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Di et al.

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(54) **FINGERPRINT RECOGNITION METHOD AND ELECTRONIC DEVICE**

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(73) Assignee: **HONOR DEVICE CO., LTD.**, Shenzhen (CN)

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(30) **Foreign Application Priority Data**

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G06Q 20/40 (2012.01)
(Continued)

(52) **U.S. Cl.**
CPC ... ***G06V 40/1376*** (2022.01); ***G06Q 20/40145*** (2013.01); ***G06V 10/454*** (2022.01);
(Continued)

(58) **Field of Classification Search**
CPC G06V 40/12–1394; G06V 10/454; G06V 10/774; G06V 10/80; G06V 40/13;
(Continued)

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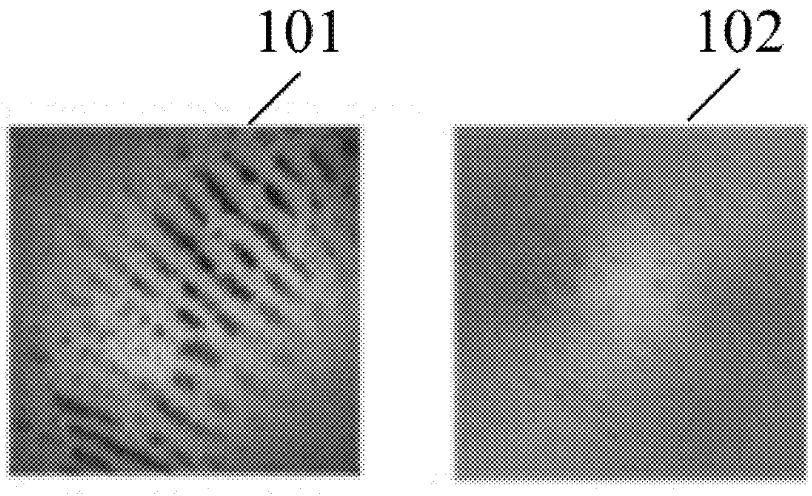
Primary Examiner — Roberto W Flores
(74) *Attorney, Agent, or Firm* — Slater Matsil, LLP

(57) **ABSTRACT**

A fingerprint recognition method and an electronic device. The electronic device includes a touch screen and a fingerprint sensor. The electronic device displays a first interface and captures first fingerprint information that is input by a user at the first interface. The electronic device determines whether the touch screen is in a first state, and the first state is used to indicate that the touch screen is in a screen protector state. If the touch screen is in the first state, the electronic device restores the first fingerprint information by using a first preset artificial intelligence (AI) restoration model to obtain second fingerprint information. The electronic device determines that the second fingerprint information matches preset fingerprint information and displays a second interface. Quality of a fingerprint image in the second fingerprint information is higher than quality of a fingerprint image in the first fingerprint information.

17 Claims, 19 Drawing Sheets



(51) **Int. Cl.**
G06V 10/44 (2022.01)
G06V 10/774 (2022.01)
G06V 10/80 (2022.01)
G06V 40/13 (2022.01)

(52) **U.S. Cl.**
CPC ***G06V 10/774*** (2022.01); ***G06V 10/80*** (2022.01); ***G06V 40/13*** (2022.01)

(58) **Field of Classification Search**
CPC .. G06V 10/82; G06V 10/70; G06Q 20/40145; G06N 3/045; G06N 3/08; G06F 18/214
See application file for complete search history.

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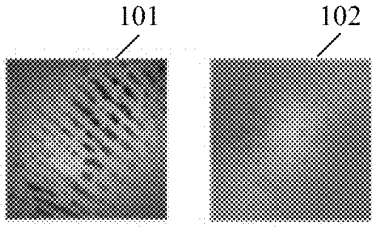
101
102

FIG. 1

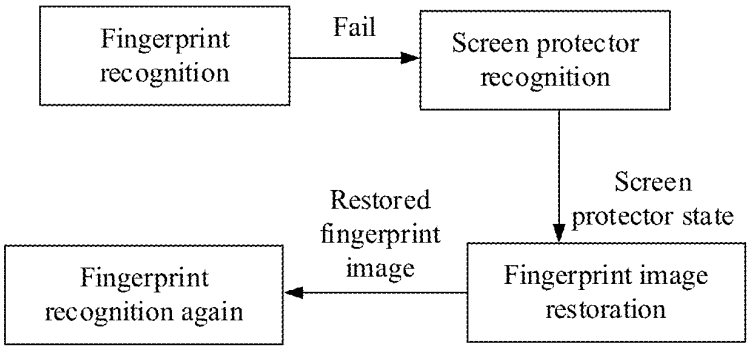
Fingerprint recognition
Fail
Screen protector recognition
Screen protector state
Fingerprint image restoration
Restored fingerprint image
Fingerprint recognition again

FIG. 2

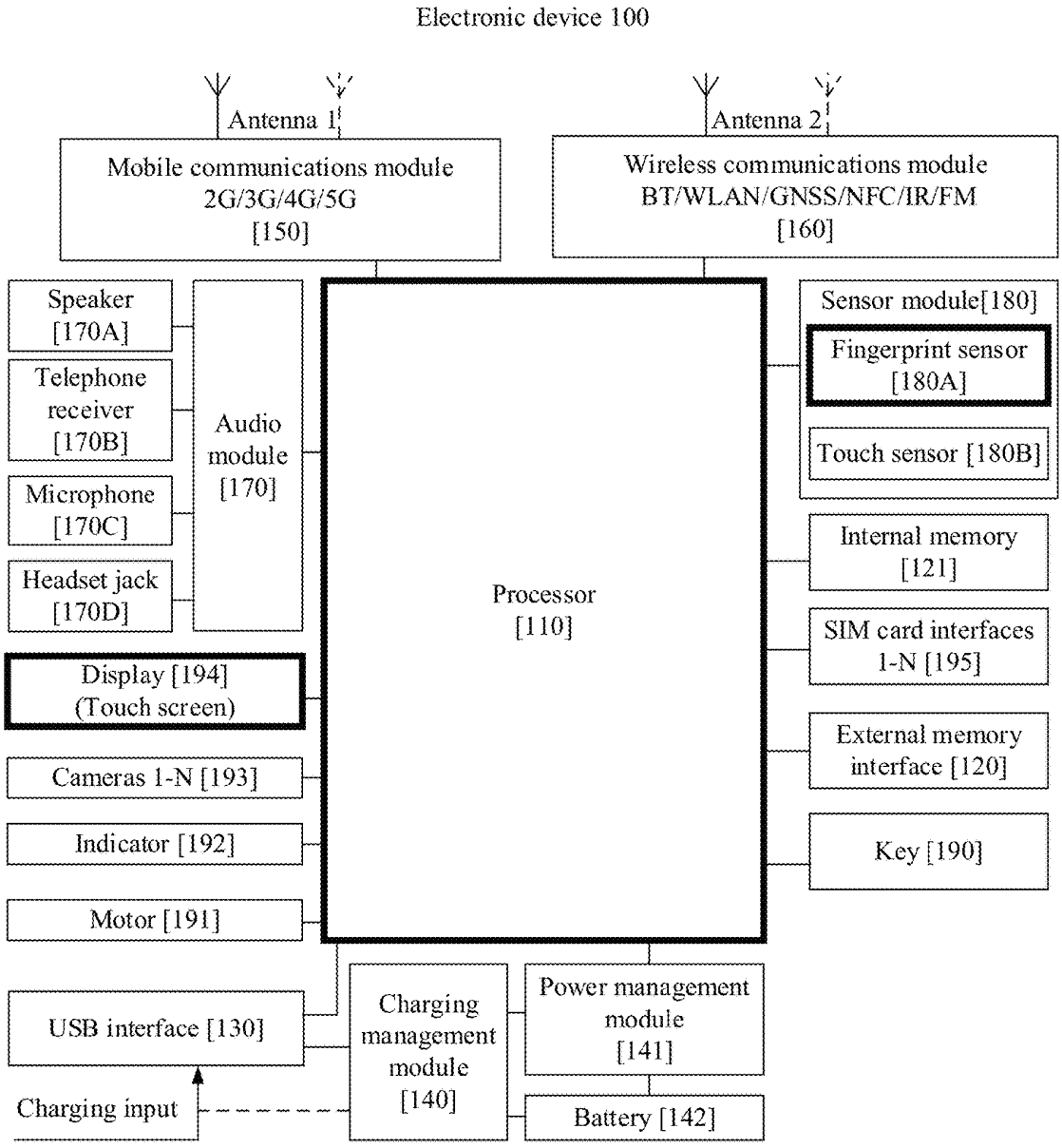
Electronic device 100
Antenna 1
Antenna 2
Mobile communications module 2G/3G/4G/5G [150]
Wireless communications module BT/WLAN/GNSS/NFC/IR/FM [160]
Speaker [170A]
Telephone receiver [170B]
Microphone [170C]
Headset jack [170D]
Audio module [170]
Processor [110]
Sensor module[180]
Fingerprint sensor [180A]
Touch sensor [180B]
Internal memory [121]
SIM card interfaces 1-N [195]
External memory interface [120]
Key [190]
Display [194] (Touch screen)
Cameras 1-N [193]
Indicator [192]
Motor [191]
USB interface [130]
Charging management module [140]
Power management module [141]
Battery [142]
Charging input

FIG. 3

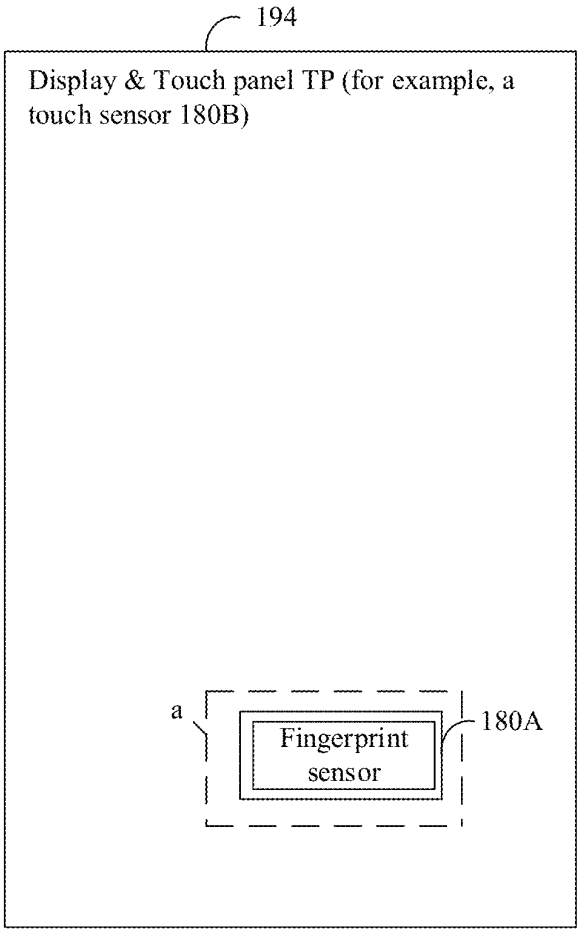
194
Display & Touch panel TP (for example, a touch sensor 180B)
a
Fingerprint sensor
180A

FIG. 4

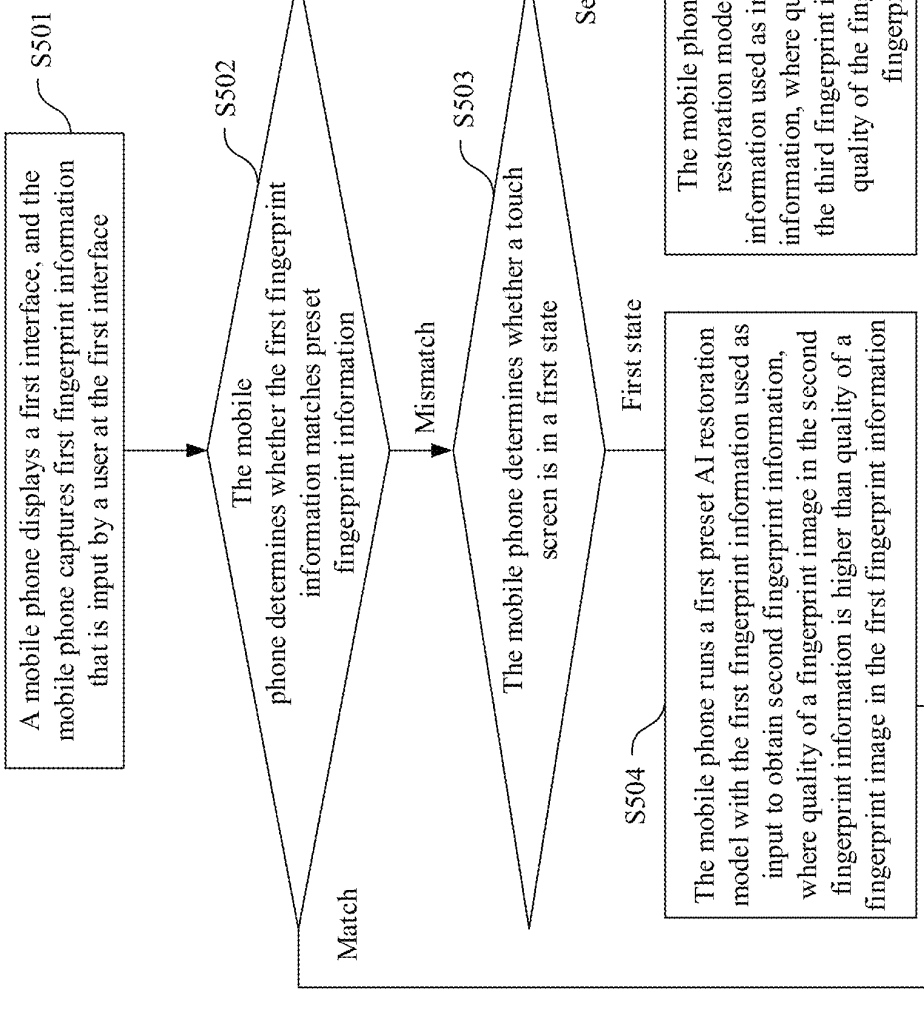
A mobile phone displays a first interface, and the mobile phone captures first fingerprint information that is input by a user at the first interface
S501
The mobile phone determines whether the first fingerprint information matches preset fingerprint information
S502
Match
Mismatch
The mobile phone determines whether a touch screen is in a first state
S503
First state
Second state
The mobile phone runs a first preset AI restoration model with the first fingerprint information used as input to obtain second fingerprint information, where quality of a fingerprint image in the second fingerprint information is higher than quality of a fingerprint image in the first fingerprint information
S504
The mobile phone runs a second preset AI restoration model with the first fingerprint information used as input to obtain third fingerprint information, where quality of a fingerprint image in the third fingerprint information is higher than the quality of the fingerprint image in the first fingerprint information
S506
TO FIG. 5B
TO FIG. 5B
TO FIG. 5B
TO FIG. 5B

FIG. 5A

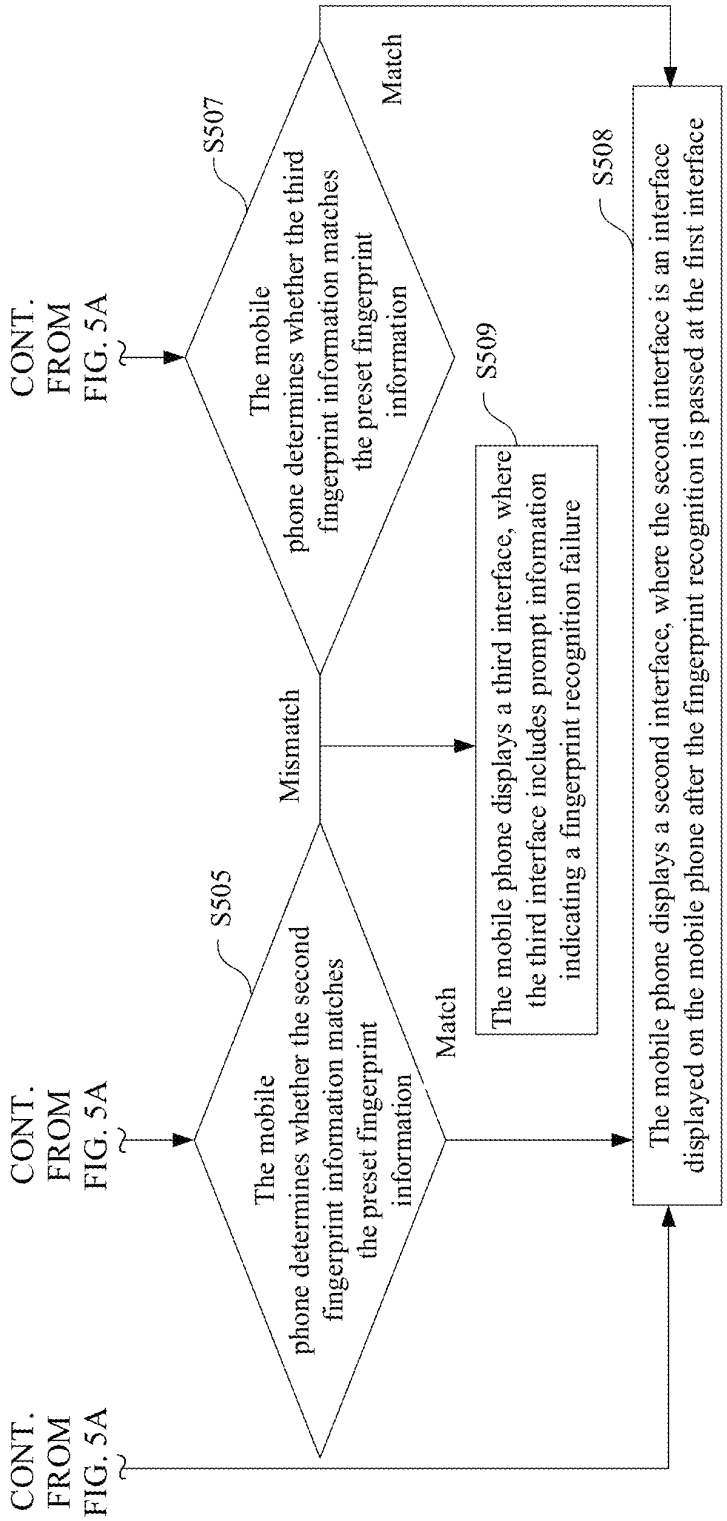
CONT. FROM FIG. 5A
CONT. FROM FIG. 5A
CONT. FROM FIG. 5A
S505
The mobile phone determines whether the second fingerprint information matches the preset fingerprint information
Match
Mismatch
S507
The mobile phone determines whether the third fingerprint information matches the preset fingerprint information
Match
S509
The mobile phone displays a third interface, where the third interface includes prompt information indicating a fingerprint recognition failure
S508
The mobile phone displays a second interface, where the second interface is an interface displayed on the mobile phone after the fingerprint recognition is passed at the first interface

FIG. 5B

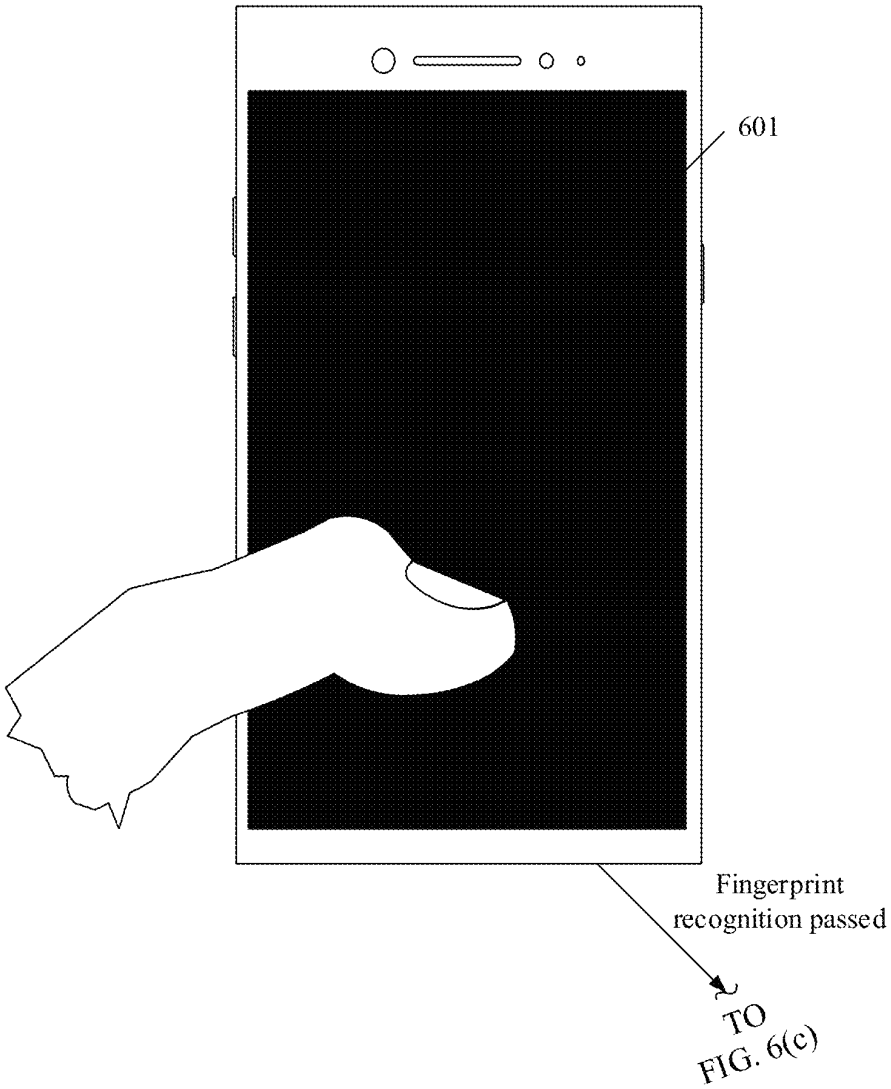

FIG. 6(a)

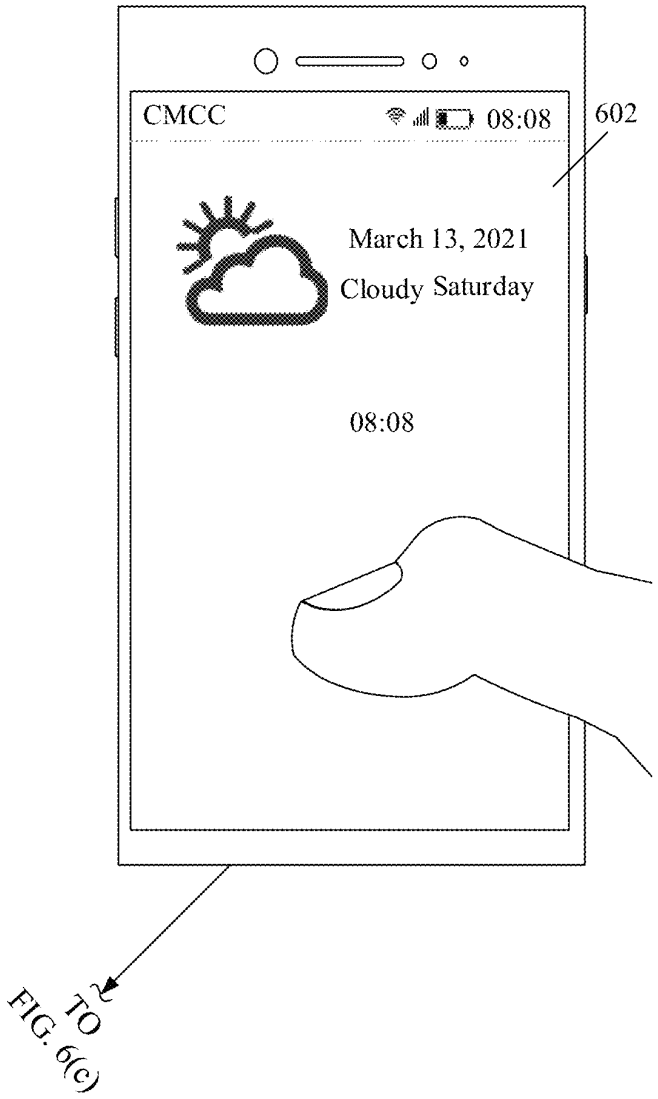

FIG. 6(b)

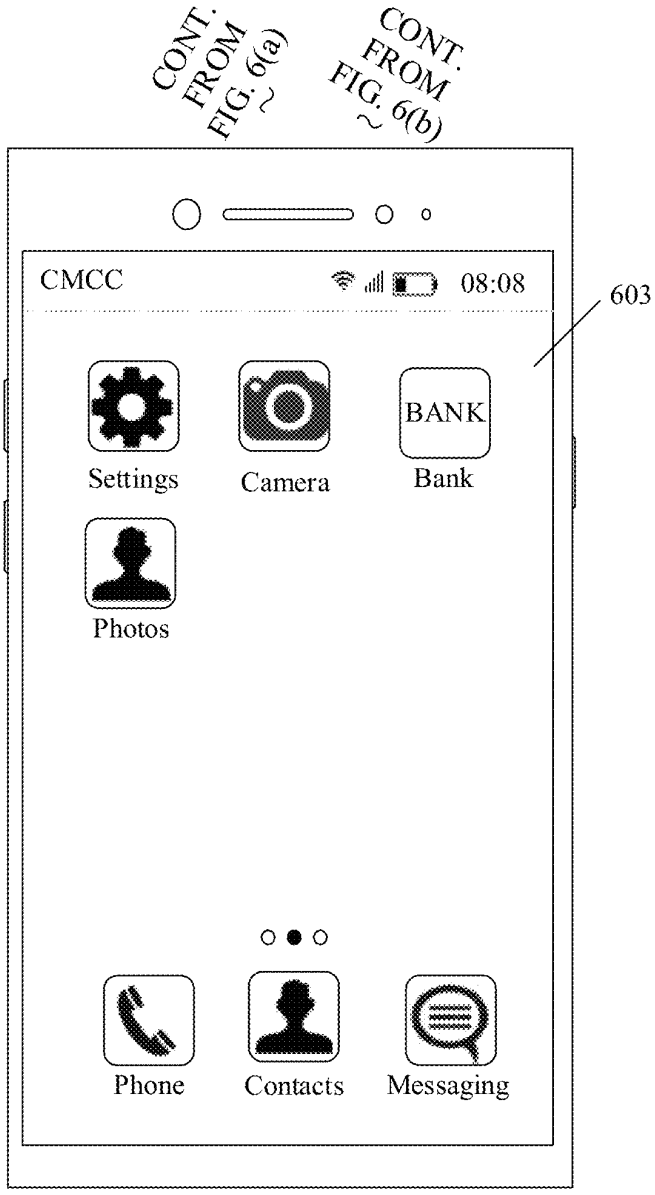
CONT. FROM FIG. 6(a)
CONT. FROM FIG. 6(b)
CMCC
08:08
603
Settings
Camera
BANK
Bank
Photos
Phone
Contacts
Messaging

FIG. 6(c)

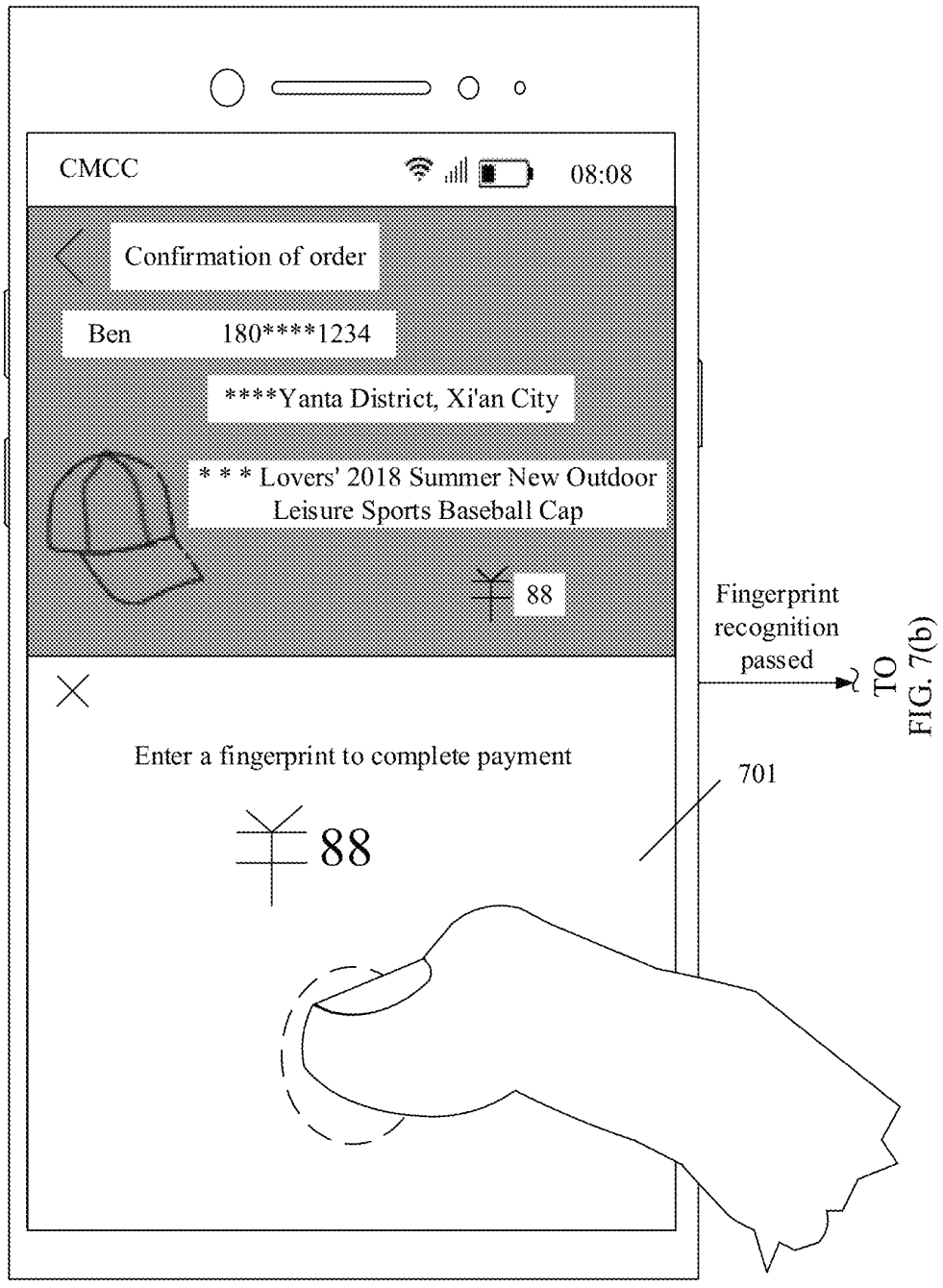
CMCC
08:08
Confirmation of order
Ben 180****1234
****Yanta District, Xi'an City
* * * Lovers' 2018 Summer New Outdoor Leisure Sports Baseball Cap
88
Fingerprint recognition passed
TO FIG. 7(b)
Enter a fingerprint to complete payment
88
701

FIG. 7(a)

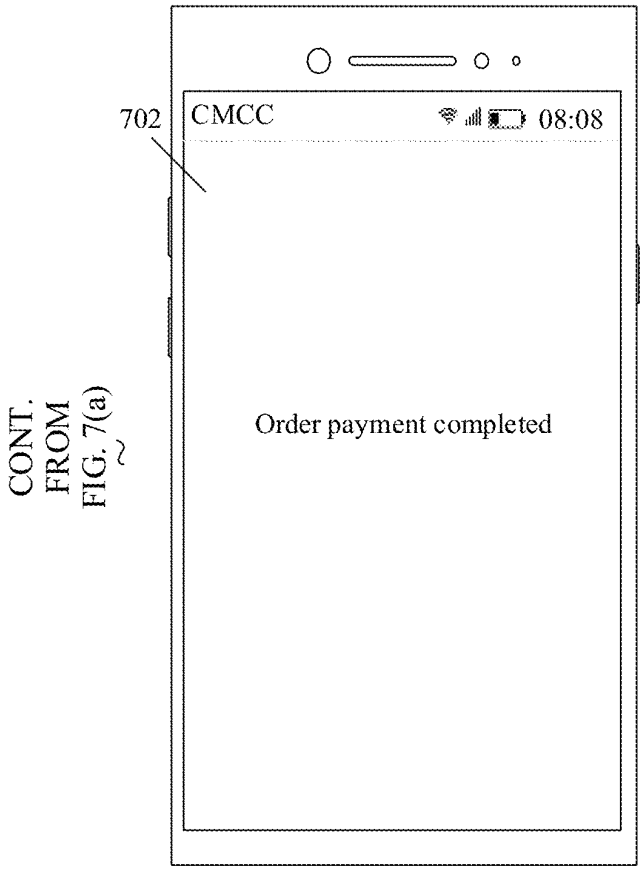

FIG. 7(b)

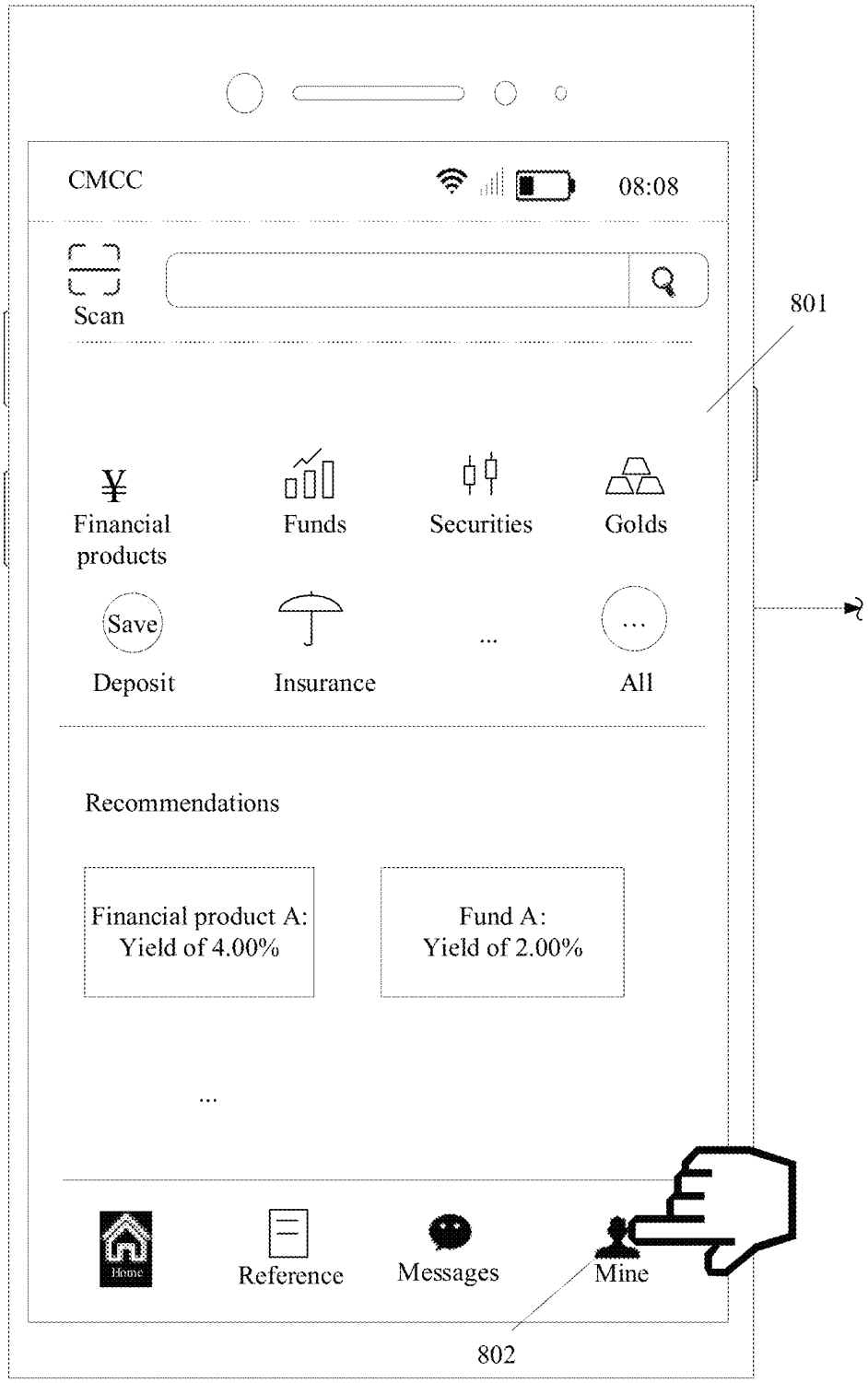
CMCC
08:08
Scan
801
Financial products
Funds
Securities
Golds
Save
Deposit
Insurance
...
All
Recommendations
Financial product A: Yield of 4.00%
Fund A: Yield of 2.00%
...
Home
Reference
Messages
Mine
802

FIG. 8(a)

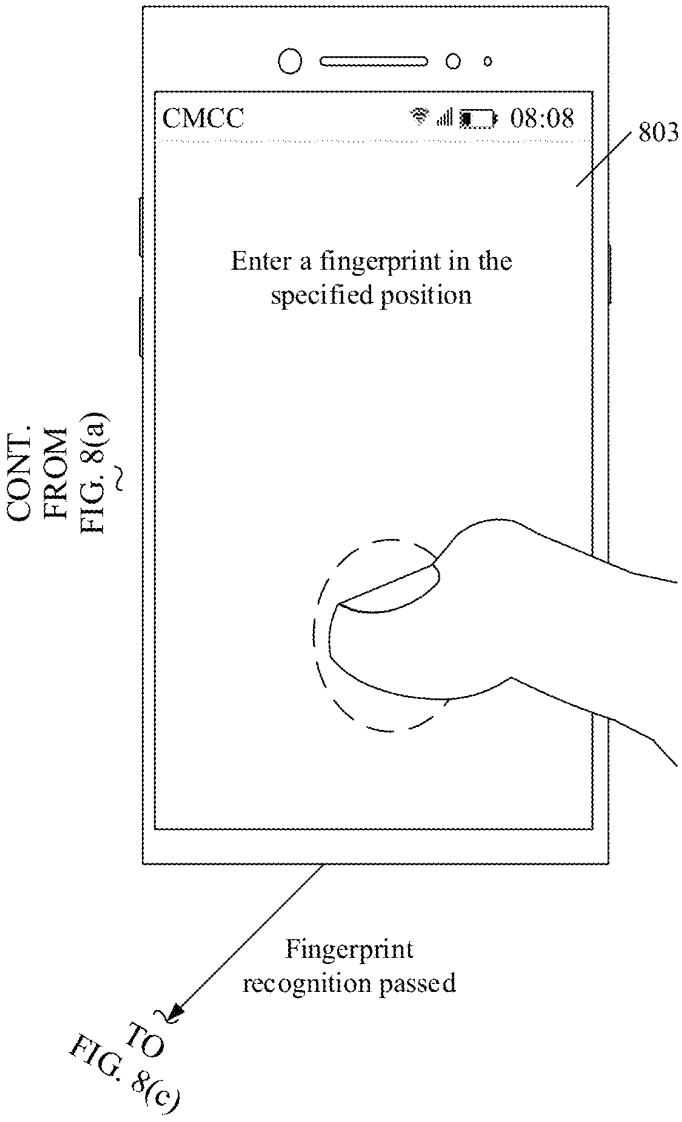
CMCC
08:08
803
Enter a fingerprint in the specified position
CONT. FROM FIG. 8(a)
Fingerprint recognition passed
TO FIG. 8(c)

FIG. 8(b)

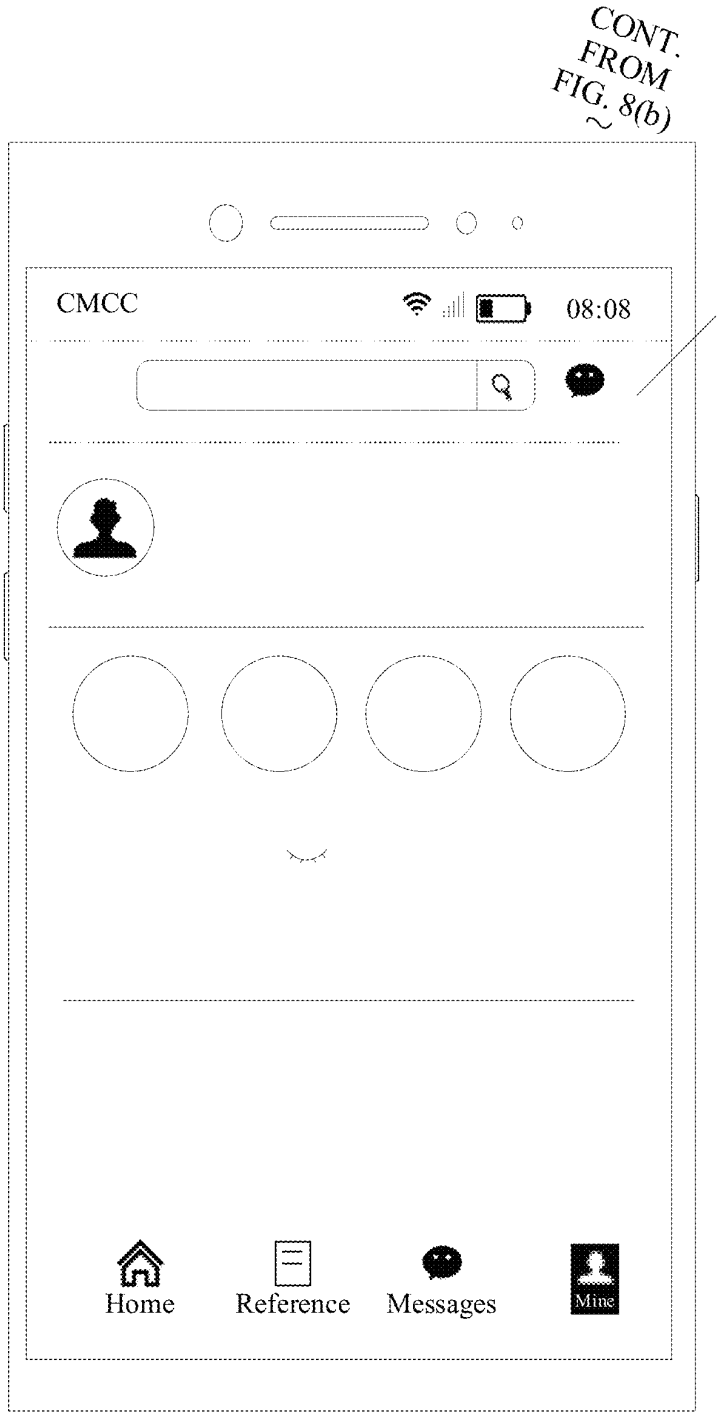

FIG. 8(c)

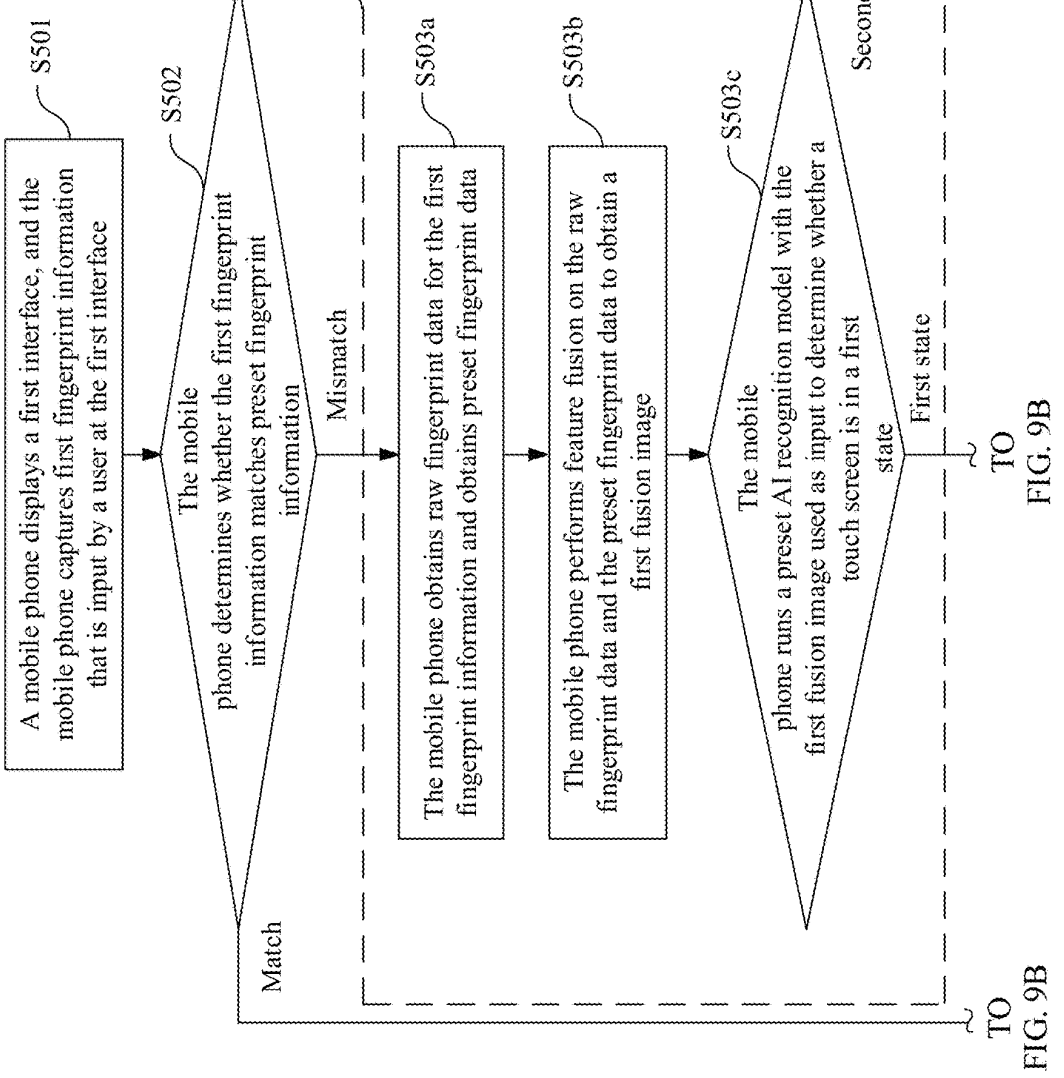
S501
A mobile phone displays a first interface, and the mobile phone captures first fingerprint information that is input by a user at the first interface
S502
The mobile phone determines whether the first fingerprint information matches preset fingerprint information
Match
Mismatch
S503
S503a
The mobile phone obtains raw fingerprint data for the first fingerprint information and obtains preset fingerprint data
S503b
The mobile phone performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image
S503c
The mobile phone runs a preset AI recognition model with the first fusion image used as input to determine whether a touch screen is in a first state
First state
Second state
TO FIG. 9B
TO FIG. 9B
TO FIG. 9B

FIG. 9A

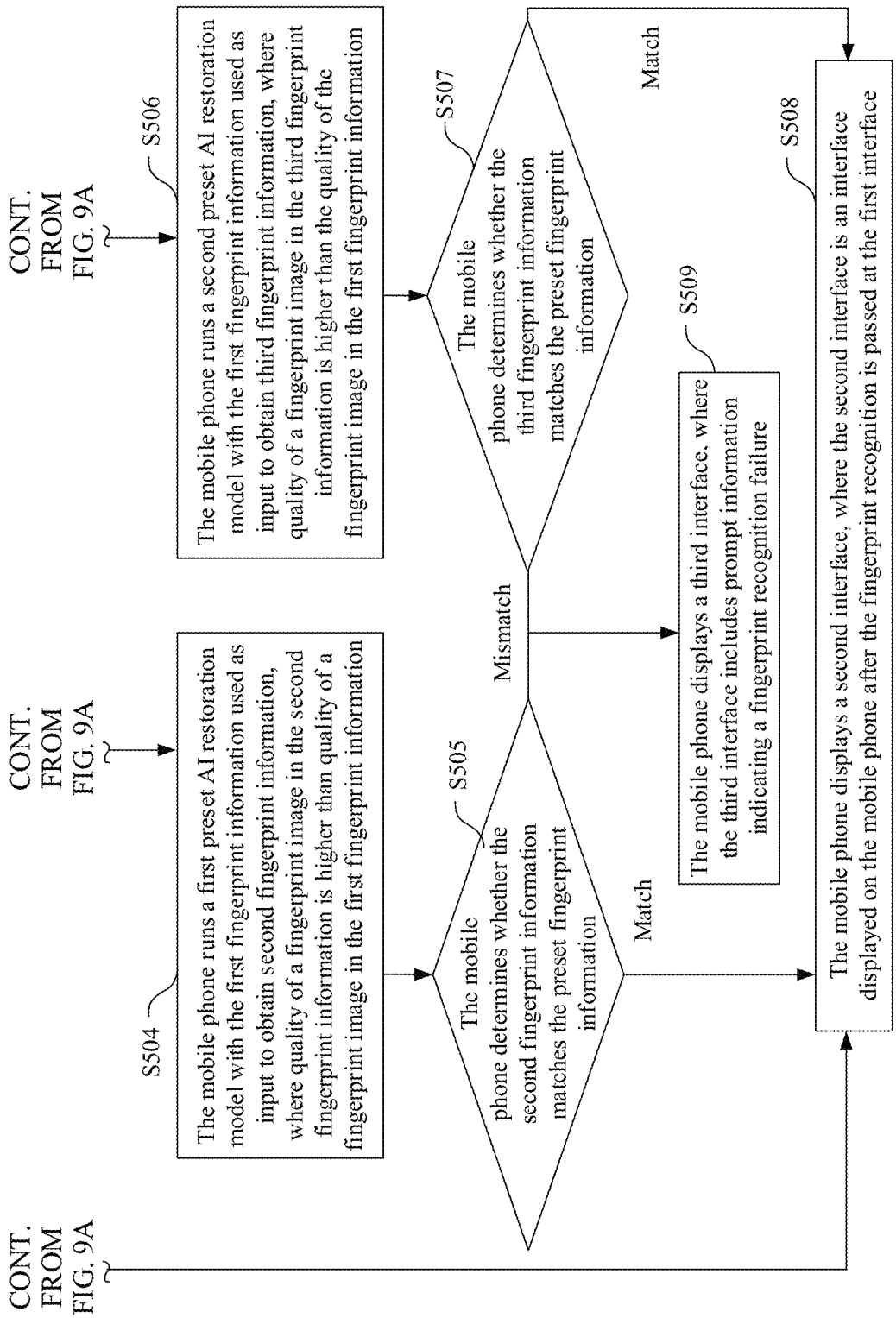
CONT. FROM FIG. 9A
S504
The mobile phone runs a first preset AI restoration model with the first fingerprint information used as input to obtain second fingerprint information, where quality of a fingerprint image in the second fingerprint information is higher than quality of a fingerprint image in the first fingerprint information
CONT. FROM FIG. 9A
S505
The mobile phone determines whether the second fingerprint information matches the preset fingerprint information
Match
Mismatch
The mobile phone displays a third interface, where the third interface includes prompt information indicating a fingerprint recognition failure
S509
CONT. FROM FIG. 9A
S506
The mobile phone runs a second preset AI restoration model with the first fingerprint information used as input to obtain third fingerprint information, where quality of a fingerprint image in the third fingerprint information is higher than the quality of the fingerprint image in the first fingerprint information
S507
The mobile phone determines whether the third fingerprint information matches the preset fingerprint information
Match
S508
The mobile phone displays a second interface, where the second interface is an interface displayed on the mobile phone after the fingerprint recognition is passed at the first interface

FIG. 9B

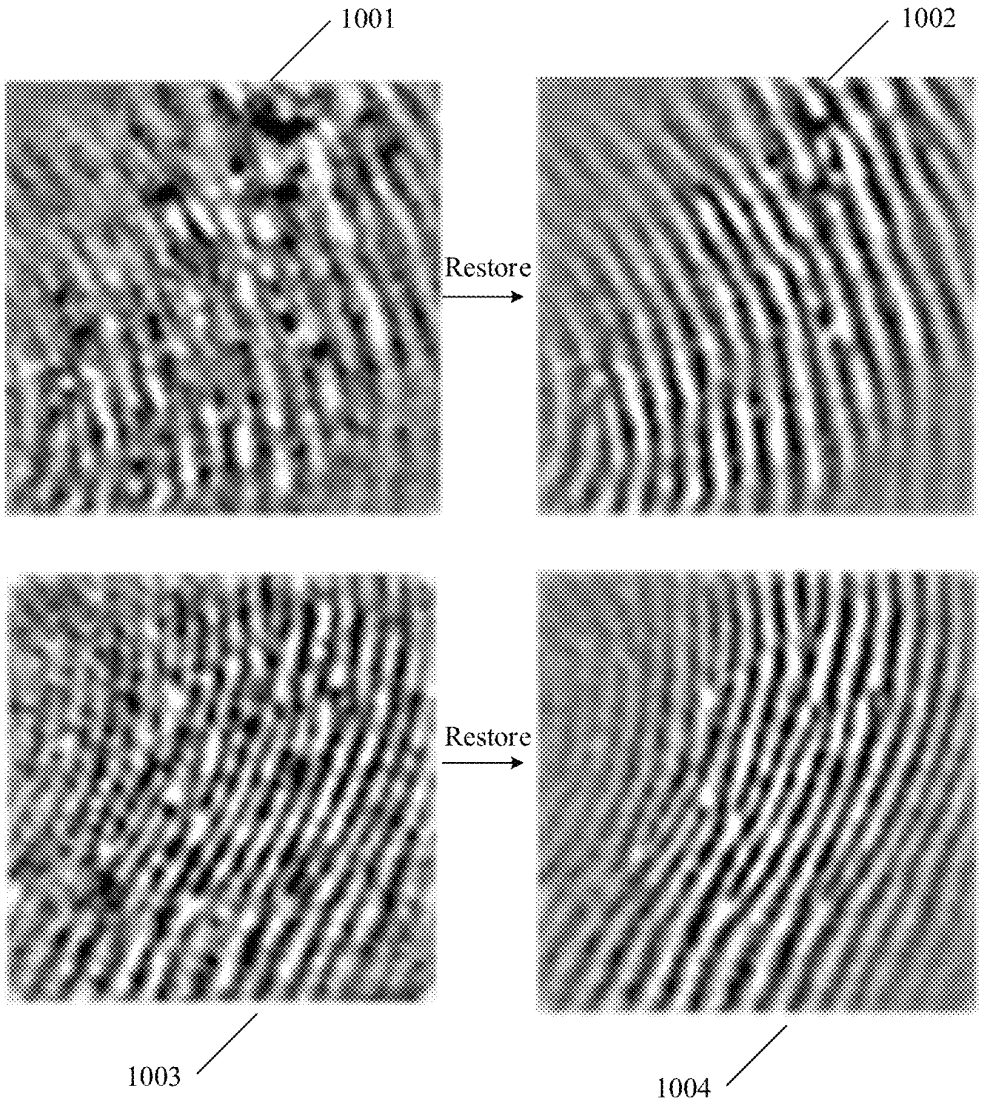

FIG. 10

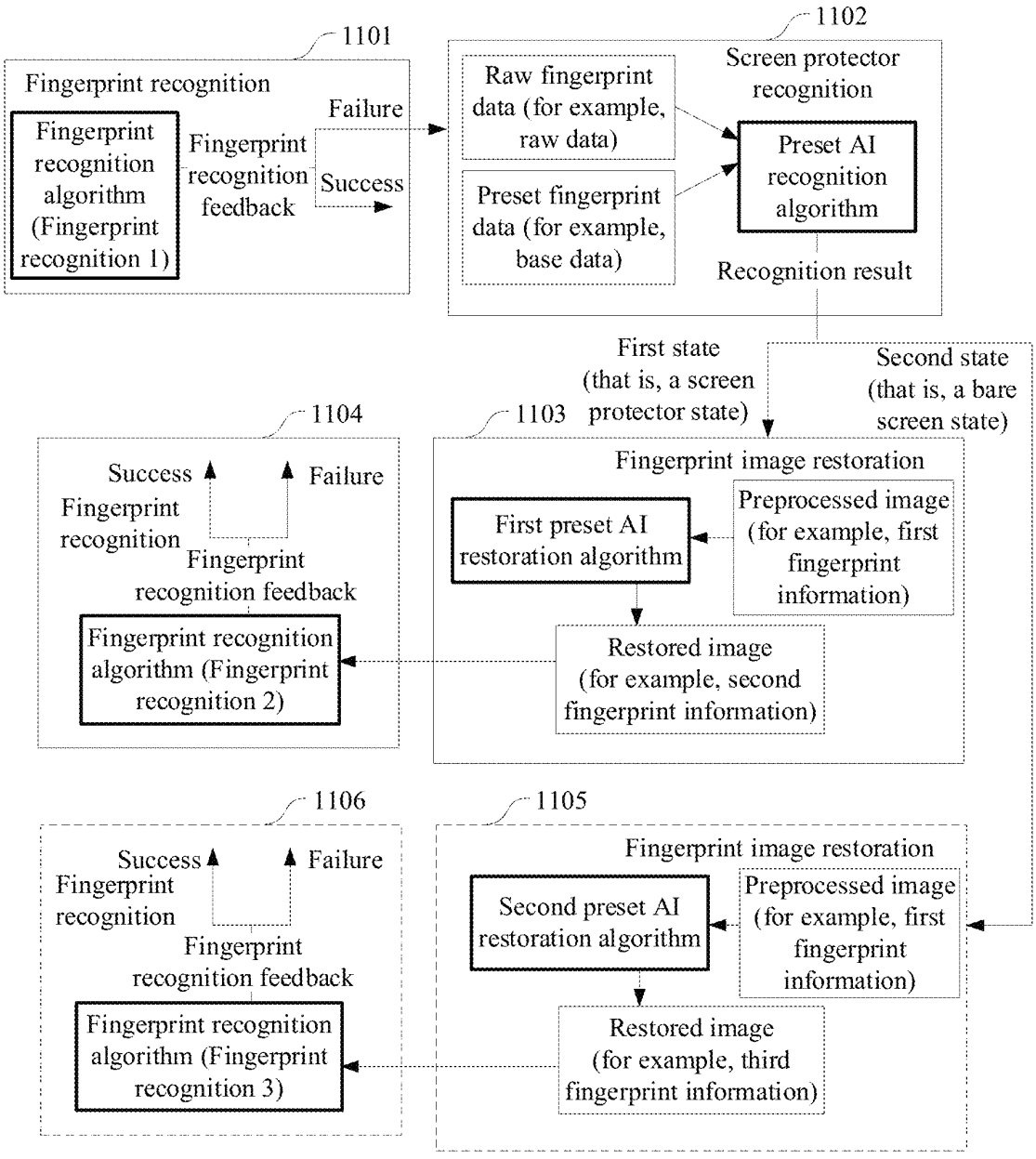
1101
Fingerprint recognition
Fingerprint recognition algorithm (Fingerprint recognition 1)
Fingerprint recognition feedback
Failure
Success
1102
Screen protector recognition
Raw fingerprint data (for example, raw data)
Preset fingerprint data (for example, base data)
Preset AI recognition algorithm
Recognition result
First state (that is, a screen protector state)
Second state (that is, a bare screen state)
1104
Success
Failure
Fingerprint recognition
Fingerprint recognition feedback
Fingerprint recognition algorithm (Fingerprint recognition 2)
1103
Fingerprint image restoration
First preset AI restoration algorithm
Preprocessed image (for example, first fingerprint information)
Restored image (for example, second fingerprint information)
1106
Success
Failure
Fingerprint recognition
Fingerprint recognition feedback
Fingerprint recognition algorithm (Fingerprint recognition 3)
1105
Fingerprint image restoration
Second preset AI restoration algorithm
Preprocessed image (for example, first fingerprint information)
Restored image (for example, third fingerprint information)

FIG. 11

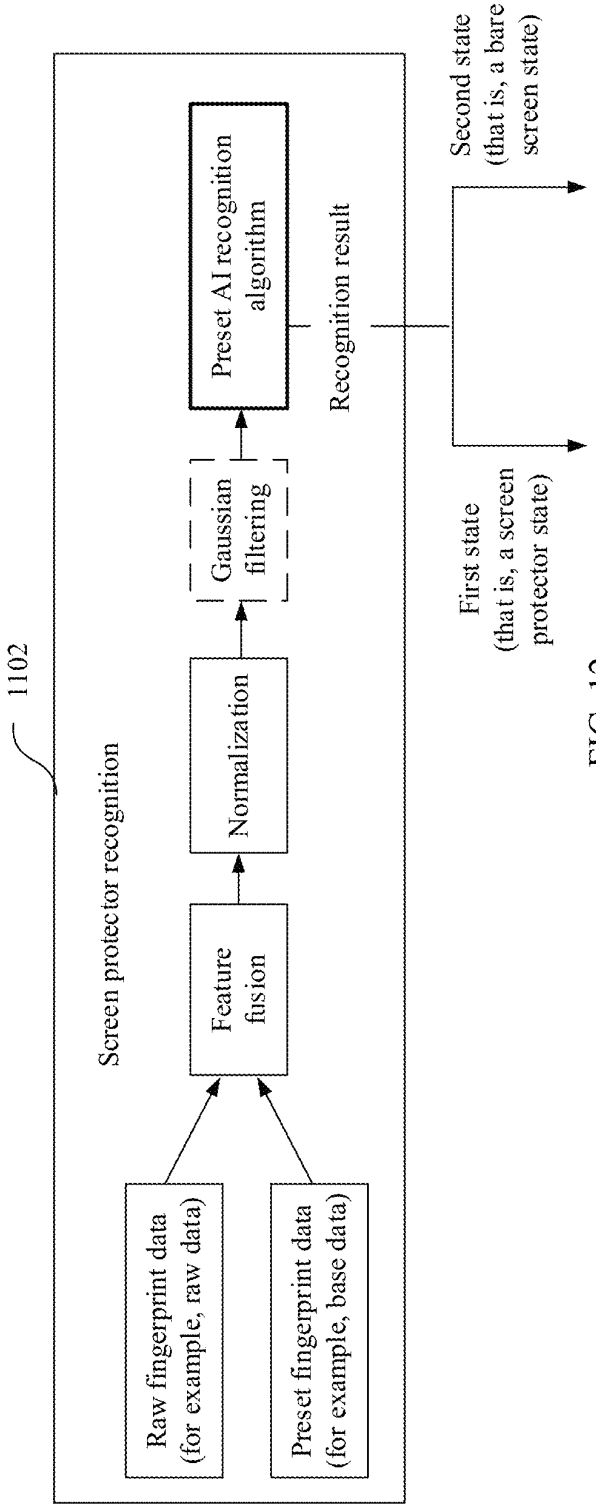
1102
Screen protector recognition
Raw fingerprint data (for example, raw data)
Preset fingerprint data (for example, base data)
Feature fusion
Normalization
Gaussian filtering
Preset AI recognition algorithm
Recognition result
First state (that is, a screen protector state)
Second state (that is, a bare screen state)

FIG. 12

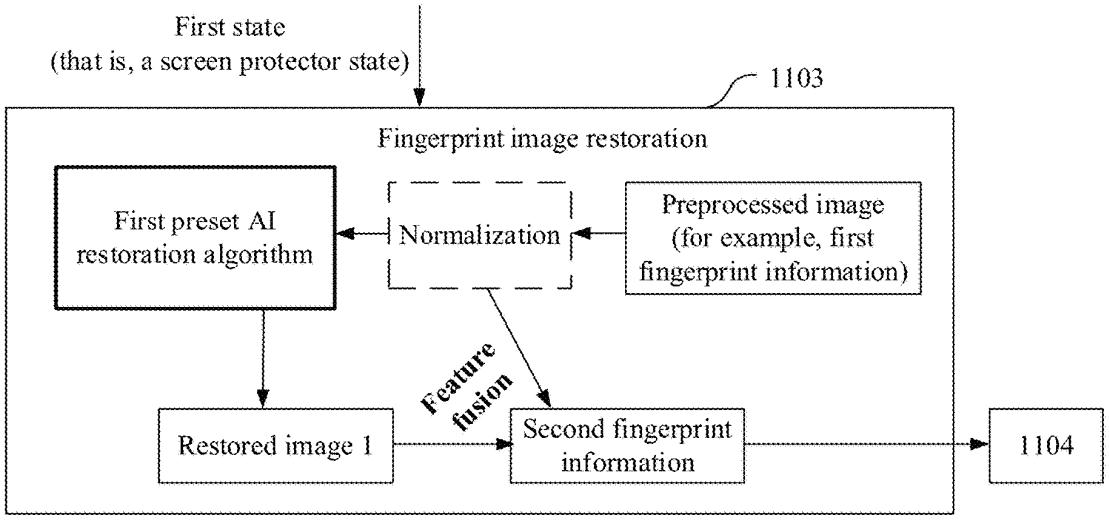
First state
(that is, a screen protector state)
1103
Fingerprint image restoration
First preset AI restoration algorithm
Normalization
Preprocessed image (for example, first fingerprint information)
Feature fusion
Restored image 1
Second fingerprint information
1104

FIG. 13

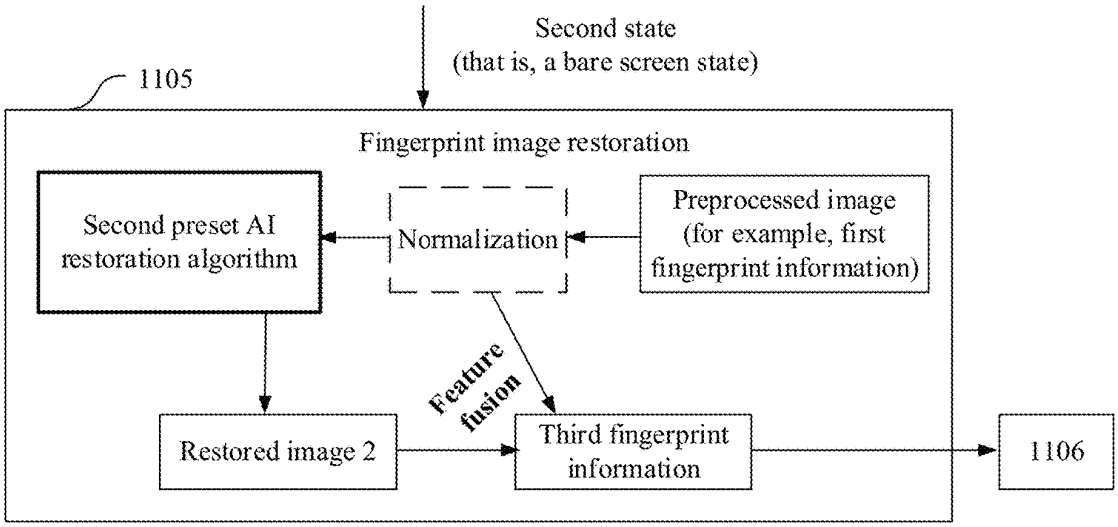
Second state
(that is, a bare screen state)
1105
Fingerprint image restoration
Second preset AI restoration algorithm
Normalization
Preprocessed image (for example, first fingerprint information)
Feature fusion
Restored image 2
Third fingerprint information
1106

FIG. 14

FINGERPRINT RECOGNITION METHOD AND ELECTRONIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national stage of International Application No. PCT/CN2022/075709 filed on Feb. 9, 2022, which claims priority to Chinese Patent Application No. 202110363678.6 filed on Apr. 2, 2021. The disclosures of both of the aforementioned applications are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

Embodiments of the present application relate to the technical fields of fingerprint recognition and artificial intelligence (artificial intelligence, AI), and more particularly, to a fingerprint recognition method and an electronic device.

BACKGROUND

As a new technical breakthrough caused by the evolution of touch screens, in-screen fingerprints are gradually applied to electronic devices (for example, mobile phones). With regard to the in-screen fingerprint, a fingerprint sensor is integrated under a touch screen of an electronic device, and the fingerprint sensor may capture fingerprint information of a user in response to a touch operation of the user in a preset position on the touch screen. The fingerprint information may be used for fingerprint recognition in a scenario such as payment or unlock.

A success rate of in-screen fingerprint recognition depends to a large extent on quality of a fingerprint image in the fingerprint information captured by the fingerprint sensor. Higher quality of the fingerprint image in the fingerprint information captured by the fingerprint sensor indicates a higher success rate of user identity verification by using the fingerprint information (that is, in-screen fingerprint recognition). The quality of the fingerprint image in the fingerprint information captured by the fingerprint sensor may be affected by a degree of fitting a user finger to the touch screen, a degree of accuracy of touching a position by a user, and the like.

There are, certainly, other factors that may affect the quality of the fingerprint image in the fingerprint information captured by the fingerprint sensor. For example, to protect a touch screen, a user often applies a film, such as a tempered film or a hydrogel film, to an electronic device (for example, a mobile phone). Applying a film to the electronic device undoubtedly increases a distance between the fingerprint sensor disposed under the touch screen and a user finger, thereby affecting the quality of the fingerprint image in the fingerprint information captured by the fingerprint sensor, and further reducing the success rate of the in-screen fingerprint recognition.

SUMMARY

The present application provides a fingerprint recognition method and an electronic device, which can increase a success rate of in-screen fingerprint recognition.

According to a first aspect, the present application provides a fingerprint recognition method, which can be applied to an electronic device including a touch screen, and the electronic device further includes a fingerprint sensor. In the method, the electronic device may display a first interface, and the electronic device may capture first fingerprint information that is input by a user at the first interface. Thereafter, the electronic device may determine whether the touch screen is in a first state. The first state is used to indicate that the touch screen is in a screen protector state. If the touch screen is in the first state, the electronic device may restore the first fingerprint information by using a first preset AI restoration model to obtain second fingerprint information. Quality of a fingerprint image in the second fingerprint information is higher than quality of a fingerprint image in the first fingerprint information. Finally, the electronic device determines that the second fingerprint information matches preset fingerprint information and displays a second interface.

The first preset AI restoration model is capable of restoring a fingerprint image to improve image quality. The first preset AI restoration model may be pre-configured on the electronic device. For example, alternatively, the quality of the fingerprint image may be indicated by sharpness and completeness of the fingerprint image. A sharper fingerprint image indicates higher quality of the fingerprint image. A more complete fingerprint image indicates higher quality of the fingerprint image.

In the present application, if the touch screen is in the first state, the electronic device may perform fingerprint image restoration on the fingerprint image captured by the fingerprint sensor, to reduce impact of the screen protector on fingerprint recognition. Then, the electronic device performs fingerprint recognition on a restored fingerprint image. In this way, the success rate of the in-screen fingerprint recognition can be increased.

In a possible design of the first aspect, before the electronic device determines whether the touch screen is in the first state, the method in the present application may further include the following steps: The electronic device determines that the first fingerprint information does not match the preset fingerprint information. The electronic device displays a third interface. The third interface includes prompt information indicating a fingerprint recognition failure.

In other words, the electronic device may determine whether the touch screen is in the first state if the first fingerprint information does not pass fingerprint recognition. It should be understood that if the first fingerprint information does not pass fingerprint recognition, a reason may be that the image quality of the fingerprint information captured by the fingerprint sensor is affected due to the touch screen protector. In this way, the electronic device may use the first preset AI restoration model to restore the first fingerprint information to obtain the second fingerprint information with high image quality, and then perform fingerprint recognition on the second fingerprint information. In this way, the success rate of the in-screen fingerprint recognition can be increased.

In another possible design of the first aspect, after the electronic device determines whether the touch screen is in the first state, the method in the present application may further include the following steps: If the touch screen is in a second state, the electronic device restores the first fingerprint information by using a second preset AI restoration model to obtain third fingerprint information. The electronic device determines that the third fingerprint information matches the preset fingerprint information and displays the second interface. The second state is used to indicate that the touch screen is in a bare screen state. Quality of a fingerprint image in the third fingerprint information is higher than the quality of the fingerprint image in the first fingerprint

information. The first preset AI restoration model is different from the second preset AI restoration model.

In this design, if the fingerprint recognition is not passed, the electronic device may use different AI restoration models to restore fingerprint images captured by the fingerprint sensor when the touch screen is in different states (such as a screen protector state or a bare screen state), to improve quality of the fingerprint images. In this way, when the touch screen is in different states, quality of the fingerprint images can be improved accordingly, so that the success rate of fingerprint recognition can be increased.

In a possible design of the first aspect, the first interface includes at least one of the following interfaces: an interface in which the electronic device is in a lock screen state, a fingerprint payment interface of the electronic device, and a fingerprint unlocking interface for one or more functions of a first application on the electronic device. Certainly, the first interface includes, but is not limited to, the lock screen interface, the payment interface, and the fingerprint unlocking interface. The first interface may be any interface capable of receiving fingerprint information for fingerprint recognition.

In another possible design of the first aspect, that the electronic device determines whether the touch screen is in a first state may include the following steps: The electronic device obtains raw fingerprint data for the first fingerprint information and obtains preset fingerprint data. The electronic device performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image. The electronic device runs a preset AI recognition model with the first fusion image used as input to determine whether the touch screen is in the first state.

The raw fingerprint data may also be referred to as raw (raw) data. "Raw" can be translated as "unprocessed". To be specific, the raw fingerprint data is an unprocessed fingerprint image captured by the fingerprint sensor. The preset fingerprint data may be referred to as base (base) data. The preset fingerprint data includes noisy image data that is generated based on actual hardware parameters of the touch screen and the fingerprint sensor and that affects the success rate of fingerprint recognition. The preset fingerprint data is pre-configured on the electronic device. The preset AI recognition model is capable of determining, based on a fingerprint image, whether a corresponding touch screen is in a screen protector state. An output result of the preset AI recognition model is used to indicate whether the touch screen is in the screen protector state. The preset AI recognition model is pre-configured on the electronic device.

It should be understood that the raw fingerprint data is captured in real time by the electronic device. The raw fingerprint data includes the noisy image data that is generated based on the actual hardware parameters of the touch screen and the fingerprint sensor and that affects the success rate of fingerprint recognition. Therefore, the electronic device can perform feature fusion on the raw fingerprint data and the preset fingerprint data to reduce the noisy image data in the raw fingerprint data to obtain the first fusion image. Running the preset AI recognition model with the first fusion image used as input to determine whether the touch screen is in a screen protector state increases an accuracy rate of recognition in a screen protector state.

In another possible design of the first aspect, the method in which the electronic device performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image may include the following steps: The electronic device removes noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image. The electronic device performs normalization on the second fusion image to obtain the first fusion image. Brightness uniformity of all pixels in the first fusion image is higher than brightness uniformity of all pixels in the second fusion image.

In this design, the electronic device may perform normalization on the second fusion image to improve the brightness uniformity of the fusion image. The brightness uniformity of the fingerprint image can be reflected by contrast of the fingerprint image. Stronger contrast of the fingerprint image indicates lower brightness uniformity of the fingerprint image. Weaker contrast of the fingerprint image indicates higher brightness uniformity of the fingerprint image. In this design, normalization can be performed on the second fusion image to reduce the contrast of the second fusion image, thereby improving the brightness uniformity of the second fusion image.

In another possible design of the first aspect, image fusion is performed on the raw fingerprint data (for example, the raw data) and the preset fingerprint data (for example, the base data), so that only part of the noisy image data in the raw fingerprint data can be removed, and some Gaussian noise cannot be removed by using image fusion. In view of this, the electronic device may perform normalization on the fusion image, and then perform Gaussian filtering on the normalized image.

Specifically, the method in which the electronic device performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image may include the following steps: The electronic device removes noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image. The electronic device performs normalization on the second fusion image to obtain a third fusion image. Brightness uniformity of all pixels in the third fusion image is higher than brightness uniformity of all pixels in the second fusion image. The electronic device performs Gaussian filtering on the third fusion image to obtain the first fusion image that does not include the Gaussian noise in the third fusion image.

The part of noisy image data in the raw fingerprint data can be removed by normalization, and the Gaussian noise in the raw fingerprint data can be removed by Gaussian filtering.

In another possible design of the first aspect, the preset AI recognition model is a convolutional neural network (convolutional neural network, CNN) model or a residual neural network (residual neural network, ResNet) model.

In another possible design of the first aspect, the method in which the electronic device restores the first fingerprint information by using the first preset artificial intelligence AI restoration model to obtain second fingerprint information may include the following step: The electronic device runs the first preset AI restoration model with the first fingerprint information used as input to obtain the second fingerprint information.

The first preset AI restoration model is trained by using a plurality of first groups of fingerprint images as training samples. Each first group of fingerprint images includes a first fingerprint image and a second fingerprint image. The first fingerprint image is captured when the touch screen is in the first state, and the second fingerprint image is a pre-configured image obtained after the first fingerprint image is restored.

In another possible design of the first aspect, that the electronic device restores the first fingerprint information by using the second preset AI restoration model to obtain third

fingerprint information includes the following step: The electronic device runs the second preset AI restoration model with the first fingerprint information used as input to obtain the third fingerprint information.

The second preset AI restoration model is trained by using a plurality of second groups of fingerprint images as training samples. Each second group of fingerprint images includes a third fingerprint image and a fourth fingerprint image. The third fingerprint image is captured when the touch screen is in the second state, and the fourth fingerprint image is a pre-configured image obtained after the third fingerprint image is restored.

It should be understood that because the orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information, the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information can be determined by using the orientation field image, and intermittent fingerprint points in the first fingerprint information can be connected based on the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information. Thus, the third fingerprint information whose image quality is higher than image quality of the first fingerprint information can be obtained.

It should be noted that the first preset AI restoration model and the second preset AI restoration model are trained by using different training samples. Specifically, the first preset AI restoration model is trained by using the plurality of first groups of fingerprint images as training samples, while the second preset AI restoration model is trained by using the plurality of second groups of fingerprint images as training samples. Each first group of fingerprint images includes a first fingerprint image captured by the fingerprint sensor when the touch screen is in the screen protector state, and a second fingerprint image obtained by restoring the first fingerprint image. Each second group of fingerprint images includes a third fingerprint image captured by the fingerprint sensor when the touch screen is in the bare screen state, and a fourth fingerprint image obtained by restoring the third fingerprint image.

In other words, the first preset AI restoration model is trained by using the fingerprint images captured by the fingerprint sensor when the touch screen is in the screen protector state, while the second preset AI restoration model is trained by using the fingerprint images captured by the fingerprint sensor when the touch screen is in the bare screen state. Therefore, the first preset AI restoration model has a better effect of restoring a fingerprint image captured in the screen protector state, while the second preset AI model has a better effect of restoring a fingerprint image captured in the bare screen state.

In another possible design of the first aspect, the first preset AI restoration model may be a fully convolutional network (fully convolutional network, FCN) model.

In another possible design of the first aspect, the first preset AI restoration model may be a Unet model.

In another possible design of the first aspect, the first preset AI restoration model may be a Garbor filter. The Garbor filter is capable of extracting an orientation field image from the first fingerprint information, and restoring the first fingerprint information with the orientation field image to obtain the second fingerprint information. The orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information.

It should be understood that because the orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information, the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information can be determined by using the orientation field image, and intermittent fingerprint points in the first fingerprint information can be connected based on the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information. Thus, the second fingerprint information whose image quality is higher than image quality of the first fingerprint information can be obtained.

In another possible design of the first aspect, the second preset AI restoration model may be an FCN model.

In another possible design of the first aspect, the second preset AI restoration model may be a Unet model.

In another possible design of the first aspect, the second preset AI restoration model may be Garbor filtering. The Garbor filter is capable of extracting an orientation field image from the first fingerprint information, and restoring the first fingerprint information with the orientation field image to obtain third fingerprint information. The orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information.

In a second aspect, the present application provides an electronic device including a touch screen, a memory, and one or more processors, and the electronic device further includes a fingerprint sensor. The touch screen, the memory, and the fingerprint sensor are coupled to the processor. The memory stores computer program code. The computer program code includes computer instructions. When the computer instructions are executed by the processor, the electronic device is enabled to perform the method described in the first aspect and any possible design thereof.

In a third aspect, the present application provides an electronic device including a touch screen, a memory, and one or more processors, and the electronic device further includes a fingerprint sensor. The touch screen, the memory, and the fingerprint sensor are coupled to the processor. The memory stores computer program code, and the computer program code includes computer instructions. When the computer instructions are executed by the processor, the electronic device is enabled to perform the following steps: The touch screen displays a first interface. The fingerprint sensor captures first fingerprint information that is input by a user at the first interface. The processor determines whether the touch screen is in a first state, and the first state is used to indicate that the touch screen is in a screen protector state. If the touch screen is in the first state, the processor restores the first fingerprint information by using a first preset AI restoration model to obtain second fingerprint information. Quality of a fingerprint image in the second fingerprint information is higher than quality of a fingerprint image in the first fingerprint information. The processor determines that the second fingerprint information matches preset fingerprint information and displays a second interface.

In a possible design of the third aspect, when the computer instructions are executed by the processor, the electronic device is further enabled to perform the following steps: Before the processor determines whether the touch screen is in the first state, the processor determines that the first fingerprint information does not match the preset fingerprint information; and the touch screen displays a third interface. The third interface includes prompt information indicating a fingerprint recognition failure.

In another possible design of the third aspect, when the computer instructions are executed by the processor, the

electronic device is further enabled to perform the following steps: After the processor determines whether the touch screen is in the first state, if the touch screen is in a second state, the processor restores the first fingerprint information by using a second preset AI restoration model to obtain third fingerprint information. The second state is used to indicate that the touch screen is in a bare screen state. Quality of a fingerprint image in the third fingerprint information is higher than the quality of the fingerprint image in the first fingerprint information. The processor determines that the third fingerprint information matches the preset fingerprint information and displays the second interface. The first preset AI restoration model is different from the second preset AI restoration model.

In another possible design of the third aspect, the first interface includes at least one of the following interfaces: an interface in which the electronic device is in a lock screen state, a fingerprint payment interface of the electronic device, and a fingerprint unlocking interface for one or more functions of a first application on the electronic device.

In another possible design of the third aspect, when the computer instructions are executed by the processor, the electronic device is further enabled to perform the following steps: The processor obtains raw fingerprint data for the first fingerprint information and obtains preset fingerprint data. The processor performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image. The processor runs a preset AI recognition model with the first fusion image used as input to determine whether the touch screen is in the first state.

In another possible design of the third aspect, when the computer instructions are executed by the processor, the electronic device is further enabled to perform the following steps: The processor removes noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image. The processor performs normalization on the second fusion image to obtain the first fusion image. Brightness uniformity of all pixels in the first fusion image is higher than brightness uniformity of all pixels in the second fusion image.

In another possible design of the third aspect, when the computer instructions are executed by the processor, the electronic device is further enabled to perform the following steps: The processor removes noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image. The processor performs normalization on the second fusion image to obtain a third fusion image. Brightness uniformity of all pixels in the third fusion image is higher than brightness uniformity of all pixels in the second fusion image. The processor performs Gaussian filtering on the third fusion image to obtain the first fusion image that does not include Gaussian noise in the third fusion image.

In another possible design of the third aspect, the preset AI recognition model includes a CNN model or a ResNet model.

In another possible design of the third aspect, when the computer instructions are executed by the processor, the electronic device is further enabled to perform the following step: The processor runs the first preset AI restoration model with the first fingerprint information used as input to obtain the second fingerprint information. The first preset AI restoration model is trained by using a plurality of first groups of fingerprint images as training samples. Each first group of fingerprint images includes a first fingerprint image and a second fingerprint image. The first fingerprint image is captured when the touch screen is in the first state, and the second fingerprint image is a pre-configured image obtained after the first fingerprint image is restored.

In another possible design of the third aspect, the first preset AI restoration model is a fully convolutional network FCN model; or the first preset AI restoration model is a Unet model; or the first preset AI restoration model is a Garbor filter.

In another possible design of the third aspect, when the computer instructions are executed by the processor, the electronic device is further enabled to perform the following step: The processor runs the second preset AI restoration model with the first fingerprint information used as input to obtain the third fingerprint information. The second preset AI restoration model is trained by using a plurality of second groups of fingerprint images as training samples. Each second group of fingerprint images includes a third fingerprint image and a fourth fingerprint image. The third fingerprint image is captured when the touch screen is in the second state, and the fourth fingerprint image is a pre-configured image obtained after the third fingerprint image is restored.

In another possible design of the third aspect, the second preset AI restoration model is an FCN model; or the second preset AI restoration model is a Unet model; or the second preset AI restoration model is a Garbor filter.

According to a fourth aspect, the present application provides a computer storage medium. The computer storage medium includes computer instructions. When the computer instructions are run on an electronic device, the electronic device is enabled to perform the method described in any one of the first aspect and the possible designs of the first aspect.

According to a fifth aspect, the present application provides a computer program product. When the computer program product is run on a computer, the computer is enabled to perform the method described in any one of the first aspect and the possible designs of the first aspect.

It may be understood that for beneficial effects that can be achieved by the electronic devices according to any one of the second aspect, the possible designs of the second aspect, the third aspect, and the possible designs of the third aspect, by the computer storage medium according to the fourth aspect, and by the computer program product according to the fifth aspect, reference may be made to the beneficial effects according to any one of the first aspect and the possible designs of the first aspect. Details are not described herein again.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of fingerprint images captured by a mobile phone in a screen protector state and in a bare screen state according to an embodiment of the present application;

FIG. **2** is a schematic diagram of a principle of a fingerprint recognition method according to an embodiment of the present application;

FIG. **3** is a schematic diagram of a hardware structure of an electronic device according to an embodiment of the present application;

FIG. **4** is a schematic diagram of a structure example of a touch screen disposed with a fingerprint sensor according to an embodiment of the present application;

FIG. **5**A and FIG. **5**B are a flowchart of a fingerprint recognition method according to an embodiment of the present application;

FIG. **6**(*a*) to FIG. **6**(*c*) are a schematic diagram of a display interface of a mobile phone in a fingerprint recognition scenario according to an embodiment of the present application;

FIG. **7**(*a*) and FIG. **7**(*b*) are a schematic diagram of a display interface of a mobile phone in another fingerprint recognition scenario according to an embodiment of the present application;

FIG. **8**(*a*) to FIG. **8**(*c*) are a schematic diagram of a display interface of a mobile phone in another fingerprint recognition scenario according to an embodiment of the present application;

FIG. **9**A and FIG. **9**B are a flowchart of a fingerprint recognition method according to an embodiment of the present application;

In the embodiment of the present application, test data is used to describe impact of applying a film to the electronic device (for example, a mobile phone) on image quality of fingerprint information captured by the fingerprint sensor disposed under the touch screen, and on a success rate of in-screen fingerprint recognition.

When touch screens of five new mobile phones of the same brand and model are in five different states separately, Table 1 shows respective image quality medians of fingerprint images captured by fingerprint sensors disposed under the touch screens, and respective success rates of fingerprint unlocking. The five different states include a bare screen state, a 0.50 millimeter (mm) tempered film protector state, a 0.36 mm tempered film protector state, a 0.26 mm hydrogel film protector state, and a 0.22 mm hydrogel film protector state.

TABLE 1

Test states	Bare screen state	0.50 mm tempered film protector state	0.36 mm tempered film protector state	0.26 mm hydrogel film protector state	0.22 mm hydrogel film protector state
Image quality medians	35.17	22.47	24.69	24.21	28.67
Unlocking success rate (in a low temperature scenario)	91%	79%	81%	83%	87%

FIG. **10** is a schematic diagram of fingerprint images before and after restoration according to an embodiment of the present application;

FIG. **11** is a schematic flowchart of a principle of another fingerprint recognition method according to an embodiment of the present application;

FIG. **12** is a schematic flowchart of a principle of another fingerprint recognition method according to an embodiment of the present application;

FIG. **13** is a schematic flowchart of a principle of another fingerprint recognition method according to an embodiment of the present application; and

FIG. **14** is a schematic flowchart of a principle of another fingerprint recognition method according to an embodiment of the present application.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The following terms "first" and "second" are merely used for description, but should not be understood as indicating or implying relative importance or implying a quantity of indicated technical features. Therefore, a feature limited by "first" or "second" may explicitly or implicitly include one or more features. In the description of embodiments, unless otherwise stated, "a plurality of" means two or more.

An embodiment of the present application provides a fingerprint recognition method, which can be applied to an electronic device having an in-screen fingerprint recognition function. The electronic device includes a touch screen, and a fingerprint sensor disposed under the touch screen.

To protect a touch screen, a user often applies a film, such as a tempered film or a hydrogel film, to an electronic device (for example, a mobile phone). Applying a film to the electronic device undoubtedly increases a distance between the fingerprint sensor disposed under the touch screen and a user finger, thereby affecting quality of a fingerprint image in fingerprint information captured by the fingerprint sensor, and further reducing a success rate of in-screen fingerprint recognition.

The quality of the fingerprint image may be represented by sharpness and/or completeness of the fingerprint image. In the embodiments of the present application, sharpness and/or completeness are collectively referred to as quality parameters of a fingerprint image. Higher sharpness indicates a larger quality parameter and higher quality of the fingerprint image. Higher completeness indicates a larger quality parameter and higher quality of the fingerprint image.

When the mobile phone is in any one of the foregoing states (for example, the 0.50 mm tempered film protector state), the fingerprint sensor may capture m fingerprint images, where m is an integer equal to or greater than 2. The m fingerprint images may be different in quality. In other words, quality parameters of the m fingerprint images may be different.

When the m fingerprint images are arranged in ascending or descending order of the quality parameters, a fingerprint image queue can be obtained. If m is an odd number, the image quality median refers to a quality parameter of a fingerprint image arranged in the middle of the fingerprint image queue. If m is an even number, the image quality median refers to an average of quality parameters of two fingerprint images arranged in the middle of the fingerprint image queue.

For example, assuming that the mobile phone is in the 0.50 mm tempered film protector state, the fingerprint sensor may capture three fingerprint images: a fingerprint image 1, a fingerprint image 2, and a fingerprint image 3. A quality parameter of the fingerprint image 1 is 22.47, a quality parameter of the fingerprint image 2 is 24, and a quality parameter of the fingerprint image 3 is 22. Because $22<22.47<24$, as shown in Table 1, in the 0.50 mm tempered film protector state, an image quality median of the fingerprint images is 22.47.

For another example, assuming that the mobile phone is in the 0.36 mm tempered film protector state, the fingerprint sensor may capture four fingerprint images: a fingerprint image a, a fingerprint image b, a fingerprint image c, and a fingerprint image d. A quality parameter of the fingerprint

image a is 24.68, a quality parameter of the fingerprint image b is 24.62, a quality parameter of the fingerprint image c is 24.68, and a quality parameter of the fingerprint image d is 24.80. Because 24.62<24.68<24.70<24.80, as shown in Table 1, in the 0.36 mm tempered film protector state, an image quality median of the fingerprint images is (24.68+24.70)/2=49.38/2=24.69.

It should be noted that the test data shown in Table 1 is obtained by inputting a touch operation to the mobile phones in the foregoing five states by a same user in a same touch manner in a same low temperature scenario.

Based on Table 1, it can be concluded that the quality median (for example, 35.17) of the fingerprint images captured by the fingerprint sensor in the bare screen state is highest compared to those in the screen protector state; and that the success rate (for example, 91%) of fingerprint unlocking is highest in the bare screen state compared to those in the screen protector state.

For example, FIG. **1** is a schematic diagram of fingerprint images separately captured by a mobile phone under a same condition (such as a same user finger or a same pressing force) in a screen protector state and in a bare screen state. As shown in FIG. **1**, a fingerprint image **101** is a fingerprint image captured by a fingerprint sensor of the mobile phone in the bare screen state; and a fingerprint image **102** is a fingerprint image captured by the fingerprint sensor of the mobile phone in the screen protector state. After the fingerprint image **101** is compared with the fingerprint image **102**, it can be concluded that the fingerprint image captured by the fingerprint sensor in the bare screen state is sharper and the image quality is better than image quality in the screen protector state.

Moreover, a thinner film applied to the touch screen indicates a higher quality median of the fingerprint images captured by the fingerprint sensor in the corresponding state, and a higher success rate of fingerprint unlocking. For example, the quality median (for example, 28.67) of the fingerprint images captured by the fingerprint sensor in the 0.22 mm hydrogel film protector state is highest, and the success rate (for example, 87%) of fingerprint unlocking is highest, as compared to those in the other screen protector states.

For example, alternatively, the quality of the fingerprint image may be indicated by sharpness and completeness of the fingerprint image. A sharper fingerprint image indicates higher quality of the fingerprint image. A more complete fingerprint image indicates higher quality of the fingerprint image. That quality of a fingerprint image (for example, the fingerprint image a) is higher than quality of another fingerprint image (for example, the fingerprint image b) may include that sharpness of the fingerprint image a is higher than sharpness of the fingerprint image b, and/or that completeness of the fingerprint image a is higher than completeness of the fingerprint image b.

Certainly, ambient light intensity, ambient humidity, and a degree of wetness of a user finger also affect the quality of the fingerprint image. Currently, in-screen fingerprint can be implemented in three manners based on different technical principles: an optical in-screen fingerprint, an ultrasonic in-screen fingerprint, and a capacitive in-screen fingerprint. Due to good image quality and relatively mature technology, the optical in-screen fingerprints are widely used in various electronic devices equipped with touch screens. Because the optical in-screen fingerprint is realized by the principle of refraction and reflection of light, optical in-screen fingerprint recognition is relatively sensitive to ambient light and humidity. It should be noted that the method according to the embodiment of the present invention can be applied to an in-screen fingerprint solution realized by the foregoing implementations such as an optical in-screen fingerprint, an ultrasonic in-screen fingerprint, and a capacitive in-screen fingerprint.

Specifically, in the fingerprint recognition method provided in the embodiment of the present application, as shown in FIG. **2**, if fingerprint recognition fails on the electronic device, the electronic device can identify whether the touch screen of the electronic device is in a screen protector state (that is, perform screen protector recognition). If the touch screen is in a screen protector state, the electronic device may perform fingerprint image restoration on the fingerprint image captured by the fingerprint sensor to reduce impact of the screen protector on fingerprint recognition. Then, the electronic device performs fingerprint recognition on a restored fingerprint image (fingerprint recognition again as shown in FIG. **2**). In this way, the success rate of the in-screen fingerprint recognition can be increased.

For example, the electronic device in this embodiment of the present application may be a portable computer (for example, a mobile phone), a tablet computer, a notebook computer, a personal computer (personal computer, PC), a wearable electronic device (for example, a smart watch), an augmented reality (augmented reality, AR)/virtual reality (virtual reality, VR) device, a vehicle-mounted computer, or the like. A specific form of the electronic device is not specially limited in the following embodiments.

For example, the foregoing electronic device is a mobile phone. FIG. **3** is a schematic diagram of a structure of an electronic device **100** according to an embodiment of the present application. The electronic device **100** may include a processor **110**, an external memory interface **120**, an internal memory **121**, a universal serial bus (universal serial bus, USB) interface **130**, a charging management module **140**, a power management module **141**, a battery **142**, an antenna **1**, an antenna **2**, a mobile communications module **150**, a wireless communications module **160**, an audio module **170**, a speaker **170**A, a telephone receiver **170**B, a microphone **170**C, a headset jack **170**D, a sensor module **180**, a key **190**, a motor **191**, an indicator **192**, a camera **193**, a display **194**, a subscriber identity module (subscriber identification module, SIM) card interface **195**, and the like.

The sensor module **180** may include a pressure sensor, a gyro sensor, a barometric pressure sensor, a magnetic sensor, an acceleration sensor, a distance sensor, an optical proximity sensor, a fingerprint sensor **180**A, a temperature sensor, a touch sensor **180**B, an ambient light sensor, a bone conduction sensor, and the like.

It can be understood that the structure illustrated in this embodiment of the present invention does not constitute a specific limitation on the electronic device **100**. In some other embodiments of the present application, the electronic device **100** may include more or fewer components than those shown in the figure, combine some components, split some components, or have different component arrangements. The components in the figure may be implemented by hardware, software or a combination of software and hardware.

The processor **110** may include one or more processing units. For example, the processor **110** may include an application processor (application processor, AP), a modem processor, a graphics processing unit (graphics processing unit, GPU), an image signal processor (image signal processor, ISP), a controller, a memory, a video codec, a digital signal processor (digital signal processor, DSP), a baseband

processor, a neural-network processing unit (neural-network processing unit, NPU), a micro controller unit (micro controller unit, MCU), and/or the like. Different processing units may be separate devices or may be integrated into one or more processors.

The controller may be a nerve center and a command center of the electronic device **100**. The controller may generate an operation control signal based on instruction operation code and a time sequence signal, and complete control of instruction fetching and instruction execution.

A memory may be disposed in the processor **110**, and is configured to store instructions and data. In some embodiments, the memory in the processor **110** is a cache. The memory may store instructions or data that are or is just used or cyclically used by the processor **110**. If the processor **110** needs to use the instructions or the data again, the processor **110** may directly invoke the instructions or the data from the memory, to avoid repeated access and reduce waiting time of the processor **110**. This improves system efficiency.

In some embodiments, the processor **110** may include one or more interfaces. The interfaces may include an inter-integrated circuit (inter-integrated circuit, I2C) interface, a serial peripheral interface (serial peripheral interface, SPI), an inter-integrated circuit sound (inter-integrated circuit sound, I2S) interface, a pulse code modulation (pulse code modulation, PCM) interface, a universal asynchronous receiver/transmitter (universal asynchronous receiver/transmitter, UART) interface, a mobile industry processor interface (mobile industry processor interface, MIPI), a general-purpose input/output (general-purpose input/output, GPIO) interface, a subscriber identity module (subscriber identity module, SIM) interface, a universal serial bus (universal serial bus, USB) interface, and/or the like.

It may be understood that an interface connection relationship between the modules that is shown in embodiments of the present invention is merely an example for description, and does not constitute a limitation on a structure of the electronic device **100**. In some other embodiments in the present application, the electronic device **100** may alternatively use an interface connection manner different from that in the foregoing embodiment, or use a combination of a plurality of interface connection manners.

The charging management module **140** is configured to receive charging input from a charger. The power management module **141** is configured to connect the battery **142** and the charging management module **140** to the processor **110**. The power management module **141** receives input from the battery **142** and/or the charging management module **140**, and supplies power to the processor **110**, the internal memory **121**, the external memory, the display **194**, the camera **193**, the wireless communications module **160**, and the like. In some other embodiments, the power management module **141** and the charging management module **140** may be disposed on a same device.

A wireless communication function of the electronic device **100** may be implemented by using the antenna **1**, the antenna **2**, the mobile communications module **150**, the wireless communications module **160**, the modem processor, the baseband processor, and the like. The antenna **1** and the antenna **2** are configured to transmit and receive electromagnetic wave signals. Each antenna in the electronic device **100** may be configured to cover one or more communication frequency bands. Different antennas may be further multiplexed to improve antenna utilization. For example, the antenna **1** may be multiplexed as a diversity antenna for a wireless local area network. In some other embodiments, the antenna may be used together with a tuning switch.

The mobile communications module **150** may provide a solution to wireless communication including 2G/3G/4G/5G and the like applied to the electronic device **100**. The wireless communications module **160** may provide a wireless communication solution that includes a wireless local area network (wireless local area network, WLAN) (for example, a Wi-Fi network), Bluetooth (Bluetooth, BT), a global navigation satellite system (global navigation satellite system, GNSS), frequency modulation (frequency modulation, FM), NFC, an infrared (infrared, IR) technology, and the like and that is applied to the electronic device **100**.

The electronic device **100** implements a display function by using the GPU, the display **194**, the application processor, and the like. The GPU is an image processing microprocessor and is connected to the display **194** and the application processor. The GPU is configured to perform mathematical and geometric calculations for graphic rendering. The processor **110** may include one or more GPUs, and the GPUs execute program instructions to generate or change display information.

The display **194** is configured to display an image, a video, or the like. The display is a touch screen. In some embodiments, the electronic device **100** may include 1 or N displays **194**, where N is a positive integer greater than 1.

The electronic device **100** can implement a photographing function by using the ISP, the camera **193**, the video codec, the GPU, the display **194**, the application processor, and the like. The ISP is configured to process data fed back by the camera **193**. The camera **193** is configured to capture a still image or a video. In some embodiments, the electronic device **100** may include 1 or N cameras **193**, where N is a positive integer greater than 1. [moo] As a neural-network (neural-network, NN) computing processor, the NPU may quickly process input information by using a biological neural network structure such as a mode of transmission between human-brain nerve cells, and may further constantly perform self-learning. The NPU can implement applications such as intelligent cognition of the electronic device **100**, for example, screen protector state recognition, image restoration, image recognition, facial recognition, speech recognition, and text understanding.

The external memory interface **120** may be configured to connect an external memory card, such as a micro SD card, to expand a storage capacity of the electronic device **100**. The external memory card communicates with the processor **110** through the external memory interface **120**, to implement a data storage function. For example, files such as music and a video are stored in the external memory card.

The internal memory **121** may be configured to store computer executable program code, and the executable program code includes instructions. The processor **110** executes various function applications and data processing of the electronic device **100** by running the instructions stored in the internal memory **121**. The internal memory **121** may include a program storage area and a data storage area. The program storage region may store an operating system, an application program required by at least one function (such as a sound play function and an image display function), and the like. The data storage area may store data (such as audio data and a phone book) created during use of the electronic device **100**, and the like. In addition, the internal memory **121** may include a high-speed random access memory, and may further include a non-volatile memory

such as at least one magnetic disk storage component, a flash memory component, or a universal flash storage (universal flash storage, UFS).

The electronic device **100** may implement an audio function by using the audio module **170**, the speaker **170**A, the telephone receiver **170**B, the microphone **170**C, the headset jack **170**D, the application processor, and the like, such as music playing and recording.

The fingerprint sensor **180**A is configured to capture fingerprint information. The electronic device **100** may use fingerprint features of the captured fingerprint information for user identity verification (that is, fingerprint recognition), to implement fingerprint unlocking, application lock accessing, fingerprint photographing, fingerprint-based call answering, and the like.

In the embodiment of the present application, the fingerprint sensor **180**A may be disposed under the display **194**; or the fingerprint sensor **180**A may be integrated in the display **194**. The fingerprint sensor **180**A may be disposed in a fixed position of the display **194**. For example, when the electronic device **100** is a touch-screen mobile phone, the fingerprint sensor **180**A may be disposed in a position that is close to the underside of the touch-screen mobile phone and that is in the touch screen (that is, the display **194**) of the touch-screen mobile phone. For example, as shown in FIG. **4**, the fingerprint sensor **180**A may be disposed in a position a of the display **194**. Alternatively, the fingerprint sensor **180**A may be disposed throughout the display **194**.

The touch sensor **180**B is also referred to as a "touch panel (TP)". The touch sensor **180**B may be disposed on the display **194**, and the touch sensor **180**B and the display **194** constitute a touch screen, which is also referred to as a "touch control screen". The touch sensor **180**B is configured to detect a touch operation performed on or near the touch sensor **180**B. The touch sensor can transmit a detected touch operation to the application processor to determine a type of a touch event. The display **194** may be configured to provide a visual output related to the touch operation. In some other embodiments, the touch sensor **180**B may be alternatively disposed on the surface of the electronic device **100** in a position different from that of the display **194**.

The key **190** includes a power-on key, a volume key, and the like. The motor **191** may generate vibration alerts. The indicator **192** may be an indicator light, and may be used to indicate a charging status and a battery level, or may be used to indicate a message, a missed call, a notification, and the like. The SIM card interface **195** is configured to connect a SIM card.

An embodiment of the present application provides a fingerprint recognition method, which can be applied to an electronic device having an in-screen fingerprint recognition function. The electronic device includes a touch screen, and a fingerprint sensor disposed under the touch screen. Based on an example in which the foregoing electronic device is a mobile phone, as shown in FIG. **5**A and FIG. **5**B, the fingerprint recognition method may include S**501** to S**509**.

S**501**. The mobile phone displays a first interface, and the mobile phone captures first fingerprint information that is input by a user at the first interface.

The first interface may include at least one of the following interfaces: an interface in which the mobile phone is in a lock screen state, a fingerprint payment interface of the mobile phone, and a fingerprint input interface for one or more functions of a first application in the mobile phone. The first application may be an application whose one or more functions will be available only when an unlock (for example, fingerprint unlock) operation is performed. For example, the first application may be a "bank" application whose account detail page will be displayed on the mobile phone only when an unlock (for example, fingerprint unlock) operation is performed. For another example, the first application may be a "settings" application whose password modification and decryption will be displayed on the mobile phone only when an unlock (for example, fingerprint unlock) operation is performed.

In a first application scenario, the first interface is an interface in which the mobile phone is in a lock screen state. The interface in which the mobile phone is in a lock screen state may be a black screen interface of the mobile phone, or may be a lock screen interface of the mobile phone.

Both the black screen interface **601** shown in FIG. **6**(*a*) and the lock screen interface **602** shown in FIG. **6**(*b*) of the mobile phone can receive fingerprint information (captured by the fingerprint sensor) that is input by the user. The fingerprint information is used for unlocking the mobile phone. For example, after the mobile phone receives fingerprint information (for example, the first fingerprint information) that is input by the user at the black screen interface **601** or the lock screen interface **602**, the mobile phone may perform S**502** to determine whether the first fingerprint information matches preset fingerprint information. After S**602**, if the first fingerprint information passes fingerprint recognition, the mobile phone may display a main interface **603** shown in FIG. **6**(*c*), in other words, a second interface.

It should be noted that "passing fingerprint recognition" described in the embodiment of the present application may also be referred to as "fingerprint recognition success", and "not passing fingerprint recognition" may also be referred to as "fingerprint recognition failure".

Specifically, the mobile phone may determine whether the first fingerprint information matches the preset fingerprint information. If the first fingerprint information matches the preset fingerprint information, it indicates that the first fingerprint information passes fingerprint recognition. If the first fingerprint information does not match the preset fingerprint information, the first fingerprint information does not pass fingerprint recognition. For example, if a matching degree of the first fingerprint information and the preset fingerprint information is higher than or equal to a preset matching degree threshold, it indicates that the first fingerprint information matches the preset fingerprint information. If the matching degree between the first fingerprint information and the preset fingerprint information is lower than the preset matching degree threshold, it indicates that the first fingerprint information does not match the preset fingerprint information. For example, the preset matching degree threshold may be any value such as 80%, 90%, or 85%. The preset matching degree threshold is stored on the mobile phone in advance. The preset fingerprint information is stored on the mobile phone in advance.

In a second application scenario, the first interface is the fingerprint payment interface of the mobile phone, such as a payment interface **701** shown in FIG. **7**(*a*). The mobile phone may receive fingerprint information (for example, first fingerprint information) (captured by the fingerprint sensor) that is input by a user at the payment interface **701**. Thereafter, the mobile phone may perform S**502** to perform fingerprint recognition on the first fingerprint information. After S**502**, if the fingerprint recognition is passed, the mobile phone may display a payment success interface **702** shown in FIG. **7**(*b*), in other words, a second interface.

In a third application scenario, the first interface is the fingerprint input interface for one or more functions of the first application in the mobile phone. For example, the

mobile phone may display a home page **801** of a "bank" application shown in FIG. **8**(*a*). In response to a user click operation on the "Mine" button **802** on the home page **801** of the "bank" application, the mobile phone may display a fingerprint entry interface **803** shown in FIG. **8**(*b*). The first interface may be the fingerprint entry interface **803**. The mobile phone may receive fingerprint information (for example, first fingerprint information) (captured by the fingerprint sensor) that is input by the user at the fingerprint entry interface **803**. Thereafter, the mobile phone may perform S**502** to perform fingerprint recognition on the first fingerprint information. After S**502**, if the fingerprint recognition is passed, the account detail page of the "bank" application is unlocked, and the mobile phone may display an account detail page **804** of the "bank" application shown in FIG. **8**(*c*), in other words, a second interface.

S**502**. The mobile phone determines whether the first fingerprint information matches the preset fingerprint information.

For a specific method in which the mobile phone determines whether the first fingerprint information matches the preset fingerprint information, refer to the fingerprint recognition method in the foregoing embodiment and the conventional technology. Details are not described herein again in this embodiment of the present application. In some embodiments, S**502** is optional. The mobile phone may perform S**503** directly after S**5***oi*.

After S**502**, if the first fingerprint information does not pass fingerprint recognition, it indicates that the first fingerprint information does not match the preset fingerprint information for fingerprint recognition previously stored in the mobile phone, and it indicates that fingerprint recognition on the first fingerprint information fails. If the first fingerprint information does not pass fingerprint recognition, there may be three reasons: (1) the user does not input the fingerprint information using the correct finger; (2) a fingerprint pattern of the user is blurred and not easily captured; and (3) when the user inputs fingerprint information, an insufficient fitting degree between the finger and the touch screen cannot ensure that the fingerprint sensor captures fingerprint information with high fingerprint image quality. Even if the second or third reason exists, if a film is not applied to the touch screen of the mobile phone, fingerprint recognition on the fingerprint information captured by the touch sensor may succeed. Therefore, the mobile phone can restore the first fingerprint information to increase the success rate of fingerprint recognition. Specifically, after S**502**, if the first fingerprint information does not match the preset fingerprint information, it indicates that the first fingerprint information does not pass fingerprint recognition, and the mobile phone may perform S**503**. If the first fingerprint information passes fingerprint recognition, the mobile phone may perform S**508**.

S**503**. The mobile phone determines whether the touch screen is in a first state.

The first state is used to indicate that the touch screen is in a screen protector state. When the touch screen is in a screen protector state, specifically, a protective film is applied to the touch screen. When the touch screen is in a bare screen state, specifically, a protective film is not applied to the touch screen. The protective film described in the embodiments of the present application may be any protective film such as a tempered film, a hydrogel film, or a high-definition plastic film.

For example, a preset AI recognition model may be pre-configured on the mobile phone. The preset AI recognition model is capable of determining, based on a fingerprint image, whether a corresponding touch screen is in a screen protector state. Specifically, the method in which the mobile phone determines whether the touch screen is in a screen protector state may include S**503***a* to S**503***c*. For example, as shown in FIG. **9**A and FIG. **9**B, S**503** may include S**503***a* to S**503***c*.

S**503***a*. The mobile phone obtains raw fingerprint data for the first fingerprint information and obtains preset fingerprint data.

The raw fingerprint data may also be referred to as raw (Raw) data. "Raw" can be translated as "unprocessed". To be specific, the raw fingerprint data is an unprocessed fingerprint image captured by the fingerprint sensor.

The preset fingerprint data may be referred to as base (Base) data. The preset fingerprint data includes noisy image data that is generated based on actual hardware parameters of the touch screen and the fingerprint sensor and that affects a success rate of fingerprint recognition. For example, the preset fingerprint data may include noisy image data generated due to a lack of close fit between the touch screen and the fingerprint sensor. The preset fingerprint data may be obtained by performing a large quantity of tests on the mobile phone before delivery from factory. The preset fingerprint data is pre-configured on the mobile phone.

S**503***b*. The mobile phone performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image.

It should be understood that the raw fingerprint data is captured in real time by the mobile phone during S**5***oi*. The raw fingerprint data includes the noisy image data that is generated based on the actual hardware parameters of the touch screen and the fingerprint sensor and that affects the success rate of fingerprint recognition. Therefore, the mobile phone can perform feature fusion on the raw fingerprint data and the preset fingerprint data to reduce the noisy image data in the raw fingerprint data to obtain the first fusion image.

In some embodiments, the method in which the mobile phone performs feature fusion on the raw fingerprint data and the preset fingerprint data to obtain the first fusion image may include S1 and S2. In other words, S**503***b* includes S1 and S2.

S1: The mobile phone removes the noisy image data from the raw fingerprint data (that is, the raw data) by using the preset fingerprint data (that is, the base data) to obtain a second fusion image.

For the method in which the mobile phone removes the noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain the second fusion image, refer to the related description in the conventional technology. Details are not described herein.

S2: The mobile phone performs normalization on the second fusion image to obtain the first fusion image.

It should be understood that quality of a fingerprint image captured by the mobile phone is affected not only by hardware parameters of the mobile phone, but also by a user operation and illumination. For example, the second fusion image obtained by performing S1 by the mobile phone may be nonuniform in brightness because the user finger sweats, the user finger does not fit the touch screen sufficiently, ambient light is too strong, and the like. If the user finger does not fit the touch screen sufficiently or the ambient light is too strong, a position that is corresponding to the fingerprint sensor and that is on the touch screen is easily reflected, resulting in nonuniform brightness of the fingerprint image.

In view of this, the mobile phone may perform S2 and perform normalization on the second fusion image to obtain the first fusion image. In this way, brightness of all pixels in

the fusion image can be made more uniform. Brightness uniformity of all pixels in the first fusion image is higher than brightness uniformity of all pixels in the second fusion image.

The brightness uniformity of the fingerprint image can be reflected by contrast of the fingerprint image. Stronger contrast of the fingerprint image indicates lower brightness uniformity of the fingerprint image. Weaker contrast of the fingerprint image indicates higher brightness uniformity of the fingerprint image. In this design, normalization can be performed on the second fusion image to reduce the contrast of the second fusion image, thereby improving the brightness uniformity of the second fusion image.

It should be noted that, in the embodiment of the present application, for the method in which the mobile phone performs normalization on a fusion image (for example, the second fusion image) to improve brightness uniformity of the fusion image, reference may be made to the related description in the conventional technology, and details are not described herein in this embodiment of the present application.

S503*c*. The mobile phone runs a preset AI recognition model with the first fusion image used as input to determine whether the touch screen is in the first state.

The preset AI recognition model is capable of determining, based on a fingerprint image, whether a corresponding touch screen is in the first state. The corresponding touch screen refers to a touch screen in which a fingerprint sensor for capturing the fingerprint image is located.

The preset AI recognition model is pre-configured on the mobile phone. An output result of the preset AI recognition model is used to indicate whether the touch screen is in a screen protector state. For example, the output result of the preset AI recognition model may be first information or second information. The first information is used to indicate that the touch screen is in a screen protector state, and the second information is used to indicate that the touch screen is in a bare screen state. For example, the first information may be "1", and the second information may be "0". Alternatively, the first information may be "10", and the second information may be "00".

For example, the preset AI recognition model may include at least any one of the following network modules: a CNN model or a ResNet model.

It should be noted that the ResNet model described in the embodiments of the present application may be obtained by modifying an existing ResNet model. Specifically, the ResNet model described in the embodiments of the present application may be a model obtained by deleting branches other than a branch for a dichotomous classification function in the ResNet model. The dichotomous classification function refers to an ability to solve a dichotomous classification problem. The dichotomous classification problem has two results: yes (YES) or no (NO). The first information is YES, and the second information is NO.

For example, the embodiment of the present application describes a training process of the preset AI recognition model.

In the embodiment of the present application, the fingerprint sensor of the mobile phone can capture a plurality of fingerprint images a and a plurality of fingerprint images b of a large quantity of users in different usage scenarios. The plurality of fingerprint images a are captured by the fingerprint sensor of the mobile phone when the touch screen of the mobile phone is in the screen protector state. The plurality of fingerprint images b are captured by the fingerprint sensor of the mobile phone when the touch screen of the mobile phone is in the bare screen state. Then, a corresponding fusion image a (that is, a first fusion image) can be obtained from each captured fingerprint image a, and a corresponding fusion image b (that is, a first fusion image) can be obtained from each captured fingerprint image b. In this way, a plurality of screen-protector training samples and a plurality of bare-screen training samples can be obtained. Each screen-protector training sample includes a fusion image a corresponding to a fingerprint image a, and each bare-screen training sample includes a fusion image b corresponding to a fingerprint image b.

Finally, the preset AI recognition model may be trained by using the plurality of screen-protector training samples (that is, the plurality of fusion images a) as input samples, and using the first information as output samples. The preset AI recognition model may be further trained by using the plurality of bare-screen training samples (that is, the plurality of fusion images b) as input samples, and using the second information as output samples. Thus, after a plurality of times of training, the preset AI recognition model is capable of determining, based on a fingerprint image, whether a corresponding touch screen is in a screen protector state.

The different usage scenarios may include a plurality of scenarios in which the mobile phone may be used. For example, the plurality of scenarios may include at least the following usage scenarios: a high-temperature scenario, a low-temperature scenario, a scenario in which ambient light brightness is relatively high, a scenario in which ambient light brightness is relatively low, an indoor scenario, an outdoor scenario, a day scenario, a night scenario, and any other scenarios corresponding to image quality factors that may affect fingerprint images captured by the fingerprint sensor. The large quantity of users may include a plurality of users at different ages, a plurality of users of different genders, a plurality of users in different professions, a plurality of users with different degrees of finger wetness, and the like.

After **S503** (or **S503***c*), if the touch screen is in the first state, it indicates that the first fingerprint information does not pass fingerprint recognition because a protective film applied to the touch screen affects quality of a fingerprint image in the first fingerprint information captured by the fingerprint sensor. In this case, the mobile phone may perform **S504** of restoring the first fingerprint information by using a first preset AI restoration model, and then perform **S505** of performing fingerprint recognition on restored second fingerprint information.

After **S503** (or **S503***c*), if the touch screen is in a second state, it indicates that the first fingerprint information does not pass fingerprint recognition, not because a protective film applied to the touch screen affects quality of a fingerprint image in the first fingerprint information captured by the fingerprint sensor, but because something else. The second state is used to indicate that the touch screen is in a bare screen state. In some embodiments, after **S503**, if the touch screen is in the bare screen state, the mobile phone may perform **S509** of indicating a fingerprint recognition failure. In some other embodiments, after **S503**, if the touch screen is in the bare screen state, the mobile phone may not perform **S509**, but use another preset AI restoration model (for example, a second preset AI restoration model) to restore the first fingerprint information to obtain third fingerprint information, and then perform fingerprint recognition on the third fingerprint information.

S504. The mobile phone runs the first preset AI restoration model with the first fingerprint information used as

input to obtain the second fingerprint information. Quality of a fingerprint image in the second fingerprint information is higher than quality of a fingerprint image in the first fingerprint information.

For example, a fingerprint image **1001** shown in FIG. **10** is the fingerprint image in the first fingerprint information, and a fingerprint image **1002** shown in FIG. **10** is the fingerprint image in the second fingerprint information. As shown in FIG. **10**, quality of the fingerprint image **1002** is higher than quality of the fingerprint image **1001**.

The first preset AI restoration model is capable of restoring a fingerprint image to improve image quality. The first preset AI restoration model is pre-configured on the mobile phone. An image before restoration (for example, the first fingerprint information) is input into the first preset AI restoration model, and an image after restoration (for example, the second fingerprint information) is output from the first preset AI restoration model.

The first preset AI restoration model is trained by using a plurality of first groups of fingerprint images as training samples. Each first group of fingerprint images includes a first fingerprint image and a second fingerprint image. The first fingerprint image is captured by the fingerprint sensor when the touch screen is in the screen protector state. The second fingerprint image is an image obtained after the first fingerprint image is restored. The second fingerprint image may be obtained by restoring the first fingerprint image using a pre-configured image restoration tool (for example, an AI model).

For example, the embodiment of the present application describes a training process of the first preset AI restoration model.

In the embodiment of the present application, a plurality of first groups of fingerprint images may be captured, and each first group of fingerprint images includes a first fingerprint image A and a second fingerprint image B. The second fingerprint image B is obtained by restoring the first fingerprint image A using a pre-configured image restoration tool (for example, an AI model). Quality of the second fingerprint image B is higher than quality of the first fingerprint image A in the same group. Then, the first preset AI restoration model may be trained by using the first fingerprint image A in each first group of fingerprint images as an input sample, and using the second fingerprint image B in the first group of fingerprint images as an output sample. Thus, after a plurality of times of training, the first preset AI restoration model is capable of restoring a fingerprint image to improve image quality.

In some embodiments, the first preset AI restoration model may be a fully convolutional network (fully convolutional network, FCN) model. In some other embodiments, the first preset AI restoration model may be a Unet model. Herein, the Unet model is more miniaturized than the FCN model. Thus, the Unet model is more suitable for a small terminal, such as a mobile phone, a tablet computer, or a wearable device.

In some other embodiments, the first preset AI restoration model is a Garbor filter. The Garbor filter is capable of extracting an orientation field image from the first fingerprint information, and restoring the first fingerprint information with the orientation field image to obtain the second fingerprint information. The orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information.

It should be understood that because the orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information, the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information can be determined by using the orientation field image, and intermittent fingerprint points in the first fingerprint information can be connected based on the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information. Thus, the second fingerprint information whose image quality is higher than image quality of the first fingerprint information can be obtained.

S505. The mobile phone determines whether the second fingerprint information matches the preset fingerprint information.

For a specific method in which the mobile phone determines whether the second fingerprint information matches the preset fingerprint information, or the mobile phone performs fingerprint recognition on the second fingerprint information, refer to the fingerprint recognition method in the foregoing embodiment and the conventional technology. Details are not described herein in this embodiment of the present application.

After **S505**, if the second fingerprint information passes fingerprint recognition (that is, the second fingerprint information matches the preset fingerprint information), the mobile phone may perform **S508**. If the second fingerprint information does not pass fingerprint recognition (that is, the second fingerprint information does not match the preset fingerprint information), the mobile phone may perform **S509**.

S506. The mobile phone runs the second preset AI restoration model with the first fingerprint information used as input to obtain the third fingerprint information. Quality of a fingerprint image in the third fingerprint information is higher than the quality of the fingerprint image in the first fingerprint information.

For example, a fingerprint image **1003** shown in FIG. **10** is the fingerprint image in the first fingerprint information, and a fingerprint image **1004** shown in FIG. **10** is the fingerprint image in the third fingerprint information. As shown in FIG. **10**, quality of the fingerprint image **1004** is higher than quality of the fingerprint image **1003**.

The second preset AI restoration model is capable of restoring a fingerprint image to improve image quality. The second preset AI restoration model is pre-configured on the mobile phone. An image before restoration (for example, the first fingerprint information) is input into the second preset AI restoration model, and an image after restoration (for example, the third fingerprint information) is output from the second preset AI restoration model.

The second preset AI restoration model is trained by using a plurality of second groups of fingerprint images as training samples. Each second group of fingerprint images includes a third fingerprint image and a fourth fingerprint image. The third fingerprint image is captured by the fingerprint sensor when the touch screen is in the bare screen state. The fourth fingerprint image is an image obtained after the third fingerprint image is restored. The fourth fingerprint image may be obtained by restoring the third fingerprint image using a pre-configured image restoration tool (for example, an AI model).

For example, the embodiment of the present application describes a training process of the second preset AI restoration model.

In the embodiment of the present application, a plurality of second groups of fingerprint images may be captured, and each second group of fingerprint images includes a third fingerprint image C and a fourth fingerprint image D. The fourth fingerprint image D is obtained by restoring the third

fingerprint image C using a pre-configured image restoration tool (for example, an AI model). Quality of the fourth fingerprint image D is higher than quality of the third fingerprint image C in the same group. Then, the second preset AI restoration model may be trained by using the third fingerprint image C in each second group of fingerprint images as an input sample, and using the fourth fingerprint image D in the second group of fingerprint images as an output sample. Thus, after a plurality of times of training, the second preset AI restoration model is capable of restoring a fingerprint image to improve image quality.

In some embodiments, the second preset AI restoration model may be an FCN model. In some other embodiments, the second preset AI restoration model may be a Unet model.

In some other embodiments, the second preset AI restoration model is a Garbor filter. The Garbor filter is capable of extracting an orientation field image from the first fingerprint information, and restoring the first fingerprint information with the orientation field image to obtain the third fingerprint information. The orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information.

It should be understood that because the orientation field image is used to represent directionality of a fingerprint ridge of the fingerprint image in the first fingerprint information, the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information can be determined by using the orientation field image, and intermittent fingerprint points in the first fingerprint information can be connected based on the directionality of the fingerprint ridge of the fingerprint image in the first fingerprint information. Thus, the third fingerprint information whose image quality is higher than image quality of the first fingerprint information can be obtained.

It should be noted that the first preset AI restoration model and the second preset AI restoration model are trained by using different training samples. Specifically, the first preset AI restoration model is trained by using the plurality of first groups of fingerprint images as training samples, while the second preset AI restoration model is trained by using the plurality of second groups of fingerprint images as training samples. Each first group of fingerprint images includes a first fingerprint image captured by the fingerprint sensor when the touch screen is in the screen protector state, and a second fingerprint image obtained by restoring the first fingerprint image. Each second group of fingerprint images includes a third fingerprint image captured by the fingerprint sensor when the touch screen is in the bare screen state, and a fourth fingerprint image obtained by restoring the third fingerprint image.

In other words, the first preset AI restoration model is trained by using the fingerprint images captured by the fingerprint sensor when the touch screen is in the screen protector state, while the second preset AI restoration model is trained by using the fingerprint images captured by the fingerprint sensor when the touch screen is in the bare screen state. Therefore, the first preset AI restoration model has a better effect of restoring a fingerprint image captured in the screen protector state, while the second preset AI model has a better effect of restoring a fingerprint image captured in the bare screen state.

According to the method in the embodiment of the present application, if fingerprint recognition is performed, the mobile phone can use different AI restoration models to restore fingerprint images captured by the fingerprint sensor when the touch screen is in different states (such as a screen protector state or a bare screen state), so as to improve quality of the fingerprint images. In this way, when the touch screen is in different states, quality of the fingerprint images can be improved accordingly, so that the success rate of fingerprint recognition can be increased.

S507. The mobile phone determines whether the third fingerprint information matches the preset fingerprint information.

For a specific method in which the mobile phone determines whether the third fingerprint information matches the preset fingerprint information, or the mobile phone performs fingerprint recognition on the third fingerprint information, refer to the fingerprint recognition method in the conventional technology. Details are not described herein in this embodiment of the present application.

After **S509**, if the third fingerprint information passes fingerprint recognition (that is, the third fingerprint information matches the preset fingerprint information), the mobile phone may perform **S508**. If the third fingerprint information does not pass fingerprint recognition (that is, the third fingerprint information does not match the preset fingerprint information), the mobile phone may perform **S509**.

S508: The mobile phone displays the second interface. The second interface is an interface displayed on the mobile phone after the fingerprint recognition is passed at the first interface.

For example, in the foregoing first application scenario, the second interface may be the main interface **603** shown in FIG. **6**(*c*). For another example, in the foregoing second application scenario, the second interface may be the payment success interface **702** shown in FIG. **7**(*b*). For another example, in the foregoing third application scenario, the second interface may be the account detail page **804** of the "bank" application.

S509: The mobile phone displays the third interface. The third interface includes prompt information indicating a fingerprint recognition failure.

For a method in which the mobile phone sends the prompt information indicating that the fingerprint recognition is not passed (that is, the fingerprint recognition failure), refer to the related description in the conventional technology. Details are not described herein.

For example, FIG. **11** is a schematic diagram of a principle of a fingerprint recognition method according to an embodiment of the present application. The mobile phone may perform fingerprint recognition **1101** shown in FIG. **11**, and perform fingerprint recognition 1 on first fingerprint information by using a fingerprint recognition algorithm to obtain a fingerprint recognition feedback (that is, a fingerprint recognition result). The fingerprint recognition feedback may be a fingerprint recognition failure or success. Herein, **1101** shown in FIG. **11** corresponds to **S502**.

After **1101** shown in FIG. **11**, if the fingerprint recognition succeeds (that is, the fingerprint recognition passes), the mobile phone may display a second interface. The second interface is an interface displayed on the mobile phone after the fingerprint recognition is passed at the first interface.

After **1101** shown in FIG. **11**, if the fingerprint recognition fails (that is, the fingerprint recognition is not passed), the mobile phone may perform screen protector recognition **1102** shown in FIG. **11** of fusing raw fingerprint data (for example, the raw data) and preset fingerprint data (for example, the base data) to obtain a fusion image (that is, a first fusion image), and using a preset AI recognition algorithm by using the fusion image as data to obtain a recognition result. The recognition result is used to indicate whether the touch screen of the mobile phone is in a screen

protector state. It should be understood that the preset AI recognition algorithm is an algorithm used by the preset AI recognition model for screen protector recognition. Herein, **1102** shown in FIG. **11** corresponds to S**503**.

After **1102** shown in FIG. **11**, if the touch screen of the mobile phone is in the screen protector state, the mobile phone may perform **1103** shown in FIG. **11** of restoring a preprocessed image (for example, the first fingerprint information) by using a first preset AI restoration algorithm to obtain a restored image (for example, second fingerprint information). It should be understood that the first preset AI restoration algorithm is an algorithm used by the first preset AI restoration model to perform image restoration. Herein, **1103** shown in FIG. **11** corresponds to S**504**.

After **1103** shown in FIG. **11**, the mobile phone may perform **1104** shown in FIG. **11** of performing fingerprint recognition 2 on a restored image (for example, the second fingerprint information) by using a fingerprint recognition algorithm to obtain a fingerprint recognition feedback (that is, a fingerprint recognition result). The fingerprint recognition feedback may be a fingerprint recognition failure or success. Herein, **1104** shown in FIG. **11** corresponds to S**505**.

After **1102** shown in FIG. **11**, if the touch screen of the mobile phone is in the bare screen state, the mobile phone may perform **1105** shown in FIG. **11** of restoring the preprocessed image (for example, the first fingerprint information) by using a second preset AI restoration algorithm to obtain a restored image (for example, third fingerprint information). It should be understood that the second preset AI restoration algorithm is an algorithm used by the second preset AI restoration model to perform image restoration. Herein, **1105** shown in FIG. **11** corresponds to S**506**.

After **1105** shown in FIG. **11**, the mobile phone may perform **1106** shown in FIG. **11** of performing fingerprint recognition 3 on a restored image (for example, the third fingerprint information) by using a fingerprint recognition algorithm to obtain a fingerprint recognition feedback (for example, a fingerprint recognition result). The fingerprint recognition feedback may be a fingerprint recognition failure or success. Herein, **1106** shown in FIG. **11** corresponds to S**507**.

As can be seen from the above description, the mobile phone performs the screen protector recognition **1102** to perform image fusion on the raw fingerprint data (for example, the raw data) and the preset fingerprint data (for example, the base data). In this way, the noisy image data in the raw fingerprint data can be reduced.

In some other embodiments, the mobile phone may also normalize the fusion image to increase brightness uniformity of all pixels in the fusion image. For example, S**503***b* may include S1 and S2.

In some other embodiments, after image fusion is performed on the raw fingerprint data (for example, the raw data) and the preset fingerprint data (for example, the base data), only part of the noisy image data can be removed from the raw fingerprint data, and some Gaussian noise cannot be removed by image fusion. In view of this, in the embodiment of the present application, as shown in FIG. **12**, the mobile phone may perform normalization on the fusion image, and then perform Gaussian filtering on the normalized image. Specifically, S**503***b* may include S-a, S-b, and S-c.

S-a: The mobile phone removes noisy image data from the raw fingerprint data (for example, the raw data) by using the preset fingerprint data (for example, the base data) to obtain a second fusion image.

For detailed description of S-a, refer to the introduction to S1 in the foregoing embodiment. Details are not described herein again in this embodiment of the present application.

S-b: The mobile phone performs normalization on the second fusion image to obtain a third fusion image.

For detailed description of S-b, refer to the introduction to S2 in the foregoing embodiment. Details are not described herein again in this embodiment of the present application.

S-c: The mobile phone performs Gaussian filtering on the third fusion image to obtain the first fusion image.

The mobile phone may perform S-c to filter out the Gaussian noise in the third fusion image to obtain the first fusion image. In the embodiment of the present application, for a method in which the mobile phone performs Gaussian filtering on a fusion image (for example, the third fusion image), refer to the related description in the conventional technology. Details are not described herein in the embodiment of the present application.

In some other embodiments, to further increase the success rate of fingerprint recognition, as shown in FIG. **13**, **1103** may further include that the mobile phone performs normalization on the preprocessed image (for example, the first fingerprint information). The normalization of the first fingerprint information can improve brightness uniformity of all pixels in the fingerprint image in the first fingerprint information. Then, as shown in FIG. **13**, the mobile phone may run the first preset AI restoration model with the normalized first fingerprint information used as input to obtain a restored image 1. Finally, as shown in FIG. **13**, the mobile phone may perform image fusion on the normalized first fingerprint information and the restored image 1 to obtain the second fingerprint image. Image fusion is performed on the normalized first fingerprint information and the restored image 1 to obtain a fingerprint image with a clearer texture and fewer intermittent points. In other words, compared with the restored image 1, the second fingerprint image obtained after fusion has a clearer texture and fewer intermittent points. In this way, the success rate of fingerprint recognition is higher for the second fingerprint image obtained after fusion.

In some other embodiments, to further increase the success rate of fingerprint recognition, as shown in FIG. **14**, **1105** may further include that the mobile phone performs normalization on the preprocessed image (for example, the first fingerprint information). The normalization of the first fingerprint information can improve brightness uniformity of all pixels in the fingerprint image in the first fingerprint information. Then, as shown in FIG. **14**, the mobile phone may run the second preset AI restoration model with the normalized first fingerprint information used as input to obtain a restored image 2. Finally, as shown in FIG. **14**, the mobile phone may perform image fusion on the normalized first fingerprint information and the restored image 2 to obtain a third fingerprint image. Image fusion is performed on the normalized first fingerprint information and the restored image 2 to obtain a fingerprint image with a clearer texture and fewer intermittent points. In other words, compared with the restored image 2, the third fingerprint image obtained after fusion has a clearer texture and fewer intermittent points. In this way, the success rate of fingerprint recognition is higher for the third fingerprint image obtained after fusion.

An embodiment of the present application provides an electronic device, and the electronic device may include: the foregoing touch screen, a memory, and one or more processors. The electronic device may also include a fingerprint sensor. The fingerprint sensor and the touch screen can

provide an in-screen fingerprint function. The touch screen, the fingerprint sensor, and the memory are coupled to the processor. The memory is configured to store computer program code, and the computer program code includes computer instructions. When the processor executes the computer instructions, the electronic device can perform the functions or steps performed by the mobile phone in the foregoing method embodiments. For a structure of the electronic device, refer to the structure of the electronic device **100** in FIG. **3**.

An embodiment of the present application further provides a computer storage medium. The computer storage medium includes computer instructions. When the computer instructions are run on an electronic device, the electronic device is enabled to perform the functions or steps performed by the mobile phone in the foregoing method embodiments.

An embodiment of the present application further provides a computer program product. When the computer program product is run on a computer, the computer is enabled to perform the functions or steps performed by the mobile phone in the foregoing method embodiments.

The foregoing descriptions about implementations allow a person skilled in the art to clearly understand that, for the purpose of convenient and brief description, division of the foregoing functional modules is used only as an example for illustration. In actual application, the foregoing functions can be allocated to different functional modules and implemented according to needs, that is, an inner structure of an apparatus is divided into different functional modules to implement all or some of the functions described above.

In the embodiments provided in the present application, it should be understood that the disclosed apparatus and method may be implemented in another manner. For example, the described apparatus embodiment is only an example. For example, the module or unit division is merely logical function division and may be other division in actual implementation. For example, a plurality of units or components may be combined or integrated into another apparatus, or some features may be ignored or not performed. In addition, the displayed or discussed mutual couplings or direct couplings or communication connections may be implemented by using some interfaces. The indirect couplings or communication connections between the apparatuses or units may be implemented in electronic, mechanical, or other forms.

The units described as separate parts may or may not be physically separate, and parts displayed as units may be one physical unit or a plurality of physical units, that is, may be located in one place, or may be distributed in a plurality of different places. Some or all of the units may be selected based on actual needs to achieve the objectives of the solutions of the embodiments.

In addition, functional units in the embodiments of the present application may be integrated into one processing unit, or each of the units may exist alone physically, or two or more units are integrated into one unit. The integrated unit may be implemented in a form of hardware, or may be implemented in a form of a software functional unit.

When the integrated unit is implemented in the form of a software functional unit and sold or used as an independent product, the integrated unit may be stored in a readable storage medium. Based on such an understanding, the technical solutions in the embodiments of the present application essentially, or the part contributing to the prior art, or all or some of the technical solutions may be implemented in the form of a software product. The software product is stored in a storage medium and includes several instructions for instructing a device (which may be a single-chip microcomputer, a chip or the like) or a processor (processor) to perform all or some of the steps of the methods described in the embodiments of the present application. The foregoing storage medium includes any medium that can store program code, such as a USB flash drive, a removable hard disk, a read-only memory (read-only memory, ROM), a random access memory (random access memory, RAM), a magnetic disk, or an optical disc.

The foregoing content is merely specific implementations of the present application, but is not intended to limit the protection scope of the present application. Any variation or replacement made within the technical scope disclosed in the present application shall fall within the protection scope of the present application. Therefore, the protection scope of the present application shall be subject to the protection scope of the claims.

What is claimed is:

1. A method, comprising:

displaying, by an electronic device, a first interface, the electronic device comprising a touch screen and a fingerprint sensor;

capturing, by the electronic device, first fingerprint information that is input by a user at the first interface;

determining, by the electronic device, that the touch screen is in a first state based on that the first fingerprint information mismatches preset fingerprint information such that the first fingerprint information fails fingerprint recognition, wherein the first state indicates that the touch screen is in a screen protector state, and wherein the determining that the touch screen is in the first state comprises:

obtaining, by the electronic device, raw fingerprint data for the first fingerprint information and obtaining preset fingerprint data;

performing, by the electronic device, feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image; and

running, by the electronic device, a preset AI recognition model with the first fusion image used as input to determine that the touch screen is in the first state, wherein the performing the feature fusion on the raw fingerprint data and the preset fingerprint data to obtain the first fusion image comprises:

removing, by the electronic device, noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image; and

performing, by the electronic device, normalization on the second fusion image to obtain the first fusion image, wherein first brightness uniformity of all pixels in the first fusion image is higher than second brightness uniformity of all pixels in the second fusion image; or performing, by the electronic device, the normalization on the second fusion image to obtain a third fusion image, wherein third brightness uniformity of all pixels in the third fusion image is higher than the second brightness uniformity of all pixels in the second fusion image;

restoring, by the electronic device based on that the touch screen is in the first state, the first fingerprint information by using a first preset artificial intelligence (AI) restoration model to obtain second fingerprint information, wherein an input of the first preset AI restoration model is the first fingerprint information including a first fingerprint image, wherein an output of the first preset AI restoration model is the second fingerprint

information including a second fingerprint image, wherein second quality of the second fingerprint image in the second fingerprint information is higher than first quality of the first fingerprint image in the first fingerprint information,

wherein the preset AI recognition model and the first preset AI restoration model are different types of AI models outputting different types of data, and

wherein the electronic device performs the capturing the first fingerprint information, the determining that the touch screen is in the first state, and the restoring the first fingerprint information while the touch screen of the electronic device is protected by a same protective film;

determining, by the electronic device, that the second fingerprint information matches the preset fingerprint information; and

displaying, by the electronic device, a second interface.

2. The method according to claim **1**, wherein the method further comprises:

before the determining, by the electronic device, that the touch screen is in the first state:

displaying, by the electronic device, a third interface, wherein the third interface comprises prompt information indicating a fingerprint recognition failure.

3. The method according to claim **1**, wherein the method further comprises:

after the determining, by the electronic device, that the touch screen is in the first state,

restoring, by the electronic device based on that the touch screen is in a second state, the first fingerprint information by using a second preset AI restoration model to obtain third fingerprint information, wherein the second state indicates that the touch screen is in a bare screen state, and third quality of a third fingerprint image in the third fingerprint information is higher than the first quality of the first fingerprint image in the first fingerprint information; and

determining, by the electronic device, that the third fingerprint information matches the preset fingerprint information; and

displaying the second interface,

wherein the first preset AI restoration model is different from the second preset AI restoration model.

4. The method according to claim **3**, wherein the restoring, by the electronic device, the first fingerprint information by using the second preset AI restoration model to obtain the third fingerprint information comprises:

running, by the electronic device, the second preset AI restoration model with the first fingerprint information used as input to obtain the third fingerprint information,

wherein the second preset AI restoration model is trained by using a plurality of second groups of fingerprint images as training samples, each second group of the plurality of second groups of fingerprint images comprises a third corresponding fingerprint image and a fourth corresponding fingerprint image, the third corresponding fingerprint image is captured when the touch screen is in the second state, and the fourth corresponding fingerprint image is a pre-configured image obtained after the third fingerprint image is restored.

5. The method according to claim **4**,

wherein the second preset AI restoration model is an FCN model, or

wherein the second preset AI restoration model is a Unet model, or

wherein the second preset AI restoration model is a Garbor filter.

6. The method according to claim **1**, wherein the first interface comprises at least one of:

an interface in which the electronic device is in a lock screen state, a fingerprint payment interface of the electronic device, or a fingerprint unlocking interface for one or more functions of a first application on the electronic device.

7. The method according to claim **1**, wherein the performing, by the electronic device, the feature fusion on the raw fingerprint data and the preset fingerprint data to obtain the first fusion image further comprises:

performing, by the electronic device, Gaussian filtering on the third fusion image to obtain the first fusion image, wherein the first fusion image does not comprise Gaussian noise in the third fusion image.

8. The method according to claim **1**, wherein the preset AI recognition model comprises a convolutional neural network (CNN) model or a residual neural network (ResNet) model.

9. The method according to claim **1**, wherein the restoring, by the electronic device, the first fingerprint information by using the first preset AI restoration model to obtain the second fingerprint information comprises:

running, by the electronic device, the first preset AI restoration model with the first fingerprint information used as input to obtain the second fingerprint information,

wherein the first preset AI restoration model is trained by using a plurality of first groups of fingerprint images as training samples, each first group of the plurality of first groups of fingerprint images comprises a first corresponding fingerprint image and a second corresponding fingerprint image, the first corresponding fingerprint image is captured when the touch screen is in the first state, and the second corresponding fingerprint image is a pre-configured image obtained after the first fingerprint image is restored.

10. The method according to claim **9**,

wherein the first preset AI restoration model is a fully convolutional network (FCN) model, or

wherein the first preset AI restoration model is a Unet model, or

wherein the first preset AI restoration model is a Garbor filter.

11. The method of claim **1**,

wherein the preset AI recognition is trained using a plurality of screen-protector training samples and a plurality of bare-screen training samples, wherein each screen-protector training sample includes a corresponding fusion image obtained from a corresponding fingerprint image captured when the touch screen is in the screen protector state, and each bare-screen training sample includes a corresponding fusion image obtained from a corresponding fingerprint image captured when the touch screen is in a bare screen state,

the plurality of screen-protector training samples including a first set of screen-protector training samples corresponding to a high temperature scenario, a second set of screen-protector training samples corresponding to a low temperature scenario, a third set of screen-protector training samples corresponding to a high ambient light brightness scenario, a fourth set of screen-protector training samples corresponding to a

low ambient light brightness scenario, a fifth set of screen-protector training samples corresponding to an indoor scenario, a sixth set of screen-protector training samples corresponding to an outdoor scenario, a seventh set of screen-protector training samples corresponding to a day scenario, and an eighth set of screen-protector training samples corresponding to a night scenario, and

wherein the second fingerprint image in the second fingerprint information has higher sharpness and completeness than the first fingerprint image in the first fingerprint information.

12. An electronic device, comprising:

a touch screen;

a fingerprint sensor;

a memory; and

one or more processors, wherein the touch screen, the memory, and the fingerprint sensor are coupled to the one or more processors, the memory stores computer program code, the computer program code comprises computer instructions, and when the computer instructions are executed by the one or more processors, the electronic device is enabled to perform operations including:

displaying a first interface;

capturing first fingerprint information that is input by a user at the first interface;

determining that the touch screen is in a first state based on that the first fingerprint information mismatches preset fingerprint information such that the first fingerprint information fails fingerprint recognition, wherein the first state indicates that the touch screen is in a screen protector state, and wherein the determining that the touch screen is in the first state comprises:

obtaining raw fingerprint data for the first fingerprint information and obtaining preset fingerprint data;

performing feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image; and

running a preset AI recognition model with the first fusion image used as input to determine that the touch screen is in the first state, wherein the performing the feature fusion on the raw fingerprint data and the preset fingerprint data to obtain the first fusion image comprises:

removing noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image; and

performing normalization on the second fusion image to obtain the first fusion image, wherein first brightness uniformity of all pixels in the first fusion image is higher than second brightness uniformity of all pixels in the second fusion image; or performing, by the electronic device, the normalization on the second fusion image to obtain a third fusion image, wherein third brightness uniformity of all pixels in the third fusion image is higher than the second brightness uniformity of all pixels in the second fusion image;

restoring, based on that the touch screen is in the first state, the first fingerprint information by using a first preset artificial intelligence (AI) restoration model to obtain second fingerprint information, wherein an input of the first preset AI restoration model is the first fingerprint information including a first fingerprint image, wherein an output of the first preset AI restoration model is the second fingerprint information including a second fingerprint image, wherein second quality of the second fingerprint image in the second fingerprint information is higher than first quality of the first fingerprint image in the first fingerprint information,

wherein the preset AI recognition model and the first preset AI restoration model are different types of AI models outputting different types of data, and

wherein the electronic device performs the capturing the first fingerprint information, the determining that the touch screen is in the first state, and the restoring the first fingerprint information while the touch screen of the electronic device is protected by a same protective film;

determining that the second fingerprint information matches the preset fingerprint information; and

displaying a second interface.

13. The electronic device according to claim **12**, the operations further comprising:

before the determining that the touch screen is in the first state:

displaying a third interface, wherein the third interface comprises prompt information indicating a fingerprint recognition failure.

14. The electronic device according to claim **12**, the operations further comprising:

after the determining that the touch screen is in the first state,

restoring, based on that the touch screen is in a second state, the first fingerprint information by using a second preset AI restoration model to obtain third fingerprint information, wherein the second state indicates that the touch screen is in a bare screen state, and third quality of a third fingerprint image in the third fingerprint information is higher than the first quality of the first fingerprint image in the first fingerprint information; and

determining that the third fingerprint information matches the preset fingerprint information; and

displaying the second interface,

wherein the first preset AI restoration model is different from the second preset AI restoration model.

15. The electronic device according to claim **12**, wherein the first interface comprises at least one of:

an interface in which the electronic device is in a lock screen state, a fingerprint payment interface of the electronic device, or a fingerprint unlocking interface for one or more functions of a first application on the electronic device.

16. The electronic device according to claim **12**, wherein the performing the feature fusion on the raw fingerprint data and the preset fingerprint data to obtain the first fusion image further comprises:

performing Gaussian filtering on the third fusion image to obtain the first fusion image, wherein the first fusion image does not comprise Gaussian noise in the third fusion image.

17. A non-transitory computer-readable storage medium, comprising computer instructions, wherein when the computer instructions are run on an electronic device, the electronic device is enabled to perform operations including:

displaying a first interface, the electronic device comprising a touch screen and a fingerprint sensor;

capturing first fingerprint information that is input by a user at the first interface;

determining that the touch screen is in a first state based on that the first fingerprint information mismatches preset fingerprint information such that the first fingerprint information fails fingerprint recognition, wherein the first state indicates that the touch screen is in a screen protector state, and wherein the determining that the touch screen is in the first state comprises:

obtaining raw fingerprint data for the first fingerprint information and obtaining preset fingerprint data;

performing feature fusion on the raw fingerprint data and the preset fingerprint data to obtain a first fusion image; and

running a preset AI recognition model with the first fusion image used as input to determine that the touch screen is in the first state, wherein the performing the feature fusion on the raw fingerprint data and the preset fingerprint data to obtain the first fusion image comprises:

removing noisy image data from the raw fingerprint data by using the preset fingerprint data to obtain a second fusion image; and

performing normalization on the second fusion image to obtain the first fusion image, wherein first brightness uniformity of all pixels in the first fusion image is higher than second brightness uniformity of all pixels in the second fusion image; or performing, by the electronic device, the normalization on the second fusion image to obtain a third fusion image, wherein third brightness uniformity of all pixels in the third fusion image is higher than the second brightness uniformity of all pixels in the second fusion image;

restoring, based on that the touch screen is in the first state, the first fingerprint information by using a first preset artificial intelligence (AI) restoration model to obtain second fingerprint information, wherein an input of the first preset AI restoration model is the first fingerprint information including a first fingerprint image, wherein an output of the first preset AI restoration model is the second fingerprint information including a second fingerprint image, wherein second quality of the second fingerprint image in the second fingerprint information is higher than first quality of the first fingerprint image in the first fingerprint information,

wherein the preset AI recognition model and the first preset AI restoration model are different types of AI models outputting different types of data, and

wherein the electronic device performs the capturing the first fingerprint information, the determining that the touch screen is in the first state, and the restoring the first fingerprint information while the touch screen of the electronic device is protected by a same protective film;

determining that the second fingerprint information matches preset fingerprint information; and

displaying a second interface.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 12,175,791 B2
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DATED : December 24, 2024
INVENTOR(S) : Di et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

Item (30), in Column 1, under "Foreign Application Priority Data", Line 1, delete "20110363678.6" and insert -- 202110363678.6 --.

Signed and Sealed this
Eleventh Day of February, 2025

Coke Morgan Stewart

Coke Morgan Stewart
Acting Director of the United States Patent and Trademark Office