Tumor Detection using Airways Asymmetry

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Abstract—**A novel tumor detection technique on CT Scan images of the neck area is detailed in this paper. This technique is based on an airways' symmetry evolution within slices. The algorithm proposes to the physician a set of three slices where a tumor (if it exists) should mostly be located. Then, he will just have to browse the three slices instead of almost 100 in a CT scan.**

Our method is very effective and shows no false alarms within the patients in our database. In each of our tests the tumors were found to be close to one of the three proposed slices.

Index Terms—**asymmetry, abnormalities detection, bilateral symmetry, tumor detection, neck CT Scan images**

I. Introduction

Symmetry is one of the most important characteristics of vision. It is a fast and high level first approach to object understanding. On Earth, because of the gravity, the bilateral symmetry is the most important as it is necessary to maintain objects equilibrium. Most of the human-made objects have a bilateral symmetry. Moreover, humans and other beings as fishes, animals, birds, insects … have a bilateral symmetry too.

In particular reference to humans, symmetry is important because it can be a sign of disease. If the human body bilateral symmetry is not respected, that is most of the time due to some abnormalities. For example, the symmetry measurement can aid in the detection of breast cancers [1] or neurological disorders [2]. Asymmetry was also used for brain tumors detection on MRI images [3].

In our case, we are interested in tumor detection on anatomical images of the head and neck areas. Fig. 1 shows a sagittal view of the head and neck areas. Even if this area has a global bilateral symmetry, things are more difficult than for the brain because symmetry is less perfect. As far as we know, there is no previous work using symmetry for the neck area. First, we looked for a reliable measure of symmetry for the neck. Cancers in this area are due to smoke and tumors first develop themselves in the tissue which is directly related with this factor. The tissues which have the greatest probability to develop a tumor is located in the mouth, the tongue and the airways. The airways present normally a bilateral symmetry. A tumor is a group of cells which develops anarchically. So, the presence of a tumor close to the airways will introduce an asymmetry by pushing the airways in a given direction.

Fig. 1. Example of sagittal view of a CT Scan image of the head and neck area.

So, if there is a tumor in this area, it will be somewhere close to the airways and it will break its symmetry. All the work presented in this paper is based on this assumption.

We will first present how to easily compute the airways' symmetry and what the definition domain is in terms of number of slices where our hypothesis is realized. Then, we present some results and a discussion about this technique.

II. Tumor Detection

A. Materials

Our work is a part of a project which aims in segmenting tumors and risk areas for radiotherapy planning. As the purpose is radiotherapy, the main modality we focus on is the CT Scan as it is an accurate anatomical imaging technique and it can be directly used to plan the radiotherapy doses.

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Our images are generally around 100 slices volumes with a resolution of 1.2 mm per pixel on X and Y axis and 2.5 mm per pixel on the Z axis. As shown in Fig. 1, the volume goes from the upper end of the lungs to the middle of the head. We use for instance a twelve patient database with various kinds of neck tumors (larynx, upper neck, tongue) and even some patients having already surgical lung or tongue extraction.

B. Definition domain:

The airways have a quite good bilateral symmetry in the neck area. When approaching the lungs, this symmetry is less well respected. Anyway, tumors in this area do not belong to the neck area, so we can eliminate it. Fig. 2 shows the lower limit of our definition domain which is simply computed by using the upper limit of the lungs. This is a coronal view showing clearly the lungs as black areas inside the white area which represent the body. The lungs can be segmented using a simple thresholding and the limit is set by using the lungs bounding box upper limit.

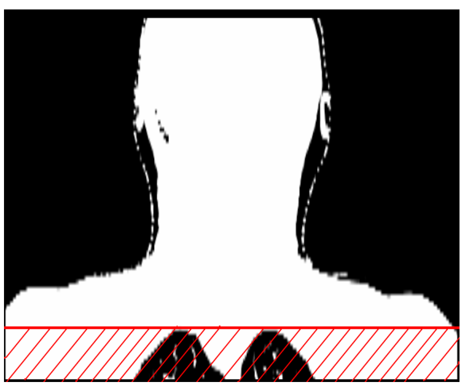

Fig. 2. A coronal view showing the lower limit of our definition domain.

On the other side of the neck, the airways asymmetry is no more a good criterion when approaching the mouth and the nose. Anyway nose or brain tumors are not our interest area, so we also eliminate all slices upper than the nose.

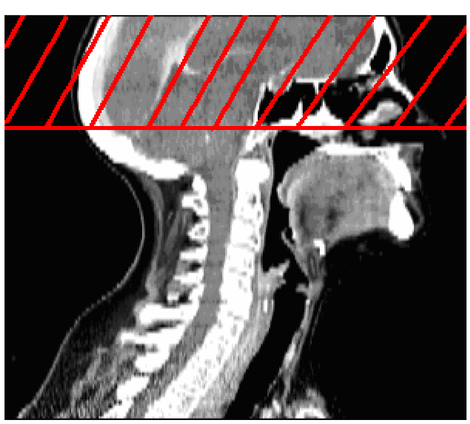

Fig. 3. A sagittal view showing the upper limit of our definition domain.

In order to achieve this, we compute the number of pixels representing the bones on all the slices. These pixels are white here as it is shown on Fig. 3, so they are also easy to extract by simple thresholding.

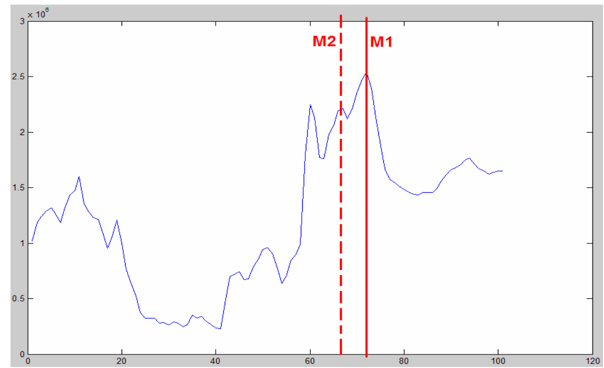

Fig. 4. Bone pixel number variation within the slices of an image.

Fig. 4 shows the variation of the amount of bone pixels within the slices of our image volume. The end of the mouth and beginning of the nose is an area where bones pixels are very numerous. We detect the maximum M1 and choose the end of the definition domain to be 5 slices below this threshold at M2 (Fig. 4).

We have automatically set our definition domain boundaries as it is shown for the lower limit in Fig. 2 and for the upper limit in Fig. 3.

C. Asymmetry computation

Fig. 5 shows an axial slice of one patient. In white, we can see the bones, in black the air and in other gray levels we can see the other tissues, mainly the muscles. We focus on the airway by plotting a circle around it. The airway which should be centered on the medial axis and symmetric is here pushed on the right side by a tumoral mass. The shape of the airway itself is no more symmetric. Our technique only analyzes the airway shape and its closed surroundings inside the circle plotted on Fig. 5. The rest of the image is not

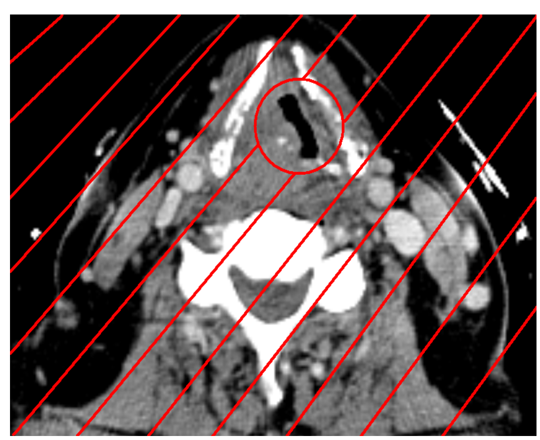

Fig. 5 : An axial view showing the upper limit of our definition domain.

relevant for the detection of asymmetry and is therefore eliminated.

The airways are black, so with only one click on one slice it is very easy to extract the airways in all slices. Then we use the center of the bounding box as the center of a circle having a diameter equal to the bounding box size augmented by ten percent. We obtain as it is shown Fig. 5 a circle including the airway and its surroundings.

In order to really focus on our circular area we decided to use a log-polar grid instead of the Cartesian grid we initially have. In the spatial domain, log-polar schemes [4] have been used to model the strongly inhomogeneous sampling of the retinal image by the human visual system. The number of receptor units (either at the retina [5] or in the later cortical stages [6]) drops rapidly with eccentricity while their size increases, causing a fast decay in visual acuity [7]. Here that is exactly what we desire: we make a fixation centered on the airway and then we are interested in having a very high resolution on the airway shape and surroundings and we do not care about what happens far from the airways.

Fig. 6 shows an example of log-polar representation of a CT Scan slice centered on the airway. The vertical axis represents the radius from the center (top) and the horizontal axis represents the angle. The black large line represents the contour of the airway in log-polar coordinates. We obtain many details on the surroundings of the airway as we can see below the black large line.

The log-polar representation has not only the advantage of a representation centered on the object of interest which is here the airway and providing a maximum level of details near to the center, but it has a practical interest too.

A circle in a Cartesian grid becomes a simple line in a polar grid. So cropping the Cartesian image on a circle centered on the airway means just cropping the log-polar image bellow a line. You can see this thin black line on Fig. 6, and we eliminate the image bellow this line.

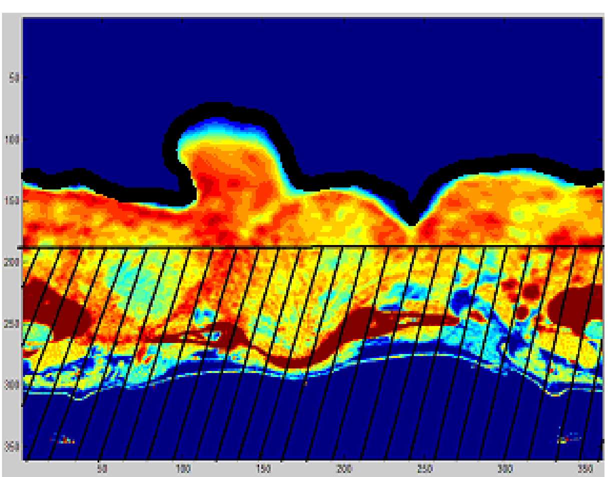

Fig. 6 : The log-polar representation of a CT Scan slice centered on the airway

The final cropped image is shown in Fig. 7: as desired we obtain the airway shape and its close surroundings with a high resolution and we eliminate the rest of the image.

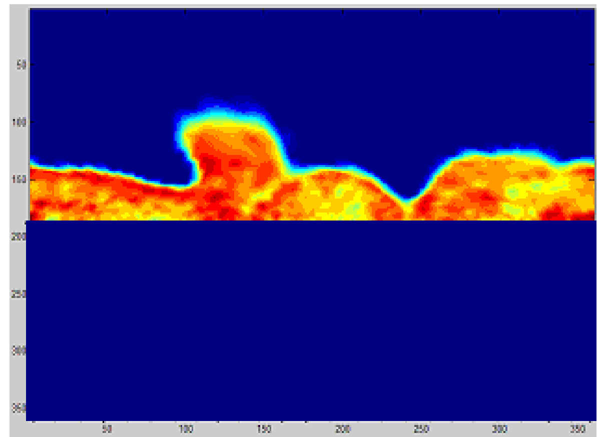

Fig. 7: The log-polar representation of a CT Scan slice centered on the airway and cropped on a circle centered on it.

We have an airway symmetry measure (S) on the log-polar representation by computing the correlation between the left side and right side of the image as the symmetry axis is in its middle.

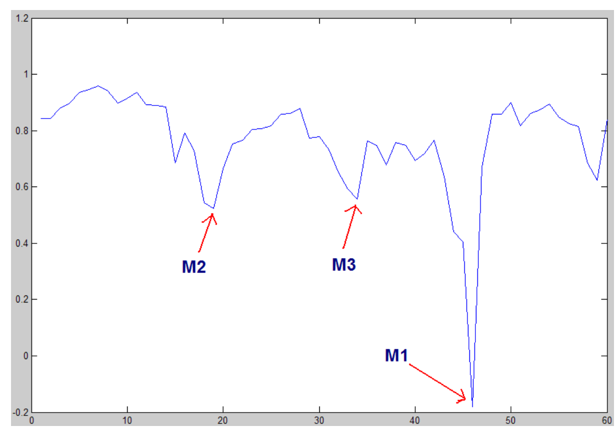

Fig. 8 : The correlation (S) between the left and right side if the log-polar representation within slices.

Finally, we can see on Fig. 8 the variation of our symmetry measure. When S is close to one, the airways are very symmetric, the minima represent the slices where there is less correlation between the right and left side of the airway, so these slices are more asymmetric.

Then we choose a set of three more important minima (called M1, M2, M3) and get the corresponding slices. This is the set of potentially pathological slices provided by the algorithm to the physician. In order not to choose minima too close to another one (in this case they could be due to the same abnormality), we use a 5 slices area on each side of a selected minimum where we do not look for another one.

III. RESULTS

A. Tests on real patients

The result of our method is a set of three propositions of slices containing a tumor. The specialist has to take a look only at the three slices proposed instead of the entire volume. If there is a tumor, it is located around one or several of these slices. If there is no tumor around one of the three proposed slices, it means that the patient has no visible tumor.

We made tests on CT Scan images of twelve patients having neck tumors. On the three proposed potential pathological slices, there was always at least one corresponding to a tumor slice for each patient, so, within our database there were **no false negatives (at least one true positive)**. The results are detailed in Table I and show that if the patient has a tumor it will be detected on at list one of the three proposed slices.

TABLE I
RESULTS ON OUR PATIENT DATABASE

Patient/ Tumor type	Potential pathological slice1 (M1)	Potential pathological slice2 (M2)	Potential pathological slice3 (M3)
A03/ Larynx	Negative	POSITIVE	Negative
A05/ Larynx	Negative	POSITIVE	POSITIVE
A07/ Larynx	Negative ?	POSITIVE	POSITIVE
A09/ Larynx	POSITIVE	Negative	Negative
A10/ Larynx	POSITIVE	Negative ?	Negative
A12/ Larynx	POSITIVE	Negative	Negative
A13/ Larynx	POSITIVE	POSITIVE	POSITIVE
B11/ Neck	POSITIVE	Negative ?	Negative
B12/ Neck	Negative	POSITIVE	Negative
B14/ Neck	POSITIVE	POSITIVE	Negative
B16/ Tongue	POSITIVE	Negative	Negative
B17/ Tongue	POSITIVE	POSITIVE	POSITIVE

The twelve patients have different kind of neck tumors: most of them have larynx and higher neck tumors. Some have tongue tumors. When we hesitated between a negative or a positive result, we declared the result as “Negative ?” in order not to add uncertain positive results.

B. Timing Results

Our method is computationally efficient. After getting only one click from the physician, it needs 2 seconds per slice by using Matlab on a P IV, 500 Mo RAM PC. It should be easy to get really faster results by implementing the method in C and doing some optimization as cropping the image before doing the Cartesian to log-polar grid.

IV. Discussion and conclusion

We presented an almost automatic method which allows the tumor and abnormalities detection in neck CT Scan images by using asymmetry considerations on the airways. This method shows that we achieved to obtain no false negatives on our database. The symmetry alone is not enough to recognize the tumor presence as benign lesions such as inflammatory conditions, vocal cord paralysis, lymph node enlargement close to the airways, etc., can all potentially cause asymmetry, but it is sensitive enough to detect abnormalities which have not to be missed by the radiologist. If the fact that this method has no false negatives is confirmed on a larger image database, radiologists will only have to take a look at the proposed slices (and eventually some neighbor slices) instead of all the volume to see if the patient has a tumor or not.

This method can also be applied on other anatomic images like MRI images. The problem to be solved is to see how to compute the definition domain, but the principle is the same.

Finally, after the physician selection of the slice(s) containing a tumor, other methods leading to localization and to segmentation of the tumor can be achieved. This is the first step of a tumor segmentation system.

Acknowledgment

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