VLSI Architecture for Real-Time Dominant Point Extraction

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Abstract

This paper presents a special-purpose VLSI architecture for dominant point extraction along 2-D contours. It is designed to be integrated as part of a machine vision system with real-time edge-extraction and edge-tracking capabilities [1] in order to allow the creation of a high-level database representation of the observed scene. Such dominant points carry useful information for shape analysis and pattern recognition applications since they represent a local shape property and segment object contours into piecewise linear segments and circular arcs. The proposed architecture implements an algorithm based on the Curvature Primal Sketch [2]. It consists of a set of 1-D systolic FIR filters performing a multiresolution analysis of the scene's object contours, a set of finite-state-machines extracting zero-crossings and extrema of the filtered data, and a set of scale-space integration cells combining the accurate locations provided by the finest filters with the noise rejection properties of the coarsest ones in order to reliably extract relevant dominant points with accurate localization. The overall architecture has been successfully simulated using real edge images. Some of these results will be presented and discussed.

1: Introduction

Significant changes in curvature have long been considered important features describing object shapes [3]. Such dominant points have been used extensively in shape analysis and pattern recognition applications. Their extraction can greatly simplify the analysis of images since they drastically reduce the amount of data to process, while at the same time preserving important information about object shapes.

To date, many dominant point extraction algorithms have been published. These can be classified as either grey-level-based [4][5] or boundary-based [2][6][7][8]. Grey-level-based approaches detect dominant points directly from the grey-level intensity image while boundary-based approaches detect dominant points from a list of connected edge elements that have been previously extracted from a grey-level image. Boundary-based algorithms are more widely used than grey-level ones because they are easy to implement and because edge detection is part of most machine vision systems. In order to be reliable for object recognition applications, a dominant point extraction scheme should be invariant to the size and orientation of objects, provide accurate localization, and be insensitive to noise. However, most of the algorithms which aim at meeting these requirements are computationally intensive, which restricts their use in real-time applications. They usually involve low-level, repetitive, highly structured processing, like filtering, which can be efficiently implemented using a special-purpose architecture.

In this paper, we present a VLSI architecture which aims at extracting dominant points in real-time. It will be integrated into a machine vision system with real-time edge-extraction and edge-tracking capabilities that has been previously developed in our laboratory [1]. Dominant points will be used as break points in the computation of a piecewise linear and circular representation of object contours. The use of a boundary-based approach is the preferred option since it will greatly benefit from the embedded edge-extraction and edge-tracking capabilities. The proposed architecture implements an algorithm based on the Curvature Primal Sketch [2]. It consists of a set of 1-D systolic FIR filters performing a multiresolution analysis of the scene's object contours, a set of finite-state-machines extracting zero-crossings and extrema of the filtered data, and a set of scale-space integration cells combining the accurate locations provided by the finest filters with the noise rejection properties of the coarsest ones in order to reliably extract relevant dominant points with accurate localization. To our knowledge, this VLSI architecture is the first hardware implementation of a dominant point extraction algorithm.

The algorithm used to extract dominant points along 2-D contours is presented in Section 2 while its VLSI implementation is extensively discussed in Section 3. The overall VLSI architecture is presented first, followed by a detailed discussion of its main components: multiresolution Gaussian filtering, extrema and zero-crossing detection, and scale-space integration. Some very promising simulation results obtained from real edge images are presented and discussed in Section 4. Finally, Section 5 presents the conclusions.