L.T.D

Phase 1: Tumors candidates detection

Presented by

Ahd Abd El-Razek Mostafa. *CS*

Fatma Mohammad Samy. *CS*

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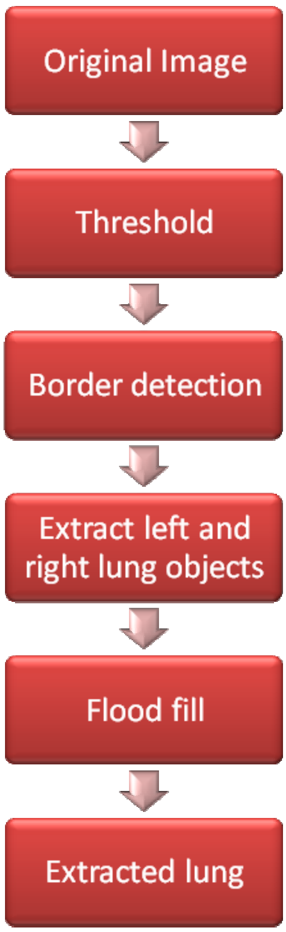
Overview

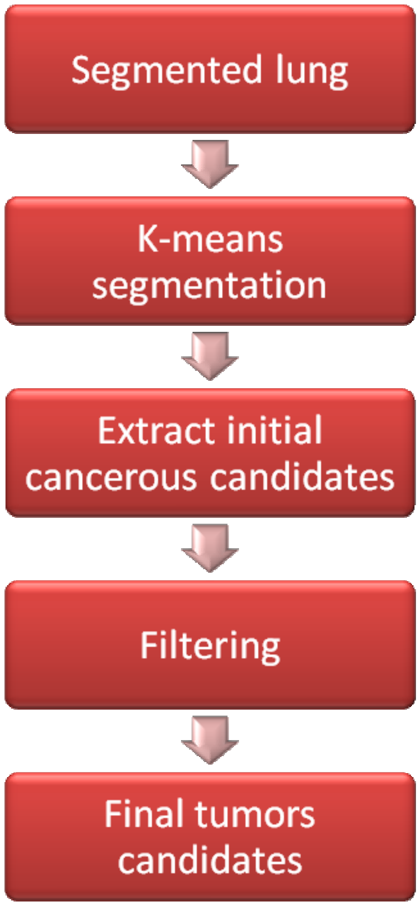
In this phase we discuss the automatic detection of lung tumors by analyzing chest computed tomography (CT) slice

The implementation goes through two modules:

1) Lung organ extraction.



2) Detect tumors from the segmented lung.

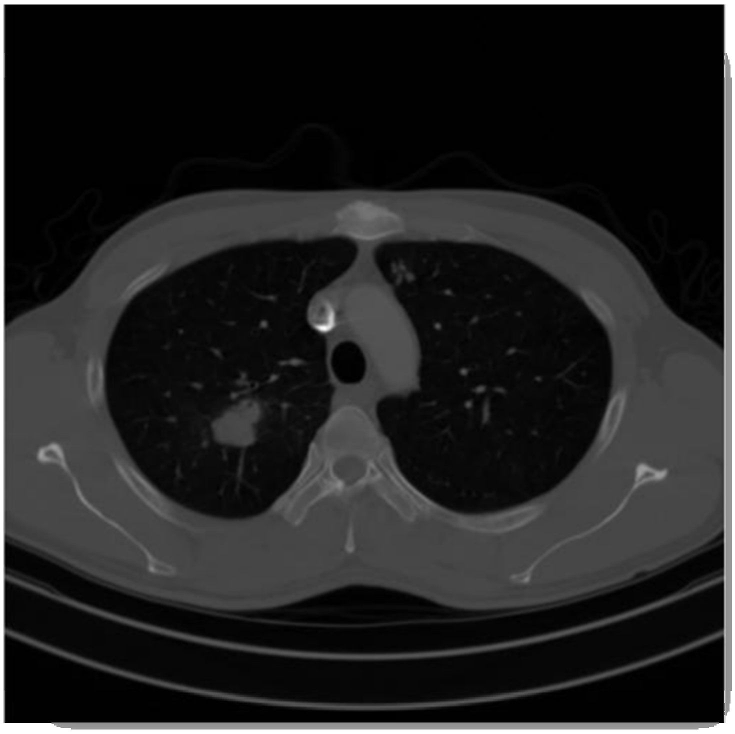


Implementation details

1. Lung organ extraction:

- Original image:

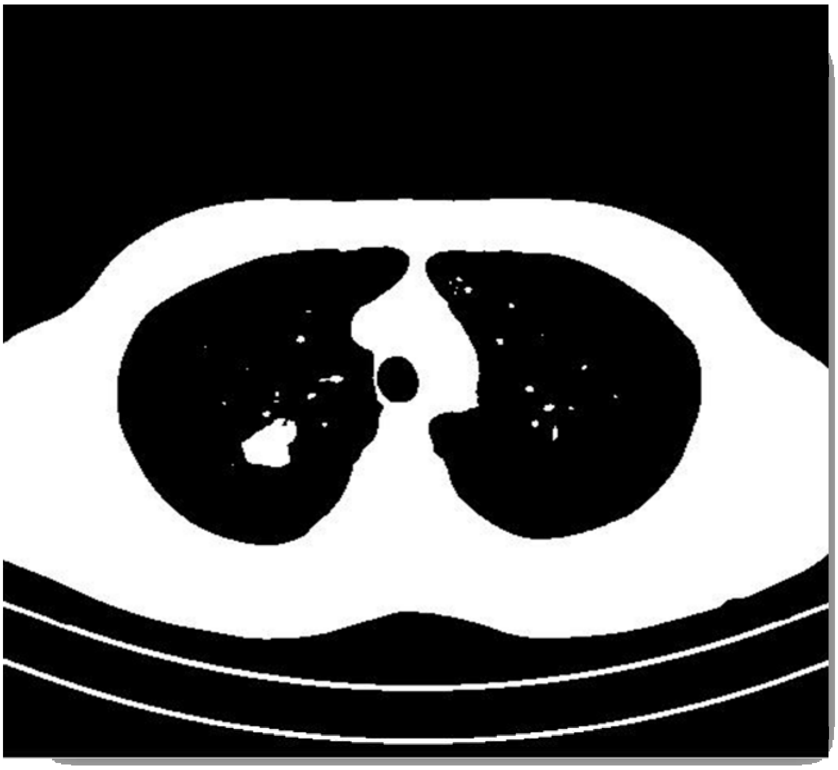
The original image expected to be entered to the system is a CT lung slice in DICOM format that looks like this image



- Threshold:

The first step of the method is to segment the image to detach the lung from the thoracic wall, the mediastinum and other structures. The slices are segmented with a global threshold of -250 HU (Hounsfield Unit) [2], because the lung is filled mainly by air. The application of Equation 1 generates a binary image:

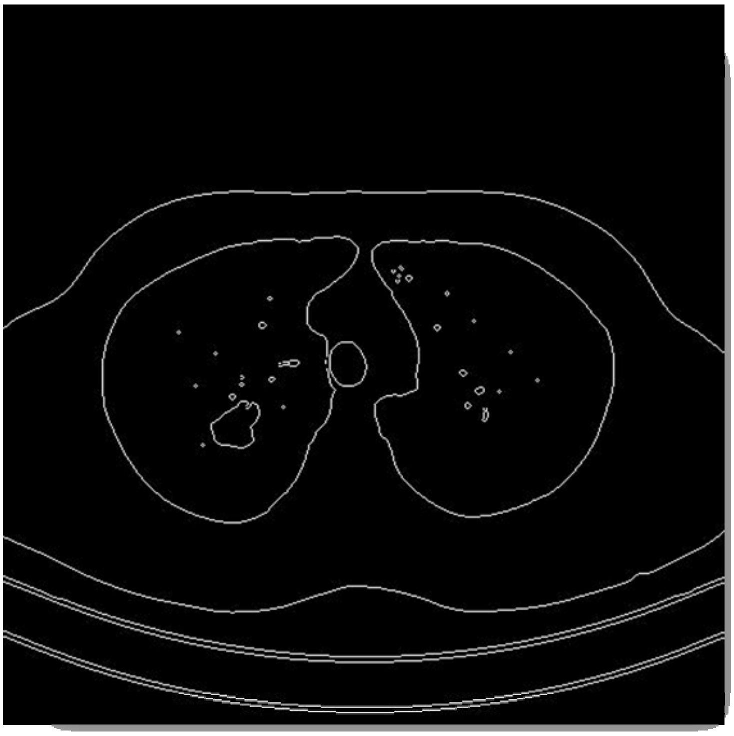
$$g(i,j) = \begin{cases} 1, \text{ if } f(i,j) >= -250HU \\ 0, \text{ if } f(i,j) < -250HU \end{cases}$$



Observing the image resulting from the threshold step, one can note that the image background has the same density as the lung. There are also some main airway structures from the windpipe bifurcation that can make the extraction of the pulmonary parenchyma more difficult. Therefore, there is the need to apply additional proceedings to complete the extraction of the pulmonary region.

- Border detection:

Detecting the image border is an essential step to continue the algorithm execution. In this step, the borders are thinned and highlighted. In this work we use Sobel's operator [Gonzalez and Woods 1992]. This operator is robust enough for this type of image, since there is no need to detect vertical or horizontal lines.



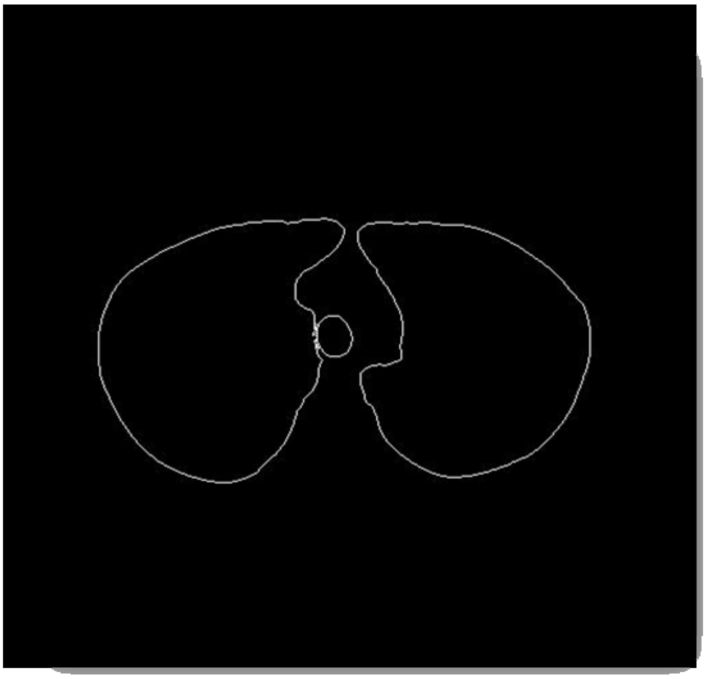
- Extract left and right lung objects:

As can be seen in previous figure, there remains in the image, structures other than the lungs, which are not interesting for the algorithm. This step removes such structures, leaving only the pulmonary parenchyma.

First find connected components in the image then remove uninteresting objects, based on the following criteria:

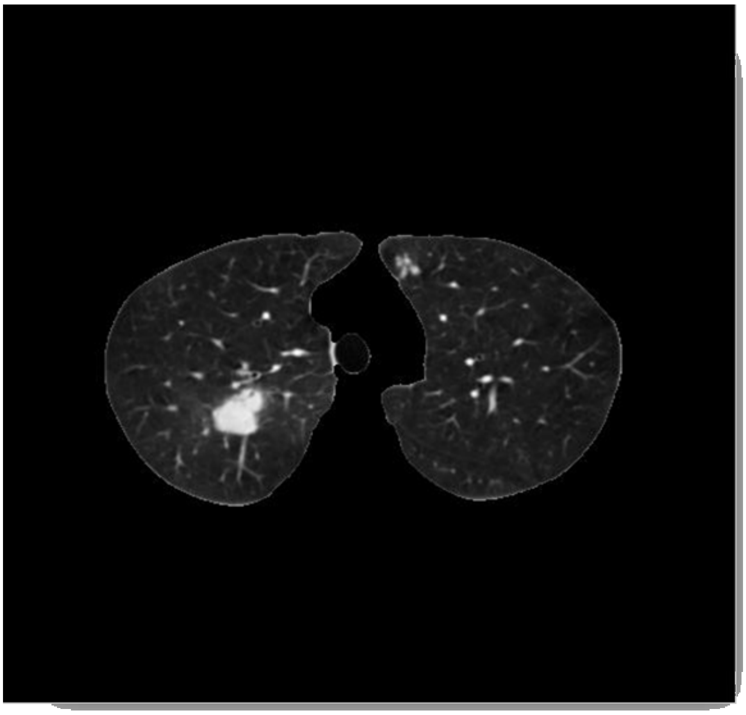
1) Small length of the object's border Objects with border length smaller than or equal to 290 pixels are eliminated.
2) Objects that are connected to the image borders are eliminated too as the lung objects are always centered so any object that's connected to the border is not a lung.

The following figure is the result of this step.



- Flood fill algorithm:

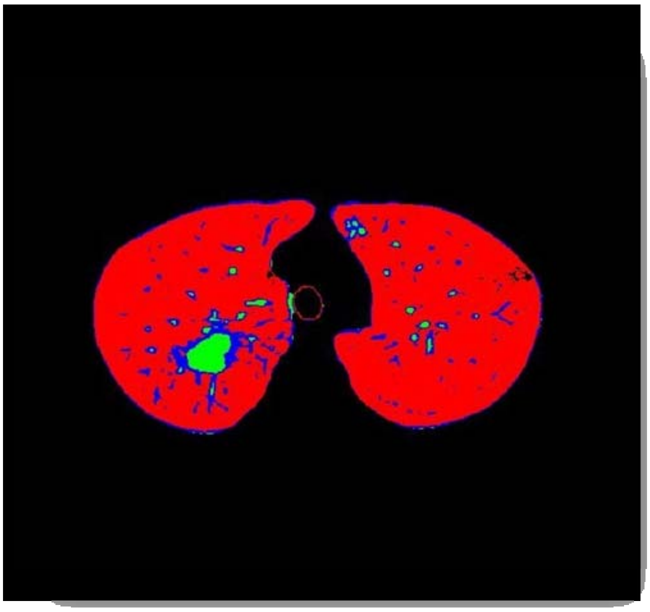
Fills holes found in image (left and right lungs) with the original image colors intensities.



2. Detect tumors from the segmented lung:

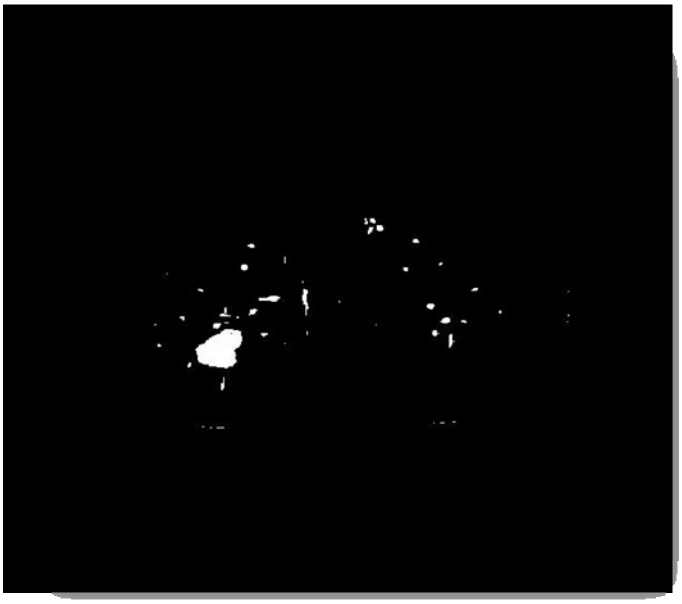
- K-means segmentation:

K-means algorithm is used for the segmentation of the extracted lung regions; it performs unsupervised clustering to each pixel in the image.



- Initial cancerous candidates:

After getting the segmentation results we start by initial cancerous candidate objects or nodules that represent all the members of one of the classes resulting from the k-means segmentation algorithm. By experiment, we consider the members of the class with maximum centroid (i.e.: mean) as the initial cancerous candidate objects and we ignore all the members of other classes because tumors have higher intensity than normal objects in lung.



- Filtering:

The image goes through three filters aiming to eliminate a huge number of false candidates that usually results from the segmentation step.

- Filter1:
  - Find area of each candidate region.
  - For each candidate objects if the area of the object is less than a threshold value T1 delete it from the candidate list. Applying this filter has the effect of decreasing the number of false positives that richly exist in the initial candidate objects. This decision may reduce the computation time needed in the following diagnostic rules.

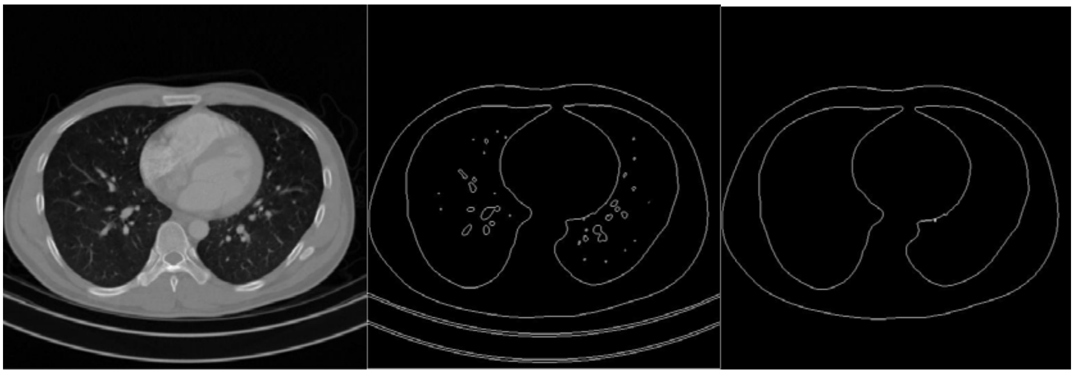
- Filter2:
  - Find the maximum drawable circle (MDC) inside each candidate region.
  - For each candidate object, if the value of maximum drawable circle (MDC) of this object is less than a threshold value T2 delete it from the candidate list. We chose T2 to be 2-pixels radius size, which means that any candidate objects with MDC less than 2-pixels radius size should be eliminated since it is away from being a nodule, and very close from being blood vessel. This rule is based on the medical fact that says that true lung nodules exhibit some circularity especially small lung nodules. Applying this filter has the effect of eliminating large number of vessels, which in general have a thin oblong, or line shape.

- Filter3:
  - Find the mean intensity value of each candidate region.
  - For each candidate object, if the value of the mean intensity value of this object lies outside a specified range, i.e. between T3 and T4, delete it from the candidate list. Medical information and experimentation lead as to choose the right values for both thresholds T3 and T4. The values we used are -9000 CT-intensity value for the threshold T3 and -12500 CT-intensity value for the threshold T4. Applying this filter has the effect of eliminating further more false positives.

Challenges

1- Lung organ extraction:

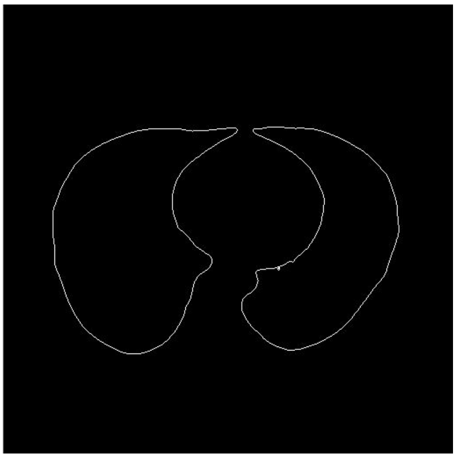
- **<u>Problem</u>:**
  The method mentioned in [2] for unwanted objects elimination resulted in inaccurate results for many images, so we replaced it with the mentioned one.
  But unfortunately it results in wrong segmentation for some cases which was like (a), after border detection was as shown in (b), so the result after elimination was (c)



(a) (b) (c)

Which is not the result we aimed to.

Solution: We added a condition that if the number of objects after elimination is 3 eliminate the largest one. This resulted in good results



2- Tumors detection phase:

- **Problem:**

In the method mentioned in [1], the initial cancerous candidates are considered the members of the class with the lowest number of members, this rule failed in case of big tumors as it occupies a large space in image and as a result a wrong class is chosen.

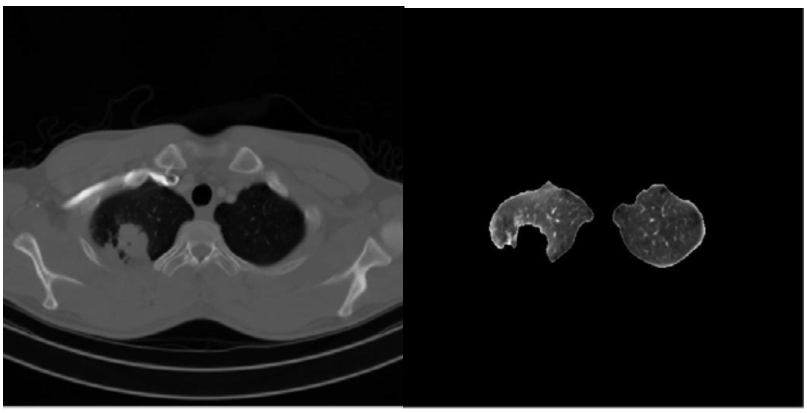
- **Solution:**

We consider the members of the class with maximum centroid (i.e.: mean) as the initial cancerous candidate objects and we ignore all the members of other classes because tumors have higher intensity than normal objects in lung.

Limitations:

- **First limitation:**

In some cases, the pulmonary lesion is adjacent to the pleura and has similar densities. Therefore, when the first step - global threshold - of our method is processed, concave depressions appear on the lesion location.
Original image in (a) after extraction results in (b).

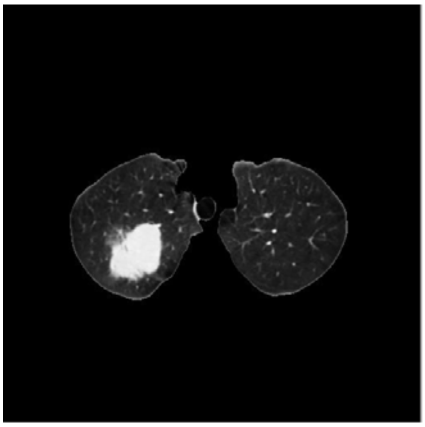


(a) (b)

We tried to apply the rolling ball method which is proposed in [2], but its results wasn't good enough as the rolling ball succeed perfectly with small depressions while in large ones like in previous figure it fails, also the size of the ball needed to reconstruct the parancheyma differs from one image to another and till now we couldn't found a fully automated solution for this.

- **Second limitation:**

  In many cases trachea is extracted with one of the lungs due to being so close to it, like the following image



But as you can notice that the intensity of the trachea is very low, so it has no effect on tumor segmentation step as it's considered as a part of the lung.

Resources used in this phase:

Papers:

1. Rachid Sammouda, Jamal Abu Hassan, Mohamed Sammouda ,Abdulridha Al-Zuhairy, Hatem abou ElAbbas, "Computer Aided Diagnosis System for Early Detection of Lung Cancer Using Chest Computer Tomography Images", GVIP Special Issue on Cancer Diagnosis, 2007.

2. Arist´ofanes C. Silva1, Paulo Cezar P. Carvalho2, Rodolfo A. Nunes3 and Marcelo Gattass4, "Segmentation and Reconstruction of the Pulmonary Parenchyma", VI Workshop
    a. de Informática Médica – WIM 2006.

3. Rachid Sammouda, Mohammed Sammouda, Jamal Abu Hassan, "Automatic lung regions extraction algorithm from 3d ct-images based on the bit-plane slicing technique", February 2006 University of Sharjah Journal of Pure & Applied Sciences Volume 3, No. 1.

4. Joris Heuberger, Antoine Geissb¨uhler, Henning M¨uller, University Hospitals of Geneva, Service of Medical Informatics, "Lung CT segmentation for image retrieval using the Insight Toolkit (ITK).

Websites:

- http://www.mathworks.com/matlabcentral/fileexchange/8379-kmeans-image-segmentation

Books:

- Digital image processing, Rafael C.Gonzalez, Richard E.Woods, Third edition.
- Pattern classification, Richard O. Duda, Peter E.Hart, David G. Stork, Second edition.