Next Generation Data Analytics at IBM Research

Oktie Hassanzadeh Anastasios Kementsietsidis Benny Kimelfeld
Rajasekar Krishnamurthy Fatma Özcan Ippokratis Pandis*

IBM Research

1. INTRODUCTION

IBM Research has a rich history of innovation in information management with several revolutionary breakthroughs, including the invention of relational databases, advanced text analytics demonstrated by Watson, and the first data mining algorithms to name a few. IBM Research has been committed to contributing to the community via seminal papers, exemplified by several 10-year awards received by IBM researchers. This short abstract is intended as a quick tour of some of the current information management projects, and not meant to be an exhaustive list by any means.

There has been many disruptive technological developments over the last decade. The emergence of cloud computing, and several large scale data processing platforms, advances in on-line social media, the explosion of data volumes, and the advances in hardware have all forced us to rethink the information management architectures and platforms. Today, enterprises are dealing with myriad of data modalities (unstructured, semi-structured, and structured) and very complex and diverse analytics on ever-expanding data volumes to drive business decisions. At IBM Research we are reinventing classical data management solutions to this high speed and volume demand (Section 2), building complex analytical platforms for end-to-end analysis of data (Section 3), building technologies for supporting large scale analytics (Section 4) and graph data (Section 5), as well as solutions that exploit new hardware (Section 6).

2. STRUCTURED DATA MANAGEMENT

In this space, DB2 v10.5 with BLU Acceleration is one of the most recent results of successful technology transfer from IBM Research to products [19]. DB2 BLU deeply integrates innovative new techniques for processing column-organized tables that speed read-mostly Business Intelligence queries by 10 to 50 times and improve compression by 3 to 10 times, compared to traditional row-organized tables, without the complexity of defining indexes or materialized views.

But DB2 BLU is much more than just a column store. DB2 BLU exploits frequency-based order-preserving dictionary compression and main-memory query processing technology from the Blink project [20]. DB2 BLU performs most SQL operations, like predication, joins, and grouping, on compressed values that can be densely packed so that multiple values fit in a register and can be processed simultaneously via SIMD instructions. Though optimized for in-memory processing employing hardware-conscious algorithms, DB2 BLU tables are not limited by the size of main memory. Fine-grained synopses, late materialization, and aggressive prefetching minimize disk I/Os. Full integration with DB2 ensures that DB2 BLU benefits from the full functionality and robust utilities of a mature product, while still enjoying order-of-magnitude performance gains without even having to change the SQL, and can mix column- and row-organized tables within the same query.

3. LARGE SCALE DATA MANAGEMENT

IBM Research has contributed significant technology and helped launch IBM BigInsights[1], a Hadoop-based analytics platform. We developed Jaql [2], a declarative scripting language for enterprise data analysis. Enterprise data comes in many forms, ranging from highly heterogeneous data, such as web pages and log files, to homogeneous data such as financial transactions. Consequently, Jaql's Data Model permits flexibility, while allowing structure to be specified when such information is available. We extend Hadoop with adaptive scheduling [23] to avoid task start-up latencies. We propose coarse-grained indexing techniques suitable for the Hadoop environment [7] and study data placement strategies for HDFS [8] to speed up query processing on Hadoop.

We developed the novel Ricardo [6] analytics system, which rests on a decomposition of data-analysis algorithms into parts executed by the R statistical analysis system and parts handled by the Hadoop scalable data management system. We propose new algorithms for stochastic gradient descent, which underlies the popular family of matrix-factorization based analyses, and it is fundamental to a variety of mining tasks that are increasingly being applied to massive datasets.

We explore the synergy between Hadoop and traditional data warehouses [17] to provide an end-to-end platform for analysis of all enterprise data. In particular, we are enhancing SQL processing on Hadoop data, and integrating advanced analytics into the platform. We exploit Jaql to deal with the rich data types in Hadoop, and use it to orchestrate the ETL and analysis workflows. Query optimization at scale, for both SQL and Jaql, is an ongoing challenge we addressing by more adaptive run-times.

* This paper has been prepared by the listed authors, but describes the work of many IBM researchers around the world.

Proceedings of the VLDB Endowment, Vol. 6, No. 11

[1] http://www-01.ibm.com/software/data/infosphere/biginsights/

4. LARGE SCALE ANALYTICS

Large-scale analytics in modern enterprises are driven by applications such as social media analytics for digital marketing and brand management, root cause analysis from system logs, and financial and counterparty analytics from public data. These applications heavily rely on key analytics phases: text analytics, entity resolution, and statistical analysis. To support these phases, IBM Research has been building innovative technologies and tools for text analytics [5], entity resolution [13] and machine learning [11]. One such technology is SystemT [5] that exploits AQL, a declarative rule language for Information Extraction (IE), where an intuitive IE algebra [10] is decoupled from the runtime optimization. A comprehensive tooling framework [15] facilitates development and maintenance of extraction rules, with tools for automatic rule production and refinement. SystemT is also used for backend analytics in an enterprise search system driven by a comprehensive, domain adaptable search architecture developed in IBM Research [1, 9]. Similarly, for enabling large-scale statistical analysis and predictive modeling, SystemML [11] implements a declarative, high-level language using an R-like syntax extended with constructs that are machine-learning specific. The SystemML compiler applies cost-based optimizations to drive low-level execution plans in a MapReduce runtime [11, 22].

5. GRAPH DATA MANAGEMENT

The increased popularity of graph data, in the web and in the enterprise, creates new data management challenges that are specific to this new form of data. At IBM Research, by tapping into 35+ years of research experience in the management of relational and semi-structured data, we have developed a novel storage and query mechanism for graph data that works on top of existing relational stores [4]. Reliance on relational representations facilitates the support of several key features for the enterprise, including, industrial-strength transaction support, locking, and security, to name a few. However, relational stores are not typically designed to deal with the data sparsity and schema variability of graph data. At the same time, typical graph queries over these data exhibit complex structures, with deep nestings, that are hard to optimize using standard techniques. Therefore, our work focuses on developing novel relational graph representations and graph query optimization techniques that maximize the advantages of our shredded graph representation. Overall, our mechanisms result in consistently good performance across many benchmarks, even when compared with current state-of-the-art stores. Our work provides the basis for graph support in DB2 v.10.1.

Large-scale graph data management enables many increasingly important applications. One such application is leveraging semantic technologies to understand, integrate, and analyze a large number of highly heterogeneous sources of data, which is the goal of our Helix project [12]. In particular, we are developing a system for guided data exploration which allows non-expert users to perform complex discovery and analysis over a large number of data sources through a simple unified user interface.

6. EXPLOITING MODERN HARDWARE

At IBM Research we have recognized the importance of hardware-conscious execution. For example, we have shown the importance of NUMA-aware execution [16, 18]. Moreover, we are investigating the acceleration of data management operations exploiting GPUs [14], FPGAs and non-volatile memory technologies [3]. An example is a GPU-based join implementation that saturates the PCIe interconnect, achieving join throughput rate of 6GB/s [14]. We have also developed novel techniques for reducing index maintenance in multiversion databases, so that indexes can be used effectively for analytical queries over current data without being a burden on transaction throughput [21].

References

[1] Z. Bao, B. Kimelfeld, and Y. Li. Automatic suggestion of query-rewrite rules for enterprise search. In *SIGIR*, 2012.

[2] K. S. Beyer, V. Ercegovac, R. Gemulla, A. Balmin, M. Y. Eltabakh, C.-C. Kanne, F. Özcan, and E. J. Shekita. Jaql: A scripting language for large scale semistructured data analysis. *PVLDB*, 4(12), 2011.

[3] B. Bhattacharjee, M. Canim, C. A. Lang, G. A. Mihaila, and K. A. Ross. Storage Class Memory Aware Data Management. *IEEE Data Eng. Bull.*, (4), 2010.

[4] M. A. Bornea, J. Dolby, A. Kementsietsidis, K. Srinivas, P. Dantressangle, O. Udrea, and B. Bhattacharjee. Building an efficient RDF store over a relational database. In *SIGMOD*, 2013.

[5] L. Chiticariu, R. Krishnamurthy, Y. Li, S. Raghavan, F. Reiss, and S. Vaithyanathan. SystemT: An algebraic approach to declarative information extraction. In *ACL*, 2010.

[6] S. Das, Y. Sismanis, K. S. Beyer, R. Gemulla, P. J. Haas, and J. McPherson. Ricardo: integrating R and Hadoop. In *SIGMOD*, 2010.

[7] M. Eltabakh, F. Özcan, Y. Sismanis, P. Haas, J. Vondrak, and H. Pirahesh. Eagle-eyed elephant: split-oriented indexing in hadoop. In *EDBT*, 2013.

[8] M. Eltabakh, Y. Tian, F. Özcan, R. Gemulla, A. Krettek, and J. McPherson. Cohadoop: Flexible data placement and its exploitation in Hadoop. *PVLDB*, 4(9), 2011.

[9] R. Fagin, B. Kimelfeld, Y. Li, S. Raghavan, and S. Vaithyanathan. Rewrite rules for search database systems. In *PODS*, 2011.

[10] R. Fagin, B. Kimelfeld, F. Reiss, and S. Vansummeren. Spanners: a formal framework for information extraction. In *PODS*, 2013.

[11] A. Ghoting, R. Krishnamurthy, E. P. D. Pednault, B. Reinwald, V. Sindhwani, S. Tatikonda, Y. Tian, and S. Vaithyanathan. SystemML: Declarative machine learning on mapreduce. In *ICDE*, 2011.

[12] O. Hassanzadeh, S. Duan, A. Fokoue, A. Kementsietsidis, K. Srinivas, and M. J. Ward. Helix: Online enterprise data analytics. In *WWW*, 2011.

[13] M. A. Hernández, G. Koutrika, R. Krishnamurthy, L. Popa, and R. Wisnesky. HIL: a high-level scripting language for entity integration. In *EDBT*, 2013.

[14] T. Kaldewey, G. Lohman, R. Mueller, and P. Volk. GPU join processing revisited. In *DaMoN*, 2012.

[15] Y. Li, L. Chiticariu, H. Yang, F. Reiss, and A. Carreno-Fuentes. WizIE: A best practices guided development environment for information extraction. In *ACL (System Demonstrations)*, 2012.

[16] Y. Li, I. Pandis, R. Mueller, V. Raman, and G. Lohman. NUMA-aware algorithms: the case of data shuffling. In *CIDR*, 2013.

[17] F. Özcan et al. Emerging trends in the enterprise data analytics: Connecting Hadoop and DB2 Warehouse. In *SIGMOD*, 2011.

[18] D. Porobic, I. Pandis, M. Branco, P. Tözün, and A. Ailamaki. OLTP on hardware islands. *PVLDB*, 5(11), 2012.

[19] V. Raman et al. DB2 with BLU Acceleration: So much more than just a column store. *PVLDB*, 6, 2013.

[20] V. Raman, G. Swart, L. Qiao, F. Reiss, V. Dialani, D. Kossmann, I. Narang, and R. Sidle. Constant-time query processing. In *ICDE*, 2008.

[21] M. Sadoghi, K. A. Ross, M. Canim, and B. Bhattacharjee. Making updates disk-I/O friendly using SSDs. *PVLDB*, 6, 2013.

[22] Y. Tian, S. Tatikonda, and B. Reinwald. Scalable and numerically stable descriptive statistics in systemml. In *ICDE*, 2012.

[23] R. Vernica, A. Balmin, K. S. Beyer, and V. Ercegovac. Adaptive MapReduce using situation-aware mappers. In *EDBT*, 2012.