

Claims

1. A method for segmenting an object of interest in an input image comprising a plurality of points having respective intensity values representing medical data, the method comprising the steps of:

(1a) segmenting the points in a region of interest in the input image into a first and second group of points using predetermined intensity threshold values;

(1b) identifying a first set of small connected components formed by points in the first group of points and transferring the points in the first set of small connected components to the second group of points;

(1c) identifying a second set of small connected components formed by points in the second group of points and transferring the points in the second set of small connected components to the first group of points; and

(1d) forming the segmented object of interest using the first group of points;

wherein each set of small connected components formed by points in the respective group of points is identified by a method comprising the steps of:

(1i) locating connected components formed by points in the respective group of points;

(1ii) calculating a cutoff value representing the maximum number of points in a small connected component, the cutoff value being calculated based on the number of points in the located connected components; and

(1iii) for each located connected component, if the number of points in the located connected component is less than the cutoff value, identifying the located connected component as a small connected component.

42. A method according to claim 1, wherein sub-step (1ii) further comprises the sub-steps of:

(4i) from the located connected components, determining the largest and smallest connected components respectively comprising the highest and lowest number of points; and

(4ii) calculating the cutoff value by comparing a rate of decrease in the number of points from the largest located connected component to the smallest located connected component against the number of points in the remaining located connected components.

53. A method according to claim-4_2, wherein sub-step (4i) further comprises the sub-step of arranging the located connected components in a descending order of the number of points in the located connected components and sub-step (4ii) further comprises the sub-steps of:

(5i) plotting the number of points in each located connected component against the order of the located connected component in the arrangement to form a plot comprising a set of data points;

(5ii) selecting a cutoff data point in the set of data points wherein the distance between the cutoff data point and a line passing through the data points corresponding to the largest and smallest located connected components is maximum; and

(5iii) calculating the cutoff value as the number of points in the located connected component corresponding to the cutoff data point.

64. A method for segmenting liver objects comprising a liver, at least one liver tumor and liver vessels in a three-dimensional input image comprising a plurality of points having respective intensity values representing medical data, the method comprising the steps of:

(6a) defining a region of interest which takes the expected shape of the liver in the input image;

(6b) segmenting the liver in the region of interest;

(6c) segmenting the at least one liver tumor in the region of interest;

(6d) segmenting the liver vessels in the region of interest;

(6e) smoothing the segmented liver objects; and

(6f) partitioning the segmented liver into functional liver segments.

75. A method according to claim-6_4, wherein step (6a) further comprises the sub-steps of:

(7i) constructing a liver surface model by generating a smooth mesh from a first setting of a plurality of control points;

(7ii) fitting the liver surface model to a liver in the input image by deforming the liver surface model by moving the plurality of control points; and

(7iii) defining the region of interest as the sub-volume of the input image enclosed by the fitted liver surface model.

86. A method according to claim-64 or-75, wherein step (6b) further comprises the sub-steps of:

(8i) segmenting the points in the region of interest into a first and second group of points using predetermined intensity threshold values;

(8ii) identifying a first set of small connected components formed by points in the first group of points and transferring the points in the first set of small connected components to the second group of points;

(8iii) identifying a second set of small connected components formed by points in the second group of points and transferring the points in the second set of small connected components to the first group of points;

(8iv) forming the segmented liver using the first group of points; and

(8v) refining the segmented liver by trimming points which do not belong to the liver.

97. A method according to claim-86, wherein step (8v) further comprises repeating the following sub-steps:

(9i) projecting the segmented liver onto a two-dimensional image;

(9ii) delineating a region in the two-dimensional image; and

(9iii) trimming the segmented liver by identifying and removing points in the segmented liver projected onto the delineated region.

408. A method according to claim-64 or-75, further comprising a step of trimming at least one of the segmented liver objects by repeating the following sub-steps:

(10i) projecting the at least one segmented liver object onto a two-dimensional image;

(10ii) delineating a region in the two-dimensional image; and

(10iii) trimming the at least one segmented liver object by identifying and removing points in the at least one segmented liver object projected onto the delineated region.

449. A method according to claim-64 or-75, wherein step (6c) further comprises the sub-steps of:

(11i) segmenting the points in the region of interest into a first and second group of points using predetermined intensity threshold values;

(11ii) identifying a first set of small connected components formed by points in the first group of points and transferring the points in the first set of small connected components to the second group of points;

(11iii) identifying a second set of small connected components formed by points in the second group of points and transferring the points in the second set of small connected components to the first group of points;

(11iv) forming the at least one segmented liver tumor using the first group of points;

(11v) merging the at least one segmented liver tumor with the segmented liver to form a combined liver object comprising a plurality of points;

(11vi) performing a morphological operation to the points in the combined liver object;

(11vii) locating connected components formed by points in the combined liver object and from the located connected components, locating a maximum connected component comprising the highest number of points; and

(11viii) forming at least one updated segmented liver tumor by removing points belonging to the segmented liver from the maximum connected component.

4210. A method according to claim ~~6~~ 4 or ~~7~~ 5, wherein the step (6d) further comprises the sub-steps of:

(12i) segmenting the points in the region of interest into a first and second group of points using predetermined intensity threshold values;

(12ii) identifying a first set of small connected components formed by points in the first group of points and transferring the points in the first set of small connected components to the second group of points;

(12iii) identifying a second set of small connected components formed by points in the second group of points and transferring the points in the second set of small connected components to the first group of points;

(12iv) forming the segmented liver vessels using the first group of points, the segmented liver vessels comprising vessel points; and

(12v) tracing vessel segments repeatedly from the vessel points to form a vessel tree, each vessel segment being traced according to the following sub-steps (12v-i to 12v-iii):

(12v-i) selecting a seed point from the vessel points in the segmented liver vessels;

(12v-ii) locating a two-dimensional connected vessel region formed by vessel points and comprising the seed point; and

(12v-iii) expanding the two-dimensional connected vessel region in directions perpendicular to the two-dimensional connected vessel region to form the vessel segment.

4311. A method according to claim ~~12~~ 10, wherein the sub-step (12v-iii) further comprises the sub-steps of:

(13i) checking if a stop condition is met and if not, generating a first further vessel region from the two-dimensional connected vessel region;

(13ii) successively checking if the stop condition is met, and if not, generating a further vessel region from the most recently generated further vessel region; and

(13iii) forming the vessel segment as a union of the two-dimensional connected vessel region and the generated further vessel regions.

4412. A method according to claim ~~13~~ 11, wherein the stop condition is met when the further vessel region to be generated is found to comprise no points or when the number of points in the further vessel region to be generated is found to be more than twice the number of points in the vessel region from which the further vessel region is to be generated.

4513. A method according to claim ~~13~~ 11 or ~~14~~ 12, wherein each further vessel region is generated according to the following sub-steps:

(15i) forming a region of interest based on the vessel region from which the further vessel region is to be generated;

(15ii) for each vessel point in the region of interest, determining if the vessel point belongs to the vessel segment; and

(15iii) generating the further vessel region as a connected component formed by vessel points in the region of interest determined as belonging to the vessel segment.

4614. A method according to claim 45 13, wherein sub-step (15ii) further comprises the following sub-steps for each vessel point in the region of interest:

(16i) calculating parameters of the vessel point in the region of interest, the parameters being dependent on the intensity values of vessel points in a plurality of neighborhoods around the vessel point in the region of interest; and

(16ii) determining if the vessel point in the region of interest belongs to the vessel segment based on the calculated parameters.

4715. A method according to claim 46 14, wherein the parameters comprise a vessel direction and a vesselness of the vessel point in the region of interest and sub-step (16i) further comprises the sub-steps of:

(17i) defining a plurality of neighborhoods around the vessel point in the region of interest, each neighborhood comprising a plurality of vessel points and a different number of points;

(17ii) for each neighborhood, forming a vessel point set comprising the vessel points in the neighborhood;

(17iii) calculating a plurality of eigenvectors and eigenvalues for each vessel point set based on the positions of the vessel points in the vessel point set;

(17iv) normalizing the first eigenvalue for each vessel point set; and

(17v) respectively calculating the vessel direction and the vesselness of the vessel point as the first eigenvector and first normalized eigenvalue of the vessel point set having the highest normalized first eigenvalue.

4816. A method according to claim 47 15, wherein the vessel point in the region of interest is determined as belonging to the vessel segment if the vesselness of the vessel point is greater than a predetermined threshold and the angle between the vessel direction of the vessel point and the vessel direction of the seed point is less than a predetermined threshold.

4917. A method according to any of claims 42 10 to 48 16, wherein prior to sub-step 12(v-ii), the method further comprises the sub-steps of calculating a vessel direction for the seed point and if the vessel direction for the seed point is not oriented along an expected direction in the input image, rotating a coordinate system of the input image until the vessel direction of the seed point is oriented along the expected direction.

2018. A method according to any of claims ~~6_4~~ — ~~19_17~~, wherein each segmented liver object comprises a subset of the points in the input image and step (6e) comprises the following sub-steps for each segmented liver object:

(20i) calculating a distance map value for each point in the input image based on a distance between the point and a boundary of the segmented liver object;

(20ii) obtaining updated distance map values by smoothing a function formed by the distance map values; and

(20iii) forming a smoothed volume of the segmented liver object using the updated distance map values.

2119. A method according to any of claims ~~6_4~~ — ~~20_18~~, wherein step (6f) further comprises the sub-steps of:

(21i) setting a first plurality of vertices on a surface of the segmented liver and generating a first minimal surface using the first plurality of vertices;

(21ii) forming a second plurality of vertices using the first plurality of vertices and generating a second minimal surface using the first and second plurality of vertices;

(21iii) forming an extensible minimal surface by combining the first and second minimal surfaces wherein the extensible minimal surface is adjustable by adjusting the first plurality of vertices; and

(21iv) partitioning the segmented liver into functional liver segments using the extensible minimal surface.

2220. A method according to claim ~~21_19~~, wherein the first minimal surface is enclosed by a first contour passing through the first plurality of vertices and sub-step (21ii) further comprises the following sub-steps for each vertex in the first plurality of vertices:

(22i) calculating a normal to the first minimal surface and a tangent to the first contour at the vertex;

(22ii) calculating a cross product between the calculated normal and the calculated tangent; and

(22iii) forming a vertex in the second plurality of vertices using the calculated cross product.

2321. A method according to claim ~~22_20~~, wherein the vertex in the second plurality of vertices lies on a vector formed by the calculated cross product and lies at a

predetermined distance away from the corresponding vertex in the first plurality of vertices.