Computer-Implemented Method for Obtaining a Combined Image

The present invention relates to obtaining a computer-implemented method for obtaining a combined image from two images.

Prior art

Combining images taken of, for example, different portions of an object like a fingerprint of a user or a face of the user is a commonly known task, particularly in cases where the user is to be identified using respective images. For aligning different portions of an object from different images, the “Ransac algorithm” was developed as explained in a “Mosaic Approach to Touchless Fingerprint Image with Multiple views” by Alkhathami et al.

The method described in the prior art is applicable for aligning parts of objects from different images. However, the approach only provides for an approximate aligning of the respective portions of different images. This has drawbacks in the context of identification accuracy if such aligned portions of images are used for identifying a user.

There is consequently a consistent need for improving the creation of combined images, particularly in the context of user identification using several images from the same biometric feature of the user, like his or her fingerprint or his or her eye.

Object

Starting from the known prior art, the object of the present invention is to improve the accuracy with which combined images are obtained from at least two images of a biometric feature.

Summary

This object is solved by a computer-implemented method for obtaining a combined image from two images and a device comprising at least one processor and a memory comprising computer-executable instructions according to aspects below. Preferred examples of the disclosure are provided in the dependent claims.

According to an aspect, a computer-implemented method for obtaining a combined image from two images is provided, the computer-implemented method comprising:
obtaining a first original image and a second original image of a biometric feature of a user, the biometric feature comprising a plurality of characteristics;
determining a frequency of at least some of the characteristics in the first original image and in the second original image;
resizing, based on the determined frequency, the first original image and/or the second original image to obtain a first image and a second image;
identifying, in the first image and in the second image, the characteristics and store the first and second image and the identified characteristics;
for at least some of the identified characteristics in the first image, identifying corresponding identified characteristics in the second image;
deriving an affine transformation for transforming the at least some of the identified characteristics in the second image into the corresponding identified characteristics in the first image;
modifying at least a portion of the second image using the Fourier transformation and obtaining a combined image comprising at least one portion of the first image and the at least one modified portion of the second image.

The frequency of the at least some of the characteristics in the first original image and the second original image can be obtained by, for example, applying a Fourier transformation to the characteristics or portions of the images in which the respective characteristics are present. For example, distances between characteristics, like for example ridges of a fingerprint, can be transformed by applying a discrete Fourier transformation into the space of reciprocal distances (i.e. “frequencies”).

Resizing the first original image and/or the second original image to obtain a first image and a second image can comprise that only one of the first and the second image is resized based on the determined frequency. For example, the first image may be maintained in its original size and only the second image may be resized so as to match the frequency determined for the first original image. In other examples, only the first original image is resized and the second image is maintained or both images are resized based on the respective frequency. For example, in one example it can be provided that at least one of the first and the second original images is resized based on the frequency so as to obtain a resolution of the characteristics that results in a geometric property of the characteristics to fulfil a particular requirement. In the case of the characteristics constituting ridges, for

example, the resizing may be done so that a distance between ridges corresponds to a particular dpi value such as, for example, 250, 300 or 500 or 650 dpi. Alternatively or additionally, it may be provided that one of the images is resized so that the frequency of the resized image matches the frequency of the other image.

This resizing can constitute a preliminary or approximate matching of the images, in one example.

In case only one of the first and the second original images is resized based on the frequency, the other original image may be maintained identical. In any case, after that step, the first original image and the second original image (irrespective of which them has been resized) are referred to as first and second images.

The affine transformation can comprise movements, rotations or stretchings or shrinkings or any combination thereof of the at least a portion of the second image. Thereby, a more accurate matching of the corresponding portions and the first and second image is obtained so that the combined image is obtained from the first and second image with increased accuracy, allowing for using the combined image for, for example, identifying a user based on the biometric feature.

In one example, the method further comprises obtaining a final combined image, comprising applying a curvature transformation to the combined image.

The curvature transformation can comprise, for example, modifying portions in the combined image so as to more closely match the shape of the three-dimensional object constituting the biometric feature or on which the biometric feature is provided. If, for example, the biometric feature is a fingerprint of a user, the curvature transformation can comprise transforming the combined image so as to more approximately match an image of the whole biometric feature if taken from a particular perspective. For example, the shape of the finger which may be assumed to be generally cylindrical influences how the biometric feature as a whole would appear if a single image of the whole biometric feature were taken from a particular perspective or viewpoint. By applying the curvature transformation to the combined image, this can properly be taken into account, further increasing the identification accuracy. In this context, the first (original) image may be identified as a center image taken from a center region where the finger is photographed from the front and the second image may be a side image that neighbors the center region of the finger and even though obtained from the front, would usually exhibit distortions if taken together with the image of the center

region. By applying the curvature transformation, this can be taken into account thereby further increasing the accuracy of the final combined image.

The method can comprise binarizing the first original image and the second original image and determining the frequency of the characteristics from the binarized first image and the binarized second image. Binarizing can comprise obtaining a black/white image. This can improve the accuracy with which the characteristics can be identified for resizing and/or determining the affine transformation.

The method can further comprise using the affine transformation for modifying at least a portion of the second image and obtaining the combined image in a non-binarized state. This can improve the identification accuracy while the accuracy would reach the combined images obtained based on binarized first and second images can be increased.

In one example, the biometric feature is a fingerprint and the plurality of characteristics are minutiae or wherein the biometric feature is an iris of an eye and the plurality of characteristics are pigments of the iris. For these biometric features, determining a combined image in the manner as provided according to examples of the present disclosure as explained above and below provides improved identification accuracy if the combined image is used for identifying a user.

It can be provided that determining the frequency is performed using first characteristics and wherein deriving the affine transformation is performed using second characteristics.

The first and second characteristics are preferably distinct from each other so that systematic errors that exist for the first and second characteristics (for example regarding their identification in an image) are not influencing both the resizing step and the determination of the affine transformation so that the overall error of obtaining the combined image can be reduced, thereby further increasing the identification accuracy.

In a more specific example, the biometric feature is a fingerprint and the first characteristics are ridges and the second characteristics are minutiae of the fingerprint.

In one example, deriving the affine transformation comprises determining, based on at least one fitting criterion, a subset of best fitting identified characteristics in the first image and corresponding characteristics in the second image and using the subset to derive the affine transformation. The fitting criteria can, for example, be a threshold value associated with for example a geometric property of the characteristics or the like. If the characteristics

exhibit a property below this threshold value, they may be discarded whereas characteristics exhibiting a property that exceeds the threshold value can be further used for determining the affine transformation for example because they can be assumed to be more reliable. In this case, the number of characteristics used can either be preset or not. Particularly, all pairs of corresponding characteristics of the first and second image that exceed the threshold value can be used irrespective of their number. It is noted that also the opposite is possible, i.e. only pairs of corresponding characteristics that exhibit values or properties below the threshold value are used for determining the affine transformation and pairs having values above the threshold are discarded. Alternatively, the fitting criterion can be a reference value and those characteristics that exhibit corresponding properties or values that come closer or closest to the reference value can be used. The number of characteristics used can be limited to a particular (for example preset) number of for example 3, 4, 5 or more so that those characteristics that most closely come to the reference value are used for determining the affine transformation. In any case, by using such fitting criterion, the affine transformation is obtained with increased accuracy.

In one example, the fitting criterion comprises at least one of a geometric property of the characteristics, a quality of an area comprising at least one of the characteristics. The geometric property can for example be a length or angular position or orientation of the characteristics. If the characteristics are, for example, ridges, their length can be used as fitting criterion. If the characteristics are minutiae, their distance can be used as fitting criterion. Particularly, the distance between minutiae in a particular image (first image and/or second image) can be used as geometric property. The fitting criterion can, for example, be a threshold value that indicates a threshold distance between minutiae in a particular image. Minutiae having a distance to each other that is larger than this threshold value can be determined to be used for determining the affine transformation. Minutiae having a distance to each other that is smaller than this threshold value can be determined to not be used for determining the affine transformation. Alternative or additionally, among all minutiae available in the respective image, those can be further used that exhibit the largest distance to each other and that have a matching minutiae in the other image. This is particularly advantageous because the longer the distance between minutiae is, the more reliable, for example, an angle of rotation as one parameter of the affine transformation can be determined.

The quality of the area in which the characteristics are provided can for example comprise a uniformity in ridge orientation or a deviation of ridge frequency within or across the respective area. A fitting criterion can be that for example the ridge orientation does not

change by more than a particular amount or is closest to a particular amount. Alternatively or additionally, the fitting criterion can comprise a deviation in the ridge frequency across the area to be below a particular value or to come closest to a particular value.

Using such criteria can ensure that preferably the most uniform characteristics are used which increases the accuracy in obtaining the affine transformation.

In one example, the subset comprises at least three identified characteristics and at least three corresponding characteristics.

An affine transformation in images (two-dimensional) can have up to five independent variables which comprise a stretching along each dimension (for example x and y axes), a displacement along each direction (x and y axes) and an angle of rotation. Considering that the resizing step equalizes the relative size of the characteristics shown in the images, the stretching can in some cases be omitted so that only three free variables remain for determining the affine transformation. Using at least three identified characteristics and corresponding characteristics in the first and second image to determine the affine transformation thus ensures that the same is determined reliably.

It can be provided that more than three identified characteristics and corresponding characteristics (i.e. more than three pairs of characteristics of the first and second image) are used where affine transformations are calculated for each group of three pairs. The resulting affine transformation can then be determined as, for example, mean value of the obtained affine transformations which can further improve the accuracy of the affine transformation.

It can be provided that deriving the affine transformation comprises using a neural network to determine at least one value characterizing the transformation. As determining the affine transformation requires the matching of points in images and their respective identification, the use of a neural network can reduce the processing time required. However, instead of using neural networks, the disclosure also encompasses examples where deterministic algorithms are used for each step of the method. In this context, deterministic algorithms are any algorithms that do not make use of a neural network and/or result in a predictable outcome when the input is known.

In one example, identifying the corresponding characteristics is performed iteratively.

Iteratively identifying the corresponding characteristics can comprise using a first identified characteristic in the first image and comparing it to the identified characteristics in the first

image until a match is found. Subsequently, a second identified characteristic that is different from the first identified characteristic in the first image is compared to the remaining identified characteristics in the second image until a match is found. This can be performed iteratively until all identified characteristics in the first image are associated with a corresponding characteristic in the second image or until there are no more characteristics identified in the first image or the second image available. For the further process, only matching pairs of identified characteristics in the first image and corresponding characteristics in the second image are used. This takes into account the fact that characteristics can be identified in both the first and the second image that are not present in the second or first image, respectively.

In one example, obtaining the first original image and the second original image comprises using an optical sensor to obtain the first original image and the second original image.

The optical sensor can for example be a camera. The first and/or second image can be obtained using either only the camera and the illumination of the environment or additionally a flashlight associated with the camera can be used to improve the illumination conditions. This can further improve the accuracy with which the combined image can be obtained.

In one example, the method further comprises:

obtaining a third original image of the biometric feature of the user;

determining a frequency of at least some of the characteristics in the first original image and in the third original image;

resizing, based on the determined frequency, the first original image and/or the third original image to obtain a first image and a second image;

identifying, in the first image and in the third image, the characteristics and store the first and third image and the identified characteristics;

for at least some of the identified characteristics in the first image, identifying corresponding identified characteristics in the third image;

deriving an affine transformation for transforming the at least some of the identified characteristics in the third image into the corresponding identified characteristics in the first image;

modifying at least a portion of the third image using the affine transformation and obtaining a combined image comprising at least one portion of the first image and the at least one modified portion of the second image and the at least one modified portion of the third image.

With this example, the combined image exhibits an increased area of the biometric feature and can therefore aid in increasing the identification accuracy.

In a further example, the first original image is a center image of a center region of the biometric feature and the second original image is an image of a first neighboring region of the center region and the third original image is an image of a second neighboring region of the center region, wherein, optionally, the first neighboring region and the second neighboring region are on approximately opposite sides of the center region.

For example, the center image may be an image of a particular region (referred to as center region) of the finger and the second image and the third image may be taken from a region that is adjacent to the center region to the left (second image) and to the right (third image). Also alternative examples like the second image being taken from a neighboring region that is above the center region and the third image being taken from a neighboring region that is below the center region can be realized or arbitrary combinations thereof. Preferably, the first neighboring region and the second neighboring region or the second original image and the third original image do not overlap. Thereby, the amount of redundant information is reduced which can improve the accuracy of obtaining the combined image.

According to an aspect of the disclosure, a device is provided that comprises at least one processor and a memory comprising computer-executable instructions that, when executed by the processor, cause the device to execute a computer-implemented method according to the above aspect.

The device can for example be a mobile device like a smartphone or laptop with an integrated optical sensor like a camera and optionally flashlight. With this device, and by employing the inventive computer-implemented method, the accuracy with which combined images can be obtained for identification of users can be increased.

Brief description of the drawings

Figure 1 shows a schematic depiction of images taken and a combined image