Chapter 3
Real-Time Primary Image Processing

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ABSTRACT

Image processing operations have been classified into three main levels, namely low (primary), intermediate, and high. In order to combine speed and flexibility, an optimum hardware/software configuration is required. For multitask primary processing, a pipeline configuration is proposed. This structure, which is an interface between the sensing element (camera) and the main processing system, achieves real time video signal preprocessing, during the image acquisition time. In order to form the working neighborhoods, the input image signal is delayed (two lines and three pixels). Thus, locally 3×3 type processing modules are created. A successive comparison median filter and a logical filter for edge detection are implemented for a pipeline configuration. On the other hand, for low level, intermediate, and high level operations, software algorithms on parallel platforms are proposed. Finally, a case study of lines detection using directional filter discusses the performance dependency on number of processors.

INTRODUCTION

Real-time image and video processing systems involve processing vast amounts of image data in a timely manner for the purpose of extracting useful information, which could mean anything from obtaining an enhanced image to intelligent scene analysis. Digital images and video are essentially multidimensional signals and are thus quite data intensive, requiring a significant amount of computation and memory resources for their processing. The amount of data increases if color is also considered. Furthermore, the time dimension of digital video demands processing massive amounts of data per second. One of the keys to real-time algorithm development is the exploitation of the information available in each dimension. For digital images, only the spatial

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information can be exploited, but for digital videos, the temporal information between image frames in a sequence can be exploited in addition to the spatial information.

The key to cope with this issue is the concept of parallel processing which deals with computations on large data sets. In fact, much of what goes into implementing an efficient image/video processing system centers on how well the implementation, both hardware and software, exploits different forms of parallelism in an algorithm, which can be data level parallelism - DLP or/ and instruction level parallelism – ILP (Hunter, 2003). DLP manifests itself in the application of the same operation on different sets of data, while ILP manifests itself in scheduling the simultaneous execution of multiple independent operations in a pipeline fashion.

Usually, in a decision theoretic based pattern recognition system for industrial applications, the classification is performed in the feature space by a distance function criterion. In applications like visual servoing, vehicle navigation, industrial inspection, multimedia, medical engineering, etc., the main requirement for the video system is the real time execution of the algorithms. In order to obtain a very high image processing speed, the primary operators (pre-processing operators) are transferred from the central computer to the sensory level.

There are two classes of digital primary image processing operators: local operators and global operators. The global operators require information from the complete image frame. They are not suitable for industrial video applications because they have two main disadvantages: long time execution and edge alteration. On the other hand, many functions like noise rejection, binary segmentation, edge extraction, erosion, dilation, area evaluation, and perimeter evaluation can be calculated with the aid of local bi-dimensional filters (Popescu, 1990).

Generally, software implementation of many image processing procedures is not compatible with on-line, real time operation requirements and with hard industrial environment conditions. Moreover, most of the required primary image processing procedures can be hardware implemented, using programmable devices. Thus, for an efficient industrial image processing system, the hardware/software co-design approach is highly recommended.

Operations like noise rejection, edge detection, binary segmentation of image, are frequently encountered. Due to the development of the integrated circuits like FPGA and DSP, these primary image processing algorithms can be implemented together with the video camera like embedded system.

There are many applications of real time primary image processing. For example, results concerning increase of image processing speed and sensor fusion for obstacle detection in robot navigation are presented in (Popescu, 2006).

Although the images can be color, for simplicity, we will consider only the grey level case. In the color image case, the results are similar; it is necessary to consider three grey level type matrices (RGB or HSV).

BACKGROUND

Definition of 'Real-Time' Concept

"Real-time" is an elusive term that is often used to describe a wide variety of image/video processing systems and algorithms. Considering the need for real-time image/video processing and how this need can be met by exploiting the inherent parallelism in an algorithm, it becomes important to discuss what exactly is meant by the term "real-time". From the literature, it can be derived that there are three main interpretations of the concept of "real-time," namely real-time in the perceptual sense, real-time in the software engineering sense, and real-time in the signal processing sense.