APPLICATION FOR THE ARTERY TRANSVERSE SECTION TRACKING WITH MANUAL INITIALISATION

Introduction:

This application allows the tracking of the borders and the cross section of an artery in an ultrasound video sequence. The application is designed for processing ultrasound images (sequences) in B-mode to track the borders of the artery and to analyse their changes in dependence on time (in ultrasound video sequence). This dependence (between geometric parameters and the time or the frame number in the video sequence) can be used for various analyses, especially for those related to blood pressure and to elasticity of arteries.

The main advantages of the presented application lie in the fact that it almost does not need any manual adjustment of parameters. It is accurate, reliable and almost automatic using different image qualities. Artery boundaries are generally not very noticeable, which makes the detection very difficult. Accuracy of the method which is implemented in this application does not depend on the clarity of the boundaries in the image, which increases its reliability. It can track the measured artery even though the ultrasonic probe is moving in the perpendicular direction to the blood flow (which causes an overall movement in the image).

At the beginning of the treatment the arterial circle must be detected in the first frame of the sequence accurately and reliably. At the same time arterial circle can theoretically be found in any place of the image. The image also contains a variety of descriptive information. In addition, the area of interest may be different for various data sources, as shown in Fig 1. For this reason, the method includes a first and only manual step in which the operator must perform a simple initialization - marking artery in the image with a mask – to the ring. The subsequent process of determining the cardiac cycle is fully automatic.

The whole method consists of several consecutive steps of processing the images. The main idea is to track the movements of the tissues near the arterial wall. This is achieved by detecting significant visual units that are present in the artery wall. These units are selected as important points (the so-called *good features to track*) which are tracked during the entire video sequence. The resulting artery cut is considered as the area that is defined by these points.

Fig 1. An ultrasonic source image.

Initialization:

Suitable features must be chosen in the first step so the artery wall could be observed during the video sequence, this is implied by finding the most significant points in the image. Through the selection of the most important points, the positions of the points should be far enough from each other, and a check whether the distance between the newly selected point and the nearest other points is greater than a given minimum distance is performed. This procedure ensures the uniform distribution of selected points in a defined area.

This initialization process should be (subject to further processing steps) implemented in the first frame from the video sequence. As mentioned in the introduction, this procedure is automatic, which means that an area must be provided for detection of significant points which are marked manually. This area must securely contain the arterial wall. A suitable shape for such an area is a ring of a variable diameter and a fixed-width edge. Example of the initialization step is shown in Fig 2.

The above mentioned ring (defined by the user) can be used as a mask for the method *Good Features to Track*, which looks for significant points for tracking.

Figure2. Initialization Step : the mask in the shape of a ring for the searching procedure for identifying points that are best suitable for tracking (cut from the source image).

Potential corners are reduced by a procedure that removes significant points accumulated in such areas where the Euclidean distance between points is less notable than a certain value. Then the initialization step produces under the mask a ring-shaped group of distinguished points (their coordinates in the image), as shown in Figure 3.

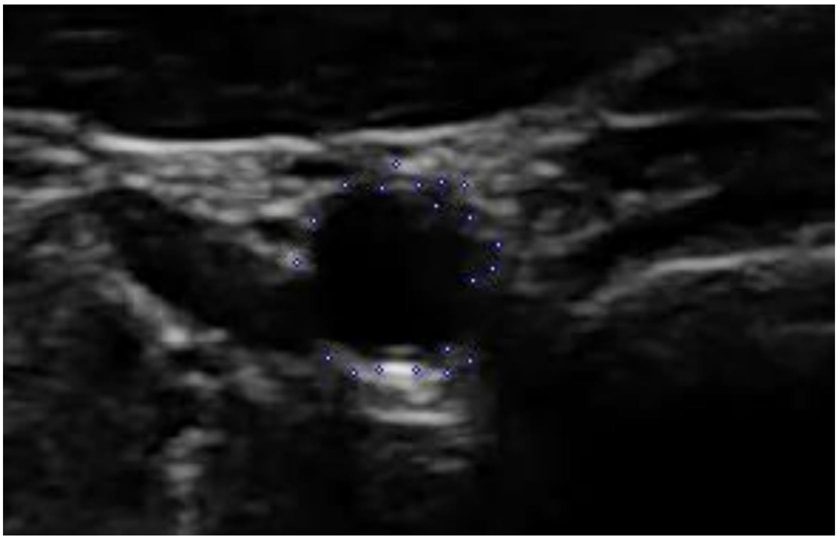

Fig.3 Detected significant points shown in the source image after the initialization procedure.

The computation of the cross-sectional area of an artery:

During the processing operation, the artery is represented by several significant points obtained in the initialization step. Significant points (features) are spread out along the edge of the artery, which implies the use of some fitting function. The shape being searched is given by an artery cut anatomy and mostly comes up to a circle or ellipse (see Fig. 4).

Fig. 4 Ellipse fitted to detected features.

The most suitable parameters of the ellipse can be extrapolated from the processing of the previous coordinates of the significant points in the sense of least squares. Area of the ellipse can be calculated easily using the equation:

$$ellipse\ area = \pi \cdot n \cdot j\ , \qquad (1)$$

where the variables are described in Fig.5.

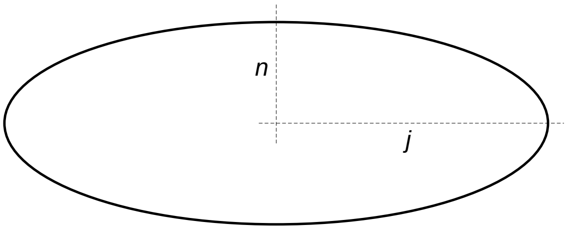

Fig. 5 Ellipse parameters.

This application allows also **the tracking of significant points in the video sequence** using *optical flow* determination method. In every frame the tracked feature points are fitted into an ellipse and the area of the ellipse is computed, after that, the curve which represents the area according to time is carried by a graph.

Application flowchart:

The mentioned processing steps are ordered by the flowchart in Figure 6. The method represented by the flowchart follows the movement of significant points (optical flow) in a video sequence. There is an ellipse in each frame. The area of this ellipse is computed in each frame and the output value (the ellipse area in pixels) is saved. This curve (cross sectional area of arteries in relation to time) is a cardiac cycle with direct relation to blood pressure and elasticity of arteries.

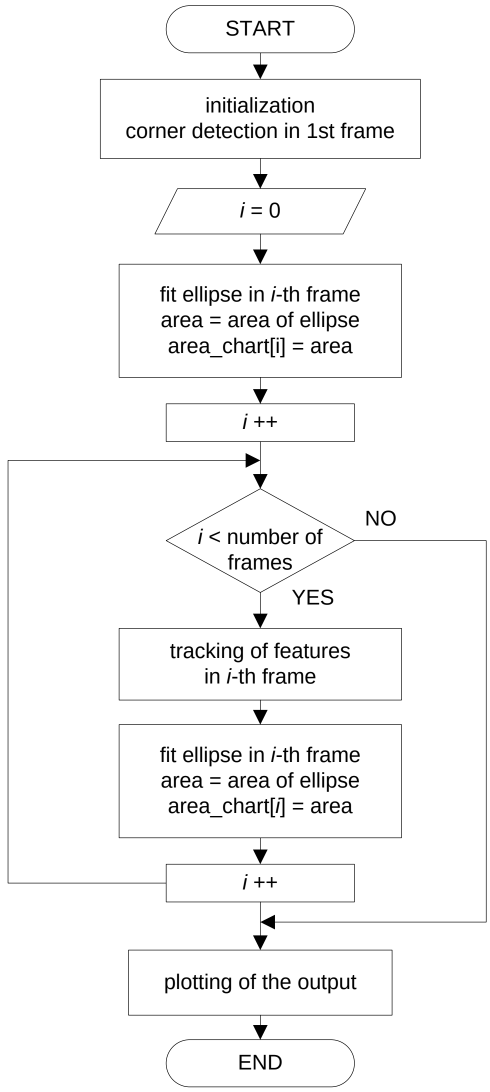

Fig.6 Flowchart of the application

The implementation of this application required the usage of some methods from OpenCV libraries.

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