

Medusa: A Parallel Graph Processing System on Graphics Processors

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ABSTRACT

Medusa is a parallel graph processing system on graphics processors (GPUs). The core design of Medusa is to enable developers to leverage the massive parallelism and other hardware features of GPUs by writing sequential C/C++ code for a small set of APIs. This simplifies the implementation of parallel graph processing on the GPU. The runtime system of Medusa automatically executes the user-defined APIs in parallel on the GPU, with a series of optimizations based on the architecture features of GPUs and characteristics of graph applications. In this paper, we present an overview of the Medusa system and a case study of adopting Medusa to a research project on social network simulations. With Medusa, users without GPU programming experience can quickly implement their graph operations on the GPU, which accelerates the discovery and findings of domain-specific applications.

1. INTRODUCTION

GPGPU (General-Purpose Computation on Graphics Processing Units) is gaining increasing popularity in performance acceleration for many applications, including graph processing [8, 10]. A Modern GPU can have over an order of magnitude higher memory bandwidth and computation power than a multi-core CPU. With intensive and application-specific optimizations, GPU-based graph algorithms have shown significant performance improvement over CPU-based implementations. For example, the GPU accelerated breadth first search (BFS) algorithm is up to 14 times faster than multi-core implementation [10]. However, despite the recent improvements on GPGPU programmability, writing a correct and efficient GPU program is challenging in general and even more difficult for the highly irregular graph applications.

To address the above-mentioned issues and simplify programming graph processing algorithms on the GPU, we propose the Medusa parallel graph processing programming framework. Like exist-

ing programming frameworks such as Hadoop [17] and Mars [9], Medusa provides a small set of APIs for developers to implement their applications by writing sequential (C/C++) code. Different from Hadoop and Mars, which adopts the MapReduce programming model [3], Medusa adopts our novel "Edge-Message-Vertex" (EMV) graph programming model for fine-grained processing on edges, messages and vertices. Medusa embraces an efficient message passing based runtime. It automatically executes user-defined APIs in parallel within one GPU and across multiple GPUs, and hides the complexity of GPU programming from developers. Thus, developers can write the same APIs, which automatically run on one or multiple GPUs. To maximally leverage the power of GPUs, Medusa embraces a series of optimizations based on the architecture features of GPUs and characteristics of graph applications.

As a case study, we adopt Medusa to implement GPU accelerated simulation of information propagation over social networks. Simulation of information propagation is computationally intensive and fortunately highly parallelizable, which makes it viable for GPU acceleration. By the case study, we demonstrate that Medusa both improves the coding productivity and brings significant performance speedups.

This paper gives an overview of Medusa based on work reported in [20, 18, 11, 12, 13]. We first present the design of the main components of Medusa's system architecture and evaluation results. We then present the case study developed based on Medusa. Finally, we conclude this paper and present the future work.

2. RELATED WORK

Parallel graph processing. It has been observed that many common graph algorithms can be formulated using a form of the bulk synchronous parallel (BSP) model [14] (we call it *GBSP*). Under

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**William Dwight Whitney, Benjamin Eli
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Web and Big Data. APWeb-WAIM 2020 International Workshops Qun Chen,Jianxin Li,2021-03-31 This book constitutes revised selected papers from the workshops of the 4th Asia Pacific Web and Web Age Information Management International Joint Conference on Web and Big Data APWeb WAIM 2020 The Third International Workshop on Knowledge Graph Management and Applications KGMA 2020 The Second International Workshop on Semi structured Big Data Management and Applications SemiBDMA 2020 and The First International Workshop on Deep Learning in Large scale Unstructured Data Analytics DeepLUDA 2020 held in Tianjin China in September 2020 Due to the COVID 19 pandemic the conference was held online The 13 papers were thoroughly reviewed and selected from the numerous submissions and present recent research on the theory design and implementation of data management systems *Principles of Big Graph: In-depth Insight* ,2023-01-24 Principles of Big Graph In depth Insight Volume 128 in the Advances in Computer series highlights new advances in the field with this new volume presenting interesting chapters on a variety of topics including CESDAM Centered subgraph data matrix for large graph representation Bivariate cluster and suitability analysis of NoSQL Solutions for big graph applications An empirical investigation on Big Graph using deep learning Analyzing correlation between quality and accuracy of graph clustering geneBF Filtering protein coded gene graph data using bloom filter Processing large graphs with an alternative representation MapReduce based convolutional graph neural networks A comprehensive review Fast exact triangle counting in large graphs using SIMD acceleration A comprehensive investigation on attack graphs Qubit representation of a binary tree and its operations in quantum computation Modified ML KNN Role of similarity measures and nearest neighbor configuration in multi label text classification on big social network graph data Big graph based online learning through social networks Community detection in large scale real world networks Power rank An interactive web page ranking algorithm GA based energy efficient modelling of a wireless sensor network The major challenges of big graph and their solutions A review and An investigation on socio cyber crime graph Provides an update on the issues and challenges faced by current researchers Updates on future research agendas Includes advanced topics for intensive research for researchers Domain-Specific Computer Architectures for Emerging Applications Chao Wang,2024-06-04 With the end of Moore s Law domain specific architecture DSA has become a crucial mode of implementing future computing architectures This book discusses the system level design methodology of DSAs and their applications providing a unified design process that guarantees functionality performance energy efficiency and real time responsiveness for the target application DSAs often start from domain specific algorithms or applications analyzing the characteristics of algorithmic applications such as computation memory access and communication and proposing the heterogeneous accelerator architecture suitable for that particular application This book places particular focus on accelerator hardware platforms and distributed systems for various novel applications such as machine learning data mining neural networks and

graph algorithms and also covers RISC V open source instruction sets It briefly describes the system design methodology based on DSAs and presents the latest research results in academia around domain specific acceleration architectures Providing cutting edge discussion of big data and artificial intelligence scenarios in contemporary industry and typical DSA applications this book appeals to industry professionals as well as academicians researching the future of computing in these areas

Information and Communication Technology for Intelligent Systems Suresh Chandra Satapathy,Amit Joshi,2018-12-30 The book gathers papers addressing state of the art research in all areas of Information and Communication Technologies and their applications in intelligent computing cloud storage data mining and software analysis It presents the outcomes of the third International Conference on Information and Communication Technology for Intelligent Systems which was held on April 6 7 2018 in Ahmedabad India Divided into two volumes the book discusses the fundamentals of various data analytics and algorithms making it a valuable resource for researchers future studies

Cloud Computing for Data-Intensive Applications Xiaolin Li,Judy Qiu,2014-12-02 This book presents a range of cloud computing platforms for data intensive scientific applications It covers systems that deliver infrastructure as a service including HPC as a service virtual networks as a service scalable and reliable storage algorithms that manage vast cloud resources and applications runtime and programming models that enable pragmatic programming and implementation toolkits for eScience applications Many scientific applications in clouds are also introduced such as bioinformatics biology weather forecasting and social networks Most chapters include case studies Cloud Computing for Data Intensive Applications targets advanced level students and researchers studying computer science and electrical engineering Professionals working in cloud computing networks databases and more will also find this book useful as a reference

Transactions on Large-Scale Data- and Knowledge-Centered Systems XV Abdelkader Hameurlain,Josef Küng,Roland Wagner,Barbara Catania,Giovanna Guerrini,Themis Palpanas,Jaroslav Pokorný,Athena Vakali,2014-12-11 The LNCS journal Transactions on Large Scale Data and Knowledge Centered Systems focuses on data management knowledge discovery and knowledge processing which are core and hot topics in computer science Since the 1990s the Internet has become the main driving force behind application development in all domains An increase in the demand for resource sharing across different sites connected through networks has led to an evolution of data and knowledge management systems from centralized systems to decentralized systems enabling large scale distributed applications providing high scalability Current decentralized systems still focus on data and knowledge as their main resource Feasibility of these systems relies basically on P2P peer to peer techniques and the support of agent systems with scaling and decentralized control Synergy between grids P2P systems and agent technologies is the key to data and knowledge centered systems in large scale environments This special issue contains extended and revised versions of 4 papers selected from the 25 papers presented at the satellite events associated with the 17th East European Conference on Advances in Databases and Information Systems ADBIS 2013 held on September 1 4 2013

in Genoa Italy The three satellite events were GID 2013 the Second International Workshop on GPUs in Databases SoBI 2013 the First International Workshop on Social Business Intelligence Integrating Social Content in Decision Making and OAIS 2013 the Second International Workshop on Ontologies Meet Advanced Information Systems The papers cover various topics in large scale data and knowledge centered systems including GPU accelerated database systems and GPU based compression for large time series databases design of parallel data warehouses and schema matching The special issue content which combines both theoretical and application based contributions gives a useful overview of some of the current trends in large scale data and knowledge management and will stimulate new ideas for further research and development within both the scientific and industrial communities Database Systems for Advanced Applications Matthias Renz,Cyrus Shahabi,Xiaofang Zhou,Muhammad Aamir Cheema,2015-04-08 This two volume set LNCS 9049 and LNCS 9050 constitutes the refereed proceedings of the 20th International Conference on Database Systems for Advanced Applications DASFAA 2015 held in Hanoi Vietnam in April 2015 The 63 full papers presented were carefully reviewed and selected from a total of 287 submissions The papers cover the following topics data mining data streams and time series database storage and index spatio temporal data modern computing platform social networks information integration and data quality information retrieval and summarization security and privacy outlier and imbalanced data analysis probabilistic and uncertain data query processing Japanese Technical Abstracts ,1988 **The Chemical Engineer** ,1989 Data Sources ,2000 *Government reports annual index* ,199? American Doctoral Dissertations ,1979 Middle East Computing ,1985 *Academic Press Dictionary of Science and Technology* Christopher G. Morris,Academic Press,1992-08-27 A Dictionary of Science and Technology Color Illustration Section Symbols and Units Fundamental Physical Constants Measurement Conversion Periodic Table of the Elements Atomic Weights Particles The Solar System Geological Timetable Five Kingdom Classification of Organisms Chronology of Modern Science Photo Credits Government Reports Announcements & Index ,1990-04 **Dissertation Abstracts International** ,1991 *The Century Dictionary and Cyclopedia: The Century dictionary ... prepared under the superintendence of William Dwight Whitney* William Dwight Whitney,Benjamin Eli Smith,1899 **New International Dictionary** ,1920 **Webster's New International Dictionary of the English Language, Based on the International Dictionary 1890 and 1900** William Torrey Harris,Frederic Sturges Allen,1911 **The Century Dictionary and Cyclopedia** William Dwight Whitney,Benjamin Eli Smith,1899

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