Semantic segmentation of angiographic images

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Abstract— **The overall purpose of this work is to identify objects in an angiographic sequence by exploiting the temporal correlation between adjacent frames for analysis and compression purposes. The detection of the vascular tree in a reference image can support segmentation in adjacent frames by reducing the detection problem to a tracking procedure along the sequence. Object identification also allows an** *object-oriented* **approach to compression, as suggested by medical images nature. A vessel segmentation algorithm has been designed and implemented; it is an extrapolation and update procedure which exploits the a priori knowledge about the image content.**

I. Introduction

In the current multimedia trend, some new medical applications require efficient image communication techniques as well as dedicated functionalities adapted to medical data exchange. Remote consulting will allow clinicians at different geographic location to share the same sequence of images, thus avoiding the need to exchange the physical support on which images are recorded, or even to transfer the patient himself. Other interesting application are also conceivable. One could be the possibility to *navigate* into the digital sequence, that is to select a predefined image, to go forward and backward in the sequence, and also to make annotations on images, to segment particular regions of interest, i.e. which identify meaningful objects, and to enjoy of facilities such as contrast enhancement, zoom, and any other tool from image processing techniques.
Altough a variety of cardiac imaging techniques are under active development, selective coronary arteriography is the only method capable of accurately depicting the details of coronary anatomy. The overall purpose of this work is to identify the objects of interest (one or more vessels) and to design a data processing scheme which exploits the object semantic meaning. The basic idea is to extract features from one (or more) image in the sequence and to exploit temporal correlation between adjacent frames both to support features extraction and to design a feature tracking based compression scheme. Particularly referring to angiographic sequences, the features of interest are structure and dynamics of vessels. The first step of the designed procedure is thus the segmentation of vessels from a still angiogram. The derived vascular skeleton and contour information will then be used both to support contour extraction in temporally adjacent frames and to design a compression method. In particular, with respect to feature extraction, vessel centerline and contours of the current frame will be considered as a first estimate of the ones concerning the adjacent frames. The skeleton and contour detection problem could thus be reduced to a tracking procedure along the sequence. From a compression point of view, the previous segmentation allows an *object–oriented* approach: more care will be devoted to the description of the relevant objects with respect to the rest of the image, leading to a bit-rate saving. Moreover, prior identification of the meaningful objects could support the design of a technique for the fast retrieval and tracking of objects in the sequence.

II. Segmentation in angiograms

The nature of medical images suggests a knowledge based approach to the feature extraction problem. The way in which knowledge will be incorporated depends on the characteristics of the image to be treated and on the philosophy of the approach.
Classic contour extraction methods are in general not suited for the medical imaging field, the main reason being their inability to incorporate the semantic a priori knowledge available about image information content. In angiographic images, the easier way to exploit knowledge about image content is to concentrate the search procedure in the vicinity of a vessel and to track luminance characteristics of the vessel itself. The robustness and accuracy of the tracking procedure can be improved by exploiting some expected continuity properties of the vessels, which could be summarized as continuity of position (centerline and edge pixel position), curvature, diameter and density. Particular care must be taken concerning the diameter variations, because the presence of a stenosis could produce an abrupt change in the lumen cross section which must be correctly identified. The tracking approach also allows efficiency in computation, due to the local nature of the search procedure. The design of a tracking procedure would require the a priori information regarding the probability distributions and spatial frequency characteristics of all these parameters. Due to unavailability of such information at present, a mathematical and heuristical approach has been followed.

III. Algorithm for vessel segmentation

An algorithm for the segmentation of the vascular tree in a digital coronary arteriogram has been designed. At

present, only the basic idea has been implemented, and a number of strategy refinement must be introduced to make it general and robust.
The algorithm is based on a vessel tracking procedure which incorporates the continuity properties of the vessel position, orientation and width by a combined mathematical and heuristical approach. The tracking method has an extrapolation and update structure [1]. It consists of three successive steps [2]. In the first step, given a user defined vessel seed point and search direction, the centerline of the vessel is identified by a tracking procedure guided by a matched filter. In particular, for each vessel section, given the estimation of the centerline point, width and orientation for the current incremental section, the centerline point relative to the next section is extrapolated by projection along the current vessel direction and successively updated by matched filtering. In the second step the edge points of each vessel section, i.e. for each estimated centerline point, are located by a gray level criterion. In the last step the seed points of the lateral vessels, *branch points*, are detected by an extrapolation and update procedure guided by a matched filter [3].

IV. Discussion and Results

At present, the algorithm is in the very first stage implementation, and a number of strategy refinements must be introduced in order to make it general and robust. These will further exploit the available knowledge; by including knowledge about spatial frequency vessel features, a valid support to search procedure could be obtained, and the search strategy could be made adaptive to the image content. The human interaction is limited to the specification of the seed point in the vessel of interest and of the starting search direction; a fully automated procedure is not the final goal of this application because, in general, clinicians prefer to maintain a certain degree of control over the automated procedure.
The algorithm performance has been tested on some still images obtained by the digital subtraction angiography (DSA) technique. The images have a resolution of 512x512 bit and a gray level resolution of 8 bit/pixel, however only a 256x256 portion containing the vascular network is shown for better visualization. The search direction has been set vertical, from top to bottom. The centerline of the three major vessels are shown in fig. 1. The seed point of the central vessel has been specified by hand, and two of the detected branch points of have been used as seed points for the detected lateral branches. The contours of the segmented vessels are shown in fig. 2. Although vessel tracking and border detection are done automatically, in general a different starting position results in a slightly different centerline point, which also affects the resampling results and thus the detected edges. Furthermore, because the tracking process is guided by a matched filter, the tracking path at a bifurcation point or at a crossover point of two overlapping vessels follows whichever one presents the strongest matching with the filter.
The presented algorithm is expected to be computationally efficient due to the use of a localized tracking procedure.
The main future developments will concern the contour tracking along the sequence and the design of the compression scheme.

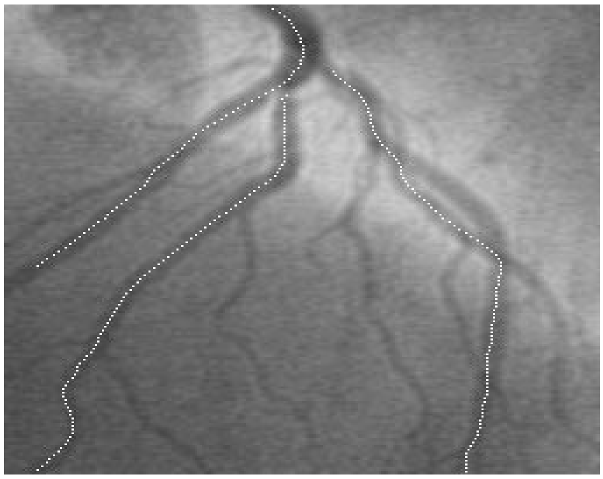

Fig. 1. Vascular tree skeleton.

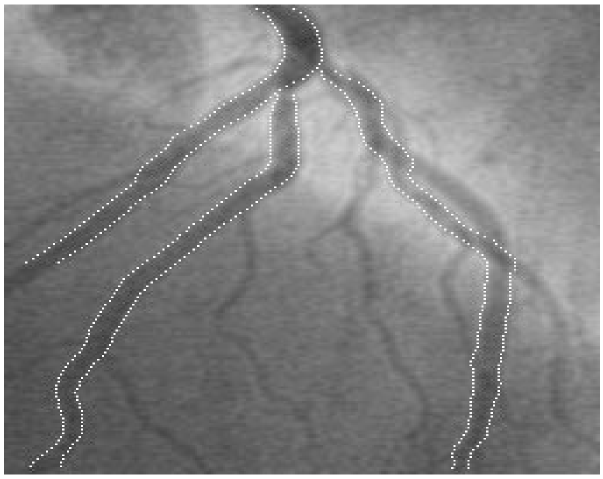

Fig. 2. Contours of the major vessels.

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