Parallelization in GPGPU of an image smoothing method based on a variational model

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Abstract Image processing has become an area of dynamic research with numerous applications in various fields. With the improvements gained in technologies related to multicomputer, multiprocessor and, more recently, to General Purpose Computing on Graphics Processing Units (GPGPUs), the parallelization of computational image processing techniques has gained extraordinary prominence. This parallelization is crucial for the use of such techniques in applications that have strong demands in terms of processing time, so that even more complex computational algorithms can be used, as well as their use on images of higher resolution. In this work, the parallelization in GPGPU of a recent image smoothing method based on a variation model is described and discussed. This method was proposed by Jin and Yang (2011) and is in-demand due to its computation time, and its use with high resolution images. The results obtained are very promising, revealing a considerable gain in terms of computational speed.

Computational image processing is a field that has been seen tremendous advances in recent years. Such advances have been instigated mainly due to the huge demand in areas such as medicine [11], agriculture [4], security systems [3], traffic and satellite data analysis [14], robot navigation and industrial inspection [8]. Usual tasks of image processing that can be found in these fields include noise removal and artifact smoothing [5], geometrical correction [1], contrast enhancement and image

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restoring [6, 16]. Briefly, the use of image processing techniques is mainly intended to enhance the data presented in the original images so that the processed data can be more easily analyzed using higher-level techniques of image analysis, such as image segmentation [10] or image registration [13]. However, many of the original images that need to be enhanced have huge resolutions, or need to be processed in real or near real-time, as in robotic navigation or assisted surgery, or even the input data may be a large sequence of 2D, 3D or 4D images, like in ultrasound imaging [2]. Additionally, to get more robust and better results, the computational complexity of more recent methods has increased considerably, leading to higher processing times. As such, the use of parallel computing strategies has gained attention in order to speedup such image processing methods [12].

In this paper, the use of the General Purpose Computing on Graphics Processing Units (GPGPU) technology [12] is addressed and discussed in one of the most common tasks of image processing: the smoothing of corrupted images. The corruption of the original images can be due to the image acquisition process or by artifacts generated by the data transmission or some other process [9]. Hence, the computational speedup that can be obtained with parallelization using the Compute Unified Device Architecture (CUDA) [15], compared to sequential processing in the Central Processing Unit (CPU), was evaluated for the smoothing of images of huge resolution. Particularity, a very recent image smoothing method based on a variational model proposed by Jin and Yang (2011) [7] and which is particularly in-demand in terms of computational times, was used. Thus, the parallelized and the sequential algorithms of this method were implemented and applied on the same high resolution images and the computational times were assessed and compared. The choice for the image smoothing method proposed by Jin and Yang was based upon the fact that it executes several iterations on the image, which necessarily requires a high computational time, especially when applied on images of huge resolution, making its application less attractive for various potential applications, despite the very good smoothing results that can be obtained. In fact, in the smoothing of each pixel of the original image, the method requires a large number of calculations, which implies the aforementioned huge processing time. Briefly, the algorithm involves the use of an *mxn* matrix that is processed for T iterations; thus, the computational complexity in the processing of an input image is equal to $0(m \cdot n \cdot T)$, where m and n are the number of rows and columns of the matrix, i.e., of the input image, respectively. The computational time required by the sequential algorithm of the smoothing method adopted was considerably reduced here due to the use of the data parallel model available in the CUDA architecture and the adoption of the GPGPU technology. In the new parallel solution, multiple threads copy the data, which initially was in the main memory of the host system, to the GPGPU memory where the highest number of accesses occurs, consequently eliminating the need for constant access to data in the main memory [12]. As such, the operations involving the input images are executed in parallel directly in the graphics hardware.

This paper proposes the combination of the parallel programming in GPGPU technique and a specific image smoothing method to reducing processing time in huge images corrupted by multiplicative noise. The experimental findings confirmed that the combination of the CUDA architecture with GPGPU technology is very promising to speedup the in-demand computational methods of image processing, in particular, of image smoothing, leading to high processing performance at low cost, principally when compared to parallel implementations in multicomputers. As far as the authors know, this is the first time that the adopted image smoothing method is parallelized using CUDA architecture and GPGPU technology, making the findings of immense interest for image processing. In our experiments, we evaluate a gain of 8 times and could observe several interesting results that validate and delimit our approach.

The experimental findings lead to conclude that the use of GPGPU technology to parallelize the image smoothing method adopted, speeds up its computational processing time considerably, with a financial cost lower than if a parallelization in a multicomputer was adopted. As for future work, the intention is to extend the comparative tests involving other methods of image processing, in particular to enhance ultrasound image sequences.

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