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Image processing method and image processing apparatus

Abstract

An object of the present invention is to determine the cause of an image defect that occurs in an image forming device with high accuracy while suppressing the amount of calculation at a processor. A processor (**80**) determines the cause of an image defect on the basis of a test image read from an output sheet of an image forming device (**2**). The processor (**80**) generates a plurality of feature images by executing a feature extraction process on the test image. Further, the processor (**80**) uses each of the plurality of feature images as an input image and determines which of a plurality of cause candidates corresponding to the image defect the input image corresponds to by pattern recognition of the input image.

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Background/Summary

FIELD
(1) The present invention relates to an image processing method and an image processing apparatus for determining a cause of an image defect based on a test image.
BACKGROUND
(2) An image forming apparatus such as a printer or a multifunction peripheral executes a print process of forming an image on a sheet. In the print process, an image defect such as a horizontal

streak, a noise point, or density unevenness may occur in an image formed on an output sheet.

(3) For example, when the image forming apparatus is an apparatus that executes the print process by an electrophotographic method, various portions such as a photoconductor, a charging portion, a developing portion, and a transferring portion can be considered as the cause of the image defect. Skill is required to determine the cause of the image defect.

(4) It is also known that, in an image processing apparatus, a phenomenon causing a vertical streak, which is an example of the image defect, and feature information such as the color, density, or number of screen lines of the vertical streak are associated in advance as table data, and the phenomenon causing the vertical streak is identified based on information on the color, density, or number of screen lines of an image of the vertical streak in a test image and the table data (see, for example, Patent Literature 1).

(5) The table data is data in which the ranges of parameters such as the color, density, or number of screen lines of the image is set by threshold values for each type of phenomenon that causes the vertical streak.

CITATION LIST

Patent Literature

(6) Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2017-83544

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

(7) When the cause of the image defect is determined by comparing the value of a specific image parameter, such as the color, density, or number of screen lines of an image, with a predetermined threshold value, omission of determination or erroneous determination is likely to occur.

(8) On the other hand, an image pattern recognition process is suitable for classifying an input image into many events with high accuracy. For example, the pattern recognition process is a process of using a trained model trained using sample images corresponding to a plurality of event candidates as training data to determine which of the event candidates the input image corresponds to.

(9) However, the amount of information of an image is large, and there are a plurality of types of image defects, such as a horizontal streak, a vertical streak, a noise point, and density unevenness. Furthermore, there are many possible cause candidates for each type of the image defect.

(10) Accordingly, when a test image including the image defect is used as an input image for the pattern recognition process, the amount of calculation for the pattern recognition process becomes very large. Thus, it is difficult to execute the pattern recognition process with a processor provided in a multifunction peripheral or the like.

(11) In addition, in order to increase the accuracy of determining the cause of the image defect, an enormous amount of the training data is required for training the trained model. However, it takes a great deal of time and effort to prepare an enormous number of test images corresponding to combinations of possible types of the image defects and possible causes of the image defects for each model of image forming device.

(12) An object of the present invention is to provide an image processing method and an image processing apparatus capable of determining the cause of an image defect that occurs in an image forming device with high accuracy while suppressing the amount of calculation at a processor.

Solution to Problem

(13) An image processing method according to one aspect of the present invention is a method in which a processor determines a cause of an image defect based on a test image read from an output sheet of an image forming device. The image processing method includes generating, by the processor, a plurality of feature images by executing a predetermined feature extraction process on the test image. Furthermore, the image processing method includes executing, by the processor, a feature pattern recognition process of using each of the plurality of feature images as an input image and determining which of a plurality of predetermined cause candidates corresponding to the

image defect the input image corresponds to by pattern recognition of the input image.

(14) An image processing apparatus according to another aspect of the present invention includes a processor for executing the processes of the image processing method.

Advantageous Effects of Invention

(15) According to the present invention, it is possible to provide an image processing method and an image processing apparatus capable of determining the cause of an image defect that occurs in an image forming device with high accuracy while suppressing the amount of calculation at a processor.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a configuration diagram of an image processing apparatus according to an embodiment.

(2) FIG. **2** is a block diagram showing a configuration of a data processing portion in the image processing apparatus according to the embodiment.

(3) FIG. **3** is a flowchart showing an example of the procedure of an image defect determination process in the image processing apparatus according to the embodiment.

(4) FIG. **4** is a flowchart showing an example of the procedure of a singular defect determination process in the image processing apparatus according to the embodiment.

(5) FIG. **5** is a flowchart showing an example of the procedure of a density unevenness determination process in the image processing apparatus according to the embodiment.

(6) FIG. **6** is a diagram showing an example of a test image including a singular part and examples of a preprocessed image and a feature image generated based on the test image.

(7) FIG. **7** is a diagram showing examples of an area of interest, which is sequentially selected from the test image in a main filter process by the image processing apparatus according to the embodiment, and adjacent areas.

(8) FIG. **8** is a diagram showing an example of a test image including periodic density unevenness and vertical waveform data derived based on the test image.

(9) FIG. **9** is a flowchart showing an example of the procedure of a feature image generation process in a first application example of the image processing apparatus according to the embodiment.

(10) FIG. **10** is a flowchart showing an example of the procedure of a feature image generation process in a second application example of the image processing apparatus according to the embodiment.

(11) FIG. **11** is a flowchart showing an example of the procedure of a feature image generation process in a third application example of the image processing apparatus according to the embodiment.

(12) FIG. **12** is a flowchart showing an example of the procedure of a feature image generation process in a fourth application example of the image processing apparatus according to the embodiment.

DETAILED DESCRIPTION

(13) An embodiment of the present invention will be described below with reference to the drawings. It is noted that the following embodiment is an example of embodying the present invention and does not limit the technical scope of the present invention.

(14) [Configuration of Image Processing Apparatus **10**]

(15) An image processing apparatus **10** according to the embodiment includes an image forming device **2** that executes a print process. The print process is a process of forming an image on a sheet. The sheet is an image forming medium such as paper or a sheet-like resin member.

(16) The image processing apparatus **10** further includes an image reading device **1** that executes a reading process of reading an image from a document sheet. For example, the image processing apparatus **10** is a copier, a facsimile machine, a multifunction peripheral, or the like.

(17) The image to be subjected to the print process is an image read from the document sheet by the image reading device **1** or an image represented by print data received from a host device (not shown). The host device is an information processing apparatus such as a personal computer or a portable information terminal.

(18) Further, the image forming device **2** may form a predetermined original test image g**01** on the sheet by the print process (see FIG. **6**). The original test image g**01** is the original image of a test image g**1** used for determining the presence/absence and the cause of an image defect in the image forming device **2** (see FIG. **6**). The test image g**1** will be described later.

(19) A process including the reading process by the image reading device **1** and the print process by the image forming device **2** based on an image obtained in the reading process is a copy process.

(20) As shown in FIG. **1**, the image forming device **2** includes a sheet conveying mechanism **3** and a printing portion **4**. The sheet conveying mechanism **3** includes a sheet feeding mechanism **31** and a plurality of sheet conveying roller pairs **32**.

(21) The sheet feeding mechanism **31** feeds the sheet from a sheet storing portion **21** to a sheet conveying path **30**. The plurality of sheet conveying roller pairs **32** convey the sheet along the sheet conveying path **30**, and discharge the sheet on which an image has been formed to a discharge tray **22**.

(22) The printing portion **4** executes the print process on the sheet conveyed by the sheet conveying mechanism **3**. In the present embodiment, the printing portion **4** executes the print process using an electrophotographic method.

(23) The printing portion **4** includes an image forming portion **4***x*, a laser scanning unit **4***y*, a transfer device **44**, and a fixing device **46**. The image forming portion **4***x* includes a drum-shaped photoconductor **41**, a charging device **42**, a developing device **43**, and a drum cleaning device **45**.

(24) In each image forming portion **4***x*, the photoconductor **41** rotates, and the charging device **42** uniformly charges the surface of the photoconductor **41**. The charging device **42** includes a charging roller **42***a* that rotates in contact with the surface of the photoconductor **41**. The laser scanning unit **4***y* writes an electrostatic latent image on the charged surface of the photoconductor **41** by scanning with a laser beam.

(25) The developing device **43** develops the electrostatic latent image into a toner image. The developing device **43** includes a developing roller **43***a* that supplies toner to the photoconductor **41**. The transfer device **44** transfers the toner image on the surface of the photoconductor **41** to the sheet. It is noted that the toner is an example of a granular developer.

(26) The fixing device **46** heats the toner image on the sheet to fix the toner image on the sheet. The fixing device **46** includes a fixing rotary body **46***a* that rotates in contact with the sheet, and a fixing heater **46***b* that heats the fixing rotary body **46***a*.

(27) The image forming device **2** shown in FIG. **1** is a tandem-type color printing device capable of executing the print process of a color image. Therefore, the printing portion **4** includes four image forming portions **4***x* respectively corresponding to toners of different colors.

(28) In addition, in the tandem-type image forming device **2**, the transfer device **44** includes four primary transfer rollers **441** corresponding to four photoconductors **41**, an intermediate transfer belt **440**, a secondary transfer roller **442**, and a belt cleaning device **443**.

(29) The four image forming portions **4***x* respectively form the toner images of cyan, magenta, yellow, and black on the surfaces of the photoconductors **41**. Each primary transfer roller **441** is also a part of the corresponding image forming portion **4***x*.

(30) In each image forming portion **4***x*, the primary transfer roller **441** urges the intermediate transfer belt **440** to the surface of the photoconductor **41** while rotating. The primary transfer roller **441** transfers the toner image from the photoconductor **41** to the intermediate transfer belt **440**.

Thus, a color image composed of the toner images of four colors is formed on the intermediate transfer belt **440**.

(31) In each image forming portion **4**x, the drum cleaning device **45** removes and collects, from the photoconductor **41**, toner remaining on the photoconductor **41** without being transferred to the intermediate transfer belt **440**.

(32) The secondary transfer roller **442** transfers the toner image in four colors on the intermediate transfer belt **440** to the sheet. It is noted that, in the image processing apparatus **10**, each of the photoconductor **41** and the intermediate transfer belt **440** of the transfer device **44** is an example of an image carrier that rotates while carrying the toner image.

(33) The belt cleaning device **443** removes and collects, from the intermediate transfer belt **440**, toner remaining on the intermediate transfer belt **440** without being transferred to the sheet.

(34) As shown in FIG. **1**, the image processing apparatus **10** includes a data processing portion **8** and a human interface device **800** in addition to the image forming device **2** and the image reading device **1**. The human interface device **800** includes an operation portion **801** and a display portion **802**.

(35) The data processing portion **8** executes various types of data processing relating to the print process or the reading process, and also controls various electrical devices.

(36) The operation portion **801** is a device for receiving a user's operation. For example, the operation portion **801** includes one or both of a push button and a touch panel. The display portion **802** includes a display panel that displays information provided to the user.

(37) As shown in FIG. **2**, the data processing portion **8** includes a central processing unit (CPU) **80**, a random access memory (RAM) **81**, a secondary storage device **82**, and a communication device **83**.

(38) The CPU **80** can execute processing of data received by the communication device **83**, various types of image processing, and control of the image forming device **2**. The received data may include the print data. The CPU **80** is an example of a processor that executes data processing including the image processing. It is noted that the CPU may be implemented by other types of processors such as a digital signal processor (DSP).

(39) The communication device **83** is a communication interface device that performs communication with other devices such as the host device through a network such as a local area network (LAN). The CPU **80** performs all of transmission and reception of data to and from the other devices through the communication device **83**.

(40) The secondary storage device **82** is a computer-readable nonvolatile storage device. The secondary storage device **82** stores computer programs executed by the CPU **80** and various types of data referred to by the CPU **80**. For example, one or both of a flash memory and a hard disk drive are employed as the secondary storage device **82**.

(41) The RAM **81** is a computer-readable volatile storage device. The RAM **81** temporarily stores the computer programs to be executed by the CPU **80** and data output and referred to in the process of the CPU **80** executing the programs.

(42) The CPU **80** includes a plurality of processing modules implemented by executing the computer programs. The plurality of processing modules include a main control portion **8**a, a job control portion **8**b, and the like. It is noted that some or all of the plurality of processing modules may be implemented by a processor separate and independent from the CPU **80**, such as a DSP.

(43) The main control portion **8**a executes a process of selecting a job corresponding to an operation to the operation portion **801**, a process of causing the display portion **802** to display information, a process of setting various types of data, and the like. Furthermore, the main control portion **8**a executes a process of determining the contents of the data received by the communication device **83**.

(44) The job control portion **8**b controls the image reading device **1** and the image forming device **2**. For example, when the data received by the communication device **83** includes the print data, the

job control portion **8***b* causes the image forming device **2** to execute the print process based on the received data.

(45) In addition, when the main control portion **8***a* detects a copy request operation to the operation portion **801**, the job control portion **8***b* causes the image reading device **1** to execute the reading process and causes the image forming device **2** to execute the print process based on an image obtained in the reading process.

(46) In the print process, an image defect such as a vertical streak Ps**11**, a horizontal streak Ps**12**, a noise point Ps**13**, or density unevenness may occur in an image formed on an output sheet (see FIG. **6** and FIG. **8**).

(47) As mentioned above, the image forming device **2** executes the print process using an electrophotographic method. In this case, various portions such as the photoconductor **41**, the charging device **42**, the developing device **43**, and the transfer device **44** are considered to be the cause of the image defect. Skill is required to determine the cause of the image defect.

(48) In the present embodiment, the image forming device **2** executes a test print process of forming a predetermined original test image g**01** on the sheet.

(49) For example, when the main control portion **8***a* detects a test output operation to the operation portion **801**, the job control portion **8***b* causes the image forming device **2** to execute the test print process. In the following description, the sheet on which the original test image g**01** has been formed will be referred to as a test output sheet **9** (see FIG. **1**).

(50) Further, the main control portion **8***a* causes the display portion **802** to display a predetermined guidance message when the test print process is executed. This guidance message is a message for urging the user to perform a reading start operation to the operation portion **801** after setting the test output sheet **9** in the image reading device **1**.

(51) When the main control portion **8***a* detects a reading start operation to the operation portion **801** after the guidance message is displayed on the display portion **802**, the job control portion **8***b* causes the image reading device **1** to execute the reading process. Thus, the original test image g**01** is read by the image reading device **1** from the test output sheet **9** output by the image forming device **2**, and a read image corresponding to the original test image g**01** is obtained.

(52) Then, as will be described later, the CPU **80** executes a process of determining the presence/absence and the cause of the image defect, based on the read image or a test image g**1** which is a compressed image of the read image (see FIG. **6**). The CPU **80** is an example of a processor that executes the processes of an image processing method for determining the presence/absence and the cause of the image defect.

(53) It is noted that the device that reads the original test image g**01** from the test output sheet **9** may be, for example, a digital camera. It is noted that the process of reading the original test image g**01** from the test output sheet **9** with the image reading device **1** or the digital camera is an example of an image reading process on the test output sheet **9**.

(54) When the cause of the image defect is determined by comparing the value of a specific image parameter, such as the color, density, or number of screen lines of the image, with a predetermined threshold value, omission of determination or erroneous determination is likely to occur.

(55) On the other hand, an image pattern recognition process is suitable for classifying an input image into many events with high accuracy. For example, the pattern recognition process is a process of using a trained model trained using sample images corresponding to a plurality of event candidates as training data to determine which of the plurality of event candidates the input image corresponds to, or the like.

(56) However, the amount of information of an image is large, and there are a plurality of types of the image defects such as the vertical streak Ps**11**, the horizontal streak Ps**12**, the noise point Ps**13**, and the density unevenness (see FIG. **6** and FIG. **8**). Furthermore, there are many possible cause candidates for each type of the image defect.

(57) Accordingly, when a test image g**1** including the image defect is used as an input image for the

pattern recognition process, the amount of calculation for the pattern recognition process becomes very large. Thus, it is difficult to execute the pattern recognition process with a processor provided in a multifunction peripheral or the like.

(58) In addition, in order to increase the accuracy of determining the cause of the image defect, an enormous amount of the training data is required for training the trained model. However, it takes a great deal of time and effort to prepare an enormous number of test images g**1** corresponding to combinations of possible types of the image defects and possible causes of the image defects for each model of image forming device **2**.

(59) In the image processing apparatus **10**, the CPU **80** executes an image defect determination process to be described later (see FIG. **3**). This allows the CPU **80** to determine the cause of the image defect that occurs in the image forming device **2** with high accuracy while suppressing the amount of calculation.

(60) In the following description, an image such as the test image g**1** to be processed by the CPU **80** is digital image data. The digital image data forms map data including a plurality of pixel values corresponding to two-dimensional coordinate areas arranged in a main scanning direction D**1** and a sub-scanning direction D**2** intersecting the main scanning direction D**1** for each of the three primary colors. The three primary colors are, for example, red, green, and blue. It is noted that the sub-scanning direction D**2** is orthogonal to the main scanning direction D**1**. It is noted that the main scanning direction D**1** is the horizontal direction in the test image g**1**, and the sub-scanning direction D**2** is the vertical direction in the test image g**1**.

(61) For example, each of the original test image g**01** and the test image g**1** is a mixed-color halftone image obtained by combining a plurality of uniform single-color halftone images corresponding to a plurality of developing colors in the image forming device **2**. Each of the plurality of single-color halftone images is an image formed uniformly at a predetermined halftone reference density.

(62) In the present embodiment, each of the original test image g**01** and the test image g**1** is a mixed-color halftone image obtained by combining four uniform single-color halftone images corresponding to all the developing colors in the image forming device **2**. In the test print process, one test output sheet **9** including one original test image g**01** is output. Accordingly, one test image g**1** corresponding to the original test image g**01** is the subject for identification of the image defect.

(63) In addition, the plurality of processing modules in the CPU **80** further include a feature image generation portion **8***c*, a singular part identification portion **8***d*, a color vector identification portion **8***e*, a periodicity determination portion **8***f*, a pattern recognition portion **8***g*, and a random unevenness determination portion **8***h* in order to execute the image defect determination process (see FIG. **2**).

(64) [Image Defect Determination Processing]

(65) An example of the procedure of the image defect determination process will be described below with reference to the flowchart shown in FIG. **3**. In the following description, S**101**, S**102**, . . . represent identification codes of a plurality of steps in the image defect determination process.

(66) The main control portion **8***a* causes the feature image generation portion **8***c* to execute the process of step S**101** in the image defect determination process when the reading process is executed in response to the reading start operation to the operation portion **801** after the guidance message is displayed on the display portion **802**.

(67) <Step S**101**>

(68) In step S**101**, the feature image generation portion **8***c* generates a test image g**1** from the read image obtained in the image reading process on the test output sheet **9**.

(69) For example, the feature image generation portion **8***c* extracts, as the test image g**1**, a portion of the original image obtained by excluding the outer margin area and the text portion from the read image.

(70) Alternatively, the feature image generation portion **8***c* generates the test image g**1** by a

compression process of compressing a portion of the original image obtained by excluding the outer margin area from the read image to a predetermined reference resolution. The feature image generation portion **8***c* compresses the read image when the resolution of the read image is higher than the reference resolution. After generating the test image g**1**, the main control portion **8***a* shifts the process to step S**102**.

(71) <Step S**102**>

(72) In step S**102**, the feature image generation portion **8***c* starts a singular defect determination process to be described later. The singular defect determination process is a process of determining the presence/absence of a singular part Ps**1** such as the vertical streak Ps**11**, the horizontal streak Ps**12**, or the noise point Ps**13** in the test image g**1** and the cause of the occurrence of the singular part Ps**1** (see FIG. **6**). The singular part Ps**1** is an example of the image defect.

(73) When the singular defect determination process is completed, the main control portion **8***a* shifts the process to step S**103**.

(74) <Step S**103**>

(75) In step S**103**, the periodicity determination portion **8***f* starts a density unevenness determination process to be described later. When the density unevenness determination process is completed, the main control portion **8***a* shifts the process to step S**104**.

(76) <Step S**104**>

(77) In step S**104**, the main control portion **8***a* shifts the process to step S**105** when it is determined that the image defect has occurred by the process of step S**102** or step S**103**, and shifts the process to step S**106** otherwise.

(78) <Step S**105**>

(79) In step S**105**, the main control portion **8***a* executes a defect handling process associated in advance with the type and cause of the image defect determined to have occurred by the process of step S**102** or step S**103**.

(80) For example, the defect handling process includes one or both of a first handling process and a second handling process to be described below. The first handling process is a process of causing the display portion **802** to display a handling message for urging replacement or cleaning of a component that is the cause of the image defect.

(81) The handling message is predetermined for each determination result of the feature pattern recognition process. The handling message is an example of a message corresponding to the determination result in the feature pattern recognition process.

(82) The second handling process is a process of correcting an image forming parameter in order to eliminate or mitigate the image defect. The image forming parameter is a parameter relating to the control of the image forming portion **4***x*.

(83) In the first handling process, the main control portion **8***a* may transmit the handling message to a predetermined terminal through the communication device **83**. Thus, the handling message is displayed on a display portion of the terminal. The terminal is used by, for example, a service person or a specific user.

(84) After executing the defect handling process, the main control portion **8***a* terminates the image defect determination process.

(85) <Step S**106**>

(86) On the other hand, in step S**106**, the main control portion **8***a* terminates the image defect determination process after executing a normality notification indicating that no image defect was identified.

(87) [Singular Defect Determination Process]

(88) Next, an example of the procedure of the singular defect determination process in step S**102** will be described with reference to the flowchart shown in FIG. **4**. In the following description, S**201**, S**202**, . . . represent identification codes of a plurality of steps in the singular defect determination process. The singular defect determination process starts from step S**201**.

(89) <Step S**201**>

(90) First, in step S**201**, the feature image generation portion **8***c* generates a plurality of feature images g**21**, g**22**, and g**23** by executing a predetermined feature extraction process on the test image g**1**. Each of the feature images g**21**, g**22**, and g**23** is an image into which a predetermined specific type of singular part Ps**1** in the test image g**1** has been extracted.

(91) In the present embodiment, the plurality of feature images g**21**, g**22**, and g**23** include a first feature image g**21**, a second feature image g**22**, and a third feature image g**23** (see FIG. **6**).

(92) The first feature image g**21** is an image into which the vertical streak Ps**11** in the test image g**1** has been extracted. The second feature image g**22** is an image into which the horizontal streak Ps**12** in the test image g**1** has been extracted. The third feature image g**23** is an image into which the noise point Ps**13** in the test image g**1** has been extracted.

(93) In the present embodiment, the feature extraction process includes first preprocessing, second preprocessing, and a singular part extraction process. In the following description, pixels sequentially selected from the test image g**1** will each be referred to as a pixel of interest Px**1** (see FIG. **6** and FIG. **7**).

(94) The feature image generation portion **8***c* generates a first preprocessed image g**11** by executing the first preprocessing on the test image g**1** with the main scanning direction D**1** used as a processing direction Dx**1** (see FIG. **6**).

(95) Further, the feature image generation portion **8***c* generates a second preprocessed image g**12** by executing the second preprocessing on the test image g**1** with the sub-scanning direction D**2** used as the processing direction Dx**1** (see FIG. **6**).

(96) Furthermore, the feature image generation portion **8***c* generates three feature images g**21**, g**22**, and g**23** by executing the singular part extraction process on the first preprocessed image g**11** and the second preprocessed image g**12**.

(97) The first preprocessing includes a main filter process with the main scanning direction D**1** used as the processing direction Dx**1**. The main filter process is a process of converting the pixel value of each pixel of interest Px**1** sequentially selected from the test image g**1** into a converted value obtained by a process of emphasizing the difference between the pixel values of an area of interest Ax**1** and the pixel values of two adjacent areas Ax**2** (see FIG. **6** and FIG. **7**).

(98) The area of interest Ax**1** is an area including the pixel of interest Px**1**, and the two adjacent areas Ax**2** are preset areas adjacent to the area of interest Ax**1** on both sides in the processing direction Dx**1**. The area of interest Ax**1** and the adjacent areas Ax**2** are areas each including one or more pixels.

(99) The sizes of the area of interest Ax**1** and the adjacent areas Ax**2** are set in accordance with the width of the vertical streak Ps**11** or the horizontal streak Ps**12** to be extracted or the size of the noise point Ps**13** to be extracted.

(100) The area of interest Ax**1** and the adjacent areas Ax**2** each occupy the same range in a direction intersecting the processing direction Dx**1**. In the example shown in FIG. **7**, the area of interest Ax**1** is a 21-pixel area spanning three columns and seven rows centered on the pixel of interest Px**1**. Each of the adjacent areas Ax**2** is also a 21-pixel area spanning three columns and seven rows. It is noted that, in each of the area of interest Ax**1** and the adjacent areas Ax**2**, the number of rows is the number of lines along the processing direction Dx**1**, and the number of columns is the number of lines along the direction intersecting the processing direction Dx**1**. The sizes of the area of interest Ax**1** and the adjacent areas Ax**2** are preset.

(101) In the main filter process, each pixel value of the area of interest Ax**1** is converted into a first corrected value using a predetermined first correction coefficient K**1**, and each pixel value of the adjacent areas Ax**2** is converted into a second corrected value using a predetermined second correction coefficient K**2**.

(102) For example, the first correction coefficient K**1** is a coefficient of 1 or greater by which each pixel value of the area of interest Ax**1** is multiplied, and the second correction coefficient K**2** is a

coefficient of less than 0 by which each pixel value of the adjacent areas Ax**2** is multiplied. In this case, the first correction coefficient K**1** and the second correction coefficient K**2** are set so that the sum of a value obtained by multiplying the first correction coefficient K**1** by the number of pixels of the area of interest Ax**1** and a value obtained by multiplying the second correction coefficient K**2** by the number of pixels of the two adjacent areas Ax**2** is zero.

(103) The feature image generation portion **8***c* derives the first corrected value corresponding to each pixel of the area of interest Ax**1** by multiplying each pixel value of the area of interest Ax**1** by the first correction coefficient K**1**, and derives the second corrected value corresponding to each pixel of the two adjacent areas Ax**2** by multiplying each pixel value of the two adjacent areas Ax**2** by the second correction coefficient K**2**. Then, the feature image generation portion **8***c* derives a value obtained by integrating the first corrected values and the second corrected values as the converted value of the pixel value of the pixel of interest Px**1**.

(104) For example, the feature image generation portion **8***c* derives the converted value by adding the sum or average value of the first corrected values corresponding to a plurality of pixels of the area of interest Ax**1** and the sum or average value of the second corrected values corresponding to a plurality of pixels of the two adjacent areas Ax**2**.

(105) The absolute value of the converted value is an amplified absolute value of the difference between the pixel values of the area of interest Ax**1** and the pixel values of the two adjacent areas Ax**2**. The process of deriving the converted value obtained by integrating the first corrected values and the second corrected values is an example of a process of emphasizing the difference between the pixel values of the area of interest Ax**1** and the pixel values of the two adjacent areas Ax**2**.

(106) It is noted that the case where the first correction coefficient K**1** is a negative number and the second correction coefficient K**2** is a positive number is also conceivable.

(107) For example, the feature image generation portion **8***c* may generate, as the first preprocessed image g**11**, first main map data including a plurality of integrated values obtained by the main filter process with the main scanning direction D**1** used as the processing direction Dx**1**.

(108) As shown in FIG. **6**, when the test image g**1** includes one or both of the vertical streak Ps**11** and the noise point Ps**13**, the first main map data into which one or both of the vertical streak Ps**11** and the noise point Ps**13** included in the test image g**1** have been extracted is generated by the main filter process with the main scanning direction D**1** used as the processing direction Dx**1**.

(109) In addition, when the test image g**1** includes the horizontal streak Ps**12**, the first main map data obtained by excluding the horizontal streak Ps**12** included in the test image g**1** is generated by the main filter process with the main scanning direction D**1** used as the processing direction Dx**1**.

(110) It is noted that the vertical streak Ps**11** corresponds to a first singular part, the horizontal streak Ps**12** corresponds to a second singular part, and the noise point Ps**13** corresponds to a third singular part.

(111) On the other hand, the second preprocessing includes the main filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(112) For example, the feature image generation portion **8***c* may generate, as the second preprocessed image g**12**, second main map data including a plurality of integrated values obtained by the main filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(113) As shown in FIG. **6**, when the test image g**1** includes one or both of the horizontal streak Ps**12** and the noise point Ps**13**, the second main map data into which one or both of the horizontal streak Ps**12** and the noise point Ps**13** included in the test image g**1** have been extracted is generated by the main filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(114) In addition, when the test image g**1** includes the vertical streak Ps**11**, the second main map data not including the vertical streak Ps**11** included in the test image g**1** is generated by the main filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(115) However, in the main filter process, an erroneous integrated value which is opposite in sign to the integrated value representing the actual state of the singular part Ps**1** may be derived in edge

portions at both ends of the singular part Ps**1** in the processing direction Dx**1**. Processing such an erroneous integrated value as a pixel value representing the singular part Ps**1** may adversely affect the determination of the image defect.

(116) Therefore, in the present embodiment, the first preprocessing further includes an edge enhancement filter process with the main scanning direction D**1** used as the processing direction Dx**1** in addition to the main filter process with the main scanning direction D**1** used as the processing direction Dx**1**.

(117) Similarly, the second preprocessing further includes the edge enhancement filter process with the sub-scanning direction D**2** used as the processing direction Dx**1** in addition to the main filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(118) The edge enhancement filter process is a process of performing edge enhancement on the area of interest Ax**1** and a predetermined one of the two adjacent areas Ax**2**.

(119) Specifically, the edge enhancement filter process is a process of converting the pixel value of each pixel of interest Px**1** sequentially selected from the test image g**1** into an edge intensity obtained by integrating a third corrected value obtained by correcting each pixel value of the area of interest Ax**1** by a positive or negative third correction coefficient K**3** and a fourth corrected value obtained by correcting each pixel value of one of the adjacent areas Ax**2** by a fourth correction coefficient K**4** opposite in sign to the third correction coefficient K**3** (see FIG. **6**).

(120) In the example shown in FIG. **6**, the third correction coefficient K**3** is a positive coefficient, and the fourth correction coefficient K**4** is a negative coefficient. The third correction coefficient K**3** and the fourth correction coefficient K**4** are set so that the sum of a value obtained by multiplying the third correction coefficient K**3** by the number of pixels of the area of interest Ax**1** and a value obtained by multiplying the fourth correction coefficient K**4** by the number of pixels of one of the adjacent areas Ax**2** is zero.

(121) When the edge enhancement filter process is executed with the main scanning direction D**1** used as the processing direction Dx**1**, horizontal edge intensity map data in which each pixel value of the test image g**1** has been converted into the edge intensity is generated.

(122) Similarly, when the edge enhancement filter process is executed with the sub-scanning direction D**2** used as the processing direction Dx**1**, vertical edge intensity map data in which each pixel value of the test image g**1** has been converted into the edge intensity is generated.

(123) In the present embodiment, the feature image generation portion **8**c generates the first main map data generated by the main filter process with the main scanning direction D**1** used as the processing direction Dx**1**.

(124) Further, the feature image generation portion **8**c generates the horizontal edge intensity map data by executing the edge enhancement filter process with the main scanning direction D**1** used as the processing direction Dx**1**.

(125) Further, the feature image generation portion **8**c generates the first preprocessed image g**11** by correcting each pixel value of the first main map data with the corresponding pixel value of the horizontal edge intensity map data. For example, the feature image generation portion **8**c generates the first preprocessed image g**11** by adding the absolute value of the corresponding pixel value of the horizontal edge intensity map data to each pixel value of the first main map data.

(126) Similarly, the feature image generation portion **8**c generates the second main map data by executing the main filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(127) Further, the feature image generation portion **8**c generates the vertical edge intensity map data by executing the edge enhancement filter process with the sub-scanning direction D**2** used as the processing direction Dx**1**.

(128) Further, the feature image generation portion **8**c generates the second preprocessed image g**12** by correcting each pixel value of the second main map data with the corresponding pixel value of the vertical edge intensity map data. For example, the feature image generation portion **8**c

generates the second preprocessed image g**12** by adding the absolute value of the corresponding pixel value of the vertical edge intensity map data to each pixel value of the second main map data.

(129) The singular part extraction process is a process of generating three feature images g**21**, g**22**, and g**23** into which the vertical streak Ps**11**, the horizontal streak Ps**12**, and the noise point Ps**13** included in the first preprocessed image g**11** or the second preprocessed image g**12** have been separately extracted respectively. The three feature images g**21**, g**22**, and g**23** are a first feature image g**21**, a second feature image g**22**, and a third feature image g**23**.

(130) The first feature image g**21** is an image into which a singular part Ps**1** that is present in the first preprocessed image g**11** and is not common to the first preprocessed image g**11** and the second preprocessed image g**12**, among the singular parts Ps**1** consisting of one or more significant pixels in the first preprocessed image g**11** and the second preprocessed image g**12**, has been extracted. The first feature image g**21** does not include the horizontal streak Ps**12** or the noise point Ps**13**, and includes the vertical streak Ps**11** when the first preprocessed image g**11** includes the vertical streak Ps**11**.

(131) It is noted that the significant pixel is a pixel that can be distinguished from other pixels by comparing each pixel value in the test image g**1** or an index value based on each pixel value with a predetermined threshold value.

(132) The second feature image g**22** is an image into which a singular part Ps**1** that is present in the second preprocessed image g**12** and is not common to the first preprocessed image g**11** and the second preprocessed image g**12**, among the singular parts Ps**1** in the first preprocessed image g**11** and the second preprocessed image g**12**, has been extracted. The second feature image g**22** does not include the vertical streak Ps**11** or the noise point Ps**13**, and includes the horizontal streak Ps**12** when the second preprocessed image g**12** includes the horizontal streak Ps**12**.

(133) The third feature image g**23** is an image into which a singular part Ps**1** common to the first preprocessed image g**11** and the second preprocessed image g**12** has been extracted. The third feature image g**23** does not include the vertical streak Ps**11** or the horizontal streak Ps**12**, and includes the noise point Ps**13** when the first preprocessed image g**11** and the second preprocessed image g**12** include the noise point Ps**13**.

(134) Various methods are conceivable for generating the three feature images g**21**, g**22**, and g**23** from the first preprocessed image g**11** and the second preprocessed image g**12**.

(135) For example, the feature image generation portion **8**c derives an index value Zi by applying a first pixel value Xi, which is each pixel value exceeding a predetermined reference value in the first preprocessed image g**11**, and a second pixel value Yi, which is each pixel value exceeding the reference value in the second preprocessed image g**12**, to the following equation (1). Here, the subscript i is the identification number of the position of each pixel.

[Equation 1]

$$Zi = (|Xi| - |Yi|)/(|Xi| + |Yi|) \qquad (1)$$

(136) The index value Zi of each pixel constituting the vertical streak Ps**11** is a relatively large positive number. In addition, the index value Zi of each pixel constituting the horizontal streak Ps**12** is a relatively small negative number. In addition, the index value Zi of each pixel constituting the noise point Ps**13** is 0 or a value close to 0. The index value Zi is an example of an index value of the difference between corresponding pixel values in the first preprocessed image g**11** and the second preprocessed image g**12**.

(137) The above-described properties of the index value Zi can be utilized to simplify the process of extracting the vertical streak Ps**11** from the first preprocessed image g**11**, extracting the horizontal streak Ps**12** from the second preprocessed image g**12**, and extracting the noise point Ps**13** from the first preprocessed image g**11** or the second preprocessed image g**12**.

(138) For example, the feature image generation portion **8**c generates the first feature image g**21** by converting the first pixel value Xi in the first preprocessed image g**11** into a first singularity degree Pi derived by the following equation (2). Thus, the first feature image g**21** into which the vertical

streak Ps**11** has been extracted from the first preprocessed image g**11** is generated.
[Equation 2]
$Pi=Xi.Math.Zi$ (2)
(139) Further, the feature image generation portion **8***c* generates the second feature image g**22** by converting the second pixel value Yi in the second preprocessed image g**12** into a second singularity degree Qi derived by the following equation (3). Thus, the second feature image g**22** into which the horizontal streak Ps**12** has been extracted from the second preprocessed image g**12** is generated.
[Equation 3]
$Qi=Yi.Math.(-Zi)$ (3)
(140) Further, the feature image generation portion **8***c* generates the third feature image g**23** by converting the first pixel value Xi in the first preprocessed image g**11** into a third singularity degree Ri derived by the following equation (4). Thus, the third feature image g**23** into which the noise point Ps**13** has been extracted from the first preprocessed image g**11** is generated.
[Equation 4]
$Ri=Xi.Math.(1-Zi)$ (4)
(141) Alternatively, the feature image generation portion **8***c* may generate the third feature image g**23** by converting the second pixel value Yi in the second preprocessed image g**12** into a third singularity degree Ri derived by the following equation (5). Thus, the third feature image g**23** into which the noise point Ps**13** has been extracted from the second preprocessed image g**12** is generated.
[Equation 5]
$Ri=Yi.Math.(Zi-1)$ (5)
(142) As described above, the feature image generation portion **8***c* generates the first feature image g**21** by the process of converting each pixel value of the first preprocessed image g**11** using the predetermined equation (2) based on the index value Zi. Equation (2) is an example of a first conversion equation.
(143) Further, the feature image generation portion **8***c* generates the second feature image g**22** by the process of converting each pixel value of the second preprocessed image g**12** using the predetermined equation (3) based on the index value Zi. Equation (3) is an example of a second conversion equation.
(144) Further, the feature image generation portion **8***c* generates the third feature image g**23** by the process of converting each pixel value of the first preprocessed image g**11** or the second preprocessed image g**12** using the predetermined equation (4) or (5) based on the index value Zi. Each of equations (4) and (5) is an example of a third conversion equation.
(145) The process of generating the first feature image g**21**, the second feature image g**22**, and the third feature image g**23** in step S**201** is an example of a process of extracting each of the vertical streak Ps**11**, the horizontal streak Ps**12**, and the noise point Ps**13** among one or more singular parts Ps**1** in the first preprocessed image g**11** and the second preprocessed image g**12** as the image defect.
(146) After generating the feature images g**21**, g**22**, and g**23**, the feature image generation portion **8***c* shifts the process to step S**202**.
(147) <Step S**202**>
(148) In step S**202**, the singular part identification portion **8***d* identifies the position of the singular part Ps**1** in each of the feature images g**21**, g**22**, and g**23**.
(149) For example, the singular part identification portion **8***d* determines that a portion having a pixel value outside a predetermined reference range in each of the feature images g**21**, g**22**, and g**23** is the singular part Ps**1**.
(150) When a plurality of singular parts Ps**1** are present within a predetermined proximity range in each of the main scanning direction D**1** and the sub-scanning direction D**2**, the singular part

identification portion **8***d* executes a combination process of combining the plurality of singular parts Ps**1** as one singular part Ps**1** including a series of singular parts Ps**1** for each of the feature images g**21**, g**22**, and g**23**.

(151) For example, when the first feature image g**21** includes two vertical streaks Ps**11** spaced apart in the sub-scanning direction D**2** within the proximity range, the singular part identification portion **8***d* combines the two vertical streaks Ps**11** as one vertical streak Ps**11** by the combination process.

(152) Similarly, when the second feature image g**22** includes two horizontal streaks Ps**12** spaced apart in the main scanning direction D**1** within the proximity range, the singular part identification portion **8***d* combines the two horizontal streaks Ps**12** as one horizontal streak Ps**12** by the combination process.

(153) In addition, when the third feature image g**23** includes a plurality of noise points Ps**13** aligned at intervals in the main scanning direction D**1** or the sub-scanning direction D**2** within the proximity range, the singular part identification portion **8***d* combines the plurality of noise points Ps**13** as one noise point Ps**13** by the combination process.

(154) When the position of the singular part Ps**1** is not identified in any of the three feature images g**21**, g**22**, and g**23**, the singular part identification portion **8***d* terminates the singular defect determination process. On the other hand, when the position of the singular part Ps**1** is identified in one or more of the three feature images g**21**, g**22** and g**23**, the singular part identification portion **8***d* shifts the process to step S**203**.

(155) <Step S**203**>

(156) In step S**203**, the color vector identification portion **8***e* identifies a color vector representing a vector in a color space from one to the other of the color of the singular part Ps**1** in the test image g**1** and the color of a reference area including the periphery of the singular part Ps**1**.

(157) The reference area is a predetermined range of area determined based on the singular part Ps**1**. For example, the reference area is an area including a peripheral area adjacent to the singular part Ps**1** and excluding the singular part Ps**1**. Alternatively, the reference area may include the singular part Ps**1** and a peripheral area adjacent to the singular part Ps**1**.

(158) The test image g**1** is originally a uniform halftone image. Therefore, when a good test image g**1** is formed on the test output sheet **9**, the singular part Ps**1** is not identified, and the color vector at any position of the test image g**1** is substantially a zero vector.

(159) On the other hand, when the singular part Ps**1** is identified, the direction of the color vector between the singular part Ps**1** and the reference area corresponding to the singular part Ps**1** indicates an excess or deficiency of the toner density of one of the four developing colors in the image forming device **2**.

(160) Accordingly, the direction of the color vector indicates which of the four image forming portions **4***x* in the image forming device **2** is the cause of the occurrence of the singular part Ps**1**.

(161) It is noted that the color vector identification portion **8***e* may identify a vector in the color space from one to the other of the color of the singular part Ps**1** in the test image g**1** and a predetermined reference color as the color vector. In this case, the reference color is the original color of the test image g**1**.

(162) Further, in step S**203**, the color vector identification portion **8***e* determines, based on the color vector, a developing color that is the cause of the singular part Ps**1** and the excess/deficiency state of the density of the developing color.

(163) For example, the secondary storage device **82** stores in advance information of a plurality of unit vectors representing the directions in which the densities of cyan, magenta, yellow, and black increase and directions in which the same densities become deficient with respect to the reference color of the test image g**1**.

(164) The color vector identification portion **8***e* normalizes the color vector to a predetermined unit length. Further, the color vector identification portion **8***e* determines which of the plurality of unit vectors corresponding to the increases or deficiencies of the densities of cyan, magenta, yellow, and

black the normalized color vector most closely approximates, thereby determining a developing color causing the singular part Ps**1** and the excess/deficiency state of the density of the developing color.

(165) After executing the process of step S**203**, the color vector identification portion **8***e* shifts the process to step S**204**.

(166) <Step S**204**>

(167) In step S**204**, the periodicity determination portion **8***f* shifts the process to step S**205** when the singular part Ps**1** is identified in one or both of the second feature image g**22** and the third feature image g**23**, and shifts the process to step S**206** otherwise.

(168) In the following description, one or both of the second feature image g**22** and the third feature image g**23** in which the singular part Ps**1** is identified will each be referred to as a periodicity determination subject image. The singular part Ps**1** in the periodicity determination subject image is the horizontal streak Ps**12** or the noise point Ps**13** (see FIG. **6**).

(169) <Step S**205**>

(170) In step S**205**, the periodicity determination portion **8***f* executes a periodic singular part determination process on the periodicity determination subject image. The periodic singular part determination process includes a number determination process, a singular part periodicity determination process, and a singular part periodicity cause determination process.

(171) The number determination process is a process of determining the number of singular parts Ps**1** aligned in the sub-scanning direction D**2** in the periodicity determination subject image.

(172) Specifically, the periodicity determination portion **8***f* determines the number of horizontal streaks Ps**12** aligned in the sub-scanning direction D**2** by counting the number of horizontal streaks Ps**12** aligned in the sub-scanning direction D**2** whose portions occupying the same range in the main scanning direction D**1** exceed a predetermined ratio in the second feature image g**22**.

(173) Further, the periodicity determination portion **8***f* determines the number of noise points Ps**13** aligned in the sub-scanning direction D**2** by counting the number of noise points Ps**13** aligned in the sub-scanning direction D**2** whose positional deviations in the main scanning direction D**1** are within a predetermined range in the third feature image g**23**.

(174) The periodicity determination portion **8***f* executes the singular part periodicity determination process only when there are two or more singular parts Ps**1** aligned in the sub-scanning direction D**2**.

(175) In addition, the periodicity determination portion **8***f* determines that the singular part Ps**1** has no periodicity when there is one singular part Ps**1** aligned in the sub-scanning direction D**2**, and skips the singular part periodicity determination process and the singular part periodicity cause determination process.

(176) The singular part periodicity determination process is a process of determining the presence/absence of one or more predetermined periodicities in the sub-scanning direction D**2** for the periodicity determination subject image.

(177) The periodicity corresponds to the outer circumferential length of each of the image forming portions **4***x*, or of the image-forming related rotary body such as the photoconductor **41**, the charging roller **42***a*, the developing roller **43***a*, or the primary transfer roller **441** in the transfer device **44**. The state of the image-forming related rotary body influences the quality of the image formed on the sheet. In the following description, the image-forming related rotary body will be referred to as an image-forming rotary body.

(178) When the image defect is caused by the defect of the image-forming rotary body, the periodicity corresponding to the outer circumferential length of the image-forming rotary body may appear as the intervals of a plurality of horizontal streaks Ps**12** or a plurality of noise points Ps**13** in the sub-scanning direction D**2**.

(179) Accordingly, when the periodicity determination subject image has the periodicity corresponding to the outer circumferential length of the image-forming rotary body, it can be said

that the image-forming rotary body corresponding to the periodicity is the cause of the horizontal streaks Ps**12** or the noise points Ps**13** in the periodicity determination subject image.

(180) When the number of singular parts Ps**1** aligned in the sub-scanning direction D**2** in the periodicity determination subject image is two, the periodicity determination portion **8***f* executes an interval derivation process as the singular part periodicity determination process.

(181) In the interval derivation process, the periodicity determination portion **8***f* derives the interval of the two singular parts Ps**1** in the sub-scanning direction D**2** as the periodicity of the two singular parts Ps**1**.

(182) When the number of singular parts Ps**1** aligned in the sub-scanning direction D**2** in the periodicity determination subject image is three or more, the periodicity determination portion **8***f* executes a frequency analysis process as the singular part periodicity determination process.

(183) In the frequency analysis process, the periodicity determination portion **8***f* performs frequency analysis, such as Fourier transform, on the periodicity determination subject image including three or more singular parts Ps**1** aligned in the sub-scanning direction D**2**, thereby identifying a singular part frequency which is a dominant frequency in the frequency distribution of the data strings of the singular parts Ps**1** in the periodicity determination subject image.

(184) Further, the periodicity determination portion **8***f* derives a period corresponding to the singular part frequency as the period of the three or more singular parts Ps**1**.

(185) In the singular part periodicity cause determination process, the periodicity determination portion **8***f* determines whether or not the outer circumferential length of each of a plurality of predetermined candidate image-forming rotary bodies satisfies a predetermined period approximation condition between the outer circumferential length of the candidate image-forming rotary body and the period of the singular parts Ps**1**. The plurality of candidate image-forming rotary bodies in step S**205** are examples of a plurality of predetermined cause candidates corresponding to the horizontal streaks Ps**12** or the noise points Ps**13**.

(186) In the following description, among the singular parts Ps**1** included in the second feature image g**22** and the third feature image g**23**, the singular parts Ps**1** for which one of the candidate image-forming rotary bodies is determined to satisfy the period approximation condition will be referred to as periodic singular parts, and the other singular parts Ps**1** are referred to as non-periodic singular parts.

(187) In the singular part cause determination process, the periodicity determination portion **8***f* determines that one of the candidate image-forming rotary bodies determined to satisfy the period approximation condition is the cause of the occurrence of the periodic singular parts. Thus, the cause of the horizontal streaks Ps**12** or the noise points Ps**13** is determined.

(188) In addition, in step S**205**, the periodicity determination portion **8***f* determines, based on the color vector determined in step S**203**, which image-forming rotary body of the four image forming portions **4***x* of different developing colors is the cause of the horizontal streaks Ps**12** or the noise points Ps**13**.

(189) In addition, when three or more singular parts Ps**1** aligned in the sub-scanning direction D**2** include the non-periodic singular part that does not correspond to the singular part frequency, the periodicity determination portion **8***f* subjects the non-periodic singular part to a feature pattern recognition process to be described later.

(190) For example, the periodicity determination portion **8***f* generates inverse Fourier transform data by performing inverse Fourier transform on a frequency distribution obtained by removing the frequency components other than the singular part frequency from the frequency distribution obtained by the Fourier transform.

(191) Further, the periodicity determination portion **8***f* determines, among the three or more singular parts Ps**1** aligned in the sub-scanning direction D**2**, one that is located off the peak position of the waveform in the sub-scanning direction D**2** indicated by the inverse Fourier transform data, as the non-periodic singular part.

(192) When it is determined as a result of the process of step S**205** that the second feature image g**22** and the third feature image g**23** do not include the non-periodic singular part, the periodicity determination portion **8***f* terminates the singular defect determination process.

(193) On the other hand, when it is determined as a result of the process of step S**205** that the second feature image g**22** and the third feature image g**23** include the non-periodic singular part, the periodicity determination portion **8***f* shifts the process to step S**206**.

(194) <Step S**206**>

(195) In step S**206**, the pattern recognition portion **8***g* executes a feature pattern recognition process on each of the first feature image g**21**, and the second feature image g**22** and third feature image g**23** each including the non-periodic singular part. The second feature image g**22** including the non-periodic singular part or the third feature image g**23** including the non-periodic singular part is an example of a non-periodic feature image.

(196) In the feature pattern recognition process, each of the first feature image g**21**, and the second feature image g**22** and third feature image g**23** each including the non-periodic singular part is used as an input image. In the feature pattern recognition process, the pattern recognition portion **8***g* determines which of a plurality of predetermined cause candidates corresponding to the image defects the input image corresponds to by pattern recognition of the input image.

(197) In addition, the input image of the feature pattern recognition process may include the horizontal edge intensity map data or the vertical edge intensity map data obtained by the edge enhancement filter process. For example, in the feature pattern recognition process for determining the vertical streak Ps**11**, the first feature image g**21** and the horizontal edge intensity map data are used as the input image.

(198) Similarly, in the feature pattern recognition process for determining the horizontal streak Ps**12**, the second feature image g**22** and the vertical edge intensity map data are used as the input image.

(199) Similarly, in the feature pattern recognition process for determining the noise point Ps**13**, the third feature image g**23** and one or both of the horizontal edge intensity map data and the vertical edge intensity map data are used as the input image.

(200) For example, the feature pattern recognition process is a process of classifying the input image into one of the plurality of cause candidates using a trained model trained in advance using a plurality of sample images corresponding to the plurality of cause candidates as training data.

(201) For example, the trained model may be a model employing a classification-type machine learning algorithm called a random forest, a model employing a machine learning algorithm called a support vector machine (SVM), or a model employing a convolutional neural network (CNN).

(202) The trained model is prepared separately for each of the first feature image g**21** and the second feature image g**22** and third feature image g**23** each including the non-periodic singular part. In addition, the plurality of sample images are used as the training data for each of the cause candidates.

(203) In addition, in step S**206**, the pattern recognition portion **8***g* determines, based on the color vector determined in step S**203**, which of the four image forming portions **4***x* of different developing colors is the cause of the vertical streak Ps**11**, the horizontal streak Ps**12**, or the noise point Ps**13**.

(204) By the process of step S**206**, the cause of the vertical streak Ps**11** and the cause of the horizontal streak Ps**12** and the noise point Ps**13** determined as the non-periodic singular part are determined. After executing the process of step S**206**, the pattern recognition portion **8***g* terminates the singular defect determination process.

(205) [Density Unevenness Determination Process]

(206) Next, an example of the procedure of the density unevenness determination process in step S**103** will be described with reference to the flowchart shown in FIG. **5**, In the following description, S**301**, S**302**, . . . represent identification codes of a plurality of steps in the density

unevenness determination process. The density unevenness determination process starts from step S**301**.

(207) <Step S**301**>

(208) In step S**301**, the periodicity determination portion **8***f* derives a vertical data string VD**1** for each predetermined specific color of the test image g**1**. The specific colors are colors corresponding to the developing colors of the image forming device **2**. The vertical data string VD**1** is a data string of representative values V**1** of a plurality of pixel values for the respective lines in the main scanning direction D**1** in each of the images of the specific colors constituting the test image g**1** (see FIG. **7**).

(209) For example, the specific colors are three colors of the four developing colors of the image forming device **2**. In this case, the periodicity determination portion **8***f* converts red, green, and blue image data constituting the test image g**1** into cyan, yellow, and magenta image data.

(210) Then, the periodicity determination portion **8***f* derives a representative value V**1** of a plurality of pixel values for each line in the main scanning direction D**1** for each of the image data of the three specific colors corresponding to the test image g**1**, thereby deriving three vertical data strings VD**1** corresponding to cyan, yellow, and magenta.

(211) It is noted that the specific colors may be three primary colors of red, green, and blue. In this case, the periodicity determination portion **8***f* converts each pixel value of each of the three image data of red, green, and blue in the test image g**1** into a value representing a ratio to an average value or a total value of the pixel values of the three image data of red, green, and blue in the test image g**1**. Furthermore, the periodicity determination portion **8***f* derives three vertical data strings VD**1** for the three image data after conversion.

(212) Here, red is a color corresponding to cyan, green is a color corresponding to magenta, and blue is a color corresponding to yellow. That is, the density unevenness of cyan appears as the density unevenness in the red image data after conversion, the density unevenness of magenta appears as the density unevenness in the green image data after conversion, and the density unevenness of yellow appears as the density unevenness in the blue image data after conversion.

(213) For example, the representative value V**1** is an average value, a maximum value, a minimum value, or the like of the remaining pixel values obtained by excluding the pixel values of the singular part Ps**1** from all the pixel values of the line extending in the main scanning direction D**1**. Alternatively, the representative value V**1** may be an average value, a maximum value, a minimum value, or the like of all the pixel values of the line extending in the main scanning direction D**1**.

(214) After executing the process of step S**301**, the periodicity determination portion **8***f* shifts the process to step S**302**.

(215) <Step S**302**>

(216) In step S**302**, the periodicity determination portion **8***f* executes a periodic unevenness determination process on the vertical data string VD**1** of each specific color.

(217) For example, the periodicity determination portion **8***f* performs frequency analysis, such as Fourier transformation, on each vertical data string VD**1**, thereby identifying a density unevenness frequency which is a dominant frequency in the frequency distribution of the vertical data string VD**1**.

(218) Further, the periodicity determination portion **8***f* derives a period corresponding to the density unevenness frequency as a period of the density unevenness in the test image g**1**.

(219) Further, the periodicity determination portion **8***f* determines, for each of the predetermined candidate image-forming rotary bodies, whether or not the outer circumferential length of the candidate image-forming rotary body satisfies the period approximation condition between the outer peripheral length of the candidate image-forming rotary body and the period of the density unevenness. The fact that it is determined that one of the plurality of candidate image-forming rotary bodies satisfies the period approximation condition means that it is determined that periodic density unevenness has occurred in the test image g**1**.

(220) The plurality of candidate image-forming rotary bodies in step S**302** are examples of a plurality of predetermined cause candidates corresponding to the periodic density unevenness in the test image g**1**. The periodic density unevenness is an example of the image defect.

(221) Further, the periodicity determination portion **8***f* determines the cause of the periodic density unevenness based on the developing color corresponding to the vertical data string VD**1** and the candidate image-forming rotary body determined to satisfy the period approximation condition.

(222) However, when the periodic density unevenness is caused by the image forming portion **4***x* of black, a pixel value variation occurs in all of the red, green, and blue image data constituting the test image g**1**.

(223) Therefore, when the periodicity determination portion **8***f* determines that the periodic density unevenness having the same periodicity has occurred in all of cyan, magenta, and yellow, the periodicity determination portion **8***f* determines that the image forming portion **4***x* of black is the cause of the periodic density unevenness.

(224) The periodicity determination portion **8***f* terminates the density unevenness determination process when it is determined that the periodic density unevenness has occurred in the test image g**1**, and shifts the process to step S**303** otherwise.

(225) <Step S**303**>

(226) In step S**303**, the random unevenness determination portion **8***h* determines the presence/absence of the occurrence of random density unevenness for each of the image data of the three specific colors corresponding to the test image g**1**. The random density unevenness is a type of the image defect.

(227) The random unevenness determination portion **8***h* determines the presence/absence of the occurrence of the random density unevenness by determining whether or not a pixel value variation of each of the image data of the three specific colors exceeds a predetermined allowable range.

(228) For example, the degree of the pixel value variation is determined based on a variance, a standard deviation, a difference between a median value and a maximum value or a minimum value, or the like in each of the image data of the three specific colors.

(229) However, when it is determined that the random density unevenness has occurred in all of cyan, magenta, and yellow, the random unevenness determination portion **8***h* determines that the image forming portion **4***x* of black is the cause of the random density unevenness.

(230) The random unevenness determination portion **8***h* shifts the process to step S**304** when it is determined that the random density unevenness is caused in the test image g**1**, and terminates the density unevenness determination process otherwise.

(231) <Step S**304**>

(232) In step S**304**, the pattern recognition portion **8***g* executes a random pattern recognition process. The random pattern recognition process is a process of using the test image g**1** determined to have the random density unevenness as an input image and determining which of one or more cause candidates the input image corresponds to by pattern recognition of the input image.

(233) After executing the process of step S**304**, the pattern recognition portion **8***g* terminates the density unevenness determination process.

(234) The CPU **80** executing the image defect determination process including the singular defect determination process and the density unevenness determination process is an example of an image processing method for determining the cause of the image defect based on the test image g**1** read from the output sheet of the image forming device **2**.

(235) As described above, the feature image generation portion **8***c* generates the first preprocessed image g**11** by executing the first preprocessing including the main filter process with the horizontal direction of the test image g**1** used as the processing direction Dx**1**. The main filter process is a process of converting the pixel value of each pixel of interest Px**1** sequentially selected from the test image g**1** into a converted value obtained by a process of emphasizing the difference between the pixel values of the area of interest Ax**1** and the pixel values of two predetermined adjacent areas

Ax**2** adjacent to the area of interest Ax**1** on both sides in the processing direction Dx**1** (see step S**201** in FIG. **4**, and FIG. **6**).

(236) Further, the feature image generation portion **8**c generates the second preprocessed image g**12** by executing the second preprocessing including the main filter process with the vertical direction of the test image g**1** used as the processing direction Dx**1** (see step S**201** in FIG. **4**, and FIG. **6**).

(237) Further, the feature image generation portion **8**c extracts each of the vertical streak Ps**11**, the horizontal streak Ps**12**, and the noise point Ps**13** among one or more singular parts Ps**1** in the first preprocessed image g**11** and the second preprocessed image g**12** as the image defects (see step S**201** in FIG. **4**, and FIG. **6**).

(238) The feature extraction process of step S**201** is a simple process with a small calculation load. By such a simple process, three feature images g**21**, g**22**, and g**23** into which singular parts Ps**1** having different shapes have been extracted from one test image g**1** can be generated.

(239) Then, the periodicity determination portion **8**f and the pattern recognition portion **8**g execute the periodic singular part determination process and the feature pattern recognition process using the first feature image g**21**, the second feature image g**22**, and the third feature image g**23**, thereby determining the causes of the vertical streak Ps**11**, the horizontal streak Ps**12**, and the noise point Ps**13**, which are types of the image defects, respectively (see step S**205** and step S**206** in FIG. **4**, and FIG. **6**).

(240) Since the determination of the cause of the image defect is separately performed for the three feature images g**21**, g**22**, and g**23** including the singular parts Ps**1** of different types, the cause of the image defect can be determined with high accuracy by a relatively simple determination process.

(241) The periodic singular part determination process in step S**205** is a process of determining the presence/absence of one or more predetermined periodicities in the sub-scanning direction D**2** for the second feature image g**22** or the third feature image g**23**, and determining the cause of the horizontal streaks Ps**12** or the noise points Ps**13** in accordance with the periodicity determination result.

(242) When the horizontal streaks Ps**12** or the noise points Ps**13** are caused by a defect in the image-forming related rotary body, the cause of the horizontal streaks Ps**12** or the noise points Ps**13** can be determined with high accuracy by the periodic singular part determination process of determining the periodicity corresponding to the outer circumferential length of the rotary body.

(243) The feature pattern recognition process in step S**206** is a process of determining which of a plurality of predetermined cause candidates corresponding to the vertical streak, the horizontal streak, and the noise point the input image corresponds to by pattern recognition of the input image. Here, the first feature image g**21** and the image determined to have no periodicity by the periodic singular part determination process among the second feature image g**22** and the third feature image g**23** are the input images in step S**206** (see steps S**204** to S**206** in FIG. **4**).

(244) The periodic singular part determination process in step S**205** and the feature pattern recognition process in step S**206** are an example of a predetermined cause determination process using the first feature image g**21**, the second feature image g**22**, and the third feature image g**23**.

(245) The feature pattern recognition process using a trained model or the like is performed for each of the feature images g**21**, g**22**, and g**23** into which specific types of singular parts Ps**1** have been extracted respectively. This allows determination of the cause of the image defect with high accuracy while suppressing the amount of calculation at the CPU **80**. Further, the trained model for each type of the singular part Ps**1** can be sufficiently trained only by preparing a relatively small amount of training data corresponding to the specific type of the singular part Ps**1**.

(246) The feature pattern recognition process in step S**206** is executed on the first feature image g**21** which was not subjected to the periodic singular part determination process in step S**205**, and the second feature image g**22** or the third feature image g**23** determined to have no periodicity by

the periodic singular part determination process in step S**205**, among the feature images g**21**, g**22**, and g**23** (see steps S**204** to S**206** in FIG. **4**).

(247) In the above case, the feature pattern recognition process can exclude the possibility that the cause of the image defect is a cause corresponding to the periodicity of an image-forming related rotary body. This simplifies the feature pattern recognition process.

(248) In addition, the color vector identification portion **8***e* identifies the color vector representing a vector in the color space from one to the other of the color of the singular part Ps**1** in the test image g**1** and the color of the reference area including the periphery of the singular part Ps**1** (see step S**203** in FIG. **4**).

(249) Then, in the cause determination process, the periodicity determination portion **8***f* in step S**205** and the pattern recognition portion **8***g* in step S**206** further use the color vector to determine the causes of the vertical streaks Ps**11**, the horizontal streaks Ps**12**, and the noise points Ps**13**. That is, the periodicity determination portion **8***f* and the pattern recognition portion **8***g* use the color vector to determine which of the plurality of developing colors in the image forming device **2** corresponds to the cause of the image defect.

(250) In the image forming device **2** capable of printing a color image, the use of the color vector makes it possible to easily and reliably determine the portion corresponding which color of the plurality of developing colors the image defect is caused by.

(251) In addition, the periodicity determination portion **8***f* executes the periodic unevenness determination process for each of the predetermined specific colors for the test image g**1** (see steps S**301** and S**302** in FIG. **5**). The periodic unevenness determination process is a process of determining the presence/absence of one or more predetermined periodicities in the sub-scanning direction D**2**, and further determining the presence/absence of the occurrence of the periodic density unevenness, which is a type of the image defect, and the cause thereof in accordance with the periodicity determination result.

(252) The cause of the periodic density unevenness can be determined with high accuracy by the periodic unevenness determination process.

(253) In addition, the random unevenness determination portion **8***h* determines the presence/absence of the occurrence of the random density unevenness by determining whether or not the pixel value variation for each specific color exceeds a predetermined allowable range for the test image g**1** determined to have no periodicity by the periodic unevenness determination process of step S**302** (see step S**303** in FIG. **5**). The random density unevenness is a type of the image defect.

(254) In addition, the pattern recognition portion **8***g* executes the random pattern recognition process using the test image g**1** determined to have the random density unevenness as the input image (see step S**304** in FIG. **5**). In the random pattern recognition process, it is determined which of the one or more cause candidates the input image corresponds to by pattern recognition of the input image.

(255) The test image g**1** is a mixed-color halftone image obtained by combining a plurality of uniform single-color halftone images corresponding to a plurality of developing colors in the image forming device **2**. This allows the CPU **80** to determine the cause of the image defect for all the developing colors in the image forming device **2**, using the test images g**1** smaller in number than the developing colors used by the image forming device **2**.

First Application Example

(256) Next, the procedure of the feature image generation process in a first application example of the image processing apparatus **10** will be described with reference to the flowchart shown in FIG. **9**.

(257) In the following description, S**401**, S**402**, . . . represent identification codes of a plurality of steps in the feature image generation process according to the present application example. The feature image generating process according to the present application example starts from step

S**401**.
(258) <Step S**401**>
(259) In step S**401**, the feature image generation portion **8***c* selects a compression ratio to be adopted from a plurality of preset compression ratio candidates, and shifts the process to step S**402**.
(260) <Step S**402**>
(261) In step S**402**, the feature image generation portion **8***c* generates a test image g**1** by compressing the read image at the selected compression ratio. The processes of steps S**401** and S**402** are an example of a compression process. Thereafter, the feature image generation portion **8***c* shifts the process to step S**403**.
(262) <Step S**403**>
(263) In step S**403**, the feature image generation portion **8***c* generates a first preprocessed image g**11** by executing the first preprocessing on the compressed test image g**1** obtained in step S**402**. Thereafter, the feature image generation portion **8***c* shifts the process to step S**404**.
(264) <Step S**404**>
(265) In step S**404**, the feature image generation portion **8***c* generates a second preprocessed image g**12** by executing the second preprocessing on the compressed test image g**1** obtained in step S**402**. Thereafter, the feature image generation portion **8***c* shifts the process to step S**405**.
(266) <Step S**405**>
(267) In step S**405**, the feature image generation portion **8***c* shifts the process to step S**406** when the processes of steps S**401** to S**404** have been executed for all of the plurality of compression ratio candidates, and otherwise executes the processes of steps S**401** to S**404** for a different compression ratio.
(268) The feature image generation portion **8***c* generates a plurality of test images g**1** having different sizes by compressing the read image at a plurality of compression ratios in the compression process of steps S**401** and S**402**.
(269) Further, in steps S**403** and S**404**, the feature image generation portion **8***c* executes the first preprocessing and the second preprocessing on the plurality of test images g**1** to generate a plurality of first preprocessed images g**11** and a plurality of second preprocessed images g**12** corresponding to the plurality of test images g**1**.
(270) <Step S**406**>
(271) In step S**406**, the feature image generation portion **8***c* executes the singular part extraction process on each of the plurality of first preprocessed images g**11** and the plurality of second preprocessed images g**12**. Thus, the feature image generation portion **8***c* generates a plurality of candidates for each of the first feature image g**21**, the second feature image g**22**, and the third feature image g**23** corresponding to the plurality of test images g**1**. Thereafter, the feature image generation portion **8***c* shifts the process to step S**407**.
(272) <Step S**407**>
(273) In step S**407**, the feature image generation portion **8***c* generates the first feature image g**21**, the second feature image g**22**, and the third feature image g**23** by aggregating the plurality of candidates obtained in step S**406**. Thereafter, the feature image generation portion **8***c* terminates the feature image generation process.
(274) For example, the feature image generation portion **8***c* sets a representative value such as a maximum value or an average value of respective pixel values in a plurality of candidates of the first feature image g**21** as the corresponding pixel value of the first feature image g**21**. The same applies to the second feature image g**22** and the third feature image g**23**.
(275) The processes of steps S**401** to S**404** are an example of a process of generating a plurality of first preprocessed images g**11** and a plurality of second preprocessed images g**12** by executing the first preprocessing and the second preprocessing a plurality of times at different size ratios to the size of the test image g**1** and the area of interest Ax**1** and the adjacent areas Ax**2**. Changing the compression ratio is an example of changing the size ratio to the size of the test image g**1** and the

area of interest Ax**1** and the adjacent areas Ax**2**.

(276) In addition, the processes of steps S**406** to S**407** is an example of a process of generating the first feature image g**21**, the second feature image g**22**, and the third feature image g**23** by the singular part extraction process based on a plurality of first preprocessed images g**11** and a plurality of second preprocessed images g**12**.

(277) This application example allows extraction of vertical streaks Ps**11** or horizontal streaks Ps**12** with different thicknesses or noise points Ps**13** with different sizes without omission.

Second Application Example

(278) Next, the procedure of the feature image generation process in a second application example of the image processing apparatus **10** will be described with reference to the flowchart shown in FIG. **10**.

(279) In the following description, S**501**, S**502**, . . . represent identification codes of a plurality of steps in the feature image generation process according to the present application example. The feature image generating process according to the present application example starts from step S**501**.

(280) <Steps S**501** to S**505**>

(281) The feature image generation portion **8***c* executes the processes of steps S**501** to S**505**, which are the same as those of steps S**401** to S**405**. In step S**505**, the feature image generation portion **8***c* shifts the process to step S**506** when the processes of steps S**501** to S**504** have been executed for all of the plurality of compression ratio candidates.

(282) <Step S**506**>

(283) In step S**506**, the feature image generation portion **8***c* aggregates each of a plurality of first preprocessed images g**11** and a plurality of second preprocessed images into one image. Thereafter, the feature image generation portion **8***c* shifts the process to step S**507**.

(284) For example, the feature image generation portion **8***c* sets a representative value such as a maximum value or an average value of respective pixel values in a plurality of first preprocessed images g**11** as the corresponding pixel value of the aggregated first feature image g**21**. The same applies to a plurality of second preprocessed images g**12**.

(285) <Step S**506**>

(286) In step S**506**, the feature image generation portion **8***c* generates a first feature image g**21**, a second feature image g**22**, and a third feature image g**23** by executing the singular part extraction process on the aggregated first preprocessed image g**11** and second preprocessed image g**12**. Thereafter, the feature image generation portion **8***c* terminates the feature image generation process.

(287) When the present application example is adopted, the same effect as that when the first application example is adopted can be obtained.

Third Application Example

(288) Next, the procedure of the feature image generation process in a third application example of the image processing apparatus **10** will be described with reference to the flowchart shown in FIG. **11**.

(289) In the following description, S**601**, S**602**, . . . represent identification codes of a plurality of steps in the feature image generation process according to the present application example. The feature image generating process according to the present application example starts from step S**601**.

(290) In the following description, the size of the area of interest Ax**1** and the adjacent areas Ax**2** in the first preprocessing and the second preprocessing will be referred to as a filter size.

(291) <Step S**601**>

(292) In step S**601**, the feature image generation portion **8***c* selects the filter size to be adopted from a plurality of preset size candidates, and shifts the process to step S**602**.

(293) <Step S**602**>

(294) In step S**602**, the feature image generation portion **8***c* generates a first preprocessed image g**11** by executing the first preprocessing with the filter size selected in step S**601** on the test image g**1**. Thereafter, the feature image generation portion **8***c* shifts the process to step S**603**.

(295) <Step S**603**>

(296) In step S**603**, the feature image generation portion **8***c* generates a second preprocessed image g**12** by executing the second preprocessing with the filter size selected in step S**601** on the test image g**1**. Thereafter, the feature image generation portion **8***c* shifts the process to step S**604**.

(297) <Step S**604**>

(298) In step S**604**, the feature image generation portion **8***c* shifts the process to step S**605** when the processes of steps S**601** to S**603** have been executed for all of the plurality of size candidates, and otherwise executes the processes of steps S**601** to S**603** with a different filter size.

(299) In steps S**601** to S**604**, the feature image generation portion **8***c* executes a plurality of times of the first preprocessing and a plurality of times of the second preprocessing with different sizes of the area of interest Ax**1** and the adjacent areas Ax**2** on one test image g**1**. Thus, the feature image generation portion **8***c* generates a plurality of first preprocessed images g**11** and a plurality of second preprocessed images g**12**.

(300) <Steps S**605** and S**606**>

(301) In steps S**605** and S**606**, the feature image generation portion **8***c* executes the same processes as those of steps S**406** and S**407** in FIG. **9**. Thereafter, the feature image generation portion **8***c* terminates the feature image generation process.

(302) By the processes of steps S**605** and S**606**, a plurality of candidates of each of the first feature image g**21**, the second feature image g**22**, and the third feature image g**23** are aggregated, and the aggregated first feature image g**21**, the second feature image g**22**, and the third feature image g**23** are generated.

(303) The processes of steps S**601** to S**604** are an example of a process of generating a plurality of first preprocessed images g**11** and a plurality of second preprocessed images g**12** by executing the first preprocessing and the second preprocessing a plurality of times at different size ratios to the size of the test image g**1** and the area of interest Ax**1** and the adjacent areas Ax**2**. Changing the filter size is an example of changing the size ratio to the size of the test image g**1** and the area of interest Ax**1** and the adjacent areas Ax**2**.

(304) This application example allows extraction of vertical streaks Ps**11** or horizontal streaks Ps**12** with different thicknesses or noise points Ps**13** with different sizes without omission.

Fourth Application Example

(305) Next, the procedure of the feature image generation process in a fourth application example of the image processing apparatus **10** will be described with reference to the flowchart shown in FIG. **11**.

(306) In the following description, S**701**, S**702**, . . . represent identification codes of a plurality of steps in the feature image generation process according to the present application example. The feature image generating process according to the present application example starts from step S**701**.

(307) <Steps S**701** to S**704**>

(308) The feature image generation portion **8***c* executes the processes of steps S**701** to S**704**, which are the same as those of steps S**601** to S**604**. In step S**704**, the feature image generation portion **8***c* shifts the process to step S**705** when the processes of steps S**701** to S**703** have been executed for all of the plurality of size candidates.

(309) <Steps S**705** and S**706**>

(310) Further, the feature image generation portion **8***c* executes the processes of steps S**705** and S**706**, which are the same processes as those of steps S**506** and S**507**. Thereafter, the feature image generation portion **8***c* terminates the feature image generation process.

(311) When the present application example is adopted, the same effect as that when the first

application example is adopted can be obtained.

Fifth Application Example

(312) Next, the feature image generating process in the fifth application example of the image processing apparatus **10** will be described.

(313) In the present application example, the feature image generation portion **8***c* compares each pixel value of the first preprocessed image g**11** and the second preprocessed image g**12** with a predetermined reference range to discriminate the pixels that constitute the singular part Ps**1** from the pixels that do not.

(314) That is, in the present application example, the feature image generation portion **8***c* identifies the singular part Ps**1** by the magnitude of each pixel value of the first preprocessed image g**11** and the second preprocessed image g**12** in the singular part extraction process.

(315) Further, the feature image generation portion **8***c* extracts the vertical streak Ps**11** by excluding the singular part Ps**1** common to the first preprocessed image g**11** and the second preprocessed image g**12** from the singular parts Ps**1** of the first preprocessed image g**11**.

(316) Further, the feature image generation portion **8***c* extracts the horizontal streak Ps**12** by excluding the singular part Ps**1** common to the first preprocessed image g**11** and the second preprocessed image g**12** from the singular parts Ps**1** of the second preprocessed image g**12**.

(317) Further, the feature image generation portion **8***c* extracts the singular part Ps**1** common to the first preprocessed image g**11** and the second preprocessed image g**12** as the noise point Ps**13**.

(318) For example, the feature image generation portion **8***c* generates a first feature image g**21** by converting a first pixel value Xi determined to be a part other than the vertical streak Ps**11** in the first preprocessed image g**11** into an interpolated value based on the surrounding pixel values.

(319) Similarly, the feature image generation portion **8***c* generates a second feature image g**22** by converting a second pixel value Yi determined to be a part other than the horizontal streak Ps**12** in the second preprocessed image g**12** into an interpolated value based on the surrounding pixel values.

(320) Similarly, the feature image generation portion **8***c* generates a third feature image g**23** by converting a first pixel value Xi determined to be a part other than the noise point Ps**13** in the first preprocessed image g**11** into an interpolated value based on the surrounding pixel values.

(321) Alternatively, the feature image generation portion **8***c* may generate the third feature image g**23** by converting the second pixel value Yi determined to be a part other than the noise point Ps**13** in the second preprocessed image g**12** into an interpolated value based on the surrounding pixel values.

Claims

1. An image processing method in which a processor determines a cause of an image defect based on a test image read from an output sheet of an image forming device, the method comprising: generating, by the processor, a plurality of feature images by executing a predetermined feature extraction process on the test image; and executing, by the processor, a feature pattern recognition process of using each of the plurality of feature images as an input image and determining which of a plurality of predetermined cause candidates corresponding to the image defect the input image corresponds to by pattern recognition of the input image, wherein the plurality of feature images include a first feature image, a second feature image, and a third feature image, and the feature extraction process includes: generating a first preprocessed image by executing, with a horizontal direction of the test image used as a processing direction, first preprocessing including a main filter process of converting a pixel value of each pixel of interest sequentially selected from the test image into a converted value obtained by a process of emphasizing a difference between pixel values of an area of interest including the pixel of interest and pixel values of two preset adjacent areas adjacent to the area of interest on both sides in the processing direction; generating a second

preprocessed image by executing second preprocessing including the main filter process with a vertical direction of the test image used as the processing direction; and generating the first feature image into which a first singular part that is present in the first preprocessed image and is not common to the first preprocessed image and the second preprocessed image among singular parts each consisting of one or more significant pixels in the first preprocessed image and the second preprocessed image has been extracted, the second feature image into which a second singular part that is present in the second preprocessed image and is not common to the first preprocessed image and the second preprocessed image among the singular parts has been extracted, and the third feature image into which a third singular part that is common to the first preprocessed image and the second preprocessed image among the singular parts has been extracted.

2. The image processing method according to claim 1, further comprising: executing, by the processor, a periodic singular part determination process of determining presence or absence of one or more predetermined periodicities in a predetermined sub-scanning direction for one or more of the plurality of feature images and determining the cause of the image defect in accordance with a periodicity determination result, wherein the feature pattern recognition process is executed for a feature image of the plurality of feature images that was not subjected to the periodic singular part determination process and a feature image of the plurality of feature images that was determined to have no periodicity by the periodic singular part determination process.

3. The image processing method according to claim 1, wherein the first preprocessing includes: generating first main map data by executing the main filter process with the horizontal direction used as the processing direction; generating horizontal edge intensity map data by executing an edge enhancement filter process on the test image targeting the area of interest and one of the two adjacent areas with the horizontal direction used as the processing direction; and generating the first preprocessed image by correcting each pixel value of the first main map data with a corresponding pixel value of the horizontal edge intensity map data, and the second preprocessing includes: generating second main map data by executing the main filter process with the vertical direction used as the processing direction; generating vertical edge intensity map data by executing the edge enhancement filter process on the test image targeting the area of interest and one of the two adjacent areas with the vertical direction used as the processing direction; and generating the second preprocessed image by correcting each pixel value of the second main map data with a corresponding pixel value of the vertical edge intensity map data.

4. The image processing method according to claim 1, further comprising: executing, by the processor, a periodic unevenness determination process of determining presence or absence of one or more predetermined periodicities in a sub-scanning direction for each predetermined color for the test image and determining presence or absence of occurrence of periodic density unevenness, which is a type of the image defect, in accordance with a periodicity determination result.

5. The image processing method according to claim 4, further comprising: determining the presence or absence of occurrence of random density unevenness, which is a type of the image defect, by determining for each predetermined color whether or not a pixel value variation exceeds a predetermined allowable range for the test image determined to have no periodicity by the periodic unevenness determination process.

6. The image processing method according to claim 5, further comprising: executing, by the processor, a random pattern recognition process of using the test image determined to have the random density unevenness as the input image and determining which one or more of the cause candidates the input image corresponds to by pattern recognition of the input image.

7. The image processing method according to claim 1, wherein the feature pattern recognition process is a process of classifying the input image into one of the plurality of cause candidates using a trained model trained in advance using a plurality of sample images corresponding to the plurality of cause candidates as training data.

8. The image processing method according to claim 1, further comprising: transmitting, by the

processor, a message corresponding to the determination result in the feature pattern recognition process to a predetermined terminal through a communication device.

9. An image processing apparatus comprising a processor for executing the processes of the image processing method according to claim 1.