

DESCRIPTION

IMAGE PROCESSING APPARATUS, IMAGE PROCESSING METHOD, AND COMPUTER-READABLE RECORDING MEDIUM

TECHNICAL FIELD

[0001] The present invention relates to an image processing apparatus and an image processing method for making it possible to build a three-dimensional shape from a plurality of images, and also to a computer-readable recording medium, in which a program for realizing the apparatus and method is recorded.

BACKGROUND ART

[0002] In recent years, techniques for building a three-dimensional shape of a target that is shown in an image have been garnering attention. SfM (Structure from Motion) is known as a representative example of such techniques. In SfM, a three-dimensional shape of a specific target is regenerated from a plurality of images acquired by shooting images of the specific target a plurality of times while changing the viewpoint of a camera.

[0003] Specifically, in SfM, first, feature amounts (SIFT feature amounts, SURF feature amounts, etc.) are calculated for each image, and feature points that are robust against enlargement, reduction, and rotation of an image and illuminance change are extracted. Next, the extracted feature points are matched between images, and pairs of feature points that match are extracted. Next, for example, geometric relationships between the respective pairs of feature points are calculated, and incorrect pairs of feature points are removed through robust estimation.

[0004] Thereafter, for each of several pairs of feature points, a fundamental matrix is calculated based on the geometric relationships of the pairs of feature points, and the geometric relationship of each pair of feature points is adjusted so as to minimize the difference between the calculated fundamental matrixes. A three-dimensional shape (a group of points) is then rebuilt based on the adjusted geometric relationships. Note that a processing technique called "Bundle Adjustment" may be adopted as an error

that a processing technique called “Bundle Adjustment” may be adopted as an error adjustment method at this time.

[0001] Incidentally, in the above-described SfM, there are cases where matching is incorrect, and, in these cases, a pair of different feature points is extracted, decreasing the accuracy of a three-dimensional shape that is regenerated. Moreover, as a result of the number of extracted pairs of feature points being small, and matching having not been entirely successful, there may be a region in which the number of pairs of feature points is small. Also in this case, the accuracy of a three-dimensional shape that is regenerated decreases.

[0002] In contrast, Patent Document 1 discloses a system for correcting the positions of corresponding feature points. Specifically, the system disclosed in Patent Document 1 first arranges two images such that the epipolar lines thereof extend in parallel with scanning lines, and extracts corresponding feature points from the images for each of the scanning lines.

[0003] Next, this system accepts user input of a line segment for designating corresponding locations, on the images. This system then determines whether or not corresponding feature points on a scanning line coincide with the intersection between this scanning line and the input line segment, and if not, corrects the positions of the feature points to the position of the intersection. Thereafter, the system regenerates a three-dimensional shape using feature points whose positions have been corrected.

[0004] As described above, according to the system disclosed in Patent Document 1, the issue of incorrect pairs of feature points being extracted and the issue of a region having a small number of pairs of feature points are solved, and thus the issue of a decrease in the accuracy of three-dimensional shape that is regenerated is solved.

LIST OF RELATED ART DOCUMENTS

PATENT DOCUMENT

[0005] Patent document 1: Japanese Patent Laid-Open Publication No. 5311465

SUMMARY

[0010] However, in the system disclosed in Patent Document 1, the positions of feature points are only corrected on scanning lines that extend along the epipolar lines of two images, and thus incorrect pairs of feature points that are not on the same scanning line are not corrected. Therefore, in the system disclosed in Patent Document 1, incorrect pairs of feature points are not sufficiently corrected, and it is difficult to suppress a decrease in the accuracy of a three-dimensional shape that is regenerated.

[0011] An example object of the disclosure is to solve the foregoing issues by providing an image processing apparatus, an image processing method, and a computer-readable recording medium that can suppress extraction of incorrect combinations of feature points when extracting combinations of corresponding feature points from a plurality of images.

[0012] In a first aspect, the present disclosure provides an image processing apparatus for building a three-dimensional shape from a plurality of images, the apparatus comprising:

- a feature point extraction unit configured to extract combinations of corresponding feature points from the plurality of images;

- a matrix calculation unit configured to, if two or more line segments or two or more points corresponding to each other, different and independent from the extracted feature points, are designated in at least two images out of the plurality of images, specify a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculate a numerical matrix that represents the specified geometric relationship; and

- a shape building unit configured to specify a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and build the three-dimensional shape using the combinations of feature points other than the specified combination of feature

points.

[0013] In addition, in a second aspect, the present disclosure provides an image processing

method for building a three-dimensional shape from a plurality of images, the method comprising:

- (a) a step of extracting combinations of corresponding feature points from the plurality of images;

- (b) a step of, if two or more line segments or two or more points corresponding to each other, different and independent from the extracted feature points, are designated in at least two images out of the plurality of images, specifying a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculating a numerical matrix that represents the specified geometric relationship; and

- (c) a step of specifying a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and building the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

[0014] Furthermore, in a third aspect, the present disclosure provides a computer-readable recording medium that includes a program recorded thereon for building a three-dimensional shape from a plurality of images, the program including instructions that cause a computer to carry out:

- (a) a step of extracting combinations of corresponding feature points from the plurality of images;

- (b) a step of, if two or more line segments or two or more points corresponding to each other, different and independent from the extracted feature points, are designated in at least two images out of the plurality of images, specifying a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculating a numerical matrix that represents the specified geometric relationship; and

- (c) a step of specifying a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using

the numerical matrix, and building the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

[0011] As described above, according to the present disclosure, it is possible to suppress extraction of an incorrect combination of feature points when extracting combinations of corresponding feature points from a plurality of images.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a block diagram illustrating a schematic configuration of an image processing apparatus according to an example embodiment of the invention.

FIG. 2 is a block diagram illustrating a specific configuration of an image processing apparatus according to an example embodiment of the invention.

FIG. 3 is a diagram illustrating an example of a plurality of images to be processed according to an example embodiment of the invention.

FIG. 4 is a diagram illustrating processing performed by a matrix calculation unit according to an example embodiment of the invention.

FIG. 5 is a diagram illustrating processing performed by a shape building unit according to an example embodiment of the invention.

FIG. 6 is a flowchart illustrating operations of an image processing apparatus according to an example embodiment of the invention.

FIG. 7 is a block diagram illustrating an example of a computer that realizes an image processing apparatus according to an example embodiment of the invention.

EXAMPLE EMBODIMENT

[0013] (Example Embodiment)

The following describes an image processing apparatus, an image processing method, and a program according to an example embodiment of the invention with reference to FIGS. 1 to 7.

[0014] [Apparatus Configuration]

illustrating the schematic configuration of the image processing apparatus according to the example embodiment of the present invention.

[0019] As shown in FIG. 1, an image processing apparatus 10 in this example embodiment is an apparatus that builds a three-dimensional shape from a plurality of images. Image data of a plurality of images to be processed is input to the image processing apparatus 10.

[0020] In addition, as shown in FIG. 1, the image processing apparatus 10 includes a feature point extraction unit 11, a matrix calculation unit 12, and a shape building unit 13. Of these, the feature point extraction unit 11 extracts combinations of corresponding feature points from a plurality of images.

[0021] If two or more line segments or two or more points corresponding to each other are designated in at least two images out of the plurality of images, the matrix calculation unit 12 specifies the geometric relationship between the two or more line segments corresponding to each other or the geometric relationship between the two or more points corresponding to each other. The matrix calculation unit 12 then calculates a numerical matrix that represents the specified geometric relationship.

[0022] The shape building unit 13 specifies a combination of feature points with a conflicting geometrical relationship, from among the extracted combinations of feature points, using the numerical matrix calculated by the matrix calculation unit 12. The shape building unit 13 then builds a three-dimensional shape using combinations of feature points other than the specified combination of feature points.

[0023] As described above, in this example embodiment, an incorrect combination of feature points is specified using the specified geometric relationship between two or more designated line segments or points, and thus it is also possible to exclude an incorrect combination of feature points that are not on the same scanning line. According to this example embodiment, when extracting combinations of corresponding feature points from a plurality of images, it is possible to suppress extraction of an incorrect combination of feature points, and it is possible to improve the accuracy of a three-dimensional shape that is regenerated.

[0024] Subsequently, the configuration of the image processing apparatus 10 in this

example embodiment will be described in more detail with reference to FIGS. 2 to 5. FIG. 2 is a block diagram illustrating a specific configuration of the image processing apparatus in the example embodiment of the invention.

[0025] As shown in FIG. 2, in this example embodiment, the image processing apparatus 10 also includes an image acquisition unit 14, a filtering unit 15, an input accepting unit 16, and a display unit 17 in addition to the feature point extraction unit 11, the matrix calculation unit 12, and the shape building unit 13.

[0026] The image acquisition unit 14 acquires image data of a plurality of images in which a target for building a three-dimensional shape is shown, from an external device such as an image capturing apparatus, a terminal device, or a storage device that stores image data. FIG. 3 is a diagram illustrating an example of a plurality of images to be processed in this example embodiment. In the example in FIG. 3, a pair of images are illustrated, but, in this example embodiment, the number of images to be processed is not particularly limited.

[0027] In this example embodiment, the feature point extraction unit 11 calculates SIFT feature amounts, SURF feature amounts, or the like for each image to specify feature points, and furthermore, extracts feature points corresponding to each other between images as a combination of corresponding feature points. Note that, in the example in FIG. 3, the number of images is two, and thus a combination of feature points is a pair of feature points. Also, in FIG. 3, each portion surrounded by a circle is a feature point.

[0028] The filtering unit 15 calculates a geometric relationship between feature points for each combination of feature points, specifies an incorrect combination of feature points based on the calculation result, and excludes the specified combination of feature points. Filtering processing that is performed by the filtering unit 15 is performed using robust estimation similarly to conventional processing. In this example embodiment, in addition to filtering that is performed by the shape building unit 13 to be described later, filtering is also performed by the filtering unit 15, and thus an incorrect combination of feature points can be excluded more reliably.

[0029] When line segments or points corresponding to each other in images to be processed are designated, the input accepting unit 16 accepts input of the designated line

segments or points. In addition, when input of line segments corresponding to each other between images is accepted, the input accepting unit 16 notifies the matrix calculation unit 12 of information regarding the line segments (the coordinates of the start points and the end points), and when input of points corresponding to each other is accepted, notifies the matrix calculation unit 12 of information regarding the points (coordinates). Note that line segments or points may be designated by the user of the image processing apparatus 10, or may also be designated by another calculator.

[0030] Upon being notified of information regarding line segments or points in images by the input accepting unit 16, the matrix calculation unit 12 specifies a geometric relationship between the line segments or points based on the notified information, calculates a numerical matrix that represents the specified geometric relationship, and defines this numerical matrix as an absolute numerical matrix. If a numerical matrix cannot be calculated from the information regarding line segments or points in the images notified from the input accepting unit 16, or there is no information regarding line segments or points depending on an image, the matrix calculation unit 12 can also calculate a numerical matrix from a combination of feature points extracted by the feature point extraction unit 11 and left with few errors after being filtered by the filtering unit 15. Note that, in this case, a numerical matrix that is calculated is a numerical matrix similar to a conventional numerical matrix, and is not an absolute numerical matrix.

[0031] Here, processing in the matrix calculation unit 12 will be described in more detail with reference to FIG. 4. FIG. 4 is a diagram illustrating processing performed by the matrix calculation unit according to the example embodiment of the invention. In FIG. 4, E denotes an epipolar plane, O_i denotes a central position of a camera of one image, and O'_i denotes a central position of a camera of the other image. Also, in FIG. 4, each of the parallelograms shown on the left and right sides indicates a frame of an image.

[0032] In addition, in the example in FIG. 4, a line segment L is designated in the one image, a line segment L' is designated in the other image, and the line segments correspond to each other. In this case, an epipolar line l_n that intersects with the start point of the line segment L and an epipolar line l_{n+m} that intersects with the end point of the line segment L are defined as absolute epipolar lines, and an epipolar line l'_n that

intersects with the start point of the line segment L' and an epipolar line l'_{n+m} that intersects with the end point of the line segment L' are also defined as absolute epipolar lines.

[0033] Furthermore, an intersection x_i between the line segment L and the absolute epipolar line l_n and an intersection x'_i between the line segment L and the absolute epipolar line l'_n are defined as a combination of absolute feature points. Also, an intersection x_j between the line segment L and the absolute epipolar line l_{n+m} and an intersection x'_j between the line segment L' and the absolute epipolar line l'_{n+m} are also defined as a combination of absolute feature points.

[0034] Note that, as shown in FIG. 4, any epipolar lines l_{n+1} and l_{n+2} may also be set between the epipolar line l_n and the epipolar line l_{n+m} . In this case, similarly, any epipolar lines l'_{n+1} and l'_{n+2} are also set between the epipolar line l'_n and the epipolar line l'_{n+m} . In addition, in this case, the intersections between the line segment L and the newly set epipolar lines l_{n+1} and l_{n+2} and the intersections between the line segment L' and the newly set epipolar lines l'_{n+1} and l'_{n+2} form a combination of absolute feature points. Note that the distances between the epipolar lines are set to any value.

[0035] Therefore, in the example in FIG. 4, the matrix calculation unit 12 obtains the combinations of absolute feature points as the geometric relationships between the line segments, and calculates a fundamental matrix (Reference document) as an absolute numerical matrix based on a relational expression (Expression 1 below) using an obtained combination of feature points. Note that, in Expression 1 below, “ x ” indicates a point on a two-dimensional plane acquired by projecting a point X in a three-dimensional space onto one image. “ x' ” indicates a point on a two-dimensional plane acquired by projecting the point X in the three-dimensional space onto the other image. T indicates a transposed matrix. Also, F indicates a fundamental matrix. In addition, in this example embodiment, a numerical matrix is not limited to a fundamental matrix, and may be any matrix that can represent a geometric relationship.

[0036]

(Expression 1)

$$x'^T F x = 0$$

[0037] Reference document: Richard Hartley and Andrew Zisserman, "Multiple View Geometry in Computer Vision Second Edition", Cambridge University Press, March 2004.

[0038] In this example embodiment, first, the shape building unit 13 removes a combination of feature points with a conflicting geometric relationship, from the combinations of feature points extracted by the feature point extraction unit 11 (excluding combinations removed by the filtering unit 15), using the numerical matrix (fundamental matrix) calculated by the matrix calculation unit 12. Thereafter, the shape building unit 13 builds a three-dimensional shape using combinations of feature points from which the combination of feature points with a conflicting geometric relationship has been removed, and, at this time, the corresponding points or points on corresponding line segments accepted by the input accepting unit 16 can also be used as one of the combinations of feature points.

[0039] In addition, the shape building unit 13 can specify feature points that overlap the designated line segments or points, from among the combinations of feature points extracted by the feature point extraction unit 11 (excluding combinations removed by the filtering unit 15), and also remove a combination of feature points that includes the specified feature points. This is because it is highly likely that, when feature points corresponding to feature points that overlap the line segments or points in one image are not on the line segments or points in the other image, a combination of the feature points is incorrect. Thereafter, the shape building unit 13 builds a three-dimensional shape using the remaining combinations of feature points.

[0040] Here, processing in the shape building unit 13 will be described in more detail with reference to FIG. 5. FIG. 5 is a diagram illustrating processing performed by the shape building unit according to the example embodiment of the present invention. In FIG. 5, parts assigned with reference signs shown in FIG. 4 indicate parts provided with the same signs in FIG. 4. In addition, in FIG. 5, a determination is made as to whether or not a combination of a feature point p_i and a feature point p'_i is incorrect.

[0041] In the example in FIG. 5, the shape building unit 13 calculates an epipolar line l'_1 corresponding to an epipolar line l_1 on which the feature point p_i is positioned, using the

relationship represented in Expression 2 below regarding an epipolar line.

[0042]

(Expression 2)

$$l' = Fx$$

[0043] The shape building unit 13 then determines whether or not a distance d between the calculated epipolar line l'_i and the feature point p'_i is larger than or equal to a threshold value, and if the distance d is larger than or equal to the threshold value, determines that the combination of the feature point p_i and the feature point p'_i is incorrect. In this case, the shape building unit 13 removes the combination of the feature point p_i and the feature point p'_i , and builds a three-dimensional shape.

[0044] In addition, in this example embodiment, the shape building unit 13 may also temporarily build a temporary three-dimensional shape using combinations of feature points filtered by the filtering unit 15. In this case, the user can specify a location in the three-dimensional shape that is not sufficiently regenerated, based on the temporary three-dimensional shape, and thus appropriate line segments or points can be designated. Thereafter, the shape building unit 13 rebuilds a three-dimensional shape.

[0045] Moreover, the display unit 17 displays the three-dimensional shape built by the shape building unit 13, on the screen of a display device 20. Specifically, the display unit 17 creates image data for displaying the built three-dimensional shape on a two-dimensional screen, and outputs the created image data to the display device 20. Furthermore, also if the shape building unit 13 builds a temporary three-dimensional shape, the display unit 17 displays this temporary three-dimensional shape on the screen of the display device 20.

[0046] [Apparatus Operations]

Next, operations of the image processing apparatus 10 in the example embodiment of the invention will be described with reference to FIG. 6. FIG. 6 is a flowchart illustrating operations of the image processing apparatus in the example embodiment of the invention. The following description is given with reference to FIGS. 1 to 5 as appropriate. In this example embodiment, an image processing method is

carried out by causing the image processing apparatus 10 to operate. Thus, description of the image processing method according to this example embodiment is substituted by the following description of the operations of the image processing apparatus 10.

[0047] As shown in FIG. 6, first, the image acquisition unit 14 acquires, from an external apparatus, image data of a plurality of images in which a target whose three-dimensional shape is to be built is shown (step A1).

[0048] Next, the feature point extraction unit 11 calculates feature amounts for each of the images of the image data acquired in step A1 to specify feature points, and extracts feature points corresponding to each other between the images, as combinations of corresponding feature points (step A2).

[0049] Next, the filtering unit 15 calculates a geometric relationship between feature points of each of the combinations of feature points extracted in step A2, specifies an incorrect combination of feature points based on the calculation result, and removes the specified combination of feature points (step A3).

[0050] Next, the shape building unit 13 builds a temporary three-dimensional shape using combinations of feature points that have been subjected to the filtering processing in step A3 (step A4). In addition, when step A4 is executed, the display unit 17 displays the temporary three-dimensional shape built in step A4, on the screen of the display device 20.

[0051] When step A4 is executed, and the temporary three-dimensional shape is displayed on the screen of the display device 20, the user designates, via an input device (not illustrated in FIG. 2), line segments or points corresponding to each other between the images. Accordingly, the input accepting unit 16 accepts input of the designated line segments or points (step A5). The input accepting unit 16 also notifies the matrix calculation unit 12 of information regarding the designated line segments or information regarding the designated points.

[0052] Next, when step A5 is executed, the matrix calculation unit 12 specifies a geometric relationship between line segments or points based on the information regarding the line segments or information regarding the points, and calculates a numerical matrix that represents the specified geometric relationship (step A6).

[0053] Next, the shape building unit 13 removes a combination of feature points with a conflicting geometric relationship, from combinations of feature points that have been subjected to the processing in step A3, using the numerical matrix calculated in step A6 (step A7).

[0054] Next, the shape building unit 13 rebuilds a three-dimensional shape using the remaining combinations of feature points (step A8). Thereafter, the display unit 17 displays the three-dimensional shape built in step A8, on the screen of the display device 20 (step A9).

[0055] [Effect of Example Embodiment]

As described above, according to this example embodiment, an incorrect combination of feature points that are not on the same scanning line can also be removed to build a three-dimensional shape. Therefore, according to this example embodiment, when extracting combinations of corresponding feature points from a plurality of images, it is possible to suppress extraction of an incorrect combination of feature points. In addition, as a result, the accuracy of a three-dimensional shape that is regenerated is improved.

[0056] [Program]

It is sufficient for a program according to this example embodiment to cause a computer to execute steps A1 to A9 shown in FIG. 6. The image processing apparatus 10 and the image processing method according to this example embodiment can be realized by installing this program in a computer and executing the installed program. In this case, the processor of the computer functions as the feature point extraction unit 11, the matrix calculation unit 12, the shape building unit 13, the image acquisition unit 14, the filtering unit 15, the input accepting unit 16, and the display unit 17, and performs processing.

[0057] In addition, the program in this example embodiment may also be executed by a computer system that includes a plurality of computers. In this case, for example, each of the computers may function as one of the feature point extraction unit 11, the matrix

calculation unit 12, the shape building unit 13, the image acquisition unit 14, the filtering unit 15, the input accepting unit 16, and the display unit 17.

[0058] Here, a computer for realizing the image processing apparatus 10 by executing the program in this example embodiment will be described with reference to FIG. 7. FIG. 7 is a block diagram showing an example of the computer that realizes the image processing apparatus according to the example embodiment of the present invention.

[0059] As shown in FIG. 7, a computer 110 includes a CPU 111, a main memory 112, a storage device 113, an input interface 114, a display controller 115, a data reader/writer 116, and a communication interface 117. These constituent elements are connected via a bus 121 to enable mutual data communication. Note that the computer 110 may also include a GPU (Graphics Processing Unit) or an FPGA (Field-Programmable Gate Array) in addition to or in place of the CPU 111.

[0060] The CPU 111 carries out various types of calculation by deploying, in the main memory 112, programs (codes) in this example embodiment stored in the storage device 113, and executing them in a predetermined order. Typically, the main memory 112 is a volatile storage device such as a DRAM (Dynamic Random Access Memory). In addition, the program in this example embodiment is provided in a state of being stored in a computer-readable recording medium 120. Note that the program in this example embodiment may also be distributed on the Internet connected via the communication interface 117.

[0061] In addition, specific examples of the storage device 113 include a hard disk drive and a semiconductor storage device, such as a flash memory. The input interface 114 mediates data transmission between the CPU 111 and an input device 118 including a keyboard and a mouse. The display controller 115 is connected to a display device 119 to control display on the display device 119.

[0062] The data reader/writer 116 mediates data transmission between the CPU 111 and the recording medium 120, reads out a program from the recording medium 120, and writes a processing result of the computer 110 to the recording medium 120. The communication interface 117 mediates data transmission between the CPU 111 and another computer.

[0063] In addition, specific examples of the recording medium 120 include a general-purpose semiconductor storage device such as a Compact Flash (CF (registered trademark)) and a Secure Digital (SD), a magnetic recording medium such as a flexible disk, or an optical recording medium such as a Compact Disk Read Only Memory (CD-ROM).

[0064] Note that the image processing apparatus 10 in this example embodiment can also be realized by using items of hardware corresponding to various constituent elements, instead of a computer in which programs are installed. Furthermore, a configuration may also be adopted in which a portion of the data management apparatus 10 is realized by a program, and the remaining portion is realized by hardware.

[0065] Part of or all of the above-described example embodiments can be expressed in the below-described Supplementary Notes 1 to 12, but the present invention is not limited to the below description.

[0066] (Supplementary Note 1)

An image processing apparatus for building a three-dimensional shape from a plurality of images, the apparatus comprising:

a feature point extraction unit configured to extract combinations of corresponding feature points from the plurality of images;

a matrix calculation unit configured to, if two or more line segments or two or more points corresponding to each other are designated in at least two images out of the plurality of images, specify a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculate a numerical matrix that represents the specified geometric relationship; and

a shape building unit configured to specify a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points using the numerical matrix, and build the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

[0067] (Supplementary Note 2)

The image processing apparatus according to Supplementary Note 1,
wherein the shape building unit specifies feature points that overlap the two or more designated line segments or points corresponding to each other, from among feature points included in the extracted combinations of feature points, removes a combination of feature points that includes the specified feature points, and builds the three-dimensional shape.

[0068] (Supplementary Note 3)

The image processing apparatus according to Supplementary Note 1 or 2, further comprising

a display unit configured to display the three-dimensional shape built by the shape building unit, on a screen.

[0069] (Supplementary Note 4)

The image processing apparatus according to Supplementary Note 3,
wherein the shape building unit builds a temporary three-dimensional shape using the combinations of feature points extracted by the feature point extraction unit, and

the display unit further displays the temporary three-dimensional shape on a screen.

[0070] (Supplementary Note 5)

An image processing method for building a three-dimensional shape from a plurality of images, the method comprising:

(a) a step of extracting combinations of corresponding feature points from the plurality of images;

(b) a step of, if two or more line segments or two or more points corresponding to each other are designated in at least two images out of the plurality of images, specifying a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculating a numerical matrix that represents the specified geometric relationship; and

(c) a step of specifying a combination of feature points with a conflicting

geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and building the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

[0071] (Supplementary Note 6)

The image processing method according to Supplementary Note 5,
wherein, in the (c) step,

feature points that overlap the two or more designated line segments or points corresponding to each other are specified from among feature points included in the combinations of feature points extracted in the (a) step, a combination of feature points that includes the specified feature points is removed, and the three-dimensional shape is built.

[0072] (Supplementary Note 7)

The image processing method according to Supplementary Note 5 or 6, further comprising

(d) a step of displaying the three-dimensional shape built in the (c) step, on a screen.

[0073] (Supplementary Note 8)

The image processing method according to Supplementary Note 7, further comprising:

(e) a step of building a temporary three-dimensional shape using the combinations of feature points extracted in the (a) step; and

(f) a step of displaying the temporary three-dimensional shape built in the (e) step, on a screen.

[0074] (Supplementary Note 9)

A computer-readable recording medium that includes a program recorded thereon for building a three-dimensional shape from a plurality of images, the program including instructions that cause a computer to carry out:

(a) a step of extracting combinations of corresponding feature points from the plurality of images;

(b) a step of, if two or more line segments or two or more points corresponding

to each other are designated in at least two images out of the plurality of images, specifying a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculating a numerical matrix that represents the specified geometric relationship; and

(c) a step of specifying a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and building the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

[0075] (Supplementary Note 10)

The computer-readable recording medium according to Supplementary Note 9, wherein, in the (c) step,

feature points that overlap the two or more designated line segments or points corresponding to each other are specified from among feature points included in the combinations of feature points extracted in the (a) step, a combination of feature points that includes the specified feature points is removed, and the three-dimensional shape is built.

[0076] (Supplementary Note 11)

The computer-readable recording medium according to Supplementary Note 9 or 10,

wherein the program further includes instructions that cause a computer to carry out

(d) a step of displaying the three-dimensional shape built in the (c) step, on a screen.

[0077] (Supplementary Note 12)

The computer-readable recording medium according to Supplementary Note 11, wherein the program further includes instructions that cause a computer to carry out:

(e) a step of building a temporary three-dimensional shape using the combinations of feature points extracted in the (a) step; and

(f) a step of displaying the temporary three-dimensional shape built in the (e) step, on a screen.

[0078] Although the present invention has been described above with reference to the example embodiments above, the invention is not limited to the above example embodiments. Various modifications understandable to a person skilled in the art can be made to configurations and details of the invention, within the scope of the invention.

[0079] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2017-190377, filed September 29, 2017, the disclosure of which is incorporated herein in its entirety by reference

INDUSTRIAL APPLICABILITY

[0080] As described above, according to the present invention, when extracting combinations of corresponding feature points from a plurality of images, it is possible to suppress extraction of an incorrect combination of feature points. The present invention is useful for a technique for building three-dimensional shape from a plurality of images, such as SfM.

REFERENCE SIGNS LIST

[0081]	10	Image processing apparatus
	11	Feature point extraction unit
	12	Matrix calculation unit
	13	Shape building unit
	14	Image acquisition unit
	15	Filtering unit
	16	Input accepting unit
	17	Display unit
	110	Computer
	111	CPU
	112	Main memory
	113	Storage device

114	Input interface
115	Display controller
116	Data reader/writer
117	Communication interface
118	Input device
119	Display device
120	Recording medium
121	Bus

CLAIMS

1. An image processing apparatus for building a three-dimensional shape from a plurality of images, the apparatus comprising:

a feature point extraction unit configured to extract combinations of corresponding feature points from the plurality of images;

a matrix calculation unit configured to, if two or more line segments or two or more points corresponding to each other, different and independent from the extracted feature points, are designated in at least two images out of the plurality of images, specify a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculate a numerical matrix that represents the specified geometric relationship; and

a shape building unit configured to specify a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and build the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

2. The image processing apparatus according to claim 1,

wherein the shape building unit specifies feature points that overlap the two or more designated line segments or points corresponding to each other, from among feature points included in the extracted combinations of feature points, removes a combination of feature points that includes the specified feature points, and builds the three-dimensional shape.

3. The image processing apparatus according to claim 1 or 2, further comprising

a display unit configured to display the three-dimensional shape built by the shape building unit, on a screen.

4. The image processing apparatus according to claim 3,

wherein the shape building unit builds a temporary three-dimensional shape using the combinations of feature points extracted by the feature point extraction unit,

and

the display unit further displays the temporary three-dimensional shape on a screen.

5. An image processing method for building a three-dimensional shape from a plurality of images, the method comprising:

(a) a step of extracting combinations of corresponding feature points from the plurality of images;

(b) a step of, if two or more line segments or two or more points corresponding to each other, different and independent from the extracted feature points, are designated in at least two images out of the plurality of images, specifying a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculating a numerical matrix that represents the specified geometric relationship; and

(c) a step of specifying a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and building the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

6. The image processing method according to claim 5,
wherein, in the (c) step,

feature points that overlap the two or more designated line segments or points corresponding to each other are specified from among feature points included in the combinations of feature points extracted in the (a) step, a combination of feature points that includes the specified feature points is removed, and the three-dimensional shape is built.

7. The image processing method according to claim 5 or 6, further comprising
(d) a step of displaying the three-dimensional shape built in the (c) step, on a

screen.

8. The image processing method according to claim 7, further comprising:

(e) a step of building a temporary three-dimensional shape using the combinations of feature points extracted in the (a) step; and

(f) a step of displaying the temporary three-dimensional shape built in the (e) step, on a screen.

9. A computer-readable recording medium that includes a program recorded thereon for building a three-dimensional shape from a plurality of images, the program including instructions that cause a computer to carry out:

(a) a step of extracting combinations of corresponding feature points from the plurality of images;

(b) a step of, if two or more line segments or two or more points corresponding to each other, different and independent from the extracted feature points, are designated in at least two images out of the plurality of images, specifying a geometric relationship between the two or more line segments corresponding to each other or a geometric relationship between the two or more points corresponding to each other, and calculating a numerical matrix that represents the specified geometric relationship; and

(c) a step of specifying a combination of feature points with a conflicting geometric relationship, from among the extracted combinations of feature points, using the numerical matrix, and building the three-dimensional shape using the combinations of feature points other than the specified combination of feature points.

10. The computer-readable recording medium according to claim 9,

wherein, in the (c) step,

feature points that overlap the two or more designated line segments or points corresponding to each other are specified from among feature points included in the combinations of feature points extracted in the (a) step, a combination of feature points that includes the specified feature points is removed, and the three-dimensional shape is built.