), which is a brightness feature value, is added to the variable val**1** and the variable count**1** is incremented by one.

[0384] In step S**215**, the apparatus determines whether or not the process from step S**212** to step S**244** has been executed on all the pixels. If the process from step S**212** to step S**244** has not been executed on all the pixels, then in step S**216**, 1 is added to the number j identifying the pixel (j=j+1) and steps S**212** to S**244** are executed on the next pixel. If the process from step S**212** to step S**244** has been executed on all the pixels, the apparatus determines whether or not count**1** is greater than the threshold the (step S**217**). If a sufficient number of pixels are present which are effective for brightness evaluation, the average luminance value Ii is calculated by dividing the variable val**1** by the variable countl (step **218**). Specifically, Ii=val**1**/count**1**.

[0385] If a sufficient number of pixels are not present which are effective for brightness evaluation, that frame image is considered to be an error, that is, an abnormal image (step S**219**). The average brightness value Ii is determined to be, for example, 0 (zero). In step S**234** in FIG. **39**, the apparatus determines that the average brightness value Ii does not exceed the threshold Th1.

[0386] In the above description, the cardia is closed. However, the present embodiment is also applicable to the open cardia. The cardia can be detected on the basis of whether or not the luminance exceeds the predetermined threshold.

[0387] Now, variations of the present embodiment will be described.

[0388] In FIGS. **39** and **40**, described above, the apparatus determines whether or not, for example, the capsule endoscope has passed through the EG junction or the cardia, on the basis of each frame image. However, as a first variation, the apparatus may determine that, for example, the capsule endoscope **103** has passed through the EG junction when the determination in step S**234** is Ii>Th11 for a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0389] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a second variation, the process shown in FIG. **39** may be executed on one particular image.

[0390] Moreover, as a third variation, the moving average of the average brightness value Ii for a plurality of consecutive images may be calculated so that the apparatus can determine whether or not, for example, the capsule endoscope **103** has passed through the EG junction, depending on whether or not the moving average value exceeds a predetermined threshold. For example, when m=2, 3, 4, . . . , and i>=m+1 (this means that m consecutive images are obtained from n images and that (m+1) is equal to or smaller than i), the moving average value is calculated on the basis of the average brightness value for images F(i−m) to Fi obtained from the m consecutive images. The apparatus then determines whether or not the moving average exceeds a predetermined threshold. Even with a very reddish intraesophageal image or the like possibly resulting from a variation in illumination conditions caused by a variation in observation distance, angle, or the like, the use of such a moving average makes it possible to eliminate the adverse effect of a slight variation in average brightness value to more accurately determine that, for example, the capsule endoscope **103** has passed through the EG junction.

[0391] Further, in the above example, the luminance calculated from the three pixel values for R, G, and B as described above is used as a brightness feature value. As a fourth variation, G or B pixel data may be used in place of the luminance.

[0392] FIG. **41** is a schematic graph illustrating a variation in G or B pixel data on a series of endoscopic images in the case in which G or B pixel data is used in place of the luminance calculated from the three pixel values for R, G, and B as described above. In FIG. **41**, the axis of abscissa indicates the image numbers (frame numbers), along the time series, of endoscopic images of the area extending from the esophagus squamous epithelium through the EG junction to the stomach. The axis of ordinate indicates the G or B pixel data value for the endoscopic image corresponding to each of the image numbers.

[0393] That is, as shown in FIG. **41**, the G or B pixel data value varies between the squamous epithelium RA of the esophagus and the stomach portion RC of the columnar epithelium. Further, the G or B pixel data value for the EG junction RB, located between the squamous epithelium RA and the stomach portion RC, is different from those for the squamous epithelium RA and the stomach portion RC. Specifically, in the EG junction RB, the G or B pixel data value decreases gradually from the squamous epithelium RA of the esophagus, which has a white color tone and thus a greater pixel data value, to the stomach portion RC of the columnar epithelium, which has a smaller pixel data value.

[0394] Accordingly, when the brightness information on the image, varying gradually, exhibits a value smaller than a predetermined threshold Th12, the apparatus determines that, for example, the capsule endoscope **103** is passing through the EG junction or is about to enter the EG junction. That is, on the basis of a variation in the brightness information on the picked-up image, the apparatus determines that, for example, the capsule endoscope **103** is passing through the EG junction. Specifically, to make a reliable determination for the

passage or the like, the average value of the G or B pixel data value is utilized as brightness information.

[0395] Moreover, as a fifth variation, a plural pieces of brightness information may be used. For example, in step S**233** in FIG. **39**, the luminance value and G pixel data for the pixel calculated from the three pixel values for R, G, and B are used to calculate the average values of these values, that is, the average brightness value I1*i* of all the pixels in each image and the average value I2*i* of the G pixel data. In step S**234**, the apparatus determines whether or not for the average brightness value I1*i* and the average value I2*i* for the G pixel data, I1*i*>Th13 and I2*i*<Th14.

[0396] Further, as a sixth variation, the passage of the capsule endoscope **103** through the EG junction or the like may be detected on the basis of the amount of variation in brightness information. That is, the apparatus may determine, instead of whether or not the brightness information obtained from each image of the series of consecutive images exceeds a predetermined threshold, whether or nor the amount of variation in the brightness information on two consecutive images exceeds a predetermined threshold. That is, for the brightness information on each image, the average luminance value for the image is compared with that for the preceding or succeeding image. If the difference between the two average luminance values exceeds a predetermined threshold, the apparatus may determine that, for example, the capsule endoscope **103** has moved from the esophagus into the EG junction or from the EG junction into the stomach. The apparatus determines whether or not the differential value (Ii−1(i−m1)) between the average luminance values I(i−m1) and Ii for the images F(i−m1) and Fi has varied by a predetermined threshold or more. m1 is 1, 2, 3, . . .

[0397] The color tone of the mucosa may vary owing to individual differences in mucosa color, the presence of a lesion such as the Barrett esophagus, or a variation among image pickup systems. The sixth variation thus makes it possible to determine whether or not, for example, the capsule endoscope **3** has passed through the EG junction without undergoing the adverse effect of the individual differences or the like.

[0398] Moreover, in this case, a variation in brightness information may be detected by calculating the differential value of the average luminance values.

[0399] FIG. **42** is a flowchart showing an example of the flow of a process of detecting a variation in brightness by calculating the differential value of the average luminance values. Steps similar to those shown in FIG. **35** are denoted by the same step numbers and the description of these steps is simplified.

[0400] As described above in conjunction with the process shown in FIG. **39**, the image data on each image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **42** is executed. The process from step S**201** to step S**233** is the same as that from step S**201** to step S**233** shown in FIG. **39**.

[0401] The apparatus determines whether or not the process has been executed on all the images, that is, the process has been finished on all the images (step S**221**). If the process has not been finished on all the images, the determination in step S**221** is NO. Then, a process of changing i to i+1 is executed (step S**207**), and the process shifts to step S**202**.

[0402] When the process has been finished on all the images, the determination in step **221** is YES, and a moving average value f(Ii) is calculated over a predetermined range, that is, over a predetermined number of consecutive images for smoothing (step S**252**). A differential value Δf(Ii) is calculated on the basis of a temporal variation in the moving average value f(Ii) (step S**253**).

[0403] The image Fi is identified and detected which corresponds to the differential value Δf(Ii) exceeding a predetermined threshold thf1 (step S**254**). Steps S**233** to S**254** constitute a detection section that detects the boundary of the gastrointestinal tract.

[0404] This enables the detection of a plurality of images for which the amount of variation in brightness exceeds the threshold. Even with individual differences in mucosa color or the like, the apparatus can determine whether or not, for example, the capsule endoscope **103** has passed through the EG junction without undergoing the adverse effects of the individual differences or the like.

[0405] Moreover, as a seventh variation, the closed cardia may be detected on the basis of the distribution of brightness. For example, instead of the average value for brightness information, the standard deviation or the variance may be used as is the case with the fourth embodiment. This makes it possible to determine whether or not, for example, the capsule endoscope **103** is passing through the EG junction on the basis of the standard deviation or variance of brightness information on a series of endoscopic images obtained. Specifically, the standard deviation of the brightness of R image data is determined If the standard deviation is smaller than a predetermined threshold, the apparatus determines that the closed cardia is being viewed from the front. This is because the brightness of the image is relatively uniform when the closed cardia is viewed from the front. Moreover, instead of the standard deviation or variance of the average luminance value, a variation coefficient for the standard deviation or variance (=standard deviation/average brightness value) may be used.

[0406] Moreover, the above examples use the pixel data on all the pixels in each frame image. However, as an eighth variation, instead of processing all the pixels, only the pixels in predetermined regions of each frame may be sampled for processing as described above with reference to FIG. **37** for the fourth embodiment. FIG. **37** shows an example of regions in each frame image which are to be subjected to the image processing in accordance with the above present embodiment and variations.

[0407] Each frame image is divided into predetermined regions. In FIG. **37**, each image is divided into 16 rectangular regions. The above process is executed only on preset ones (R**2**, R**3**, R**5**, R**8**, R**9**, R**12**, R**14**, and R**15**) of the resulting regions, that is, only on the regions of interest (ROI). In particular, since the esophagus is a luminal organ, the regions other than the one corresponding to the center of the visual field may be set to be the regions of interest (ROI) in order to more accurately calculate the color tone of the mucosa surface.

[0408] Accordingly, processing only the regions of interest (ROI) reduces the amount of calculation required, enabling an increase in processing speed.

[0409] Moreover, when only the regions of interest (ROI) are processed, the processing speed may further be increased by, instead of processing all the frames, processing only the pixels in the regions of interest (ROI) in every k (k=1, 2, 3, . . .) frames. In particular, a large number of images are picked up for the interior of the esophagus. Consequently, accurate determinations may be made in spite of minor decimations.

[0410] As described above, the present embodiment (including the variations) makes it possible to determine, on the basis of brightness information on each image, whether or not, for example, the image shows that the capsule endoscope is about to enter the EG junction or is passing through the EG junction.

[0411] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect whether or not each image shows that the capsule endoscope is about to enter the EG junction or is passing through the EG junction. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Sixth Embodiment

[0412] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with a sixth embodiment. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **101** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus is similar to that in the fourth embodiment and will not be described below.

[0413] The above fourth embodiment uses the color tone feature value. However, the cardia detection apparatus, a luminal image processing apparatus in accordance with the present embodiment, is characterized by detecting the open cardia to determine whether or not each image shows that, for example, the capsule endoscope moving from the esophagus toward the stomach is located near and in front of the cardia.

[0414] FIG. **43** is a diagram showing an example of an image in which the capsule endoscope **103** is located in front of the open cardia.

[0415] When the capsule endoscope **103** picks up an image of the open cardia in the lumen, the brightness of the open cardia is significantly lower than that of the surroundings. As shown in FIG. **43**, when the cardia **132** is open, in the image **131** picked up by the capsule endoscope **103**, the open cardia **132** appears to be a dark area. Accordingly, as the capsule endoscope **103** moves from the esophagus, through the EG junction, and closer to the cardia, the area of the cardia **132** in the image **131** increases. According to the present embodiment, when the area of the open cardia exceeds a predetermined size, the apparatus determines that the capsule endoscope **103** moving from the stomach side of the esophagus is passing through the cardia.

[0416] FIG. **44** is a flowchart showing an example of the flow of a process of detecting the open cardia on the basis of a series of endoscopic images obtained. The series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **44** is executed on each of the frames. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **44** is executed.

[0417] To start processing with the first frame of the series of images to be subjected to the process shown in FIG. **44**, first, the frame number i is set at 1 (step S**261**). Reference character i denotes an integer from 1 to n.

[0418] Then, R image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **7** (step S**262**). The image Fi comprises three planes for R, G, and B. In this case, only the R image data is read.

[0419] Although in this case, the R image data is read in order to make a cardia determination as described below, G image data or B image data on the image Fi may be used.

[0420] A dark portion pixel binarization is executed on all the pixels in the read R image data on the image Fi (step S**263**). Specifically, the pixel value of each pixel is compared with the predetermined threshold Th2 to execute a binarization such that dark portion pixels are set to have a value of 1, whereas the other pixels are set to have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value rj for each pixel is smaller than the threshold Th2 is checked to set 1 for pixels having a value smaller than the threshold Th2, while setting 0 (zero) for the other pixels.

[0421] Then, the ratio ϵ of the dark pixels to all the pixels is calculated (step S**264**). In other words, the ratio ϵ is the rate of the area of the dark portion in the image. Specifically, the ratio ϵ is calculated by dividing the number of pixels determined to be dark portion pixels by the binarization in step S**263**, by the total number of the pixels in the R image data. When the number of dark portion pixels is defined as **p1** and the size of the image Fi is defined as ISX×ISY, the ratio ϵ is **p1**/(ISX×ISY). Step S**264** constitutes a dark portion ratio calculation step or a dark portion ration calculation section which calculates the ratio of the dark portion pixels in each image Fi.

[0422] The ratio ϵ is compared with the predetermined threshold Thr to determine whether or not the ratio ϵ of the dark portion pixels exceeds the predetermined threshold Thr (step S**265**). The threshold Thr is, for example, 0.8.

[0423] If the determination in step S**265** is YES, that is, the dark portion accounts for more than 80% of the entire image, the image is determined to show the open cardia (step S**266**). The process is then ended.

[0424] If the determination in step S**265** is NO, that is, the dark portion accounts for at most 80% of the entire image, the image is determined not to show the cardia (step S**267**). The apparatus determines whether or not the process shown in FIG. **44** has been finished on all of the series of images to be subjected to the process shown in FIG. **44** (step S**268**). When the process has been finished on all the images, the determination in step S**268** is YES and the process is ended. If the determination in step S**268** is NO, there remains an unprocessed image. Thus, a process of changing i to i+1 is executed (step S**269**). Subsequently, steps S**262** to S**265** are repeatedly executed on the next image.

[0425] In step S**266**, when the ratio ϵ of the dark portion pixels exceeds the predetermined threshold Thr, the apparatus determines that the open cardia has been detected. In other words, the apparatus may also determine that the endoscope will subsequently pass through the cardia or reach the interior of the stomach. Steps S**263** to S**266** constitute a detection section that detects the boundary of the gastrointestinal tract.

[0426] Now, variations of the present embodiment will be described below.

[0427] In the above example, only the R image data is read in order to make a cardia determination. However, G or B image data or G and B image data may further be read, and a dark portion pixel binarization may be executed on the at least two image data. Then, when the ratios ϵ of the dark portion pixels in the at least two image data all exceed the predetermined threshold Thr, the apparatus may determine that the cardia has been detected.

[0428] In FIG. **44**, described above, the cardia is detected on the basis of each frame image. However, as a second

variation, the apparatus may determine that the cardia has been detected when the determination in step S**265** is ϵ>Thr for a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0429] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a third variation, the process shown in FIG. **44** may be executed on one image.

[0430] Moreover, as a fourth variation, a cardia determination may be made by, instead of calculating the ratio ϵ of the dark portion pixels to all the pixels, for example, calculating and dividing the total number of pixels in the non-dark portion, in the above example, pixels P**0** having a value of at least the threshold Th2, by the total number of pixels in the image to calculate the ratio ϵ**1** of the pixels in the non-dark portion, or calculating the ratio of the number p**0** of the non-dark portion pixels to the number p**1** of the dark potion pixels (p**0**/p**1**; p**1** is not 0 (zero)).

[0431] Further, as a fifth variation, the threshold Thr may be varied depending on the distance between the capsule endoscope **103** and the cardia observed when the cardia is detected. In other words, the threshold Thr may be varied depending on the distance between the capsule endoscope **3** and the cardia observed when the cardia is to be detected. For example, setting Thr at 0.5 enables the cardia to be detected more quickly than setting Thr at 0.8 as described above.

[0432] As described above, the present embodiment enables the cardia to be detected on the basis of the area of the dark portion in the image.

[0433] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect the open cardia. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Seventh Embodiment

[0434] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with a seventh embodiment. The present embodiment is characterized by detecting the open cardia on the basis of a shape. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **101** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus is similar to that in the fourth embodiment and will not be described below.

[0435] The cardia detection apparatus, a luminal image processing apparatus in accordance with the present embodiment, is characterized by detecting the shape of the open cardia to determine whether or not each image shows that, for example, the capsule endoscope moving from the esophagus toward the stomach is located near and in front of the cardia.

[0436] FIG. **45** is a diagram showing an example of an image picked up when the capsule endoscope **103** passes through the open cardia. An image **131**A contains the open cardia **132**A, corresponding to a dark image.

[0437] FIG. **46** is a flowchart showing an example of the flow in which the open cardia is detected on the basis of a series of endoscopic images obtained. The series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **46** is executed on each of the frames. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **46** is executed.

[0438] To start processing with the first frame of the series of images to be subjected to the process shown in FIG. **46**, first, the frame number i is set at 1 (step S**271**). Reference character i denotes an integer from 1 to n.

[0439] Then, R image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **7** (step S**272**). The image Fi comprises three planes for R, G, and B. In this case, only the R image data is read.

[0440] A bandpass filtering process is executed on the read R image data on the image Fi (step S**273**). The bandpass filtering is implemented by a convolution process using a well-known digital filter or on a Fourier surface.

[0441] The bandpass filter has, for example, such a property as shown in FIG. **47**. FIG. **47** is a diagram showing the filter property of a bandpass filtering process. The filter property is such that a large number of passing components are present in a slightly low frequency band in order to suppress the adverse effect of fine edge components such as vessels as shown in FIG. **47**. The filter property is such that, for example, within a spatial frequency band from 0 (zero) to π (rad), the passing property exhibits a peak value of (1.0) at π/4.

[0442] Then, a binarization is executed on edge components of an image resulting from the bandpass filtering process, using a threshold (step S**274**). The binarization sets a predetermined threshold Th3 at 10.0 and extracts an edge component exhibiting a variation of a value larger than the threshold Th3. Pixels with the edge component exhibiting a variation of a value larger than the threshold Th3 are set to have a value 1, whereas the other pixels are set to have a value of 1. The other pixels are set have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value for the edge component of each pixel exceeds the threshold Th3 is checked to set 1 for the pixels rj having a value larger than the threshold Th3, while setting 0 (zero) for the other pixels. As described above, an image containing the cardia exhibits a rapid variation in brightness. Accordingly, setting a higher threshold Th3 enables the exclusion of other edge components, for example, wrinkles resulting from the deformation of the mucosa.

[0443] Then, a cardia determination process is executed to determine whether or not the image with the extracted edge component results from the cardia to determine whether or not the image shows the cardia (step S**275**). The present embodiment determines whether or not the image shows the cardia by thinning the extracted edge component and using a coincidence with an approximate circle as an evaluation value to determine whether or not the edge component is shaped generally like a circle. Whether or not the edge component is shaped generally like a circle is determined by a Haff conversion or the like.

[0444] FIG. **48** is a diagram showing an example of an image showing the result of execution of a predetermined process of bandpass filtering and binarization on the image shown in FIG. **45**. As shown in FIG. **48**, the open cardia has a generally circular shape **132**B. Accordingly, the Haff conversion or the like is executed on the edge component image **131**B in FIG. **48** to determine whether or not the edge component **132**B is shaped like a circle.

[0445] If the image is determined to show the cardia on the basis of the result of the cardia determination process, the

determination in step S**275** is YES. The apparatus thus determines that the cardia has been detected (step S**276**). The process is then ended.

[0446] If the determination in step S**275** is NO, that is, the image does not show the cardia, then the apparatus determines that the target site is not the cardia (step S**277**). The apparatus then determines whether or not the process shown in FIG. **46** has been finished on all of the series of images to be subjected to the process shown in FIG. **46** (step S**278**). When the process has been finished on all the images, the determination in step S**278** is YES. The process is then ended. If the determination in step S**278** is NO, there remains an unprocessed image. Thus, a process of changing i to i+1 is executed (step S**279**). Subsequently, steps S**272** to S**274** are repeatedly executed on the next image. Steps S**273** to S**276** constitute a feature value calculation section and a detection section that detects the boundary of the gastrointestinal tract.

[0447] Now, variations of the present embodiment will be described below.

[0448] In the above example, only the R image data is read in order to make a cardia determination. However, G or B image data or G and B image data may further be read so that a dark portion pixel binarization can be executed on the at least two image data. Then, when the dark portion pixel is determined to have a circular shape in the at least two image data, the apparatus may determine that the cardia has been detected.

[0449] In FIG. **46**, described above, the cardia is detected on the basis of each frame image. However, as a second variation, the apparatus may determine that the cardia has been detected when the dark portion pixel is determined to have a circular shape in a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0450] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a third variation, the process shown in FIG. **46** may be executed on one image.

[0451] As described above, the present embodiment enables the cardia to be detected on the basis of the shape of the open cardia in the image.

[0452] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect the open cardia. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Eighth Embodiment

[0453] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with an eighth embodiment. The present embodiment is characterized by, in detecting the open cardia on the basis of the shape, utilizing both the detection of the dark portion region boundary and the edge detection, described in the seventh embodiment, to determine whether or not a picked-up image contains the open cardia. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **1** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus, a luminal image processing apparatus, is similar to that in the fourth embodiment and will not be described below.

[0454] FIG. **49** is a flowchart showing an example of the flow in which the cardia is detected on the basis of a series of endoscopic images obtained. The series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **49** is executed on each of the frames. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **49** is executed.

[0455] To start processing with the first frame of the series of images to be subjected to the process shown in FIG. **49**, first, the frame number i is set at 1 (step S**281**). Reference character i denotes an integer from 1 to n.

[0456] Then, R image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **7** (step S**282**). The image Fi comprises three planes for R, G, and B. In this case, only the R image data is read.

[0457] A dark portion pixel binarization is executed on all the pixels in the read R image data on the image Fi (step S**283**). Specifically, the pixel value of each pixel is compared with the predetermined threshold Th2 to execute a binarization such that dark portion pixels are set to have a value of 1, whereas the other pixels are set to have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value rj for each pixel is smaller than the threshold Th2 is checked to set 1 for pixels having a value smaller than the threshold Th2, while setting 0 (zero) for the other pixels.

[0458] Then, a boundary extraction process is executed to extract the boundary of the extracted dark portion, in other words, to extract the corresponding edge (step S**284**). The boundary extraction process involves, for example, using a pixel with a value of 1 (dark portion pixel) as a pixel of interest to set a mask region of size 3×3 around the pixel of interest, and if any of the eight pixels in the mask region has a value of 0 (zero), defining the pixel of interest as a boundary pixel having a value of 1. Step S**284** constitutes a dark portion boundary extraction step or a dark portion boundary extraction section which extracts the boundary of the dark portion pixel from each image Fi. The boundary extraction process is executed on all the dark portion pixels. FIG. **50** shows an image of an extracted boundary. Executing boundary extraction on an image **131**C shown in FIG. **50** results in a generally circular shape **132**C along the boundary of the open cardia.

[0459] Then, a bandpass filtering process is executed on the read R image data on the image Fi (step S**285**). The bandpass filtering is implemented by a convolution process using a well-known digital filter or on a Fourier surface as described in the seventh embodiment.

[0460] The bandpass filter has, for example, such a property as shown in FIG. **47**, described above. The filter property is such that a large number of passing components are present in a slightly low frequency band in order to suppress the adverse effect of fine edge components such as vessels.

[0461] Then, a binarization is executed on edge components of an image resulting from the bandpass filtering process, using a threshold (step S**286**). As described in the seventh embodiment, the binarization, for example, extracts an edge component exhibiting a variation of a value larger than the threshold Th3. Pixels with the edge component exhibiting a variation of a value larger than the threshold Th3 are set to have a value 1, whereas the other pixels are set to have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value for the edge component of each pixel exceeds the threshold Th3 is checked to set 1 for the pixels rj having a

value larger than the threshold Th3, while setting 0 (zero) for the other pixels. As described above, an image containing the cardia exhibits a rapid variation in brightness. Accordingly, setting a higher threshold Th3 enables the exclusion of other edge components, for example, wrinkles resulting from the deformation of the mucosa. An expansion process may be executed on the extracted pixel in order to suppress the adverse effect of the inaccurate detection of the dark portion boundary.

[0462] Then, a calculation is made of the coincidence between the boundary pixel extracted in step S**284** and the edge component extracted pixel extracted in step S**286** as an edge component (step S**287**). Specifically, the apparatus determines, for each extracted boundary pixel ek**1** (k**1**=1, 2, 3, . . . , K; reference character K denotes the total number of pixels detected as boundary pixels), whether or not a pixel with the same coordinates on the image has also been extracted as an edge component pixel. The number n1 of pixels which are boundary pixels ek1 and which have also been extracted as edge component pixels is counted. This is achieved by performing the logical AND of the boundary pixel ek1 and the edge component of the pixel with the same coordinates on the image. The ratio (n1/K) of the number n1 to the total number K of boundary pixels is calculated.

[0463] Then, the apparatus determines whether or not the image contains the cardia on the basis of the ratio (n1/K) indicating the coincidence between the boundary pixel and the edge component extracted pixel (step S**288**). FIG. **51** is a diagram showing an example of an image obtained by executing a predetermined process of bandpass filtering and binarization on the processing target image. The open cardia has a generally circular shape **32**B. However, FIG. **51** shows a break in a part of the circle. In this case, the ratio of the boundary of the dark portion region in FIG. **50** to the edge component in FIG. **51** is calculated to determine whether or not the image shows the cardia.

[0464] If the image is determined to show the cardia on the basis of the result of the cardia determination process, the determination in step S**288** is YES. The apparatus thus determines that the cardia has been detected (step S**289**). The process is then ended. Specifically, when the ratio (n1/K) exceeds a predetermined threshold the, the determination in step S**288** is YES. The apparatus thus determines that the cardia has been detected (step S**289**). The process is then ended.

[0465] If the determination in step S**288** is NO, that is, the ratio (n1/K) does not exceed the predetermined threshold the, then the apparatus determines that the target site is not the cardia (step S**290**). The apparatus then determines whether or not the process shown in FIG. **49** has been finished on all of the series of images to be subjected to the process shown in FIG. **49** (step S**291**). When the process has been finished on all the images, the determination in step S**291** is YES. The process is then ended. If the determination in step S**291** is NO, there remains an unprocessed image. Thus, a process of changing i to i+1 is executed (step S**292**). Subsequently, steps S**282** to S**288** are repeatedly executed on the next image. Steps S**283** to S**289** constitute a feature value calculation section and a detection section that detects the boundary of the gastrointestinal tract.

[0466] Now, variations of the present embodiment will be described below.

[0467] In the above example, only the R image data is read in order to make a cardia determination. However, G or B image data or G and B image data may further be read so that a dark portion pixel binarization can be executed on the at least two image data. Then, when the coincidence between the at least two image data exceeds the predetermined threshold, the apparatus may determine that the cardia has been detected.

[0468] In FIG. **49**, described above, the cardia is detected on the basis of each frame image. However, as a second variation, the apparatus may determine that the cardia has been detected when the coincidence exceeds the predetermined threshold in a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0469] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a third variation, the process shown in FIG. **49** may be executed on one image.

[0470] As described above, the present embodiment determines whether or not the area extracted as a dark portion has a large edge and can thus make an accurate cardia determination.

[0471] Further, the present embodiment can make an accurate cardia determination even if the cardia is not circularly open or if the long distance between the capsule endoscope **3** and the cardia results in a distant view of the cardia.

[0472] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect the open cardia. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Ninth Embodiment

[0473] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with a ninth embodiment. The present embodiment is characterized by, in detecting the open cardia on the basis of the shape, utilizing both the detection of the dark portion centroid and the edge detection, described in the seventh embodiment, to determine whether or not a picked-up image contains the open cardia. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **101** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus, a luminal image processing apparatus, is similar to that in the fourth embodiment and will not be described below.

[0474] Process steps similar to those in the eighth embodiment are denoted by similar step numbers and the description of these steps is simplified.

[0475] FIG. **52** is a flowchart showing an example of the flow in which the open cardia is detected on the basis of a series of endoscopic images obtained. In FIG. **52**, process steps similar to those in the eighth embodiment are denoted by similar step numbers and the description of these steps is simplified.

[0476] The series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **52** is executed on each of the frames. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **52** is executed.

[0477] To start processing with the first frame of the series of images to be subjected to the process shown in FIG. **52**, first, the frame number i is set at 1 (step S**281**). Reference character i denotes an integer from 1 to n.

[0478] Then, R image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **7** (step S**282**).

[0479] A dark portion pixel binarization is executed on all the pixels in the read R image data on the image Fi (step S**283**). Specifically, the pixel value of each pixel is compared with the predetermined threshold Th2 to execute a binarization such that dark portion pixels are set to have a value of 1, whereas the other pixels are set to have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value rj for each pixel is smaller than the threshold Th2 is checked to set 1 for pixels having a value smaller than the threshold Th2, while setting 0 (zero) for the other pixels.

[0480] Then, on the basis of coordinate data on the dark portion region detected by the binarization, the coordinates of the centroid of the dark portion region are calculated (step S**301**). Step S**301** constitutes a dark portion region centroid coordinate calculation step or a dark portion region centroid coordinate calculation section which calculates the coordinates of the centroid of the dark portion region in the image Fi. FIG. **53** shows the centroid position calculated by the dark portion region centroid coordinate calculation section. In an image **131**E in FIG. **53**, the centroid **132**Ec of the dark portion region **132**E of the generally circular open cardia is shown at the position of the calculated centroid coordinates.

[0481] Then, a bandpass filtering process is executed on the read R image data on the image Fi as described in the eighth embodiment (step S**285**). Moreover, an edge component binarization is executed on the image resulting from the bandpass filtering process, using a threshold (step S**286**).

[0482] In step S**286**, circumferential character is evaluated by determining whether or not the pixel of an edge component extracted in step S**286** lies so as to surround the dark portion region (step S**307**). Specifically, as shown in FIG. **54**, the apparatus determines whether or not the extracted edge component pixel is penetrated in predetermined radial directions from the calculated centroid coordinates **132**Ec. FIG. **54** is intended to describe the evaluation of the circumferential character. In the example shown in FIG. **54**, the number m2 of those of a plurality of radial lines **132**Ed extending from the centroid coordinates **132**Ec which cross the edge component pixel (this number is hereinafter referred to as the intersection count) is counted. Then, the lines **132**Ed cross or penetrate the edge component in seven of the eight directions. Consequently, the intersection count m2 is 7.

[0483] Then, the apparatus determines whether or not the image contains the cardia on the basis of the intersection count m2 (step **288**). As shown in FIG. **54**, even with a break in a part of the circle formed by the edge component pixel, the apparatus determines the image to contain the cardia when the ratio (m2/m3) of the intersection count m2 to the number m3 of the plurality of lines **132**Ed exceeds a predetermined threshold Thm In other words, whether or not the image shows the cardia is determined on the basis of the ratio (m2/m3) of those of the plurality of lines extending radially from the centroid position of the dark portion region in FIG. **53** which cross the edge component pixel in FIG. **54**.

[0484] If the ratio of the intersection count m2 to the number m3 of the plurality of segments **132**Ed exceeds the threshold Thm, the determination in step S**288** is YES. The apparatus thus determines that the cardia has been detected (step S**289**). The process is then ended. Specifically, when the ratio (m2/m3), indicating an evaluative value for the circumferential character, exceeds the predetermined threshold thm, for example, 0.7, the determination in step S**88** is YES. The apparatus thus determines that the cardia has been detected (step S**289**). The process is then ended.

[0485] If the determination in step S**288** is NO, that is, the ratio (m2/m3) does not exceed the predetermined threshold thm, then the apparatus determines that the target site is not the cardia (step S**290**). The apparatus then determines whether or not the process shown in FIG. **52** has been finished on all of the series of images to be subjected to the process shown in FIG. **52** (step S**291**). When the process has been finished on all the images, the determination in step S**291** is YES. The process is then ended. If the determination in step S**291** is NO, there remains an unprocessed image. Thus, a process of changing i to i+1 is executed (step S**292**). Subsequently, steps S**282** to S**288** in FIG. **52** are repeatedly executed on the next image. Steps S**283** to S**289** constitute a feature value calculation section and a detection section that detects the boundary of the gastrointestinal tract.

[0486] Now, variations of the present embodiment will be described below.

[0487] In the above example, only the R image data is read in order to make a cardia determination. However, G or B image data or G and B image data may further be read so that a dark portion pixel binarization can be executed on the at least two image data. Then, when the evaluative value for the circumferential character exceeds the predetermined threshold for the at least two image data, the apparatus may determine that the cardia has been detected.

[0488] In FIG. **52**, described above, the cardia is detected on the basis of each frame image. However, as a second variation, the apparatus may determine that the cardia has been detected when the evaluative value for the circumferential character exceeds the predetermined threshold for a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0489] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a third variation, the process shown in FIG. **52** may be executed on one image.

[0490] As a fourth variation, the circumferential character may be evaluated on the basis of the number or ratio of those of a plurality of predetermined regions in which the edge component image is present. FIG. **55** is a diagram illustrating that the evaluation of the circumferential character in accordance with the fourth variation is based on the ratio of regions. For example, as shown in FIG. **55**, the image is divided into, for example, eight regions around the centroid **132**Ec, the regions spanning between 0° and 45°, between 45° and 90°, between 90° and 135°, between 135° and 180°, between 180° and 225°, between 225° and 270°, between 270° and 315°, and between 315° and 360°. The apparatus then determines whether or not each of the regions contains the edge component pixel obtained in step S**286**. When the number of regions containing the edge component pixel **132**G is at least the predetermined threshold, the apparatus may determine that the cardia has been detected. FIG. **56** shows that the edge component pixel is present in 6 shaded regions. If the threshold is 6, the apparatus determines, in the case of FIG. **55**, that the cardia has been detected.

[0491] Moreover, the apparatus may determine that the cardia has been detected on the basis of the angular range in which the edge component pixel is present, instead of the number of regions. For example, as shown in FIG. **56**, the angular range θ around the centroid **132**Ec in which the edge component pixel is present is determined. The apparatus may determine that the cardia has been detected on the basis of whether or not the angular range θ is equal to at least the predetermined threshold, for example, at least 270°. FIG. **56**

is a diagram illustrating that the circumferential character is evaluated on the basis of the angular range. If a plurality of edge component pixel lines are present, the apparatus may determine whether or not the cardia has been detected by comparing the edge component pixel in the greatest angular range with the predetermined threshold.

[0492] As described above, although the dark portion region binarization may undergo a variation in the position of the boundary depending on the threshold Th2, the present embodiment can make an accurate cardia determination without suffering from the adverse effect of a possible variation in boundary position.

[0493] Further, the present embodiment can make an accurate cardia determination even if the cardia is not circularly open or if the long distance between the capsule endoscope **103** and the cardia results in a distant view of the cardia.

[0494] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect the open cardia. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Tenth Embodiment

[0495] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with a tenth embodiment. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **101** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus, a luminal image processing apparatus, is similar to that in the fourth embodiment and will not be described below.

[0496] In the above sixth to ninth embodiments, the open cardia is detected. However, the cardia may be closed. The cardia detection apparatus in accordance with the present embodiment is characterized by detecting the closed cardia to determine whether or not each image shows that, for example, the capsule endoscope moving from the esophagus toward the stomach is located near and in front of the cardia.

[0497] FIG. **57** is a diagram showing an example of an image in which the capsule endoscope **103** is located in front of the cardia.

[0498] When the capsule endoscope **103** picks up an image of the closed cardia in the lumen, the picked-up image contains no definite dark portion region owing to the closed cardia. Moreover, the brightness in the screen is relatively uniform because the periphery of the cardia is viewed from the front at the terminal of the esophagus. The present embodiment determines that the closed cardia has been detected when the area of the closed cardia is smaller than a predetermined size.

[0499] FIG. **58** is a flowchart showing an example of the flow in which the closed cardia is detected on the basis of a series of endoscopic images obtained. The series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **58** is executed on each of the frames. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **58** is executed. The process shown in FIG. **58** includes process steps similar to those of the process shown in FIG. **44**. Accordingly, process steps similar to those shown in FIG. **44** are denoted by similar step numbers and the description of these steps is simplified.

[0500] To start processing with the first frame of the series of images to be subjected to the process shown in FIG. **58**, first, the frame number i is set at 1 (step **S261**). Reference character i denotes an integer from 1 to n.

[0501] Then, R image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **7** (step **S262**). The image Fi comprises three planes for R, G, and B. In this case, only the R image data is read.

[0502] Although in this case, the R image data is read in order to make a cardia determination described below, G or B image data on the image Fi may be used.

[0503] A dark portion pixel binarization is executed on all the pixels in the read R image data on the image Fi (step **S263**). Specifically, the pixel value of each pixel is compared with the predetermined threshold Th2 to execute a binarization such that dark portion pixels are set to have a value of 1, whereas the other pixels are set to have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value rj for each pixel is smaller than the threshold Th2 is checked to set 1 for pixels having a value smaller than the threshold Th2, while setting 0 (zero) for the other pixels.

[0504] Then, a labeling process is executed to label a plurality of regions of the dark portion pixel, and a dark portion region with the largest area D is then identified (step **S314**). Step **S314** constitutes a largest dark portion region identification step or a largest dark portion region identification section which identifies the dark portion region with the largest area D in each image Fi. FIG. **57** shows an image **1321** containing a dark portion region **1321** with the largest area D.

[0505] The apparatus then determines whether or not the largest area D is smaller than a predetermined threshold Thd1 (step **S315**). The threshold Thd1 is, for example, 0.1.

[0506] If the determination in step **S315** is YES, that is, the dark portion accounts for less than 10% of the entire image, the apparatus determines that the cardia has been detected (step **266**). The process is then ended.

[0507] If the determination in step **S315** is NO, that is, the dark portion does not account for less than 10% of the entire image, the apparatus determines that the image does not show the cardia (step **267**). The apparatus then determines whether or not the process shown in FIG. **58** has been finished on all of the series of images to be subjected to the process shown in FIG. **58** (step **S268**). When the process has been finished on all the images, the determination in step **S268** is YES. The process is then ended. If the determination in step **S268** is NO, there remains an unprocessed image. Thus, a process of changing i to i+1 is executed (step **S269**). Subsequently, steps **S262** to **S264** are repeatedly executed on the next image.

[0508] In step **S266**, the apparatus determines that the cardia has been detected when the area D of the largest dark portion region is smaller than the predetermined threshold Thd1. In other words, the apparatus may also determine that the capsule endoscope will subsequently pass through the cardia or reach the interior of the stomach. Steps **S263** to **S266** constitute a feature value calculation section and a detection section that detects the boundary of the gastrointestinal tract.

[0509] Now, variations of the present embodiment will be described below.

[0510] In the above example, only the R image data is read in order to make a cardia determination. However, G or B image data or G and B image data may further be read so that a dark portion pixel binarization can be executed on the at

least two image data. Then, when the areas D of the dark portion regions with the largest area in the at least two image data are all smaller than the predetermined threshold Thd1, the apparatus may determine that the cardia has been detected.

[0511] In FIG. **58**, described above, the cardia is detected on the basis of each frame image. However, as a second variation, the apparatus may determine that the cardia has been detected when the determination in step S**315** is D<Thd1 for a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0512] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a third variation, the process shown in FIG. **58** may be executed on one image.

[0513] As a fourth variation, a region of interest (ROI) of such a predetermined size as shown by a dotted line in FIG. **57** may be set around the above dark portion region with the largest area. The standard deviation, variance, or variation coefficient of the brightness in the region of interest (ROI) may then be calculated so that the apparatus can determine that the closed cardia has been detected on the basis of whether or not the value of the standard deviation or the like is smaller than a predetermined threshold.

[0514] As described above, the present embodiment allows the closed cardia to be detected on the basis of the area of the dark portion in the image.

[0515] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect the closed cardia. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

Eleventh Embodiment

[0516] Now, with reference to the drawings, description will be given of a cardia detection apparatus utilizing a capsule endoscope apparatus and a method for the cardia detection in accordance with an eleventh embodiment. Endoscopic images to be processed in accordance with the present embodiment are a series of endoscopic images picked up by the capsule endoscope apparatus **101** as in the case of the fourth embodiment. Accordingly, the configuration of the cardia detection apparatus is similar to that in the fourth embodiment and will not be described below.

[0517] The cardia detection apparatus, a luminal image processing apparatus in accordance with the present embodiment, is characterized by detecting the closed cardia to determine whether or not each image shows that, for example, the capsule endoscope moving from the esophagus toward the stomach is located near and in front of the cardia.

[0518] FIG. **59** is a flowchart showing an example of the flow in which the closed cardia is detected on the basis of a series of endoscopic images obtained. The series of endoscopic images picked up by the endoscope swallowed through the subject's mouth comprise a plurality of frames. The process shown in FIG. **59** is executed on each of the frames. The image data on each endoscopic image is subjected to a preprocess such as inverse gamma correction or noise removal before the process shown in FIG. **59** is executed.

[0519] To start processing with the first frame of the series of images to be subjected to the process shown in FIG. **59**, first, the frame number i is set at 1 (step S**321**). Reference character i denotes an integer from 1 to n.

[0520] Then, R image data on the image Fi with the frame number i is read from the storage device (not shown) in the terminal apparatus **7** (step S**322**). The image Fi comprises three planes for R, G, and B. In this case, only the R image data is read.

[0521] Although in this case, the R image data is read in order to make a cardia determination described below, G or B image data on the image Fi may be used.

[0522] A dark portion pixel binarization is executed on all the pixels in the read R image data on the image Fi (step S**323**). Specifically, the pixel value of each pixel is compared with the predetermined threshold Th2 to execute a binarization such that dark portion pixels are set to have a value of 1, whereas the other pixels are set to have a value of 0 (zero). Reference character j denotes a number identifying a pixel in the image data on each frame. Then, whether or not the value rj for each pixel is smaller than the threshold Th2 is checked to set 1 for pixels having a value smaller than the threshold Th2, while setting 0 (zero) for the other pixels.

[0523] Then, a thinning process is executed on the binarized image (step S**324**). FIG. **60** shows an image **131**J containing a cardia shape **132**J obtained by thinning the image of the closed cardia. FIG. **60** is a diagram illustrating the cardia shape obtained by thinning the image of the closed cardia. Branching or intersecting points (hereinafter referred to as branching points) are calculated for each of the lines resulting from the thinning operation (step **325**). Coordinate data on the branching points is stored in the storage device as data indicating the concentration level.

[0524] Then, the concentration level of the calculated branching points is calculated (step S**326**). Step **326** constitutes a concentration level calculation step or a concentration level calculation section which calculates the concentration level of the branching points in each image Fi. For the concentration level, the variance of the coordinate values of the branching points is used as a parameter.

[0525] FIG. **61** is a flowchart showing an example of the flow of a process of calculating the variance value, which is a parameter for the concentration level. First, coordinate data on the calculated branching points is acquired from the storage device (step S**341**). For example, when N branching points have been calculated, the variance vx of the x coordinate of each of the N branching points and the variance vy of the y coordinate of the branching point are calculated (step S**342**). The variances vx, vy are stored for each of the N branching points.

[0526] Referring back to FIG. **59**, the apparatus determines whether or not the concentration level is high depending on whether or not the variances vx, vy, which are data indicating the concentration level, are less than thresholds thv1, thv2 (step S**327**).

[0527] If the determination in step S**327** is YES, that is, the variances vx, vy are less than thresholds thv1, thv2, respectively, the apparatus determines that the cardia has been detected (step S**328**). The process is then ended.

[0528] If the determination in step S**327** is NO, that is, the variances vx, vy are not less than thresholds thv1, thv2, respectively, the apparatus determines that the image does not show the cardia (step S**329**). The apparatus then determines whether or not the process shown in FIG. **59** has been finished on all of the series of images to be subjected to the process shown in FIG. **59** (step S**330**). When the process has been finished on all the images, the determination in step S**330** is YES. The process is then ended. If the determination in step S**330** is NO, there remains an unprocessed image. Thus, a process of changing i to i+1 is executed (step S**331**). Subsequently, steps S**322** to S**327** are repeatedly executed on the

next image. Steps S323 to S328 constitute a feature value calculation section and a detection section that detects the boundary of the gastrointestinal tract.

[0529] FIG. 62 is a diagram showing an example of an image illustrating branching points. In FIG. 62, for the closed cardia, branching points 133J on a line in the image 131J concentrate in a part of the image 131J. The level of the concentration is digitized on the basis of the above variance to determine, for example, a variance value as described above. The level, for example, the variance value is compared with a predetermined threshold to determine whether or not the closed cardia has been detected. The branching points concentrate in one part when the closed cardia is thinned Accordingly, the apparatus determines that the cardia has been detected when the branching points are found to concentrate in one part.

[0530] In step S328, the apparatus determines that the closed cardia has been detected when the variance value is smaller than the predetermined threshold. In other words, the apparatus may also determine that the capsule endoscope 103 will subsequently pass through the cardia or reach the interior of the stomach.

[0531] Now, variations of the present embodiment will be described below.

[0532] In the above example, only the R image data is read in order to make a cardia determination. However, G or B image data or G and B image data may further be read so that the concentration level can be calculated for the at least two image data. Then, the apparatus may determine that the cardia has been detected on the basis of the concentration levels for the at least two image data.

[0533] In FIG. 59, described above, the cardia is detected on the basis of each frame image. However, as a second variation, the apparatus may determine that the closed cardia has been detected when the determination in step S327 is YES for a plurality of consecutive images or at least a predetermined rate (for example, 80%) of the plurality of consecutive images.

[0534] Further, in the above description, the process is executed on the plurality of consecutive images. However, as a third variation, the process shown in FIG. 29 may be executed on one image.

[0535] In accordance with the present embodiment, the threshold process is applied to the calculated feature value to detect the closed cardia. However, for example, an identification function such as a well-known linear discrimination function may be used for the detection. Alternatively, a feature value in accordance with another embodiment may be combined with the present embodiment.

[0536] The plurality of embodiments described above each make it possible to detect when, for example, the endoscope has passed through the EG junction or is about to reach the cardia, on the basis of one endoscopic image or a series of consecutive endoscopic images. This enables images required for diagnosing the esophageal disease to be selected from a large number of picked-up endoscopic images, allowing the esophageal disease to be quickly diagnosed.

[0537] Therefore, the plurality of embodiments described above can provide a luminal image processing apparatus that can detect the cardia.

[0538] For example, a determination for the Barrett esophagus is made on the basis of an image of the vicinity of the EG junction. Thus, the ability to detect the cardia as described above enables the disease to be carefully diagnosed while viewing only that image or only the image preceding or succeeding that image. This allows the diagnosis to be quickly achieved.

[0539] Description has been given of the example of the process using images picked up by the capsule endoscope 3. However, of course, the above process may be executed on images picked up by a normal endoscope, that is, an endoscope having an elongate, flexible insertion portion. Both the capsule endoscope and the normal endoscope can provide intraluminal images.

[0540] Moreover, the cardia can be detected by each of the techniques in accordance with the plurality of embodiments described above (including the variations). However, the cardia may be detected by a combination of a plurality of the techniques.

[0541] The above fourth to eleventh embodiments and variations thereof can provide a luminal image processing apparatus that can detect the cardia on the basis of intraluminal images.

INDUSTRIAL APPLICABILITY

[0542] To make a determination for the Barrett esophagus condition or the like on the basis of a large amount of endoscopic image data obtained by picking up images of the interior of the esophagus, a process of detecting a first feature such as the EG junction or the epithelium boundary which is located around the target site is repeated with a frame number sequentially changed until the presence of the feature is determined For images succeeding the image determined to contain the first feature, the process shifts to detection of a second feature such as the Barrett esophagus which corresponds to a determination target. This process is more efficient than a process of detecting the second feature and then making a determination therefor without detecting the first feature.

1. A luminal image processing apparatus comprising:
a feature value calculating section that calculates a predetermined feature value by executing image processing on one or a plurality of intraluminal images obtained by picking up an image of the gastrointestinal tract; and
a boundary detection section that detects a boundary of the gastrointestinal tract on the basis of the calculated feature value.

2. The luminal image processing apparatus according to claim 1, further comprising a determination section that determines that the intraluminal image shows a part extending from the esophagus to the cardia, on the basis of a detection result obtained by the boundary detection portion.

3. The luminal image processing apparatus according to claim 1, wherein the predetermined feature value is a color tone of the one or plurality of intraluminal images.

4. The luminal image processing apparatus according to claim 1, wherein the predetermined feature value is a brightness of the one or plurality of intraluminal images.

5. The luminal image processing apparatus according to claim 1, wherein the boundary is the EG junction.

6. The luminal image processing apparatus according to claim 1, wherein the feature value calculation section calculates the feature value for pixels in the one or plurality of intraluminal images other than dark portion pixels and halation pixels.

7. The luminal image processing apparatus according to claim 1, wherein if the predetermined feature value is calculated from the plurality of intraluminal images, the determination section determines that the image shows the boundary when a differential value of moving average of the calculated predetermined feature values is at least a predetermined threshold.

8. The luminal image processing apparatus according to claim **1**, wherein the feature value calculation section executes image processing on pixels in a predetermined region in each of the one or plurality of intraluminal images to calculate the predetermined feature value.

9. The luminal image processing apparatus according to claim **1**, wherein the predetermined feature value is an area of a dark portion region or a non-dark portion region in the one or plurality of intraluminal images.

10. The luminal image processing apparatus according to claim **9**, wherein

the boundary is the open cardia, and

the boundary detection section detects the boundary by comparing the area with a predetermined threshold.

11. The luminal image processing apparatus according to claim **1**, wherein the predetermined feature value is a shape of the dark portion region in the one or plurality of intraluminal images.

12. The luminal image processing apparatus according to claim **11**, wherein the boundary detection section detects the boundary depending on whether or not the shape is a circle.

13. The luminal image processing apparatus according to claim **11**, wherein

the shape of the dark portion region includes a shape of a boundary of the dark portion region and an edge portion, and

the boundary detection section detects the boundary by comparing a coincidence between the boundary and the edge portion with a predetermined threshold.

14. The luminal image processing apparatus according to claim **11**, wherein

the shape of the dark portion region includes the edge portion of the dark portion region, and

the boundary detection section detects the boundary by comparing a rate at which the edge portion is present around a predetermined point in the dark portion region, with a predetermined threshold.

15. The luminal image processing apparatus according to claim **14**, wherein the boundary detection section determines the rate on the basis of whether or not the edge portion is present in a plurality of predetermined areas in each of the one or plurality of intraluminal images.

16. The luminal image processing apparatus according to claim **14**, wherein the boundary detection section determines the rate on the basis of an angular range in which the edge portion is present around a predetermined point in the dark potion region.

17. The luminal image processing apparatus according to claim **1**, wherein the predetermined feature value is an area of the dark portion region in the one or plurality of intraluminal images.

18. The luminal image processing apparatus according to claim **9**, wherein

the boundary is the closed cardia, and

the boundary detection section detects the boundary by comparing the area with a predetermined threshold.

19. The luminal image processing apparatus according to claim **18**, wherein the boundary detection section detects the boundary by executing a labeling process to label a plurality of regions of a dark portion pixel in each of the one or plurality of intraluminal images and determining whether or not an area of one of the labeled plurality of regions which has the largest area is smaller than the predetermined threshold.

20. The luminal image processing apparatus according to claim **1**, wherein the boundary detection section detects the boundary by executing a thinning process on the dark portion pixel in each of the one or plurality of intraluminal images, calculating branching or intersecting points on each segment obtained by the thinning process, and executing the detection on the basis of a concentration level of the branching or intersecting points in each of the images.

21. The luminal image processing apparatus according to claim **20**, wherein

the boundary is the closed cardia, and

the boundary detection section detects the boundary by comparing the concentration level with a predetermined threshold.

22. A luminal image processing method comprising:

a step of calculating a predetermined feature value by executing image processing on one or a plurality of intraluminal images obtained by picking up an image of the gastrointestinal tract; and

a step of detecting a boundary of the gastrointestinal tract on the basis of the calculated feature value.

23. A program embodied on non-transitory computer-readable medium allowing a computer to execute:

a function of calculating a predetermined feature value from one or a plurality of intraluminal images obtained by picking up an image of the gastrointestinal tract; and

a function of detecting a boundary of the gastrointestinal tract on the basis of the calculated feature value.

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