

IMAGE DEDUPLICATION PROCESSING METHOD AND APPARATUS, STORAGE MEDIUM, AND ELECTRONIC DEVICE

[0001] This application claims the priority to Chinese Patent Application No. 202311803404.X, titled "IMAGE DEDUPLICATION PROCESSING METHOD AND APPARATUS, STORAGE MEDIUM, AND ELECTRONIC DEVICE", filed on December 26, 2023 with the China National Intellectual Property Administration, which is incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates to the field of image processing, and in particular to a method for image deduplication, an apparatus for image deduplication, a storage medium, and an electronic device.

BACKGROUND

[0003] With the improvement of computer processing capabilities, computer vision technology is increasingly applied in various scenarios. On one hand, images involve large amounts of data and complex calculations; on the other hand, in practical application scenarios, a large number of images may be collected, resulting in high information redundancy. Therefore, image deduplication is required. Through the image deduplication, some desired images may be extracted from a large number of images for subsequent applications.

[0004] For example, in high-precision technical fields such as wafers, the yield requirements for manufactured products are extremely high. Learning models such as neural network models are often used to automatically detect wafer yield. During the collecting process of sample images for training the learning model, the collected sample images generally have overly abundant data and high information redundancy. Therefore, it is required to perform image deduplication on the collected sample images.

[0005] Methods for image deduplication in the prior art mostly perform indiscriminate comparison directly between various images, thereby filtering out images with high redundancy based on the comparison results. This type of method for image deduplication requires a large

amount of computation and has poor real-time performance.

SUMMARY

[0006] The present disclosure is provided in view of the above-mentioned issues.

5 **[0007]** In a first aspect of the present disclosure, a method for image deduplication is provided.

The method comprises:

determining a template image from a plurality of sample images;

for each sample image of the plurality of sample images,

10 acquiring a frequency spectrum image of a to-be-processed image, where the to-be-processed image comprises the sample image and/or a feature image of the sample image;

determining a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image;

15 determining a total similarity between the sample image and the template image based on the frequency similarity; and

determining a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image.

20 **[0008]** In a possible implementation, the determining a template image from a plurality of sample images comprises:

calculating cosine similarities between respective sample images among the plurality of sample images;

25 for each sample image of the plurality of sample images, counting the number of first sample images, where a cosine similarity between each of the first sample images and the sample image is greater than a similarity threshold; and

comparing the respective numbers of first sample images which are counted for the plurality of sample images, and determining, as the template image, a sample image among the plurality of sample images for which the counted number of first sample images is the largest

among the respective numbers.

[0009] In a possible implementation, the frequency similarity comprises a high-frequency similarity and/or a low-frequency similarity, and

the acquiring a frequency spectrum image of a to-be-processed image comprises:

5 performing a Fourier transform on the to-be-processed image to obtain the frequency spectrum image of the to-be-processed image, and where

the determining a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image comprises:

10 determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image, and determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the template image ;

performing an inverse Fourier transform on the determined high-pass filtering regions and/or low-pass filtering regions to obtain corresponding high-pass filtered images and/or
15 corresponding low-pass filtered images; and

calculating a high-frequency similarity between the to-be-processed image and the template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image, and/or, calculating a low-frequency similarity between the to-be-processed image and the template image based
20 on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image.

[0010] In a possible implementation, the determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image, and determining a high-pass filtering region and/or a low-pass filtering region in the frequency
25 spectrum image of the template image comprises:

for the frequency spectrum image of the to-be-processed image or the frequency spectrum image of the template image,

determining a reference point in the frequency spectrum image, where the reference point is a center point of the frequency spectrum image; and

determining, within the frequency spectrum image, a rectangular region centered at the reference point as the low-pass filtering region, and a region outside the determined low-pass filtering region as the high-pass filtering region.

[0011] In a possible implementation, the calculating a high-frequency similarity between the to-be-processed image and the template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image comprises:

calculating a structural similarity between the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image as the high-frequency similarity between the to-be-processed image and the template image;

and/or

the calculating a low-frequency similarity between the to-be-processed image and the template image based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image comprises:

calculating a structural similarity between the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image as the low-frequency similarity between the to-be-processed image and the template image.

[0012] In a possible implementation, the frequency similarity comprises a high-frequency similarity and a low-frequency similarity, and the determining a total similarity between the sample image and the template image based on the frequency similarity comprises:

calculating a product of a high-frequency similarity between the feature image of the sample image and a feature image of the template image and a high-frequency similarity between the sample image and the template image as a first similarity;

calculating a product of a low-frequency similarity between the feature image of the sample image and the feature image of the template image and a low-frequency similarity between the sample image and the template image as a second similarity; and

calculating a sum of the first similarity and the second similarity as the total similarity between the sample image and the template image.

[0013] In a possible implementation, the determining a preset number of target images from

the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image comprises:

performing clustering on the total similarities between the plurality of sample images and the template image, where the number of obtained clusters is the preset number; and

5 selecting, for each cluster of the clusters, one target image from sample images in the cluster based on a clustering result.

[0014] In a second aspect of the present disclosure, an apparatus for image deduplication is provided. The apparatus comprises:

10 a selection module, configured to determine a template image from a plurality of sample images;

an acquisition module, configured to, for each sample image of the plurality of sample images, acquire a frequency spectrum image of a to-be-processed image, where the to-be-processed image comprises the sample image and/or a feature image of the sample image;

15 a determination module, configured to determine a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image;

a comparison module, configured to determine a total similarity between the sample image and the template image based on the frequency similarity; and

20 a deduplication module, configured to determine a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image.

[0015] In a third aspect of the present disclosure, a storage medium, storing a program instruction, is further provided. The program instruction, when executed, performs the method for image deduplication described above.

25 **[0016]** In a fourth aspect of the present disclosure, an electronic device, comprising a processor and a memory, is provided. The memory stores a computer program instruction, and the computer program instruction, when executed by the processor, performs the method for image deduplication described above.

[0017] In the above embodiments, firstly, a template image is determined from a plurality of

sample images, and then, deduplication is performed on the set of sample images based on the frequency similarities between the sample images and the template image. This not only ensures the accuracy of the image deduplication but also ensures the processing speed and improves real-time performance.

5 **[0018]** The above description is only an overview of the technical solutions of the present disclosure. It is intended to provide a better understanding of the technical means of the present disclosure so that it can be implemented in accordance with the specification, and to make the above and other objectives, features, and advantages of the present disclosure more apparent and comprehensible. The specific embodiments of the present disclosure are exemplified below.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The above and other objectives, features, and advantages of the present disclosure will become more apparent by describing the embodiments of the present disclosure in more detail with reference to the accompanying drawings. The accompanying drawings are intended to
15 provide a further understanding of the embodiments of the present disclosure, constitute a part of the specification, and are used for explaining the present disclosure together with the embodiments of the present disclosure, and do not constitute a limitation to the present disclosure. In the drawings, the same reference numerals generally represent the same components or steps.

20 **[0020]** FIG. 1 shows a flowchart of a method for image deduplication according to an embodiment of the present disclosure;

[0021] FIG. 2 shows a flowchart of determining a template image according to an embodiment of the present disclosure;

[0022] FIG. 3 shows a schematic block diagram of an apparatus for image deduplication
25 according to an embodiment of the present disclosure; and

[0023] FIG. 4 shows a schematic block diagram of an electronic device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0024] To make the objectives, technical solutions, and advantages of the present disclosure apparent, exemplary embodiments of the present disclosure are described in detail below with reference to the drawings. Apparently, the described embodiments are only a part of the
5 embodiments of the present disclosure, rather than all of them. It should be understood that the present disclosure is not limited by the exemplary embodiments described herein. Based on the embodiments of the present disclosure described in the present disclosure, all other embodiments obtained by those skilled in the art without creative efforts shall fall within the protection scope of the present disclosure.

10 [0025] To at least partially address the above technical issues, according to an aspect of the present disclosure, a method for image deduplication is provided.

[0026] FIG. 1 shows a flowchart of a method for image deduplication according to an embodiment of the present disclosure. As shown in FIG. 1, the method includes steps S110, S120, S130, S140, and S150.

15 [0027] In step S110, a template image is determined from multiple sample images.

[0028] Sample images are images to be deduplicated. For example, in the wafer production field, a large number of wafer images may be collected for training an artificial intelligence model. Since repeated information exists among the large number of wafer images, these wafer images may be deduplicated to extract desired images for subsequent training of the artificial
20 intelligence model.

[0029] Sample images may be RGB images or grayscale images. Sample images may be images of any suitable size and resolution. Sample images may be original images directly collected by an image acquisition apparatus, or images obtained by performing preprocessing operations on the original images. The preprocessing operation may include all operations for
25 improving the visual effect of the sample images, enhancing the clarity of the sample images, or highlighting certain features (e.g., the above-mentioned wafer) in the sample images. By way of example and not limitation, preprocessing operations may include digitization, geometric transformation, normalization, filtering, etc., on the original images.

[0030] A template image may be determined from multiple sample images. Alternatively, a
30 template image may be randomly selected from the multiple sample images. Alternatively, an

image with the highest similarity to other images among the multiple sample images may be determined as the template image based on the similarities between the multiple sample images. The template image may be used for similarity determination through comparison with each sample image among the multiple sample images.

- 5 **[0031]** In step S120, for each sample image of the multiple sample images, a frequency spectrum image of a to-be-processed image is acquired, where the to-be-processed image includes the sample image and/or a feature image of the sample image.

[0032] The feature image of the sample image may be a feature map extracted through a convolution operation of a convolutional neural network (CNN). The convolution operation achieves extraction and processing of spatial information of the image through the movement of a filter and element-wise multiplication. Additionally, weights and biases corresponding to different features may be learned, thereby enabling the CNN to effectively identify and classify images. Specifically, feature extraction may be performed using feature extraction networks such as ResNet50.

- 15 **[0033]** In step S120, each sample image and/or the feature image of the sample image is converted into a frequency spectrum image in a frequency domain representation. Since the template image is one of the sample images, a frequency spectrum image corresponding to the template image is further obtained.

[0034] It can be understood that converting the to-be-processed image into the frequency spectrum image may be implemented using any existing or future-developed algorithm.

[0035] In step S130, for each to-be-processed image, determine a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image.

[0036] The to-be-processed image includes a sample image and/or the feature image of the sample image, and the template image includes a template image and/or a feature image of the template image. A similarity between the frequency spectrum image of the sample image and the frequency spectrum image of the template image is calculated or a similarity between the frequency spectrum image of the feature image of the sample image and the frequency spectrum image of the feature image of the template image is calculated. Thus, for each to-be-processed image, a frequency similarity corresponding to the to-be-processed image is obtained. It can be

understood that, based on the respective frequency similarity corresponding to each to-be-processed image, a respective frequency similarity corresponding to each sample image is determined.

5 [0037] It can be understood that, for different frequency bands, the frequency similarity between the to-be-processed image and the template image may be calculated based on the frequency spectrum image of the to-be-processed image and the frequency spectrum image of the template image. Exemplarily, for each to-be-processed image, a high-frequency similarity and/or a low-frequency similarity between the to-be-processed image and the template image is calculated. The high-frequency similarity and the low-frequency similarity may be
10 determined based on a frequency threshold. The high-frequency similarity represents the similarity for a frequency above the frequency threshold, and the low-frequency similarity represents the similarity for a frequency below the frequency threshold.

[0038] In step S140, for each to-be-processed image, determine a total similarity between the sample image and the template image based on the frequency similarity.

15 [0039] In an embodiment, in step S130, the high-frequency similarity and the low-frequency similarity between the to-be-processed image and the template image may be determined. Furthermore, the above-mentioned to-be-processed image may include both the sample image and the feature image of the sample image. In step S140, the total similarity between each sample image and the template image may be calculated based on all the frequency similarity
20 corresponding to the sample image, which is determined in step S130. The total similarity comprehensively reflects the overall degree of similarity between two images, enabling a more accurate determination of the similarity between the two images.

[0040] In step S150, a preset number of target images are determined from the multiple sample images according to the respective total similarity between each sample image of the
25 multiple sample images and the template image.

[0041] The preset number may represent the number of images to be retained after the image deduplication operation on the sample images. It may be set based on the desired deduplication effect. A high desired deduplication ratio indicates a small preset number.

[0042] Based on the total similarities of all the sample images and the preset number, a total
30 similarity meeting the requirements is selected. Based on the sample image corresponding to

the selected total similarity, the required target image is then determined. The sample images other than the target image are removed to complete the image deduplication operation.

[0043] In the above embodiments, firstly, a template image is determined from multiple sample images, and then, deduplication is performed on the set of sample images based on the frequency similarities between the sample images and the template image. This not only ensures the accuracy of the image deduplication but also ensures the processing speed and improves real-time performance.

[0044] In some embodiments, FIG. 2 shows a flowchart of determining a template image according to one embodiment of the present disclosure. As shown in FIG. 2, step S110, determining a template image from multiple sample images, includes steps S111 to S113.

[0045] In step S111, cosine similarities between respective sample images among the multiple sample images are calculated.

[0046] A cosine similarity between each pair of sample images among the multiple sample images may be calculated to determine the template image based on the cosine similarity. All the sample images, including the template image, are converted into vector representations. The cosine similarity between each pair of vectors is calculated, which may be used to determine the similarity between two images.

[0047] The value of cosine similarity may range from -1 and 1. A value closer to 1 indicates that the two vectors are more similar to each other, that is, the similarity between the two images is higher. A value closer to -1 indicates that the two vectors are less similar to each other, that is, the similarity between the two images is lower.

[0048] In step S112, for each sample image of the multiple sample images, the number of first sample images is counted, where a cosine similarity between each of the first sample images and the sample image is greater than a similarity threshold.

[0049] The similarity threshold may be set according to the requirements of the application scenario, for example: 0.9.

[0050] The cosine similarities between each sample image and the remaining sample images are calculated sequentially. In a case that the cosine similarity between two sample images is greater than the similarity threshold, the number of first sample images counted for each of the two is increased by 1. In other words, each of the two sample images serves as a first sample

image with respect to the other. In a case that the cosine similarity between two sample images is less than or equal to the similarity threshold, the respective numbers of first sample images for the two sample images remain unchanged. After the calculations are completed for all the sample images, the number of first sample images for each sample image is obtained.

5 **[0051]** In step S113, the respective numbers of first sample images which are counted for the multiple sample images are compared, and a sample image among the multiple sample images, for which the counted number of first sample images is the largest among the respective numbers, is determined as the template image.

10 **[0052]** In an embodiment, the number of the multiple sample images is 200, since each sample image is used to calculate cosine similarities with the other 199 sample images, the number of first sample images counted for the sample image may be at least 0 and at most 199. If, for one sample image among the multiple sample images, the counted number of first sample images is the largest, i.e., if one sample image has the most sample images whose cosine similarity with this sample image is greater than the similarity threshold, then this sample image
15 is determined as the template image. In a case that the counted numbers of first sample images for two or more sample images are the same, one of the two or more sample images may be randomly selected as the template image.

20 **[0053]** In the above embodiments, by calculating the cosine similarities between the multiple sample images, the sample image that has the highest number of occurrences of having a cosine similarity greater than the similarity threshold with other sample images is determined as the template image. The template image better reflects the characteristics of the multiple sample images. The template image used for subsequent image deduplication operations effectively improves the effect of image deduplication.

25 **[0054]** As described above, the frequency similarity in step S130 may include a high-frequency similarity and/or a low-frequency similarity.

[0055] In some embodiments, step S120, acquiring the frequency spectrum image of the to-be-processed image, includes: performing a Fourier transform on the to-be-processed image to obtain the frequency spectrum image of the to-be-processed image.

30 **[0056]** Through a Fourier transform, an image is converted from the spatial domain to the frequency domain. A grayscale distribution function of the to-be-processed image is

transformed into a frequency distribution function of the to-be-processed image via the Fourier transform. The frequency spectrum image obtained by performing a Fourier transform on the to-be-processed image is a distribution map of the image gradient. The spots of varying brightness seen on the frequency spectrum image actually represent the degree of the difference between a pixel point in the to-be-processed image and neighboring pixel points of the pixel point, i.e., the magnitude of the gradient, which is also the magnitude of the frequency at the pixel point. If there are more dark pixel points in the frequency spectrum image, the to-be-processed image is softer; conversely, if there are more bright pixel points in the frequency spectrum image, the to-be-processed image is sharper, with a clear boundary and a large pixel difference between two sides of the boundary. In summary, the frequency spectrum image of the to-be-processed image represents the characteristics of the to-be-processed image from a frequency perspective.

[0057] In step S130, determining the frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and the frequency spectrum image of the template image, may include following process. A high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image is determined, and a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the template image is determined. An inverse Fourier transform is performed on the determined high-pass filtering regions and/or low-pass filtering regions to obtain corresponding high-pass filtered images and/or corresponding low-pass filtered images. A high-frequency similarity between the to-be-processed image and the template image is calculated based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image, and/or, a low-frequency similarity between the to-be-processed image and the template image is calculated based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image.

[0058] The frequency spectrum image of the to-be-processed image may include a high-pass filtering region and a low-pass filtering region. A region closer to the center point of the frequency spectrum image corresponds to a lower frequency; conversely, a region closer to the edge of the frequency spectrum image corresponds to a higher frequency. The center point of the frequency spectrum image may represent the average grayscale of the to-be-processed image, and the frequency at the center point is 0. Radially outward from the center point of the

frequency spectrum image, the frequency increases sequentially. That is, a central region of the frequency spectrum image corresponds to the low-pass filtering region, and a peripheral region corresponds to the high-pass filtering region. Based on the above principle, the high-pass filtering regions and/or the low-pass filtering regions in the respective frequency spectrum images of the to-be-processed image and the template image are determined. By setting the spectrum values of the low-pass filtering region of the frequency spectrum image of the to-be-processed image to 0 and keeping the spectrum values of the high-pass filtering region unchanged, the high-pass filtering region is obtained. By setting the spectrum values of the high-pass filtering region of the frequency spectrum image to 0 and keeping the spectrum values of the low-pass filtering region unchanged, the low-pass filtering region is obtained.

[0059] An inverse Fourier transform is performed on the high-pass filtering region and/or the low-pass filtering region to obtain a corresponding high-pass filtered image and/or low-pass filtered image. Through the inverse Fourier transform, the frequency distribution of the image is transformed back into the grayscale distribution.

[0060] In some embodiments, the high-frequency similarity between the to-be-processed image and the template image is calculated based on the respective high-pass filtered images corresponding to the to-be-processed image and the template image. Alternatively, the low-frequency similarity between the to-be-processed image and the template image is calculated based on the respective low-pass filtered images corresponding to the to-be-processed image and the template image. In a preferable embodiment, both the high-frequency similarity and the low-frequency similarity may be calculated. For some images, high-frequency details are more prominent, while low-frequency parts are attenuated or filtered out; therefore, the high-pass filtering region in the frequency spectrum image of such an image has higher brightness and is more meaningful. Similarly, for some images, low-frequency components are more prominent, while high-frequency details are blurred or suppressed; therefore, the low-pass filtering region in the frequency spectrum image of such an image has higher brightness and is more meaningful. In practical application scenarios, either or both of the high-frequency similarity and the low-frequency similarity may be calculated as needed.

[0061] In the above embodiments, calculation is performed based on the high-pass filtered image and/or the low-pass filtered image of the to-be-processed image and the high-pass filtered image and/or the low-pass filtered image of the template image to obtain the corresponding

high-frequency similarity and/or low-frequency similarity. The high-frequency similarity and low-frequency similarity indicate the similarity relationship between the images. Based on the high-frequency similarity and/or low-frequency similarity, the accuracy of image deduplication is effectively improved, thereby ensuring that the removed images have high redundancy with the retained images. Particularly, in embodiments where both the high-frequency similarity and the low-frequency similarity are calculated, the image features are compared more comprehensively, further effectively improving the accuracy of image deduplication.

[0062] In some embodiments, the process of determining the high-pass filtering region and/or the low-pass filtering region in the frequency spectrum image of the to-be-processed image and determining the high-pass filtering region and/or the low-pass filtering region in the frequency spectrum image of the template image may include: performing the following operations on the frequency spectrum image of the to-be-processed image or the frequency spectrum image of the template image. First, a reference point is determined in the frequency spectrum image, where the reference point is a center point of the frequency spectrum image. Then a rectangular region which is centered at the reference point and located within the frequency spectrum image is determined as the low-pass filtering region, and a region which is located outside the determined low-pass filtering region and within the frequency spectrum image is determined as the high-pass filtering region.

[0063] In an embodiment, the center point of the frequency spectrum image, determined based on the length and width of the frequency spectrum image, is used as the reference point. A rectangular region is determined with the reference point as the center point of the rectangular region. It can be understood that the determined rectangular region is located at the center of the frequency spectrum image. For example, through the above operations, a rectangular region of, for example, 60×60 is set at the center of the frequency spectrum image. The rectangular region is the low-pass filtering region, and the region outside the rectangular region is the high-pass filtering region. The size of the rectangular region in the frequency spectrum image may be adjusted according to specific practical requirements. By adjusting the size of the rectangular region, the respective ranges of the low-pass filtering region and the high-pass filtering region in the frequency spectrum image are modified accordingly.

[0064] In the above embodiments, the low-pass filtering region and the high-pass filtering region are determined by setting a rectangular region in the frequency spectrum image. This

solution allows flexible adjustment of the ranges of the low-pass filtering region and the high-pass filtering region, and is computationally simple and easily implementable.

[0065] In some embodiments, the process of calculating the high-frequency similarity between the to-be-processed image and the template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image may include: calculating a structural similarity (Structural Similarity Index, SSIM) between the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image as the high-frequency similarity between the to-be-processed image and the template image.

[0066] Structural similarity may be used to measure the similarity between two images. Structural similarity is perception-based and aligns more with human visual perception. Structural similarity mainly considers three key features of an image: luminance, contrast, and structure. Luminance may be measured by the average grayscale, obtained by averaging the pixel values of all pixels. Contrast may be measured by the grayscale standard deviation. Structure may be measured based on a correlation coefficient.

[0067] Similarly, the process of calculating the low-frequency similarity between the to-be-processed image and the template image based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image may include: calculating a structural similarity between the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image as the low-frequency similarity between the to-be-processed image and the template image.

[0068] For the case where the to-be-processed image is the sample image, SSIM similarity calculation is performed between the high-pass filtered image corresponding to the sample image and the high-pass filtered image corresponding to the template image to obtain the image high-frequency similarity (ISH).

[0069] For the case where the to-be-processed image is the sample image, SSIM similarity calculation is performed between the low-pass filtered image corresponding to the sample image and the low-pass filtered image corresponding to the template image to obtain the image low-frequency similarity (ISL).

[0070] For the case where the to-be-processed image is the feature image of the sample image, SSIM similarity calculation is performed between the high-pass filtered image corresponding to the feature image of the sample image and the high-pass filtered image corresponding to the feature image of the template image to obtain the feature high-frequency similarity (FSH).

5 **[0071]** For the case where the to-be-processed image is the feature image of the sample image, SSIM similarity calculation is performed between the low-pass filtered image corresponding to the feature image of the sample image and the low-pass filtered image corresponding to the feature image of the template image to obtain the feature low-frequency similarity (FSL).

[0072] It can be understood that, since the to-be-processed image includes all sample images
10 of the multiple sample images and/or respective feature images of all the sample images, the to-be-processed image includes the template image and/or the feature image of the template image. Therefore, when the structural similarity is calculated, if the similarity is calculated between an image and itself, for example, between the template image and itself, or between the feature image of the template image and itself, then both the high-frequency similarity and
15 the low-frequency similarity may be 1.

[0073] In the above embodiments, performing image deduplication based on the structural similarity calculation better conforms to human visual perception, thereby improving the accuracy of deduplication.

[0074] In some embodiments, the frequency similarity includes a high-frequency similarity
20 and a low-frequency similarity.

[0075] The above step S140, determining the total similarity between the sample image and the template image based on the frequency similarity, includes the following steps S141 to S143.

[0076] In step S141, a product of the high-frequency similarity between the feature image of the sample image and the feature image of the template image and the high-frequency similarity
25 between the sample image and the template image is calculated as a first similarity.

[0077] In step S142, a product of the low-frequency similarity between the feature image of the sample image and the feature image of the template image and the low-frequency similarity between the sample image and the template image is calculated as a second similarity.

[0078] In step S143, a sum of the first similarity and the second similarity is calculated as the
30 total similarity between the sample image and the template image.

[0079] In an embodiment, the total similarity Y may be calculated by the following formula:

$$Y = ISH \times FSH + ISL \times FSL$$

where ISH represents the image high-frequency similarity, FSH represents the feature high-frequency similarity, ISL represents the image low-frequency similarity, and FSL represents the feature low-frequency similarity. The image high-frequency similarity is the high-frequency similarity between the sample image and the template image. The feature high-frequency similarity is the high-frequency similarity between the feature image of the sample image and the feature image of the template image. The image low-frequency similarity is the low-frequency similarity between the sample image and the template image. The feature low-frequency similarity is the low-frequency similarity between the feature image of the sample image and the feature image of the template image.

[0080] In the above embodiments, the calculation of the total similarity involves not only the sample image itself but also the feature image of the sample image, and is further based on not only the high-frequency similarity between the images but also the low-frequency similarity between the images. This ensures the effectiveness of image deduplication. Moreover, the above calculation method is simple, has a fast calculation speed and low implementation cost, making it suitable for scenarios requiring rapid processing of large amounts of image data. Furthermore, the total similarity calculation method is applicable to various types of images, possessing strong universality.

[0081] In some embodiments, the above step S150, determining a preset number of target images from the multiple sample images according to the respective total similarity between each sample image of the multiple sample images and the template image includes: performing clustering on the total similarities between the multiple sample images and the template image, where the number of obtained clusters is the preset number; and selecting, for each cluster of the clusters, one target image from sample images in the cluster based on a clustering result.

[0082] K-Means clustering algorithm may be used to perform clustering on the total similarities between the multiple sample images and the template image. Through K-Means clustering, data points are divided into K clusters, where K is a pre-determined parameter. In the embodiments of the present disclosure, K represents the preset number of target images, i.e., the number of images remaining after the image deduplication operation. In the K-Means clustering algorithm, an iterative calculation is performed to move the centroids of the clusters

until the optimal clustering is determined. In the embodiments of the present disclosure, no limitation is made on the clustering method. Any method capable of grouping data falls within the protection scope of the present disclosure.

[0083] In an embodiment, a case that the number of sample images is 200 and the deduplication ratio is set to 90% is taken as an example, the preset number is $200 \times (1 - 0.9) = 20$. In this case, K-Means clustering is performed on the total similarities to divide the total similarities of the sample images into 20 clusters, and the centroid of each cluster is the mean of the similarities included in the cluster. Based on a respective centroid of each cluster, a total similarity closest to the centroid is selected from the cluster, and a sample image corresponding to the selected total similarity is determined. Thus, for each cluster of the clusters, one sample image is determined. The sample images determined from all the clusters in this manner ultimately constitute the 20 images retained after image deduplication.

[0084] In the above embodiments, deduplication is implemented on the sample images by using a clustering method, simplifying and efficiently processing a large number of sample images, thereby effectively ensuring processing speed. Furthermore, the accuracy of the image deduplication method is further improved.

[0085] According to another aspect of the present disclosure, an apparatus for image deduplication is further provided. FIG. 3 shows a schematic block diagram of an apparatus for image deduplication according to an embodiment of the present disclosure. As shown in FIG. 3, the apparatus 300 for image deduplication includes a selection module 310, an acquisition module 320, a determination module 330, a comparison module 340, and a deduplication module 350.

[0086] The selection module 310 is configured to determine a template image from multiple sample images. The acquisition module 320 is configured to, for each sample image of the multiple sample images, acquire a frequency spectrum image of a to-be-processed image, where the to-be-processed image includes the sample image and/or a feature image of the sample image. The determination module 330 is configured to determine a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image. The comparison module 340 is configured to determine a total similarity between the sample image and the template image based on the frequency similarity. The deduplication module 350

is configured to determine a preset number of target images from the multiple sample images according to the respective total similarity between each sample image of the multiple sample images and the template image.

[0087] According to another aspect of the present disclosure, an electronic device is further provided. FIG. 4 shows a schematic block diagram of an electronic device 400 according to an embodiment of the present disclosure. As shown in FIG. 4, the electronic device 400 includes a processor 410 and a memory 420. The memory 420 stores a computer program instruction, and the computer program instruction, when executed by the processor, performs the method for image deduplication described above.

[0088] According to another aspect of the present disclosure, a storage medium is further provided. A program instruction is stored on the storage medium. The program instruction, when executed by a computer or a processor, causes the computer or the processor to perform the corresponding steps of the method for image deduplication of the embodiments of the present disclosure, and to realize the corresponding modules of the above-described apparatus for image deduplication or the corresponding modules of the above-described electronic device according to the embodiments of the present disclosure. The storage medium may include, for example, a storage component of a tablet computer, a hard disk of a personal computer, a read-only memory (ROM), an erasable programmable read-only memory (EPROM), a portable compact disc read-only memory (CD-ROM), a USB memory, or any combination of the above storage media. The computer-readable storage medium may be any combination of one or more computer-readable storage media.

[0089] By reading the above detailed description of the method for image deduplication, those skilled in the art can understand the specific implementation and beneficial effects of the above apparatus for image deduplication, storage medium, and electronic device. For brevity, the details are not repeated here.

[0090] Embodiments

[0091] Embodiment 1

A method for image deduplication is provided, and the method comprises:

determining a template image from a plurality of sample images;

for each sample image of the plurality of sample images,

acquiring a frequency spectrum image of a to-be-processed image, where the to-be-processed image comprises the sample image and/or a feature image of the sample image;

determining a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image;

determining a total similarity between the sample image and the template image based on the frequency similarity; and

determining a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image.

[0092] Embodiment 2

The method described in embodiment 1 is provided, where the determining a template image from a plurality of sample images comprises:

calculating cosine similarities between respective sample images among the plurality of sample images;

for each sample image of the plurality of sample images, counting the number of first sample images, where a cosine similarity between each of the first sample images and the sample image is greater than a similarity threshold; and

comparing the respective numbers of first sample images which are counted for the plurality of sample images, and determining, as the template image, a sample image among the plurality of sample images for which the counted number of first sample images is the largest among the respective numbers.

[0093] Embodiment 3

The method described in embodiments 1 or 2 is provided, where the frequency similarity comprises a high-frequency similarity and/or a low-frequency similarity, and the acquiring a frequency spectrum image of a to-be-processed image comprises:

performing a Fourier transform on the to-be-processed image to obtain the frequency spectrum image of the to-be-processed image, and where

the determining a frequency similarity between the to-be-processed image and the

template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image comprises:

determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image, and determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the template image ;

performing an inverse Fourier transform on the determined high-pass filtering regions and/or low-pass filtering regions to obtain corresponding high-pass filtered images and/or corresponding low-pass filtered images; and

calculating a high-frequency similarity between the to-be-processed image and the template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image, and/or, calculating a low-frequency similarity between the to-be-processed image and the template image based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image.

[0094] Embodiment 4

The method described in any one of embodiments 1 to 3 is provided, where the determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image, and determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the template image comprises:

for the frequency spectrum image of the to-be-processed image or the frequency spectrum image of the template image,

determining a reference point in the frequency spectrum image, where the reference point is a center point of the frequency spectrum image; and

determining, within the frequency spectrum image, a rectangular region centered at the reference point as the low-pass filtering region, and a region outside the determined low-pass filtering region as the high-pass filtering region.

[0095] Embodiment 5

The method described in any one of embodiments 1 to 4 is provided, where the calculating

a high-frequency similarity between the to-be-processed image and the template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image comprises:

5 calculating a structural similarity between the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image as the high-frequency similarity between the to-be-processed image and the template image;

and/or

10 the calculating a low-frequency similarity between the to-be-processed image and the template image based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image comprises:

calculating a structural similarity between the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image as the low-frequency similarity between the to-be-processed image and the template image.

[0096] Embodiment 6

15 The method described in any one of embodiments 1 to 5 is provided, where the frequency similarity comprises a high-frequency similarity and a low-frequency similarity, and

the determining a total similarity between the sample image and the template image based on the frequency similarity comprises:

20 calculating a product of a high-frequency similarity between the feature image of the sample image and a feature image of the template image and a high-frequency similarity between the sample image and the template image as a first similarity;

calculating a product of a low-frequency similarity between the feature image of the sample image and the feature image of the template image and a low-frequency similarity between the sample image and the template image as a second similarity; and

25 calculating a sum of the first similarity and the second similarity as the total similarity between the sample image and the template image.

[0097] Embodiment 7

The method described in any one of embodiments 1 to 6 is provided, where the determining a preset number of target images from the plurality of sample images according to

the respective total similarity between each sample image of the plurality of sample images and the template image comprises:

performing clustering on the total similarities between the plurality of sample images and the template image, where the number of obtained clusters is the preset number; and

5 selecting, for each cluster of the clusters, one target image from sample images in the cluster based on a clustering result.

[0098] Embodiment 8

An apparatus for image deduplication is provided, and the apparatus comprises:

10 a selection module, configured to determine a template image from a plurality of sample images;

an acquisition module, configured to, for each sample image of the plurality of sample images, acquire a frequency spectrum image of a to-be-processed image, where the to-be-processed image comprises the sample image and/or a feature image of the sample image;

15 a determination module, configured to determine a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image;

a comparison module, configured to determine a total similarity between the sample image and the template image based on the frequency similarity; and

20 a deduplication module, configured to determine a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image.

[0099] Embodiment 9

25 A storage medium, storing a program instruction, is provided. The program instruction, when executed, performs the method for image deduplication described in any one of embodiments 1 to 7.

[0100] Embodiment 10

An electronic device, comprising a processor and a memory, is provided. The memory stores a computer program instruction, and the computer program instruction, when executed

by the processor, performs the method for image deduplication described in any one of embodiments 1 to 7.

[0101] Although the embodiments have been described herein with reference to the drawings, it should be understood that the above embodiments are merely exemplary and are not intended to limit the scope of the present disclosure. Various changes and modifications may be made by those skilled in the art without departing from the scope and spirit of the present disclosure. All such changes and modifications are deemed to fall into the scope claimed by the claims of the present disclosure.

[0102] Those skilled in the art may realize that the units and algorithm steps of each example described in conjunction with the embodiments herein may be implemented by electronic hardware, or a combination of computer software and electronic hardware. Whether these functions are performed in hardware or software depends on the specific application and design constraints of the technical solution. Those skilled in the art may use different methods to implement the described functions for each specific application, but such implementation should not be regarded as exceeding the scope of the present disclosure.

[0103] It should be understood that the devices and methods disclosed in the embodiments of the present disclosure may be implemented in other manners. For example, the device embodiments described hereinabove are only schematic. For example, the division of the units is only based on logical functions, and there may be other division manners in practical implementation, such as multiple units or components may be combined or integrated into another device, or some features may be neglected or not executed.

[0104] In the specification provided herein, a lot of specific details are explained. However, it may be understood that the embodiments of the present disclosure may be practiced without these specific details. In some embodiments, well-known methods, structures and techniques are not shown in detail in order to avoid obscuring understanding of the specification.

[0105] Similarly, it should be understood that in order to simplify the present disclosure and facilitate understanding one or more of the various aspects of the disclosure, in the description of the exemplary embodiments of the present disclosure, the various features of the present disclosure are sometimes grouped together into a single embodiment, figure, or description thereof. However, the method according to the present disclosure should not be interpreted as reflecting the following intention: the claimed disclosure requires more features than those

explicitly stated in each claim. More specifically, as reflected in the corresponding claims, the inventive point is that the corresponding technical problem can be solved with features fewer than all the features of a single embodiment being disclosed. Therefore, the claims following the detailed description are hereby expressly incorporated into the detailed description, where
5 each claim itself serves as an independent embodiment of the present disclosure.

[0106] It can be understood by those skilled in the art that, except for mutually exclusive features, all features disclosed in this specification (including the claims, abstract and drawings) and all processes or units of any method or device disclosed in the specification may be combined in any way. Unless otherwise expressly stated, each feature disclosed in this
10 specification (including the claims, abstract and drawings) may be replaced by an alternative feature that provides the same, equivalent or similar purpose.

[0107] In addition, it can be understood by those skilled in the art that, although some embodiments described herein include certain features included in other embodiments instead of other features, the combination of features of different embodiments is meant to be within
15 the scope of the present disclosure and form different embodiments. For example, in the claims, any one of the claimed embodiments may be used in any combination.

[0108] The various component embodiments of the present disclosure may be implemented in hardware, or in software modules running on one or more processors, or in a combination thereof. It can be understood by those skilled in the art that a microprocessor or a digital signal
20 processor (DSP) may be adopted in practice to realize some or all of the functions of some of the modules of the apparatus for image deduplication according to the embodiments of the present disclosure. The present disclosure may alternatively be implemented as a device program (such as a computer program and computer program product) for performing part or all of the methods described herein. Such a program implementing the present disclosure may
25 be stored on a computer-readable medium, or may be in the form of one or more signals. Such a signal may be downloaded from an Internet website, or provided on a carrier signal, or provided in any other form.

[0109] It should be noted that the above embodiments illustrate rather than limit the present disclosure, and alternative embodiments may be designed by those skilled in the art without
30 departing from the scope of the claims. In the claims, any reference symbol between parentheses shall not be construed as a limitation of the claims. The word "comprising/including" does not

exclude the presence of elements or steps not listed in the claims. The word "a" or "an" preceding an element does not exclude the presence of multiple of such elements. The present disclosure may be implemented by means of hardware including several different elements and by means of a suitably programmed computer. In a unit claim enumerating several apparatuses,
5 several of these apparatuses may be embodied by a same hardware item. The use of the words "first", "second", "third" and the like does not indicate any order. These words may be interpreted as names.

[0110] Described above are only specific embodiments of the present disclosure or explanation for the specific embodiments of the present disclosure, and the protection scope of
10 the present disclosure is not limited thereto. Any changes or alternations that can be easily envisaged by those familiar with the art within the technical scope disclosed in the present disclosure shall fall within the protection scope of the present disclosure. The protection scope of the present disclosure shall be in accordance with the protection scope of the claims.

CLAIMS

1. A method for image deduplication, comprising:

determining a template image from a plurality of sample images;

5 for each sample image of the plurality of sample images,

acquiring a frequency spectrum image of a to-be-processed image, wherein the to-be-processed image comprises the sample image and/or a feature image of the sample image;

10 determining a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image;

determining a total similarity between the sample image and the template image based on the frequency similarity; and

15 determining a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image.

2. The method according to claim 1, wherein the determining a template image from a plurality of sample images comprises:

20 calculating cosine similarities between respective sample images among the plurality of sample images;

for each sample image of the plurality of sample images, counting the number of first sample images, wherein a cosine similarity between each of the first sample images and the sample image is greater than a similarity threshold; and

25 comparing the respective numbers of first sample images which are counted for the plurality of sample images, and determining, as the template image, a sample image among the plurality of sample images for which the counted number of first sample images is the largest among the respective numbers.

3. The method according to claim 1, wherein the frequency similarity comprises a high-frequency similarity and/or a low-frequency similarity, and

the acquiring a frequency spectrum image of a to-be-processed image comprises:

performing a Fourier transform on the to-be-processed image to obtain the frequency spectrum image of the to-be-processed image, and wherein

the determining a frequency similarity between the to-be-processed image and the
5 template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image comprises:

determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image, and determining a high-pass
10 filtering region and/or a low-pass filtering region in the frequency spectrum image of the template image;

performing an inverse Fourier transform on the determined high-pass filtering regions and/or low-pass filtering regions to obtain corresponding high-pass filtered images and/or corresponding low-pass filtered images; and

calculating a high-frequency similarity between the to-be-processed image and the
15 template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image, and/or, calculating a low-frequency similarity between the to-be-processed image and the template image based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image.

20 4. The method according to claim 3, wherein the determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the to-be-processed image, and determining a high-pass filtering region and/or a low-pass filtering region in the frequency spectrum image of the template image comprises:

for the frequency spectrum image of the to-be-processed image or the frequency spectrum
25 image of the template image,

determining a reference point in the frequency spectrum image, wherein the reference point is a center point of the frequency spectrum image; and

determining, within the frequency spectrum image, a rectangular region centered at the reference point as the low-pass filtering region, and a region outside the determined
30 low-pass filtering region as the high-pass filtering region.

5. The method according to claim 3, wherein,

the calculating a high-frequency similarity between the to-be-processed image and the template image based on the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image comprises:

5 calculating a structural similarity between the high-pass filtered image corresponding to the to-be-processed image and the high-pass filtered image corresponding to the template image as the high-frequency similarity between the to-be-processed image and the template image;

and/or

10 the calculating a low-frequency similarity between the to-be-processed image and the template image based on the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image comprises:

calculating a structural similarity between the low-pass filtered image corresponding to the to-be-processed image and the low-pass filtered image corresponding to the template image as the low-frequency similarity between the to-be-processed image and the template image.

15 6. The method according to any one of claims 1 to 5, wherein the frequency similarity comprises a high-frequency similarity and a low-frequency similarity, and

the determining a total similarity between the sample image and the template image based on the frequency similarity comprises:

20 calculating a product of a high-frequency similarity between the feature image of the sample image and a feature image of the template image and a high-frequency similarity between the sample image and the template image as a first similarity;

calculating a product of a low-frequency similarity between the feature image of the sample image and the feature image of the template image and a low-frequency similarity between the sample image and the template image as a second similarity; and

25 calculating a sum of the first similarity and the second similarity as the total similarity between the sample image and the template image.

7. The method according to claim 1, wherein the determining a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image comprises:

performing clustering on the total similarities between the plurality of sample images and the template image, wherein the number of obtained clusters is the preset number; and

selecting, for each cluster of the clusters, one target image from sample images in the cluster based on a clustering result.

5 8. An apparatus for image deduplication, comprising:

a selection module, configured to determine a template image from a plurality of sample images;

an acquisition module, configured to, for each sample image of the plurality of sample images, acquire a frequency spectrum image of a to-be-processed image, wherein the to-be-processed image comprises the sample image and/or a feature image of the sample image;

10 a determination module, configured to determine a frequency similarity between the to-be-processed image and the template image based on the frequency spectrum image of the to-be-processed image and a frequency spectrum image of the template image;

a comparison module, configured to determine a total similarity between the sample image and the template image based on the frequency similarity; and

15 a deduplication module, configured to determine a preset number of target images from the plurality of sample images according to the respective total similarity between each sample image of the plurality of sample images and the template image.

9. A storage medium, storing a program instruction, wherein the program instruction, when executed, performs the method for image deduplication according to any one of claims 1 to 7.

10. An electronic device, comprising a processor and a memory, wherein the memory stores a computer program instruction, and the computer program instruction, when executed by the processor, performs the method for image deduplication according to any one of claims 1 to 7.

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