CLAIMS

1. A calibration method for a sensor, wherein the sensor comprises a radar and a camera, and a first calibration plate is located within a common field of view range of the radar and the camera, the method comprising:

collecting a plurality of first images by the camera, wherein position-orientation information of the first calibration plate in respective position-orientations in the plurality of first images is different;

obtaining a first intrinsic parameter of the camera calibrated in advance;

respectively determining an extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera according to the first intrinsic parameter and the plurality of first images;

obtaining multiple sets of radar point cloud data of the first calibration plate in the respective position-orientations; and

determining a target extrinsic parameter between the radar and the camera according to the extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera and the multiple sets of radar point cloud data.

2. The calibration method according to claim 1, wherein, before obtaining the first intrinsic parameter of the camera calibrated in advance, the calibration method further comprises:

in response to determining that an initial calibration of the sensor is being performed for a first time, calibrating the camera to obtain the first intrinsic parameter of the camera, and

wherein obtaining the first intrinsic parameter of the camera calibrated in advance comprises:

in response to calibrating the sensor again, obtaining the first intrinsic parameter of the camera obtained by the initial calibration of the sensor.

3. The calibration method according to claim 2, wherein a second calibration plate is located within a field of view range of the camera, and

wherein calibrating the camera to obtain the first intrinsic parameter of the camera comprises:

collecting a plurality of second images by the camera, wherein position-orientation information of the second calibration plate in the plurality of second images is different;

respectively determining a plurality of first candidate intrinsic parameters of the camera according to the plurality of second images, wherein each of the plurality of second images corresponds to a respective one of the plurality of first candidate intrinsic parameters; and

determining one of the plurality of first candidate intrinsic parameters as the first intrinsic parameter.

4. The calibration method according to claim 3, wherein determining one of the plurality of first candidate intrinsic parameters as the first intrinsic parameter comprises:

projecting, by the camera, a preset point located in a camera coordinate system to a pixel coordinate system according to the plurality of first candidate intrinsic parameters, to obtain a plurality of first coordinate values of the preset point in the pixel coordinate system;

for each of the plurality of first candidate intrinsic parameters, obtaining a second coordinate value of the preset point in a verification image, and determining a first coordinate value corresponding to the second coordinate value to obtain a set of coordinate pairs with a corresponding relationship, wherein the verification image comprises one or more of the plurality of second images;

for each of the plurality of first candidate intrinsic parameters, determining a respective distance between the first coordinate value and the second coordinate value in the set of coordinate pairs included in the first candidate intrinsic parameter; and

determining a first candidate intrinsic parameter with a smallest distance among the respective distances for the plurality of first candidate intrinsic parameters as the first intrinsic parameter of the camera.

5. The method according to any one of claims 1 to 4, wherein respectively determining the extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera according to the first intrinsic parameter and the plurality of first images comprises:

for each of the plurality of first images, performing de-distortion processing on the first image according to the first intrinsic parameter to obtain a third image corresponding to the first image;

determining a second intrinsic parameter of the camera according to a plurality of third images corresponding to the plurality of first images; and

respectively determining the extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera according to the plurality of the third images and the second intrinsic parameter of the camera.

6. The method according to claim 5, wherein respectively determining the extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera according to the plurality of the third images and the second intrinsic parameter of the camera comprises:

determining a respective homography matrix corresponding to each of the plurality of the third images to obtain a plurality of respective homography matrices; and

determining the extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera according to the second intrinsic parameter of the camera and the plurality of respective homography matrices.

7. The method according to claim 6, wherein determining the target extrinsic parameter between the radar and the camera according to the extrinsic parameter of the first calibration plate in each of the respective position-orientations relative to the camera and the multiple sets of radar point cloud data comprises:

for the first calibration plate in each of the respective position-orientations, determining a set of target radar point cloud data matching the first calibration plate from the multiple sets of radar point cloud data in the position-orientation according to the extrinsic parameter of the first calibration plate in the position-orientation relative to the camera and an extrinsic parameter reference value between the radar and the camera; and

determining the target extrinsic parameter between the radar and the camera according to matching relationships between multiple sets of target radar point cloud data and the first calibration plate in the respective position-orientations.

8. The method according to claim 7, wherein determining the set of target radar point cloud data matching the first calibration plate from multiple sets of radar point cloud data in the position-orientation according to the extrinsic parameter of the first calibration plate in the position-orientation relative to the camera and the extrinsic parameter reference value between the radar and the camera comprises:

determining a candidate position where the first calibration plate is located according to the extrinsic parameter of the first calibration plate in the position-orientation relative to the camera and the extrinsic parameter reference value between the radar and the camera;

determining a target plane where the first calibration plate is located from the multiple sets of radar point cloud data in the position-orientation according to the candidate position; and

determining the set of target radar point cloud data matching the first calibration plate on the target plane corresponding to the multiple sets of radar point cloud data in the position-orientation.

9. The method according to claim 8, wherein determining the target plane where the first calibration plate is located from the multiple sets of radar point cloud data in the position-orientation according to the candidate position comprises:

determining two or more first radar groups from the multiple sets of radar point cloud data in the position-orientation, wherein each of the two or more first radar groups comprises a plurality of first radar points randomly selected and located in an area corresponding to the candidate position;

for each of the two or more first radar groups, determining a first plane corresponding to the first radar group, wherein the first plane corresponding to the first radar group comprises a plurality of first radar points of the first radar group;

for each of the first planes for the two or more first radar groups, respectively determining distances from other radar points except the plurality of first radar points in the multiple sets of radar point cloud data in the position-orientation to the first plane;

for each of the first planes, determining radar points with a distance less than a threshold among the other radar points as second radar points;

for each of the first planes, determining the second radar points as radar points included in the first plane; and

determining a first plane comprising a largest number of radar points as the target plane among the two or more of the first planes.

10. The method according to claim 8 or 9, wherein determining the set of target radar point cloud data matching the first calibration plate on the target plane corresponding to the multiple sets of radar point cloud data in the position-orientation comprises:

determining an initial first circular area according to a size of the first calibration plate on the target plane;

randomly selecting a radar point located in the initial first circular area from the multiple sets of radar point cloud data as a first center of a first circular area to determine a position of the first circular area in the multiple sets of radar point cloud data;

respectively obtaining a plurality of first vectors by taking the first circle center as a starting point and a plurality of third radar points located in the first circular area in the multiple sets of radar point cloud data as ending points;

adding the plurality of first vectors to obtain a second vector;

determining a target center position of the first calibration plate based on the second vector; and

determining the set of target radar point cloud data matching the first calibration plate from the multiple sets of radar point cloud data according to the target center position of the first calibration plate and the size of the first calibration plate.

11. The method according to claim 10, wherein determining the target center position of the first calibration plate based on the second vector comprises:

determining an ending point of the second vector as a second circle center, and determining a second circular area according to the second circle center and the size of the first calibration plate;

respectively determining a plurality of third vectors by taking the second circle center as a starting point and a plurality of fourth radar points located in the second circular area in the multiple sets of radar point cloud data as ending points;

adding the plurality of third vectors to obtain a fourth vector;

determining whether a vector value of the fourth vector converges to a preset value;

if the vector value of the fourth vector converges to the preset value, determining the second circle center corresponding to the fourth vector which converges as a candidate center position of the first calibration plate; and

if the candidate center position is coincident with a center position of the first calibration plate, determining the candidate center position as the target center position.

12. The method according to claim 11, further comprising:

if the vector value of the fourth vector does not converge to the preset value, determining an ending point of the fourth vector which does not converge as the second circle center, and redetermining the plurality of third vectors and the fourth vector.

13. The method according to claim 11, further comprising:

if the candidate center position is not coincident with the center position of the first calibration plate, redetermining the candidate center position.

14. The method according to any one of claims 7 to 13, wherein determining the target extrinsic parameter between the radar and the camera according to the matching relationships between multiple sets of the target radar point cloud data and the first calibration plate in the position-orientations comprises:

determining a candidate extrinsic parameter between the radar and the camera according to g matching relationships, wherein g is an integer greater than or equal to 3; and

determining the target extrinsic parameter between the radar and the camera according to a plurality of the candidate extrinsic parameters between the radar and the camera.

15. The method according to claim 14, wherein determining the target extrinsic parameter between the radar and the camera according to the plurality of the candidate extrinsic parameters between the radar and the camera comprises:

projecting, by the radar, the first calibration plate onto a first image of the plurality of first images based on each of the plurality of candidate extrinsic parameters to generate a respective set of projection data;

determining a set of projection data having a highest matching degree with the first image among the respective sets of projection data corresponding to the plurality of candidate extrinsic parameters as target projection data; and

determining a candidate extrinsic parameter corresponding to the target projection data as the target extrinsic parameter between the radar and the camera.

16. The method according to any one of claims 1 to 15, wherein the radar and the camera are deployed on a vehicle, and the radar is a lidar.

17. The method according to claim 16, wherein a second calibration plate is located within a field of view range of the camera and is configured to calibrate the first intrinsic parameter of the camera,

wherein a distance between the camera and a ground is greater than a distance between the radar and the ground,

wherein a horizontal distance between the second calibration plate and the camera is less than a horizontal distance between the first calibration plate and the camera, and

wherein a plurality of second images collected using the second calibration plate comprise a complete second calibration plate.

18. The method according to any one of claims 1 to 17, wherein the plurality of first images comprise a complete first calibration plate, and the multiple sets radar point cloud data comprise point cloud data obtained based on the complete first calibration plate.

19. A calibration apparatus for a sensor, comprising:

a processor;

a memory for storing executable instructions of the processor;

wherein the processor is configured to invoke the executable instructions to implement the calibration method for a sensor according to any one of claims 1 to 18.

20. A calibration system, comprising a camera, a radar and a first calibration plate, wherein the first calibration plate is located within a common field of view range of the camera and the radar, and position-orientation information of the first calibration plate at different collection times is different.