Use of an Assumption-based Truth Maintenance System to Record and Resolve Ambiguity in Cardiac Angiograms.

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Introduction

Over a number of years the IBM UK Scientific Centre and the Brompton Hospital have been interested in the analysis of medical images and, in particular, the analysis of cardiac angiograms with the aim of producing quantitative, moving, three dimensional models of the left ventricle from biplane coronary arteriograms(1,2,4).

The process of extracting data from the images (identifying and naming the arteries, tracking the centre lines, measuring the diameters at frequent intervals along the artery and identifying corresponding bifurcations in each view of each frame) can be performed manually(3) but is very time consuming for a trained cardiologist/radiologist. However, we have automated the process so that the only operator input now required is the identification of bifurcations in the first frame of each view. Thereafter bifurcations are found in all subsequent frames, and vessel sections between bifurcations are tracked and diameters measured automatically.

The techniques used in this sort of automatic vessel tracking involve algorithms that perform local analysis of the image and rely on identification of some characteristic pattern of pixels which match some form of template of an arterial centre line, edge or branch. This approach has at least three major problems.

1. There is no means of verifying that a pattern identified as a possible feature of interest really is a feature of interest. As a result, in the noisy, complex and ambiguous images obtained by arteriography this pattern recognition approach often results in failure of the system accurately to track the artery.

2. Because the analysis is essentially local, it is left to the operator to indicate the features of interest (in this case bifurcations of arteries) and their connectivity.

3. The operator must also identify the true structure of ambiguous features that can have a number of different interpretations.

In this paper we are particularly interested in the resolution of ambiguous features - that is, developing a unique explanation of data that can have a number of different interpretations. We describe some of the structures produced by the low level processes

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1 S.T. Rake is registered for a PhD at the University of Reading and the study of Truth Maintenance Systems has been conducted in conjunction with the Intelligent Systems Group of the Department of Computer Science.
that are required to allow knowledge encapsulated in a computer program (known as a knowledge source) to resolve the ambiguous features.

**Ambiguous Features**

In any 'real world' scene (i.e. a scene that has not been specially constructed) features will appear that cannot be completely resolved by local analysis.

For instance, in cardiac angiography local analysis will not distinguish between arteries which are near the camera and arteries which are farther away. Figure 1 shows a typical image with an ambiguous feature indicated by the arrow.

Low-level processes will describe the features extracted from this region of the image, but it is the domain knowledge that will make assumptions about the actual construction of the arteries in three dimensional space. The domain knowledge knows that cardiac arteries do not actually cross on one surface of the heart, but, without data from other parts of the image or images, will not be able to decide which of the possible hypotheses is correct. Some of the possible hypotheses are shown in Figure 1

![Figure 1. Ambiguous Features](image)

As the analysis proceeds the emerging network of arteries will constrain the possible hypotheses, and eventually allow the ambiguity to be resolved. A Truth Maintenance System (TMS) can be used to record data about ambiguous features so as to allow the ambiguity to be resolved at a later time.