

DETECTION SYSTEM OF BUILDING SPACE STATE BASED ON LIDAR POINT CLOUD FEATURES AND DETECTION METHOD THEREOF

FIELD OF THE INVENTION

[0001] The present disclosure relates to a detection method of a building space state, and more particularly to a novel efficient detection system of a building space state based on LiDAR point cloud features and a detection method thereof.

BACKGROUND OF THE INVENTION

[0002] Autonomous Mobile Robots (AMRs) are increasingly utilized in a variety of industries and application to automate the moving and handling of various goods and materials. However, in most applications, AMRs can only operate in a single floor space or level in a building. This is due to the limited capability of AMRs to access, move in and out of and operate elevators.

[0003] Recent urban buildings have introduced smart elevators that can controlled by AMRs through various communication channels. The conventional smart elevator system includes a communication interface for getting elevator information, elevator call, elevator state monitoring, and call monitoring.

[0004] Challenges remain for AMR to access most elevators in urban buildings which do not have such communication interface. That is a legacy elevator. Recent work has proposed AMR that can ride a legacy elevator, but they require human intervention. Some proposed methods for AMR to ride legacy elevators without human intervention, but have limitations.

[0005] Therefore, there is a need of providing a detection system of a building space state based on LiDAR point cloud features and a detection method thereof, which is provided for an autonomous mobile robot (AMR) to utilized an elevator autonomously without human intervention and without communication interface with the building control system, so as to overcome the drawbacks of the conventional technologies.

SUMMARY OF THE INVENTION

[0006] An object of the present disclosure is to provide a detection system of a building space state based on LiDAR point cloud features and a detection method thereof. By detecting the state and the position of a building space base on LiDAR point cloud feature technology, it allows an autonomous mobile robot (AMR) to realize autonomous perception of a building space without human intervention and without communication interface with a building control system. The building space may include a bordered space, such as an elevator with an entrance. The detection method allows to find the elevator reference coordinates, the space state of elevator entrance area and the space state of the elevator inside area, detect human/obstacle inside/blocking the elevator and determine their location, and further perform exception state recognition. With the detection system and the detection method of the present disclosure, it facilitates AMR to autonomously perceive various elevator information and provide the reference coordinates of the elevator for the trajectory controller to take the elevator without a building space communication interface.

[0007] In accordance with an aspect of the present disclosure, a detection system of a building space state based on Lidar point cloud features is provided. The detection system includes a point cloud filtering and

segmentation module, a building space feature analysis module, an obstacle detection module and a building space state recognition module. The point cloud filtering and segmentation module receives LiDAR point cloud data of a building space relative to an autonomous mobile robot (AMR) for filtering, merging and segmenting the LiDAR point cloud data to obtain LiDAR point cloud features. The building space feature analysis module is connected to the point cloud filtering and segmentation module and configured to extract the LiDAR point cloud features and analyze reference coordinates relative to the AMR and an interior space size based on the point cloud features. The obstacle detection module is connected to the building space feature analysis module and configured to detect at least one obstacle in the building space relative to the AMR based on the point cloud features from the building space feature analysis module, so as to locate the at least one obstacle and obtain a speed and a direction of the at least one obstacle relative to the AMR. The building space state recognition module is connected to the building space feature analysis module and the obstacle detection module, and configured to recognize space states of the building space based on the reference coordinates, the interior space size, and the at least one obstacle detected.

[0008] In an embodiment, the building space includes a bordered space with an entrance, and the AMR and the at least one obstacle are allowed to enter or leave the bordered space through the entrance, wherein the point cloud data are obtained from LiDAR sensors on the AMR. The LiDAR point cloud data include a plural of point clouds, and a portion of the point clouds that diffract at object edges are filtered out.

[0009] In an embodiment, adjacent ones of the point clouds are merged into one point.

[0010] In an embodiment, the plurality of point clouds are arranged in order based on an original sensor return.

[0011] In an embodiment, the plurality of point clouds are segmented into several groups by using a clustering algorithm.

[0012] In an embodiment, the point cloud data include an entrance open feature and an entrance close feature.

[0013] In an embodiment, a continuous point cloud gap search is performed by the building space feature analysis module to extract the entrance open feature with several gaps.

[0014] In an embodiment, the entrance open feature is compared with a known entrance width to find the reference coordinates.

[0015] In an embodiment, an interior corner search is performed based on the reference coordinates to find the interior space size of the bordered space.

[0016] In an embodiment, a right-angle vertex search is performed by the building space feature analysis module to extract the entrance close feature with a regular geometric line segments and several right-angle vertices.

[0017] In an embodiment, the entrance close feature is compared with a known entrance width to find the elevator reference coordinates.

[0018] In accordance with an aspect of the present disclosure, a detection method of a building space state based on Lidar point cloud features is provided. The detection method includes steps of: (a) receiving LiDAR point cloud data of a building space relative to an autonomous mobile robot (AMR); (b) filtering, merging and segmenting a plurality of point clouds of the LiDAR point cloud data to obtain point cloud features; (c) extracting an entrance open feature or an entrance close feature based on

the point cloud features; (d) obtaining reference coordinates; and (e) recognizing space states of the building space based on when the entrance open feature is determined.

[0019] In an embodiment, the step (b) further includes steps of: (b1) filtering out a part of the point clouds that diffract at object edges; and (b2) merging adjacent ones of the point clouds into one point.

[0020] In an embodiment, the step (b) further includes steps of: (b3) arranging the plurality of point clouds in order based on an original sensor return; and (b4) segmenting the plurality of point clouds into several groups by using a clustering algorithm.

[0021] In an embodiment, the step (c) further includes steps of: (c1) performing a continuous point cloud gap search to extract the entrance opening feature with several gaps; and (c2) performing a right-angle vertex search to extract the entrance close feature with a regular geometric line segments and several right-angle vertices.

[0022] In an embodiment, the step (d) further includes a step of: (d1) comparing the entrance open feature or the entrance close feature with a known entrance width to find the reference coordinates.

[0023] In an embodiment, the building space includes a bordered space with an entrance, and the AMR is allowed to enter or leave the bordered space through the entrance, wherein the step (e) further includes steps of: (e1) performing an interior corner search based on the reference coordinates to find four internal corners of the bordered space when the entrance open feature is determined; and (e2) calculating an interior space size according to the four internal corners.

[0024] In an embodiment, the plurality of point clouds are divided into a part of bordered space area and a part of entrance area, and the step (e)

comprises a step of (e3) calculating an available space state of the bordered space area and the entrance area.

[0025] In an embodiment, the AMR decides to move inside the bordered space or wait for another free area of the bordered space to increase before entering the bordered space according to the available space state.

[0026] In an embodiment, the detection method further includes a step of (f) calculating a number of obstacles in the entrance area and the bordered space area.

[0027] In an embodiment the step of (f) further includes a step of (f1) calculating a direction and a speed of each one of the obstacles.

[0028] In an embodiment, the step of (f) further includes a step of (f2) using the space state of entrance area to estimate an entrance state.

[0029] In an embodiment, the step of (f) further includes a step of (f3) using obstacle information to calculate whether the entrance area is blocked by the obstacles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The above contents of the present disclosure will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

[0031] FIG. 1 is a block diagram illustrating a detection system of a building space state based on point cloud features according to an embodiment of the present disclosure;

[0032] FIG. 2 shows a process flow for finding the elevator entrance reference coordinates and the space state of entrance open;

[0033] FIG. 3 is a schematic diagram illustrating the elevator entrance opening scene;

- [0034]** FIG. 4 shows the point cloud data corresponding the elevator entrance opening scene of FIG. 3;
- [0035]** FIG. 5 shows a process flow for finding the elevator entrance reference coordinates and the space state of entrance close;
- [0036]** FIG. 6 is a schematic diagram illustrating the elevator entrance opening scene;
- [0037]** FIG. 7 shows the point cloud data corresponding the elevator entrance close scene of FIG. 6;
- [0038]** FIG. 8 shows a process flow for detecting the elevator space state;
- [0039]** FIG. 9 is a schematic diagram illustrating the elevator space state scene;
- [0040]** FIG. 10 shows the point cloud data corresponding the elevator space state scene of FIG. 9;
- [0041]** FIG. 11 shows a process flow for detecting human/obstacle inside/entrance the elevator and determining their location;
- [0042]** FIG. 12 shows a process flow for performing exception state recognition;
- [0043]** FIG. 13 is a schematic diagram illustrating the exception state recognition scene when the elevator entrance is closed;
- [0044]** FIG. 14 shows the point cloud data corresponding the exception state recognition scene of FIG. 13;
- [0045]** FIG. 15 is a schematic diagram illustrating the exception state recognition scene when the elevator entrance is opened; and
- [0046]** FIG. 16 shows the point cloud data corresponding the exception state recognition scene of FIG. 15.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0047] The present disclosure will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this disclosure are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

[0048] For an AMR to travel in a building space with limited size and monotonous features, sometimes it would be difficult to navigate using 3D machine vision or location-based sensors, such as cameras or GPS, since the computation load is heavy or the communication quality may be poor due to physical constraints of the space. For example, the communication quality can be very poor in elevators or underground basements, the GPS or cellular communication may not work. Also, landscape and lighting of such space may be simple and result in poor image quality for recognition. Comparing with 2D or 3D camera, the processing of image data and point cloud generation is significantly reduced if LiDAR is used. In addition, LiDAR has the advantage of insensitive to brightness of environment. Thus, for an AMR with limited computation power and communication capability, it would be more effective and efficient to identify state of building space with limited size and monotonous features, for example an elevator, by using LiDAR.

[0049] FIG. 1 is a block diagram illustrating a detection system of a building space state based on LiDAR point cloud features according to an embodiment of the present disclosure. In the embodiment, there provides a detection system 1 including a point cloud filtering and segmentation module 10, a building space feature analysis module 20, a building space state recognition module 30 and an obstacle detection module 40. The point cloud filtering and segmentation module 10 receives LiDAR point cloud data of a

building space that an autonomous mobile robot (AMR) travels and performs filtering, merging and segmentation of the LiDAR point cloud data to obtain LiDAR point cloud features of the building space. In the embodiment, the building space includes a bordered space with an entrance, and the AMR and at least one obstacle are allowed to enter or leave the bordered space through the entrance. In the following embodiments, the space nearby and internal to the elevator is taken as an example of the building space which may include an entrance area and an interior area, and the space inside the elevator is regarded as the bordered space which includes the interior area. Certainly, the present disclosure is not limited thereto. In the embodiment, the building space feature analysis module 20 is connected to the point cloud filtering and segmentation module 10 and configured to extract the LiDAR point cloud features and analyze reference coordinates relative to the AMR and an interior size of the bordered space based on the LiDAR point cloud features. The obstacle detection module 30 is connected to the elevator feature analysis module 20 and configured to detect at least one obstacle in the building space relative to the AMR based on the point cloud features extracted and analyzed through the building space feature analysis module 20, so as to find the at least one obstacle and obtain a speed and a direction of the at least one obstacle relative to the AMR. The building space state recognition module 40 is connected to the building space feature analysis module 20 and the obstacle detection module 30, and is configured to recognize space states of entrance area and interior area based on the reference coordinates, the interior space size, and the at least obstacle detected. With the detection system 1 of the present disclosure, the LiDAR sensors on the AMR is used to obtain LiDAR point cloud data, and it allows the AMR to determine the reference coordinates, the entrance open state, the

entrance close state, the space state of entrance area and the space state of the bordered space, detect human/obstacle inside the bordered space (e.g., inside the elevator) and determine their location, and further perform exception state recognition, for example, human blocking elevator entrance/exit, human blocking elevator space. It facilitates to realize autonomous perception of elevator state and landmark positioning for AMR to automatically ride elevators. Different from other conventional elevator state detection methods with sensors or communication devices disposed inside the elevator, the detection system 1 uses AMR's own LiDAR sensor to detect the elevator state with LiDAR point cloud data and feature analysis algorithm, which has higher accuracy and with wide measuring range.

[0050] Furthermore, in comparison to the prior art, the detection system 1 has the following advantages. 1). The detection system 1 can be used in various forms of building spaces with the bordered space, such as various elevators (including legacy elevators, intelligent elevator, etc.) garages, or storage rooms. 2). The algorithm works even in the absence of light sources. 3). The detection system 1 requires minimal core module functionality, high efficiency for building space feature and state extraction. 4). AMR has expanded from the original 2D navigation to 3D navigation. How the detection system 1 and the detection method of the present disclosure achieve the aforementioned functions will be described in detail below.

[0051] FIG. 2 shows a process flow for finding the elevator entrance reference coordinates and the space state of entrance in open. FIG. 3 is a schematic diagram illustrating the elevator entrance opening scene. FIG. 4 shows the point cloud data corresponding the elevator entrance opening scene of FIG. 3. Refer to FIG. 1 to FIG. 4. In the embodiment, upon the

AMR 9 reaches near the elevator 8 using a predefined floor map, the process in FIG. 2 is performed to find the entrance open feature and the reference coordinates of the elevator. AMR 9 can be used for positioning and control in the inner/outer area of the elevator. First of all, AMR 9 needs to obtain raw point cloud data from sensors 91 such as 2D/3D LiDAR (laser scanner). In other embodiments of the present disclosure, the sensor 91 can also include depth camera (3D camera) or binocular camera. Preferably but not exclusively, each point of the LiDAR point cloud data includes three-dimensional coordinates X, Y, Z, classification value, intensity value and time, and other information in the point data set under the elevator reference coordinate system.

[0052] In the embodiment, the point cloud preprocessing includes the following steps of: 1) filtering out a portion of the point clouds that diffract at object edges, and 2) merging adjacent ones of the point clouds into one point. Preferably but not exclusively, if the image-based 3D reconstruction technology is used, the point cloud data generated by the laser sensor has a higher amplitude and more noise in the point clouds data will be processed. If the number of point clouds is still too large, a down-sampling step is performed. Unnecessary calculations can be reduced greatly, thereby improving the speed of the program. A continuous point cloud feature shown in FIG. 4 is used for searching. In the embodiment, the plurality of LiDAR point clouds are arranged in order based on an original sensor return order. Furthermore, in case that the elevator entrance is opened, the plurality of point clouds are segmented into several groups G1, G2, G3 by using a clustering algorithm. In the embodiment, a continuous point cloud gap search is performed to extract the elevator entrance opening feature with several gaps G1', G2', G3'. Thereby, the elevator entrance open feature can

be determined by the building space feature analysis module 20. Furthermore, the elevator entrance open feature with a known elevator entrance width DW to find the elevator reference coordinates, such as the elevator entrance center DC in the gaps G1', G2', G3'. In the embodiment, a building space interior corner search is performed by the building space feature analysis module 20 based on the reference coordinates to find four internal corners CN1, CN2, CN3, CN4 of the elevator 8 when the elevator entrance open feature is determined. Preferably but not exclusively, the elevator reference coordinate ratio is used to find the four internal corners CN1, CN2, CN3, CN4 of the elevator internal features (even the parts that are blocked by humans can be predicted). Furthermore, an interior space size of the elevator is calculated according to the four internal corners CN1, CN2, CN3, CN4. From the above conditions, it can be estimated that the elevator entrance is opened through the analysis of the building space feature analysis module 20. Accordingly, it allows the AMR 9 to use the elevator reference coordinates to estimate the position of AMR 9 relative to the elevator 8. The AMR 9 can be positioned to approach the elevator entrance center DC, the elevator call button panel, and the elevator call button. Certainly, the present disclosure is not limited thereto.

[0053] FIG. 5 shows a process flow for finding the elevator entrance reference coordinates and the space state of entrance in close. FIG. 6 is a schematic diagram illustrating the elevator entrance close scene. FIG. 7 shows the point cloud data corresponding the elevator entrance close scene of FIG. 6. Refer to FIG. 1, and FIG. 5 to FIG. 7. In the embodiment, upon the AMR 9 reaches near the elevator 8 using a predefined floor map, the process in FIG. 5 is performed to find the entrance close feature and the reference coordinates of the elevator. AMR 9 can be used for positioning

and control in the inner/outer area of the elevator. First of all, AMR 9 needs to obtain raw point cloud data from sensors 91. In the embodiment, the point cloud preprocessing includes the following steps of: 1) filtering out a portion of the point clouds that diffract at object edges, and 2) merging adjacent ones of the point clouds into one point. A continuous point cloud feature shown in FIG. 7 is used to search. In the embodiment, the plurality of point clouds are arranged in order based on an original sensor return order. Furthermore, when the elevator entrance is closed, the plurality of point clouds are segmented into several groups G1 by using a clustering algorithm. In the embodiment, a right-angle vertex search is performed by the building space feature analysis module 20 to extract the elevator entrance close feature with a regular geometric line segments and several right-angle vertices. There are two right-angle vertices on both sides of the elevator entrance. Thereby, the elevator entrance close feature is determined. Furthermore, the elevator entrance close feature with a known elevator entrance width DW to find the elevator reference coordinates, such as the elevator entrance center DC. From the above conditions, it can be estimated that the elevator entrance is closed. Accordingly, it allows the AMR 9 to use the elevator reference landmarks to estimate the relative position of AMR 9. The AMR 9 can be positioned to approach the elevator entrance center DC, the elevator call button panel, and the elevator call button. Certainly, the present disclosure is not limited thereto.

[0054] FIG. 8 shows a process flow for detecting the elevator space state. FIG. 9 is a schematic diagram illustrating the elevator space state scene. FIG. 10 shows the point cloud data corresponding the elevator space state scene of FIG. 9. Refer to FIG. 1, FIG. 9 to FIG. 11. In the embodiment, upon the AMR 9 arrives near the elevator 8 using a predefined floor map, AMR 9

obtains the original point cloud data from the sensor 91. In the embodiment, AMR 9 can know the reference coordinates of the elevator 8 and the state of the elevator entrance according the above embodiments. In the embodiment, the detection system 1 further performs the process flow in FIG. 8 to determine the elevator space state, such as the space state of the elevator entrance area and the space state of the elevator interior area. Similarly, the plurality of point clouds are segmented into several groups by using a clustering algorithm. In the embodiment, the plurality of point clouds are divided into a first portion of interior area A1 and a second portion of entrance area A2, the two portions/areas are not identical or only partially overlapped. Thereafter, an available space state of the elevator interior area A1 and the entrance area A2 is determined. Namely, the space detection is used to analyze the available space as shown in FIG. 9 and FIG. 10. It allows the AMR 9 to recognize the space state of interior area A1 and the entrance area A through the building space state recognition module 40 and then decide to move into the elevator 8 or wait until the elevator 8 has sufficient free space before entering the elevator 8 according to the available space state. Certainly, the present disclosure is not limited thereto.

[0055] FIG. 11 shows a process flow for detecting human/obstacle inside/blocking the elevator and determining their location. Refer to FIG. 1, FIG. 9 to FIG. 11. In the embodiment, upon the AMR 9 arrives near the elevator 8 using a predefined floor map, AMR 9 obtains the original point cloud data from the sensor 91. In the embodiment, AMR 9 can know the reference coordinates of the elevator 8 and the space states of the elevator interior area and the elevator entrance area according the above embodiments. In the embodiment, the detection system 1 further performs the process flow in FIG. 11 to determine human/obstacle information (at entrance and inside),

such as the number of human/obstacles in the elevator entrance area and their speed and direction through the obstacle detection module 30. Similarly, the plurality of point clouds are segmented into several groups by using a clustering algorithm. Through selected human/obstacle grouping by the building space feature analysis module 20, a number of human/obstacles 7 in the elevator entrance area A2 and the elevator inside area A1 is calculated by the obstacle detection module 30. Furthermore, a human/obstacle speed and direction calculation is performed by the obstacle detection module 30 to calculate a direction and a speed of each one of the human/obstacles 7. In an embodiment, it allows the AMR 9 to use human/obstacle information to perform obstacle avoidance actions, so as to avoid collisions with objects. Certainly, the present disclosure is not limited thereto.

[0056] Notably, in the embodiment, the detection system 1 and the detection method of the present disclosure allows to perform exception state recognition. FIG. 12 shows a process flow for performing exception state recognition. FIG. 13 is a schematic diagram illustrating the exception state scene when the elevator entrance is closed. FIG. 14 shows the point cloud data corresponding the exception state scene of FIG. 13. FIG. 15 is a schematic diagram illustrating the exception state scene when the elevator entrance is opened. FIG. 16 shows the point cloud data corresponding the exception state scene of FIG. 15. Refer to FIG. 1, and FIG. 12 to FIG. 16. In the embodiment, upon the AMR 9 arrives near the elevator 8 using a predefined floor map, AMR 9 obtains the original point cloud data from the sensor 91. In the embodiment, the building space recognition module 40 of AMR 9 can know the reference coordinates of the elevator 8, the space states of the elevator, and the information of humans/obstacles according the above embodiments. In the embodiment, the space state of elevator entrance area

A1 is used to estimate a building space entrance state. Preferably but not exclusively, through a point cloud elevator inside and outside distribution determination, the elevator entrance state is determined. In an embodiment, there is no point clouds distributed in the elevator interior area A1, and the entrance close state is determined, as shown in FIG. 13, and FIG. 14. In an embodiment, there are several point clouds distributed in the elevator interior area A1, and the entrance open state is determined as shown in FIG. 15 and FIG. 16. In the embodiment, the human/obstacle information is used to calculate whether the elevator entrance area A2 is blocked by human/obstacle 7. In an embodiment, there are several point clouds distributed in the elevator entrance area A2 and located between the elevator entrance center DC and the AMR 9, and it is determined that the elevator entrance is blocked by human/obstacle 7, as shown in FIG. 13 and FIG. 14 or FIG. 15 and FIG. 16. Certainly, the present disclosure is not limited thereto, and not redundantly described hereafter.

[0057] In summary, the present disclosure provides a detection system of a building space state based on LiDAR point cloud features and a detection method thereof. By detecting the state and the position of a building space base on LiDAR point cloud feature technology, it allows an autonomous mobile robot (AMR) to realize autonomous perception of an building space without human intervention and without communication interface with a building control system. The building space may include a bordered space, such as an elevator with an entrance. The detection method allows to find the elevator reference coordinates, the space state of elevator entrance area and the space state of the elevator interior area, detect human/obstacle inside/entrance the elevator and determine their location, and further perform exception state recognition. With the detection system and the detection

method of the present disclosure, it facilitates AMR to autonomously perceive various elevator information and provide the reference coordinates of the elevator for the trajectory controller to take the elevator without a building space communication interface.

[0058] While the disclosure has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the disclosure needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

WHAT IS CLAIMED IS:

1. A detection system of a building space state, comprising:

a point cloud filtering and segmentation module, receiving LiDAR point cloud data of a building space relative to an autonomous mobile robot (AMR) for filtering, merging and segmenting the LiDAR point cloud data to obtain LiDAR point cloud features;

a building space feature analysis module connected to the point cloud filtering and segmentation module, and configured to extract the LiDAR point cloud features and analyze reference coordinates and an interior space size relative to the AMR based on the point cloud features;

an obstacle detection module connected to the elevator feature analysis module and configured to detect at least one obstacle in the building space relative to the AMR based on the point cloud features extracted and analyzed through the building space feature analysis module, and obtain a speed and a direction of the at least one obstacle relative to the AMR; and

a building space state recognition module connected to the building space feature analysis module and the obstacle detection module, and configured to recognize space states of the building space based on the reference coordinates, the interior space size, and the at least one obstacle detected.

2. The detection system according to claim 1, wherein the building space comprises a bordered space with an entrance, and the AMR and the at least one obstacle are allowed to enter or leave the bordered space through the entrance, wherein the point cloud data are obtained from LiDAR sensors on the AMR, the LiDAR point cloud data comprises a plural of point clouds, and a portion of the point clouds that diffract at object edges are filtered out.

3. The detection system according to claim 2, wherein adjacent ones of the point clouds are merged into one point, wherein the plurality of point

clouds are arranged in order based on an original sensor return order, and wherein the plurality of point clouds are segmented into several groups by using a clustering algorithm.

4. The detection system according to claim 2, wherein the point cloud data include an entrance open feature and an entrance close feature.

5. The detection system according to claim 4, wherein the building space feature analysis module is further configured to perform a continuous point cloud gap search to extract the entrance open feature with several gaps, wherein the entrance open feature is compared with a known entrance width to find the reference coordinates.

6. The detection system according to claim 5, wherein the building space feature analysis module is further configured to perform an interior corner search based on the reference coordinates to find the interior space size of the bordered space.

7. The detection system according to claim 4, the building space feature analysis module is further configured to perform a right-angle vertex search to extract the entrance close feature with a regular geometric line segments and several right-angle vertices.

8. The detection system according to claim 2, wherein the entrance close feature is compared with a known entrance width to find the elevator reference coordinates.

9. A detection method of a building space state, comprising steps of:

(a) receiving LiDAR point cloud data of a building space relative to an autonomous mobile robot (AMR);

(b) filtering, merging and segmenting a plurality of point clouds of the LiDAR point cloud data to obtain point cloud features;

(c) extracting an entrance open feature or an entrance close feature based

on the point cloud features;

(d) obtaining reference coordinates; and

(e) recognizing space states of the building space upon the entrance open feature is determined.

10. The detection method according to claim 9, wherein the step (b) further comprises steps of:

(b1) filtering out a portion of the point clouds that diffract at object edges; and

(b2) merging adjacent ones of the point clouds into one point;

(b3) arranging the plurality of point clouds in order based on an original sensor return order; and

(b4) segmenting the plurality of point clouds into several groups by using a clustering algorithm.

11. The detection method according to claim 9, wherein the step (c) further comprises steps of:

(c1) performing a continuous point cloud gap search to extract the entrance opening feature with several gaps; and

(c2) performing a right-angle vertex search to extract the entrance close feature with a regular geometric line segments and several right-angle vertices.

12. The detection method according to claim 9, wherein the step (d) further comprises a step of: (d1) comparing the entrance open feature or the entrance close feature with a known entrance width to find the reference coordinates.

13. The detection method according to claim 9, wherein the building space includes a bordered space with an entrance, and the AMR is allowed to enter or leave the bordered space through the entrance, wherein the step (e) further comprises steps of:

(e1) performing an interior corner search based on the reference coordinates to find four internal corners of the bordered space upon the entrance open feature is determined; and

(e2) calculating an interior space size according to the four internal corners.

14. The detection method according to claim 13, wherein the plurality of point clouds are divided into a first portion of the bordered space area and a second portion of an entrance area, and the step (e) comprises a step of (e3) determining an available space state of the bordered space area and the entrance area.

15. The detection method according to claim 13, wherein the AMR is configured to decide whether to move into the bordered space according to the available space state.

16. The detection method according to claim 13, further comprising a step of (f) determining a number of obstacles in the entrance area and the bordered space area.

17. The detection method according to claim 16, wherein the step of (f) further comprises steps of:

(f1) calculating a direction and a speed of each one of the obstacles;

(f2) using the space state of the entrance area to estimate an entrance state;
and

(f3) using obstacle information to determine whether the entrance area is blocked by the obstacles.