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SPECIAL ISSUE

Fast recursive grayscale morphology operators: from the algorithm to the pipeline architecture

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Abstract This paper presents a new algorithm for efficient computation of morphological operations for gray images and the specific hardware. The method is based on a new recursive morphological decomposition method of 8-convex structuring elements by only causal two-pixel structuring elements (2PSE). Whatever the element size, erosion or/and dilation can then be performed during a unique raster-like image scan involving a fixed reduced analysis neighborhood. The resulting process offers low computation complexity combined with easy description of the element form. The dedicated hardware is generic and fully regular, built from elementary interconnected stages. It has been synthesized into an FPGA and achieves high-frequency performances for any shape and size of structuring element.

Keywords Mathematical morphology · 8-Convex structuring element operators · Regular dedicated pipeline architecture

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1 Introduction

Mathematical morphology was first introduced as a method to measure binary objects, but soon became a complete theory based on set operations [14]. Morphology relies on the use of set operators (intersection, union, inclusion, complement) to transform an image. The transformed image usually has fewer details, but its main characteristics are still present. Once the image has been simplified, measurements can be computed to give a quantitative analysis of the image. Morphological transformation is based on a structuring element ($\boldsymbol{B}$) characterized by its shape, size and center location, also called origin. Each pixel in an image is compared with $\boldsymbol{B}$ by moving $\boldsymbol{B}$ so that its center hits the pixel. Depending on the type of morphological transformation, the pixel value is set to the minimal or maximal value of the pixels in the translated structuring element.

Performing a morphological operation directly from its formal definition would imply that all the neighbors present within the structuring element should be sought for each pixel. Of course, this process becomes time consuming for large elements. Fortunately, mathematical morphology properties led to the introduction of methods which partially solve this problem.

The main goal of the decomposition algorithms is to reduce the number of basic dilations needed to generate the desired structuring element. Different ways to decompose structuring elements have been investigated exploiting two fundamental properties: dilations [2, 19] and set unions of elements [9, 18]. More particularly, Chen has defined a decomposition method using only two non-connected pixel elements. On the other hand, Xu demonstrated how any 8-convex polygon could be constructed from a set of elements included in a 4-neighborhood.