Sensitivity Analysis for Graph Matching from Large Structural Libraries

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1 Introduction

The problem of retrieving a graph from a large structural data-base the most closely resembles a query is a task of pivotal importance. For instance the recognition of relational descriptions of line-patterns is central to the manipulation of large data-bases of both CAD models and structural representations of pictorial shape. From a practical standpoint the difficulty stems from the fact that the target graph and the query may be inexact variants of one-another. For example the query may be a subgraph of the target or, on the other hand, the target may be a poorly segmented or noisy version of the query. Broadly speaking there are two contrasting approaches to the problem. The first of these is to compute a compact summary of the node image attributes. One of the best known examples here is the attribute histogram originally popularised by Swain and Ballard [1] for retrieving colour images from data-bases. The idea has been extended to texture [2], local feature orientation representations [3, 4] and the geometry of line-patterns [5]. The alternative to the use of attributes is to retrieve images based on their structural information content [6, 7]. Here the basic idea is to recognise relational object descriptions by comparing graph-structure. This approach has been successfully used to recall object-models from large data-bases of engineering drawings by Costa and Shapiro [6].

Because of the perceived fragility of the graph matching process, there has been rather less effort directed at attempting to retrieve shapes using relational information [7, 8] than in the use of low-level attribute histograms [9, 10]. Here we aim to fill this gap in the literature by using graph-matching as a means of retrieving the shape from a large data-base that most closely resembles a query shape. We investigate three different recognition stratgies. The simplest uses a histogram representation of graph-structure, the second uses the similarity of features-sets defined on the graph-edges and the final algorithm uses an iterative process to compare the relational consistency of correspondence match.

2 Framework

Formally our recognition problem is posed as follows. We abstract the shapes to be recognised as attributed relational graphs (ARG's). Each ARG in the database is a triple, $G = (V_G, E_G, A_G)$, where V_G is the set of vertices (nodes), E_G is the edge set ($E_G \subset V_G \times V_G$), and A_G is the set of node attributes. In our experimental example, the nodes represent line-structures segmented from 2D images. The edges are established by computing the N-nearest neighbour graph for the line-centres. Each node $j \in V$ is characterised by a vector of attributes, $\underline{x}_j$ and hence $A_G = \{\underline{x}_j | j \in V\}$. In the work reported here the attribute-vector is represents the contents of a normalised pairwise attribute histogram.

The data-base of line-patterns is represented by the set of ARG's $\mathcal{D} = \{G\}$. The goal is to retrieve from the data-base $\mathcal{D}$, the individual ARG that most closely resembles a query pattern $Q = (V_Q, E_Q, A_Q)$.

We now furnish some details of the shape retrieval task used in our experimental evaluation of the recognition method. In particular, we focus on the problem of recognising 2D line patterns in a manner which is invariant to rotation, translation and scale. The raw information available for each line segment

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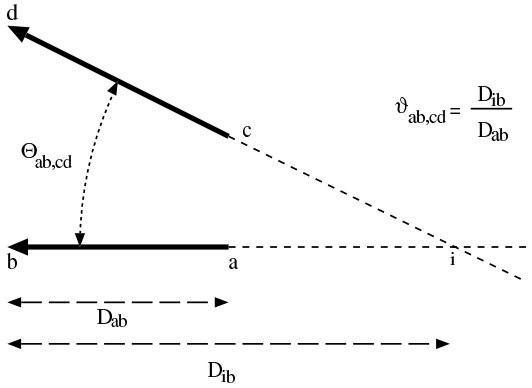
are its orientation (angle with respect to the horizontal axis) and its length (see figure 1). To illustrate how the Euclidean invariant pairwise feature attributes are computed, suppose that we denote the line segments associated with the nodes indexed a and b by the vectors $\underline{v}_a$ and $\underline{v}_b$ respectively. We use two pairwise attributes. The first these is the relative angle given by

$$\theta_{a,b} = \arccos\left[\frac{\underline{v}_a \cdot \underline{v}_b}{|\underline{v}_a||\underline{v}_b|}\right]$$