HEART SHADOW COMPENSATION

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I. Introduction

Chest radiographs can help the detection of lung cancers, tuberculosis (TB) and other lung diseases. The early detection of cancer is very important as it significantly increases the chance to cure the disease. Global screening is a relatively cheap way to detect lung cancers and TB. Such screening programs generate a vast amount of pictures to be analyzed by experts. This is where computer-aided detection (CAD) can help the work of radiologists.

CAD systems are not reliable enough to do the work alone at the moment. The current goal is only to create a system that can help the detection and increase the accuracy of examination by searching suspicious areas (region of interest, ROI) or by enhancing the visibility of the picture at the darker regions.

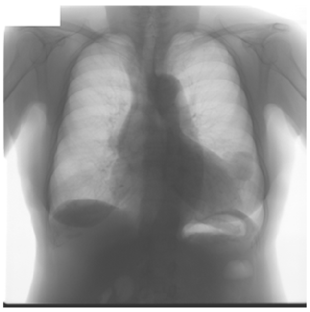

Figure 1.a

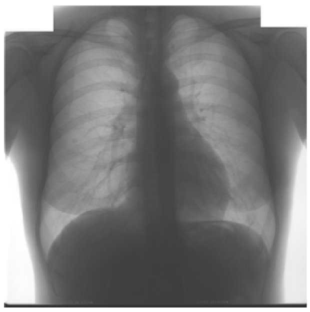

Figure 1.b

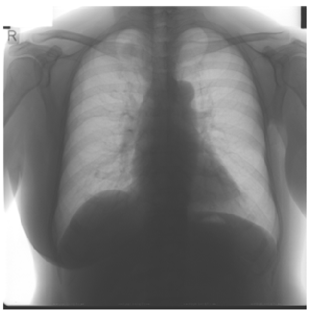

Figure 1.c

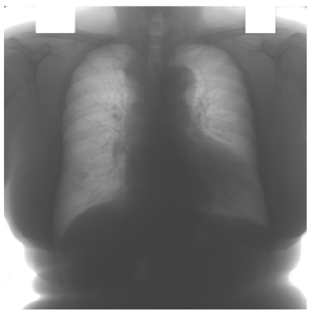

Figure 1.d

Figure 1: Examples of different heart shadows

The first step in such an evaluation would be the delineation of the organs' boundaries. Searching the contour of the lung, the heart, the clavicles and the ribs determine the area of processing and the raw data for image enhancing. The lung contour has diagnostic value without further processing too as it can show cardiomegaly and pneumothorax.

The next step is image enhancing. It contains techniques to make the image less noisy, to correct the brightness of the image and to reduce the shadows of other organs. Promising results have been reached at the field of rib and clavicle shadow compensation [4]. Heart shadow compensation has not been solved yet.

Finally the detection of lung diseases gives regions that doctors should closely check. Nodule detection and texture analysis are used at this stage. Nodule detection can profit from image enhancing [3]. Nodules can be seen better without the ribs and the false positive number can be decreased as the intersection of ribs will disappear.

Figure 1 gives a few examples of chest radiographs from the JSRT database [2]. Heart shadows show great variety in shape, size, position and darkness. The contours also vary from sharp to diffuse. Image 1.a is very difficult for several reasons: there is a nodule next to the heart in the left lung, a potential threat for contour detection; air bubbles are visible under the diaphragm making its border less prominent; the heart shadow is bigger than average and the shadow of the breasts adds another shadow layer with new edges. Image 1.b shows the typical heart shape and size. Image 1.c is an example where the border of the heart is not a strong edge rather a diffuse continuation into the area of the lung. Image 1.d shows an above average sized heart shadow.

The heart shadow is usually dark enough to make the detection of lung nodules in the same area almost impossible, thus heart shadow compensation can help both nodule detection algorithms and doctors. The goal is to make the area of the dark region more visible without destroying its inner structure. We must avoid creating artificial shadows and keep the anatomical structure.

II. Delineation of the heart

Shadow compensation algorithms usually need the contour of the object as an input. The precision of the contour is very important because if the calculated contour goes inside or outside the real contour then the compensation will create artifacts: darker and brighter structures along the border of the heart. This will create false positive hits in nodule detection or reduce the area that can be analyzed reliably. Figure 2 shows an example of such areas. The dotted line is a bad heart contour segment. After the shadow compensation new structures will appear on the image: a lighter than the average background area where the calculated contour was too big and a darker area where it was too small. Note the pecked line that is the border of the aorta descendens. We should determine that boundary too because the aorta descendens has a strong additional shadow inside the heart shadow. For the shadow compensation the dark area around the heart is used. This is not the exact anatomical border of the heart. The goal of the compensation is to make the lung area more visible everywhere where it is shadowed by something.

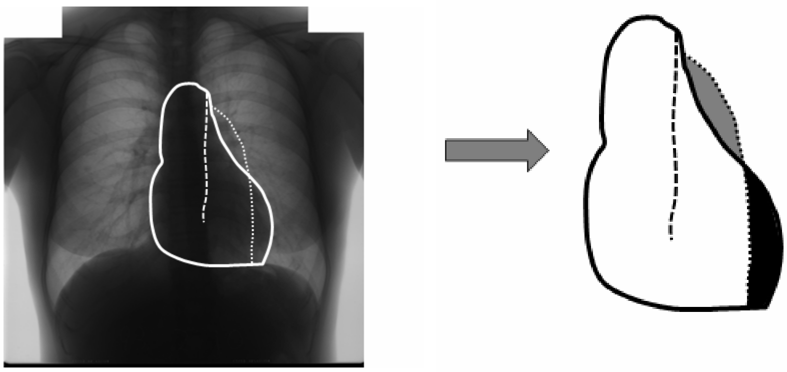

Figure 2: Effect of bad contour after the shadow compensation

A Active Shape Model (ASM)

ASM was used successfully for lung contour detection earlier. It can determine the heart boundaries the same way. It is able to generate complex contours, not only a closed loop, so it can be used to simultaneously determine the inner contours of the heart, the heart boundary and the lung boundaries as well. The algorithm is very fast. The only drawbacks are that its result is usually not accurate enough for the shadow elimination and it needs a good initial contour to guarantee that the algorithm converges to the right contour. See [1] and [4] for details.

B Active Appearance Model (AAM)

The AAM algorithm not only determines the contour of the object but generates the inner texture too. This type of combined search can lead to more robust solutions. Unfortunately the price of robustness is the relative slowness of the algorithm and the contours are far from the subpixel accuracy. See [1] for a comparative study of several contour detecting algorithms.

C Multistep Algorithms

For precise contour detection the examples above are not enough. We have to make sure that the algorithm is robust and accurate at the same time. A multistep method is used to guarantee this:

- First we calculate the approximate boundary box of the heart. This is useful because the position and size of the heart have great variability. The boundary box can be acquired using the position of the diaphragm and the result of an ASM for the lung contour detection which is quite reliable.
- After we have a good initial position we can use ASM to determine the heart boundary with little error.
- A final step is used to make the boundaries as close to the real contours of the shadow as possible [5]. We build a database of the contour's normal vectors' directions. The average direction of each contour normal vector is calculated using a training set of images. Edges are searched in the neighborhood of each contour point along the direction of the average normal vector. Within a range we move the contour to the strongest edge found. Outlier contour points are replaced using interpolation.

III. Heart shadow compensation techniques

Heart shadow compensation can never be perfect as we don't know the fine structure of the heart and in some cases the shadow is too dark, only noise is left after the compensation. But a relatively good image intensity correction can be made in most cases.

A Compensation using stripes

A simple model of the heart shadow intensity can be made if we assume that the intensity at a location is the function of only the distance from the heart contour. This is approximately true for many images. We only have to determine this intensity for every stripe. Figure 3 shows how we divide the image into regions. We generate stripes parallel to the left side of the heart's contour. A polynomial fit is made to the intensity of the pixels along curves parallel to the ribs outside the heart contour. These functions are used for extrapolation to estimate the intensity under the heart. The difference of this estimation and the real intensity is created by the heart's shadow. The average intensity is calculated in each stripe and the stripes' intensities are multiplied to the necessary level. The modifications are blurred to avoid strong stripes in the resulting image.

This technique is useful only for partial compensation. It can only be used on the left side of the heart shadow to the left of the mediastinum.

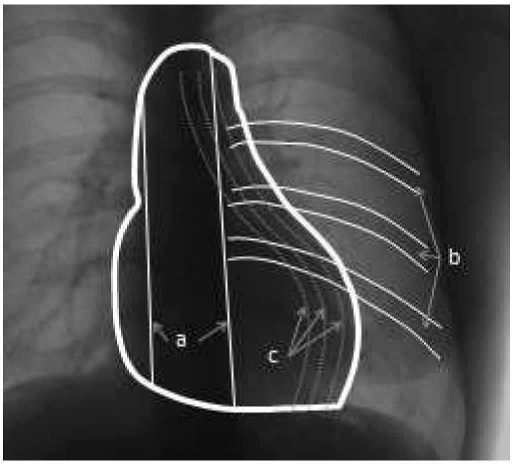

Figure 3: Areas used during the compensation. a shows the mediastinum boundaries, b indicates the ribs and c points to equidistant contours

B Compensation using models with global parameters

The previous model had many parameters. Each stripe had a unique average intensity that had to be calculated. A different approach is to use fewer global parameters inside the heart shadow. We can use the distance of the heart contour and the distance of a certain rib as coordinates. 1D and 2D polynomials can be fit to this intensity surface. The parameter fitting can be made with well-known algorithms.

The advantage of this kind of fitting is that there won't be artificial jumps in the corrected image, the polynomial guarantees the smoothness.

Conclusion and future work

The frameworks of heart compensation algorithms were introduced. In the future these will be optimized using a large image database.

References

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