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Big Data 4.0: The Era of Big Intelligence

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ABSTRACT

Big data has had significant impacts on our lives, economies, academia and industries over the past decade. The current equations are: What is the future of big data? What era do we live in? This article addresses these questions by looking at meta as an operation and argues that we are living in the era of big intelligence through analyzing from meta (big data) to big intelligence. More specifically, this article will analyze big data from an evolutionary perspective. The article overviews data, information, knowledge, and intelligence (DIKI) and reveals their relationships. After analyzing meta as an operation, this article explores Meta (DIKE) and its relationship. It reveals 5 Bigs consisting of big data, big information, big knowledge, big intelligence and big analytics. Applying meta on 5 Bigs, this article infers that Big Data 4.0 = $meta^4$ (big data) = big intelligence. This article analyzes how intelligent big analytics support big intelligence. The proposed approach in this research might facilitate the research and development of big data, big data analytics, business intelligence, artificial intelligence, and data science.

Keywords: Big Data 4.0; Big analytics; Business intelligence; Artificial intelligence; Data science

1. Introduction

Big data has had significant impacts on our lives, economies, academia and industries over the past decade [1–4]. Big data has also been a key enabler in 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 is leading to big information although the information explosion was mentioned many years ago [7]. Big data also leads to big information, big knowledge, big intelligence and big wisdom that we are enjoying [8].

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In fact, the knowledge economy and knowledge industry were launched by many developed countries like Australia decades ago. They are still the national goals of many developing countries. Big intelligence is the result not only of market-oriented artificial intelligence (AI), big data-based AI, and business intelligence [9,10]. ChatGPT, driverless cars, TikTok, and artificial drones have made us in the era of big intelligence. Big wisdom might be the final goal for realizing human intelligence through big technologies, systems and tools for processing big data, big information and big knowledge.

However, what is the future of big data? What era do we live in? Some scholars consider that big data has entered another stage, that is, big data 3.0 [11]. Other companies consider that we are entering an era of big data 4.0 [12]. The current era of big data 3.0 began in 2010 with the rise of the smartphone, GPS sensors, cloud computing, and the Internet of Thing (IoT) [12]. Even so, the following fundamentals of big data, big knowledge, and big intelligence are still open for comprehending big data. For example,

- What are the relationships between big data, big knowledge, and big intelligence?
- How can we understand the relationships between big data and big data analytics?
- How can big data analytics support the era of big intelligence?

Further, no keywords on "big data 4.0" have been integrated into either the title or abstract in the published papers that are listed and indexed in Google Scholar. Therefore, this article will address these three issues using meta as an operation and prove that big data 4.0 is the big intelligence in the era we are living in. To address the first issue, this article, different from the existing literature on big data, proposes and looks at 10 Bigs rather than 3 Vs [13], 4 Vs [14] or 56 Vs [15] as the ten big characteristics of big data. These 10 Bigs consist of big volume, big velocity, big variety, big veracity, big technologies, big systems, big infrastructure, big service, big value, and big market. The article overviews data, information, knowledge, and intelligence (DIKI) and reveals their relationships. After analyzing meta as an operation, this article explores Meta (DIKI) and its relationship. It reveals 5 Bigs of DIKI consisting of big data, big information, big knowledge, big intelligence, and big analytics. Applying meta on 5 Bigs of DIKI, this article infers that Big Data 4.0 = meta^4 (big data) = big intelligence. This article analyzes how intelligent big analytics (not only data analytics) support big intelligence and then Big Data 4.0. ChatGPT 4.0, driverless cars, intelligent drones, intelligent big data analytics, and other AI products encompass the era of big data 4.0, which is an era of big intelligence.

The remainder of this article is organized as follows. Section 2 overviews the characteristics of big data from an evolutionary perspective, based on a framework for 10 Bigs of big data. Section 3 looks at data, information, knowledge, and intelligence (DIKI) and reveals their relationships. Section 4 analyzes meta as a mathematical operation and discusses meta (DIKI) with examples used in computer science, AI, and information systems. Section 5 examines 5 Bigs of DIKI and analytics. Section 6 applies meta on big data with power operations and infers that big data 4.0 = meta^4 (big data) = big intelligence; it also analyzes how intelligent big analytics support big intelligence. The final section ends this article with some concluding remarks and future work.

2. Big data: An evolutionary perspective

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

The characteristics of big data have been scattered in various publications. From an evolutionary perspective, Doug Laney of the META Group (now Gartner) used 3 Ds: data volume, data velocity, and data variety to represent the characteristics of data in e-commerce in 2001 [16]. Lately, these 3 Ds have been changed into 3 Vs (volume, velocity, and variety) which have been explained as three characteristics of big data [13,17]. Furthermore, these 3 Vs have been extended first to 4 Vs as four characteristics of big data by adding veracity [14,18], and then to 5 Vs as five characteristics of big data (volume, variety, velocity, veracity, value) [19], to 10 Vs by adding another 5 Vs: validity, variability, venue, vocabulary and vagueness [20] and finally to 56 Vs [15]. With the development of big data research, more Vs might be proposed to extend these 56 Vs. However, the research is a kind of linear thinking and reasoning, because, from 3V we can have 4V, and then, mathematically speaking, we can have infinite Vs (at least a big number) for understanding data rather than big data, because all the mentioned Vs are used to characterize data rather than big data.

The core of big data is "big". Then incorporating "big" with data becomes more important for business, industry, and government. It is necessary to characterize the "big" of the big data. This is the difference between what Sun et al. did [16] from others [15], as shown in **Figure 1**. In **Figure 1**, level 1 illustrates what most researchers have done as discussed above, whereas level 2 illustrates what Sun et al. delve into the 10 Bigs of big data.

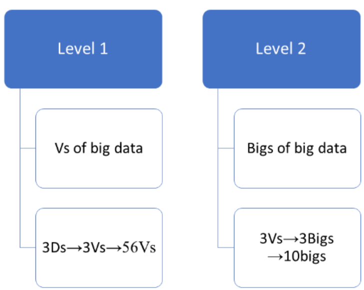

Figure 1. An evolutionary perspective to characteristics of big data.

This framework, illustrated in **Figure 2**, consists of three levels: a fundamental level, a technological level, and a socio-economical level, covering the 10 Bigs along with their interrelationships.

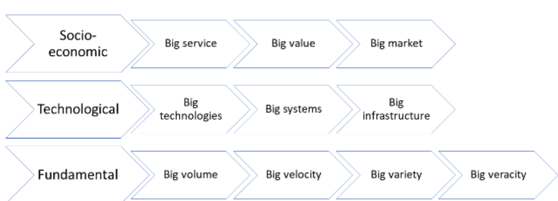

Figure 2. A framework for 10 Bigs of big data.

At the fundamental level, there are 4 Bigs: big volume, big velocity, big variety, and big veracity. There are four fundamental characteristics of big data from a data science viewpoint in specific and a computing viewpoint in general [21]. Integrating the definition of McKinsey on big data [22] and Gartner's definition of big data [5], this framework can define big data as a set of datasets, each of which satisfies that:

1) It has big volume, big velocity, big variety, and big veracity;

2) It is beyond the ability of typical ICT and digital systems or tools to capture, store, manage, and analyse;

3) It demands cost-effective, innovative technologies of data processing for enhanced insight and decision making.

Another 3 Bigs (i.e., big technologies, big systems, and big infrastructure) are technological characteristics of big data. Big technologies consist of ICT (information communications technology), digital technology, and computing technology. Big systems are made up of enterprise systems such as Oracle and Alibaba cloud (https://www.alibabacloud.com/). Big infrastructure is composed of SpaceX'starlink, GPS, and Baidu.

The remaining 3 Bigs (i.e., big service, big value, and big market) are socioeconomic characteristics of big data. The fundamental characteristics, technological characteristics, and socioeconomic characteristics of big data have either directly or indirectly significant implications for socioeconomic development. For example, according to the research by SiliconANGLE and Wikibon, the global big data market is projected to generate $103 billion in revenue by 2027 [3].

3. DIKI and its relationships

In the big data world, it seems that all digital things online are data, big data, but much of it is not really "data" outside the big data world [23]. Information, knowledge, and intelligence are more popular than data and big data in computer science, business and management, markets, even AI, and many other fields. This section will overview them and explore DIKI (data, information, knowledge, and intelligence) using an integrated framework and their impacts on industry, economy, and society. This research demonstrates that data are mainly for computers and computerized systems, while information, knowledge, and intelligence are all for both humans and computers. The research questions are:

1) Why Data ≠ information ≠ knowledge?

2) Why can data and information be used interchangeably?

3) Can data, information, knowledge, and intelligence be used interchangeably?

The remainder of this section is organized as follows: Subsections 1–4 explore DIKI and its relationships. Subsection 5 presents an integrated framework of DIKI.

3.1 Data

Data are streams of raw facts representing events occurring in organizations or the physical environment before they have been organized and arranged into a form that people can understand and use [10]. This means that data are raw facts. These facts represent events in organizations or the physical environment. These facts will be organized and arranged into a form for computerized systems to process. The form can be understood and used by people, machines, and computerized systems. Briefly speaking, data are streams of raw facts for computerized systems processing through organizing and arranging to become information that can be understood and used by people.

The example of data is that it consists of 0 and 1, which are the fundamentals of computer science and data science [24].

Data are "the facts and figures collected, analyzed, and summarized for presentation and interpretation" [25]. All the data collected in a particular research are referred to as the data set. Overall, data is all the input of computerized and digital systems [10,16]. For example, data is first as an input of database management systems [26].

3.2 Information

Information is defined in terms of data [27]. Information is the processed data, a set of data, with usefulness, content, relevance, purpose, and value [28,29]. For example, the manipulation of raw data for a company, as data processing, is to obtain more meaningful information on the trend for daily sales [29].

Information is data that has been processed, so that it is meaningful and useful to human beings for a purpose [10]. Two important points should be discussed from these definitions of data and information. First, generally, information is the processed data. More specifically, information is the data processed by ICT, that is, the input for ICT processing is data, and the output of the ICT processing is information. In relational databases, data processing consists of data definition and data manipulation. Data manipulation has 6 basic commands: SELECT, INSERT, UPDATE, DELETE, COMMIT, and ROLLBACK [26]. It should be noted that in databases, the processed data are still data, we do not consider the processed data as information [26].

Furthermore, different from data, information is visible in the majority of the cases. For example, we can see the picture on the Internet. We can read the story displayed on the screen of either laptop or smartphone. Therefore, we should use visibility as a feature for information rather than for data. Roughly speaking, information is visible, meaningful, and useful data that is easily understood by human beings.

3.3 Knowledge

knowledge is defined in terms of information and data [29]. Knowledge is processed, organized, or structured information with the insight of experts [10,30]. Knowledge is a central concept in intelligent systems and cognitive systems [9,31,32]. In computer science and information science, knowledge is usually defined as the beliefs, objects, concepts, and relationships that are assumed to exist in some areas of interest [29].

Knowledge is the processed information [33]. Because information is processed data, therefore, knowledge also includes data. In other words, knowledge is the processed data and/or information.

3.4 Intelligence

Intelligence is the ability to "learn, think, and understand" [34]. These three abilities are the core of basic human intelligence. Machine learning, including deep learning, aims to automate the ability of human learning through "improving the performance on future tasks after making observations about the world" to pursue learning intelligence [9]. However, only learning, thinking, and understanding are not enough in the digital society, because a human is also a social animal, connecting (or connection) should be another component of human intelligence. Advanced communication technologies and tools such as email, WeChat, TikTok, Twitter, and information sharing on the Web aim to develop the skill of connecting as a form of intelligence, connecting intelligence. For example, the current advanced ICT technology and systems have brought about social networking services such as Meta (formerly Facebook), LinkedIn, and WeChat [10]. All these have developed the skill of connecting as a part of intelligence (e.g., human intelligence). Connectivity is ubiquitous in the digital world. Therefore, the dimension of intelligence (e.g., human intelligence) consists of learning, thinking, understanding, and connecting.

The nomenclature "intelligence" means intelligence in artificial intelligence (AI), machine intelligence, cognitive intelligence, and human intelligence [31,35]. Intelligence also consists of data intelligence [32], information intelligence, knowledge intelligence, and experience intelligence [32].

3.5 An integrated framework of DIKI

DIKI is an abbreviated form for data, information, knowledge, and intelligence, as illustrated in **Figure 3**, which is an integrated framework for the DIKI Pyramid. In this DIKI Pyramid, we have the following inclusion relationships for DIKI based on the above analysis and a set viewpoint:

$$\text{data} \subset \text{information} \subset \text{knowledge} \subset \text{intelligence} \quad (1)$$

We will prove Equation (1) in Section 4.

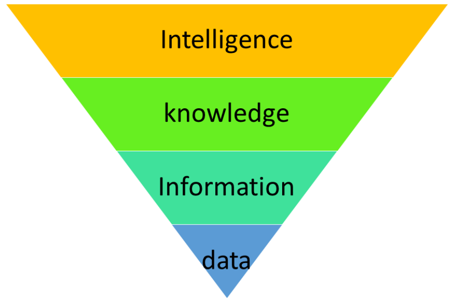

Figure 3. DIKI pyramid: An integrated framework.

Data, information, knowledge, and intelligence or DIKI have played a vital role in computing and ICT in the past few decades and led to data computing, information computing, knowledge computing, and intelligence computing (for short, DIKI computing) [24,36].

$$\begin{aligned}\text{DIKI computing} = {} & \text{data computing} \\ & + \text{information computing} \\ & + \text{knowledge computing} \\ & + \text{intelligence computing}\end{aligned} \quad (2)$$

For example, knowledge computing encompasses knowledge science, engineering, technology, systems, management, and so on [36,37]. That is,

$$\begin{aligned}\text{knowledge computing} = {} & \text{knowledge science} \\ & + \text{knowledge engineering} \\ & + \text{knowledge technology} \\ & + \text{knowledge system} \\ & + \text{knowledge management}\end{aligned} \quad (3)$$

Knowledge engineering aims to use knowledge science and knowledge technology to develop knowledge systems and knowledge management to create knowledge and knowledge services and applications.

DIKI computing covers almost all the aspects of current ICT and digital technology with applications. Therefore, data, information, knowledge, and intelligence are elements of the digital age. All sciences in the digital age are like a tree of which four elements, namely, data, information, knowledge, and intelligence are the roots, mathematics and computing the trunk, and all the other sciences the branches that grow out of this trunk, inspired by the work of Descartes [38], Sun and Stranieri [8].

4. Meta (DIKI)

Based on the Merriam-Webster dictionary (https://www.merriam-webster.com/dictionary/meta), meta can be defined as:

1) a): Occurring later than or in succession to; b): Situated behind or beyond; c): Later or more highly organized or specialized form of;

2) Change: transformation;

3) [Metaphysics]: More comprehensive: transcending.

Sense 1 covers "later, after or beyond or more organized and specialized". Sense 2 means change and transformation. Sense 3 means more comprehensive and transcending.

We will use these three senses of meta hereafter.

Meta originally was introduced by the Greek philosopher Aristotle (384–322 B.C.) in his metaphysics (related to sense 3) [39] more than 2000 years ago. Metaphysics is one of the greatest philosophical works that has been influencing science and technology as well as philosophy worldwide since then. It is metaphysics that has led to our rationality and systematic thinking in research and development since then [39].

Meta in computing might be influenced by metamathematics, which mainly follow senses 2 and 3. The latter is the study of mathematics itself using mathematical methods. Metamathematics includes many metatheories and metalogics as well as mathematical techniques for investigating a great number of foundation problems for mathematics and logic [40]. A metatheory is a mathematical theory about other mathematical theories. Following metatheory, metadata in database systems is data about data [26]. Therefore, metaintelligence is originally from metaphysics and metamathematics as well as metatheories. In computing, metamathematics and metalogic are theoretical and methodological foundations of metaintelligence. Metalanguage as language about languages, metalevel, metalevel state space, metareasoning, and metarule have been used in artificial intelligence [9]. Meta-Dendral as a metasystem has been used to generate rules useful for analytical chemistry [9].

As mentioned above, meta can be defined as a change or transformation. Then meta can be defined as a mathematical operation M, that is,

$$M: U \rightarrow U$$

where U is the universe of discourse. For example, M(data) = metadata. M(knowledge)= metaknowledge, M(analysis) = metaanalysis. M(approach) = metaapproach.

It is not enough for meta to be only an operation. The parent company of Facebook, now Meta, certainly does not consider meta as an operation. If so, then the business value of Meta (formerly Facebook) will become very tiny. In fact, meta should be considered an algebra, an algebraic system from a mathematical perspective [37]. That is, meta is an algebra consisting of a non-empty set and a set of meta operations. For example, in the competitive data world [41], a non-empty set is the big dataset. The meta has an operation set consisting of meta operations that transform big data into big knowledge. For example, meta operations at least consist of data mining and data warehousing [42]. In such a way, data mining and data warehousing are the realization of mathematical meta operations.

Furthermore, not only data mining and data warehousing, expert systems and knowledge base systems are the realization of mathematical operations, because expert systems and knowledge base systems are the realization of mathematical logic such as propositional logic and predicate logic [9], and they are also the realization of algebraic systems. The equivalence between mathematical logic, algebra, expert systems, and knowledge-base systems is the essence behind the evolution of expert systems and knowledge-base systems [43]. Another essence behind expert systems, knowledge base systems, information systems, and intelligent systems is meta as an operation and as an algebra, although the scholars in these areas might not know meta in their research and development.

DIKI is independent, because each DIKI is an element for research in computer science, AI, and data science in the digital age. We will use meta to replace the above M to examine meta (DIKI) hereafter.

$$\text{Meta (data)} = \text{information} \tag{4}$$

Information is data about data [26].

Example 1. The input of information systems is data, whereas the output of information systems is information [10]. This implies that information systems realize the meta operation from transforming data to information.

$$\text{Meta}^2\text{ (data)} = \text{meta (information)} = \text{knowledge} \quad (5)$$

Knowledge is information about information [41].

Example 2. Data mining is about the knowledge discovery from a large database [44]. Therefore, the input of the data mining system is data, whereas the output of the data mining system is knowledge. This implies that the data mining system realizes the meta operation from transforming information to knowledge.

$$\begin{aligned}\text{Meta}^3\text{ (data)} &= \text{meta}^2\text{ (information)}\\ &= \text{meta (knowledge)}\\ &= \text{intelligence}\end{aligned} \quad (6)$$

Intelligence is knowledge about knowledge [41].

Example 3. An intelligent system is based on intelligent techniques that capture individual and collective knowledge, discover patterns and behaviors in large quantities of data, and generate solutions to problems that are too large and complex for human beings to solve on their own [10]. Therefore, the input of the intelligent system is knowledge, whereas the output of the intelligent system is intelligence. This implies that an intelligent system realizes the meta operation from transforming knowledge to intelligence.

If O_d, O_i, O_k, O_I are identity operations in the universe of data, information, knowledge, and intelligence, we briefly have that:

1) $O_d(Data) = Information$,
2) $O_i(Information) = Knowledge$,
3) $O_k(Knowledge)$ = intelligence,

$$\begin{aligned}OI\ (Data) &= OI\text{ (information)}\\ &= OI\text{ (knowledge)}\\ &= OI\text{ (intelligence)}\end{aligned} \quad (7)$$

Therefore, we infer Equation (1), that is, data $\subset$ information $\subset$ knowledge $\subset$ Intelligence. We also answer why data and information can be used interchangeably. In fact, Equation (7) implies that data, information, knowledge, and intelligence have been used interchangeably from a mathematical operation viewpoint, at least identity operation plays an important role in this pyramid (see **Figure 3**). This is also the reason why many people have flattened them together as data in the data world although it is necessary to explore each of them in more depth.

5. 5 Bigs of DIKI and analytics

This section proposes and examines 5 Bigs of DIKI and analytics and their relationships.

5.1 Big data

McKinsey defines big data as "the datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze" [22]. This definition makes McKinsey one of the most important players ushering big data into the frontier for innovation, competition, and productivity. Gartner as another global consulting company 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 academic communities for research and development of big data as computing, science, and technology.

At least in the past decade, big data and its emerging technologies including big data analytics 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 [6,45–47].

5.2 Big information

Big data has certainly ushered in the coming of big information. The dramatic development of the Internet and WWW since the middle of the 1990s has made huge amounts of information available to everyone in the world. The significant development of social media or social networking services such as Meta, Twitter, QQ and WeChat have produced not only big data but also big information, because everyone has been contributing to this big data and big information through online shopping, email communication, online communication, and social networking services, and etc. In developed countries, everyone has been working online for about a few hours on the Web using the Internet. they also contribute data and information to the digital world, just as everyone consumes electricity.

5.3 Big knowledge

Big data has also led to big knowledge that we are enjoying. As well known, knowledge is power, knowledge can change a person's destiny; knowledge can also change the destiny of a country. Knowledge can change one country from a developing country into a developed one. Such knowledge is big knowledge! Many countries (including Australia) have been working hard to develop knowledge economies and knowledge societies. China is no exception. The Chinese dream lies in making China develop into a highly developed knowledge economy and knowledge society. Thus, mining big data for big knowledge is an important basis for realizing the Chinese dream of rejuvenation. Mining big data for big knowledge is also an important basis for keeping the USA as a continuous superpower in the world.

In computer science, discovering knowledge from a database (KDD), coined by Gregory Piatetsky-Shapiro in 1989, is the main task of knowledge discovery and data mining (EMC, 2015) [44]. The research and development of KDD and data mining have also been for over 40 years, where Michael Lovell coined this term in 1983 [48]. Now the combination of KDD and data mining with big data aims to promote further development of mining big data for big knowledge.

5.4 Big intelligence

Intelligence has been not only a lasting topic for computer science under the flagship of artificial intelligence (AI) and intelligence computing, but also an exciting topic for industries, organizations, and businesses under the flagship of business intelligence (BI) [6,10]. AI has facilitated the development of intelligent services, intelligent manufacturing, and intelligent systems [9,47]. BI has promoted the improvement of competitiveness of business performance, supported management decision making of organisations and produced the billionaire level enterprises such as Google and Meta [29].

Big data intelligence (BDI) is a kind of intelligence-driven by big data [16]. In the big data world, big intelligence particularly refers to big data intelligence. Big data intelligence is big data-driven intelligence, which can be defined as a set of ideas, technologies, systems, and tools that can imitate and augment human intelligence related to big data management and processing, like business intelligence [16]. For example, intelligent methods for searching big data, and visualizing knowledge mined from big data belong to big data intelligence.

Big intelligence has drawn increasing attention with the development of BI, big data analytics, and big data computing. Just as intelligence is a part of computing, big intelligence will be developed as an important part of big data computing [6,19]. Starlink satellites are also a big intelligence, because they meet the big expectation from billions of people to receive Wi-Fi communications [16].

Discovering intelligence from big data is the main task of data-based artificial intelligence [32], and it is also an important task and direction of market-based AI. This can be called data-intelligence. The advances of driverless cars, drones, and ChatGPT are examples of this trend. The perseverance of human beings in liberating their intelligence is an important basis for the development of mining big data for big intelligence. No one likes to be stupid. Everyone wants to be smart, intelligent, and more intelligent beyond others including intelligent machines, AI machines and systems. Therefore, China and the USA have promulgated national plans for the development of artificial intelligence. Research and development of smart or smart cities, smart societies and smart countries have become an important development direction. Mining big data for big intelligence is not only important for China's future. It is also the direction of the efforts of all other countries in the world. In the coming few decades, more and more countries and individuals will struggle for and benefit from mining big data for big intelligence.

As well known, big data is significant for innovation, competition, and productivity in the digital age [22,49], then big information, big knowledge, and big intelligence are also significant for effective management, decision making and innovation for the development of the economy, society, and even countries, because many governments and organizations have carried out a number of initiatives to develop big intelligence industry, knowledge economy (e.g. Australia) and wisdom cities (e.g. China).

5.5 Big analytics

Big analytics is an emerging science and technology involving multidisciplinary state-of-art information and communication technology (ICT), mathematics, operations research (OR), machine learning (ML), data sciences, and decision sciences [8]. Augmented analytics platforms as an example of big analytics represent the mainstream market for data and analytics leaders in the areas of BI, data science, and machine learning [50].

In the world of big data, big analytics is a brief representation of big data analytics or big data-based analytics or big data-driven analytics [21,51]. However, big data analytics is not unique to big analytics. In fact, big analytics encompasses big data analytics, big information analytics, big knowledge analytics and big intelligence analytics. Therefore, big analytics can be defined as the process of collecting, organizing, and analyzing big data, big information, big knowledge, and big intelligence to discover and visualize patterns, knowledge, insights, and intelligence within them for supporting decision making.

The rest of this section will look at the analytics from a most general viewpoint [8,47].

Data analytics can be defined as the "art of examining, summarizing, and drawing conclusions from data" [52]. Let x be a variable, then, this definition of data analytics can be extended below [8].

x analytics can be defined as the "art of examining, summarizing, and drawing conclusions from x."

When x is information, knowledge, and intelligence respectively, we have information analytics, knowledge analytics, and intelligence analytics, at least from a definition level. For example, knowledge analytics can be defined as the "art of examining, summarizing, and drawing conclusions from knowledge."

Data analytics can also be defined as a method that "uses data to learn, describe, and predict something" [33]. Let y be variable, this definition of analytics can be extended below:

y analytics can also be defined as a method that "uses y to learn, describe, and predict something"

When y is information, knowledge, and intelligence respectively, we have information analytics, knowledge analytics, and intelligence analytics. For example, knowledge analytics can be defined as a method that "uses y to learn, describe, and predict something".

Then we have:

x analytics can be defined as the art of examining, summarizing, and drawing conclusions from x to learn, describe and predict something.

x is an element of {data, information, knowledge, intelligence}. We have data analytics, information analytics, knowledge analytics, and intelligence analytics. For example, intelligence analytics can be defined as the art of examining, summarizing, and drawing conclusions from x to learn, describe and predict something.

Therefore, data, information, knowledge, and intelligence can be considered as input for an analytics system for processing. The processing of this analytics system is to examine, summarize, and draw conclusions from x. The goal of this analytics is to learn, describe, and predict something [8]. The something here is patterns, associations, knowledge, insights, and intelligence.

The above discussion demonstrates that data analytics is not all forms of analytics. Information analytics, knowledge analytics, and intelligence analytics are extended forms of data analytics. In such a way, data analytics, information analytics, knowledge analytics, and intelligence analytics (for short, DIKI analytics) can be considered as the basic form of analytics, taking into account DIKI [36,37]. Briefly,

$$\begin{aligned}\text{Analytics} = &\ \text{data analytics}\\ &+ \text{information analytics}\\ &+ \text{knowledge analytics}\\ &+ \text{intelligence analytics}\end{aligned} \tag{8}$$

In other words, analytics consists of data analytics, information analytics, knowledge analytics and intelligence analytics, at a fundamental level.

Google Web and Google Scholar search and summarize their popularity for each of analytics on data, information, knowledge, and intelligence. This is a kind of analytics on data, information, knowledge and intelligence (retrieved on October 28, 2023).

From **Table 1**, Google Scholar implies that data analytics and information analytics are similar in academia, while Google Web means that information analytics plays a more vital role than data analytics in academia and industry although data analytics are very popular in the big data and BI world [8,53]. Knowledge analytics and intelligence analytics have also played an important role in academia and industry although they are not popular in the BI world. This implies that not only data analytics but also information analytics, knowledge analytics, and intelligence analytics (DIKI analytics) have played a vital role in computer science, AI, data science, business and management.

Table 1. Data analytics, information analytics, knowledge analytics, and intelligence analytics.

Analytics	Google Web	Google Scholar
Data analytics	1,970,000,000	4,390,000
Information analytics	2,630,000,000	4,560,000
Knowledge analytics	894,000,000	3,170,000
Intelligence analytics	823,000	5,050

At a higher level, analytics can be a system of integrating a few analytics at the fundamental level. If we consider data analytics, information analytics, knowledge analytics, and intelligence analytics as the atomic level, then we have three levels of integrated analytics. The top (4th) level of analytics is the analytics integrating data analytics, information analytics, knowledge analytics and intelligence analytics. From a Boolean structure viewpoint [54,55], there are 16 (2^4) different kinds of analytics based on Equation (8).

Therefore, big information analytics, big knowledge analytics, and big intelligence analytics would have played the same significant role as big data analytics in the digital age, although currently some academia, industries, and governments have technically ignored them. Applying big as an operation [35] to both sides of Equation (8), we have [8]:

$$\begin{aligned}\text{Big analytics} = &\ \text{big data analytics}\\ &+ \text{big information analytics}\\ &+ \text{big knowledge analytics}\\ &+ \text{big intelligence analytics}\end{aligned} \tag{9}$$

Equation (9) has extended the result on big analytics used to be a representation of big data analytics [16]. Applying intelligent as another operation to (9), we have [47]:

$$\begin{aligned}\text{Intelligent big analytics} = &\ \text{intelligent big data analytics}\\ &+ \text{intelligent big information analytics}\\ &+ \text{intelligent big knowledge analytics}\\ &+ \text{intelligent big intelligence analytics}\end{aligned} \tag{10}$$

So far, we have proved that analytics has experienced five stages from a computer science viewpoint, that is, analytics, data analytics, big data analytics, big analytics, and intelligent big analytics. All these form an analytics computing [36], that is:

$$\begin{aligned}\text{Analytics computing} = &\ \text{analytics science}\\ &+ \text{analytics engineering}\\ &+ \text{analytics technology}\\ &+ \text{analytics systems}\\ &+ \text{analytics management}\end{aligned} \tag{11}$$

Big data 4.0 will be supported not only by AI and BI but also by intelligent big analytics and analytics computing as mentioned in the following section.

6. Big Data 4.0: The era of big intelligence we are living in

Big data had a revolution that would transform and manage how we live, work, and think a decade ago [13,56]. We were in the trinity of big data, analytics, and AI [22,57]. What is the future of big data? What era will we live in? This section argues that big data 4.0 = meta^4 (big data) is the era of big intelligence we are living in, through exploring from big data 1.0 to big data 4.0 using meta as an operation.

6.1 Big Data 1.0 = meta0 (big data)

Big data 1.0 = meta^0 (big data) is the next frontier for innovation, competition, and productivity since 2011 [22]. Big data and big data analytics have become a booming area for research and development in the USA and other countries that launched national strategies to develop big data and big data technology [16].

6.2 Big Data 2.0 = meta (big data)

Big data 2.0 = meta (big data) = big information, implying that we are in the era of big information. Big information can be considered at the same time as big data 1.0, because data ⊏ information, is from a set viewpoint. Many scholars and business people have used big data and big information interchangeably. In fact, information exploration was more popular than big data a few decades ago [7]. Information computing consisting of Information science, engineering, technology, systems, industry, management and service has still become an important field in academia and industry. For example, information technology and information systems are disciplines offered for postgraduate and postgraduate degree programs by many universities. However, most researchers and business people have flattened big information with big data. For example, many public media including books have intentionally or technologically flattened big information with big data [42,46]. Data service and information service have been explored in an integrated way [58]. Therefore, this research also considers big information as big data.

6.3 Big Data 3.0 = big knowledge

Meta^3 (big data) = meta^2 (big information) = meta (big knowledge). Data ⊏ information ⊏ knowledge implies that we are also in the era of big knowledge. In fact, the knowledge economy and knowledge society used to be launched by many countries like Australia by the end of the last century. To develop a knowledge economy and knowledge society is still a dream of many developing countries. The era of big data has surpassed the era of big knowledge at the moment, although big knowledge should be becoming more important for the time being. We still believe that big knowledge can be the next step of big data in the time to come.

6.4 Big Data 4.0 = big intelligence

Big data 4.0 = meta^4 (big data) = meta (big knowledge) = big intelligence, and big data ⊏ big information ⊏ big knowledge ⊏ big intelligence implies that we are in the era of big intelligence.

Big intelligence encompasses not only AI, but also big data intelligence, big information intelligence, big knowledge intelligence, big data analytics intelligence, big information analytics intelligence, and big knowledge analytics intelligence. It also includes business intelligence (BI), market intelligence, organizational intelligence, supply chain intelligence, customer intelligence, and more [42,46]. All these can be considered as the era of big intelligence, because only AI and BI are not enough. ChatGPT 4.0, driverless cars, intelligent drones, intelligent big data analytics and other AI products encompass the era of big data 4.0; that is an era of big intelligence. We can find that all are big intelligence products and services around us: intelligent washing machines, cleaners, smart TVs, smartphones, smart earphones, intelligent VR, and intelligent IoT (the Internet of Things). We are immersed in the era of big intelligence. Therefore, we have entered the era of big intelligence, from big data 1.0 to big data 4.0.

Big intelligence has been supported by intelligent computing, which is formed as intelligent computing = intelligent science + intelligent engineering + intelligent technology + intelligent system + intelligent management.

Intelligent business analytics is an emerging paradigm in the age of big data, intelligent big analytics (see Section 5), AI, and Intelligent computing [8]. Intelligent business analytics is intelligence that integrates AI, BI, business analytics, intelligent big analytics, data, information, knowledge, and intelligence using advanced ICT computing, digital technology, and DIKI computing to provide smart services for improving business, management, and governance to create big intelligence to revolutionize our work, life, business, marketing, management, and organization as well as healthcare, finance, e-commerce, and web services in the setting of cloud computing, the Internet of Everything, and social networking computing [10].

More specifically, intelligent business analytics is science and technology about collecting, organizing, and analyzing big data, big information, big knowledge, and big intelligence to discover and visualize patterns, knowledge, insights, and intelligence within the big data, information, knowledge, and intelligence based on big business analytics, AI, and intelligent systems [8]. Intelligent business analytics at least includes intelligent data analytics, intelligent information analytics, intelligent knowledge analytics, and intelligent intelligence analytics for business and business decision making, all of which are underpinned by intelligent statistical modeling, machine learning, intelligent visualization, and intelligent optimization. Intelligent data analytics further includes big data, intelligent big data analytics, intelligent data analysis, intelligent data warehousing, intelligent data mining, and intelligent data visualization. Intelligent information analytics at least includes big information, intelligent information analysis, intelligent information warehousing, intelligent information retrieval, and intelligent information visualization.

7. Conclusions

The objective of this research is to address two significant questions: what is the future of big data? What era do we live in? This article addresses these two questions by looking at meta as an operation and argues that we are living in the era of big intelligence through analyzing from meta (big data) to big intelligence, using a power operation. The three main contributions of this research consist of 1) It overviewed data, information, knowledge and intelligence (DIKI) using a DIKI Pyramid. 2) It analyzed meta (DIKI) and revealed 5 Bigs of DIKI consisting of big data, big information, big knowledge, big intelligence and big analytics. 3) Applying meta on 5 Bigs of DIKI, this research inferred that big data 4.0 = $meta^4$ (big data) = big intelligence, where we are living in, supported by big data, big information, big knowledge, intelligent big analytics and intelligent business analytics.

In future work, as an extension of future research directions and our research of this article, we will delve into real world cases such as cloud computing, IoT including the Internet of People (IoP) and the Internet of Services (IoS), and ChatGPT to further verify big intelligence where we are living in. We will also look at the relationship between big data 4.0 and Industry 4.0.

Conflict of Interest

There is no conflict of interest.

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