Big Data with Ten Big Characteristics

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Abstract. This paper reveals ten big characteristics (10 Bigs) of big data and explores their non-linear interrelationships through presenting a unified framework of big data. The framework has three levels: fundamental level, technological level, and socio-economic level. The fundamental level has four big fundamental characteristics of big data. The technological level consists of three big technological characteristics of big data. The socioeconomic level has three big socioeconomic characteristics of big data. The paper looks at each level of the proposed framework from a service-oriented perspective. The proposed approach in this paper might facilitate the research and development of big data, big data analytics, business intelligence, and business analytics.

CCS Concepts

• Information systems→ Information systems applications Decision support systems→ Data analytics • Information systems→Information retrieval→Retrieval tasks and goals→Business intelligence.

Keywords: big data, big data analytics, business analytics, business intelligence, artificial intelligence.

1 INTRODUCTION

Big data has become one of the most important frontiers for innovation, research and development in computer science [1, 2], industry and business [3, 4]. Big data has been also a key enabler of exploring business insights, business intelligence, and economics of services. This has drawn an unprecedented interest in industries, universities, governments and organizations [5] [6]. Big data and its emerging technologies including big data analytics [7] have been not only making big changes in the way the business operates but also making traditional data analytics and business analytics bring about new big opportunities for academia and enterprises [8]. However, the following fundamental issues are still open for comprehending big data,

- What are the characteristics of big data?
- How can we understand the relationships among the characteristics of big data?

This paper will address these two issues. To address the first issue, this paper, different from the existing literature on big data, directly proposes and looks at 10 Bigs rather than 10 Vs [9] or 3 Vs [9] or 4 Vs [10] as the ten big characteristics of big data. This 10 Bigs consist of big volume, big velocity, big variety, big veracity, big intelligence, big analytics, big infrastructure, big service, big value, and big market. Then this paper explores the non-linear interrelationships among these 10 Bigs through presenting a unified framework. The framework reveals that 4 Bigs (i.e. big volume, big velocity, big variety, and big veracity) are fundamental characteristics of big data. Another 3 Bigs (i.e. big intelligence, big analytics, big infrastructure) are technological characteristics of big data. The remainder 3 Bigs (i.e. big service, big value, and big market) are socioeconomic characteristics of big data. The paper examines each level of the proposed framework from a service-oriented perspective

The remainder of this paper is organized as follows. Section 2 overviews the existing characteristics of big data from an evolutionary perspective. Section 3 proposes and looks at 10 Bigs as the ten big characteristics of big data. Section 4 examines the interrelationships among the 10 Bigs through a unified framework. The final sections discuss the related work, future directions and end this paper with some concluding remarks and future work.

It should be noted that big might not be the best term to represent the characteristics of big data in some cases. However, it is only "big" of data that makes everyone draw increasing attention to big data, big analytics, and big market, because everyone can engage in big data and enjoy big services from big data [12]. Everyone can understand and use "big" well in practice although not everyone can image how big the 100 Zettabytes (ZB) of data is and why ZB size of data is important for our life and society.

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2 AN EVOLUTIONARY PERSPECTIVE ON BIG DATA

This section overviews the characteristics of big data from an evolutionary perspective.

McKinsey defines big data as "the datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze" [9]. Gartner defines big data as the "high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making" [5]. This definition, because of its marketing feature, has been most-frequently used in both analyst communities and academia communities for research and development of big data [1].

The characteristics of big data have been studied in various publications. From an evolutionary perspective, Doug Laney uses 3 Ds: data volume, data velocity and data variety to represent the characteristics of data in e-commerce in 2001 [10]. Late these 3 Ds have been changed into 3 Vs (volume, velocity, and variety) which have been explained as three characteristics of big data [11, 12]. Furthermore, these 3 Vs has been extended first to 4 Vs as four characteristics of big data by adding veracity [13, 14], and then to 5 Vs as five characteristics of big data (volume, variety, velocity, veracity, value) [15, 16], finally to 10 Vs by adding another 5 Vs: validity, variability, venue, vocabulary and vagueness [17].

The importance of "big" has deeply been minded in a big data world. It is necessary to characterize "big" of the big data. We can then change 3 Vs to 3 Bigs for big volume, big variety, big velocity as the three "big" characteristics of big data to reflect the importance of "big" in big data. This paper extends 3 Bigs to 10 Bigs to examine ten big characteristics of big data and their interrelationships in terms of big data computing.

3 10 BIGS AS TEN BIG CHARACTERISTICS OF BIG DATA

This section proposes and examines ten big characteristics of big data.

3.1 Big Volume

The big volume of big data reflects the size of the data set, which is typically in exabytes (EB) or ZB [9] although many, like a child, might consider 10 is big as an integer [18]. Nowadays, many data-driven companies are working with petabytes (PB) of data daily. Google processes over 20 PB of data daily. Walmart collects more than 2.5 PB of unstructured data from its 1 million customers every hour. Big data repositories for future generation parallel and distributed systems currently exceed EB and are increasing at a rapid speed in size. The volume of big data has been increased from EB or ZB [1].

To overcome the challenge arising from big data with big volume, massively parallel computing and distributed computing platform is a practical choice, because its underlying principle is a distribution of workload across many processors as well as storage and transportation of underlying data across a set of parallel storage units and streams [15]. Hadoop has become the de facto standard for storing, processing and analyzing the data with big volume of hundreds of terabytes, and even PB [1]. For example, Hadoop clusters at Yahoo! span over 40,000 servers, and store 40 PB of application data [1].

3.2 Big Velocity

Big velocity is related to throughput and latency of data [13]. For throughput, big velocity means that at a big speed, data in and out from the networked systems in a real time [19, 3]. In other words, it is the high rate of data and information flowing into and out of interworked systems with real-time [17, 5].

Big velocity of big data is more important than big volume for many real-world applications [12]. Latency is another measure of velocity. Low latency is the requirement of modern businesses and individuals. For example, Turn (www.turn.com) is conducting its analytics in 10 milliseconds to place advertisements in online advertising platforms [13]. IBM's InfoSphere Streams has been successfully used for low-latency, real-time analytics [13].

3.3 Big Variety

Big variety means that big diversity or big different types of data sources with different structures from which it arrived, and the types of data available to everyone [19, 1, 20]. Big data can be classified into three types: structured, semi-structured, and unstructured at a higher level. The data stored in relational database systems like Oracle are structured. The data available on the Web are unstructured. 80% of the world's data is unstructured [1, 13]. The big variety exists in the data on the Web. Blogs and tweets on social media are not structured data, because they contain a large amount of slang words, with a mix of languages in a multiethnic, multi-language environment [13].

3.4 Big Veracity

Big veracity refers to the accuracy, truth and truthfulness of big data. Veracity was introduced by IBM researchers as the 4th V for characterizing big data [11]. The reality is that there exits big ambiguity, incompleteness, uncertainty of big data [11] [9]. This might be the reason why vagueness has been considered as one of ten challenges of big data [9]. Accuracy and reliability are less controllable for many forms of big data, for example, Twitter posts a number of tweets with hash tags, abbreviations, typos and colloquial speech. Big veracity is a big characteristics of big data, this is particularly true in big data analytics for business decision-making [20]. Therefore, in order to get big veracity, we have to use intelligent technologies to remove the ambiguous, incomplete, uncertain data.

Fuzzy logic and fuzzy sets have developed significant methods and techniques to address ambiguity and incompleteness of data and therefore they will play an important role in overcoming big ambiguity and incompleteness of big data [21].

3.5 Big Intelligence

Intelligence has been not only a lasting topic for computer science under the flagship of artificial intelligence (AI) [23], but also an exciting topic for industries, organizations and businesses under the flagship of business intelligence (BI) [21]. AI has facilitated the development of intelligent services, intelligent manufacturing, and intelligent systems [21]. BI has promoted the improvement of competitiveness of business performance, and supported management decision making of organizations and produced the billionaire level enterprises such as Google and Facebook [18].

Big intelligence refers to big data intelligence or big data-driven intelligence, which can be defined as a set of ideas, technologies, systems and tools that can imitate and augment the human intelligence related to big data management and processing [18]. For example, intelligent methods for searching big data, visualizing knowledge mined from big data belongs to big data intelligence [21].

Big intelligence will be developed as an important part of big data computing [6]. Global free WIFI [22] is a big intelligence, because it meets the big expectation from billions of people [18].

3.6 Big Analytics

Big analytics is a brief representation of big data analytics or big data based analytics [23] [18]. Big analytics can be defined as the process of collecting, organizing and analyzing big data to

discover and visualize patterns, knowledge, and intelligence as well as other information within the big data for supporting decision making [24]. The main components of big analytics include big descriptive analytics, big predictive analytics and big prescriptive analytics [18][6]. For example, big prescriptive analytics can be used to provide an optimal marketing strategy for an e-commerce company [18].

Analytics leaders are rapidly reshaping the nature of industry competition and consolidating big market, big value and big advantages in the age of big data and analytics [25]. For example, big analytics leaders such as Apple, Alphabet/Google, Amazon, Facebook, Alibaba and Tencent have become some of the most valuable companies in the world through integrating big data, analytics and artificial intelligence (AI) [25] [26].

3.7 Big Infrastructure

Infrastructure refers to structures, systems, and facilities serving a country, city, or area, including the services and facilities necessary for its economy to function [26]. Big infrastructure, abbreviated from big data infrastructure refers to all the structures, technologies, systems, platforms, and facilities serving the big data processing in a country, city or area. Currently, Apache Hadoop ecosystem has been considered as an important part of big infrastructure [1]. Big infrastructure is a decisive factor for the utility of big data with applications, reflecting the level of national big data research and development.

3.8 Big Service

Big services are big data driven services or big data based services. It can provide services to at least hundreds of millions of people. For example, big data infrastructure services, cloud services, mobile services, big analytics services [18], social networking services are big services.

Big services, the web of services, and the Internet of services (IoS) are interchangeably. The IoS is a big service covering all the services on the Internet based on big data. For example, online storage services are a kind of big services. Big services are an emerging frontier for innovations, competences, and improving business performance of governments, organizations and enterprises as well as individuals.

3.9 Big Value

Big value indicates the importance and context of the big data. It characterizes the big business value and potential of big data to transform an organization to have more competitiveness in the global platform [17]. Big data has extremely big value for increasing productivity, efficiency and revenues, lowering costs and reducing risk in businesses and management [3, 20] [16]. For example, big data and big data analytics have brought big value for Facebook, Google, Amazon and made them become the top companies in the world [27, 28].

Big value also implies that big data brings big social value. The big social value means that big data has been revolutionizing the society in terms of working, living and thinking [29].

3.10 Big Market

Big market refers to big data driven market. Big market includes market of big data technologies, systems, platforms, tools and services. According to IDC's research, the big data technology and services market is expected to grow at a five-year compound annual growth rate (CAGR) of more than 28% from US$260.3 million in 2014 to US$711.2 million in 2018 [30].

The big market attracts the CEOs of big companies to make big decisions for developing big data and related technologies. For example, Gartner predicts that 30% of new revenue growth from industry-specific solutions will include big data and AI technology by 2021 [4].

4 INTERRELATIONSHIPS AMONG 10 BIGS OF BIG DATA

The non-linear interrelationships among these 10 big characteristics of big data can be represented as a framework, illustrated in Figure 1. This framework consists of three levels: a fundamental level, technological level, and socio-economical level.

In what follows, we will examine each level of the proposed framework from a service-oriented perspective.

At the fundamental level, there are 4 Bigs: Big volume, big velocity, big variety, big veracity, they are four fundamental characteristics of big data.

The main service providers on this level include computing scientists, and cloud services providers including Amazon, Google, Facebook, and Tableau [6]. The main service requestors on this level include everyone who can access to the Internet. The main service brokers on this level include big consulting groups like McKinsey and Gartner as well as public media [18].

At the technological level, there are 3 Bigs: Big intelligence, big analytics, and big infrastructure. They are the three technological characteristics of big data. These 3 Bigs provide intelligent solutions and technologies to meet the challenges arising from the 4 Bigs of the fundamental level. The intelligent solutions and technologies include MapReduce NoSQL technology [7], MPP (Massively Parallel Processing), in memory database technologies [32, 33] and augmented analytics [6]. Apache Spark is a popular big data analytics platform for a number of enterprises [33, 34].

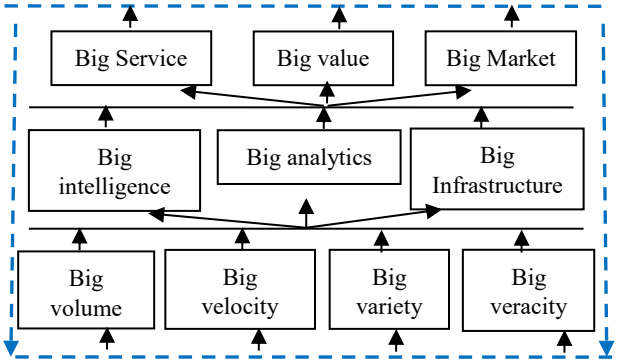

Figure 1. A unified framework of big data

The main service providers on this level include Google, Amazon, Tableau [33, 3] and other technology-driven companies, computing scientists and students. Big analytics service providers include developers, vendors, systems or software and other intermediaries that can provide big analytics services [24] [6]. For example, Amazon, Google and Microsoft, and Baidu are examples of big analytics service providers [24] [6].

The main service requestors on this level include everyone who can access the Internet. Big analytics service requestors include organizations, governments and all level business decision makers. More generally, big analytics service requestors include people who like to acquire information based on analytical reports provided by big data analytics service providers [35].

The main service brokers on this level are all the entities that facilitate the development of big intelligence, big analytics and

big infrastructure, which include popular presses, traditional media and social media, consulting companies, scholars and university students, and so on [35].

At the socio-economical level, there are 3 Bigs: Big service, big value, and big market. They are the three socioeconomic characteristics of big data. The dramatic development of big intelligence, big analytics and big infrastructure brings about big service, big value [36], and big market [37] [4] to the society. The main service providers on this level include big global industries such as manufacturing, healthcare, finance and insurance, social networking. The main service requestors on this level include everyone in the big data age. The main service brokers on this level include big consulting groups like Gartner and IDC and the big data intermediaries [29] [18].

The arrows with dash line represent that big service, big value and big market will bring about big impacts on the 4 big fundamental characteristics of big data at the bottom level. For example, it will increase the big volume of data from petabyte level to zettabyte level. It will improve the big velocity of big data in the Internet. It leads to bigger variety and veracity of big data. One the other side, the arrows with dash line and other arrows form a cycle from and to big volume, big velocity, big variety and big veracity via big service, big value and big market to expedite the research and development of big data.

5 DISCUSSION AND FUTURE DIRECTIONS

This section will focus on related work and discussion on characteristics of big data.

Oweis et al [38] discuss 3 Vs, 4 Vs (3 Vs and veracity) and 5 Vs (4 Vs and value) as five characteristics of big data. Borne [17] extends the 5 Vs to 10 Vs of big data and considers the 10 Vs as ten challenges of big data. Both of them have not examined the interrelationships among these mentioned Vs. This paper has proposed the 10 Bigs as ten big characteristics of big data and discussed their interrelationships from a service-oriented perspective. The 10 Bigs have not yet been wholly addressed in the literature.

This paper only focuses on the 10 Bigs of big data taking into account the limitation of space. If one likes to put more Bigs to characterize big data, then big opportunity, big challenge, and big impact are good choices for addition, because all these three have been closely associated with the research and development of big data as well as big data industry [9] [12].

Two most important future directions from this research are as follows. 1. We will use these ten big characteristics as the elements of big data to develop big data systems, intelligent analytics systems and then provide big data and analytics services to organizations and individuals. 2. We will use the elements of big data to examine the impacts of big data, big analytics, and big intelligence on business, management, marketing, industry and governance as well as society.

6 CONCLUSION

This paper revealed ten big characteristics of big data and explored their non-linear interrelationships through presenting a unified framework. The framework covers the 10 Bigs of big data and their non-linear interrelationships based on three levels: fundamental level, technological level, and socio-economic level. This paper examined each level of the proposed framework from a service-oriented perspective.

In the future work, we will delve into the service-oriented framework for big data through analyzing the 10 Bigs of big data and viability of the proposed framework. We will also explore the applications of the framework in cloud services, and the Internet of things through providing real-world cases in a big data world.

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