QUANTIFICATION OF CORONARY OCCLUSIONS FROM CINE-CORONARY ANGIOGRAMS

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Introduction

Coronary angiography plays an important role in the clinical management of patients with ischemic heart disease. This procedure provides the clinician with detailed information about the morphology of the coronary arterial system. To be able to interprete the functional significance of a coronary obstruction, the three-dimensional location within the arterial system and the severity of the obstruction must be known. The usual visual interpretation of the two-dimensional cineangiograms from different projections severely limits the extraction of the necessary information. Only a small part of the total amount of information inherent in these images becomes available. Due to this subjective process large inter- and intra-observer variations have been found in the estimation of the location and severity of coronary occlusions. As a first step in an attempt to improve the interpretation of the coronary arteriograms by reproducible objective quantitative analysis, a software algorithm has been developed for detecting the contours of selected coronary lesions from video digitized matrices. For this and other applications in the field of quantitative analysis of cardiac images, a computer based operator interactive Cardiac Image Analysis System (CIAS) has been implemented at the Thoraxcenter Image Processing Laboratory (2). Presently this system is used for the quantitative analysis of:

1. cine-coronary angiograms.
2. marker cinefilms; the radiopaque markers are detected automatically to assess left ventricular segmental motion abnormalities (1).
3. left ventricular angiographic contours, automatically detected in video format with a hard-wired contour detector, the Contouromat (3,4).

Fig. 1. Example of selected cineframe of a right coronary artery in the AP orientation. The outer borders of a 64x64 matrix have been superimposed.

Contour detection coronary obstructions

Figure 1 is an example of a selected cineframe of a right coronary artery in the AP orientation. The outer borders of a 64x64 digitization matrix encompassing a coronary obstruction have been superimposed in the original video image. To better understand the problems concerning the automated detection of the contours of the coronary artery, the two-dimensional brightness function of this matrix is displayed in figure 2 as a three-dimensional structure with the brightness level plotted along the z-axis. The indicated positive x and y axes correspond with the horizontal and vertical video scan directions, respectively.

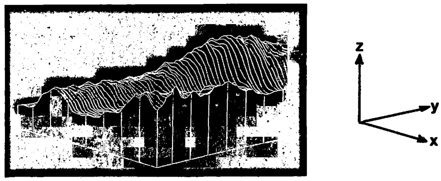

Fig. 2. Three-dimensional representation of the brightness function of the 64x64 matrix of figure 1, encompassing a coronary obstruction.

From figure 2 the coronary artery can be recognized as a mountain-ridge; it is clear, that the brightness level along the base of the ridge is not constant, but dependent on background structures. Therefore, a simple threshold operator on the brightness function cannot be applied. The edge-detection operator to be applied must satisfy the following requirements:

1. the contour positions must be defined along the base of the mountain-like structure.
2. the detected positions should be independent of background brightness levels and contrast, i.e. independent of external factors.
3. the detected positions should be independent of other objects or arteries present in the neighborhood of the lesion to be analyzed.
4. the operator should be little sensitive to noise influences.
5. to be able to apply the analysis procedure in clinical practice, the speed of the operator is important; this can be defined in terms of the number of add/subtract and multiply/divide operations.

For the edge-detection algorithm an average derivative operator has been defined. By including derivative values obtained from areas of different sizes, the final operator combines "minor edge" as well as "major edge" properties.

The brightness function along a matrix scanline perpendicular to the centerline of the artery is denoted $g(k)$, $k=1,2,\dots,n$. Two edge detector operators are defined, one for the left edge and one for the right edge. The derivative suboperator for the left edge $m_{iL}(k)$, which determines the difference in brightness levels for i pixels on either side of the position k ($1<k<n$) is defined by:

$$m_{iL}(k)=\frac{1}{i}\sum_{j=0}^{i-1}\{g(k+j)-g(k-1-j)\} \qquad (1)$$

Because of the amount of noise present in these radiographic images, the suboperator with i=1 is not used. The maximal number i of pixels to be included in the derivative operator has been determined empirically to be three. The average derivative operator $M_L(k)$ for the left contour is then defined by:

$$M_L(k) = \frac{1}{2}\{ m_{2L}(k) + m_{3L}(k) \} \qquad (2)$$

Similarly, the average derivative operator $M_R(k)$ for the right edge is defined.