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(54) **METHOD FOR CONTROLLING STRUCTURED LIGHT PROJECTOR, DEPTH CAMERA AND ELECTRONIC DEVICE**

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(52) **U.S. Cl.**
CPC ***H04N 13/254*** (2018.05); ***G06T 7/521*** (2017.01); ***H04N 5/2253*** (2013.01);
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CPC H04N 13/254; H04N 13/296; H04N 5/23219; H04N 5/2253; H04N 5/2256;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,466,360 B1 * 11/2019 Bardagjy H04N 5/2256
10,567,641 B1 * 2/2020 Rueckner H04N 5/2257
(Continued)

FOREIGN PATENT DOCUMENTS

CN 103870824 A 6/2014
CN 104616438 A 5/2015
(Continued)

OTHER PUBLICATIONS

International Search Report in the international application No. PCT/CN2019/075380, dated Apr. 26, 2019.
(Continued)

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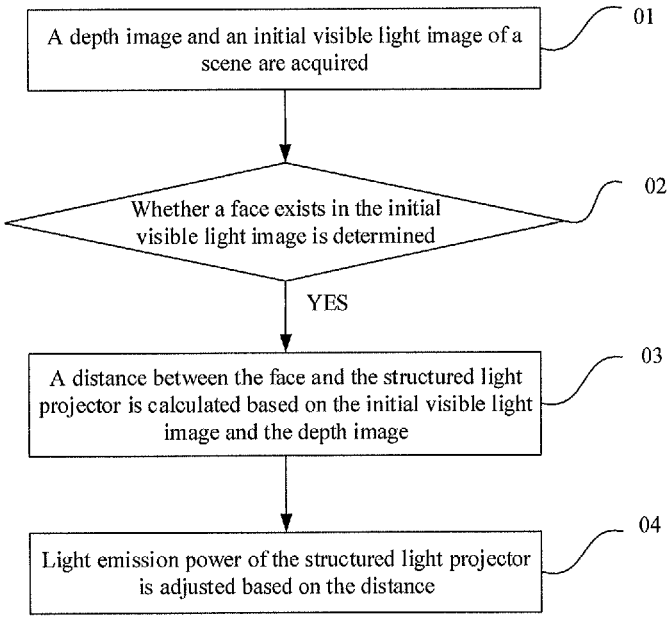
(57) **ABSTRACT**

A method for controlling a structured light projector is provided. The method includes that: a depth image and an initial visible light image of a scene are acquired; whether a face exists in the initial visible light image is determined; responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector is calculated based on the initial visible light image and the depth image; and light emission power of the structured light projector is adjusted based on the distance. A depth camera and an electronic device are also provided.

20 Claims, 11 Drawing Sheets



(51) **Int. Cl.**
H04N 13/296 (2018.01)
H04N 5/232 (2006.01)
H04N 5/225 (2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/23219*** (2013.01); ***H04N 13/296*** (2018.05); *G06T 2207/10028* (2013.01); *G06T 2207/10152* (2013.01); *G06T 2207/30201* (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0177929	A1*	7/2010	Kurtz	H04N 9/3161 382/103
2018/0217234	A1*	8/2018	Skowronek	G01S 17/89
2018/0227567	A1*	8/2018	Chao	G01S 17/46
2019/0051005	A1*	2/2019	Chang	H04N 13/268
2019/0142524	A1*	5/2019	Hladio	A61B 90/361 600/249
2019/0302581	A1*	10/2019	Zhao	H04N 5/74
2019/0377856	A1*	12/2019	Zhang	G06F 21/32
2019/0379880	A1*	12/2019	Zhang	H04N 13/254

FOREIGN PATENT DOCUMENTS

CN	106331517	A	1/2017
CN	107944422	A	4/2018
CN	108281880	A	7/2018
CN	108376251	A	8/2018
CN	108376252	A	8/2018
CN	108508620	A	9/2018
CN	108509867	A	9/2018
CN	108523819	A	9/2018
CN	108564041	A	9/2018
CN	108615012	A	10/2018
CN	109194869	A	1/2019

OTHER PUBLICATIONS

Written Opinion of the International Search Authority in the international application No. PCT/CN2019/076380, dated Apr. 28, 2019.
First Office Action of CN application No. 201811180890.3, dated May 22, 2019.
European Search Report in corresponding European application No. 19186238.2, dated Jan. 27, 2020.
Second Office Action in corresponding Chinese application No. 201811180890.3, dated Dec. 4, 2019.
Third Office Action of Chinese application No. 201811180890.3, dated May 20, 2020.
Notice of Rejection of the Chinese application No. 201811180890.3, dated Jul. 15, 2020.

* cited by examiner

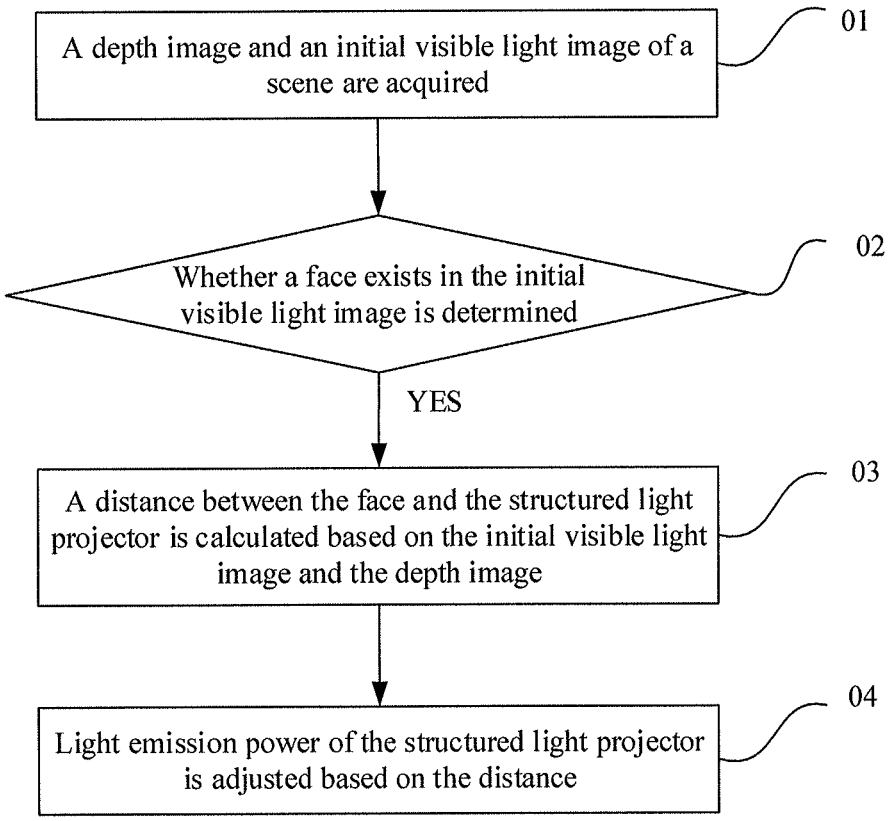
A depth image and an initial visible light image of a scene are acquired
01
Whether a face exists in the initial visible light image is determined
02
YES
A distance between the face and the structured light projector is calculated based on the initial visible light image and the depth image
03
Light emission power of the structured light projector is adjusted based on the distance
04

FIG. 1

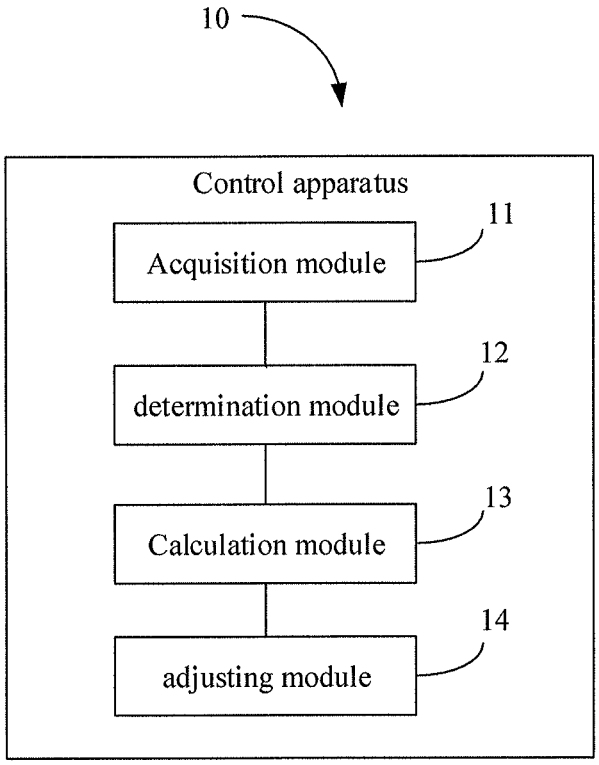
10
Control apparatus
Acquisition module
11
determination module
12
Calculation module
13
adjusting module
14

FIG. 2

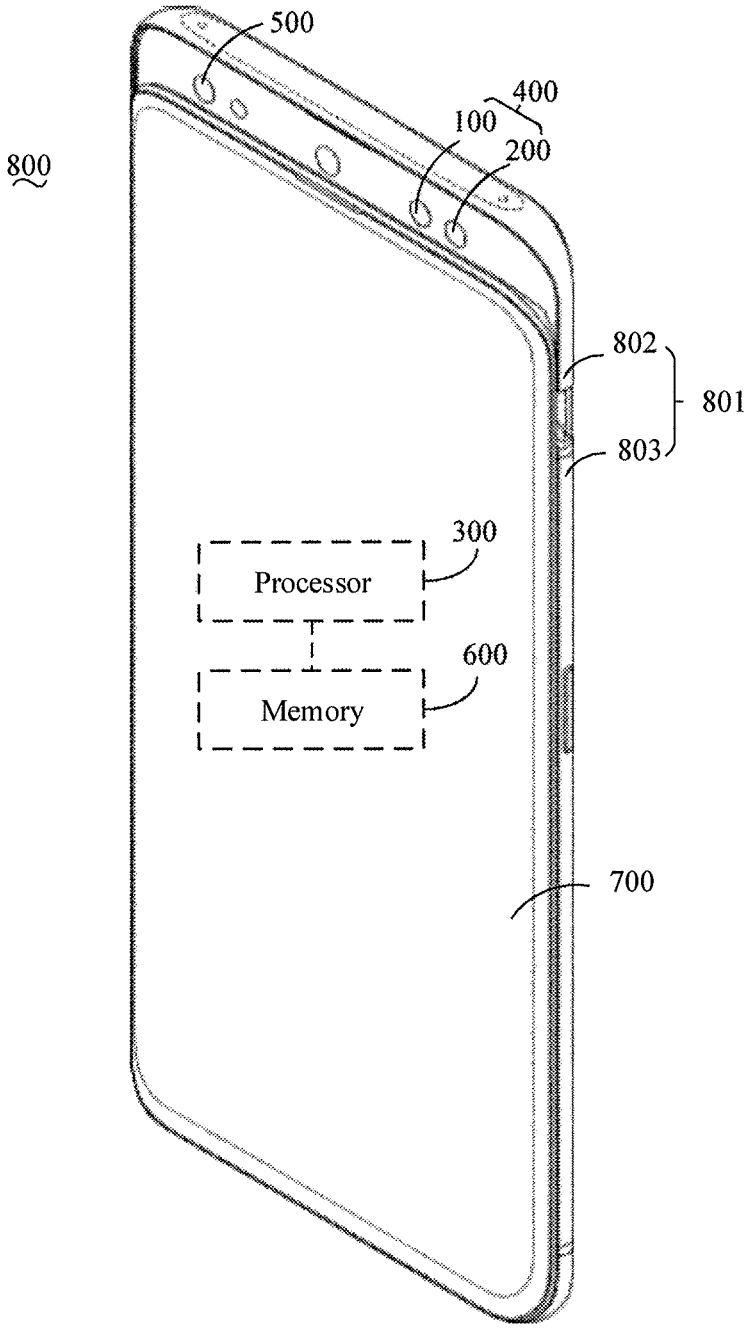

FIG. 3

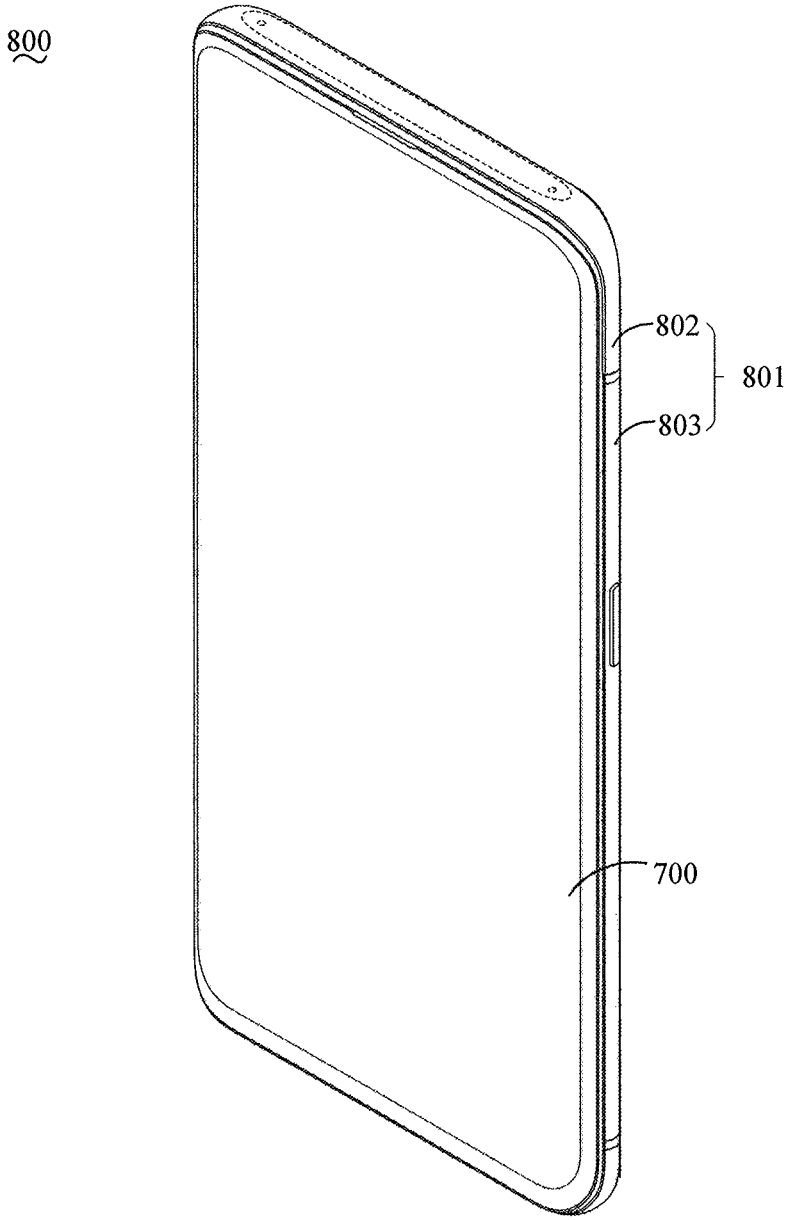

FIG. 4

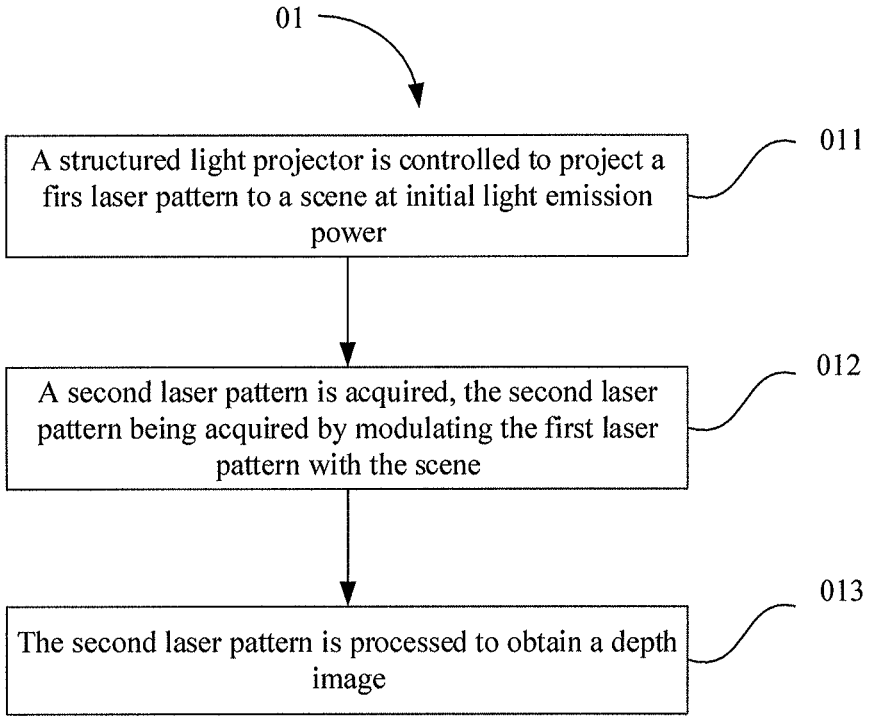
01
A structured light projector is controlled to project a firs laser pattern to a scene at initial light emission power
011
A second laser pattern is acquired, the second laser pattern being acquired by modulating the first laser pattern with the scene
012
The second laser pattern is processed to obtain a depth image
013

FIG. 5

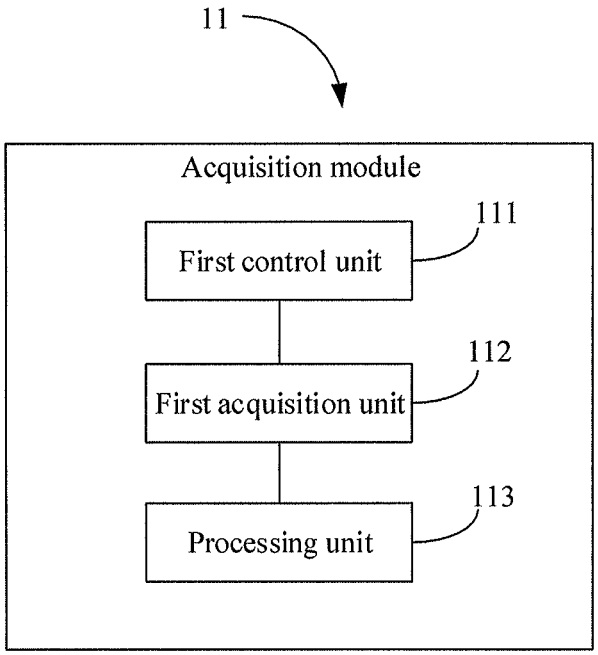
11
Acquisition module
First control unit
111
First acquisition unit
112
Processing unit
113

FIG. 6

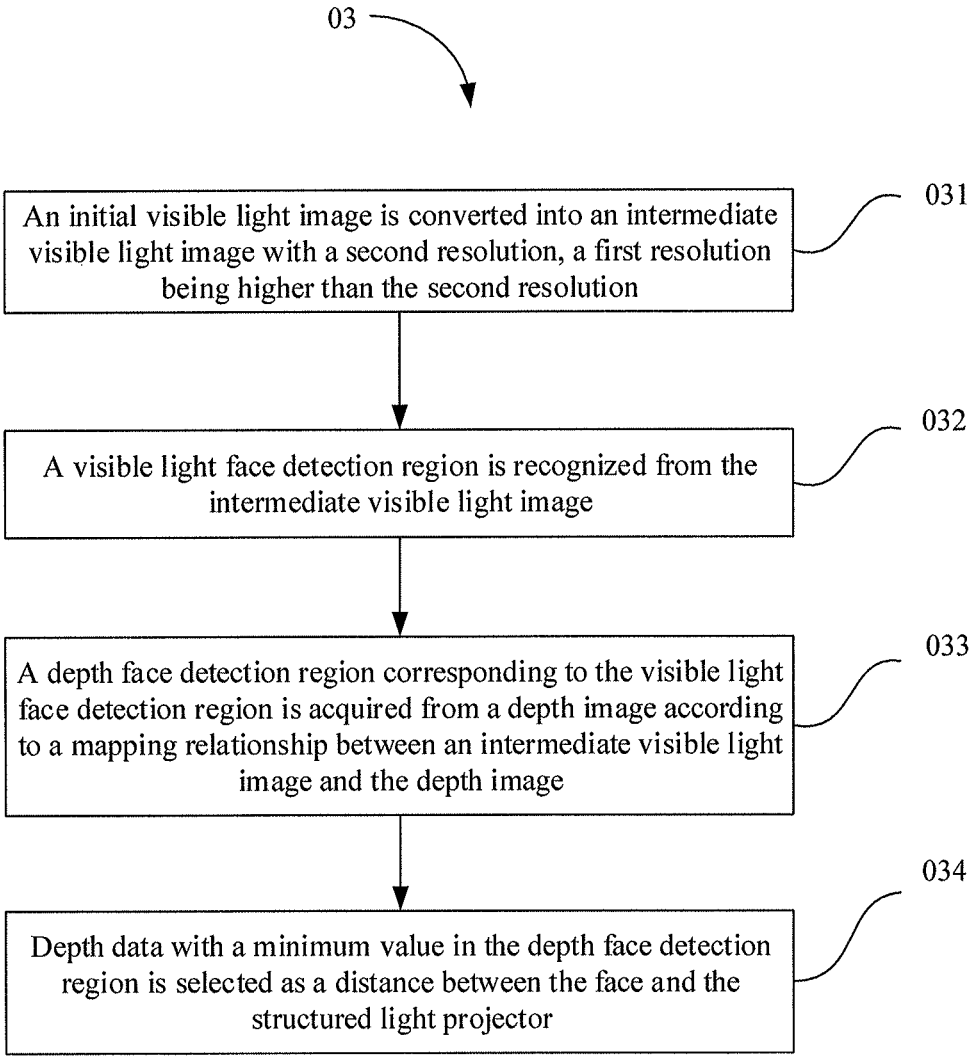
03
An initial visible light image is converted into an intermediate visible light image with a second resolution, a first resolution being higher than the second resolution
031
A visible light face detection region is recognized from the intermediate visible light image
032
A depth face detection region corresponding to the visible light face detection region is acquired from a depth image according to a mapping relationship between an intermediate visible light image and the depth image
033
Depth data with a minimum value in the depth face detection region is selected as a distance between the face and the structured light projector
034

FIG. 7

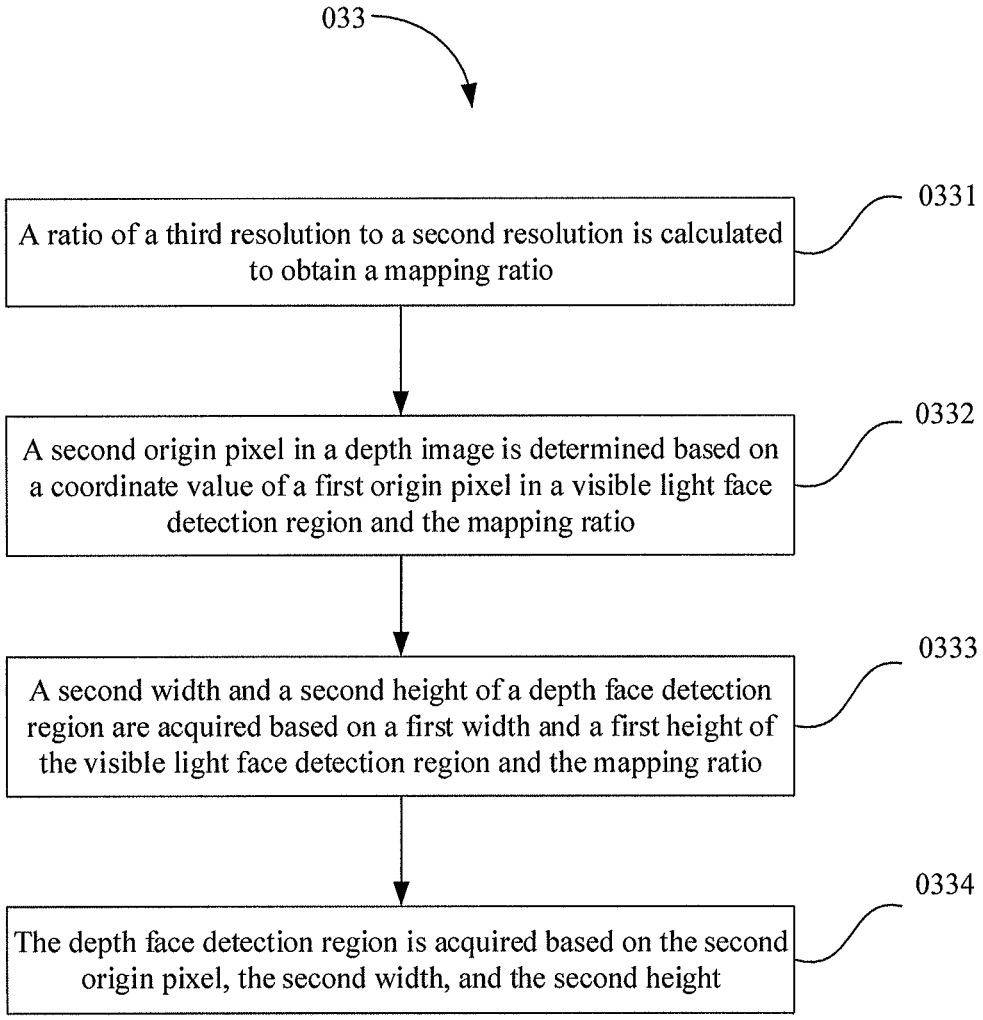
033
A ratio of a third resolution to a second resolution is calculated to obtain a mapping ratio
0331
A second origin pixel in a depth image is determined based on a coordinate value of a first origin pixel in a visible light face detection region and the mapping ratio
0332
A second width and a second height of a depth face detection region are acquired based on a first width and a first height of the visible light face detection region and the mapping ratio
0333
The depth face detection region is acquired based on the second origin pixel, the second width, and the second height
0334

FIG. 8

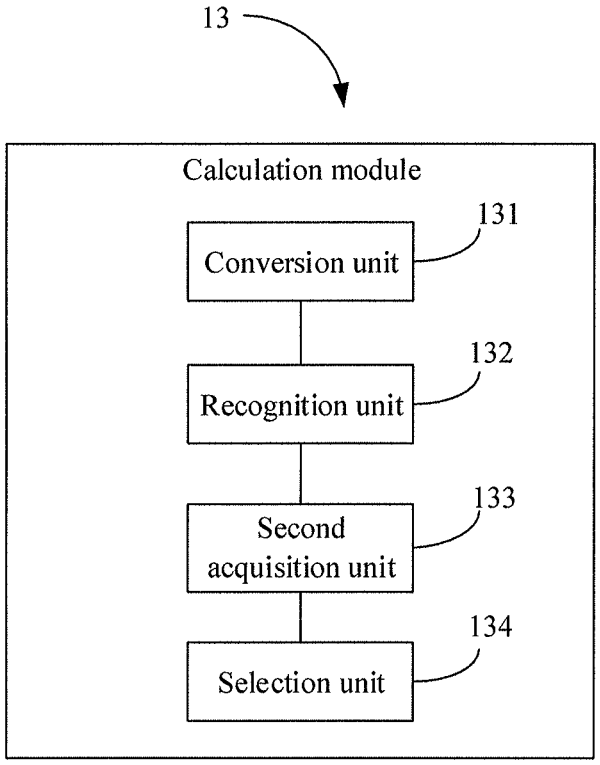
13
Calculation module
Conversion unit
131
Recognition unit
132
Second acquisition unit
133
Selection unit
134

FIG. 9

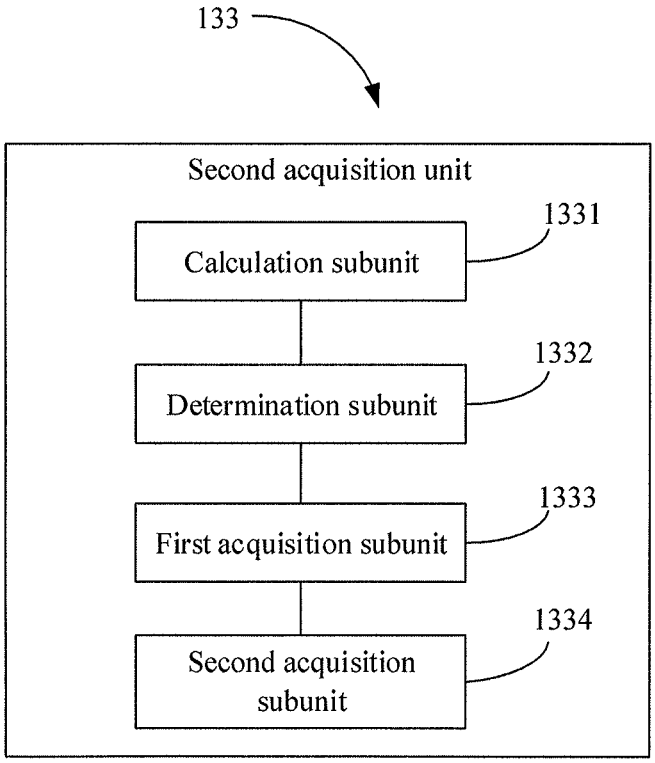
133
Second acquisition unit
Calculation subunit
1331
Determination subunit
1332
First acquisition subunit
1333
Second acquisition subunit
1334

FIG. 10

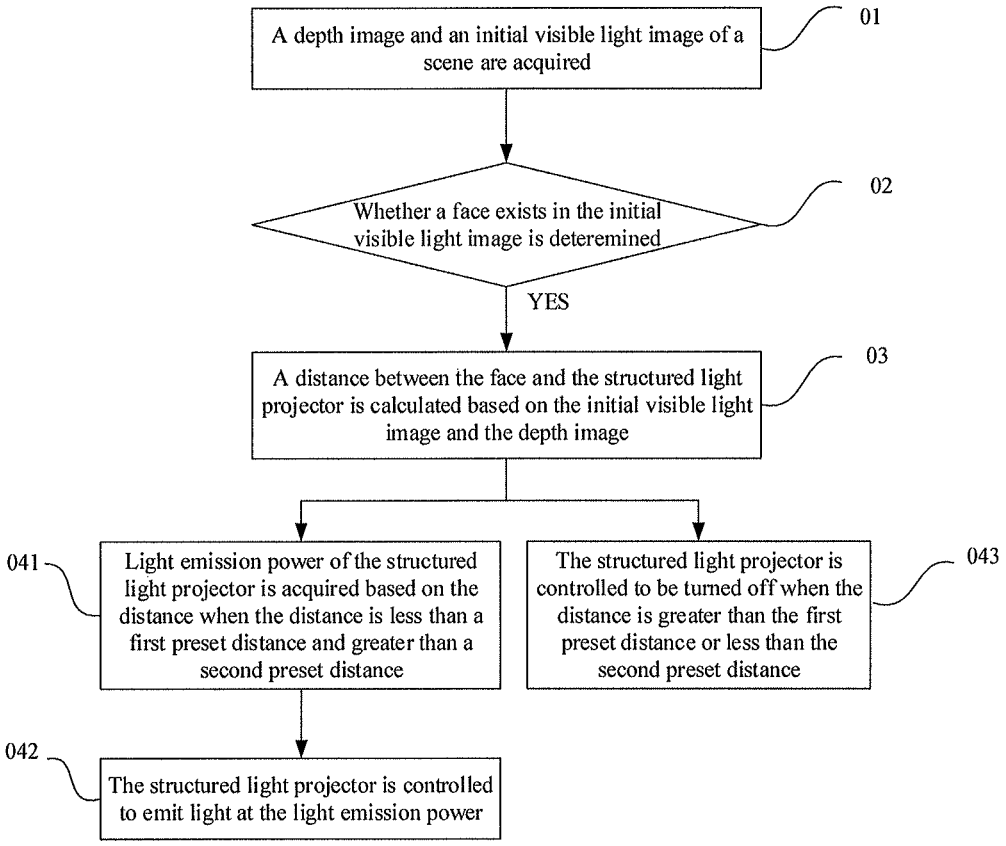
A depth image and an initial visible light image of a scene are acquired
01
Whether a face exists in the initial visible light image is deteremined
02
YES
A distance between the face and the structured light projector is calculated based on the initial visible light image and the depth image
03
041
Light emission power of the structured light projector is acquired based on the distance when the distance is less than a first preset distance and greater than a second preset distance
The structured light projector is controlled to be turned off when the distance is greater than the first preset distance or less than the second preset distance
043
042
The structured light projector is controlled to emit light at the light emission power

FIG. 11

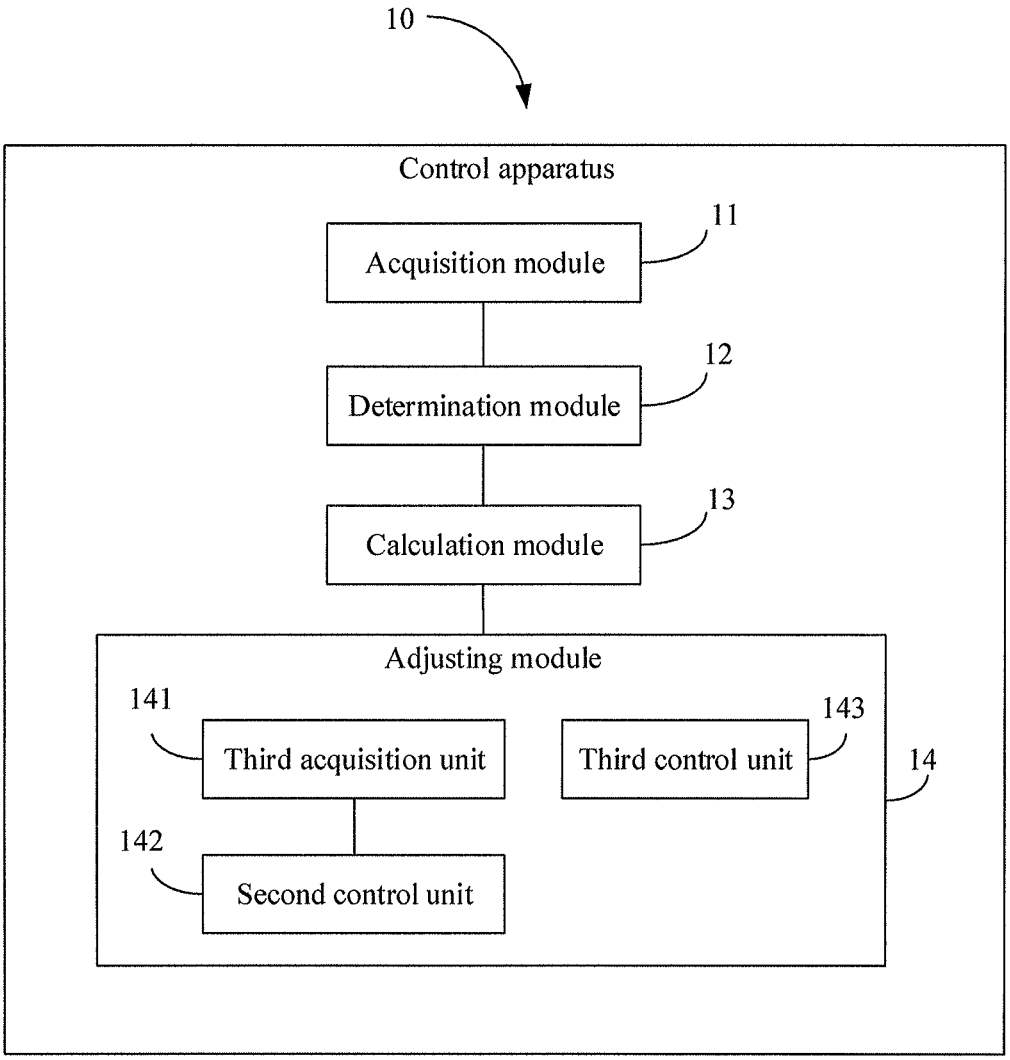
10
Control apparatus
Acquisition module
11
Determination module
12
Calculation module
13
Adjusting module
141
Third acquisition unit
143
Third control unit
14
142
Second control unit

FIG. 12

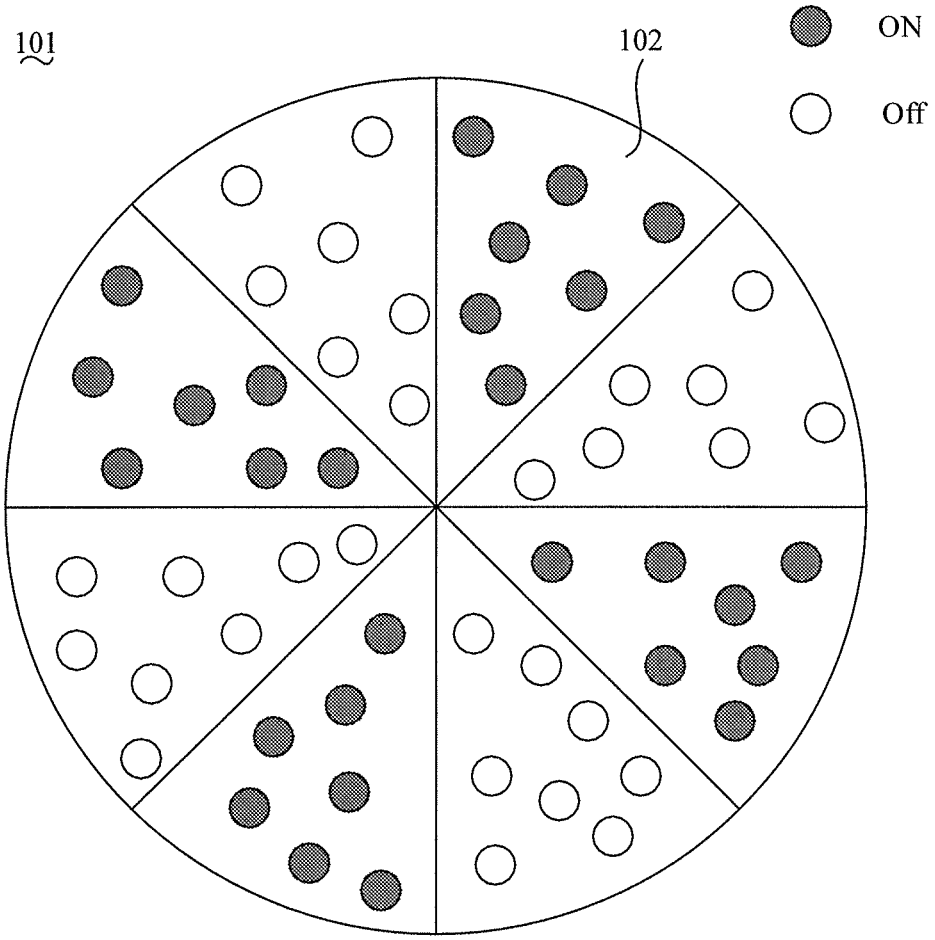

FIG. 13

METHOD FOR CONTROLLING STRUCTURED LIGHT PROJECTOR, DEPTH CAMERA AND ELECTRONIC DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to Chinese Patent Application No. 201811180890.3, entitled "CONTROL METHOD, CONTROL APPARATUS, DEPTH CAMERA AND ELECTRONIC DEVICE", filed on Oct. 9, 2018, the disclosure of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to the technical field of three-dimensional imaging, and particularly to a method for controlling a structured light projector, a depth camera and an electronic device.

BACKGROUND

A structured light projector can project laser with predetermined pattern information. The structured light projector projects laser onto a target user in a space, then an image acquisition device acquires a laser pattern obtained by reflecting the laser pattern projected by the structured light projector with the target user, and finally the laser pattern acquired by the image acquisition device is further processed to obtain a depth image of the target user.

SUMMARY

The aspects of the present disclosure provide a method for controlling a structured light projector, a depth camera and an electronic device.

A first aspect of the disclosure provides a method for controlling a structured light projector, which includes that: a depth image and an initial visible light image of a scene are acquired; whether a face exists in the initial visible light image is determined; responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector is calculated based on the initial visible light image and the depth image; and light emission power of the structured light projector is adjusted based on the distance.

A second aspect of the disclosure provides a depth camera, which includes a structured light projector and a processor. The processor may be configured to acquire a depth image and an initial visible light image of a scene, determine whether a face exists in the initial visible light image, calculate, responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector based on the initial visible light image and the depth image, and adjust light emission power of the structured light projector based on the distance.

A third aspect of the disclosure provides an electronic device, which includes a shell and a depth camera. The depth camera may be arranged on the shell. The depth camera may include a structured light projector and a processor. The processor may be configured to acquire a depth image and an initial visible light image of a scene, determine whether a face exists in the initial visible light image, calculate, responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector based on the initial visible light image and the depth image, and adjust light emission power of the structured light projector based on the distance.

BRIEF DESCRIPTION OF DRAWINGS

The abovementioned and/or additional aspects and advantages of the present disclosure will become apparent and easy to understand from the descriptions made to the embodiments below in combination with the drawings.

FIG. **1** illustrates a flowchart of a control method according to some embodiments of the present disclosure.

FIG. **2** illustrates a module schematic diagram of a control apparatus according to some embodiments of the present disclosure.

FIG. **3** and FIG. **4** illustrate structure diagrams of an electronic device according to some embodiments of the present disclosure.

FIG. **5** illustrates a flowchart of a control method according to some embodiments of the present disclosure.

FIG. **6** illustrates a schematic diagram of an acquisition module of a control apparatus according to some embodiments of the present disclosure.

FIG. **7** illustrates a flowchart of a control method according to some embodiments of the present disclosure.

FIG. **8** illustrates a flowchart of a control method according to some embodiments of the present disclosure.

FIG. **9** illustrates a module schematic diagram of a calculation module of a control apparatus according to some embodiments of the present disclosure.

FIG. **10** illustrates a module schematic diagram of a second acquisition unit of a control apparatus according to some embodiments of the present disclosure.

FIG. **11** illustrates a flowchart of a control method according to some embodiments of the present disclosure.

FIG. **12** illustrates a module schematic diagram of a control apparatus according to some embodiments of the present disclosure.

FIG. **13** illustrates a schematic diagram of light source partitions of a structured light projector according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

The embodiments of the present disclosure will be described below in detail. Examples of the embodiments are illustrated in the drawings and the same or similar reference signs always represent the same or similar components or components with the same or similar functions. The embodiments described below with reference to the drawings are exemplary and intended to explain the present disclosure and do not mean to improperly limit to the present disclosure.

In the related art, the laser emitted by the structured light projector is usually infrared laser, and thus, when the energy of the infrared laser is too high, it is easy to cause damage to eyes of the user.

As illustrated in FIG. **1** and FIG. **3**, the present disclosure provides a method for controlling a structured light projector **100**. The method includes the following operations illustrated in blocks of FIG. **1**.

At block **01**, a depth image and an initial visible light image of a scene are acquired.

At block **02**, whether a face exists in the initial visible light image is determined.

At block **03**, responsive to determining that the face exists in the initial visible light image, a distance between the face

and the structured light projector **100** is calculated based on the initial visible light image and the depth image.

At block **04**, light emission power of the structured light projector **100** is adjusted based on the distance.

As illustrated in FIG. **2** and FIG. **3**, the present disclosure also provides an apparatus **10** for controlling the structured light projector **100**. The control method according to the embodiments of the present disclosure may be implemented by the control apparatus **10** of the embodiments of the present disclosure. As illustrated in FIG. **2**, the control apparatus **10** includes an acquisition module **11**, a determination module **12**, a calculation module **13** and an adjusting module **14**. Block **01** may be implemented by the acquisition module **11**. Block **02** may be implemented by the determination module **12**. Block **03** may be implemented by the calculation module **13**. Block **04** may be implemented by the adjusting module **14**.

That is, the acquisition module **11** may be configured to acquire the depth image and the initial visible light image of the scene. The determination module **12** may be configured to determine whether the face exists in the initial visible light image. The calculation module **13** may be configured to, respective to determining that the face exists in the initial visible light image, calculate a distance between the face and the structured light projector **100** based on the initial visible light image and the depth image. The adjusting module **14** may be configured to adjust the light emission power of the structured light projector **100** based on the distance.

As illustrated in FIG. **3**, the present disclosure also provides a depth camera **400**. The depth camera **400** includes the structured light projector **100**, a structured light camera **200** and a processor **300**. All of block **01**, block **02**, block **03** and block **04** may be implemented by the processor **300**. That is, the processor **300** may be configured to acquire the depth image and an initial visible light image of a scene, determine whether the face exists in the initial visible light image, calculate, responsive to determining that the face exists in the initial visible light image, the distance between the face and the structured light projector **100** based on the initial visible light image and the depth image, and adjust the light emission power of the structured light projector **100** based on the distance.

As illustrated in FIG. **3** and FIG. **4**, the present disclosure also provides an electronic device **800**. The electronic device **800** includes a shell **801** and the depth camera **400**. The depth camera **400** is arranged on the shell **801**. The processor **300** of the depth camera **400** may be an independent processor **300** integrated in the depth camera **400**. Or, the depth camera **400** may also share a processor with the electronic device **800**, and in such case, the processor is independent of the depth camera **400** and integrated in the electronic device **800**. In a specific embodiment of the present disclosure, the depth camera **400** shares a processor with the electronic device **800**. Herein, the electronic device **800** may be a mobile phone, a tablet computer, a game console, a smart watch, a smart band, a head-mounted display device, an unmanned aerial vehicle and the like. Descriptions are made in the embodiments of the present disclosure with the condition that the electronic device **800** is a mobile phone as an example. It can be understood that a specific form of the electronic device **800** is not limited to a mobile phone.

The shell **801** is a carrier on which functional components of the electronic device are mounted. The shell **801** may provide protection such as dust prevention, drop prevention and waterproofing for the functional components. The functional components may include a display screen **700**, a visible light camera **500**, a receiver and the like. In the embodiments of the present disclosure, the shell **801** includes a main body **803** and a movable bracket **802**. The movable bracket **802** may be driven by a driving device to move relative to the main body **803**. For example, the movable bracket **802** may slide relative to the main body **803** to slide into the main body **803** (as shown in FIG. **4**) or slide out of the main body **803** (as shown in FIG. **3**). Part of functional components (for example, the display screen **700**) may be mounted on the main body **803**. Another part of functional components (for example, the depth camera **400**, the visible light camera **500** and the receiver) may be mounted on the movable bracket **802**. The movable bracket **802** may move to drive the another part of functional components to retract into the main body **803** or extend out of the main body **803**. Of course, FIG. **3** and FIG. **4** only illustrate examples of specific forms of the shell **801** and should not be understood as limits to the shell **801** of the present disclosure.

The depth camera **400** is mounted on the shell **801**. Specifically, an acquisition window may be formed in the shell **801**, and the depth camera **400** is aligned with the acquisition window to enable the depth camera **400** to acquire depth information. In a specific embodiment of the present disclosure, the depth camera **400** is mounted on the movable bracket **802**. When a user is required to use the depth camera **400**, the movable bracket **802** may be triggered to slide out of the main body **803** to drive the depth camera **400** to extend out of the main body **803**. When the depth camera **400** is not required to be used, the movable bracket **802** may be triggered to slide into the main body **803** to drive the depth camera **400** to retract into the main body **803**.

In the method for controlling the structured light projector **100** according to the embodiments of the present disclosure, the depth image may be captured by the depth camera **400**, and the initial visible light image may be captured by the visible light camera **500** (for example, a Red, Green and Blue (RGB) camera). The depth image indicates the depth information of each object in the scene, and the visible light image indicates color information of each object in the scene.

The processor **300**, after controlling the depth camera **400** to capture the depth image and controlling the visible light camera **500** to capture the initial visible light image, further recognizes whether the face exists in the initial visible light image according to a face recognition algorithm. For example, the processor **300** may recognize whether the face exists in the initial visible light image by use of a Haar feature or a Local Binary Pattern (LBP) feature.

Specifically, the Haar feature is a rectangular feature including a white region and a black region, and may reflect a gray-scale change condition of the image. The Haar feature includes multiple rectangular feature templates, and sizes and positions of the rectangular feature templates may be changed to exhaust numerous rectangular features in a child window of the image. In a face detection process, a frame of the initial visible light image is divided into multiple child windows at first, and proper rectangular features are searched to describe each child window, thereby representing feature information of each child window by use of the rectangular features. Herein, there are multiple rectangular features configured to describe the child window. After the feature information of each child window is described by use of multiple rectangular features, a pre-trained face classifier is adopted to detect each child window according to the rectangular features corresponding to each child

window to determine whether the child window is in a face region part. Finally, the child window determined to belong to the face region part is classified to obtain a face region in the initial visible light image. In such a manner, if all child windows in the initial visible light image are classified into a non-face region part by the trained face classifier, the face region may not be acquired in the initial visible light image, and thus it is indicated that the face does not exist in the initial visible light image.

The LBP feature is an operator configured to describe a local texture feature of the image, and has remarkable advantages of rotational invariance and gray-scale invariance. The LBP feature is defined as follows: in a size adjustable window, a center pixel of the window is taken as a threshold, gray-scale values of multiple adjacent pixels are compared with a gray-scale value of the center pixel; if the gray-scale value of a surrounding pixel is larger than the gray-scale value of the center pixel, a position corresponding to the pixel is marked to be 1 and on the contrary, if the gray-scale value of a surrounding pixel is less than or equal to the gray-scale value of the center pixel, a position corresponding to the pixel is marked to be 0. In such a manner, an LBP value of the center pixel of each window may be adopted to reflect texture information of a region where the window is located. In a face recognition process, an LBP value of each pixel in the initial visible light image is calculated at first. Since each pixel corresponds to a window when serving as a center pixel, a statistical histogram of an LBP value corresponding to each window is calculated immediately when the LBP value of each pixel is calculated. Then, the statistical histograms of multiple windows are connected into a feature vector to obtain an LBP texture feature vector of the initial visible light image. Finally, whether the face exists in the initial visible light image may be determined by use of a support vector machine (SVM) according to the LBP texture feature vector of the initial visible light image.

When the depth camera **400** is a front camera or a rear camera, if the face exists in the initial visible light image, the processor **300** calculates the distance between the face and the structured light projector **100** based on the initial visible light image and the depth image and adjusts the light emission power of the structured light projector **100** based on the distance, thereby solving the problem that eyes of the user are harmed by excessively high light emission power of the structured light projector **100**.

When the depth camera **400** is the front camera, if the face does not exist in the initial visible light image, it is considered that the depth camera **400** is in an out-of-service state. In such case, the processor **300** turns off the depth camera **400** to reduce power consumption of the electronic device **800**.

According to the control method of the embodiments of the present disclosure, the light emission power of the depth camera **400** may be adjusted according to whether the face exists in the initial visible light image or not. When the face exists in the initial visible light image, the light emission power of the structured light projector **100** is adjusted based on the distance between the face and the structured light projector **100**, thereby solving the problem that the eyes of the user are harmed by excessively high light emission power of the structured light projector **100** and improving safety in use of the electronic device **800**.

As illustrated in FIG. **3** and FIG. **5**, in some embodiments, the operation **01** that the depth image and the initial visible light image of the scene are acquired includes the following actions illustrated in blocks of FIG. **5**.

At block **011**, the structured light projector **100** is controlled to project a first laser pattern to the scene at initial light emission power.

At block **012**, a second laser pattern is acquired; herein the second laser pattern is acquired by modulating the first laser pattern with the scene.

At block **013**, the second laser pattern is processed to obtain the depth image.

As illustrated in FIG. **3** and FIG. **6**, in some embodiments, the acquisition module **11** includes a first control unit **111**, a first acquisition unit **112** and a processing unit **113**. Block **011** may be implemented by the first control unit **111**. Block **012** may be implemented by the first acquisition unit **112**. Block **013** may be implemented by the processing unit **113**. That is, the first control unit **111** may be configured to control the structured light projector **100** to project the first laser pattern to the scene at the initial light emission power. The first acquisition unit **112** may be configured to acquire a second laser pattern; herein, the second laser pattern is acquired by modulating the first laser pattern with the scene. The processing unit **113** may be configured to process the second laser pattern to obtain the depth image.

As illustrated in FIG. **3**, in some embodiments, all of block **011**, block **012** and block **013** may be implemented by the processor **300**. That is, the processor **300** may further be configured to control the structured light projector **100** to project a first laser pattern to the scene at the initial light emission power; acquire a second laser pattern, herein the second laser pattern is acquired by modulating the first laser pattern with the scene; and process the second laser pattern to obtain the depth image.

Herein, the initial light emission power may be obtained by calibration with multiple preliminary experiments, and is stored in a memory **600** of the electronic device **800**. When the structured light projector **100** emits structured light at the initial light emission power, no matter how short a distance between the user and the structured light projector **100** is, the eyes of the user may be prevented from being harmed by energy of laser.

After the structured light projector **100** is turned on, the laser pattern with multiple speckles may be projected to the scene. Since each object in the scene is at a different distance far away from the structured light projector **100**, the laser pattern projected onto the objects may be modulated because of different surface heights of the objects, and the speckles in the laser pattern may be offset. The structured light camera **200** acquires the laser pattern of which the speckles are shifted, i.e., the laser pattern modulated by the object. A reference pattern is stored in the memory **600**, and the processor **300** may calculate depth data of multiple pixels based on offsets of the speckles in the laser pattern relative to speckles in the reference pattern. Multiple pixels with depth data may form a depth image.

According to the control method of the embodiments of the present disclosure, the depth data of the object in the scene may be measured by use of the depth camera **400** to form the depth image. Moreover, the structured light projector **100** projects the laser pattern at a relatively low initial light emission power, so that the eyes of the user are prevented from being harmed, and the user may use the electronic device **800** safely.

As illustrated in FIG. **3**, FIG. **7** and FIG. **8**, in some embodiments, the initial visible light image has a first resolution, and the depth image has a third resolution. The block **03** that the distance between the face and the structured light projector **100** is calculated based on the initial visible light image and the depth image responsive to that

the face exists in the initial visible light image includes the following actions illustrated in blocks of FIG. **7**.

At block **031**, the initial visible light image is converted into an intermediate visible light image with a second resolution. Herein, the first resolution is higher than the second resolution.

At block **032**, a visible light face detection region in the intermediate visible light image is recognized.

At block **033**, a depth face detection region corresponding to the visible light face detection region is acquired from the depth image according to a mapping relationship between an intermediate visible light image and a depth image.

At block **034**, depth data with a minimum value in the depth face detection region is selected as the distance between the face and the structured light projector **100**.

Herein, block **033** further includes the following actions illustrated in blocks of FIG. **8**.

At block **0331**, a ratio of the third resolution to the second resolution is calculated to obtain a mapping ratio.

At block **0332**, a second origin pixel in the depth image is determined based on a coordinate value of a first origin pixel in the visible light face detection region and the mapping ratio.

At block **0333**, a second width and second height of the depth face detection region are acquired based on a first width and first height of the visible light face detection region and the mapping ratio.

At block **0334**, the depth face detection region is acquired based on the second origin pixel, the second width and the second height.

As illustrated in FIG. **3**, FIG. **9** and FIG. **10**, in some embodiments, the calculation module **13** includes a conversion unit **131**, a recognition unit **132**, a second acquisition unit **133** and a selection unit **134**. The second acquisition unit **133** includes a calculation subunit **1331**, a determination subunit **1332**, a first acquisition subunit **1333** and a second acquisition subunit **1334**. Block **031** may be implemented by the conversion unit **131**. Block **032** may be implemented by the recognition unit **132**. Block **033** may be implemented by the second acquisition unit **133**. Block **034** may be implemented by the selection unit **134**. Block **0331** may be implemented by the calculation subunit **1331**. Block **0332** may be implemented by the determination subunit **1332**. Block **0333** may be implemented by the first acquisition subunit **1333**. Block **0334** may be implemented by the second acquisition subunit **1334**.

That is, the conversion unit **131** may be configured to convert the initial visible light image into the intermediate visible light image with the second resolution; herein, the first resolution is higher than the second resolution. The recognition unit **132** may be configured to recognize the visible light face detection region in the intermediate visible light image. The second acquisition unit **133** may be configured to acquire, from the depth image, the depth face detection region corresponding to the visible light face detection region according to the mapping relationship between the intermediate visible light image and the depth image. The selection unit **134** may be configured to select the depth data with the minimum value in the depth face detection region as the distance between the face and the structured light projector **100**. The calculation subunit **1331** may be configured to calculate the ratio of the third resolution to the second resolution to obtain the mapping ratio. The determination subunit **1332** may be configured to determine the second origin pixel in the depth image based on the coordinate value of the first origin pixel in the visible light face detection region and the mapping ratio. The first acquisition subunit **1333** may be configured to acquire the second width and second height of the depth face detection region based on the first width and first height of the visible light face detection region and the mapping ratio. The second acquisition subunit **1334** may be configured to acquire the depth face detection region based on the second origin pixel, the second width and the second height.

As illustrated in FIG. **3**, in some embodiments, all of block **031**, block **032**, block **033**, block **0331**, block **0332**, block **0333**, block **0334** and block **034** may be implemented by the processor **300**. That is, the processor **300** may be configured to convert the initial visible light image into the intermediate visible light image with the second resolution, recognize the visible light face detection region in the intermediate visible light image, acquire from the depth image, the depth face detection region corresponding to the visible light face detection region according to the mapping relationship between the intermediate visible light image and the depth image and select the depth data with the minimum value in the depth face detection region as the distance between the face and the structured light projector **100**. The processor **300**, when executing block **033**, specifically executes the actions of calculating the ratio of the third resolution to the second resolution to obtain the mapping ratio, determining the second origin pixel in the depth image based on the coordinate value of the first origin pixel in the visible light face detection region and the mapping ratio, acquiring the second width and second height of the depth face detection region based on the first width and first height of the visible light face detection region and the mapping ratio and acquiring the depth face detection region based on the second origin pixel, the second width and the second height.

Specifically, the first resolution refers to an initial resolution after the initial visible light image is captured. In general, the first resolution of the initial visible light image is relatively high. The third resolution of the depth image is usually lower than the first resolution of the initial visible light image. For finding the depth data of the face in the depth image and reducing the amount of data required to be processed by the processor **300**, the processor **300** is required to perform compressive conversion on the initial visible light image with the first resolution to obtain the intermediate visible light image with the second resolution at first, for example, compressing the initial visible light image with the first resolution into the intermediate visible light image with the second resolution of 640×480. Then, the processor **300** recognizes the visible light face detection region from the intermediate visible light image. The face region recognized by the processor **300** usually refers to a region including parts such as a forehead, eyebrows, eyes, cheeks, ears, a nose, a mouth and a jaw. The processor **300**, after recognizing the face region, is required to clip the face region to obtain the visible light face detection region. Specifically, the processor **300** further recognizes the eyebrows and the jaw from the face region and clip the visible light face detection region in a manner of bounding by the eyebrows and the jaw. Herein, the visible light face detection region may be a rectangle, a square, a round and the like, and is not limited herein. In a specific embodiment of the present disclosure, the visible light face detection region is a rectangle. The processor **300** determines a pixel in the top left corner of the visible light face detection region as the first origin pixel. A coordinate of the first origin pixel is marked as (left, top). A value of (left, top) corresponds to a pixel coordinate value of the first origin pixel in a pixel coordinate system of the initial visible light image. The processor **300**

determines a pixel coordinate value (right, bottom) of a bottom right pixel in the initial visible light pixel and calculates a first width (represented as width) and a first height (represented as height) of the visible light face detection region based on the coordinate (left, top) and the coordinate (right, bottom). Finally, the processor **300** defines a position and a size of the visible light face detection region in the intermediate visible light image by use of (left, top, width, height).

Then, the processor **300** may determines, from the depth image, the depth face detection region corresponding to the visible light face detection region based on the visible light face detection region. For example, the third resolution of the depth image is 640×400. The processor **300** is required to calculate a mapping ratio of the visible light face detection region to the depth face detection region at first. Herein, the mapping ratio=the third resolution/the second resolution=

(640×400)/(640×480)=400/480=5/6. Then, the processor **300** calculates a coordinate value (left', top') of the top left pixel (i.e., the second origin pixel) in the depth face detection region in the depth image based on the mapping ratio and the coordinate value (left, top) of the first origin pixel. Herein, left'=(left×5)/6, and top'=(top×5)/6. Then, the processor **300** may determine a position of the second origin pixel based on the coordinate value (left', top'). Next, the processor **300** calculates a second width (represented as width') of the depth face detection region based on the first width of the visible light face detection region and the mapping ratio, namely width'=(width×5)/6, and calculates a second height (represented by height') of the depth face detection region based on the first height (height) of the visible light face detection region and the mapping ratio, namely height'=(height×5)/6. Then, the processor **300** may determine a position and a size of the depth face detection region in the depth image by use of (left', top', width', height').

Finally, the processor **300** selects the depth data with the minimum value from multiple pieces of depth data of the depth face detection region as the distance between the face and the structured light projector **100**. The minimum depth data refers to a distance between a point closest to the structured light projector **100** in the face and the structured light projector **100**. Compared with adjusting the light emission power of the structured light projector **100** by selecting a mid-value or mean value of the depth data, adjusting the light emission power of the structured light projector **100** on the basis of the minimum value may further prevent excessively high energy of the projected laser and improve safety of the eyes of the user.

According to the control method of the embodiments of the present disclosure, on one hand, the amount of the data required to be processed by the processor **300** may be reduced by compressing the resolution, and on the other hand, the depth face detection region corresponding to the visible light face detection region may be determined from the depth image according to a ratio relationship between the second resolution and the third resolution, thereby obtaining the depth data of the face. In such a manner, the distance between the face and the structured light projector **100** may be acquired to facilitate subsequent adjustion of the light emission power of the structured light projector **100**.

As illustrated in FIG. **3** and FIG. **11**, in some embodiments, the block **04** that the light emission power of the structured light projector **100** is adjusted based on the distance includes the following actions illustrated in blocks of FIG. **11**.

At block **041**, the light emission power of the structured light projector **100** is acquired based on the distance when the distance is less than a first preset distance and greater than a second preset distance. Herein, the second preset distance is less than the first preset distance.

At block **042**, the structured light projector **100** is controlled to emit light at the light emission power.

At block **043**, the structured light projector **100** is controlled to be turned off when the distance is greater than the first preset distance or less than the second preset distance.

As illustrated in FIG. **3** and FIG. **12**, in some embodiments, the adjusting module **14** includes a third acquisition unit **141**, a second control unit **142** and a third control unit **143**. Block **041** may be implemented by the third acquisition unit **141**. Block **042** may be implemented by the second control unit **142**. Block **043** may be implemented by the third control unit **143**. That is, the third acquisition unit **141** may be configured to acquire the light emission power of the structured light projector **100** based on the distance when the distance is less than the first preset distance and greater than the second preset distance. Herein, the second preset distance is less than the first preset distance. The second control unit **142** may be configured to control the structured light projector **100** to emit the light at the light emission power. The third control unit **143** may be configured to control the structured light projector **100** to be turned off when the distance is greater than the first preset distance or less than the second preset distance.

As illustrated in FIG. **3**, in some embodiments, all of block **041**, block **042** and block **043** may be implemented by the processor **300**. That is, the processor **300** may further be configured to acquire the light emission power of the structured light projector **100** based on the distance when the distance is less than the first preset distance and greater than the second preset distance, control the structured light projector **100** to emit the light at the light emission power, and control the structured light projector **100** to be turned off when the distance is greater than the first preset distance or less than the second preset distance. Herein, the second preset distance is less than the first preset distance.

Specifically, when the distance between the face and the structured light projector **100** is less than the second preset distance (for example, 2 centimeters, 3.5 centimeters, 4 centimeters and 5 centimeters), it is considered that the distance between the user and the structured light projector **100** is too short, and thus the processor **300** may directly turn off the structured light projector **100** to reduce the harms of laser to the eyes. In addition, when the distance between the face and the structured light projector **100** is less than the second preset distance, the depth camera **400** may usually not acquire complete depth data of the face of the user. In such case, the structured light projector **100** may also be directly turned off to reduce the power consumption of the electronic device **800**.

When the distance between the face and the structured light projector **100** is greater than the second preset distance and less than the first preset distance (for example, 50 centimeters, 53 centimeters, 55.9 centimeters, 58 centimeters and 100 centimeters), the processor **300** adjusts a driving current of the structured light projector **100** based on the distance between the face and the structured light projector **100** to enable the structured light projector **100** to emit the light at target light emission power, thereby meeting a requirement on depth data acquisition accuracy and also ensuring the safety of the eyes of the user. In general, as the distance increases, the light emission power also increases; and as the distance decreases, the light emission power also

decreases. A corresponding relationship between a distance and the light emission power may be as follows. (1) The distance is a value, the light emission power is also a value, and the distance corresponds to the light emission power one to one. (2) The distance is a range, the light emission power is a value, and the distance corresponds to the light emission power one to one. The correspondences between the distance and the light emission power may be obtained by calibration with numerous preliminary experiments, and the calibrated correspondence is stored in the memory **600**. When the structured light projector **100** works, the processor **300** determines, based on the calculated distance, the light emission power corresponding to the calculated distance according to the correspondences stored in the memory **600** and controls the structured light projector **100** to emit the light at the light emission power.

When the depth camera **400** is the front camera, if the distance between the face and the structured light projector **100** is greater than the first preset distance, it is considered that the user is not using the structured light projector **100**, and the processor **300** may directly turn off the structured light projector **100** to reduce the power consumption of the electronic device **800**.

As illustrated in FIG. **3** and FIG. **13**, in some embodiments, a light source **101** of the structured light projector **100** may be divided into multiple light emission regions **102**, and each light emission region **102** may include multiple light emission devices. The light emission devices in each of the multiple light emission regions can be independently controlled with respect to light emission devices in other light emission regions. When the distance between the face and the structured light projector **100** is greater than the second preset distance and less than the first preset distance, the processor **300**, besides adjusting the driving current of the structured light projector **100** to enable the structured light projector **100** to emit the light at the target light emission power, may further control the light source **101** to turn on light emission devices in a number of light emission regions **102** determined based on the distance to enable the structured light projector **100** to emit the light at the target light emission power. For example, when the distance is 10 centimeters, light emission devices in two light emission regions **102** of the light source **101** are turned on. When the distance is 20 centimeters, light emission devices in four light emission regions **102** of the light source **101** are turned on. Herein, a shape of the light emission region **102** may be a sector (as illustrated in FIG. **13**), a ring, a hollow square and the like, and is not limited herein.

As illustrated in FIG. **13**, when not all of the light emission regions **102** are turned on, the turned-on light emission regions **102** in which the light emission devices has been turned on are distributed centrosymmetrically around a center point of the light source **101** (as illustrated in FIG. **13**), so that brightness uniformity of the laser emitted by the structured light projector **100** may be improved, and the depth data acquisition accuracy may be improved.

In the descriptions of the specification, the descriptions made with reference to terms "an embodiment", "some embodiments", "example", "specific example", "some examples" or the like refer to that specific features, structures, materials or characteristics described in combination with the embodiment or the example are included in at least one embodiment or example of the present disclosure. In the specification, these terms are not always schematically expressed for the same embodiment or example. Moreover, the specific described features, structures, materials or characteristics may be combined in a proper manner in any one or more embodiments or examples. In addition, those skilled in the art may integrate and combine different embodiments or examples described in the specification and features of different embodiments or examples without conflicts.

In addition, terms "first" and "second" are only adopted for description and should not be understood to indicate or imply relative importance or implicitly indicate the number of indicated technical features. Therefore, features defined by "first" and "second" may explicitly or implicitly indicate inclusion of at least one such feature. In the descriptions of the present disclosure, "multiple" means at least two, for example, two and three, unless otherwise limited definitely and specifically.

Any process or method in the flowcharts or described herein in another manner may be understood to represent a module, segment or part including codes of one or more executable instructions configured to realize specific logic functions or operations of the process and, moreover, the scope of the preferred implementation mode of the present disclosure includes other implementation, not in a sequence shown or discussed herein, including execution of the functions basically simultaneously or in an opposite sequence according to the involved functions. This should be understood by those skilled in the art of the embodiments of the present disclosure.

Logics and/or operations represented in the flowcharts or described herein in another manner, for example, may be considered as a fixed sequence list of executable instructions configured to realize the logic functions and may specifically implemented in any computer-readable medium for an instruction execution system, device or equipment (for example, a computer-based system, a system including a processor or another system capable of reading instructions from the instruction execution system, device or equipment and executing the instructions) to use or for use in combination with the instruction execution system, device or equipment. For the specification, "computer-readable medium" may be any device capable of including, storing, communicating with, propagating or transmitting a program for the instruction execution system, device or equipment to use or for use in combination with the instruction execution system, device or equipment. A more specific example (non-exhaustive list) of the computer-readable medium includes: an electric connection portion (electronic device) with one or more wires, a portable computer disk (magnetic device), a Random Access Memory (RAM), a Read-Only Memory (ROM), an Erasable Programmable ROM (EPROM) (or flash memory), an optical fiber device and a portable Compact Disc Read-Only Memory (CD-ROM). In addition, the computer-readable medium may even be paper or another medium on which the program may be printed because, for example, the paper or the other medium may be optically scanned then edited, explained or, when necessary, processed in another proper manner to obtain the program in an electronic manner for storage in the computer memory.

It should be understood that each part of the present disclosure may be implemented by hardware, software, firmware or a combination thereof. In the abovementioned embodiments, multiple operations or methods may be implemented by software or firmware stored in a memory and executed by a proper instruction execution system. For example, in case of implementation with the hardware, like another implementation mode, any one or combination of the following technologies well-known in the art may be adopted for implementation: a discrete logic circuit with a logic gate circuit configured to realize a logic function for a data signal, an present disclosure-specific integrated circuit

with a proper combined logic gate circuit, a Programmable Gate Array (PGA), a Field Programmable Gate Array (FPGA) and the like.

Those of ordinary skill in the art should understand that all or part of the operations in the method of the abovementioned embodiment may be completed through related hardware instructed by a program, the program may be stored in a computer-readable storage medium, and when the program is executed, one or combination of the operations of the method embodiment is included.

In addition, each functional unit in each embodiment of the present disclosure may be integrated into a processing module, each unit may also physically exist independently, and two or more than two units may also be integrated into a module. The integrated module may be implemented in a hardware form and may also be implemented in form of software functional module. When being implemented in form of software functional module and sold or used as an independent product, the integrated module may be stored in a computer-readable storage medium.

The storage medium may be a ROM, a magnetic disk, an optical disk or the like. The embodiments of the present disclosure have been shown or described above. However, it can be understood that the abovementioned embodiments are exemplary and should not be understood as limits to the present disclosure and those of ordinary skill in the art may make variations, modifications, replacements, transformations to the abovementioned embodiments within the scope of the present disclosure.

The invention claimed is:

1. A method for controlling a structured light projector, comprising:

acquiring a depth image and an initial visible light image of a scene;

determining whether a face exists in the initial visible light image;

calculating, responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector based on the initial visible light image and the depth image; and

adjusting light emission power of the structured light projector based on the distance.

2. The method of claim **1**, wherein acquiring the depth image of the scene comprises:

controlling the structured light projector to project a first laser pattern to the scene at an initial light emission power;

acquiring a second laser pattern, wherein the second laser pattern is acquired by modulating the first laser pattern with the scene; and

processing the second laser pattern to obtain the depth image.

3. The method of claim **1**, wherein the initial visible light image has a first resolution, the depth image has a third resolution, and

wherein calculating the distance between the face and the structured light projector based on the initial visible light image and the depth image comprises:

converting the initial visible light image into an intermediate visible light image with a second resolution, wherein the first resolution is higher than the second resolution;

recognizing a visible light face detection region from the intermediate visible light image;

acquiring from the depth image, a depth face detection region corresponding to the visible light face detection region according to a mapping relationship between the intermediate visible light image and the depth image; and

selecting depth data with a minimum value in the depth face detection

region as the distance between the face and the structured light projector.

4. The method of claim **3**, wherein acquiring from the depth image, the depth face detection region corresponding to the visible light face detection region according to the mapping relationship between the intermediate visible light image and the depth image comprises:

calculating a ratio of the third resolution to the second resolution to obtain a mapping ratio;

determining a second origin pixel in the depth image based on a coordinate value of a first origin pixel in the visible light face detection region and the mapping ratio;

acquiring a second width and a second height of the depth face detection region based on a first width and a first height of the visible light face detection region and the mapping ratio; and

acquiring the depth face detection region based on the second origin pixel, the second width, and the second height.

5. The method of claim **1**, wherein adjusting the light emission power of the structured light projector based on the distance comprises:

acquiring the light emission power of the structured light projector based on the distance when the distance is less than a first preset distance and greater than a second preset distance, wherein the second preset distance is less than the first preset distance;

controlling the structured light projector to emit light at the light emission power; and

controlling the structured light projector to be turned off when the distance is greater than the first preset distance or less than the second preset distance.

6. The method of claim **3**, wherein the depth data with the minimum value comprises a distance between a point closest to the structured light projector in the face and the structured light projector.

7. A depth camera, comprising a structured light projector and a processor, wherein the processor is configured to:

acquire a depth image and an initial visible light image of a scene;

determine whether a face exists in the initial visible light image;

calculate, responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector based on the initial visible light image and the depth image; and

adjust light emission power of the structured light projector based on the distance.

8. The depth camera of claim **7**, wherein the processor is further configured to:

control the structured light projector to project a first laser pattern to the scene at an initial light emission power;

acquire a second laser pattern, wherein the second laser pattern is acquired by modulating the first laser pattern with the scene; and

process the second acquired laser pattern to obtain the depth image.

9. The depth camera of claim **7**, wherein the initial visible light image has a first resolution, the depth image has a third resolution, and the processor is further configured to:

convert the initial visible light image into an intermediate visible light image with a second resolution, wherein the first resolution is higher than the second resolution;

recognize a visible light face detection region from the intermediate visible light image;

acquire from the depth image, a depth face detection region corresponding to the visible light face detection region according to a mapping relationship between the intermediate visible light image and the depth image; and

select depth data with a minimum value in the depth face detection region as the distance between the face and the structured light projector.

10. The depth camera of claim **9**, wherein the processor is further configured to:

calculate a ratio of the third resolution to the second resolution to obtain a mapping ratio;

determine a second origin pixel in the depth image based on a coordinate value of a first origin pixel in the visible light face detection region and the mapping ratio;

acquire a second width and a second height of the depth face detection region based on a first width and a first height of the visible light face detection region and the mapping ratio; and

acquire the depth face detection region based on the second origin pixel, the second width, and the second height.

11. The depth camera of claim **7**, wherein the processor is further configured to:

acquire the light emission power of the structured light projector based on the distance when the distance is less than a first preset distance and greater than a second preset distance, wherein the second preset distance is less than the first preset distance;

control the structured light projector to emit light at the light emission power; and

control the structured light projector to be turned off when the distance is greater than the first preset distance or less than the second preset distance.

12. An electronic device, comprising:

a shell; and

a depth camera, wherein the depth camera is arranged on the shell and the depth camera comprises a structured light projector and a processor,

wherein the processor is configured to:

acquire a depth image and an initial visible light image of a scene;

determine whether a face exists in the initial visible light image;

calculate, responsive to determining that the face exists in the initial visible light image, a distance between the face and the structured light projector based on the initial visible light image and the depth image; and

adjust light emission power of the structured light projector based on the distance.

13. The electronic device of claim **12**, wherein the processor is further configured to:

control the structured light projector to project a first laser pattern to the scene at an initial light emission power;

acquire a second laser pattern, wherein the second laser pattern is acquired by modulating the first laser pattern with the scene; and

process the second acquired laser pattern to obtain the depth image.

14. The electronic device of claim **12**, wherein the initial visible light image has a first resolution, the depth image has a third resolution, and the processor is further configured to:

convert the initial visible light image into an intermediate visible light image with a second resolution, wherein the first resolution is higher than the second resolution;

recognize a visible light face detection region from the intermediate visible light image;

acquire from the depth image, a depth face detection region corresponding to the visible light face detection region according to a mapping relationship between the intermediate visible light image and the depth image; and

select depth data with a minimum value in the depth face detection region as the distance between the face and the structured light projector.

15. The electronic device of claim **14**, wherein the processor is further configured to:

calculate a ratio of the third resolution to the second resolution to obtain a mapping ratio;

determine a second origin pixel in the depth image based on a coordinate value of a first origin pixel in the visible light face detection region and the mapping ratio;

acquire a second width and a second height of the depth face detection region based on a first width and a first height of the visible light face detection region and the mapping ratio; and

acquire the depth face detection region based on the second origin pixel, the second width, and the second height.

16. The electronic device of claim **12**, wherein the processor is further configured to:

acquire the light emission power of the structured light projector based on the distance when the distance is less than a first preset distance and greater than a second preset distance, wherein the second preset distance is less than the first preset distance;

control the structured light projector to emit light at the light emission power; and

control the structured light projector to be turned off when the distance is greater than the first preset distance or less than the second preset distance.

17. The electronic device of claim **12**, wherein the shell is provided with an acquisition window, and the depth camera is aligned with the acquisition window to enable the depth camera to capture the depth image.

18. The electronic device of claim **12**, wherein the shell comprises a movable bracket, and the depth camera is mounted on the movable bracket.

19. The electronic device of claim **16**, wherein a light source of the structured light projector is divided into a plurality of light emission regions, each of the plurality of light emission regions comprises a plurality of light emission devices, and light emission devices in each of the plurality of light emission regions are independently controlled with respect to light emission devices in other light emission regions; and

wherein in terms of controlling the structured light projector to emit light at the light emission power, the processor is configured to:

adjust a driving current of the structured light projector to enable the structured light projector to emit the light at the target light emission power; or

determine a number of light emission regions in which light emission devices are to be turned on, and turn on the light emission devices in the light emission regions to enable the structured light projector to emit the light at the target light emission power.

20. The electronic device of claim **19**, wherein the light emission regions in which the light emission devices has

been turned on are distributed centrosymmetrically around a center point of the light source.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,880,539 B2
APPLICATION NO. : 16/534549
DATED : December 29, 2020
INVENTOR(S) : Xiaopeng Li

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

(71) Applicant reads:
"Guangdong (CN)"
Should read:
--Dongguan, Guangdong (CN)--

(73) Assignee reads:
"Guangdong (CN)"
Should read:
--Dongguan, Guangdong (CN)--

Signed and Sealed this
Ninth Day of March, 2021

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office