

Modeling and Optimization in Science and Technologies

Volume 4

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Admir Barolli · Petraq Papajorgji
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Modeling and Processing for Next-Generation Big-Data Technologies

With Applications and Case Studies

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Preface by Editors

Nowadays, we are witnessing an exponential growth in data sets, coined as Big Data era. The data being generated in large Internet-based IT systems is becoming a cornerstone for cyber-physical systems, administration, enterprises, businesses, academia and all human activity fields. Indeed, there is data being generated everywhere: in IT systems, biology, genomics, financial, geospatial, social networks, transportation, logistics, telecommunications, engineering, digital content, to name a few. Unlike recent past where the focus of IT systems was on functional requirements and services, now data is seen as a new asset and data technologies are needed to support IT systems with knowledge, analytics and decision support systems.

Researchers and developers are facing challenges in dealing with this data deluge. Challenges arise due to the extremely large volumes of data, their heterogenous nature (structured & unstructured) and the pace at which data is generated requiring both offline and online processing of large streams of data as well as storing, security, anonymity, etc. Obviously, most traditional database solutions may not be able to cope with such challenges and non-traditional database and storage solutions are imperative today. Novel modelling, algorithms, software solutions and methodologies to cover full data cycle (from data gathering to visualisation and interaction) are in need for investigation.

This Springer book brings together nineteen chapter contributions on new models and analytic approaches for the modelling of large data sets, efficient data processing (online/offline) and analysis (analytics, mining, etc.) to enable next generation data aware systems offering quality content and innovative services in a reliable and scalable way. The book chapters critically analyze the state of the art and envision the road ahead on modelling, analysis and optimisation models for next generation big data technologies. Finally, benchmarking, frameworks, applications, case studies and best practices for big data are also included in the book.

Main contributions of this book

Specifically, the contributions of this book focus on the following research topics and development areas of big data:

Data Modelling and Analysis

Data modelling is among the foremost building blocs in today's data technologies. Because data comes in a variety of formats and from various sources and could be structured, semi-structured or unstructured, the mission of the data modelling is to bring structure to the data in a transparent way for efficient storage and further processing by the applications and systems consuming the data. These issues are dealt with in three first chapters of the book:

[1] *Rodolfo da Silva Villaça, Rafael Pasquini, Luciano Bernardes de Paula and Maurício Ferreira Magalhães. Exploring the Hamming distance in distributed infrastructures for similarity search.*

[2] *Radu-Ioan Ciobanu, Ciprian Dobre, and Fatos Xhafa. Data Modeling for Socially-Based Routing in Opportunistic Networks.*

[3] *Petra Perner. Decision Tree Induction Methods and Their Application to Big Data.*

Specifically, in the chapter by **Villaça et al.** is presented a vector space model for structuring data and support efficient similarity search techniques. In the second chapter, **Dobre et al.** deal with data modelling from the emerging paradigm of opportunistic networks aiming to support efficient data routing and dissemination algorithms. The presented model can found application to many other scenarios from information-centric networks to the Internet of Things. **Perner**, in the third chapter, introduces the decision tree induction model and its use for data mining/learning algorithms. The author then gives an outlook on the application of decision tree induction to Big Data scenarios.

Data Gathering, Aggregation and Replication

The need for big data solutions has led to the definition of a whole data life cycle. In such cycle, data gathering, aggregation, structuring, storing and replication are fundamentals steps. Indeed, unlike traditional approaches when most data is stored into databases in a straightforward way, big data sources emerge from various wireless and mobile networked devices, known as "world sensing data". Additionally, not all data is or should be stored as is, but can be classified and grouped/gathered into larger data entities or objects. In many such scenarios, data is also replicated to increase availability and reliability. Several approaches to such issues are presented in the next three chapters, as follows:

[4] *Suchetana Chakraborty, Sandip Chakraborty, Sukumar Nandi, and Sushanta Karmakar. Sensory Data Gathering for Road-Traffic Monitoring: Energy Efficiency, Reliability and Fault-tolerance*

[5] *Kazuya Matsuo, Keisuke Goto, Akimitsu Kanzaki, Takahiro Hara, Shojiro Nishio. Data aggregation and forwarding route control for efficient data gathering in dense mobile wireless sensor networks*

[6] *Evjola Spaho, Admir Barolli, Fatos Xhafa, and Leonard Barolli. P2P Data Replication: Techniques and Applications*

Respectively, **Chakraborty et al.** present a novel tree based data gathering scheme for data gathering in Vehicular Sensor Networks. The presented approach enables an efficient design of data collection protocol through which delay sensitivity and reliability of the large volume of application data as well as the scarcity of sensor resources can be addressed. **Matsuo et al.** present a data gathering method considering geographical distribution of data values for reducing traffic in dense mobile wireless sensor networks. Data replication and the usefulness of P2P techniques to increase availability and reliability are presented in the chapter by **Spaho et al.**

High Performance and MapReduce Processing

Efficient data processing has become a must for big data approaches to meet the timely processing needs (both online/real-time and offline), due to large volumes of data and the continuous increasing amounts of data. Two chapters cover the challenges and present solutions to achieve high performance processing:

[7] Alexey Cheptsov, Bastian Koller. *Leveraging High Performance Computing Infrastructures to Web Data Analytic Applications by means of Message-Passing Interface.*

[8] Jia-Chun Lin, Fang-Yie Leu, Ying-ping Chen. *ReHRS: A Hybrid Redundant System for Improving MapReduce Reliability and Availability.*

Cheptsov and Koller present an approach to parallelise data-centric applications based on the known Message-Passing Interface. Although MPI is a long standing parallel computing framework, the authors have introduced novel features to achieve high utilisation rate and low costs of using productional high performance computing and Cloud computing infrastructures. They also discuss on OMPIJava –Java bindings for Open MPI—as an alternative to MapReduce Hadoop framework. On the other hand, **Lin et al.** make an indepth analysis of MapReduce framework and present techniques to improve the availability and reliability to support robust data processing applications.

Data Analytics and Visualisation

With the emergence of the Big Data, data analysis and data analytics are taking great importance as means to support knowledge extraction and decision support systems. Under the name of data analytics are comprised various specific forms of analytics such as business analytics, health analytics, learning analytics, security analytics, etc. On the other hand, closely related to analytics is the visualisation, which becomes challenging due to the size and multi-dimensionality of the data. The three next chapters bring issues, challenges and approaches to data analytics and data visualisation.

[9] Patricia Morreale, Allan Goncalves, and Carlos Silva. *Analysis and Visualization of Large Scale Time Series Network Data*

[10] Yoshihiro Okada. *Parallel Coordinates Version of Time-tunnel (PCTT) and Its Combinatorial Use for Macro to Micro Level Visual Analytics of Multidimensional Data*

[11] Martin Strohbach, Holger Ziekow, Vangelis Gazis, Navot Akiva. *Towards a Big Data Analytics Framework for IoT and Smart City Applications*

Concretely, **Morreale *et al.*** present a methodology for data cleaning and preparation to support big data analysis along with a comparative examination of three widely available data mining tools. The proposed methodology is used for analysis and visualisation of a large scale time series dataset of environmental data. The research issues related to visualisation of multidimensional data is studied in the chapter by **Okada**, where the author introduces an interactive visual analysis tool for multidimensional data and multi-attributes data. **Strohbach *et al.*** analyse the high level requirements of big data analytics and then provide a Big Data Analytics Framework for IoT and their application to smart city. Their approach is exemplified through a case study in the smart grid domain. A prototype of the framework addressing the volume and velocity challenges is also presented.

Big Data, Cloud Computing and Auditing

Big Data and Cloud computing are penetrating and impacting each time more the businesses and enterprises in various forms, including business intelligence, decision making, business processes, innovation, etc. However, the adoption of these new technologies by businesses and enterprises is facing many challenges. The two chapters below analyse such challenges in the interdisciplinary field of ICT, businesses, innovation auditing and control.

[12] Antonio Scarfò and Francesco Palmieri. How the big data is leading the evolution of ICT technologies and processes

[13] David Simms. Big Data, Unstructured Data and the Cloud: Perspectives on Internal Controls

Scarfò and Palmieri highlight the most important innovation and development trends in the new arising scenarios of Big Data and its impact on the organisation of ICT-related companies and enterprises. The authors make a critical analysis and address the missing links in the ICT big Picture and present the emerging data-driven reference models for the modern information-empowered society. **Simms** analyses the increasing awareness by businesses and enterprises about the value of Big Data to the world of corporate information systems. Through his analysis it is shown nevertheless that inspite of the potential advantages brought by Big Data and Cloud computing, like the use of outsourcing, their adoption requires addressing issues of confidentiality, integrity and availability of applications and data. An appropriate understanding of risk and control issues is advocated in the chapter as a need for a successful adoption of these new technologies.

Big Data, Mobile Computing and IoT

With the fast increase in the number of smartphones, tablets as well as all sorts of smart devices, the mobile computing and Internet of Things have fast become among most important Big Data sources. It is expected that processing of such data will significantly contribute to smart applications and environments, with a human-centric focus. The fol-

lowing two chapters address the challenges to be faced for achieving user-centric aware IoT that brings together people and devices into a sustainable eco-system.

[14] *María V. Moreno-Cano, José Santa, Miguel A. Zamora-Izquierdo, and Antonio F. Skarmeta. Future Human-Centric Smart Environments*

[15] *Tor-Morten Grønli, Gheorghita Ghinea, Muhammad Younas, Jarle Hansen. Automatic Configuration of Mobile Applications using Context-Aware Cloud Based Services*

Moreno-Cano et al. bring a user-centric perspective of IoT and present a management platform for smart environments. Their platform is based on a layered architecture and uses artificial intelligent methods to transform raw data into semantically-meaningful information used by services. Their approach is exemplified with real use cases from smart buildings. **Grønli et al.** discuss several challenges in the area of context-awareness in the cloud setup, whereby context-aware information is harvested from several dimensions to build a rich foundation for context-aware computation. The authors have combined and exploited the Cloud and Mobile computing paradigms to create a new user experience and a new way to invoke control over user's mobile phone.

Social Networking and Crowd-sourcing

Social networking is yet another important source for Big Data, referred to also as Social Big Data, Social Data Sensing and Crowd-sourcing Big Data, which consist of user activity data collected by social networks and crowd-sourced, participatory activities. As the number of users of social networks keeps increasing, pushed by advances in mobile computing and smartphones, this kind of big data is seen as a real asset that could bring value to companies such as by providing users with personalized content. Nevertheless, extracting the real value from such data is challenging due to the data volume and growth and the various data formats, which make the data not ready for processing straightway. The two chapters below discuss these issues.

[16] *Ryoichi Shinkuma, Yasuharu Sawada, Yusuke Omori, Kazuhiro Yamaguchi, Hiroyuki Kasai, Tatsuro Takahashi. Socialized system for enabling to extract potential 'values' from natural and social sensing data*

[17] *G. Piro, V. Ciancaglini, R. Loti, L.A. Grieco, and L. Liquori. Providing crowd-sourced and real-time media services through a NDN-based platform*

The chapter by **Shinkuma et al.** mainly considers two problems faced when extracting values from sensing data, namely, dealing with raw/unprocessed sensing data and the inefficiency in terms of management costs to keep all sensing data usable. The authors propose a relational graph-based approach to encode the characteristics of sensing data. On the other hand, **Piro et al.** use crowd-sourcing for providing real-time media contents. To that aim, the design of a network architecture, based on the emerging Named Data Networking is used to support crowd-sourced real-time media contents.

Open Data, Benchmarking, Frameworks, Best Practices and Experiences

As in the case of other emerging research fields, Big Data calls for benchmarking, standardisation and evaluation frameworks. The book includes two chapters bringing a set of best practices and experiences in open data projects and frameworks addressing the needs and challenges in this regard.

[18] Mikel Emaldi, Oscar Peña, Jon Lázaro, Diego López-de-Ipiña. *Linked Open Data for Smarter Cities*

[19] Franck Le Gall, Sophie Vallet Chevillard, Alex Gluhak, Nils Walravens, Zhang Xueli, Hend Ben Hadji. *Benchmarking Internet of Things Deployment: Frameworks, Best Practices and Experiences*

The chapter by **Emaldi et al.** proposes the use of Linked Open Data together with a set of best practices to publish data on the Web recommended by the W3C, in a new data life cycle management model. Their approach is exemplified for the case of open data for smart cities, namely, smart data, enabling automatic consumption of big amounts of data, providing relevant and high quality data to end users with low maintenance costs. Finally, **Le Gall et al.** critically analyse existing gaps in assessing the utility and benefits of IoT deployments and propose a novel benchmarking framework for IoT deployments. The proposed framework is complementary to the emerging tools for the analysis of Big Data and allows a better decision making for policy makers for regulatory frameworks.

Emerging Applications

Altogether, the chapters of the book bring a variety of big data applications from *IoT systems, smart cities, traffic control, energy efficient systems, disaster management, etc.* shedding light on the great potential of Big Data but also envisioning the road ahead in this exciting field of the data science.

Targeted Audience and Last Words

The contributions of the chapters of the book are researchers and practitioners from academia and industry, who bring their expertise and experience in the Big Data, comprising fundamental approaches, implementations and experimental approaches as well as benchmarking and best practices. The variety of approaches, examples and applications along the chapters makes the book interesting to ample audiences of academics, instructors and senior students, researchers and senior graduates from academia, networking and software engineers, data analysts, business analysts from industries and businesses.

We hope that the readers and practitioners of Big Data will find this book useful in their academic, research and professional activities!

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