COMPUTATION OF A CLASS OF DETAIL PRESERVING FILTERS IN PIPELINE ARCHITECTURES

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Abstract

Recently a new class of non-linear hybrid filters which combine FIR substructures with median operations were proposed and analyzed. They are shown to have excellent detail preserving properties and are computationally more efficient than conventional median and K-nearest neighbour averaging filters. In this paper, we propose a class of parallel algorithms for their computation using pipeline architectures. We described the algorithms for different hardware configuration, i.e. for the case where one comparator is available and for machines with two comparators. Analysis of the algorithms for both cases are also given. It is shown that using a commercial pipeline processor which can perform each processing pass at video refresh rate (30 frames per sec), except for the three-level bidirectional hybrid filter, all the filters can be computed using the proposed algorithms in less than one second. The minimum number of refresh memories needed without having to perform image transfer to and from disk are also derived and its implications for the choice of algorithms are discussed.

Keywords: Image enhancement, non-linear digital filters, parallel computation, pipeline architectures.

I. Introduction

A fundamental problem in image restoration is to remove the additive noise produced by the imaging system without blurring the fine details of the image. This problem arises in e.g. machine vision, computer tomography and in other X-ray imaging system [RNR, 1984]. One major class of filters for image enhancement is based on ranked order statistics [BHM, 1983]. The best known of these is the median filter, whose statistical properties are well understood [AAW, 1981], [AG, 1982], [GW, 1981], [NG, 1984]. Two dimensional median filters can smooth noisy images while retaining the edge structures almost intact [AC, 1984], [SF, 1985], [NG, 1983]. However, median filters have poor abilities to retain fine details like lines.

Recently, a new class of nonlinear filters called FIR-Median Hybrid filters (FMH filters) was introduced in [NHN, 1987]. Also, a multilevel operation that makes it possible to build multilevel FMH filters that retain details of the image irrespective of their orientation was also introduced. It was shown also that the FMH filters preserves more subtle details than the median and K-nearest neighbor averaging (KAVE) filters [DR, 1978]. The FMH filters also preserve edges in noisy images better than the median and the KAVE filters, see [NHN, 1987].

The main problem with non-linear filters involving ordering is that they are very computationally intensive especially when higher order filters or large windows are used. In many real time applications, such as automated visual inspection where speed requirement is important, techniques for fast computation of image processing filters are of great interest. In these type of applications often parallel architectures are used. Recently there has been many new algorithms developed for pipeline architectures. [S, 1988], [SD, 1987], [SDP, 1988], [DF, 1988]. Often, we must rethink traditional approaches used for sequential computers to take advantage of the parallelism. In this paper we propose a technique for computing the class of FMH filters in a pipeline image processing system equipped with hardware comparators. Section II describes the class of algorithms. These include algorithms for the class of unidirectional, bidirectional and the multilevel FMH filters. Section III gives the algorithms for the above three classes of FMH filters if multiple processing units are available.

Section IV contains analysis of the algorithms and its implication on the choice of algorithms based on the resource available. Section V concludes the paper.

II. The Algorithms

The architecture we are assuming is a pipeline architecture such as in [SD, 1987], [DF, 1988]. A schematic diagram is shown in Fig. 1. There are a number of refresh memories or image buffers. We assume that that the output from the image buffers can be shifted horizontally and/or vertically. We further assume that one of the pipeline processing stage is a hardware comparator. Most of the commercially available general purpose pipeline architectures are equipped with such comparator. For example, the DeAnza IP8500 has two such comparators which can be set independently to output either the maximum or the minimum of the two input pixel values.

In standard median filters, the median is taken over all samples inside the window. However when the number of samples is large, the ordering procedure is computationally intensive. In [NHN, 1987] a class of new filters called FMH filters are defined, and their properties are analyzed. Unlike linear filters which give good noise attenuation, but tend to smear edges and attenuate fine lines, these class of hybrid filters performs much better in preserving fine details. Also the ordering portion of the filters are independent of the size of the windows chosen.