Claims

1. A method of generating quantitative data for biliary tree structures from volumetric medical imaging scan data; the method comprising:

performing tubular enhancement on the volumetric medical imaging scan data to derive at least one tubeness measure for each voxel within the volumetric medical imaging scan data

performing segmentation of a volume of the medical imaging scan data to identify tubular biliary structures within the volume of the medical imaging scan data based at least partly on the at least one tubeness measure for each voxel;

for at least one segmented tubular biliary structure within the volume of the medical imaging scan data, computing at least one set of quantitative structural parameters for at least one location along the length of the tubular biliary structure; and

outputting quantitative biliary tree data comprising the at least one set of quantitative structural parameters for the at least one segmented tubular biliary structure.

2. The method of Claim 1, wherein the set of quantitative structural parameters comprises at least one parameter representative of at least one of:

a centre-line position of the at least one segmented tubular biliary structure at the at least one location;

a centre-line orientation of the at least one segmented tubular biliary structure at the at least one location;

a radius of the at least one segmented tubular biliary structure at the at least one location;

a diameter of the at least one segmented tubular biliary structure at the at least one location;

a cross-sectional orientation of the at least one segmented tubular biliary structure at the at least one location;

a cross-section profile of the at least one segmented tubular biliary structure at the at least one location;

an indication of the presence of a branching point for the at least one segmented tubular biliary structure at the at least one location; and

an orientation of a branching point for the at least one segmented tubular biliary structure at the at least one location.

3. The method of Claim 1 or Claim 2, wherein the method comprises determining centre-line positions at a plurality of locations along the length of the at least one segmented tubular biliary structure.

4. The method of Claim 3, wherein determining centre-line positions for the at least one segmented tubular biliary structure comprises:

identifying a starting centre-line point for the at least one segmented tubular biliary

structure;

identifying an ending centre-line point for the at least one segmented tubular biliary structure; and

incrementally from the starting centre-line point, determining successive centre-line points for the at least one segmented tubular biliary structure until the ending centre-line point is reached.

5. The method of Claim 4, wherein a successive centre-line point is determined by:

identifying a set of viable successor points;

evaluating a cost function for each point within the set of viable successor points; and

selecting a successive centre-line point from the set of viable successor points based on the cost functions therefor.

6. The method of any one of Claims 3 to 5, wherein the method further comprises, for each of the plurality of locations along the length of the at least one segmented tubular biliary structure, determining a tube-width estimation for the at least one segmented tubular biliary structure.

7. The method of Claim 6, wherein the tube-width estimation for each location is computed by determining a cross-sectional orientation of the at least one segmented tubular biliary structure at the respective location and determining a tube-width estimation for the at least one segmented tubular biliary structure in the determined cross-sectional orientation.

8. The method of Claim 6 or Claim 7, wherein the method further comprises detecting patterns of change within the at least one segmented tubular structure based on the tube-width estimations along the length of the at least one segmented tubular structure.

9. The method of Claim 8, wherein the method comprises detecting patterns of change within the at least one segmented tubular structure by applying at least one pattern detection window to the tube-width estimation data.

10. The method of Claim 8 or Claim 9, wherein the method comprises detecting at least one of:

strictures;

dilatations; and

beading.

11. The method of any one of the preceding Claims, wherein the method comprises:

identifying a first tubular biliary structure within the volume of the medical imaging scan data;

determining branch node locations along the length of the first tubular biliary structure; and

identifying further tubular biliary structures branching off from the branch nodes along the length of the first tubular biliary structure.

12. The method of Claim 11, wherein the method comprises recursively identifying further tubular biliary structures branching off from identified tubular biliary structures to derive a hierarchical biliary tree structure.

13. The method of Claim 12, wherein the method comprises computing at least one set of quantitative structural parameters for each location along the length of each identified tubular biliary structure.

14. The method of any preceding Claim , wherein the tubular enhancement comprises, for each voxel within the volume of the medical imaging scan data, computing at least one metric distinguishing tubular structures from other structures and computing a tubeness measure for the respective voxel based at least partly on the at least one metric.

15. The method of Claim 14, wherein the tubular enhancement comprises, for each voxel within the volume of the medical imaging scan data, computing a first metric distinguishing tubular structures from spherical structures and a second metric distinguishing tubular structures from plate-like structures, and computing a tubeness measure for the respective voxel based at least partly on the first metric, the second metric and a scan intensity value for the respective voxel.

16. The method of any one of any preceding Claim, wherein the method comprises using multi-scale Hessian based tubular biliary structure enhancement.

17. The method of any one of the preceding Claims, wherein the volumetric medical imaging scan data comprises imaging scan data obtained via a magnetic resonance imaging modality.

18. An image processing system arranged to generate quantitative data for biliary tree structures from volumetric medical imaging scan data, the image processing system comprising at least one processing device arranged to:

perform tubular enhancement on the volumetric medical imaging scan data to derive at least one tubeness measure for each voxel within the volumetric medical imaging scan data;

perform segmentation of a volume of the medical imaging scan data to identify tubular biliary structures within the volume of the medical imaging scan data based at least partly on the at least one tubeness measure for each voxel;

for at least one segmented tubular biliary structure within the volume of the medical imaging scan data, compute at least one set of quantitative structural parameters for at least one location along the length of the tubular biliary structure; and

output quantitative biliary tree data comprising the at least one set of quantitative structural parameters for the at least one segmented tubular biliary structure.

19. The image processing system of Claim 18, wherein the set of quantitative structural parameters comprises at least one parameter representative of at least one of:

a centre-line position of the at least one segmented tubular biliary structure at the at least one location;

a centre-line orientation of the at least one segmented tubular biliary structure at the at least one location;

a radius of the at least one segmented tubular biliary structure at the at least one location;

a diameter of the at least one segmented tubular biliary structure at the at least one location;

a cross-sectional orientation of the at least one segmented tubular biliary structure at the at least one location;

a cross-section profile of the at least one segmented tubular biliary structure at the at least one location;

an indication of the presence of a branching point for the at least one segmented tubular biliary structure at the at least one location; and

an orientation of a branching point for the at least one segmented tubular biliary structure at the at least one location.

20. The image processing system of Claim 18 or Claim 19, wherein the at least one processing device is arranged to determine centre-line positions at a plurality of locations along the length of the at least one segmented tubular biliary structure.

21. The image processing system of Claim 20, wherein the at least one processing device is arranged to determine centre-line positions for the at least one segmented tubular biliary structure by:

identifying a starting centre-line point for the at least one segmented tubular biliary structure;

identifying an ending centre-line point for the at least one segmented tubular biliary structure; and

incrementally from the starting centre-line point, determining successive centre-line points for the at least one segmented tubular biliary structure until the ending centre-line point is reached.

22. The image processing system of Claim 21, wherein the at least one processing device is arranged to determine a successive centre-line point by:

identifying a set of viable successor points;

evaluating a cost function for each point within the set of viable successor points; and

selecting a successive centre-line point from the set of viable successor points based on the cost functions therefor.

23. The image processing system of any one of Claims 20 to 22, wherein the at least one processing device is further arranged to, for each of the plurality of locations along the length of the at least one segmented tubular biliary structure, determine a tube-width estimation for the at least one segmented tubular biliary structure.

24. The image processing system of Claim 23, wherein at least one processing device is arranged to compute the tube-width estimation for each location by determining a cross-sectional orientation of the at least one segmented tubular biliary structure at the respective location and determining a tube-width estimation for the at least one segmented tubular biliary structure in the determined cross-sectional orientation.

25. The image processing system of Claim 23 or Claim 24, wherein the at least one processing device is further arranged to detect patterns of change within the at least one segmented tubular structure based on the tube-width estimations along the length of the at least one segmented tubular structure.

26. The image processing system of Claim 25, wherein the at least one processing device is further arranged to detect patterns of change within the at least one segmented tubular structure by applying at least one pattern detection window to the tube-width estimation data.

27. The image processing system of Claim 25 or Claim 26, wherein the at least one processing device is arranged to detect at least one of:

strictures;

dilatations; and

beading.

28. The image processing system of any one of Claims 18 to 27, wherein the at least one processing device is arranged to:

identify a first tubular biliary structure within the volume of the medical imaging scan data;

determine branch node locations along the length of the first tubular biliary structure; and

identify further tubular biliary structures branching off from the branch nodes along the length of the first tubular biliary structure.

29. The image processing system of Claim 28, wherein the at least one processing device is arranged to recursively identify further tubular biliary structures branching off from identified tubular biliary structures to derive a hierarchical biliary tree structure.

30. The image processing system of Claim 29, wherein the at least one processing device is arranged to compute at least one set of quantitative structural parameters for each location along the length of each identified tubular biliary structure.

31. The image processing system of any of Claims 18-30, wherein the at least one processing device is arranged to perform tubular enhancement comprising, for each voxel within the volume of the medical imaging scan data, computing at least one metric distinguishing tubular structures from other structures and computing a tubeness measure for the respective voxel based at least partly on the at least one metric.

32. The image processing system of Claim 31, wherein the at least one processing device is arranged to perform tubular enhancement comprising, for each voxel within the volume of the medical imaging scan data, computing a first metric distinguishing tubular structures from spherical structures and a second metric distinguishing tubular structures from plate-like structures, and computing a tubeness measure for the respective voxel based at least partly on the first metric, the second metric and a scan intensity value for the respective voxel.

33. The image processing system of any one of Claims 18 to 32, wherein the at least one processing device is arranged to use multi-scale Hessian based tubular biliary structure enhancement.

34. The image processing system of any one of Claims 18 to 33 , wherein the volumetric medical imaging scan data comprises imaging scan data obtained via a magnetic resonance imaging modality.

35. A non-transitory computer program product having stored therein executable computer program code for generating quantitative data for biliary tree structures from volumetric medical imaging scan data, the executable computer program code operable to perform the method of any one of Claims 1 to 17.

36. The non-transitory computer program product of Claim 35, wherein the non-transitory computer program product comprises one of a hard disk, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, an Electrically Erasable Programmable Read Only Memory, and a Flash memory.