# Incorporating Big Data Analytics into Enterprise Information Systems

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**Abstract**. Big data analytics has received widespread attention for enterprise development and enterprise information systems (EIS). However, how can it enhance the development of EIS? How can it be incorporated into EIS? Both are still big issues. This paper addresses these two issues by proposing an ontology of a big data analytics. This paper also examines incorporation of big data analytics into EIS through proposing BABES: a model for incorporating big data analytics services into EIS. The proposed approach in this paper might facilitate the research and development of EIS, business analytics, big data analytics, and business intelligence as well as intelligent agents.

**Keywords**: big data, big data analytics, enterprise information systems, business intelligence, intelligent agents.

## 1 Introduction

Big data has become a big gold mine of the 21st century because of the miraculous success for big data companies such as Facebook, Google and QQ in the recent years. Big data and its emerging technologies including big data analytics have been making not only big changes in the way the business operates but also traditional data analytics and business analytics become new big opportunities for academicians and enterprise CEOs [1]. Big data analytics is an emerging big data science, and has become a mainstream market adopted broadly across industries, organizations, and geographic regions and among individuals to facilitate data-driven decision making [2] [3]. According to a study of Gartner, worldwide BI (business intelligence) and analytics software, consisting of BI platforms, analytic applications and advanced analytics, totalled $14.4 billion in 2013, an 8% increase from 2012 revenue [4]. This fact enhances unprecedented interest and adoption of big data analytics. According to the annual survey results of 850 CEOs and other C-level executives of global organizations, McKinsey [5] concludes that 45% of executives put "big data and advanced analytics" as the first three strategic priorities in both strategy and spending

in three years' time and more than one thirds of executives will now spend or in three years' time in this area. IDC (International Data Corporation) predicts that the business analytics software market will grow at a 9.7% compound annual growth rate over the next five years from 2012 to 2017 [3].

Enterprise information systems (EIS) have been implemented or adopted in many firms in general and Fortune 500 companies in particular, and achieved performance excellence and enhanced decision making over the past few decades [6, p. 381]. EIS are based on organization-wide data and big data beyond the enterprise including that from the Web [7]. How to use big data and big data analytics for improving EIS has become a big challenge for enterprises and the development of EIS recently [1, 7].

The above brief literature review and discussion implies that the following important issues have not drawn significant attention in the scholarly peer-reviewed literature:

- What is the relationship between big data analytics and EIS?

- How can big data analytics be incorporated into EIS?

This paper will address these two issues through reviewing and extending our early research on analytics service oriented architecture for EIS [1]. More specifically, we first propose an ontology of big data analytics in Section 2 through overviewing our early work on business analytics and big data analytics [1]. To address the first issue, this paper looks at EIS and its relationship with big data analytics in Section 3. To address the second issue, this paper proposes BABES: a model for incorporating big data analytics into EIS. The final sections discuss the related work and end this paper with some concluding remarks and future work.

## 2   An Ontology of Big Data Analytics

This section proposes an ontology of big data analytics and looks at the interrelationship between big data analytics and data analytics. To begin with, this section first examines big data analytics.

Big data analytics is an integrated form of data analytics and web analytics for big data [1]. According to Beal [8] and Gandomi and Haider [9], big data analytics can be defined as a process of collecting, organizing and analyzing big data to discover patterns, knowledge, and intelligence as well as other information within the big data. Based on this definition, big data analytics can be considered a combination of big data management and big data mining, because the process of collecting and organizing big data belongs to big data management while the process of 'analyzing big data to discover patterns, knowledge, and intelligence as well as other information within the big data' is the main task of big data mining, where big data mining is a modern form of traditional data mining in the age of big data.

More generally, big data analytics is an emerging science and technology involving the multidisciplinary state-of-art information and communication technology (ICT), mathematics, operations research (OR), machine learning, and decision science for big data [1, 10]. The main components of big data analytics include big data

descriptive analytics, big data predictive analytics, and big data prescriptive analytics [11].

- Big data descriptive analytics is descriptive analytics for big data [12]. It is used to discover and explain the characteristics of entities and relationships among entities within the existing big data [13, p. 611]. Big data descriptive analytics addresses what happened, and when, as well as what is happening through analyzing the existing big data using analytical techniques and tools.
- Big data predicative analytics is predicative analytics for big data, which focuses on forecasting trends by addressing the problems such as what will happen, what is likely to happen and why it will happen [12] [14]. Big data predicative analytics is used to create models to predict future outcomes or events based on the existing big data [13, p. 611].
- Big data prescriptive analytics is prescriptive analytics for big data, which addresses the problems such as what we should do, why we should do it and what should happen with the best outcome under uncertainty through analyzing the existing big data using analytical techniques and tools [11, p. 5].

An ontology is a formal naming and definition of a number of concepts and their interrelationships that really or fundamentally exist for a particular domain of discourse [15]. Then, an ontology of big data analytics is a network consisting of a number of concepts and their interrelationships for big data analytics.

Based on the above discussion, we propose an ontology of big data analytics, as illustrated in Figure 1. In this ontology, big data analytics is at the top while big data and data analytics are at the bottom. Big data descriptive analytics, big data predictive analytics, and big data prescriptive analytics are at the middle level as the core parts of any big data analytics.
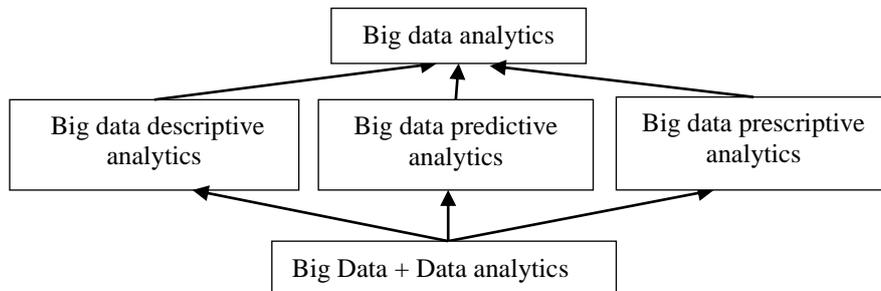


Figure 1.  An ontology of big data analytics

In Figure 1, data analytics refers to as a method or technique that uses data, information, and knowledge to learn, describe and predict something [14, p. 341]. Data analytics is a science and technology about examining, summarizing, and drawing conclusions from data to learn, describe and predict something. In brief, data

analytics can be then considered as data-driven discoveries of knowledge and intelligence and communications [12].

The fundamentals of big data analytics consists of mathematics, statistics, engineering, human interface, computer science and information technology [1, 10]. The techniques for big data analytics encompass a wide range of mathematical, statistical, and modeling techniques [13, p. 590]. Big data analytics always involves historical or current data and visualization [16]. This requires big data analytics to use data mining (DM) to discover knowledge from a data warehouse (DW) or a big dataset in order to aid decision making, in particular in the text of big business and management [14, p. 344]. DM employs advanced statistical tools to analyze the big data available through DW and other sources to identify possible relationships, patterns and anomalies and discover information or knowledge for rational decision making [13, p. 590]. DW extracts or obtains its data from operational databases as well as from external open sources, providing a more comprehensive data pool including historical or current data [13, p. 590]. Big data analytics is also required to use statistical modelling (SM) to learn something that can aid decision making [1]. Visualization techniques as an important part of big data analytics make any knowledge patterns and information for decision making in a form of figure or table or multimedia. In summary, big data analytics can facilitate business decision making and realization of business objectives through analyzing current problems and future trends, creating predictive models to forecast future threats and opportunities, and optimizing business processes based on involved historical or current big data to enhance organizational performance [12]. Therefore, big data analytics can be represented below.

$$\text{Big data analytics} = \text{Big data} + \text{data analytics} + \text{DW} + \text{DM} + \text{SM} + \text{Visualization} + \text{optimization} \qquad 1$$

This representation reveals the fundamental relationship between big data, data analytics and big data analytics, that is, big data analytics is based on big data and data analytics. It also shows that computer science and information technology play a dominant role in the development of big data analytics through providing sophisticated techniques and tools of DM, DW, machine learning and visualization [1]. SM and optimization still play a fundamental role in the development of big data analytics, in particular in big data prescriptive analytics [11].

## 3   Enterprise Information Systems and Big Data Analytics

This section examines enterprise information systems (EIS) and its relationships with big data analytics.

EIS has drawn increasing attention in academia, organizations and enterprises over the past decades. EIS is also called enterprise systems [14]. There are many different definitions on EIS. For example, EIS refers to as

1. Systems that help managers and companies to improve their performance by enabling them to seamlessly share data and information among departments and with external business partners [14, p. 287]. These systems integrate the functional systems such as accounting, finance and marketing as well as operations.
2. Enterprise software that are based on a suite of integrated software modules and a common central database [6, p. 363].
3. Information systems that support activities in multiple departments of an enterprise [17, p. 605].

The first definition is self-contained for an EIS and emphasizes sharing data and information. The second stresses enterprise software with a common central database. The third one is a general definition. By integrating these three definitions, we can define an EIS as an information system that has a common central database and support activities in multiple departments of the enterprise through integrating the functional information systems (IS) such as accounting, finance, marketing and other operations' IS, and accessing the data resources available in the enterprise and on the Web. The support activities included will help managers and the enterprise to improve their business performance and decision making by enabling them to seamlessly share data and information among departments and with external business partners [1].

EIS mainly consist of ERP (enterprise resource planning) systems, SCM (supply chain management) systems, CRM (Customer relationship management) systems and KM (knowledge management) systems [14, 6]. The ERP system is an EIS that processes the information of multiple departments such as human resources management, finance and accounting management, sales and marketing management, manufacturing and production management of an enterprise in a unified way [6, pp. 81-2]. The SCM system is used to manage the relationships with the suppliers. The CRM system is used to manage the relationships with the customers of the enterprise. The KM system is used to manage the processes for capturing and applying knowledge and expertise of enterprise.

Based on the previous subsection's discussion, big data analytics can facilitate the development of EIS, because it can support business decision making in the age of big data [1]. Big data analytics also allows enterprises to enhance business performance, efficiencies and guides decision processes [18]. Both EIS and big data analytics are common in emphasizing the big data as a strategic resource for the development of enterprises, in particular for global enterprises. EIS involves interactive visualization for data exploration and discovery [19], which can be considered as a part of big data analytics, as mentioned in Equation 1 of Section 2. EIS include analytical tools for using big data to evaluate the business and marketing performance [1]. The analytical tools are a fundamental part of any big data analytics systems. This implies that EIS and big data analytics share some common tools to support business decision making and improve the business performance of enterprises.

Based on the research of IDC [20], Australian organizations expect big data and advanced analytics projects to deliver outcomes that will improve competitive advantage, enhance customer service and support, and aid with customer acquisition and retention. However, big data and big data analytics technology in the Australian

industry demonstrate considerable variation in progress with some quite advanced with sophisticated and deeply embedded deployments within core business processes, whilst others are just beginning the journey [21].

EIS are important information systems for improving business performance and business decision making of CEOs and enterprises. Big data analytics is a pivotal part for developing EIS [1]. From a technological viewpoint, big data analytics is data-driven business oriented technique and facilitates business decision making, and improves EIS as a system component. From a data viewpoint, big data analytics relies on big data and data analytics; and big data have become a strategic resource for any organization and enterprise, in particular for multinational organisations as well as any EIS. Discovering useful patterns, information and knowledge from big data has become the central topic both for business operations and marketing and for EIS. This is just the task of big data analytics.

## 4    BABES: A Model for Incorporating Big Data Analytics into EIS

This section addresses how big data analytics can be incorporated into EIS through presenting a model for big data analytics-based EIS, for short, BABES.

Standalone enterprise systems have become a thing of the past [22, p. 382]. BABES incorporates big data analytics services into an EIS that consists of main functions of SCM systems, CRM systems and KM systems, as shown in Figure 2. In what follows, we will examine this model in some detail.

SCM systems are classified as either SC (supply chain) planning systems or SC execution systems [6, p. 370]. Then SC planning and SC execution are main functions of SCM systems. CRM systems mainly consist of sales, marketing and services [6, p. 379]. A KM system mainly is used to create, capture, refine, store, manage, disseminate, and share knowledge [23]. Therefore, BABES includes SC planning analytics, SC execution analytics, marketing analytics, sales analytics, service analytics and big data analytics.

Master enterprise data warehouse (MEDW) mainly consists of data related to sales, marketing, services, customers, SC planning, and SC execution flowing from departments of marketing, human resources, and other data related to departments. All these can be considered as structured data. Enterprise knowledge base (EKB), a part of the KM system, consists of information and knowledge from the Web, call centers, direct mails, emails, retail stores, and clients and partners [6]. All these data of EKB are mainly semi-structured or unstructured data and information. EKB will play a more important role in EIS with incorporating big data analytics, because unstructured data constitutes about 95% of big data [9].

Big data analytics is based on MEDW and EKB, and provides related information and techniques for sales analytics, marketing analytics, service analytics, SC planning analytics and SC execution analytics, each of them can be considered as an intelligent agent [24].

Analytics engine is a mechanism, as an intelligent agent, for managing and producing SC planning analytics, SC planning analytics, marketing analytics, service

analytics, customer analytics, and big data analytics. Based on the foregoing equation (1), Analytics engine has OLAP, data mining, statistical modelling, optimization, visualisation tools and other data and knowledge analytical tools including soft computing, fuzzy neural networks, decision trees, and probabilistic models [10].
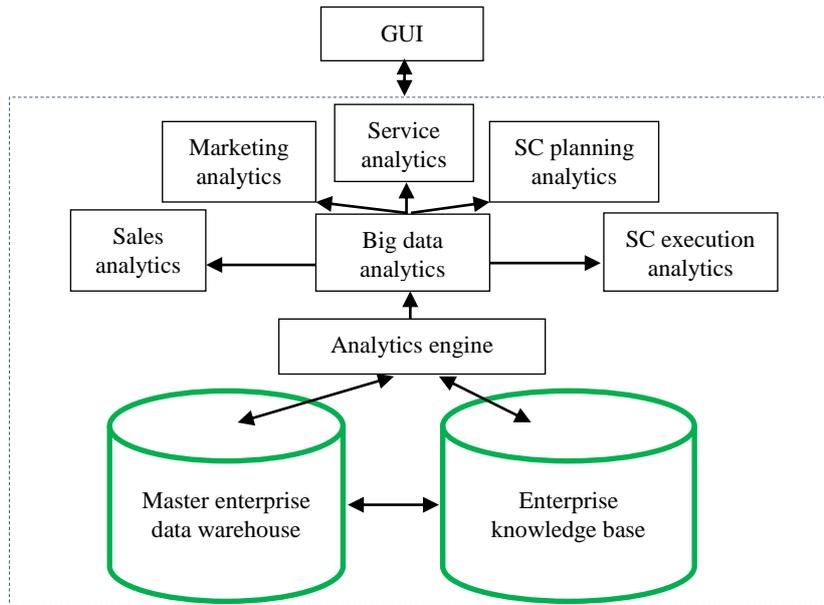


Figure 2. BAES: A model for incorperating big data analytics into EIS

It should be noted that our proposed model BAES is to integrate SCM and CRM and KM, without including ERP, with big data analysis into EIS at the moment.

## 5 Related Work and Discussion

The authors have searched "enterprise systems" "big data" using ScienceDirect (on 18 May 2015), and there are a few real development of applying big data in enterprise systems. In which, two articles are related to our research. One is the Special Issue on "Intelligent Enterprise Systems" which means that big data has drawn attention from the intelligent systems community. Another is on ERP and big data [7], which focuses on aligning big data with ERP and suggesting a future research agenda to bring together big data and ERP whereas our research focuses on techniques of incorporating big data analytics into EIS. We share the similar observation to that of Elragal [7] that there are only a few research reports on how to integrate big data analytics into EIS although there are a significant number of researches on big data analytics. Furthermore, a basic search in Scopus and Google scholar (i.e. article title and key words) reveals that the number of papers published on "big data analytics

enterprise system" (in the title of papers) in journals and proceedings is small excepted our earlier work (retrieved on 8 April 2015). Therefore, how to integrate big data analytics with EIS is still a big issue for research communities. This motivates us to examine techniques for how to incorporate big data analytics into EIS.

We have mentioned a number of scholarly researches on data analytics, big data analytics, and EIS. In what follows, we will focus on related work and discussion on ontology of big data analytics, and the work of SAP as well as incorporation of big data analytics into EIS.

Ontology has been important in computer science and artificial intelligence [1]. A basic search in Google scholar (i.e. article title and key words) reveals that there are a few publications entitled "ontology of big data analytics". We then explored it and put it as a part of this research through updating our early work on data analytics, business analytics and big data analytics [1]. We try to explore the interrelationship among big data analytics, big data descriptive analytics, big data predictive analytics, and big data prescriptive analytics using the proposed ontology. The result reported in this paper on ontology of big data analytics and big data analytics equation, which is an updated form of our early work, is only a beginning for providing a relatively comprehensive ontology of big data analytics. In this direction, we will investigate more academic reviewed sources as a future work to develop an ontology of big data analytics with three levels of knowledge concepts for each related analytics, that is, for each analytics in the ontology of big data analytics, we will examine its concepts, fundamentals, methodologies, tools and applications. Such an investigation would become an important guide for the research and development of big data analytics, and EIS.

SAP, one of the leading vendors of ERP [7], has introduced its enterprise service-oriented architecture [6, p. 383]. SAP's architecture specifies general services to enterprise services whereas our BABES model specifies general services to big data analytics as a service. Big data analytics services should be a part of enterprise services, and then our BABES can be considered as a concrete application for the enterprise service-oriented architecture of SAP. However, SAP's enterprise system focuses on enterprise services in finance, logistics, procurement and human resources management as a part of its ERP system [6]. We conceive that our DBAES will be incorporated into the next generation EIS integrating SCM, CRM, and KM systems, in particular the cloud-based version of EIS.

## 6  Conclusion

The paper presented a timely critical investigation of an emerging area of big data analytics and its relationships to existing fields of IS research in general and EIS in specific. The two main contributions of this paper are an ontology of big data analytics and BABES: a model for incorporating big data analytics into EIS. The ontology of big data analytics is used to address what is the constitution of big data analytics and how its components are networked. The BABES reveals how to incorporate big data analytics into EIS. The discussion of the related work of SAP

implies that the proposed DABES is useful for the development of EIS. The proposed approach in this paper might facilitate research and development of business analytics, big data analytics, EIS, and BI.

Besides mentioning in the previous section, in our future work, we will explore enterprise acceptability of DABES for EIS. We will also explore how to design and implement DABES. More specifically, we will address the main functions of EIS that should be based on DABES, and how DABES can be developed in order to incorporate big data analytics into EIS using intelligent agents technology [24].

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## References

[1]     Z. Sun, K. Strang and J. Yearwood, "Analytics service oriented architecture for enterprise information systems," in *Proceedings of iiWAS2014, CONFENIS 2014, 4 - 6 Dec 14*, Hanoi, 2014.

[2]     Z. Sun, S. Firmin and J. Yearwood, "Integrating online social networking with e-commerce based on CBR," in *The 23rd ACIS 2012 Proceedings, 3-5 Dec*, Geelong, 2012.

[3]     D. Vesset, B. McDonough, D. Schubmehl and M. Wardley, "Worldwide Business Analytics Software 2013–2017 Forecast and 2012 Vendor Shares (Doc # 241689)," 6 2013. [Online]. Available: http://www.idc.com/getdoc.jsp?containerId=241689. [Accessed 28 6 2014].

[4]     R. van der Meulen and J. Rivera, "Gartner Says Worldwide Business Intelligence and Analytics Software Market Grew 8 Percent in 2013," 29 4 2014. [Online]. Available: http://www.gartner.com/newsroom/id/2723717. [Accessed 28 6 2014].

[5]     McKinsey, "The digital tipping point: McKinsey Global Survey results," June 2014. [Online]. Available: http://www.mckinsey.com/insights/business_technology/the_digital_tipping_point_mckinsey_global_survey_results. [Accessed 1 7 2014].

[6]     K. G. Laudon and K. C. Laudon, Management Information Systems: Managing the Digital Firm (12th Ed), Harlow, England: Pearson, 2012.

[7]     A. Elragal, "ERP and Big Data: The Inept Couple," *Procedia Technology,* vol. 16, p. 242 – 249, 2014.

[8]     V. Beal, "Big data analytics," 2014. [Online]. Available: http://www.webopedia.com/TERM/B/big_data_analytics.html. [Accessed 20 8 2014].

[9]     A. Gandomi and . M. Haider, "Beyond the hype: Big data concepts, methods, and analytics," *International Journal of Information Management 35 (2015),* vol. 35, p. 137–

144, 2015.

[10] C. P. Chen and C.-Y. Zhang, "Data-intensive applications, challenges, techniques and technologies: A survey on Big Data," *Information Sciences,* vol. 275 , p. 314–347, 2014.

[11] M. Minelli, M. Chambers and A. Dhiraj, Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses, Wiley & Sons (Chinese Edition 2014), 2013.

[12] D. Delena and H. Demirkanb, "Data, information and analytics as services," *Decision Support Systems,* vol. 55, no. 1, p. 359–363, 2013.

[13] C. Coronel, S. Morris and P. Rob, Database Systems: Design, Implementation, and Management (11th edition), Boston: Course Technology, Cengage Learning, 2015.

[14] E. Turban and L. Volonino, Information Technology for Management: Improving Strategic and Operational Performance (8th Edition), Danvers, MA: Wiley & Sons, 2011.

[15] T. Gruber, "Toward principles for the design of ontologies used for knowledge sharing," *International Journal of Human-Computer Studies ,* vol. 43, no. 5-6, p. 907–928, 1995.

[16] Z. Sun and J. Yearwood, "A theoretical foundation of demand-driven web services," in *Demand-Driven Web Services: Theory, Technologies, and Applications*, IGI-Global, 20014, pp. 1-25.

[17] D. Kroenke, D. Bunker and D. Wilson, Exerperiencing MIS (3rd Edition), Australia: Person, 2014.

[18] K. Kambatla, G. Kollias, V. Kumar and A. Grama, "Trends in big data analytics," *Journal of Parallel and Distributed Computing,* vol. 74 , no. 7, p. 2561–2573, 2014.

[19] A. Brust, "Gartner releases 2013 BI Magic Quadrant," 2013. [Online]. Available: http://www.zdnet.com/gartner-releases-2013-bi-magic-quadrant-7000011264/. [Accessed 14 2 2014].

[20] S. Parker and A. T. Hira, "Australia Reaches a Tipping Point for Big Data Adoption, Says IDC Australia," 23 6 2015. [Online]. Available: http://www.idc.com/getdoc.jsp?containerId=prAU25707715.

[21] E. Ditton and S. Parker, "Big Data and Analytics in the Australia Industry," April 2014. [Online]. Available: http://www.idc.com/getdoc.jsp?containerId=AU245426.

[22] K. Laudon and J. Laudon, Management Information Systems-Managing the Dgital Firm, Boston: Person, 2012.

[23] Z. Sun and G. Finnie, "Experience management in knowledge management," in *LNAI 3681*, Berlin Heidelberg, 2005.

[24] Z. Sun and G. Finnie, Intelligent Techniques in E-Commerce: A Case-based Reasoning Perspective, Heidelberg Berlin: Springer-Verlag, 2004; 2010.