CLAIMS

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

collecting a plurality of images of the calibration plate in respective position-orientations by the camera;

collecting multiple sets of radar point cloud data of the calibration plate in the respective position-orientations by the radar;

establishing corresponding relationships between the plurality of images and the multiple sets of radar point cloud data based on the respective position-orientations of the calibration plate, wherein, for each of the respective position-orientations of the calibration plate, a corresponding relationship exists between an image of the plurality of images and a set of the multiple sets of radar point cloud data that are collected in the respective position-orientations of the calibration plate;

respectively determining multiple sets of target radar point cloud data matched with the calibration plate in the respective position-orientations among the multiple sets of radar point cloud data; and

determining a target extrinsic parameter between the radar and the camera according to the multiple sets of target radar point cloud data and multiple sets of corresponding relationships.

2. The method according to claim 1, wherein respectively determining of the multiple sets of target radar point cloud data matched with the calibration plate in the respective position-orientations among the multiple sets of radar point cloud data comprises:

obtaining an intrinsic parameter of the camera calibrated in advance;

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

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

3. The method according to claim 2, wherein determining the set of target radar point cloud data matched with the calibration plate in the position-orientation among the multiple sets of radar point cloud data according to the extrinsic parameter of the calibration plate relative to the camera and the extrinsic parameter reference value between the radar and the camera comprises:

determining a candidate position of the calibration plate in the position-orientation among the multiple sets of radar point cloud data according to the extrinsic parameter of the calibration plate relative to the camera and an extrinsic parameter reference value between the radar and the camera;

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

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

4. The method according to claim 3, wherein determining the target plane where the calibration plate is located in the position-orientation among the multiple sets of radar point cloud data according to the candidate position comprises:

determining a plurality of first radar groups among the multiple sets of radar point cloud data in the position-orientation, wherein each of the plurality of first radar groups comprises a plurality of first radar points randomly selected and located in an area corresponding to the candidate position, and parts of the plurality of first radar points included in different first radar groups are same or different;

for each of the plurality of first radar group, 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 plurality of first radar groups, determining distances from other radar points except the plurality of the 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 having 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 first planes.

5. The method according to claim 3 or 4, wherein determining the set of target radar point cloud data matched with the 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 calibration plate on the target plane;

selecting a radar point located in the initial first circular area among 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 calibration plate based on the second vector; and

determining the set of target radar point cloud data matched with the calibration plate among the multiple sets of radar point cloud data according to the target center position of the calibration plate and the size of the calibration plate.

6. The method according to claim 5, wherein determining the target center position of the calibration plate based on the second vector comprises:

taking 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 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;

in response to determining that the vector value of the fourth vector does not converge to the preset value, taking 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;

in response to determining that the vector value of the fourth vector converges to the preset value, taking the second circle center corresponding to the fourth vector which converges as a candidate center position of the calibration plate; and

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

7. The method according to claim 6, further comprising:

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

8. The method according to any one of claims 1 to 7, wherein each of the multiple sets of corresponding relationships comprises a plurality of corresponding relationships, and parts of the plurality of corresponding relationships included in different sets of corresponding relationships are the same or different, and

wherein determining the target extrinsic parameter between the radar and the camera according to the multiple sets of target radar point cloud data and the multiple sets of corresponding relationships comprises:

respectively determining a plurality of candidate extrinsic parameters between the radar and the camera according to the multiple sets of target radar point cloud data and the multiple sets of corresponding relationships; and

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

9. The method according to claim 8, wherein determining the target extrinsic parameter between the radar and the camera according to the plurality of candidate extrinsic parameters comprises:

projecting the calibration plate on one of the plurality of images by the radar based on each of the plurality of candidate extrinsic parameters to generate a set of projection data;

determining a set of projection data having a highest matching degree with the image among multiple sets of projection data 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.

10. The method according to any one of claims 1 to 9, wherein the radar and the camera are deployed on a vehicle.

11. The method according to any one of claims 1 to 10, wherein the plurality of images comprise a complete calibration plate, and the multiple sets of radar point cloud data comprise point cloud data obtained based on the complete calibration plate.

12. The method according to any one of claims 1 to 11, wherein the radar comprises a lidar, and a laser line emitted by the lidar intersects a plane where the calibration plate is located.

13. The method according to any one of claims 1 to 12, wherein the calibration plate in the respective position-orientations comprises: a calibration plate which is different from a distance between the camera and the radar and/or an orientation in a horizontal direction.

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

a collecting module configured to collect a plurality of images of the calibration plate in respective position-orientations by the camera, and collect multiple sets of radar point cloud data of the calibration plate in the respective position-orientations by the radar;

a first determining module configured to establish corresponding relationships between the plurality of images and the multiple sets of radar point cloud data based on the respective position-orientations of the calibration plate, wherein, for each of the respective position-orientations of the calibration plate, a corresponding relationship exists between an image of the plurality of images and a set of the multiple sets of radar point cloud data that are collected in the respective position-orientations of the calibration plate;

a second determining module configured to respectively determine multiple sets of target radar point cloud data matched with the calibration plate in the respective position-orientations among the multiple sets of radar point cloud data; and

a third determining module configured to determine a target extrinsic parameter between the radar and the camera according to the multiple sets of target radar point cloud data and multiple sets of corresponding relationships.

15. The apparatus according to claim 14, wherein the second determining module is further configured to:

obtain an intrinsic parameter of the camera calibrated in advance;

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

for the calibration plate in each of the respective position-orientations, determine a set of target radar point cloud data matched with the calibration plate in the position-orientation among the multiple sets of radar point cloud data according to the extrinsic parameter of the calibration plate relative to the camera and an extrinsic parameter reference value between the radar and the camera.

16. The apparatus according to claim 15, wherein the second determining module is further configured to:

determine a candidate position of the calibration plate in the position-orientation among the multiple sets of radar point cloud data according to the extrinsic parameter of the calibration plate relative to the camera and an extrinsic parameter reference value between the radar and the camera;

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

determine the set of target radar point cloud data matched with the calibration plate in the position-orientation on the target plane corresponding to the multiple sets of radar point cloud data.

17. A computer readable storage medium having a computer program stored thereon, wherein the computer program, when being executed by a processor, causes the processor to implement the calibration method for a sensor according to any one of claims 1 to 13.

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

a processor; and

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 13.

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

20. A computer program product comprising computer readable codes, wherein the computer readable codes, when running on a device, cause the device to execute to implement the calibration method for a sensor according to any one of claims 1 to 13.