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(71) Applicant(s): L&T TECHNOLOGY SERVICES LIMITED

(72) Inventor(s): Babu, Akshaya
Kareeparambath, Anusree
Jogihalli, Rohan

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(54) Title: METHOD AND SYSTEM FOR GUIDING NAVIGATION OF AN IMAGING TOOL

(57) Abstract: The disclosure relates to a method and system for guiding navigation of an imaging tool is disclosed. The method may include receiving a first three-dimensional (3D) model representative of a bronchial tree structure associated with lungs and a second 3D model representative of blood vessels associated with the lungs. The first 3D model and the second 3D model may be superimposed, to obtain a superimposed 3D model. The method may further include generating a path from an origin location to an abnormality location within the superimposed 3D model, such that the path bypasses the blood vessels. The method may further include receiving real-time images from an imaging tool and plotting a location of the imaging tool in the superimposed 3D model, based on a mapping of the real-time images with the superimposed 3D model.

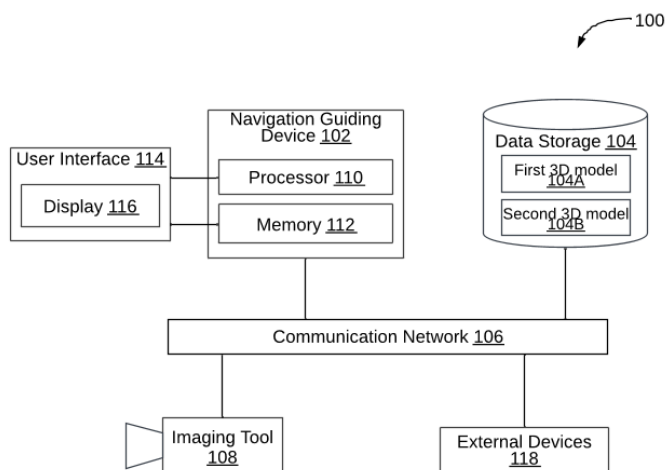


FIG. 1

FORM 2

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

METHOD AND SYSTEM FOR GUIDING NAVIGATION OF AN IMAGING TOOL

2. APPLICANT(S)

(a) NAME : **L&T TECHNOLOGY SERVICES LIMITED**

(b) NATIONALITY : **INDIAN**

(c) ADDRESS : DLF IT SEZ Park, 2nd Floor – Block 3

1/124, Mount Poonamallee Road,

Ramapuram, Chennai – 600 089,

INDIA.

3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is
to be performed

DESCRIPTION

Technical Field

[001] This disclosure relates generally to virtual bronchoscopy, and in particular to a method and a system for guiding navigation of an imaging tool through body organs, such as lungs.

Background

[002] Virtual bronchoscopy is a popular medical imaging technique that leverages sophisticated computer technology to generate detailed three-dimensional representations of a patient's airways, particularly the bronchial tree. As such, virtual bronchoscopy enables healthcare professionals to conduct a virtual "fly-through" exploration of the airways, thereby facilitating a non-invasive visual assessment of the structure, size, and condition of the bronchial passages. Further, virtual bronchoscopy obviates the need for invasive procedures like traditional bronchoscopy. Therefore, virtual bronchoscopy serves as a valuable diagnostic tool for a range of respiratory conditions, including the identification of tumors, airway obstructions, and lung diseases. Moreover, it plays a pivotal role in guiding treatment decisions and surgical planning while minimizing patient discomfort and risks associated with invasive bronchoscopy techniques.

[003] Existing techniques of virtual bronchoscopy include conventional bronchoscopy, which relies on manual navigation or electromagnetic navigation bronchoscopy (ENB) that use sensors for real-time guidance. Further, robot-assisted bronchoscopy is used for precision work. Some other techniques of virtual bronchoscopy include fluoroscopy-guided bronchoscopy which uses X-rays, endobronchial ultrasound (EBUS) for visualizing structures beyond airway walls, and augmented reality (AR) navigation for enhanced navigation precision. However, the existing techniques of virtual bronchoscopy are complicated and require specialized and expensive equipment.

[004] Therefore, there is a need for a simpler technique for virtual bronchoscopy that allows an effective and efficient way of assessment of organs (e.g. lungs) and is capable of guiding navigation of an imaging tool through the organs.

SUMMARY

[005] In an embodiment, a method of guiding navigation of an imaging tool is disclosed. The method may include receiving a first three-dimensional (3D) model

representative of a bronchial tree structure associated with lungs. A location of an abnormality associated with the lungs within the first 3D model is predetermined. The method may further include receiving a second 3D model representative of blood vessels associated with the lungs and superimposing the first 3D model and the second 3D model, to
5 obtain a superimposed 3D model representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs. The method may further include generating a path from an origin location to an abnormality location within the superimposed 3D model, such that the path bypasses the blood vessels. The method may further include receiving, in real-time, at least one real-time image from an imaging tool when the imaging
10 tool moves through a bronchial tree associated with the lungs. The method may further include plotting a location of the imaging tool in the superimposed 3D model, based on a mapping of the at least one real-time image with the superimposed 3D model.

[006] In another embodiment, a system for guiding navigation of an imaging tool. The system includes a processor and a memory communicatively coupled to the processor.
15 The memory stores a plurality of instructions, which upon execution by the processor, cause the processor to receive a first three-dimensional (3D) model representative of a bronchial tree structure associated with lungs. A location of an abnormality associated with the lungs within the first 3D model is predetermined. The plurality of instructions further cause the processor to receive a second 3D model representative of blood vessels associated with the
20 lungs, and superimpose the first 3D model and the second 3D model, to obtain a superimposed 3D model representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs. The plurality of instructions further cause the processor to generate a path from an origin location to an abnormality location within the superimposed 3D model, such that the path bypasses the blood vessels. The plurality of
25 instructions further cause the processor to receive, in real-time, at least one real-time image from an imaging tool when the imaging tool moves through the bronchial tree. The plurality of instructions further cause the processor to plot a location of the imaging tool in the superimposed 3D model, based on a mapping of at least one real-time image with the superimposed 3D model.

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BRIEF DESCRIPTION OF THE DRAWINGS

[007] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

[008] FIG. 1 is a block diagram of an exemplary system for guiding navigation of an imaging tool, in accordance with some embodiments of the present disclosure;

[009] FIG. 2 is a block diagram of an overall architecture of the system of FIG. 1, in accordance with an embodiment of the present disclosure;

5 [010] FIGs. 3A, 3B illustrate exemplary 2D image and a 3D model of bronchial tree along with an abnormality, respectively, in accordance with an embodiment of the present disclosure;

[011] FIG. 4 illustrates an exemplary superimposed 3D model generated by superimposing the bronchial tree structure of the first 3D model and the blood vessels of the
10 second 3D model, in accordance with an embodiment of the present disclosure;

[012] FIG. 5 illustrates an example superimposed 3D model with a path from an origin location to an abnormality location within the superimposed 3D model, in accordance with an embodiment of the present disclosure;

[013] FIG. 6 illustrates a flowchart of a method of guiding navigation of the
15 imaging tool, in accordance with some embodiments;

[014] FIG. 7 illustrates a flowchart of a method of labeling branches within the centerline, in accordance with some embodiments;

[015] FIG. 8 illustrates a flowchart of a method of generating an alert to notify a user about proximity of the imaging tool to the blood vessels, in accordance with some
20 embodiments; and

[016] FIG. 9 is an exemplary computing system that may be employed to implement processing functionality for various embodiments.

DETAILED DESCRIPTION

25 [017] Exemplary embodiments are described with reference to the accompanying drawings. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the spirit and scope of the disclosed embodiments. It is
30 intended that the following detailed description be considered as exemplary only, with the true scope and spirit being indicated by the following claims. Additional illustrative embodiments are listed below.

[018] The present disclosure relates to a method and system for guiding navigation of an imaging tool through a body part, in particularly, human lungs. According to some embodiments of the present disclosure, medical images, for example, Computed Tomography (CT) scans are used for three-dimensional (3D) reconstruction of airways of the lungs, and identification of abnormalities using deep learning models. Bronchial tree segmentation and blood vessel segmentation operations are performed within the lung region. Further, the identified abnormalities are located within the (3D) reconstruction of the airways, and a shortest path from the trachea to the point identified at abnormality location is determined. Furthermore, branch labeling operation is performed that facilitates precise navigation during real-time navigation. The real time navigation is executed by aligning the 3D reconstruction with real-time video frames obtained from an imaging tool. Such integration of the 3D reconstruction with the real-time video frames enables simultaneous visualization of real-time data and corresponding locations in the constructed airway, and therefore, is used to guide pulmonologists with directional cues (left, right, top, bottom) based on labeled branches, thereby aiding navigation. As will be appreciated by those skilled in the art, the blood vessel segmentation prevents potential vessel damage during the navigation procedures. By superimposing blood vessels onto the airways, proximity to the imaging tool's current location is calculated, that enables the pulmonologist to adjust the path or proceed with heightened caution during the intervention.

[019] Referring now to **FIG. 1**, a block diagram of an exemplary system 100 for guiding navigation of an imaging tool is illustrated, in accordance with some embodiments of the present disclosure. The system 100 may implement a navigation guiding device 102. Further, the system 100 may include a data storage 104. In some embodiments, the data storage 104 may store first three-dimensional (3D) model(s) representative of a bronchial tree structure associated with lungs and second 3D model(s) representative of blood vessels associated with the lungs. The system 100 may further include an imaging tool 108 which may be used for inspecting the airways of the lungs and identifying abnormalities associated with the lungs. For example, the imaging tool 108 may be a camera, in particular, an endoscope camera. The navigation guiding device 102 may be a computing device having data processing capability. In particular, the navigation guiding device 102 may have the capability for plotting a location of the imaging tool 108 in a superimposed 3D model (obtained by superimposing the first 3D model and the second 3D model), based on a mapping of the at least one image obtained by the imaging tool 108 with the superimposed

3D model. Examples of the navigation guiding device 102 may include, but are not limited to a desktop, a laptop, a notebook, a netbook, a tablet, a smartphone, a mobile phone, an application server, a web server, or the like.

[020] Additionally, the navigation guiding device 102 may be communicatively coupled to an external device 118 for sending and receiving various data. Examples of the external device 118 may include, but are not limited to, a remote server, digital devices, and a computer system. The navigation guiding device 102 may connect to the external device 118 over a communication network 106. The navigation guiding device 102 may connect to external device 118 via a wired connection, for example via Universal Serial Bus (USB). A computing device, a smartphone, a mobile device, a laptop, a smartwatch, a personal digital assistant (PDA), an e-reader, and a tablet are all examples of external devices 118.

[021] The navigation guiding device 102 may be configured to perform one or more functionalities that may include receiving the first 3D model representative of the bronchial tree structure associated with lungs. A location of an abnormality associated with the lungs is within the first 3D may be predetermined. The one or more functionalities may further include receiving the second 3D model representative of blood vessels associated with the lungs, and superimposing the first 3D model and the second 3D model, to obtain a superimposed 3D model. The superimposed 3D model is representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs. The one or more functionalities may further include generating a path from an origin location to an abnormality location within the superimposed 3D model, wherein the path bypasses the blood vessels. The one or more functionalities may further include receiving, in real-time, at least one image from an imaging tool when the imaging tool moves through a bronchial tree associated with the lungs. The one or more functionalities may further include plotting a location of the imaging tool in the superimposed 3D model, based on a mapping of at least one image with the superimposed 3D model.

[022] To perform the above functionalities, the navigation guiding device 102 may include a processor 110 and a memory 112. The memory 112 may be communicatively coupled to the processor 110. The memory 112 stores a plurality of instructions, which upon execution by the processor 110, cause the processor 110 to perform the above functionalities. The system 100 may further include a user interface 114 which may further implement a display 116. Examples may include, but are not limited to a display, keypad, microphone, audio speakers, vibrating motor, LED lights, etc. The user interface 114 may receive input

from a user and also display an output of the computation performed by the navigation guiding device 102.

[023] Referring now to **FIG. 2**, a block diagram of the navigation guiding device 102 showing one or more modules is illustrated, in accordance with some embodiments. In some embodiments, the navigation guiding device 102 may include a superimposing module 202, a path generating module 204, a real-time image receiving module 206, a location plotting module 208, and a proximity detection module 210.

[024] The superimposing module 202 may be configured to receive a first three-dimensional (3D) model and a second 3D model. The first 3D model may be representative of a bronchial tree structure associated with lungs. In some embodiments, the first 3D model may be generated from a plurality of two-dimensional (2D) images associated with the lungs. By way of an example, each of the plurality of 2D images may be a Computed Tomography (CT) scan.

[025] The first 3D model may be generated from the plurality of 2D images using a region-growing method. The region-growing method may be performed based on seed selection. It should be noted that the airways in the lung region have a specific range of Hounsfield unit (HU) values. The seed selection may be performed in such a way that the HU value lies in the specific range. Accordingly, relevant structures within the volume data are identified and isolated, creating a clear definition of the airway. Subsequently, surface data may be extracted that provides a 3D representation of the bronchial tree structure, i.e. the first 3D model. The first 3D model allows for accurate visualization and analysis, aiding in the diagnosis and assessment of respiratory conditions with precision.

[026] It should be noted that a location of an abnormality associated with the lungs within the first 3D model (received by the superimposing module 202) may be predetermined. In particular, a abnormality location associated with the lungs may be predetermined in the plurality of 2D images. In some example embodiments, the abnormality may be detected in the plurality of 2D images (e.g. CT scans) using a Machine Learning (ML) model. To this end, the ML model may be first trained using a training dataset. For example, the training dataset may include more than one hundred CT scans, each CT scan being of NIfTI (Neuroimaging Informatics Technology Initiative) format. As will be understood by those skilled in the art, NIfTI format is used for storing and sharing imaging data, such as CT scan data, Magnetic Resonance Imaging (MRI) and functional MRI (fMRI) data. Further, by way of an example, the ML model may be a Fastai unet model, having a

ResNet34 backbone, and 200 epoch. As will be further understood, Fastai's U-Net is an implementation of U-Net architecture within Fastai deep learning library. The U-Net is a convolutional neural network (CNN) architecture which may be used for biomedical image segmentation tasks, especially in tasks related to semantic segmentation for classifying each pixel in an image. Furthermore, in the context of deep learning, the epoch refers to a single pass or iteration through the entire training dataset during the training of a neural network.

[027] The abnormality associated with the lungs in the first 3D model may be located by spatially correlating the abnormality location within the plurality of 2D images with the first 3D model. Once the abnormality is identified within an image of the medical image dataset (i.e. the plurality of 2D images), the abnormality location in the 2D images may be mapped onto the existing first 3D model representative of the bronchial tree structure associated with lungs. Further, positional information of the abnormality may be integrated within the existing first 3D model. As such, the mapping spatially correlates the abnormality within the first 3D model, thereby providing a targeted visualization of the precise abnormality location. In order to locate the abnormality associated with the lungs in the first 3D model, pixel spacing data and slice thickness data associated with the 2D images may be extracted. Further, the 2D pixel coordinates of each pixel of the 2D images may be converted to corresponding 3D coordinates based on the pixel spacing information and the slice thickness data. As such, the 3D model may be generated based on the 3D coordinates.

[028] The 2D image, for example, may be based on Digital Imaging and Communications in Medicine (DICOM) - a standard protocol for the management and transmission of medical images. As such, in some embodiments, mapping the 2D images onto the first 3D model may include utilizing spatial information encoded in DICOM metadata. Using the DICOM metadata, pixel spacing and slice thickness may be extracted, particularly, from the DICOM header. Further, 2D pixel coordinates (x, y) may be converted to real-world coordinates (X, Y), for example, in millimeters, using the pixel spacing information. The slice thickness is considered to determine the position along the Z-axis, in the corresponding 3D model. Therefore, the resulting coordinates (X, Y, Z) represent the 3D point corresponding to the original 2D point in the DICOM slice. **FIGs. 3A, 3B** illustrate exemplary 2D image and the 3D model of the lungs along with an abnormality. In particular, FIG. 3A shows an exemplary 2D image 300A of lungs and an abnormality 302 associated with the lungs. FIG. 3B shows a 3D model 300B of the lungs and the corresponding abnormality 302 associated with the lungs.

[029] As mentioned above, the superimposing module 202 may be configured to receive the second 3D model that may be representative of blood vessels associated with the lungs. In some embodiments, in order to generate the second 3D model representative of the blood vessels, lung segmentation operation may be performed on the plurality of 2D images, for example, using Otsu method. The segmented lung may be applied as a mask to the plurality of 2D images (i.e. the 2D CT scans). Subsequently, blood vessel segmentation may be performed exclusively within the delineated lung region by thresholding method, to generate the second 3D model. For example, a thresholding technique (i.e. Otsu method) may be applied to discern optimal intensity thresholds within the 2D image, thereby effectively isolating the lung area from the rest of the anatomical structures. Following the segmentation of the lungs, the resulting mask may be applied to the original 2D images, with the focus exclusively to the lung region. Subsequently, a targeted blood vessel segmentation may be implemented within the lung region. The sequential approach of utilizing the lung mask as a spatial constraint enhances the precision of the blood vessel segmentation. Further, the approach allows for a more localized and accurate identification of blood vessels within the anatomical context of the segmented lungs. This helps to avoid unwanted information in the segmented blood vessels.

[030] Once the segmentation with respect to both the bronchial tree structure (i.e. the first 3D model) and the blood vessels associated with the lungs (i.e. second 3D model) is performed, the resulting blood vessels may be superimposed on the airways. In other words, the superimposing module 202 may be further configured to superimpose the first 3D model and the second 3D model, to obtain a superimposed 3D model representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs. **FIG. 4** illustrates an exemplary superimposed 3D model 400 generated by superimposing the bronchial tree structure of the first 3D model and the blood vessels of the second 3D model. As such, the superimposed 3D model includes both the airways associated with the bronchial tree structure as well as the blood vessels.

[031] The path generating module 204 may be configured to generate a path from an origin location to a abnormality location within the superimposed 3D model. The path generating module 204 may generate the path, such that the path bypasses the blood vessels. **FIG. 5** illustrates an example superimposed 3D model 500 with a path from an origin location to an abnormality location within the superimposed 3D model. As shown in **FIG. 5**, the path generating module 204 may execute a centerline extraction procedure. To this end,

the path generating module 204 may identify a plurality of points representative of end-points of a plurality of branches of the bronchial tree structure. Further, the path generating module 204 may generate a centerline through the plurality of points. In some embodiments, Voronoi algorithm may be used for the centerline extraction procedure. The path generating module 5 204 may further select an origin point and a destination point corresponding to the abnormality location within the superimposed 3D model, and generate the path along a shortest centerline connecting the origin point to the destination point. As shown in FIG. 5, an initial point (i.e. origin location 504) may be selected from a trachea 502. Subsequently, an endpoint may be determined based on the identified abnormality location 506. A centerline 10 508 may be then generated from the origin location 504 to the abnormality location 506, that provides a representation of the airway structure from the origin location 504 to the abnormality location 506.

[032] In some embodiments, upon generating the centerline through the plurality of points, the path generating module 204 may further identify one or more branches within the centerline. Further, the path generating module 204 may label each of the one or more 15 branches within the centerline, with a predetermined label. The labeling may facilitate precise navigation during real-time navigation, aligning with real-time video frame.

[033] Once the centerline 508 is extracted, a navigation operation may be initiated for guiding the movement of the imaging tool 108 along the computed centerline 508. The 20 navigation allows for exploration of the airway structure associated with the lungs. In some embodiments, a “vtkcamera” may be used for capturing navigation sequences. To this end, the coordinates of the centerline 508 may be extracted. The imaging tool 108 may follow the coordinate positions associated with the centerline 508 and covers the entire path.

[034] As the imaging tool 108 moves along centerline 508, the imaging tool 108 25 may capture images which may be used for subsequent operation, i.e. plotting a location of the imaging tool 108 in the superimposed 3D model. The real-time image receiving module 206 may receive, in real-time, at least one real-time image from the imaging tool 108 when the imaging tool moves through the bronchial tree. The location plotting module 208 may be configured to plot a location of the imaging tool 108 in the superimposed 3D model, based on 30 a mapping of at least one real-time image with the superimposed 3D model. In real-time navigation, the real-time images captured by the imaging tools 108 in real-time may be aligned and matched with virtual navigation frames (i.e. the superimposed 3D model). To this end, Scale Invariant Feature Transform (SIFT) or Speed Up Robust Feature (SURF) feature

extraction and template matching techniques may be used for aligning and matching the real-time images with the superimposed 3D model. As will be understood, the SIFT technique is used to detect and describe local features in digital images that locate key points and then furnishes them with quantitative information (descriptors) which can be used for object
5 recognition. The SURF technique relies on determination of Hessian matrix for scale and location.

[035] As such, each real-time image may be compared with a template of the animated airway, thereby allowing for precise correlation and alignment. A template matching algorithm may be used for identifying similarities between the real-time image and
10 the animated airway model. This allows for accurate synchronization and simultaneous visualization of the real-time imaging tool location and its corresponding location in the superimposed 3D model. The template matching algorithm may compare each real-time image with the initial airway template. Upon finding the match, subsequent real-time images may be evaluated against the subsequent frames of the initially matched 3D airway template
15 (the superimposed 3D model). This ensures continuous and accurate tracking of the airway structure throughout a video stream.

[036] In some embodiments, a recommendation may be generated with respect to providing directional guidance to the imaging tool when the imaging tool moves through the bronchial tree. In other words, a notification may be generated for notifying a user (i.e. a
20 pulmonologist) about when a turn is needed, thereby providing guidance with respect to the abnormality location. In particular, the notification may be indicative of the direction of movement, such as left, right, bottom, or top. This allows for precise navigation process. As such, visualizations of a position of the imaging tool in real-time and a location of the imaging tool
25 in the superimposed 3D model may be simultaneously generated. The simultaneously generated visualizations may guide the pulmonologist with directional cues (i.e. left, right, top, bottom) based on the predetermined labels, thereby aiding navigation.

[037] Further, during the navigation, information about the blood vessels may be constantly monitored. As the navigation progresses, the real-time data of the proximity of the blood vessels in relation to the current position of the imaging tool 108 may be retrieved. In
30 some embodiments, the location plotting module 208 may further determine a proximity of blood vessels to the imaging tool 108. To this end, 3D coordinates of the blood vessels and the location of the imaging tool 108 may be extracted. Further, the location plotting module

208 may determine the spatial relationship between the blood vessels and the imaging tool 108, for example, using Euclidean distance metric. Further,

[038] In some embodiments, the proximity detection module 210 may determine a proximity value corresponding to a distance of the imaging tool 108 from surrounding blood vessels. To this end, the proximity detection module 210 may determine a spatial relationship between the imaging tool and the surrounding blood vessels using Euclidean distance metric. The proximity detection module 210 may further compare the proximity value with a predefined threshold value, and generating an alert to notify a user, based on the comparison of the proximity value with the predefined threshold value. As such, the proximity detection module 210 may trigger an alert when the proximity is below a predetermined threshold, to notify the user and prompt them to intervene and temporarily halt the procedure. An absence of intervention may lead to breaking the blood vessels.

[039] Referring now to **FIG. 6**, a flowchart of a method 600 of guiding navigation of the imaging tool 108 is illustrated, in accordance with some embodiments. The method 600, for example, may be performed by the navigation guiding device 102 or the processor 110 of the navigation guiding device 102.

[040] At step 602, the first 3D model representative of the bronchial tree structure associated with lungs may be received. A location of an abnormality associated with the lungs within the first 3D model may be predetermined. As mentioned above, the first 3D model may be generated from a plurality of 2D images using a region-growing procedure. By way of applying the region-growing method, relevant structures within the volume data may be identified and isolated, creating a clear definition of the airways associated with the lungs. Subsequently, surface data may be extracted to generate a 3D representation of the bronchial tree structure, i.e. the first 3D model. In some example embodiments, the abnormality may be detected in the plurality of 2D images (e.g. CT scans) using a ML model. The ML model may be first trained using a training dataset. For example, the ML model may be a Fastai unet model, having a ResNet34 backbone, and 200 epoch. The abnormality associated with the lungs in the first 3D model may be located by spatially correlating the abnormality location within the plurality of 2D images with the first 3D model. Once the abnormality is identified within an image of the medical image dataset (i.e. the plurality of 2D images), the abnormality location in the 2D images may be mapped onto the existing first 3D model representative of the bronchial tree structure associated with lungs. Further, positional information of the abnormality may be integrated within the existing first 3D model. As such,

the mapping spatially correlates the abnormality within the first 3D model, thereby providing a targeted visualization of the precise abnormality location. Further, pixel spacing data and slice thickness data associated with the 2D images may be extracted. The 2D pixel coordinates of each pixel of the 2D images may be converted to corresponding 3D coordinates based on the pixel spacing information and the slice thickness data, and the first 3D model may be generated based on the 3D coordinates.

[041] At step 604, a second 3D model representative of blood vessels associated with the lungs may be received. As mentioned above, to generate the second 3D model representative of the blood vessels, first a lung segmentation operation may be performed on the plurality of 2D images, for example, using the Otsu method. The segmented lung may be applied as a mask to the plurality of 2D images, and blood vessel segmentation may be performed exclusively within the delineated lung region by thresholding method, to generate the second 3D model. The sequential approach of utilizing the lung mask as a spatial constraint enhances the precision of the blood vessel segmentation and allows for a more localized and accurate identification of blood vessels within the anatomical context of the segmented lungs.

[042] At step 606, the first 3D model and the second 3D model may be superimposed, to obtain a superimposed 3D model representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs. Once the segmentation with respect to both the bronchial tree structure (i.e. the first 3D model) and the blood vessels associated with the lungs (i.e. second 3D model) is performed, the resulting blood vessels may be superimposed on the airways.

[043] At step 608, a path may be generated from an origin location to an abnormality location within the superimposed 3D model, such that the path bypasses the blood vessels. In order to generate the path, first, a plurality of points representative of end-points of a plurality of branches of the bronchial tree structure may be identified. Thereafter, a centerline may be generated through the plurality of points. In some embodiments, once the centerline is generated through the plurality of points, one or more branches within the centerline may be identified, and each of the one or more branches within the centerline may be labeled with a predetermined label. The labeling is explained in detail, in conjunction with FIG. 7. Once the centerline is generated through the plurality of points, an origin point (corresponding to a point in the trachea) and a destination point (corresponding to the abnormality location within the superimposed 3D model) may be selected. Further, the path

may be generated along a shortest centerline connecting the origin point to the destination point. For example, as shown in FIG. 5, the initial point (i.e. origin location 504) may be selected from the trachea 502, and the endpoint may be determined based on the identified abnormality location 506. The centerline 508 is then generated from the origin location 504 to the abnormality location 506.

[044] Referring now to **FIG. 7**, a flowchart of a method 700 of labeling branches within the centerline is illustrated, in accordance with some embodiments. At step 702, the plurality of points representative of end-points of the plurality of branches of the bronchial tree structure may be identified. At step 704, the centerline may be generated through the plurality of points. In some embodiments, Voronoi algorithm may be used for generating the centerline.

[045] At step 706, once the centerline is generated through the plurality of points, the centerline may be split as non-intersecting branches. As such, one or more branches within the centerline may be identified. At step 708, each of the one or more branches within the centerline may be labeled with a predetermined label. In particular, the centerline may be labeled starting at the trachea, and the left and right main bronchi (LMB and RMB) leading to the left and right lungs. Further, the labeling may continue beneath the LMB and RMB, bronchi leading to the left and right upper lobes, right middle lobe, and the left and right lower lobes. The labeling may facilitate precise navigation during real-time navigation, aligning with real-time video frame.

[046] Referring once again to FIG. 6, at step 608, at least one real-time image may be received, in real-time, from the imaging tool 108, when the imaging tool 108 moves through the bronchial tree. As the imaging tool 108 moves through the bronchial tree along centerline 508, the imaging tool 108 may capture real-time images.

[047] At step 610, a location of the imaging tool 108 may be plotted in the superimposed 3D model, based on a mapping of the at least one real-time image with the superimposed 3D model. The real-time images captured by the imaging tool 108 may be aligned and matched with virtual navigation frames (i.e. the superimposed 3D model), for example, using SIFT or SURF feature extraction and template matching techniques. Each real-time image may be compared with a template of the animated airway, using a template matching algorithm. As such, visualizations of a position of the imaging tool in real-time and a location of the imaging tool in the superimposed 3D model may be simultaneously generated.

[048] Additionally, at step 612, a recommendation may be generated with respect to providing directional guidance to the imaging tool when the imaging tool 108 moves through the bronchial tree. A notification may be generated for notifying a user (i.e. a pulmonologist) about when a turn of the imaging tool 108 is needed, thereby providing
5 guidance with respect to the abnormality location. The notification may be indicative of the direction of movement, such as left, right, bottom, or top. The simultaneously generated visualizations may guide the pulmonologist with directional cues (i.e. left, right, top, bottom) based on the predetermined labels, thereby aiding navigation. Further, in some embodiments, at step 612, an alert may be generated to notify a user about proximity of the imaging tool
10 108 to the blood vessels. The step 612 is explained in detail in conjunction with FIG. 8.

[049] Referring now to **FIG. 8**, a flowchart of a method 800 of generating an alert to notify a user about proximity of the imaging tool 108 to the blood vessels is illustrated, in accordance with some embodiments. It should be noted that during the navigation of the imaging tool 108, information about the blood vessels may be constantly monitored. As the
15 navigation progresses, the real-time data of the proximity of the blood vessels in relation to the current position of the imaging tool 108 may be retrieved.

[050] At step 802, features may be extracted from real-time images 814A captured by the imaging tool 108, for example, using SIFT or SURF feature extraction techniques. To this end, as shown in FIG. 8, the real-time images 814A captured by the imaging tool 108
20 may be received from the imaging tool 108. Further, animated video frame template 814B may be received. It should be noted that the animated video frame template 814B may be pre-obtained and stored in a database.

[051] At step 804, a template matching may be performed. To this end, the real-time image 814A may be compared with the animated video frame template 814B, thereby
25 allowing for precise correlation and alignment. A template matching algorithm may be used for identifying similarities between the real-time image 814A and the animated video frame template 814B. The template matching algorithm may compare the real-time image 814A with the animated video frame template 814B. Upon finding the match, subsequent real-time images may be evaluated against the subsequent animated video frame templates. At step
30 806, based on the template matching, the imaging tool 108 may be displayed in the animated video frame template 814B.

[052] At step 808, a proximity value corresponding to a distance of the imaging tool from surrounding blood vessels may be determined. To this end, the superimposed 3D

model 400 may be received, and analyzed for proximity of the imaging tool from surrounding blood vessels. At step 810, a comparison may be performed between the proximity value with a predefined threshold value to determine whether the proximity value is greater than the predefined threshold value. If, at step 810, it is determined that the proximity value is greater than the predefined threshold value, then the method 800 may proceed to step 812. At step 812, an alert may be generated to notify a user (e.g. a pulmonologist), and then the method 800 may continue and proceed back to step 802 to analyze new real-time image obtained from the imaging tool 108. However, if, at step 810, it is determined that the proximity value is lesser greater than the predefined threshold value, then the method 800 may continue and proceed back to step 802 to analyze new real-time image obtained from the imaging tool 108.

[053] Referring now to **FIG. 9**, an exemplary computing system 900 that may be employed to implement processing functionality for various embodiments (e.g., as a SIMD device, client device, server device, one or more processors, or the like) is illustrated. Those skilled in the relevant art will also recognize how to implement the invention using other computer systems or architectures. The computing system 900 may represent, for example, a user device such as a desktop, a laptop, a mobile phone, personal entertainment device, DVR, and so on, or any other type of special or general-purpose computing device as may be desirable or appropriate for a given application or environment. The computing system 900 may include one or more processors, such as a processor 902 that may be implemented using a general or special purpose processing engine such as, for example, a microprocessor, microcontroller or other control logic. In this example, the processor 902 is connected to a bus 904 or other communication media. In some embodiments, the processor 902 may be an Artificial Intelligence (AI) processor, which may be implemented as a Tensor Processing Unit (TPU), or a graphical processor unit, or a custom programmable solution Field-Programmable Gate Array (FPGA).

[054] The computing system 900 may also include a memory 906 (main memory), for example, Random Access Memory (RAM) or other dynamic memory, for storing information and instructions to be executed by the processor 902. The memory 906 also may be used for storing temporary variables or other intermediate information during the execution of instructions to be executed by processor 902. The computing system 900 may likewise include a read-only memory (“ROM”) or other static storage device coupled to bus 904 for storing static information and instructions for the processor 902.

[055] The computing system 900 may also include storage devices 908, which may include, for example, a media drive 910 and a removable storage interface. The media drive 910 may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an SD card port, a USB port, a micro-USB, an optical disk drive, a CD or DVD drive (R or RW), or other removable or fixed media drive. A storage media 912 may include, for example, a hard disk, magnetic tape, flash drive, or other fixed or removable media that is read by and written to by the media drive 910. As these examples illustrate, the storage media 912 may include a computer-readable storage medium having stored therein particular computer software or data.

[056] In alternative embodiments, the storage devices 908 may include other similar instrumentalities for allowing computer programs or other instructions or data to be loaded into the computing system 900. Such instrumentalities may include, for example, a removable storage unit 914 and a storage unit interface 916, such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units and interfaces that allow software and data to be transferred from the removable storage unit 914 to the computing system 900.

[057] The computing system 900 may also include a communications interface 918. The communications interface 918 may be used to allow software and data to be transferred between the computing system 900 and external devices. Examples of the communications interface 918 may include a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a USB port, a micro-USB port), Near field Communication (NFC), etc. Software and data transferred via the communications interface 918 are in the form of signals which may be electronic, electromagnetic, optical, or other signals capable of being received by the communications interface 918. These signals are provided to the communications interface 918 via a channel 920. The channel 920 may carry signals and may be implemented using a wireless medium, wire or cable, fiber optics, or other communications medium. Some examples of the channel 920 may include a phone line, a cellular phone link, an RF link, a Bluetooth link, a network interface, a local or wide area network, and other communications channels.

[058] The computing system 900 may further include Input/Output (I/O) devices 922. Examples may include, but are not limited to a display, keypad, microphone, audio

speakers, vibrating motor, LED lights, etc. The I/O devices 922 may receive input from a user and also display an output of the computation performed by the processor 902. In this document, the terms “computer program product” and “computer-readable medium” may be used generally to refer to media such as, for example, the memory 906, the storage devices 5 908, the removable storage unit 914, or signal(s) on the channel 920. These and other forms of computer-readable media may be involved in providing one or more sequences of one or more instructions to the processor 902 for execution. Such instructions, generally referred to as “computer program code” (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system 900 to perform features or 10 functions of embodiments of the present invention.

[059] In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into the computing system 900 using, for example, the removable storage unit 914, the media drive 910 or the communications interface 918. The control logic (in this example, software instructions or 15 computer program code), when executed by the processor 902, causes the processor 902 to perform the functions of the invention as described herein.

[060] One or more techniques for guiding navigation of an imaging tool, such as an endoscope camera used for assessing body organs. The above techniques provide for branch labeling which facilitates precise navigation during the real-time navigation. Further, the 20 above techniques allow simultaneous visualization of real-time images and corresponding locations in an animated airway template. As such, the techniques guide pulmonologists with directional cues (left, right, top, bottom) based on labeled branches, thereby aiding navigation. Further, the techniques provide for blood vessel segmentation to prevent potential vessel damage during the navigation of the imaging tool through the lungs. By superimposing 25 blood vessels onto the airway, proximity of the blood vessels to the current location of the imaging tool is calculated, that enables the pulmonologists to adjust the path or proceed with heightened caution during the intervention.

[061] It is intended that the disclosure and examples be considered as exemplary only, with a true scope and spirit of disclosed embodiments being indicated by the following 30 claims.

WE CLAIM:

1. A method of guiding navigation of an imaging tool, the method comprising:

receiving a first three-dimensional (3D) model representative of a bronchial tree structure associated with lungs, wherein a location of an abnormality associated with the lungs within the first 3D model is predetermined;

receiving a second 3D model representative of blood vessels associated with the lungs;

superimposing the first 3D model and the second 3D model, to obtain a superimposed 3D model representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs;

generating a path from an origin location to an abnormality location within the superimposed 3D model, wherein the path bypasses the blood vessels;

receiving, in real-time, at least one real-time image from an imaging tool when the imaging tool moves through bronchial tree associated with the lungs; and

plotting a location of the imaging tool in the superimposed 3D model, based on a mapping of the at least one real-time image with the superimposed 3D model.

2. The method as claimed in claim 1 comprising:

generating the first 3D model from a plurality of two-dimensional (2D) images associated with the lungs, wherein a location of an abnormality associated with the lungs is predetermined in the plurality of 2D images; and

locating the abnormality associated with the lungs in the first 3D model, by spatially correlating the abnormality location within the plurality of 2D images with the first 3D model.

3. The method as claimed in claim 1 comprising:

wherein the abnormality location associated with the lungs in the 2D images is determined, using a Machine Learning (ML) model.

4. The method as claimed in claim 2, wherein the first 3D model is generated from the plurality of 2D images associated with the lungs, using a region-growing procedure.
5. The method as claimed in claim 4, wherein the second 3D model representative of the blood vessels is generated by:
 - applying segmented lung as a mask to the plurality of 2D images; and
 - generating the second 3D model from the plurality of 2D images associated with the lungs based on the mask applied, using the Otsu segmentation procedure.
6. The method as claimed in claim 1, wherein locating the abnormality associated with the lungs in the first 3D model comprises:
 - extracting pixel spacing data and slice thickness data associated with the 2D images;
 - and
 - converting 2D pixel coordinates of each pixel of the 2D images to corresponding 3D coordinates based on the pixel spacing information and the slice thickness data, wherein the 3D model is generated based on 3D coordinates.
7. The method as claimed in claim 2, wherein the first 3D model is generated from the plurality of 2D images using a region-growing procedure, and wherein each of the plurality of 2D images is a Computed Tomography (CT) scan.
8. The method as claimed in claim 1, wherein generating the path from the origin location to the abnormality location within the superimposed 3D model comprises:
 - identifying a plurality of points representative of end-points of a plurality of branches of the bronchial tree structure;
 - generating a centerline through the plurality of points;
 - selecting an origin point and a destination point corresponding to the abnormality location within the superimposed 3D model; and
 - generating the path along a shortest centerline connecting the origin point to the destination point.

9. The method as claimed in claim 8, wherein the centerline is generated using Voronoi technique.

10. The method as claimed in claim 9 further comprising:

upon generating the centerline through the plurality of points, identifying one or more branches within the centerline; and

labelling each of the one or more branches within the centerline, with a predetermined label.

11. The method as claimed in claim 1 further comprising simultaneously generating visualizations of:

a position of the imaging tool in real-time; and

a location of the imaging tool in the superimposed 3D model.

12. The method as claimed in claim 1 further comprising:

generating a recommendation with respect to providing directional guidance to the imaging tool when the imaging tool moves through the bronchial tree.

13. The method as claimed in claim 1 further comprising:

determining a proximity value corresponding to a distance of the imaging tool from surrounding blood vessels, by determining a spatial relationship between the imaging tool and the surrounding blood vessels using Euclidean distance metric;

comparing the proximity value with a predefined threshold value; and

generating an alert to notify a user, based on the comparison of the proximity value with the predefined threshold value.

15. A system for guiding navigation of an imaging tool, the system comprising:

a processor; and

a memory communicatively coupled to the processor, wherein the memory stores a plurality of instructions, which upon execution by the processor, cause the processor to:

receive a second 3D model representative of blood vessels associated with the lungs;

superimpose the first 3D model and the second 3D model, to obtain a superimposed 3D model representative of a combination of the bronchial tree structure and the blood vessels associated with the lungs;

generate a path from an origin location to an abnormality location within the superimposed 3D model, wherein the path bypasses the blood vessels;

receive, in real-time, at least one real-time image from an imaging tool when the imaging tool moves through the bronchial tree; and

plot a location of the imaging tool in the superimposed 3D model, based on a mapping of the at least one real-time image with the superimposed 3D model.

15. The system as claimed in claim 14, wherein generating the path from the origin location to the abnormality location within the superimposed 3D model comprises:

identifying a plurality of points representative of end-points of a plurality of branches of the bronchial tree structure;

generating a centerline through the plurality of points;

selecting an origin point and a destination point corresponding to the abnormality location within the superimposed 3D model; and

generating the path along a shortest centerline connecting the origin point to the destination point.

16. The system as claimed in claim 14, wherein the plurality of instructions further cause the processor to simultaneously generate visualizations of:

a position of the imaging tool in real-time; and

a location of the imaging tool in the superimposed 3D model.

17. The system as claimed in claim 14, wherein the plurality of instructions further cause the processor to:

generate a recommendation with respect to providing directional guidance to the imaging tool when the imaging tool moves through the bronchial tree.

18. The system as claimed in claim 14, wherein the plurality of instructions further cause the processor to:

determine a proximity value corresponding to a distance of the imaging tool from surrounding blood vessels, by determining a spatial relationship between the imaging tool and the surrounding blood vessels using Euclidean distance metric;
compare the proximity value with a predefined threshold value; and
generate an alert to notify a user, based on the comparison of the proximity value with the predefined threshold value.

Dated this 22nd day of December 2023

--Digitally Signed--
Bhanu Prasad (INPA No: 3253)
Head, IPR Dept.,
L&T Technology Services Limited,
DLF 3rd Block, 2nd Floor,
Manapakkam, Chennai, TN, 600089.

ABSTRACT

METHOD AND SYSTEM FOR GUIDING NAVIGATION OF AN IMAGING TOOL

The disclosure relates to a method and system for guiding navigation of an imaging tool is disclosed. The method may include receiving a first three-dimensional (3D) model representative of a bronchial tree structure associated with lungs and a second 3D model representative of blood vessels associated with the lungs. The first 3D model and the second 3D model may be superimposed, to obtain a superimposed 3D model. The method may further include generating a path from an origin location to an abnormality location within the superimposed 3D model, such that the path bypasses the blood vessels. The method may further include receiving real-time images from an imaging tool and plotting a location of the imaging tool in the superimposed 3D model, based on a mapping of the real-time images with the superimposed 3D model.

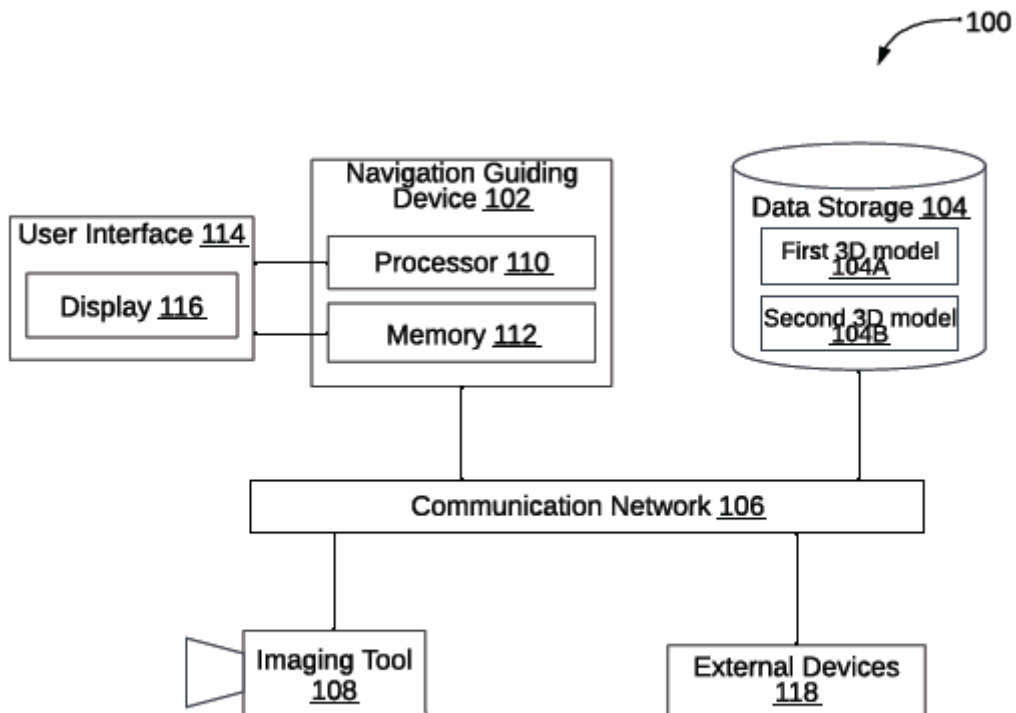


FIG. 1

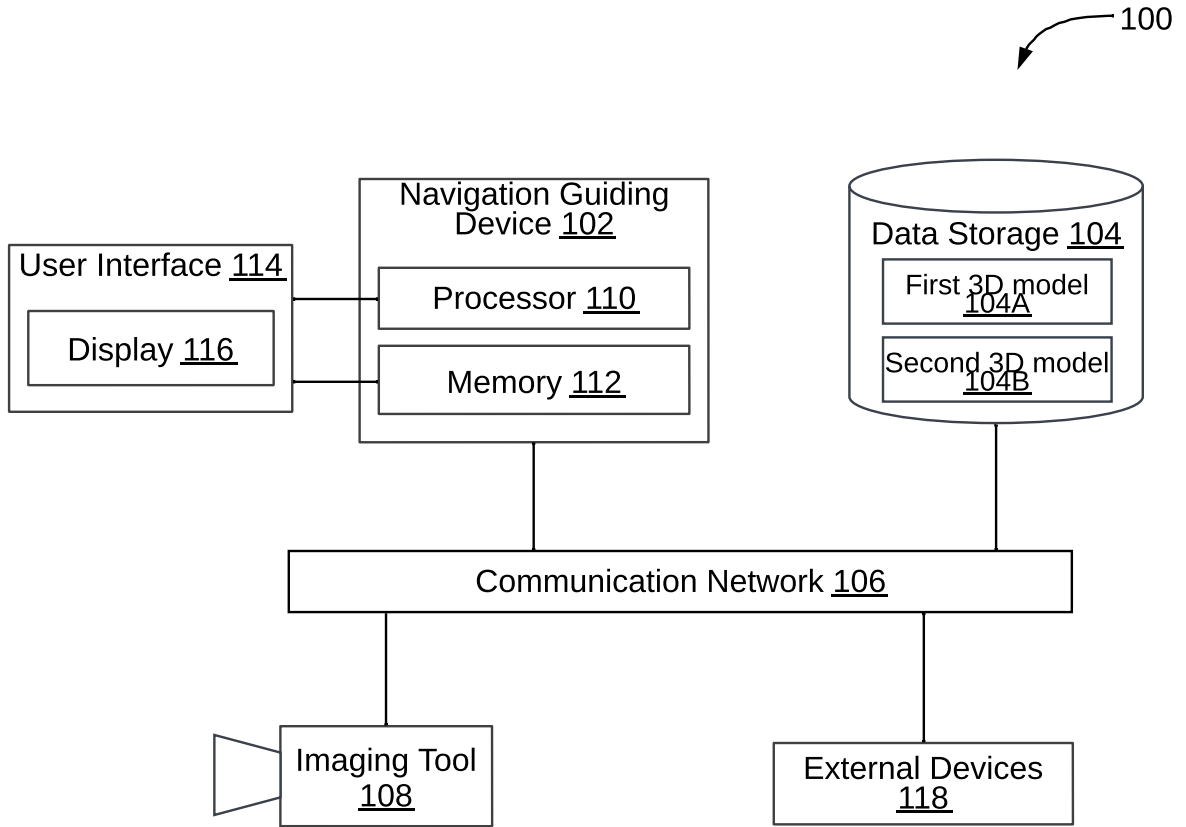


FIG. 1

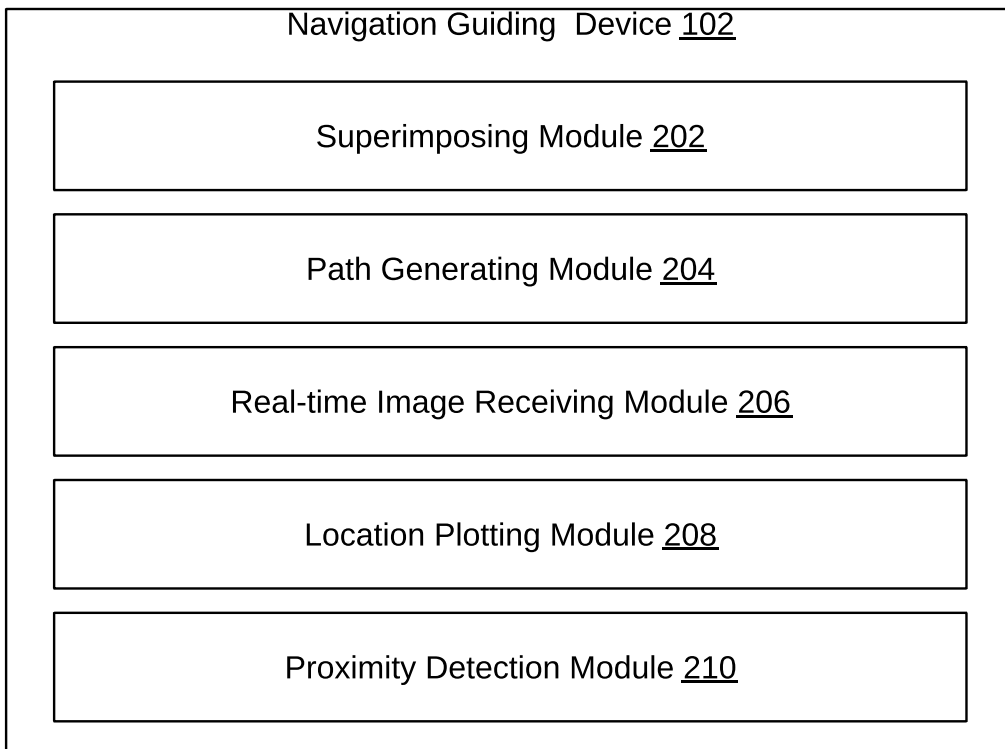


FIG. 2

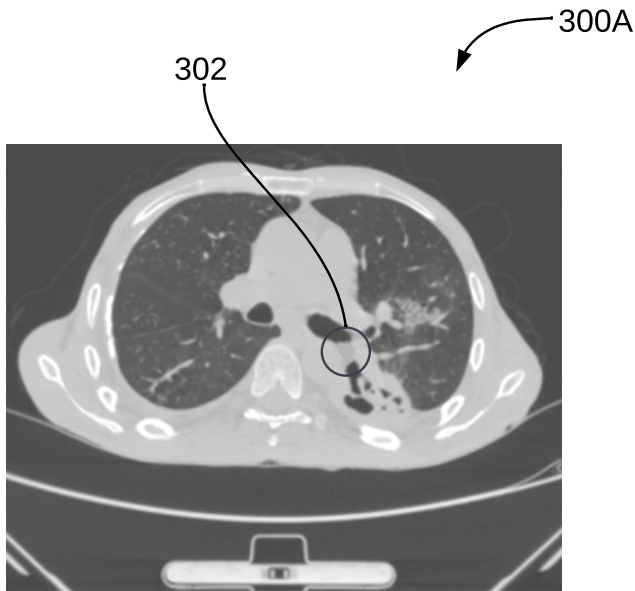


FIG. 3A

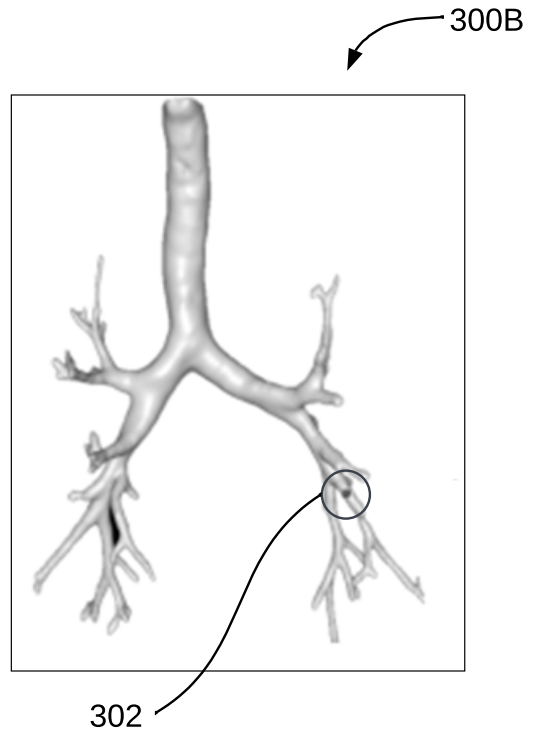


FIG. 3B

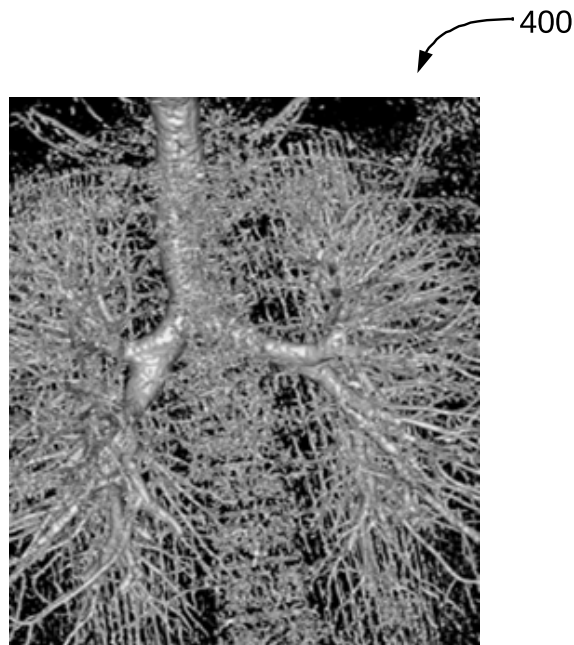


FIG. 4

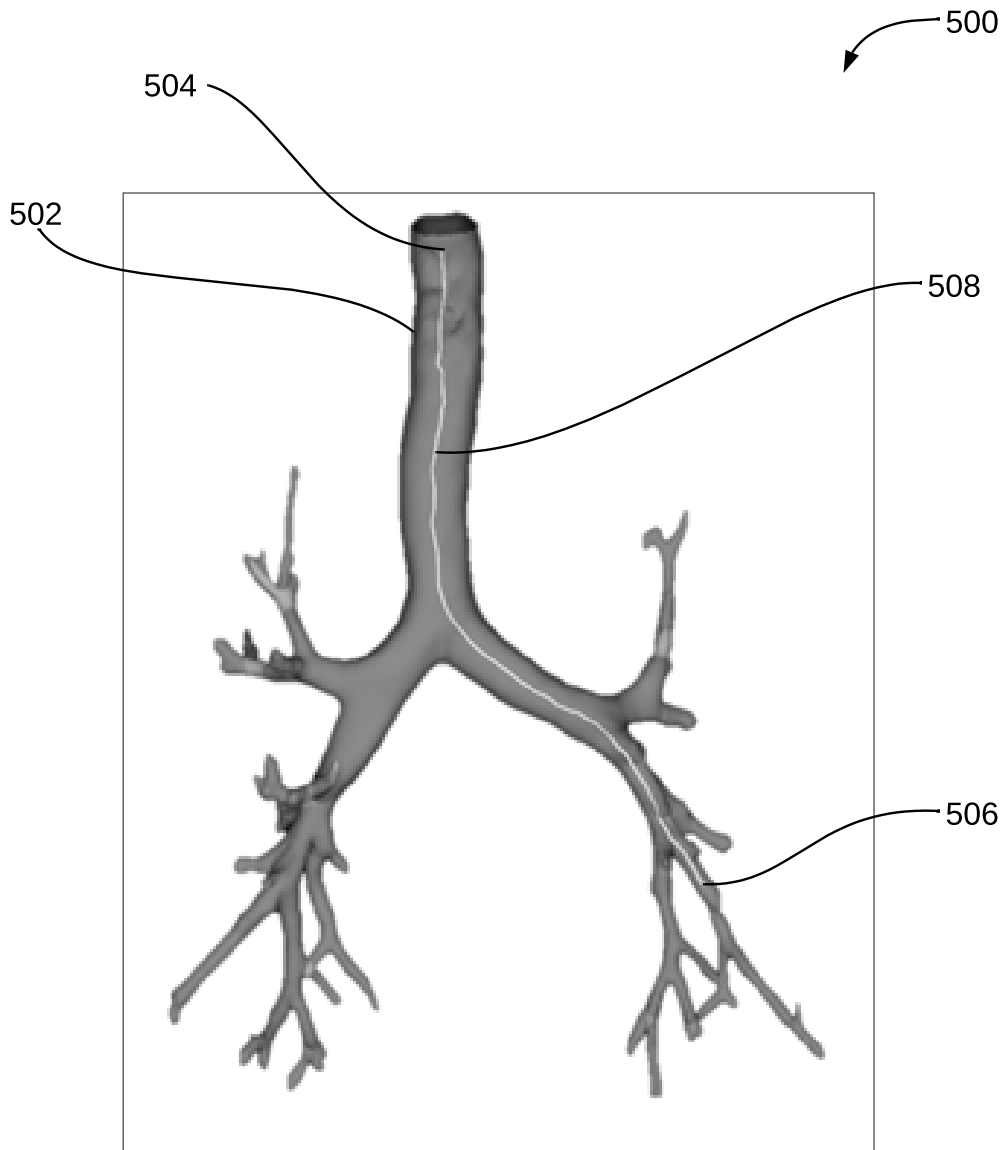


FIG. 5

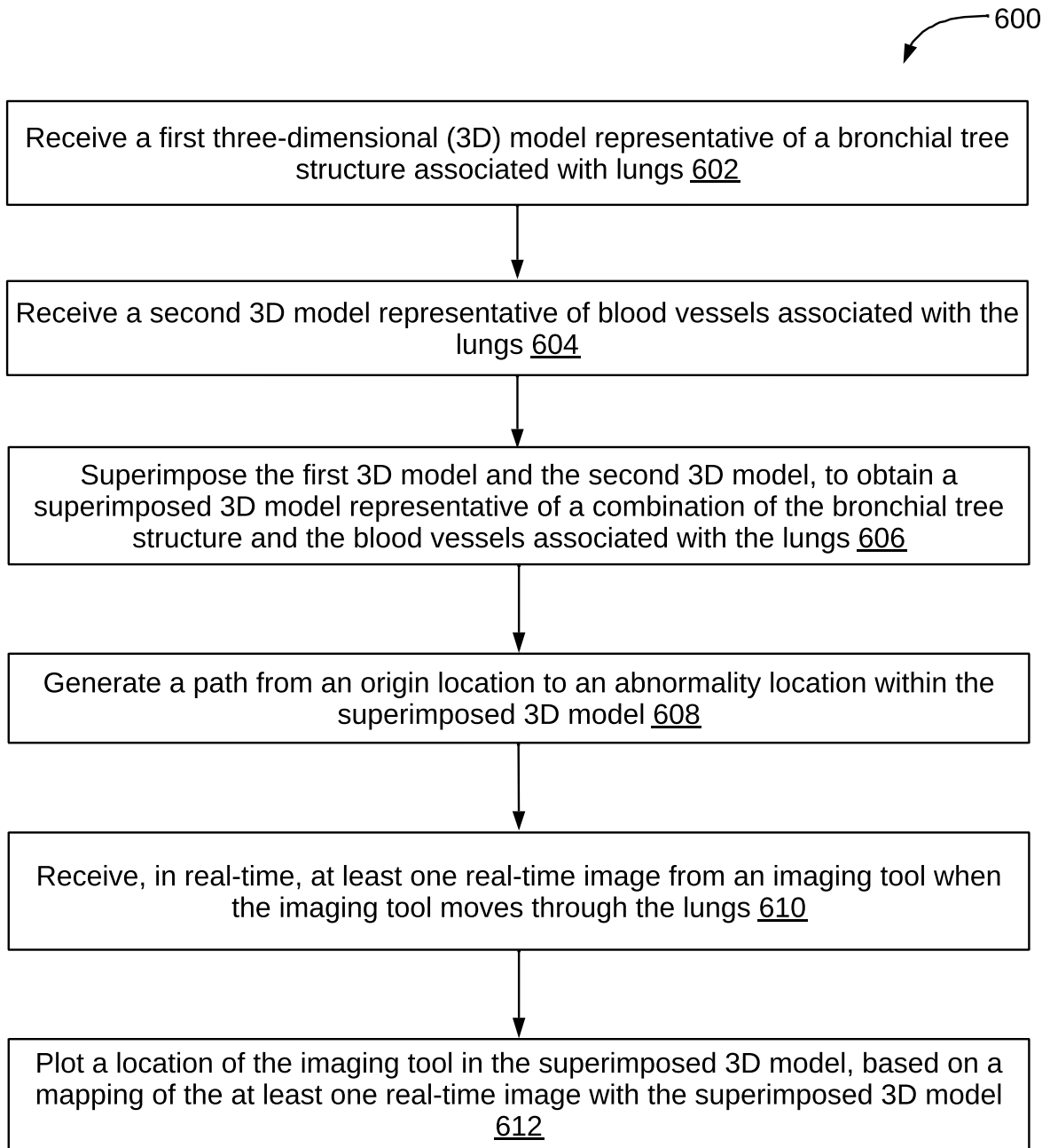


FIG. 6

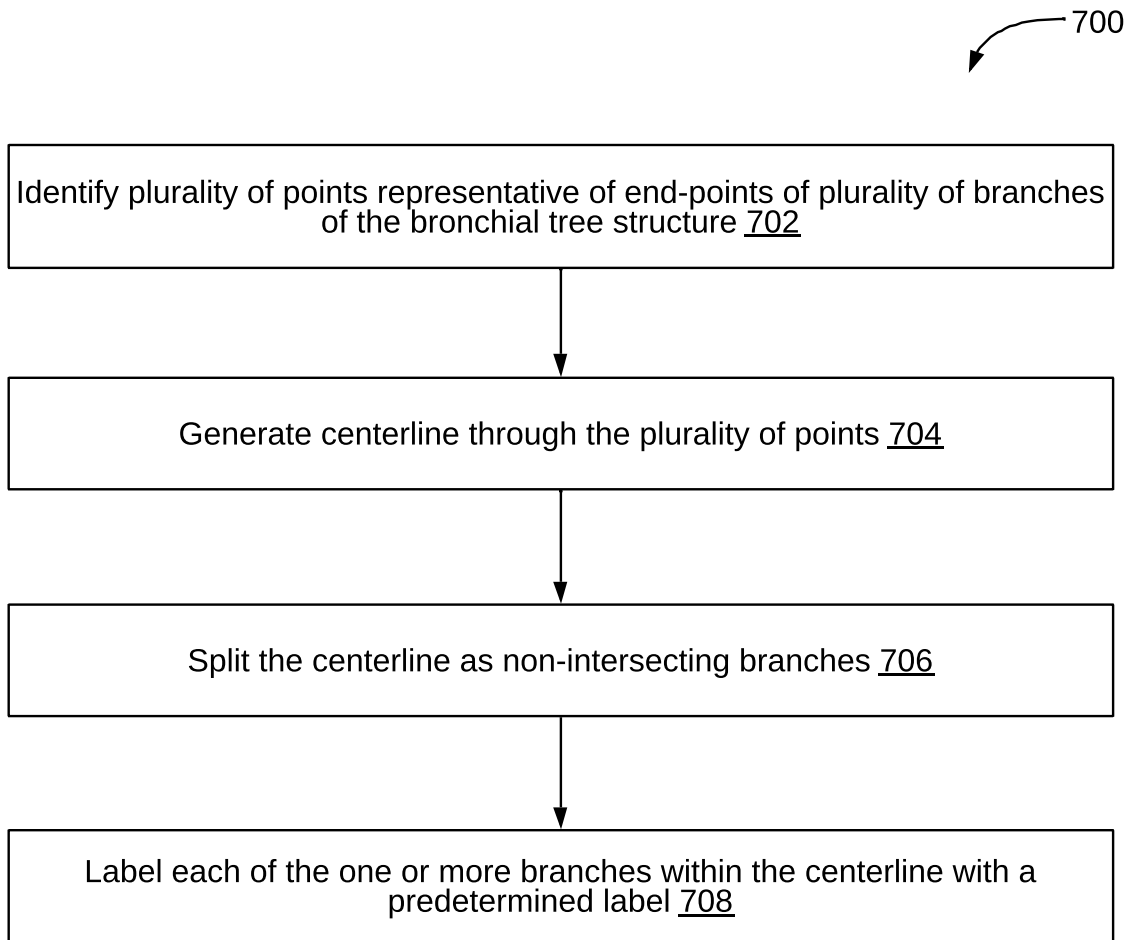


FIG. 7

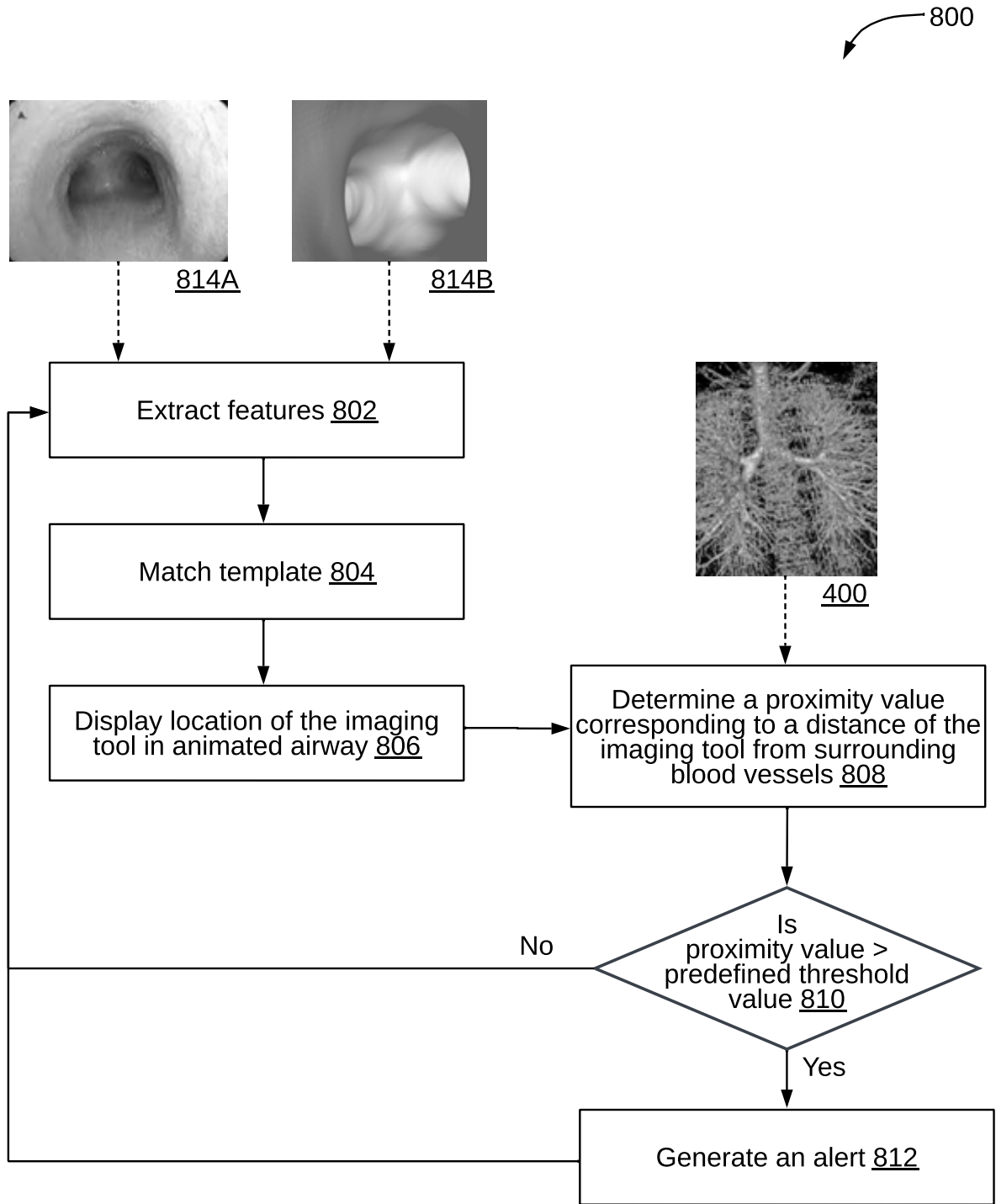


FIG. 8

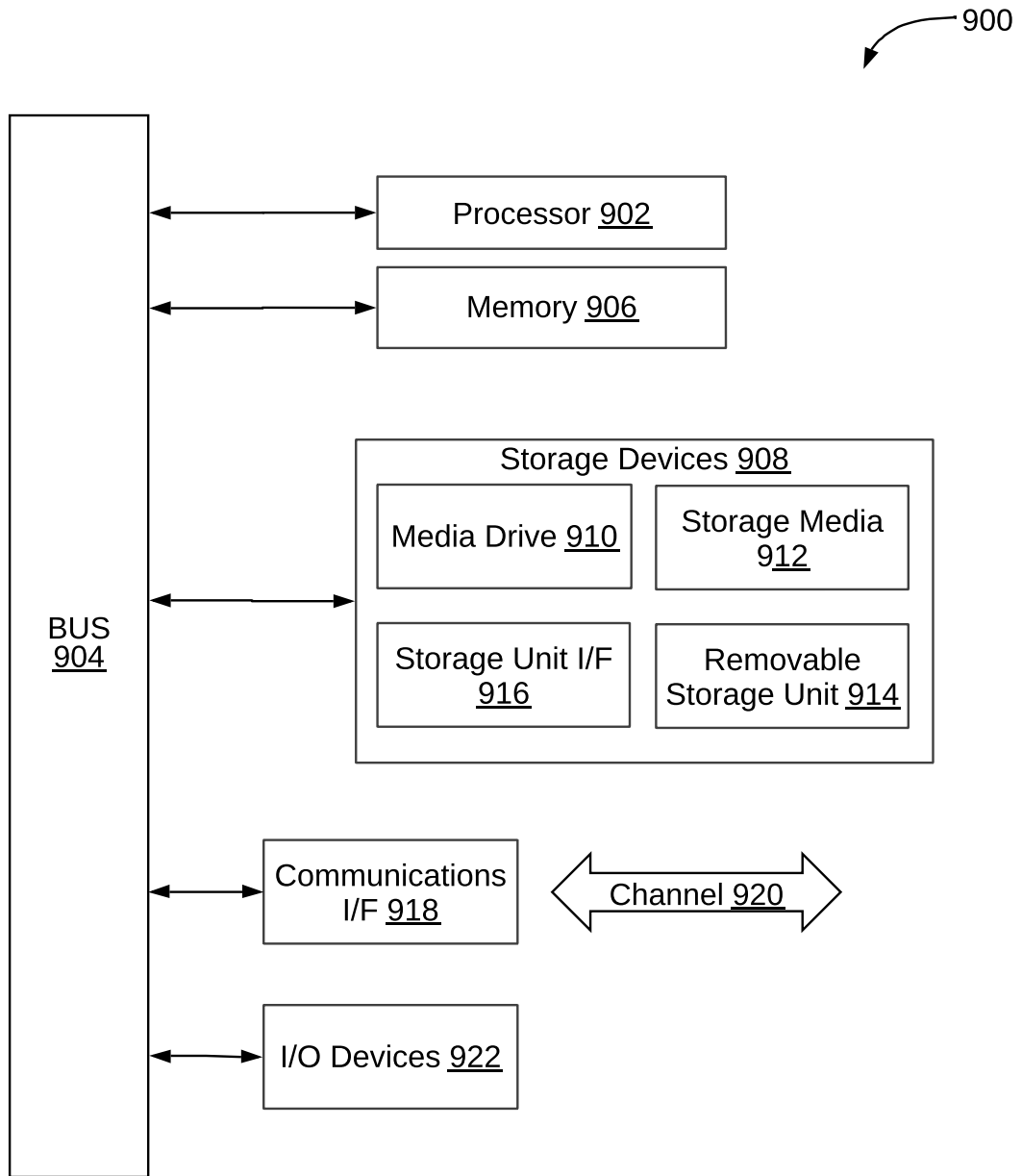


FIG. 9