Claims

1. A method of detecting a lane and a raised boundary of a routeway for a mobile object, comprising:

(i) receiving LiDAR data of an environment of the mobile object captured by a LiDAR device, the LiDAR data comprising a plurality of beams, each beam comprising a plurality of projected points each captured according to a common pitch angle of the LiDAR device;

(ii) identifying a plurality of break points, each break point of the plurality of break points being in a respective linearity of consecutive projected points of at least one beam from the plurality of beams;

(iii) locating edge points of the raised boundary from the plurality of identified break points;

(iv) extracting routeway marking edge points from the LIDAR data using adaptive thresholding; and

(v) locating lane edge points based on the extracted routeway marking edge points,

wherein locating the edge points of the raised boundary from the plurality of identified break points and locating the lane edge points based on the extracted routeway marking edge points comprises fitting parallel linear models to selected points of the plurality of identified break points and to selected points of the extracted routeway marking edge points respectively to simultaneously generate respective lane and raised boundary models.

2. The method of detecting a lane and a raised boundary of a routeway for a mobile object according to claim 1, wherein identifying each respective break point of the plurality of break points further comprises:

determining selected consecutive projected points of the at least one beam including a respective candidate break point;

determining at least one opposing projected point of the at least one beam;

determining an angle between a selected linearity of the selected consecutive points and an opposing linearity of the at least one opposing projected point and the respective candidate break point; and

identifying the respective break point based on the determined angle.

3. The method of detecting a lane and a raised boundary of a routeway for a mobile object according to claim 2, wherein determining the selected consecutive projected points of the at least one beam comprises:

determining first consecutive projected points of the at least one beam including the respective candidate break point;

determining second consecutive projected points of the at least one beam including the respective candidate break point;

comparing a first linearity of the first consecutive projected points with a second linearity of the second consecutive projected points; and

selecting the first or second consecutive projected points as the selected consecutive projected points based on the comparison.

4. The method of detecting a lane and a raised boundary of a routeway for a mobile object according to any one of the preceding claims, further comprising:

identifying height variations in selected projected points of the at least one beam adjacent to each of the identified break points in the at least one beam and filtering the identified plurality of break points based on the identified height variations.

5. The method of detecting a lane and a raised boundary of a routeway for a mobile object according to any one of the preceding claims, further comprising:

grouping identified plurality of break points into pairs based on a monotonic change in a height of the projected points of the at least one beam between the respective break points of each pair; and

locating upper and lower edge points of the raised boundary based on the grouped pairs.

6. The method of detecting a lane and a raised boundary of a routeway for a mobile object according to any one of the preceding claims, further comprising:

identifying a first plurality of break points, each break point of the first plurality of break points being in a respective linearity of consecutive projected points of a first beam from the plurality of beams;

identifying a second plurality of break points, each break point of the second plurality of break points being in a respective linearity of consecutive projected points of a second beam from the plurality of beams;

locating first edge points of the raised boundary from the identified first plurality of break points;

locating second edge points of the raised boundary from the identified second plurality of break points; and

determining a piece-wise representation of the raised boundary by tracing straight lines from each of the first edge points to a respective one of the second edge points.

7. The method of detecting a lane and a raised boundary of a routeway for a mobile object according to claim 1, wherein

fitting parallel linear models to selected points of the plurality of identified break points and to selected points of the extracted routeway marking edge points respectively to simultaneously obtain respective lane and raised boundary models comprises: applying random sample consensus (RANSAC) to optimize parameters of the parallel linear models with respect to the plurality of identified break points and the extracted routeway marking edge points, respectively.

8. A method of lane and raised boundary detection for a mobile object, comprising:

(i) determining a set of raised boundary edge candidates using LiDAR data of an environment of the mobile object captured by a LiDAR device, the LiDAR data comprising a plurality of beams, each beam comprising a plurality of projected points each captured according to a common pitch angle of the LiDAR device;

(ii) determining a set of lane marking edge candidates from the LiDAR data; and

(iii) fitting parallel linear models to selected candidates of the set of raised boundary edge candidates and to selected candidates of the set of lane marking edge candidates, respectively, to simultaneously generate lane and raised boundary models.

9. The method of lane and raised boundary detection for a mobile object according to claim 8, wherein:

fitting parallel linear models to selected candidates of the set of raised boundary edge candidates and selected candidates of the set of lane edge candidates to simultaneously generate lane and raised boundary models, respectively comprises: applying random sample consensus (RANSAC) to optimize parameters of the parallel linear models with respect to the determined set of raised boundary edge candidates and to the determined set of lane marking edge candidates, respectively.

10. A system for detecting a lane and a raised boundary of a routeway for a mobile object, the system comprising:

(i) a LiDAR device arranged to capture LiDAR data of an environment of the mobile object at a plurality of pitch angles, the LiDAR data comprising a plurality of beams, each beam comprising a plurality of projected points each captured according to a common pitch angle of the plurality of pitch angles;

(ii) a processor configured to:

a. identify a plurality of break points, each break point of the plurality of break points being in a respective linearity of consecutive projected points of at least one beam from the plurality of beams;
b. locate edge points of the raised boundary from the plurality of identified break points;
c. extract routeway marking edge points from the LiDAR data based on adaptive thresholding; and
d. locate lane edge points based on the extracted routeway marking edge points,

wherein the processor is configured to locate the edge points of the raised boundary from the plurality of identified break points and to locate the lane edge points based on the extracted routeway marking edge points by fitting parallel linear models to selected points of the plurality of identified break points and to selected points of the extracted routeway marking edge points respectively to simultaneously generate lane and raised boundary models.

11. The system for detecting a lane and a raised boundary of a routeway for a mobile object according to claim 10, wherein the processor is configured to identify each respective break point of the plurality of break points by:
determining selected consecutive projected points of the at least one beam including a respective candidate break point;
determining at least one opposing projected point of the at least one beam;
determining an angle between a selected linearity of the selected consecutive points and an opposing linearity of the at least one opposing projected point and the respective candidate break point; and
identifying the respective break point based on the determined angle.

12. The system for detecting a lane and a raised boundary of a routeway for a mobile object according to claim 11, wherein determining the selected consecutive projected points of the at least one beam comprises:
determining first consecutive projected points of the at least one beam including the respective candidate break point;
determining second consecutive projected points of the at least one beam including the respective candidate break point;
comparing a first linearity of the first consecutive projected points with a second linearity of the second consecutive projected points; and
selecting the first or second consecutive projected points as the selected consecutive projected points based on the comparison.

13. The system for detecting a lane and a raised boundary of a routeway for a mobile object according to any one of claims 10 to 12, wherein the processor is further configured to identify height variations in selected projected points of the at least one beam adjacent to each of the plurality of identified break points and to filter the plurality of identified break points based on the identified height variations.

14. The system for detecting a lane and a raised boundary of a routeway for a mobile object according to any one of claims 10 to 13, wherein the processor is further configured to:
group the plurality of identified break points into pairs based on a monotonic change in a height of the projected points of the at least one beam between the respective break points of each pair; and
locate upper and lower edge points of the raised boundary based on the grouped pairs.

15. The system for detecting a lane and a raised boundary of a routeway for a mobile object according to any one of claims 10 to 14, wherein the processor is further configured to:

identify a first plurality of break points, each break point of the first plurality of break points being in a respective linearity of consecutive projected points of a first beam from the plurality of beams;

identify a second plurality of break points, each break point of the second plurality of break points being in a respective linearity of consecutive projected points of a second beam from the plurality of beams;

locate first edge points of the raised boundary from the identified first break points;

locate second edge points of the raised boundary from the identified second break points; and

determine a piece-wise representation of the raised boundary by tracing straight lines from each of the first edge points to a respective one of the second edge points.

16. The system for detecting a lane and a raised boundary of a routeway for a mobile object according to claim 10, wherein fitting parallel linear models respectively to selected points of the plurality of identified break points and to selected points of the extracted routeway marking edge points respectively to simultaneously generate lane and raised boundary models comprises: applying random sample consensus (RANSAC) to optimize parameters of the parallel linear models with respect to the plurality of identified break points and the extracted routeway marking edge points, respectively.

17. A mobile object comprising a system for detecting a raised boundary of a routeway for a mobile object according to any one of claims 10 to 16.

18. A computer readable medium storing instructions which, when executed by a processor, cause the processor to perform a method according to any one of claims 1 to 9.

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