J Real-Time Image Proc
DOI 10.1007/s11554-013-0378-6

ORIGINAL RESEARCH PAPER

GPU-accelerated level-set segmentation

Julián Lamas-Rodríguez · Dora B. Heras · Francisco Argüello · Dagmar Kainmueller · Stefan Zachow · Montserrat Bóo

Received: 4 October 2012 / Accepted: 22 October 2013

Abstract The level-set method, a technique for the computation of evolving interfaces, is a solution commonly used to segment images and volumes in medical applications. GPUs have become a commodity hardware with hundreds of cores that can execute thousands of threads in parallel, and they are nowadays ideal platforms to execute computational intensive tasks, such as the 3D level-set-based segmentation, in real time. In this paper, we propose two GPU implementations of the level-set-based segmentation method called Fast Two-Cycle. Our proposals perform computations in independent domains called tiles and modify the structure of the original algorithm to better exploit the features of the GPU. The implementations were tested with real images of brain vessels and a synthetic MRI image of the brain. Results show that they execute faster than a CPU-sequential implementation of the same method, without any significant loss of the segmentation quality and without requiring distributed parallel computer infrastructures.

Keywords Level-set · Segmentation · GPU · CUDA · GPGPU

J. Lamas-Rodríguez (✉) · D. B. Heras
Centro de Investigación en Tecnoloxías da Información da Universidade de Santiago de Compostela (CITIUS), Santiago de Compostela, Spain
e-mail: julian.lamas@usc.es

F. Argüello · M. Bóo
Department of Electronics and Computer Science, University of Santiago de Compostela, Santiago de Compostela, Spain

D. Kainmueller · S. Zachow
Department of Visualization and Data Analysis, Konrad-Zuse-Zentrum für Informationstechnik, Berlin, Germany

1 Introduction

The level-set method [28] is a numerical technique for analyzing and computing interface motion. Propagating interfaces occur in a wide variety of settings, and level-set methods have a high number of applications, including physics, chemistry, fluid mechanics, combustion, materials sciences, fabrication of microelectronic components, computer vision, and image processing [34]. A key task in computer vision, medical visualization and medical image processing is the identification of regions of interest using, for example, a segmentation process. Surgical planning, navigation, simulation, diagnosis, and therapy evaluation all benefit from the segmentation of anatomical structures, based on the properties of the images, such as the observed intensities, as well as anatomical knowledge on the subjects [17]. The use of level-set methods for image and volume segmentation has been demonstrated as an effective technique [42]. The level-set segmentation process depends upon extrinsic factors (e.g., the intensities or the texture of the image) and intrinsic factors (e.g., the curvature of the segmented region) [32].

The graphics processing unit (GPU) has evolved from a graphics-specific accelerator, with a fixed-function graphics pipeline, into a programmable vector processor with computing power exceeding that of a multicore CPU [19]. Nowadays, GPUs are high-performance many-core processors capable of very high computation and data throughput. GPUs have become general-purpose parallel processors with support for accessible application programming interfaces (APIs) and industry-standard languages, which has spawned a research community that has successfully mapped a broad range of computationally demanding, complex problems to the GPU [29], developing the field of GPGPU (General Purpose Computing on

Published online: 26 November 2013