CLAIMS

What is claimed is:

1. A method for generating a three-dimensional (3D) ultrasound image of a tissue volume using at least one processor, the method comprising:

generating a series of two-dimensional (2D) ultrasound images of the tissue volume associated with a plurality of positions, respectively, along a scanning direction of the tissue volume;

estimating, for each pair of consecutive 2D ultrasound images of the series of 2D ultrasound images, a distance between the positions associated with the pair of consecutive 2D ultrasound images based on a classification of a difference image generated from the pair of consecutive 2D ultrasound images using a deep neural network to produce a plurality of estimated distances associated with the plurality of pairs of consecutive 2D ultrasound images, respectively;

modifying the number of 2D ultrasound images in the series of 2D ultrasound images based on the plurality of estimated distances to produce a modified series of 2D ultrasound images; and

rendering the 3D ultrasound image of the tissue volume based on the modified series of 2D ultrasound images.

2. The method according to claim 1, wherein the deep neural network is trained to classify the difference image into one of a plurality of classes, the plurality of classes corresponding to a plurality of distance values, respectively; and said distance is estimated to be the distance value corresponding to the class in which the difference image is classified into.

3. The method according to claim 2, wherein the difference image comprises pixels, each pixel having a difference pixel value determined based on a difference between pixel values of corresponding pixels of the pair of consecutive 2D ultrasound images.

4. The method according to claim 2 or 3, wherein said modifying the number of 2D ultrasound images comprises removing each 2D ultrasound image of the series of 2D ultrasound images that satisfies a predetermined image removal condition; and inserting one or more additional 2D ultrasound images in between each pair of consecutive 2D ultrasound images that satisfies a predetermined image insertion condition.

5. The method according to claim 4, wherein the one or more additional 2D ultrasound images are each generated based on an interpolation of the pair of consecutive 2D ultrasound images in between which the one or more additional 2D ultrasound images are to be inserted.

6. The method according to claim 4 or 5, wherein the plurality of distance values of the plurality of classes, respectively, do not overlap and are each configured based on a scan resolution.

7. The method according to claim 6,

wherein the scan resolution is a scan resolution of a 3D ultrasound transducer, and

wherein the deep neural network is trained based on a training dataset comprising a plurality of labelled difference images, each labelled difference image being labelled with one of the plurality of classes which the labelled difference image belongs to and each labelled difference image being formed based on two 2D ultrasound images extracted at a predefined distance apart from a 3D ultrasound image volume acquired by the 3D ultrasound transducer, the predefined distance apart corresponding to one of the plurality of classes.

8. The method according to claim 6 or 7,

wherein each of the plurality of distance values is configured as a multiple of the scan resolution,

wherein the predetermined image removal condition for removing a 2D ultrasound image is based on whether the estimated distance associated with a first pair of consecutive 2D ultrasound images including the 2D ultrasound image is equal to a predefined multiple of the scan resolution, and

wherein the predetermined image insertion condition for inserting one or more additional 2D ultrasound images in between a pair of consecutive 2D ultrasound images is based on whether the estimated distance associated with the pair of consecutive 2D ultrasound images is greater than the predefined multiple of the scan resolution.

9. The method according to claim 8,

wherein the predetermined image removal condition is further based on whether the estimated distance associated with a second pair of consecutive 2D ultrasound images including the 2D ultrasound image is equal to the predefined multiple of the scan resolution,

wherein if the estimated distances associated with the first pair and the second pair are both equal to the predefined multiple of the scan resolution, a second distance between the positions associated with the other 2D ultrasound image of the first pair and the other 2D ultrasound image of the second pair is estimated based on a classification of a second difference image generated from the other 2D ultrasound image of the first pair and the other 2D ultrasound image of the second pair using the deep neural network, and the predetermined image removal condition is further based on whether the second estimated distance is equal to the predefined multiple of the scan resolution.

10. The method according to claim 8 or 9, wherein the number of additional 2D ultrasound images generated is based on the number of times the estimated distance is a multiple of the scan resolution.

11. The method according to any one of claims 8 to 10, wherein the predefined multiple of the scan resolution is one.

12. A system for generating a three-dimensional (3D) ultrasound image of a tissue volume, the system comprising:

an ultrasound transducer;

a memory; and

at least one processor communicatively coupled to the memory and the ultrasound transducer, and configured to:

generate a series of two-dimensional (2D) ultrasound images of the tissue volume associated with a plurality of positions, respectively, along a scanning direction of the tissue volume based on a series of ultrasound waves acquired by the ultrasound transducer at the plurality of positions;

estimate, for each pair of consecutive 2D ultrasound images of the series of 2D ultrasound images, a distance between the positions associated with the pair of consecutive 2D ultrasound images based on a classification of a difference image generated from the pair of consecutive 2D ultrasound images using a deep neural network to produce a plurality of estimated distances associated with the plurality of pairs of consecutive 2D ultrasound images, respectively;

modify the number of 2D ultrasound images in the series of 2D ultrasound images based on the plurality of estimated distances to produce a modified set of 2D ultrasound images; and

render the 3D ultrasound image of the tissue volume based on the modified series of 2D ultrasound images.

13. The system according to claim 12, wherein the deep neural network is trained to classify the difference image into one of a plurality of classes, the plurality of classes corresponding to a plurality of distance values, respectively; and said distance is estimated to be the distance value corresponding to the class in which the difference image is classified into.

14. The system according to claim 13, wherein the difference image comprises pixels, each pixel having a difference pixel value determined based on a difference

between pixel values of corresponding pixels of the pair of consecutive 2D ultrasound images.

15. The system according to claim 13 or 14, wherein said modify the number of 2D ultrasound images comprises removing each 2D ultrasound image of the series of 2D ultrasound images that satisfies a predetermined image removal condition; and inserting one or more additional 2D ultrasound images in between each pair of consecutive 2D ultrasound images that satisfies a predetermined image insertion condition.

16. The system according to claim 15, wherein the one or more additional 2D ultrasound images are each generated based on an interpolation of the pair of consecutive 2D ultrasound images in between which the one or more additional 2D ultrasound images are to be inserted.

17. The system according to claim 15 or 16, wherein the plurality of distance values of the plurality of classes, respectively, do not overlap and are each configured based on a scan resolution.

18. The system according to claim 17,

wherein the scan resolution is a scan resolution of a 3D ultrasound transducer, and

wherein the deep neural network is trained based on a training dataset comprising a plurality of labelled difference images, each labelled difference image being labelled with one of the plurality of classes which the labelled difference image belongs to and each labelled difference image being formed based on two 2D ultrasound images extracted at a predefined distance apart from a 3D ultrasound image volume acquired by the 3D ultrasound transducer, the predefined distance apart corresponding to one of the plurality of classes.

19. The system according to claim 17 or 18,

wherein each of the plurality of distance values is configured as a multiple of the scan resolution,

wherein the predetermined image removal condition for removing a 2D ultrasound image is based on whether the estimated distance associated with a first pair of consecutive 2D ultrasound images including the 2D ultrasound image is equal to a predefined multiple of the scan resolution, and

wherein the predetermined image insertion condition for inserting one or more additional 2D ultrasound images in between a pair of consecutive 2D ultrasound images is based on whether the estimated distance associated with the pair of consecutive 2D ultrasound images is greater than the predefined multiple of the scan resolution.

20. The system according to claim 19,

wherein the predetermined image removal condition is further based on whether the estimated distance associated with a second pair of consecutive 2D ultrasound images including the 2D ultrasound image is equal to the predefined multiple of the scan resolution,

wherein if the estimated distances associated with the first pair and the second pair are both equal to the predefined multiple of the scan resolution, a second distance between the positions associated with the other 2D ultrasound image of the first pair and the other 2D ultrasound image of the second pair is estimated based on a classification of a second difference image generated from the other 2D ultrasound image of the first pair and the other 2D ultrasound image of the second pair using the deep neural network, and the predetermined image removal condition is further based on whether the second estimated distance is equal to the predefined multiple of the scan resolution.

21. The system according to claim 19 or 20, wherein the number of additional 2D ultrasound images generated is based on the number of times the estimated distance is a multiple of the scan resolution.

22. The system according to any one of claims 19 to 21, wherein the predefined multiple of the scan resolution is one.

23. The system according to any one of claims 12 to 22, wherein the ultrasound transducer is installed in a freehand ultrasound probe.

24. A computer program product, embodied in one or more non-transitory computer-readable storage mediums, comprising instructions executable by at least one processor to perform a method for generating a three-dimensional (3D) ultrasound image of a tissue volume, the method comprising:

generating a series of two-dimensional (2D) ultrasound images of the tissue volume associated with a plurality of positions, respectively, along a scanning direction of the tissue volume;

estimating, for each pair of consecutive 2D ultrasound images of the series of 2D ultrasound images, a distance between the positions associated with the pair of consecutive 2D ultrasound images based on a classification of a difference image generated from the pair of consecutive 2D ultrasound images using a deep neural network to produce a plurality of estimated distances associated with the plurality of pairs of consecutive 2D ultrasound images, respectively;

modifying the number of 2D ultrasound images in the series of 2D ultrasound images based on the plurality of estimated distances to produce a modified set of 2D ultrasound images; and

rendering the 3D ultrasound image of the tissue volume based on the modified series of 2D ultrasound images.