

the camera position of the panoramic camera when shooting the at least one panoramic image of each three-dimensional object according to a position of the at least one video frame.

[0017] Optionally, the camera position is predetermined or obtained in the camera position acquisition step, the camera position acquisition step comprises: using a geometric relationship of at least two panoramic images shot for each three-dimensional object of the at least one three-dimensional object to be processed, performing feature point matching between the at least two panoramic images of each three-dimensional object, and recording feature points that match with each other in the at least two panoramic images of each three-dimensional object as the matching feature points; and for each panoramic image of the at least two panoramic images of each three-dimensional object, reducing reprojection errors of the matching feature points on each panoramic image to obtain the camera position of the panoramic camera when shooting each panoramic image and the three-dimensional point coordinates of the matching feature points on each panoramic image.

[0018] Optionally, the scale normalization step comprises: in a case where the camera position is obtained in the camera position acquisition step, sorting from small to large height values of all three-dimensional point coordinates, which are obtained when the camera position is obtained, on at least one panoramic image of each three-dimensional object, and taking a median value or an average value of the height values sorted in front as an extracted contour height h_c' of the contour of the specific category; and by using a ratio of the assumed contour height h_c of the contour of the specific category to the extracted contour height h_c' of the contour of the specific category, generating normalized plane contours of at least two panoramic images of each three-dimensional object in the three-dimensional space based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space. The assumed contour height h_c of the contour of the specific category is an arbitrarily assumed height.

[0019] Optionally, the scale normalization step comprises: in a case where the camera position is a camera definition height $\underline{H_c} \cdot h_e$ that is predetermined, by using a ratio of a camera assumed height $\underline{H_c} h_e$ that is assumed to the camera definition height $\underline{H_c} \cdot h_e$, generating normalized plane contours of at least two panoramic images of each three-dimensional object in the three-dimensional space based on the plane contours of the at

least two panoramic images of each three-dimensional object in the three-dimensional space. The camera assumed height H_c is an arbitrarily assumed height.

[0020] Optionally, after the scale normalization step, the three-dimensional object modeling method further comprises a single-object plane contour generation step, which comprises: for at least two panoramic images shot for the at least one three-dimensional object to be processed, determining whether there are a plurality of panoramic images belong to the same three-dimensional object one by one in a following method: if there are matching feature points, a ratio of which is more than a specific ratio, between two panoramic images, then it is determined that the two panoramic images belong to a same three-dimensional object; and if it is determined that the plurality of panoramic images belong to the same three-dimensional object, for respective plane contours of the same three-dimensional object obtained according to the plurality of panoramic images, a union of all the plane contours of the same three-dimensional object is taken as a plane contour of the three-dimensional object in the three-dimensional space.

[0021] Optionally, in the multi-object splicing step, the multi-object plane contour in the three-dimensional space can be obtained by splicing based on the plane contours of respective single three-dimensional objects in the three-dimensional space.

[0022] Optionally, the multi-object splicing step comprises: assuming that there are N plane contours of all panoramic images in the three-dimensional space, a p -th three-dimensional point of an n -th plane contour is indicated as X_p^n , and the camera position where a panoramic image corresponding to the n -th plane contour is shot is indicated as $\{R_n, t_n\}$, where R_n is a rotation matrix used to represent a rotation parameter of the camera position, and t_n is a translation vector used to represent a translation parameter of the camera position, where N is an integer greater than 1, and n is an integer greater than or equal to 1, selecting the camera position where a panoramic image corresponding to an i -th plane contour is shot as a reference coordinate system, and unifying the three-dimensional points of other plane contours under the reference coordinate system through a formula below:

$$X_p^{n \rightarrow i} = R_i R_n^{-1} (X_p^n - t_n) + t_i,$$

converting all the three-dimensional points of the plane contours after the scale normalization

of each three-dimensional object, and recording feature points that match with each other in the at least two panoramic images of each three-dimensional object as the matching feature points; and for each panoramic image of the at least two panoramic images of each three-dimensional object, reducing reprojection errors of the matching feature points on each panoramic image to obtain the camera position of the panoramic camera when shooting each panoramic image and the three-dimensional point coordinates of the matching feature points on each panoramic image.

[0027] Optionally, the scale normalization device is further configured to: in a case where the camera position is extracted, sort from small to large height values of all three-dimensional point coordinates, which are obtained when the camera position is obtained, on at least one panoramic image of each three-dimensional object, and take a median value or an average value of the height values sorted in front as an extracted contour height h_c' of the contour of the specific category; and by using a ratio of the assumed contour height h_c of the contour of the specific category to the extracted contour height h_c' of the contour of the specific category, generate normalized plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space. The assumed contour height h_c of the contour of the specific category is an arbitrarily assumed height.

[0028] Optionally, the scale normalization device is further configured to: in a case where the camera position is a camera definition height $\underline{H_c} \cdot h_e^2$ that is predetermined, by using a ratio of a camera assumed height $\underline{H_c} h_e$ that is assumed to the camera definition height $\underline{H_c} \cdot h_e^2$, generate normalized plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space. The camera assumed height $\underline{H_c} h_e$ is an arbitrarily assumed height.

[0029] Optionally, a single-object plane contour generation device is configured to: for the at least two panoramic images shot for the at least one three-dimensional object to be processed, determine whether there are a plurality of panoramic images belong to the same three-dimensional object one by one in a following method: if there are matching feature

and the scale of the three-dimensional spatial plane contour of the panoramic images obtained in step S110 are normalized (scale normalization).

[00143] It should be noted that the purpose of the scale normalization is to unify the scales of the camera positions and the scales of the plane contours of the respective panoramic images, and the scale of the camera position and the scale of the plane contour may be actual scales, such as meter. In other words, the coordinate of the camera position and the size of the plane contour must be in a uniform unit of measurement.

[00144] For example, the camera position includes the coordinate and direction of the camera.

[00145] Because the assumed height h_c from the camera to the ceiling is used to obtain the three-dimensional spatial plane contour of the room in step S110 (the camera height is not known at that time), the scale of the camera position (the actual height of the camera) and the scale of the three-dimensional spatial plane contour of the three-dimensional object are not uniform, which causes certain difficulties in subsequent splicing of the room contour.

[00146] In step S110, the scale of the camera position when shooting at least one panoramic image of each three-dimensional object and the scale of the plane contour of at least one panoramic image of each three-dimensional object in the three-dimensional space are normalized, so that the subsequent multi-object splicing process can be performed.

[00147] In this normalization step, there may be two cases: a first case is that there is a certain camera position (actual camera height), and a second case is that the camera position is still uncertain.

[00148] In a case where the camera position is a camera definition height $\underline{H_c} \cdot h_e$ that is predetermined, using a ratio of the assumed height h_c , which is assumed in the plane contour extraction step S110, from the camera to the ceiling to the camera definition height $\underline{H_c} \cdot h_e$, normalized plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space is generated based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space. Here, the assumed contour height h_c of the contour of the specific category may be an arbitrarily assumed height, for example, the coordinate value of the assumed contour height h_c is 100 or any other value.

modeling method of the present invention. In fact, the present invention should not be limited to the application scenes of house modeling, but can be applied to a variety of image-based modeling scenes, such as modeling a vehicle to achieve VR (Virtual Reality) car viewing, etc. The present invention actually provides an innovative and comprehensive image processing scheme.

[00212] FIG. 3 shows a schematic block diagram of a three-dimensional object modeling equipment according to an exemplary embodiment of the present invention.

[00213] As shown in FIG. 3, a three-dimensional object modeling equipment 100 according to an exemplary embodiment of the present invention may include a plane contour extraction device 110, a scale normalization device 120, and a multi-object splicing device ~~140~~130.

[00214] The plane contour extraction device 110 may be configured to: for at least one panoramic image shot for each three-dimensional object of at least one three-dimensional object to be processed, extract a plane contour of the at least one panoramic image of each three-dimensional object in a three-dimensional space.

[00215] Here, as described above, at least one panoramic image is shot for one three-dimensional object, and each three-dimensional object corresponds to one or more panoramic images.

[00216] The scale normalization device 120 may be configured to normalize a scale of the camera position and a scale of the plane contour of the at least one panoramic image of each three-dimensional object in the three-dimensional space, to obtain a normalized plane contours of respective panoramic images in the three-dimensional space.

[00217] The multi-object splicing device ~~140~~130 may be configured to perform rotation and translation operations on the three-dimensional point coordinates of the normalized plane contours of respective panoramic images in the three-dimensional space, so as to unify the three-dimensional point coordinates in the same coordinate system, to splice the plane contours of respective panoramic images in the three-dimensional space into a multi-object plane contour.

[00218] Therein, optionally, the above-mentioned camera position may be predetermined.

[00219] Alternatively, the above-mentioned camera position may also be obtained in the following method:

[00220] 1) By using a geometric relationship of at least two panoramic images shot for each three-dimensional object of the at least one three-dimensional object to be processed, performing feature point matching between these panoramic images, and recording feature points that match with each other in these panoramic images as matching feature points; and

[00221] 2) For each panoramic image of the at least two panoramic images of each three-dimensional object, reducing reprojection errors of the matching feature points on each panoramic image, to obtain the camera position of the panoramic camera when shooting each panoramic image and the three-dimensional point coordinates of the matching feature points on each panoramic image.

[00222] Here, in a case where the camera position is obtained in the camera position acquisition step, height values of all three-dimensional point coordinates, which are obtained when the camera position is obtained, on at least one panoramic image of each three-dimensional object may be sorted from small to large, and a median value or an average value of the height values sorted in front is taken as an extracted contour height h_c' of the contour of the specific category; and by using a ratio of the assumed contour height h_c of the contour of the specific category to the extracted contour height h_c' of the contour of the specific category, normalized plane contours of at least two panoramic images of each three-dimensional object in the three-dimensional space are generated based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space.

[00223] Therein, the camera assumed ~~contour~~-height $H_c h_e$ here (i.e., the assumed height from the camera to the ceiling) is an arbitrarily assumed height.

[00224] In addition, in a case where the camera position is a camera definition height $H_c' h_e'$ that is predetermined, by using a ratio of a camera assumed height $H_c h_e$ that is assumed in the plane contour extraction step S110 to the camera definition height $H_c' h_e'$, normalized plane contours of respective panoramic images of each three-dimensional object in the three-dimensional space are generated based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space. Similarly,

the camera assumed height H_{ch} here (i.e., the assumed height from the camera to the ceiling) is also an arbitrarily assumed height. It should be noted that in this application, the camera assumed height is the same as the assumed contour height of the contour of the specific category. Similarly, the camera definition height is the same as the extracted contour height of the contour of the specific category.

[00225] Optionally, the three-dimensional object modeling equipment 100 further includes a single-object plane contour generation device 125, which is configured to:

for the at least two panoramic images, determine whether there are a plurality of panoramic images belong to the same three-dimensional object one by one in a following method: if there are matching feature points, a ratio of which is more than a specific ratio, between two panoramic images, it can be determined that the two panoramic images belong to the same three-dimensional object; and

if it is determined that a plurality of panoramic images belong to the same three-dimensional object, a union of the plane contours of the plurality of panoramic images in the three-dimensional space is taken as the plane contour of the three-dimensional object in the three-dimensional space.

[00226] In addition, optionally, the multi-object splicing device ~~140130~~ is further configured to be able to obtain the multi-object plane contour in the three-dimensional space by splicing based on the plane contours of respective single three-dimensional objects in the three-dimensional space.

[00227] In addition, optionally, the multi-object splicing device ~~140130~~ may implement the splicing of a plurality of plane contours through the following coordinate transformation:

[00228] Assuming that there are N plane contours of all panoramic images in the three-dimensional space, a p -th three-dimensional point of an n -th plane contour is indicated as X_p^n , and the camera position where the panoramic image corresponding to the n -th plane contour is shot is indicated as $\{R_n, t_n\}$, where R_n is a rotation matrix used to represent a rotation parameter of the camera position, and t_n is a translation vector used to represent a translation parameter of the camera position, where N is an integer greater than 1, and n is an integer greater than or equal to 1. In this case, the camera position where the panoramic

image corresponding to an i-th plane contour is taken may be selected as the reference coordinate system, and the three-dimensional points of other plane contours may be unified under this reference coordinate system through the formula below:

$$X_p^{n \rightarrow i} = R_i R_n^{-1} (X_p^n - t_n) + t_i,$$

[00229] All the three-dimensional points of the plane contours after the scale normalization except the i-th plane contour are transformed through this formula, so as to unify the three-dimensional points of all the plane contours under the same coordinate system, thereby splicing the plane contours of respective panoramic images in the three-dimensional space into a multi-object plane contour, i.e., splicing the plane contours of respective three-dimensional objects into a multi-object plane contour.

[00230] In addition, optionally, the three-dimensional object modeling equipment 100 may further include a multi-object contour optimization device 145, which is configured to calculate a distance between adjacent edges of two single-object plane contours in the multi-object plane contour, and if the distance is non-zero and less than a certain threshold, the two single-object plane contours are shifted to make the distance between the adjacent edges become to zero.

[00231] In addition, optionally, the three-dimensional object modeling equipment 100 may further include a 3D model generation device ~~150~~140, which is configured to convert the multi-object plane contour obtained by splicing in the three-dimensional space into a multi-object 3D model.

[00232] Here, the devices 110, 120, 125, 140, 145, and 150 of the above-mentioned three-dimensional object modeling equipment 100 respectively correspond to the steps S110, S120, S125, S140, S145, and S150 described in detail above, and similar portions will not be repeated here.

[00233] Thus, through the above-mentioned three-dimensional object modeling equipment of the present invention, the resolution and accuracy of the generated model can be effectively improved.

[00234] Moreover, it should be pointed out that for ease of understanding and description, the modeling of the three-dimensional object (e.g., house) is taken as an example

for each panoramic image, extract a plane contour of the panoramic image in the three-dimensional space through the deep learning model for extracting an image contour.

[00383] The scale normalization device 530 may be configured to normalize the scales of the obtained positions of the panoramic camera when shooting at least two panoramic images of each three-dimensional object and the scales of the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space, to obtain normalized plane contours of respective panoramic images in the three-dimensional space.

[00384] Optionally, the deep learning model is trained in the following manner: by manually labeling contour features of three-dimensional objects of a type of interest on a plurality of panoramic images serving as training images, a contour feature training data set of the three-dimensional objects of the type of interest is generated; and the contour feature training data set of the three-dimensional objects of the type of interest is used to train a deep learning model, and the output of the deep learning model comprises categories of the contour features of the three-dimensional objects of the type of interest.

[00385] Optionally, the single-image plane contour generation device 520 may be further configured to: input at least one panoramic image into the trained deep learning model to obtain the category of the contour feature corresponding to each pixel in the panoramic image; extract edge pixels that are at the edges among pixels, whose contour features belong to a specific category, on each panoramic image as specific category edge pixels; assume that all the specific category edge pixels on the at least one panoramic image have the same height h_c that serves as the assumed contour height of the contour of the specific category, and project the specific category edge pixels on each panoramic image onto a three-dimensional plane to obtain specific category three-dimensional points corresponding to each panoramic image, and then form plane contours of respective panoramic images in the three-dimensional space based on the specific category three-dimensional points corresponding to each panoramic image.

[00386] Optionally, the camera position acquisition device ~~440~~510 may be further configured to: using a geometric relationship of at least two panoramic images of each three-dimensional object, perform feature point matching between the at least two panoramic

WHAT IS CLAIMED IS:

1. A three-dimensional object modeling method, comprising:

a plane contour extraction step, wherein for at least ~~two~~one panoramic images shot for each three-dimensional object of at least one three-dimensional object to be processed, a plane contour of the at least ~~two~~one panoramic images of each three-dimensional object in a three-dimensional space is extracted;

a scale normalization step, wherein a scale of the plane contour of the at least ~~two~~one panoramic images of each three-dimensional object in the three-dimensional space is normalized based on a camera position, to obtain normalized plane contours of respective panoramic images in the three-dimensional space; and

a multi-object splicing step, wherein based on the camera position, rotation and translation operations are performed on three-dimensional point coordinates of the normalized plane contours of the respective panoramic images in the three-dimensional space, so as to unify the three-dimensional point coordinates in same one coordinate system, to splice plane contours of respective three-dimensional objects into a multi-object plane contour.

2. The three-dimensional object modeling method according to claim 1, wherein the plane contour extraction step comprises:

a camera position acquisition step, wherein according to a geometric relationship of at least two panoramic images shot for each three-dimensional object of the at least one three-dimensional object to be processed, the camera position of a panoramic camera when shooting each panoramic image of the at least two panoramic images of each three-dimensional object and three-dimensional point coordinates of matching feature points on each panoramic image are obtained;

a single-image plane contour generation step, wherein for each panoramic image of the at least two panoramic images of each three-dimensional object, a plane contour of the panoramic image in the three-dimensional space is generated based on a contour surrounded by edge pixels in pixels, whose contour features belong to a specific category, on the

panoramic image,

wherein the specific category comprises at least a top portion, a bottom portion, and a support portion of a three-dimensional object in the panoramic image.

5 3. The three-dimensional object modeling method according to claim 2, wherein the single-image plane contour generation step comprises:

based on a feature similarity among pixels on each panoramic image of the at least two panoramic images of each three-dimensional object, determining the edge pixels in the pixels, whose contour features belong to the specific category, on each panoramic image of the at
10 least two panoramic images of each three-dimensional object,

wherein a feature similarity of two pixels is an absolute value of a difference between features of the two pixels, and features of each pixel comprise grayscale and color.

15 4. The three-dimensional object modeling method according to claim 1, wherein the plane contour extraction step comprises:

a camera position acquisition step, wherein according to a geometric relationship of at least two panoramic images shot for each three-dimensional object of the at least one three-dimensional object to be processed, the camera position of a panoramic camera when shooting each panoramic image of the at least two panoramic images of each
20 three-dimensional object and three-dimensional point coordinates of matching feature points on each panoramic image are obtained; and

a single-image plane contour generation step, wherein for each panoramic image of the at least two panoramic images of each three-dimensional object, a plane contour of the panoramic image in the three-dimensional space is extracted through a deep learning model
25 used for extracting an image contour.

5. The three-dimensional object modeling method according to claim 4, wherein the deep learning model is trained in a following manner:

by manually labeling contour features of three-dimensional objects of a type of interest
30 on a plurality of panoramic images serving as training images, generating a contour feature

training data set of the three-dimensional objects of the type of interest; and

training the deep learning model using the contour feature training data set of the three-dimensional objects of the type of interest, to obtain a trained deep learning model,

wherein an output of the deep learning model comprises categories of the contour
 5 features of the three-dimensional objects of the type of interest.

6. The three-dimensional object modeling method according to claim 5, wherein the single-image plane contour generation step comprises:

inputting the at least two panoramic images of each three-dimensional object into the
 10 trained deep learning model to obtain a category of a contour feature corresponding to each pixel in the at least two panoramic images of each three-dimensional object;

extracting edge pixels that are at edges among pixels, whose contour features belong to a specific category, on each panoramic image of the at least two panoramic images of each three-dimensional object as specific category edge pixels;

15 assuming that all specific category edge pixels on each panoramic image of the at least two panoramic images of each three-dimensional object have the same height h_c that serves as an assumed contour height of a contour of the specific category, projecting the specific category edge pixels on each panoramic image onto a three-dimensional plane to obtain specific category three-dimensional points corresponding to each panoramic image, and then
 20 forming a plane contour of each panoramic image in the three-dimensional space based on the specific category three-dimensional points corresponding to each panoramic image,

wherein the specific category comprises a top portion of a three-dimensional object in the panoramic image.

25 7. The three-dimensional object modeling method according to any one of claims 2-6, wherein the camera position is obtained in the camera position acquisition step,

the camera position acquisition step comprises:

obtaining a video stream and a timestamp corresponding to at least one panoramic
 image of each three-dimensional object;

30 determining at least one video frame corresponding to the at least one panoramic

image of each three-dimensional object in the video stream based on the timestamp; and
 determining the camera position of the panoramic camera when shooting the at least
 one panoramic image of each three-dimensional object according to a position of the at
 least one video frame.

5

8. The three-dimensional object modeling method according to any one of claims 2-6,
 wherein the camera position is predetermined or obtained in the camera position acquisition
 step,

the camera position acquisition step comprises:

10

using a geometric relationship of at least two panoramic images shot for each
 three-dimensional object of the at least one three-dimensional object to be processed,
 performing feature point matching between the at least two panoramic images of each
 three-dimensional object, and recording feature points that match with each other in the
 at least two panoramic images of each three-dimensional object as the matching feature
 points; and

15

for each panoramic image of the at least two panoramic images of each
 three-dimensional object, reducing reprojection errors of the matching feature points on
 each panoramic image to obtain the camera position of the panoramic camera when
 shooting each panoramic image and the three-dimensional point coordinates of the
 matching feature points on each panoramic image.

20

9. The three-dimensional object modeling method according to claim 8, wherein the
 scale normalization step comprises:

in a case where the camera position is obtained in the camera position acquisition step,

25

sorting from small to large height values of all three-dimensional point coordinates,
 which are obtained when the camera position is obtained, on at least one panoramic image of
 each three-dimensional object, and taking a median value or an average value of the height
 values sorted in front as an extracted contour height h_c' of the contour of the specific category;
 and according to a ratio of the assumed contour height h_c of the contour of the specific
 category to the extracted contour height h_c' of the contour of the specific category, generating

30

normalized plane contours of at least two panoramic images of each three-dimensional object in the three-dimensional space based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space; and

in a case where the camera position is a camera definition height H_c that is predetermined,

according to a ratio of a camera assumed height H_e that is assumed to the camera definition height H_c , generating normalized plane contours of at least two panoramic images of each three-dimensional object in the three-dimensional space based on the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space,

wherein the assumed contour height h_c of the contour of the specific category is an arbitrarily assumed height.

10. The three-dimensional object modeling method according to any one of claims 1-9, after the scale normalization step, further comprising a single-object plane contour generation step, which comprises:

for at least two panoramic images shot for the at least one three-dimensional object to be processed, determining whether there are a plurality of panoramic images belong to the same three-dimensional object one by one in a following method: if there are matching feature points, a ratio of which is more than a specific ratio, between two panoramic images, then it is determined that the two panoramic images belong to a same three-dimensional object; and

if it is determined that the plurality of panoramic images belong to the same three-dimensional object, for respective plane contours of the same three-dimensional object obtained according to the plurality of panoramic images, a union of all the plane contours of the same three-dimensional object is taken as a plane contour of the three-dimensional object in the three-dimensional space.

11. The three-dimensional object modeling method according to claim 10, wherein in the multi-object splicing step, the multi-object plane contour in the three-dimensional space is obtained by splicing based on the plane contours of respective single three-dimensional

objects in the three-dimensional space.

12. The three-dimensional object modeling method according to any one of claims 1-11, wherein the multi-object splicing step comprises:

5 assuming that there are N plane contours of all panoramic images in the three-dimensional space, a p-th three-dimensional point of an n-th plane contour is indicated as X_p^n , and the camera position where a panoramic image corresponding to the n-th plane contour is shot is indicated as $\{R_n, t_n\}$, where R_n is a rotation matrix used to represent a rotation parameter of the camera position, and t_n is a translation vector used to represent a translation parameter of the camera position, where N is an integer greater than 1, and n is an integer greater than or equal to 1,

selecting the camera position where a panoramic image corresponding to an i-th plane contour is shot as a reference coordinate system, and unifying the three-dimensional points of other plane contours under the reference coordinate system through a formula below:

$$15 \quad X_p^{n \rightarrow i} = R_i R_n^{-1} (X_p^n - t_n) + t_i, \text{ and}$$

converting all the three-dimensional points of the plane contours after the scale normalization except the i-th plane contour through the formula, to unify the three-dimensional points of all the plane contours under the same coordinate system, so as to splice the plane contours of the respective three-dimensional objects into the multi-object plane contour.

13. The three-dimensional object modeling method according to claim 12, wherein the three-dimensional object modeling method further comprises:

a multi-object contour optimization step, wherein a distance between adjacent edges of two single-object plane contours in the multi-object plane contour is calculated, and if the distance is non-zero and less than a certain threshold, the two single-object plane contours are shifted to make the distance between the adjacent edges become to zero.

14. The three-dimensional object modeling method according to any one of claims 1-13,

further comprising:

a 3D model generation step, wherein after the multi-object splicing step, the multi-object plane contour obtained by splicing in the three-dimensional space is converted into a multi-object 3D model.

5

15. The three-dimensional object modeling method according to claim 14, wherein the 3D model generation step comprises:

performing three-dimensional point interpolation on an inside of a top plane contour of the multi-object plane contour obtained by splicing, and projecting all obtained
10 three-dimensional point coordinates on respective top plane contours into a corresponding panoramic image coordinate system to obtain a top texture;

performing the three-dimensional point interpolation on an inside of a bottom plane contour of the multi-object plane contour obtained by splicing, and projecting all obtained three-dimensional point coordinates on respective bottom plane contours into the
15 corresponding panoramic image coordinate system to obtain a bottom texture;

connecting three-dimensional vertices on the same plane position between the top plane contour and the bottom plane contour to form a plane contour of a support portion, performing the three-dimensional point interpolation on an inside of the plane contour of the support portion, and projecting all obtained three-dimensional point coordinates of the plane
20 contours of respective support portions into the corresponding panoramic image coordinate system to obtain a support portion texture; and

generating a 3D texture model of the entire three-dimensional object based on the top texture, the bottom texture, and the support portion texture.

25 16. The three-dimensional object modeling method according to claim 15, wherein in the 3D model generation step, a height value of an extracted height, which is taken as the extracted contour height h_c' of the contour of the specific category, from the camera to a top portion of a corresponding three-dimensional object in all the obtained three-dimensional point coordinates on the top plane contour of each three-dimensional object is replaced by an
30 extracted height h_f' from the camera to a bottom portion of the corresponding

three-dimensional object and length values and width values in all the obtained three-dimensional point coordinates on the top plane contour of each three-dimensional object remain unchanged, to obtain the bottom plane contour of each three-dimensional object,

5 the extracted contour height h_c' , which is a height from the camera to the top portion of the corresponding three-dimensional object, of the contour of the specific category is obtained in a following manner: sorting from small to large height values of all three-dimensional point coordinates, which are obtained when the camera position is obtained, on at least one panoramic image of each three-dimensional object, and taking a median value
10 or an average value of the height values sorted in front as the extracted contour height h_c' , which is the height from the camera to the top portion of the corresponding three-dimensional object, of the contour of the specific category, and

the extracted height h_f' from the camera to the bottom portion of the corresponding three-dimensional object is obtained in a following manner: sorting from small to large the
15 height values of all three-dimensional point coordinates, which are obtained when the camera position is obtained, on the at least one panoramic image of each three-dimensional object, and taking a median value or an average value of the height values sorted in rear as the extracted height h_f' from the camera to the bottom portion of the corresponding three-dimensional object.

20

17. An image processing method, comprising:

a camera position acquisition step, wherein using a geometric relationship of at least two panoramic images shot for each three-dimensional object of at least one three-dimensional object to be processed, a position of a panoramic camera when shooting the at least two
25 panoramic images of each three-dimensional object and three-dimensional point coordinates of matching feature points on the at least two panoramic images of each three-dimensional object are obtained;

a single-image plane contour generation step, wherein for each panoramic image of the at least two panoramic images of each three-dimensional object, a plane contour of the
30 panoramic image in the three-dimensional space is generated based on a contour surrounded

by edge pixels in pixels, whose contour features belong to a specific category, on the panoramic image; and

a scale normalization step, wherein a scale of the position that is obtained of the panoramic camera when shooting the at least two panoramic images of each three-dimensional object and scales of the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space are normalized, to obtain normalized plane contours of respective panoramic images in the three-dimensional space.

18. An image processing method, comprising:

a camera position acquisition step, wherein using a geometric relationship of at least two panoramic images shot for each three-dimensional object of at least one three-dimensional object to be processed, a position of a panoramic camera when shooting the at least two panoramic images of each three-dimensional object and three-dimensional point coordinates of matching feature points on the at least two panoramic images of each three-dimensional object are obtained;

a single-image plane contour generation step, wherein for each panoramic image of the at least two panoramic images of each three-dimensional object, a plane contour of each panoramic image in the three-dimensional space is extracted through a deep learning model used for extracting an image contour; and

a scale normalization step, wherein a scale of the position, which is obtained, of the panoramic camera when shooting the at least two panoramic images of each three-dimensional object and scales of the plane contours of the at least two panoramic images of each three-dimensional object in the three-dimensional space are normalized, to obtain normalized plane contours of respective panoramic images in the three-dimensional space.

19. An image processing device, comprising:

a processor; and

a memory, having executable codes stored thereon, wherein when the executable codes

are executed by the processor, the processor is caused to execute the method according to any one of claims 1-16.

20. A three-dimensional object modeling method, comprising:

5 an image processing step, wherein using the image processing method according claim 17 or 18, image processing is performed on at least one panoramic image of each three-dimensional object, to obtain normalized plane contours of respective panoramic images in the three-dimensional space; and

10 a multi-object splicing step, wherein based on the normalized plane contours of the respective panoramic images in the three-dimensional space, a multi-object plane contour is obtained by splicing.

21. The three-dimensional object modeling method according to claim 20, further comprising:

15 a single-object plane contour generation step, wherein plane contours of respective single three-dimensional objects in the three-dimensional space are obtained based on the normalized plane contours of the respective panoramic images obtained in the image processing step.