

TITLE OF INVENTION: INFORMATION PROCESSING APPARATUS, INFORMATION PROCESSING METHOD, AND PROGRAM

5 BACKGROUND

The present disclosure relates to an information processing apparatus, an information processing method, and a program.

With the miniaturization of semiconductor process nodes, there is an urgent need to further increase the sensitivity of inspection of semiconductor wafers, photomasks, and the like. For example, as an inspection method for a sample such as a mask, a technique for performing inspection by imaging the sample is widely known (Japanese Unexamined Patent Application Publication No. 2022-161475 and Japanese Unexamined Patent Application Publication No. 2023-117036).

In order to evaluate a size and the like of a target object in a captured image, a method of calculating an evaluation value based on a pixel value of pixels in a region in which the target object appears and evaluating the target object in accordance with a magnitude of the evaluation value is known (Terasawa Tsuneo et al. "Actinic Mask Blank Inspection and Signal Analysis for Detecting Phase Defects Down to 1.5 nm in Height." Japanese Journal of Applied Physics, vol. 48, 06FA04, 2009). This method proposes that, at a location in which the target object in the image appears, a value obtained by removing a background component from a total value of pixel values within a predetermined region including an integer number of pixels is calculated as the evaluation value.

25 SUMMARY

In inspection of a sample such as a photomask, a plurality of inspection apparatuses may be used for the inspection. However, when imaging the sample with the plurality of inspection apparatuses, pixel size may differ due to individual differences, model difference, or the like of the inspection apparatuses. If the pixel size is different, the number of pixels whose pixel values represent an image of the same target object differs, even when imaging a region of a sample with the same size.

On the other hand, it is desirable to calculate evaluation values that are equal or approximate to one another to an extent of being considered equal, even when

the pixel sizes of an image captured by the inspection apparatuses are different, because it is preferable to be able to evaluate the same target object similarly. However, when calculating the evaluation values, even if one image includes an integer number of pixels within a region of a predetermined size, it is assumed that
5 pixels are present that are only partially included within the predetermined region of the same size in another image, because the pixel size differs. In this case, it is not possible to simply calculate the evaluation value as proposed in Terasawa Tsuneo et al.

Therefore, there is a need for a method of calculating evaluation values that
10 are equal or approximate to one another to an extent of being considered equal, even when pixel sizes of an image captured by inspection apparatuses are different.

An information processing apparatus according to the present disclosure includes: a data reading unit configured to read target image data obtained by imaging a sample; a reference frame setting unit configured to set, with respect to
15 the target image data, a reference frame defined so as to include an integer number of pixels of reference image data whose pixel size is different from that of the target image data; a first evaluation value calculation unit configured to calculate a first evaluation value based on pixels included in the reference frame in the target image data; a second evaluation value calculation unit configured to calculate a second
20 evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an area of the reference frame in the target image data; a third evaluation value calculation unit configured to calculate a third evaluation value based on the pixels included in the reference frame and
25 pixels partially included in the reference frame, in the target image data; and an evaluation value determination unit configured to determine any one of the first evaluation value, the second evaluation value, or the third evaluation value as an evaluation value calculated for the reference frame, based on a magnitude relationship between the first evaluation value, the second evaluation value, and
30 the third evaluation value.

An information processing apparatus according to the present disclosure includes: a data reading unit configured to read target image data obtained by imaging a sample; a reference frame setting unit configured to set, with respect to the target image data, a reference frame defined so as to include an integer number

of pixels of reference image data whose pixel size is different from that of the target image data; a first evaluation value calculation unit configured to calculate a first evaluation value based on pixels included in the reference frame in the target image data; a second evaluation value calculation unit configured to calculate a second evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an area of the reference frame in the target image data; and an evaluation value determination unit configured to determine the second evaluation value as an evaluation value calculated for the reference frame.

An information processing method according to the present disclosure includes: reading target image data obtained by imaging a sample; setting, with respect to the target image data, a reference frame defined so as to include an integer number of pixels of reference image data whose pixel size is different from that of the target image data; calculating a first evaluation value based on pixels included in the reference frame in the target image data; calculating a second evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an area of the reference frame in the target image data; calculating a third evaluation value based on the pixels included in the reference frame and pixels partially included in the reference frame, in the target image data; and determining any one of the first evaluation value, the second evaluation value, or the third evaluation value as an evaluation value calculated for the reference frame, based on a magnitude relationship between the first evaluation value, the second evaluation value, and the third evaluation value.

A program according to the present disclosure causes a computer to execute: processing of reading target image data obtained by imaging a sample; processing of setting, with respect to the target image data, a reference frame defined so as to include an integer number of pixels of reference image data whose pixel size is different from that of the target image data; processing of calculating a first evaluation value based on pixels included in the reference frame in the target image data; processing of calculating a second evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an

area of the reference frame in the target image data; processing of calculating a third evaluation value based on the pixels included in the reference frame and pixels partially included in the reference frame, in the target image data; and processing of determining any one of the first evaluation value, the second evaluation value, or the third evaluation value as an evaluation value calculated for the reference frame, based on a magnitude relationship between the first evaluation value, the second evaluation value, and the third evaluation value.

According to the present disclosure, it is possible to calculate an evaluation value of a target object in image data, based on pixels inside and around a predetermined region, regardless of a pixel size of the image data.

The above and other objects, features and advantages of the present disclosure will become more fully understood from the detailed description given hereinbelow and the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a diagram showing an example of an optical apparatus including an information processing apparatus according to a first embodiment;

Fig. 2 is a diagram schematically showing reference image data and target image data;

Fig. 3 is a diagram showing when a reference frame in the reference image data is applied to the target image data;

Fig. 4 is a diagram showing a configuration example of the information processing apparatus according to the first embodiment;

Fig. 5 is an enlarged view of the target image data in Fig. 3;

Fig. 6 is a diagram schematically showing Case 1 being an example of a relationship between the reference frame and a target object;

Fig. 7 is a diagram schematically showing Case 2 being an example of the relationship between the reference frame and the target object;

Fig. 8 is a diagram schematically showing Case 3 being an example of the relationship between the reference frame and the target object;

Fig. 9 is a flowchart showing an evaluation value calculation operation in the information processing apparatus according to the first embodiment; and

Fig. 10 is a diagram showing a configuration example of a computer for realizing the information processing apparatus.

DESCRIPTION OF EMBODIMENTS

Hereinafter, specific configurations of embodiments will be described with reference to the drawings. The following description presents preferable
5 embodiments of the present disclosure, and the scope of the present disclosure is not limited to the embodiments described below. In the following description, elements denoted by the same reference sign represent essentially the same content.

First Embodiment

10 An information processing apparatus according to a first embodiment will be described. The information processing apparatus according to the present embodiment is configured to calculate an evaluation value of the target object in target image data whose pixel size is different from that of the reference image data, by using a method in accordance with a size of the target object.

15 Note that in the following description, image data may be data that has not yet been converted into an image, such as so-called RAW data, acquired through imaging by an image capturing apparatus such as a camera. The image data may also be an image generated by performing predetermined processing on numerical data such as the RAW data.

20 Fig. 1 is a diagram showing an example of an optical apparatus including the information processing apparatus according to the first embodiment. An optical apparatus 1000 includes an image capturing apparatus 1100 and an information processing apparatus 100 according to the first embodiment. The image capturing apparatus 1100 outputs, to the information processing apparatus 100, target image data IMG acquired by imaging a sample 1200.

25 The information processing apparatus 100 calculates an evaluation value for a region in which a target object appears included in the target image data IMG. Here, a reference frame being a region including pixels used for calculating the evaluation value is predetermined based on a pixel size in the reference image data, which is captured by a reference image capturing apparatus and whose pixel size is
30 different from that of the target image data. In this example, the reference frame is defined as a rectangular region including an integer number of pixels in the reference image data. However, the reference frame is not limited thereto and may be a region of any other shape than a rectangle, such as a cross shape, including an integer number of pixels in the reference image data.

As described below, the information processing apparatus 100 applies the reference frame to the target image data whose pixel size is different from that of the reference image data, and calculates the evaluation value based on pixels inside the reference frame or pixels inside and around the reference frame.

5 Next, a problem caused by the difference in pixel size between the reference image data and the target image data will be described. Fig. 2 is a diagram schematically showing the reference image data and the target image data. The same target object on the sample is present in reference image data REF and the target image data IMG. In Fig. 2, a pixel value of each pixel is displayed in
10 grayscale. White pixels near a center of the reference image data REF and the target image data IMG indicate pixels representing the target object.

In order to evaluate target object in the image data, the evaluation value is calculated based on the pixel values of the pixels representing the target object. Here, a total value of the pixel values of the pixels within the reference frame of a
15 predetermined size is calculated as the evaluation value. Note that when calculating the total value of the pixel values of the pixels within the reference frame, a background component may be removed from the total value of the pixel values as in, for example, Terasawa Tsuneo et al.

In the reference image data REF in Fig. 2, a reference frame F is
20 predetermined with a size of two rows and two columns, that is, $2 \times 2 = 4$ pixels. In the reference image data REF, the reference frame F is disposed so that an upper left edge of the reference frame F matches an upper left edge of one pixel. In the reference image data REF, it is possible to sweep an entirety of the reference image data REF using the reference frame F, by successively changing the pixels that are
25 the reference for the placement of the reference frame F. With this, it is possible to calculate the evaluation value for the target object appeared in the reference image data REF.

However, when the model of the apparatus for imaging the sample differs or when individual differences are present even when using the same type of apparatus,
30 the pixel size in the image data obtained by imaging the same target may differ between the reference image data REF and the target image data IMG, as shown in Fig. 2. For example, even if the sample is imaged with different image capturing apparatuses including an optical system having the same structure, the pixel sizes of the image capturing apparatuses may not match due to manufacturing errors or

the like. For example, it is assumed that the pixel size differs between an older model and a newer model of the image capturing apparatus due to a difference in resolution.

Even in this case, it is preferable to be able to perform similar evaluation for the same target object. Therefore, it is desirable that evaluation values calculated from image data acquired by different apparatuses are calculated as equal values or values that are approximate to one another as closely as possible. However, the following problems occur when trying to calculate the evaluation value of a target object by using a plurality of images with different pixel sizes.

Fig. 3 is a diagram showing when the reference frame F in the reference image data REF is applied to the target image data IMG. In Fig. 3, the reference image data REF includes four pixels in the reference frame F. In contrast, in the target image data IMG, each side of the reference frame F is 4.1 times longer than a side of the pixel. Thus, when the upper left edge of the reference frame F matches the upper left edge of one pixel in the target image data IMG, the reference frame F includes $4 \times 4 = 16$ pixels and the right side and the bottom side of the reference frame F intersect nine pixels.

Therefore, in the target image data IMG, the number of pixels included in the reference frame F is not an integer number as in the reference image data REF, and pixels are present that are only partially included. As such, it is no longer possible to simply calculate the evaluation value as in the reference image data REF.

Hereinafter, the information processing apparatus will be described that calculates an appropriate evaluation value, as in the target image data IMG in Fig. 3, by using the pixel values, even when pixels are present that are only partially included in the reference frame F.

Fig. 4 is a diagram showing a configuration example of the information processing apparatus according to the first embodiment. The information processing apparatus 100 includes a data reading unit 1, a reference frame setting unit 2, an inclusion region evaluation value calculation unit 3, a reference frame conversion evaluation value calculation unit 4, an extended region evaluation value calculation unit 5, and an evaluation value determination unit 6.

The data reading unit 1 reads the target image data IMG being a calculation target of the evaluation value. The data reading unit 1 may read the target image data IMG from the image capturing apparatus that images the sample. For example,

the target image data IMG may be stored in advance in a storage apparatus (not illustrated), and the data reading unit 1 may read the target image data IMG from the storage apparatus as necessary.

5 The reference frame setting unit 2 holds information indicating the reference frame F of a predetermined size, that is predetermined based on the pixel size of the reference image data REF. Fig. 5 is an enlarged view of the target image data IMG in Fig. 3. The reference frame setting unit 2 sets the reference frame F in a two-dimensional plane in which the pixels of the target image data IMG are arrayed. In this example, as shown in Fig. 5, the reference frame F is set so that the upper
10 left edge of the reference frame F matches the upper left edge of the pixel.

The reference frame setting unit 2 may hold information specifying the size, position, and the like of the reference frame F in advance. The reference frame F may also be given to the reference frame setting unit 2 via various input or communication means. The reference frame setting unit 2 may also acquire the
15 information specifying the size, position, and the like of the reference frame F stored in the storage apparatus (not illustrated), directly or via a reading means (not illustrated) as necessary.

In the present embodiment, a region consisting of pixels that are included in the reference frame F, that is, pixels that are present inside the reference frame F
20 without being intersected by the reference frame F, is referred to as an inclusion region A1. A region that includes the inclusion region A1 and pixels intersected by the reference frame F, that is, the region within the reference frame F and a portion outside of the reference frame F of the pixels intersected by the reference frame F, is referred to as an extended region A2.

25 The inclusion region evaluation value calculation unit 3 calculates a total value of pixel values of the pixels included in the inclusion region A1 as an inclusion region evaluation value E1. In the example of Fig. 5, the inclusion region evaluation value E1 is calculated for the pixel values of 16 pixels included in the inclusion region A1. Note that the inclusion region evaluation value
30 calculation unit 3 may calculate other statistics, such as an average value of the pixel values of the pixels included in the inclusion region A1, as the inclusion region evaluation value E1.

The reference frame conversion evaluation value calculation unit 4 calculates a reference frame conversion evaluation value E2 based on the inclusion region

evaluation value E1, and a predetermined coefficient α based on a relationship between an area of the inclusion region A1 consisting of the pixels included in the reference frame F and an area of the reference frame F. For example, the reference frame conversion evaluation value calculation unit 4 calculates, as the reference frame conversion evaluation value E2, a value obtained by dividing the total value of the pixel values included in the reference frame F by the predetermined coefficient α . In this case, for example, the coefficient α may be a value obtained by dividing the area of the inclusion region A1 by the area of the reference frame F. In the example of Fig. 5, it is assumed that a length of each side of the reference frame F is 4.1 times a length of the pixels in the target image data IMG. Therefore, since $16/(4.1 \times 4.1) = 0.9518\dots$, 0.95 may, for example, be used as the coefficient α .

The reference frame conversion evaluation value calculation unit 4 may hold information indicating the coefficient α in advance. The information indicating the coefficient α may be provided to the reference frame conversion evaluation value calculation unit 4 via various input or communication means. The reference frame conversion evaluation value calculation unit 4 may also acquire the information indicating the coefficient α stored in the storage apparatus (not illustrated), directly or via a reading means (not illustrated) as necessary.

The extended region evaluation value calculation unit 5 calculates a total value of pixel values of the pixels included in the extended region A2 as an extended region evaluation value E3. In the example of Fig. 5, the extended region evaluation value E3 is calculated for the pixel values of 25 pixels included in the extended region A2. Note that the extended region evaluation value calculation unit 5 may calculate other statistics, such as an average value of the pixel values of the pixels included in the extended region A2, as the extended region evaluation value E3.

The evaluation value determination unit 6 determines a magnitude relationship between the inclusion region evaluation value E1, the reference frame conversion evaluation value E2, and the extended region evaluation value E3. The evaluation value determination unit 6 selects one of the inclusion region evaluation value E1, the reference frame conversion evaluation value E2, or the extended region evaluation value E3 as an evaluation value E of the pixels in the reference frame F based on a determination result.

Next, a relationship between the reference frame F, a target object OBJ, and the evaluation value calculated by the evaluation value determination unit 6 will be described. In the present embodiment, the evaluation value determination unit 6 estimates a size of the target object OBJ based on the magnitude relationship between the inclusion region evaluation value E1, the reference frame conversion evaluation value E2, and the extended region evaluation value E3, and determines the evaluation value E based on an estimation result. In the present embodiment, the size of the target object OBJ is classified into the following Cases 1 to 3, and the evaluation value E is calculated.

Case 1

A case is assumed in which the target object OBJ is included in the inclusion region A1. Fig. 6 is a diagram schematically showing Case 1 being an example of the relationship between the reference frame F and the target object OBJ. In this case, the target object OBJ is included in both the inclusion region A1 and the extended region A2. Thus, it is possible to expect the inclusion region evaluation value E1 and the extended region evaluation value E3 to be equal or approximate to one another to an extent of being considered equal. On the other hand, the reference frame conversion evaluation value E2 is greater than the inclusion region evaluation value E1 and the extended region evaluation value E3.

Therefore, when the reference frame conversion evaluation value E2 is greater than the inclusion region evaluation value E1 and the extended region evaluation value E3, it is possible to determine that the target object OBJ is included in the inclusion region A1. At this time, it is considered that the reference frame conversion evaluation value E2 overevaluates the region occupied by the target object OBJ. As such, in Case 1, a ratio of the region occupied by the target object OBJ within the reference frame F can be reflected appropriately, by using the inclusion region evaluation value E1 or the extended region evaluation value E3 as the evaluation value E of the target object OBJ.

Case 2

A case is assumed in which the target object OBJ is not contained in the inclusion region A1, but is included in the reference frame F. Fig. 7 is a diagram schematically showing Case 2 being an example of the relationship between the reference frame F and the target object OBJ. In this case, since the target object OBJ extends outside the inclusion region A1, it is assumed that the extended region

evaluation value $E3$ is greater than the inclusion region evaluation value $E1$. Since an area of a portion of the target object OBJ that is not contained in the inclusion region $A1$ but protrudes within the reference frame F is small, it is assumed that the reference frame conversion evaluation value $E2$ calculated by dividing the inclusion region evaluation value $E1$ by the coefficient $\alpha = 0.95$ is greater than the inclusion region evaluation value $E1$ and the extended region evaluation value $E3$.

Therefore, when the reference frame conversion evaluation value $E2$ is the greatest and the inclusion region evaluation value $E1$ is the smallest, that is, when $E1 < E3 < E2$, it is possible to determine that the target object OBJ is not contained in the inclusion region $A1$ but is included in the reference frame F . At this time, it is considered that the inclusion region evaluation value $E1$ underevaluates the region occupied by the target object OBJ and the reference frame conversion evaluation value $E2$ overevaluates the region occupied by the target object OBJ. As such, in Case 2, the ratio of the region occupied by the target object OBJ within the reference frame F can be reflected appropriately, by using the extended region evaluation value $E3$ as the evaluation value E of the target object OBJ.

Case 3

A case is assumed in which the target object OBJ extends outside of the reference frame F . Fig. 8 is a diagram schematically showing Case 3 being an example of the relationship between the reference frame F and the target object OBJ. In this case, the target object OBJ occupies the region in the reference frame F and an entirety or part of the extended region $A2$. Thus, the extended region evaluation value $E3$ is greater than the inclusion region evaluation value $E1$ and the reference frame conversion evaluation value $E2$. Note that the reference frame conversion evaluation value $E2$ is greater than the inclusion region evaluation value $E1$, similar to Case 2.

Therefore, when the extended region evaluation value $E3$ is the greatest and the inclusion region evaluation value $E1$ is the smallest, that is, when $E1 < E2 < E3$, it is possible to determine that the target object OBJ extends outside of the reference frame F . At this time, it is considered that the inclusion region evaluation value $E1$ underevaluates the region occupied by the target object OBJ. The extended region evaluation value $E3$ is considered to be too great as the evaluation value the target object OBJ in the reference frame F , because the extended region evaluation value $E3$ incorporates too many pixel values outside of

the reference frame F. Thus, in Case 3, the ratio of the region occupied by the target object OBJ within the reference frame F can be reflected appropriately, by using the reference frame conversion evaluation value E2 as the evaluation value E of the target object OBJ.

5 Next, an evaluation value calculation operation in the information processing apparatus 100 will be described. Fig. 9 is a flowchart showing the evaluation value calculation operation in the information processing apparatus according to the first embodiment.

Step S1

10 The data reading unit 1 reads the target image data IMG being the calculation target of the evaluation value.

Step S2

 The reference frame setting unit 2 sets the reference frame F to a pixel array in the target image data IMG. In this example, the reference frame F is disposed
15 so that the upper left edge of the reference frame F matches the upper left edge of one pixel. In this example, 16 pixels are included within the reference frame F, and these 16 pixels constitute the inclusion region A1. At a right side and a bottom side of the inclusion region A1, the reference frame F intersects 9 pixels. Therefore, the extended region A2 includes $16 + 9 = 25$ pixels.

20 Step S3

 The inclusion region evaluation value calculation unit 3 calculates the total value of the pixel values of the pixels included in the inclusion region A1 as the inclusion region evaluation value E1.

Step S4

25 The reference frame conversion evaluation value calculation unit 4 calculates, as the reference frame conversion evaluation value E2, the value obtained by dividing the total value of the pixel values included in the reference frame F by the predetermined coefficient α . Here, α is 0.95.

Step S5

30 The extended region evaluation value calculation unit 5 calculates the total value of the pixel values of the pixels included in the extended region A2 as the extended region evaluation value E3.

Step S6

 The evaluation value determination unit 6 determines whether the extended

region evaluation value E3 is greater than the reference frame conversion evaluation value E2. With this, the evaluation value determination unit 6 can determine whether the size of the target object OBJ corresponds to Case 3.

Step S7

5 When the extended region evaluation value E3 is greater than the reference frame conversion evaluation value E2, that is, when the size of the target object OBJ corresponds to Case 3, the evaluation value determination unit 6 selects the reference frame conversion evaluation value E2 as the evaluation value E.

Step S8

10 When the extended region evaluation value E3 is equal to or smaller than the reference frame conversion evaluation value E2, that is, when the size of the target object OBJ does not correspond to Case 3, the evaluation value determination unit 6 determines whether a difference between the extended region evaluation value E3 and the inclusion region evaluation value E1 is smaller than a predetermined value β . That is, the evaluation value determination unit 6 determines whether $-\beta < E3 - E1 < \beta$, in other words, whether $|E3 - E1| < \beta$. With this, the evaluation value determination unit 6 can determine whether the size of the target object OBJ corresponds to Case 1.

20 The evaluation value determination unit 6 may hold information indicating the predetermined value β in advance. The information indicating the predetermined value β may be given to the evaluation value determination unit 6 via various input or communication means. The evaluation value determination unit 6 may also acquire the information indicating the predetermined value β stored in the storage apparatus (not illustrated), directly or via a reading means (not illustrated) as necessary.

Step S9

30 When the difference between the extended region evaluation value E3 and the inclusion region evaluation value E1 is smaller than the predetermined value β , that is, when the size of the target object OBJ corresponds to Case 1, the evaluation value determination unit 6 selects the inclusion region evaluation value E1 as the evaluation value E.

Step S10

 When the difference between the extended region evaluation value E3 and the inclusion region evaluation value E1 is equal to or greater than the predetermined

value β , that is, when the size of the target object OBJ corresponds to Case 2, the evaluation value determination unit 6 determines the extended region evaluation value E3 as the evaluation value E in the reference frame F.

According to the above procedure, it is possible to determine a suitable value as the evaluation value E from among the inclusion region evaluation value E1, the reference frame conversion evaluation value E2, and the extended region evaluation value E3, in accordance with the size of the target object OBJ in the reference frame F.

It should be noted that the above description mainly assumes a case where the target image data represents an image in which the target object OBJ appears brighter than the background signal. Meanwhile, it may be assumed that the target image data represents an image in which the target object OBJ appears darker than the background signal. In this case, the direction of the inequality signs used in the comparison of evaluation values may be appropriately reversed (specifically, in Step S6 of Fig. 9, $E3 > E2$ will be replaced with $E3 < E2$).

Alternatively, if the evaluation values E1 and E3 described above are defined as the total, average, or other statistical measures of the absolute differences between the signal values of each pixel and the background signal value, then it may not be necessary to distinguish whether the target object OBJ appears brighter or darker than the background signal in the target image data.

With this, even in the target image data IMG whose pixel size is different from that of the reference image data REF, it is possible to calculate an evaluation value to be equal to or approximate to an extent of being considered equal to that of the reference image data REF.

As a result, it is possible to evaluate the target object in the image data, by using evaluation values that are equal or approximate to one another to an extent of being considered equal, regardless of the image capturing apparatus that acquires the image data.

Other Embodiments

The present disclosure has been described above with reference to the embodiment, but the present disclosure is not limited to the above-described embodiment. Various changes can be made to the configurations, contents, and the like of the present disclosure that can be understood by those skilled in the art within the scope of the present disclosure. However, the embodiment can be

combined with the other embodiments as appropriate.

In the above-described embodiment, the evaluation value determination unit 6 has been described as determining one of the inclusion region evaluation value E1, the reference frame conversion evaluation value E2, and the extended region evaluation value E3 as the evaluation value E. In contrast, the evaluation value determination unit 6 may determine, as the evaluation value E, a value obtained by converting the inclusion region evaluation value E1 calculated for the inclusion region A1 in accordance with the size of the reference frame F. The evaluation value determination unit 6 may determine, as the evaluation value E, the reference frame conversion evaluation value E2 calculated based on the inclusion region evaluation value E1 and the coefficient α . With this, the information processing apparatus 100 may include the data reading unit 1, the reference frame setting unit 2, the inclusion region evaluation value calculation unit 3, the reference frame conversion evaluation value calculation unit 4, and the extended region evaluation value calculation unit 5, resulting in a simpler configuration.

In the above-described embodiment, the reference frame conversion evaluation value calculation unit 4 is described as calculating, as the reference frame conversion evaluation value E2, the value obtained by dividing the total value of the pixel values included in the reference frame F by the coefficient α being the value obtained by dividing the area of the inclusion region A1 by the area of the reference frame F. In contrast, the calculation processing is essentially the same, but the reference frame conversion evaluation value calculation unit 4 may calculate, as the reference frame conversion evaluation value E2, a value obtained by multiplying the total value of the pixel values included in the reference frame F with a coefficient being a value obtained by dividing the area of the reference frame F by the area of the inclusion region A1.

The evaluation value determination unit 6 has been described as determining the magnitude of two values in steps S6 and S8 of Fig. 9, but the evaluation value determination unit 6 is not limited to this method of determining the magnitude relationship between the values. The evaluation value determination unit 6 may determine whether a first value is greater than a second value as in step S6 of Fig. 9, or may determine whether the first value is equal to or greater than the second value. The evaluation value determination unit 6 may determine whether the first value is smaller than the second value as in step S8 of Fig. 9, or may determine

whether the first value is equal to or smaller than the second value. That is, when determining the magnitude of the two values, it is sufficient that the evaluation value determination unit 6 is able to at least distinguish when the first value is greater than the second value and when the first value is smaller than the second value. When the first value is equal to the second value, the evaluation value determination unit 6 may perform the same processing as when the first value is greater than the second value, and may perform the same processing when the first value is smaller than the second value.

In the above-described embodiment, the data reading unit 1 has been described as reading the target image data IMG from the image capturing apparatus 1100, but this is merely an example. For example, the data reading unit 1 may read the target image data IMG stored in advance in a storage apparatus (not illustrated) as necessary. The storage apparatus on which the target image data IMG is stored may be part of the information processing apparatus 100, or may be provided separately from the information processing apparatus 100. The image data and other information used by the information processing apparatus 100 may be read from the image capturing apparatus 1100, and part of the information processing apparatus 100 or part of or an entirety of an external storage apparatus as necessary.

The size and placement of the reference frame are merely an example, and the reference frame may be set to any size as needed and may be disposed at any position relative to the pixels of the target image data IMG.

In the above-described embodiment, the optical apparatus according to the present disclosure is described mainly as a hardware configuration but is not limited thereto. It is also possible to realize the optical apparatus according to the present disclosure by causing a computer to execute a computer program for performing freely-selected processing. This processing may be realized by causing a computer including at least one processor (for example, microprocessor, CPU, GPU, MPU, or digital signal processor (DSP)) execute a program. To be specific, one or more programs including a set of commands for causing the computer to perform an algorithm related to this transmission signal processing or reception signal processing may be created, and the program may be supplied to the computer.

The computer program can be stored and supplied to the computer, by using various types of non-transitory computer-readable media. The non-transitory

computer-readable media include various types of tangible storage media. Examples of the non-transitory computer-readable media include magnetic recording media (for example, flexible disks, magnetic tape, or hard disk drives), magneto-optical recording media (for example, magneto-optical disks), CD read-only memory (ROM), CD-R, CD-R/W, CD-R/W, and semiconductor memory (for example, mask ROM, programmable ROM (PROM), erasable PROM (EPROM), flash ROM, random-access memory (RAM)). The program can be supplied to the computer via various types of transitory computer-readable media. Examples of the transitory computer-readable media include electrical signals, optical signals, and electromagnetic waves. The transitory computer-readable media can supply the program to the computers via a wired or wireless communication path, such as an electric wires and optical fiber.

Hereinafter, a configuration example is shown of a computer for realizing the information processing apparatus 100. Fig. 10 is a diagram showing the configuration example of the computer for realizing the information processing apparatus 100. The information processing apparatus 100 can be realized by a computer 9000, such as a dedicated computer or a personal computer (PC). However, the computer need not be a single physical apparatus, but may be a plurality of apparatuses when executing distributed processing. As shown in Fig. 10, the computer 9000 includes, for example, a processor 9001, a read-only memory (ROM) 9002, a random-access memory (RAM) 9003, a storage unit 9004, a communication interface 9005, and a user interface 9006.

The processor 9001, the ROM 9002, the RAM 9003, the storage unit 9004, the communication interface 9005, and the user interface 9006 are communicably connected via a bus 9007. Note that description of OS software or the like for causing the computer to operate is omitted but is introduced in the computer 9000 as appropriate.

The ROM 9002 consists of, for example, a non-volatile semiconductor storage apparatus. The ROM 9002 stores information such as various programs used by the computer 9000.

The storage unit 9004 consists of, for example, various storage apparatuses such as hard disks or solid-state disks. The storage unit 9004 is not limited to the storage apparatuses installed in the computer 9000, but may be external storage apparatuses of the computer 9000. The external storage apparatuses may be a

cloud storage or the like connected the computer 9000 via various communication means, for example, a network. The storage unit 9004 stores information such as various programs or data used by the computer 9000.

5 The RAM 9003 consists of, for example, a volatile semiconductor storage apparatus. In the RAM 9003, information such as programs or data used by the processor 9001 is loaded from one or both of the ROM 9002 and the storage unit 9004 as appropriate.

10 The processor 9001 may consist of, for example, a central processing unit (CPU). The processor 9001 may include not only a CPU, but also a graphics processing unit (GPU). The GPU is suitable for performing routine processing in parallel, and can also enhance processing speed as compared to the CPU, by applying the GPU to processing in a neural network, for example. The processor 9001 executes various processing based on various programs stored in the ROM 9002 or various programs and data held in the RAM 9003 as appropriate. The
15 processor 9001 may also store data generated by the processing in the RAM 9003, the storage unit 9004, or the like as appropriate.

The communication interface 9005 is an interface that connects the computer 9000 to a communication network, such as the Internet, an intranet, or the like, via various wired or wireless communication means. With this, the computer 9000
20 can communicate with another apparatus, a system, a sensor, and the like connected to the communication network.

The user interface 9006 includes, for example, a display part, a speech output part, or the like that provides information for a user to recognize via a display apparatus, via speech, or the like. The user interface 9006 includes an input part
25 that allows information to be input to the computer 9000 through a user operation, such as a keyboard, a mouse, or a touch panel. The user interface 9006 may also include equipment such as a sensor that acquires information useful to the user.

Here, the computer 9000 has been described here as one apparatus, but this is merely an example. The computer 9000 may consist of a plurality of
30 apparatuses that are physically separated. Part of the plurality devices may be transportable devices, and others may be stationary apparatuses.

The present disclosure has been described above with reference to the embodiments, but the present disclosure is not limited to the above-described embodiments. Various changes can be made to the configurations, contents, and

the like of the present disclosure that can be understood by those skilled in the art within the scope of the present disclosure. However, the embodiments can be combined with the other embodiments as appropriate.

Each drawing is merely an example for describing one or more embodiments.

- 5 Each drawing need not be associated with only one particular embodiment, but may be associated with one or more other embodiments. As those skilled in the art will appreciate, the various features or steps described with reference to any one drawing may be combined with features or steps shown in one or more drawings, for example, to produce an embodiment not explicitly illustrated or described.
- 10 Not all of the features or steps shown in any one drawing to illustrate an exemplary embodiment are necessarily required, and some features or steps may be omitted. The order of the steps shown in any one drawing may be modified as appropriate.

- From the disclosure thus described, it will be obvious that the embodiments of the disclosure may be varied in many ways. Such variations are not to be
- 15 regarded as a departure from the spirit and scope of the disclosure, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An information processing apparatus, comprising:

a data reading unit configured to read target image data obtained by imaging
5 a sample;

a reference frame setting unit configured to set, with respect to the target
image data, a reference frame defined so as to include an integer number of pixels
of reference image data whose pixel size is different from that of the target image
data;

10 a first evaluation value calculation unit configured to calculate a first
evaluation value based on pixels included in the reference frame in the target image
data;

a second evaluation value calculation unit configured to calculate a second
evaluation value based on the first evaluation value, and a predetermined
15 coefficient based on a relationship between an area of a region consisting of the
pixels included in the reference frame and an area of the reference frame in the
target image data;

a third evaluation value calculation unit configured to calculate a third
evaluation value based on the pixels included in the reference frame and pixels
20 partially included in the reference frame, in the target image data; and

an evaluation value determination unit configured to determine any one of
the first evaluation value, the second evaluation value, or the third evaluation value
as an evaluation value calculated for the reference frame, based on a magnitude
relationship between the first evaluation value, the second evaluation value, and
25 the third evaluation value.

2. The information processing apparatus according to claim 1, wherein the
evaluation value determination unit:

determines the second evaluation value as the evaluation value calculated for
30 the reference frame, in a case where the third evaluation value is greater than the
second evaluation value; and

in a case where the third evaluation value is smaller than the second
evaluation value:

determines the first evaluation value as the evaluation value calculated for

the reference frame, in a case where a difference between the third evaluation value and the first evaluation value is smaller than a predetermined value; and

determines the third evaluation value as the evaluation value calculated for the reference frame, in a case where the difference between the third evaluation value and the first evaluation value is greater than the predetermined value.

3. The information processing apparatus according to claim 2, wherein the evaluation value determination unit determines the second evaluation value as the evaluation value calculated for the reference frame, in a case where the third evaluation value and the second evaluation value are equal.

4. The information processing apparatus according to claim 2, wherein the evaluation value determination unit determines the first evaluation value or the third evaluation value as the evaluation value calculated for the reference frame, in a case where the third evaluation value is equal to or smaller than the second evaluation value and the difference between the third evaluation value and the first evaluation value is equal to the predetermined value.

5. The information processing apparatus according to claim 3, wherein the evaluation value determination unit determines the first evaluation value or the third evaluation value as the evaluation value calculated for the reference frame, in a case where the third evaluation value is smaller than the second evaluation value and the difference between the third evaluation value and the first evaluation value is equal to the predetermined value.

6. The information processing apparatus according to claim 1 or 2, wherein the first evaluation value calculation unit and the third evaluation value calculation unit respectively calculate the first evaluation value and the third evaluation value based on a total value of pixel values of pixels being calculation targets.

7. The information processing apparatus according to claim 6, wherein the first evaluation value calculation unit and the third evaluation value calculation unit respectively calculate the first evaluation value and the third evaluation value, by removing a background component from the total value of the pixel values of

the pixels being the calculation targets.

8. The information processing apparatus according to claim 1 or 2, wherein the reference frame is a rectangular region, and

5 the reference frame setting unit sets the reference frame so that a vertex of the rectangular region matches a vertex of one of the pixels.

9. The information processing apparatus according to claim 1 or 2, wherein the predetermined coefficient is a value obtained by dividing the area of the region
10 consisting of the pixels included in the reference frame in the target image data by the area of the reference frame.

10. The information processing apparatus according to claim 1 or 2, wherein the predetermined coefficient is a value obtained by dividing the area of the
15 region consisting of the pixels included in the reference frame in the target image data by the area of the reference frame, and

the second evaluation value calculation unit calculates the second evaluation value, by dividing the first evaluation value by the predetermined value.

20 11. An information processing apparatus, comprising:

a data reading unit configured to read target image data obtained by imaging a sample;

a reference frame setting unit configured to set, with respect to the target image data, a reference frame defined so as to include an integer number of pixels
25 of reference image data whose pixel size is different from that of the target image data;

a first evaluation value calculation unit configured to calculate a first evaluation value based on pixels included in the reference frame in the target image data;

30 a second evaluation value calculation unit configured to calculate a second evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an area of the reference frame in the target image data; and

an evaluation value determination unit configured to determine the second evaluation value as an evaluation value calculated for the reference frame.

12. An information processing method, comprising:

5 reading target image data obtained by imaging a sample;

setting, with respect to the target image data, a reference frame defined so as to include an integer number of pixels of reference image data whose pixel size is different from that of the target image data;

10 calculating a first evaluation value based on pixels included in the reference frame in the target image data;

calculating a second evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an area of the reference frame in the target image data;

15 calculating a third evaluation value based on the pixels included in the reference frame and pixels partially included in the reference frame, in the target image data; and

20 determining any one of the first evaluation value, the second evaluation value, or the third evaluation value as an evaluation value calculated for the reference frame, based on a magnitude relationship between the first evaluation value, the second evaluation value, and the third evaluation value.

13. A program for causing a computer to execute:

processing of reading target image data obtained by imaging a sample;

25 processing of setting, with respect to the target image data, a reference frame defined so as to include an integer number of pixels of reference image data whose pixel size is different from that of the target image data;

processing of calculating a first evaluation value based on pixels included in the reference frame in the target image data;

30 processing of calculating a second evaluation value based on the first evaluation value, and a predetermined coefficient based on a relationship between an area of a region consisting of the pixels included in the reference frame and an area of the reference frame in the target image data;

processing of calculating a third evaluation value based on the pixels included

in the reference frame and pixels partially included in the reference frame, in the target image data; and

5 processing of determining any one of the first evaluation value, the second evaluation value, or the third evaluation value as an evaluation value calculated for the reference frame, based on a magnitude relationship between the first evaluation value, the second evaluation value, and the third evaluation value.