# Accelerating Cone Beam Reconstruction Using the CUDA-enabled GPU*

Yusuke Okitsu, Fumihiko Ino, and Kenichi Hagihara

Graduate School of Information Science and Technology, Osaka University
1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan
{y-okitu,ino}@ist.osaka-u.ac.jp

**Abstract.** Compute unified device architecture (CUDA) is a software development platform that enables us to write and run general-purpose applications on the graphics processing unit (GPU). This paper presents a fast method for cone beam reconstruction using the CUDA-enabled GPU. The proposed method is accelerated by two techniques: (1) off-chip memory access reduction; and (2) memory latency hiding. We describe how these techniques can be incorporated into CUDA code. Experimental results show that the proposed method runs at 82% of the peak memory bandwidth, taking 5.6 seconds to reconstruct a $512^3$-voxel volume from 360 $512^2$-pixel projections. This performance is 18% faster than the prior method. Some detailed analyses are also presented to understand how effectively the acceleration techniques increase the reconstruction performance of a naive method.

## 1 Introduction

Cone beam (CB) reconstruction is an imaging process for producing a three-dimensional (3-D) volume from a sequence of 2-D projections obtained by a CB computed tomography (CT) scan. This reconstruction technique is integrated into many mobile C-arm CT systems in order to assist the operator during image-guided surgery. In general, a CB reconstruction task should be completed within ten seconds because the operator has to stop the surgical procedure until obtaining the intraoperative volume. However, it takes 3.21 minutes to obtain a $512^3$-voxel volume on a single 3.06 GHz Xeon processor [1]. Accordingly, many projects are trying to accelerate CB reconstruction using various accelerators, such as the graphics processing unit (GPU) [2–6], Cell [1], and FPGA [7].

To the best of our knowledge, Xu et al. [2] show the fastest method using the GPU, namely a commodity chip designed for acceleration of graphics tasks. Their method is implemented using the OpenGL library in order to take an advantage of graphics techniques such as early fragment kill (EFK). It takes 8.3 seconds to reconstruct a $512^3$-voxel volume from 360 projections. In contrast to this graphics-based implementation strategy, a non-graphics implementation strategy is proposed by Scherl et al. [3]. They use compute unified device architecture (CUDA) [8] to implement CB reconstruction

# Accelerating Cone Beam Reconstruction Using The Cuda

**Bhaumik Vaidya**

**Accelerating Cone Beam Reconstruction Using The Cuda:**

**High Performance Computing - HiPC 2008** P. Sadayappan,Manish Parashar,Viktor K. Prasanna,Ramamurthy Badrinath,2008-11-23 This book constitutes the refereed proceedings of the 15th International Conference on High Performance Computing HiPC 2008 held in Bangalore India in December 2008 The 46 revised full papers presented together with the abstracts of 5 keynote talks were carefully reviewed and selected from 317 submissions The papers are organized in topical sections on applications performance optimizazion parallel algorithms and applications scheduling and resource management sensor networks energy aware computing distributed algorithms communication networks as well as architecture **CUDA Accelerated Cone-beam Reconstruction** Albert W. Sze,2011 Cone Beam Computed Tomography CBCT is an imaging method that reconstructs a 3D representation of the object from its 2D X ray images It is an important diagnostic tool in the medical field especially dentistry However most 3D reconstruction algorithms are computationally intensive and time consuming this limitation constrains the use of CBCT In recent years high end graphics cards such as the ones powered by NVIDIA graphics processing units GPUs are able to perform general purpose computation Due to the highly parallel nature of the 3D reconstruction algorithms it is possible to implement these algorithms on the GPU to reduce the processing time to the level that is practical Two of the most popular 3D Cone Beam reconstruction algorithms are the Feldkamp Davis Kress algorithm FDK and the Algebraic Reconstruction Technique ART FDK is fast to construct 3D images but the quality of its images is lower than the quality of ART images However ART requires significantly more computation Material ART is a recently developed algorithm that uses beam hardening correction to eliminate artifacts In this thesis these three algorithms were implemented on the NVIDIA s CUDA platform These CUDA based algorithms were tested on three different graphics cards using phantom and real data The test results show significant speedup when compared to the CPU software implementation The speedup is sufficient to allow a moderate cost personal computer with NVIDIA graphics card to process CBCT images in real time Abstract **High Performance and Hardware Aware Computing** Rainer Buchty,2008

**5th European Conference of the International Federation for Medical and Biological Engineering 14 - 18 September 2011, Budapest, Hungary** Ákos Jobbágy,2012-02-02 This volume presents the 5th European Conference of the International Federation for Medical and Biological Engineering EMBEC held in Budapest 14 18 September 2011 The scientific discussion on the conference and in this conference proceedings include the following issues Signal Image Processing ICT Clinical Engineering and Applications Biomechanics and Fluid Biomechanics Biomaterials and Tissue Repair Innovations and Nanotechnology Modeling and Simulation Education and Professional **Computer and Information Technology** Prasad Yarlagadda,Seung Bok Choi,Yun Hae Kim,2014-02-06 Selected peer reviewed papers from the International Forum on Computer and Information Technology IFCIT 2013 December 24 25 2013 Shenzhen China

**Evaluation of State-of-the-Art Hardware Architectures for Fast Cone-Beam CT Reconstruction** Holger

Scherl,2011-07-29 Holger Scherl introduces the reader to the reconstruction problem in computed tomography and its major scientific challenges that range from computational efficiency to the fulfillment of Tuy s sufficiency condition The assessed hardware architectures include multi and many core systems cell broadband engine architecture graphics processing units and field programmable gate arrays **Accelerating Live Graph-Cut-Based Object Tracking Using CUDA** Ismael Daribo,2011 Accelerating Live Graph Cut Based Object Tracking Using CUDA *Hands-On GPU-Accelerated Computer Vision with OpenCV and CUDA* Bhaumik Vaidya,2018-09-26 Discover how CUDA allows OpenCV to handle complex and rapidly growing image data processing in computer and machine vision by accessing the power of GPU Key FeaturesExplore examples to leverage the GPU processing power with OpenCV and CUDAEnhance the performance of algorithms on embedded hardware platformsDiscover C and Python libraries for GPU accelerationBook Description Computer vision has been revolutionizing a wide range of industries and OpenCV is the most widely chosen tool for computer vision with its ability to work in multiple programming languages Nowadays in computer vision there is a need to process large images in real time which is difficult to handle for OpenCV on its own This is where CUDA comes into the picture allowing OpenCV to leverage powerful NVDIA GPUs This book provides a detailed overview of integrating OpenCV with CUDA for practical applications To start with you ll understand GPU programming with CUDA an essential aspect for computer vision developers who have never worked with GPUs You ll then move on to exploring OpenCV acceleration with GPUs and CUDA by walking through some practical examples Once you have got to grips with the core concepts you ll familiarize yourself with deploying OpenCV applications on NVIDIA Jetson TX1 which is popular for computer vision and deep learning applications The last chapters of the book explain PyCUDA a Python library that leverages the power of CUDA and GPUs for accelerations and can be used by computer vision developers who use OpenCV with Python By the end of this book you ll have enhanced computer vision applications with the help of this book s hands on approach What you will learnUnderstand how to access GPU device properties and capabilities from CUDA programsLearn how to accelerate searching and sorting algorithmsDetect shapes such as lines and circles in imagesExplore object tracking and detection with algorithmsProcess videos using different video analysis techniques in Jetson TX1Access GPU device properties from the PyCUDA programUnderstand how kernel execution worksWho this book is for This book is a go to guide for you if you are a developer working with OpenCV and want to learn how to process more complex image data by exploiting GPU processing A thorough understanding of computer vision concepts and programming languages such as C or Python is expected **Cone-beam Reconstruction Using Filtered Backprojection** Henrik Turbell,Universitet i Linköping. Department of Electrical Engineering,2001 **GPU-Accelerated Research in Quant Finance** Thomas V. Trex,2025-12-01 GPU Accelerated Research in Quant Finance Using CUDA to Speed Up Backtests and Analytics This book is for quantitative researchers systematic portfolio managers and technologists who want to turn GPUs from a buzzword into a practical edge It bridges the gap between theoretical quant finance and high

performance computing showing how to move real research workloads backtests risk engines and pricing libraries from CPU bound prototypes to production ready GPU pipelines Readers will learn the mathematical and statistical foundations most relevant to GPU acceleration then build a rigorous research and backtesting methodology that survives contact with real markets and regulators The core chapters develop a working mental model of modern GPU architectures and the CUDA programming model before introducing powerful patterns and libraries for Monte Carlo PDE FFT pricing portfolio optimization and risk analytics Throughout the focus is on trustworthy speedups performance engineering profiling validation and reproducibility The book assumes comfort with Python and basic quantitative finance but no prior CUDA experience All examples are designed for implementation in a modern research stack with LaTeX quality formulas and code that map cleanly onto Python CUDA tooling The result is a practical end to end guide to designing faster research loops and more ambitious models without sacrificing transparency or control **Graphics Processing Unit-Based High Performance Computing in Radiation Therapy** Xun Jia,Steve B. Jiang,2018-09-21 Use the GPU Successfully in Your Radiotherapy Practice With its high processing power cost effectiveness and easy deployment access and maintenance the graphics processing unit GPU has increasingly been used to tackle problems in the medical physics field ranging from computed tomography reconstruction to Monte Carlo radiation transport simulation Graphics Processing Unit Based High Performance Computing in Radiation Therapy collects state of the art research on GPU computing and its applications to medical physics problems in radiation therapy Tackle Problems in Medical Imaging and Radiotherapy The book first offers an introduction to the GPU technology and its current applications in radiotherapy Most of the remaining chapters discuss a specific application of a GPU in a key radiotherapy problem These chapters summarize advances and present technical details and insightful discussions on the use of GPU in addressing the problems The book also examines two real systems developed with GPU as a core component to accomplish important clinical tasks in modern radiotherapy Translate Research Developments to Clinical Practice Written by a team of international experts in radiation oncology biomedical imaging computing and physics this book gets clinical and research physicists graduate students and other scientists up to date on the latest in GPU computing for radiotherapy It encourages you to bring this novel technology to routine clinical radiotherapy practice Accelerating MATLAB with GPU Computing Jung W. Suh,Youngmin Kim,2013-11-18 Beyond simulation and algorithm development many developers increasingly use MATLAB even for product deployment in computationally heavy fields This often demands that MATLAB codes run faster by leveraging the distributed parallelism of Graphics Processing Units GPUs While MATLAB successfully provides high level functions as a simulation tool for rapid prototyping the underlying details and knowledge needed for utilizing GPUs make MATLAB users hesitate to step into it Accelerating MATLAB with GPUs offers a primer on bridging this gap Starting with the basics setting up MATLAB for CUDA in Windows Linux and Mac OS X and profiling it then guides users through advanced topics such as CUDA libraries The authors share

their experience developing algorithms using MATLAB C and GPUs for huge datasets modifying MATLAB codes to better utilize the computational power of GPUs and integrating them into commercial software products Throughout the book they demonstrate many example codes that can be used as templates of C MEX and CUDA codes for readers projects Download example codes from the publisher s website http booksite elsevier com 9780124080805 Shows how to accelerate MATLAB codes through the GPU for parallel processing with minimal hardware knowledge Explains the related background on hardware architecture and programming for ease of use Provides simple worked examples of MATLAB and CUDA C codes as well as templates that can be reused in real world projects **Accelerating Live Graph-Cut-Based Object Tracking Using CUDA.** Ismael Daribo,Hideo Saito,Yuki Takaya,Zachary A. Garrett,2011 <u>Accelerating and Predicting Map Projections with CUDA and MLP</u> Jiaqi Zhang (Data science engineer),2018 We provide a precise mathematical definition of map distortion and introduce three strategies for finding the best oblique map projections having the same distortion properties as their normal aspect counterparts on earth regions that have minimal distortion for certain specific regions of the earth namely regions whose boundary consists of one or two parallels of latitude We use heap map to visualize the distortion of several unusually shaped countries under particular oblique projection applying our strategies and then optimize the time efficiency of original sequential executed programs with CUDA a GPU parallel computation method impressively *Geometry of Cone-beam Reconstruction* Xiaochun Yang,2002 Geometry is the synthetic tool we use to unify all existing analytical cone beam reconstruction methods These reconstructions are based on formulae derived by Tuy Tuy 1983 Smith Smith 1985 and Grangeat Grangeat 1991 which explicitly link the cone beam data to some intermediate functions in the Radon transform domain However the essential step towards final reconstruction that is differential backprojection has not yet achieved desired efficiency A new inversion formula is obtained directly from the 3D Radon inverse Radon 1917 Helgason 1999 It incorporates the cone beam scanning geometry and allows the theoretical work mentioned above to be reduced to exact and frugal implementations Extensions can be easily carried out to 2D fan beam reconstruction as well as other scanning modalities such as parallel scans by allowing more abstract geometric description on the embedding subspace of the Radon manifold The new approach provides a canonical inverse procedure for computerized tomography in general with applications ranging from diagnostic medical imaging to industrial testing such as X ray CT Emission CT Ultrasound CT etc It also suggests a principled frame for approaching other 3D reconstruction problems related to the Radon transform The idea is simple as was spelled out by Helgason on the opening page of his book The Radon Transform Helgason 1999 a remarkable duality characterizes the Radon transform and its inverse Our study shows that the dual space the so called Radon space can be geometrically decomposed according to the specified scanning modality

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