Innovative Diagnostic Imaging Method Based on New 3D Segmentation Method and 3D U-Net

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Disclosure of Conflict of Interest

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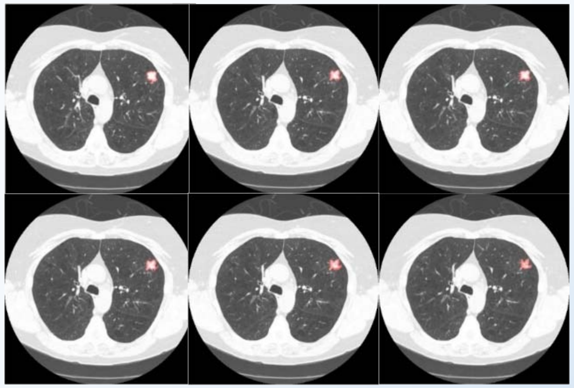
Introduction

- CT has a history of 50 years since the first successful imaging in 1971.
- At present, 3D measurement is typical practice in CT, but the image diagnosis is still performed in 2D (planar image).
- Although image diagnosis is a difficult task performed while estimating the three-dimensional structure of organs or lesions from planar images, humans have the ability to intuitively grasp the three-dimensional shape.
- With the rapid advances in semiconductors and image processing technology, the use of 3D information is common nowadays, as is typical in games and autonomous driving of cars.
- **3D information should be used to reduce the radiologist's hardship.**

Current Method



Proposed Method

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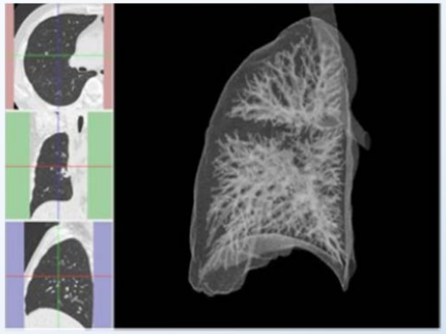
Purpose

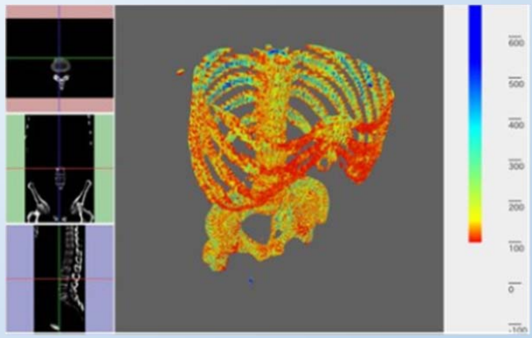
- We propose a new segmented surface rendering method named **2.5D Plus** for diagnostic imaging.

Method		Characteristics
2.5D	Surface Rendering	The outline of 3D shape is displayed translucently. The shape can be grasped, but most of the detailed information is lost.
3D	Volume Rendering	Color and transparency is given to each voxel. The amount of information increases compared to the surface rendering, but it is not suitable for finding small nodules.
2.5D+	Colored Surface Rendering	Organ and lesion shapes are detected by using state-of-the-art segmentation technology, and prominently colored in surface rendering technique.

Surface Rendering



Volume Rendering



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Limitations of 3D U-Net

- U-Net is a convolutional neural network that was developed for biomedical image segmentation, and it shows excellent performance to locate lesions.
- However, for applications that detect nodules from 3D data, U-Net has two limitations.

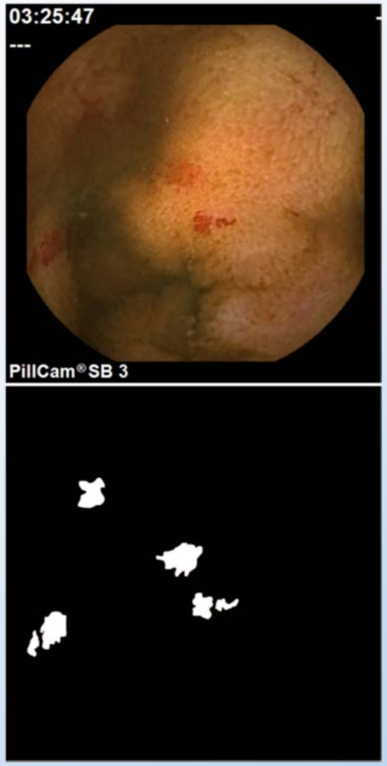
1. Large memory size

Calculations tends to be difficult due to memory size limitations.

2. Non-negligible variability on training data

Training data for nodule shape varies depending on the radiologist who created it, but the accurate 3D shape of the nodule is important for estimating malignancy and treatment.

U-Net detects lesions from endoscopy image



https://github.com/ternaus/angiodysplasia-segmentation

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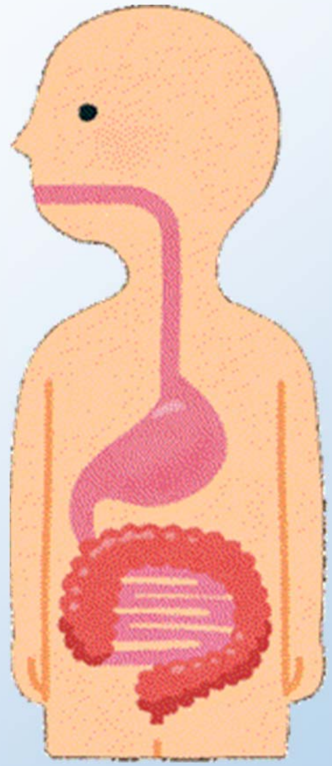
Existing Segmentation Methods

- Series of organs that make up a system, such as respiratory, digestive, and circulatory systems, are connected without any clear boundary between adjacent organs to allow the passage of air, food, and blood, respectively.
- Many methods are known as segmentation techniques, such as GraphCut, Watershed, Region growing, but they all search for boundaries based on numerical differences, and therefore, cannot separate the organs that make up the system.

Example of the Digestive System



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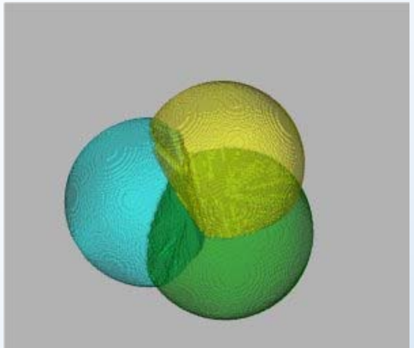
New Segmentation Method: ICF

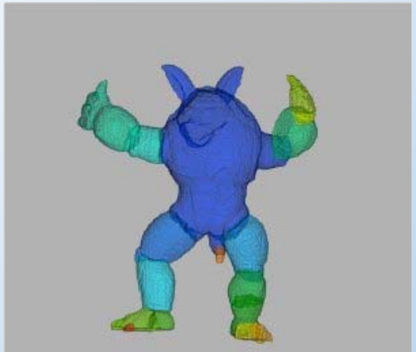
- ICF (Incremental Contour Flow) is a new segmentation method that separates binary 3D shape at narrow parts.
- ICF Algorithm

  1. Input of ICF is 3D binary data composed of foreground and background voxels.
  2. Value of the fore ground voxels is converted to Euclid distance from a nearest background voxel by applying distance transformation.
  3. The distances are converted to integers.
  4. Group of connected voxels having a same distance value is defined as an equality set, and a set of value larger than a surrounding set is defined as a local maximum.
  5. The 3D object is divided into as many segments as the maximum by expanding the local maximum to adjacent voxels of the surrounding set, one step at a time.

ICF Segmentation Examples



Three Spheres



Scanned Figure

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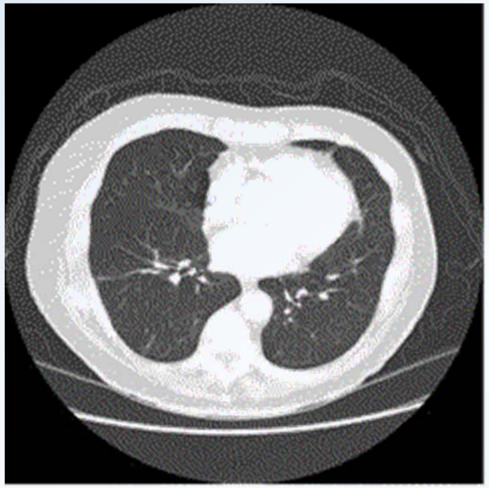
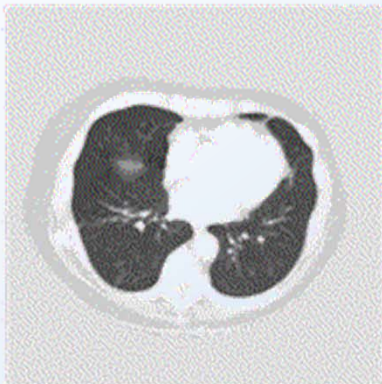
Preprocessing

- This example shows how ICF segments the respiratory system into individual organs.
  - Data is taken from an open database of LIDC-IDRI.
- In the preprocessing, the respiratory system is defined as a largest air-like region in the body, and 3D binary data is created.



(a) Original LIDC data, 512x512x133

(b) Size reduced data, 192x192x59



(c) Outside of body is filled by 0, HU of water

(d) Largest air-like region in the body

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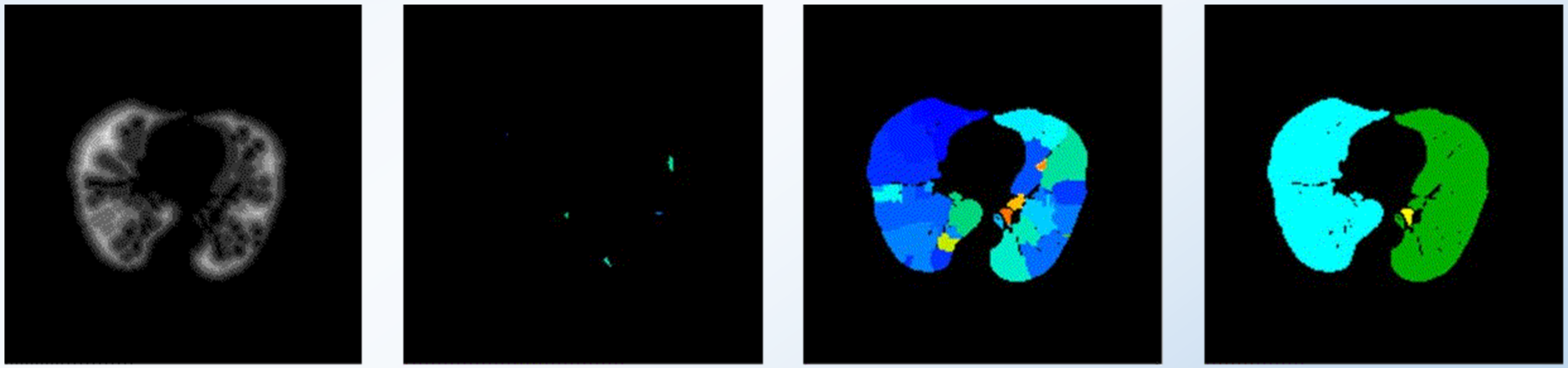
ICF and Postprocessing

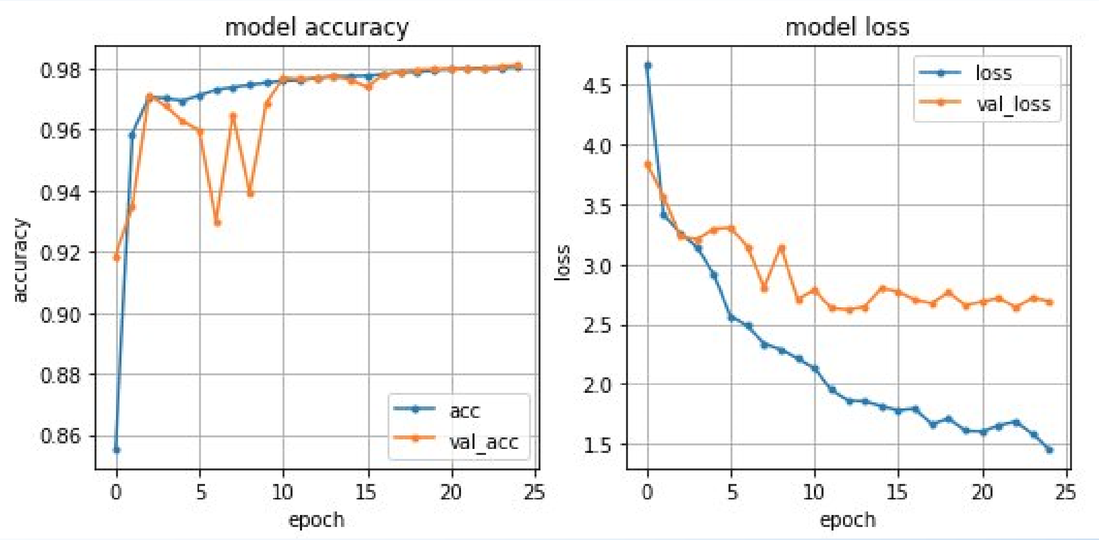
- Variations in tracheal thickness and dendritic structure inside the lungs create many segments, but post-processing that applies simple conditions to segment adjacency results in three segments of trachea / bronchi, left lung, and right lung.
- The size of the rectangular area for the left and right lungs are 13.5% and 14.8% of the original data, respectively.

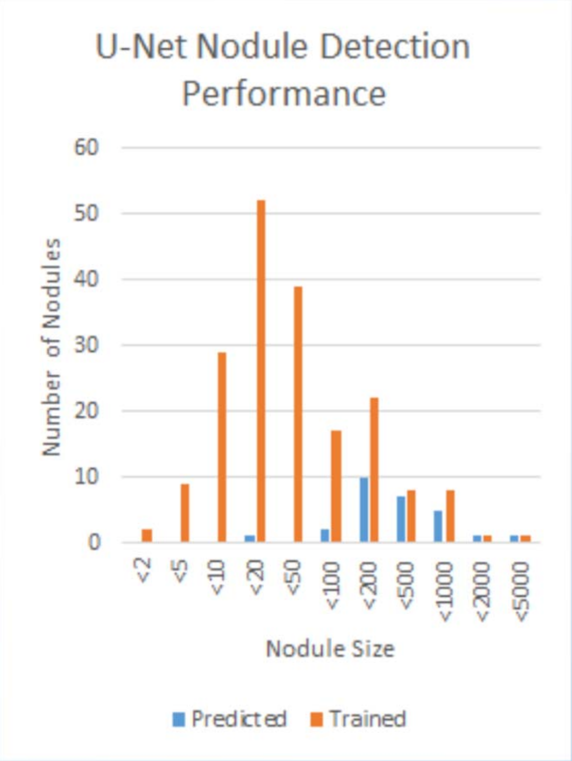


(a) Distance transfer (b) Local maximum (c) ICF segmented (d) Postprocessed

3D U-Net

- 3D U-Net is applied for left lung with 3 segments of background, lung and nodule.
- Train data:500, Verification data: 293
- Data size: 128x128x64
- Small nodules cannot be detected by this test.





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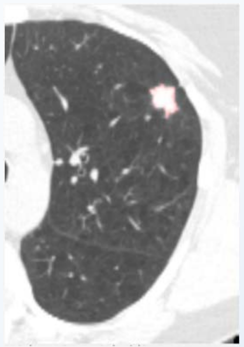
Results

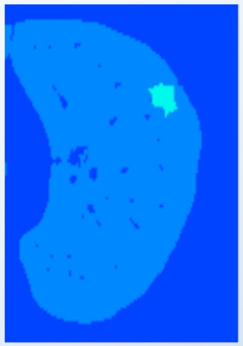
- ICF allowed the left and right lungs to be processed separately.
  - The reduced data size has made it easier to apply 3D U-Net.
  - The concept of 2.5D plus was demonstrated by samples that could detect nodules.
- Small nodules were difficult to detect.
  - It was found that the detection performance of U-Net decreased when there are large size differences between segments.

2.5D Plus Concept

(a) LIDC data



(b) Left lung area



(c) Ground truth

(d) 3D U-net predicted

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Conclusion and Future Work

Conclusion

- The concept of 3D presentation-based CT image diagnosis method that allows intuitive recognition was presented.
- It was shown that ICF, which divides a three-dimensional object at narrow parts, can divide a respiratory system into organs of trachea/bronchi, left lung, and right lung.

Future Work

- As the limitation of 3D U-Net are identified, we will try to detect nodules using the segment capability of ICF.
- Specifically, it may be a method that creates binary data including the lung walls, bronchioles, and nodules, applies ICF to this data to creates number of segments, and applies deep learning to identify nodule segments.

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