CLAIMS

1. A visual odometry method comprising:

receiving a plurality of stereo image pairs captured by a stereo image camera, each stereo image pair comprising a first image captured by a first image sensor of the stereo image camera and a second image captured by a second image sensor of the stereo image camera;

for each first image of the plurality of stereo image pairs:

extracting point features;

matching the point features to a preceding key frame corresponding to a stereo image pair captured by the stereo image camera to obtain a set of matched point features;

extracting line features in the respective first image;

associating the line features with the point features to obtain a set of associated point-line features;

matching the associated point-line features to the preceding key frame using the matched point features to obtain matched point-line features;

determining an initial pose estimation using the matched point-line features; and

based on the initial pose estimation for the first image of a stereo image pair, determining if the stereo image pair corresponds to a key frame, and

for each key frame:

extracting point features from a second image of the key frame;

extracting line features in the second image of the key frame;

associating the line features with the point features to obtain a set of associated point-line features;

performing stereo point matching between respective points in the second image of the key frame and a first image of the key frame to obtain a set of stereo matched points;

performing stereo line matching using the associated point-line features and the set of stereo matched points to obtain a set of stereo matched lines;

performing triangulation using the set of stereo matched points and the set of stereo matched lines; and

determining a relative pose for the key frame based on the triangulation.

2. The method according to claim 1, wherein extracting line features in the respective first image comprises detecting line segments in the respective first image and merging the line segments in the respective first image, and extracting line features in the second image of the key frame comprises detecting line segments in the second image of the key frame and merging the line segments in the second image of the key frame.

3. The method according to claim 2, wherein merging the line segments comprises determining if an angular difference between a pair of line segments is smaller than a threshold angle and merging the pair of line segments if the angular difference is less than the threshold angle.

4. The method according to claim 2 or claim 3, wherein merging the line segments comprises determining if a distance between midpoints of a pair of line segments is less than a threshold distance and merging the pair of line segments if the distance between midpoints is less than the threshold distance.

5. The method according to any one of claims 2 to 4, wherein merging the line segments comprises determining, for a pair of line segments for which projections on an x-axis and a y-axis do not overlap, a distance between closest endpoints and merging the pair of line segments if the distance between closest endpoints is less than a separation threshold.

6. The method according to any one of claims 2 to 5, wherein extracting line features further comprises filtering line segments based on length.

7. The method according to any preceding claim, wherein determining if a stereo image pair corresponds to a key frame comprises determining if one or more of the following conditions are met:

a distance to the last key frame is larger than a key frame distance threshold;

an angle to the last key frame is larger than a key frame angle threshold;

a number of tracked map points is between a first map point threshold and a second map point threshold;

a number of tracked map points in a frame is less than the second map point threshold; and

the number of frames since the last key frame is greater than a threshold number of frames.

8. The method according to any preceding claim wherein extracting line features, associating the line features with the point features, and determining an initial pose estimation is performed in a first thread; and extracting point features, matching the point features to a preceding key frame, and matching the associated point-line features to the preceding key frame is performed in a second thread.

9. The method according to claim 8, wherein the first thread is executed in parallel with the second thread.

10. A computer readable medium carrying computer executable instructions which when executed on a processor cause the processor to perform a method according to any one of claims 1 to 9.

11. A visual odometry system comprising:

a stereo image camera configured to capture stereo image pairs, each stereo image pair comprising a first image captured by a first image sensor of the stereo image camera and a second image captured by a second image sensor of the stereo image camera; and

a processing unit configured to:

for each first image of the plurality of stereo image pairs:

extract point features;

match the point features to a preceding key frame corresponding to a stereo image pair captured by the stereo image camera to obtain a set of matched point features;

extract line features in the respective first image;

associate the line features with the point features to obtain a set of associated point-line features;

match the associated point-line features to the preceding key frame using the matched point features to obtain matched point-line features;

determine an initial pose estimation using the matched point-line features; and

based on the initial pose estimation for the first image of a stereo image pair, determine if the stereo image pair corresponds to a key frame, and

for each key frame:

extract point features from a second image of the key frame;

extract line features in the second image of the key frame;

associate the line features with the point features to obtain a set of associated point-line features;

perform stereo point matching between respective points in the second image of the key frame and a first image of the key frame to obtain a set of stereo matched points;

perform stereo line matching using the associated point-line features and the set of stereo matched points to obtain a set of stereo matched lines;

perform triangulation using the set of stereo matched points and the set of stereo matched lines; and

determine a relative pose for the key frame based on the triangulation.

12. The visual odometry system according to claim 11, wherein the processing unit is configured to extract line features in the respective first image by detecting line segments in the respective first image and merging the line segments in the respective first image, and extract line features in the second image of the key frame by detecting line segments in the second image of the key frame and merging the line segments in the second image of the key frame.

13. The visual odometry system according to claim 12, wherein the processing unit is configured to merge the line segments by determining if an angular difference between a pair of line segments is smaller than a threshold angle and merging the pair of line segments if the angular difference is less than the threshold angle.

14. The visual odometry system according to claim 12 or claim 13, wherein the processing unit is configured to merge the line segments by determining if a distance between midpoints of a pair of line segments is less than a threshold distance and merging the pair of line segments if the distance between midpoints is less than the threshold distance.

15. The visual odometry system according to any one of claims 12 to 14, wherein the processing unit is configured to merge the line segments by determining, for a pair of line segments for which projections on an x-axis and a y-axis do not overlap, a distance between closest endpoints and merging the pair of line segments if the distance between closest endpoints is less than a separation threshold.

16. The visual odometry system according to any one of claims 12 to 15, wherein the processing unit is configured to extract line features by filtering line segments based on length.

17. The visual odometry system according to any one of claims 11 to 16, wherein the processing unit is configured to determine if a stereo image pair corresponds to a key frame by determining if one or more of the following conditions are met:

a distance to the last key frame is larger than a key frame distance threshold;

an angle to the last key frame is larger than a key frame angle threshold;

a number of tracked map points is between a first map point threshold and a second map point threshold;

a number of tracked map points in a frame is less than the second map point threshold; and

the number of frames since the last key frame is greater than a threshold number of frames.

18. The visual odometry system according to any one of claims 11 to 17, wherein the processing unit is configured to extract line features, associate the line features with the point features, and determine an initial pose estimation in a first thread; and extract point features, match the point features to a preceding key frame, and match the associated point-line features to the preceding key frame in a second thread.

19. The visual odometry system according to claim 18, wherein the processing unit is configured to execute the first thread in parallel with the second thread.

20. The visual odometry system according to claim 18 or claim 19, wherein the processing unit comprises a central processing unit configured to execute the first thread and a graphics processing unit configured to execute the second thread.