Journal of Business Data Science Research

Big Data Analytics and Cognitive Computing: A Review Study

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ABSTRACT

With the development of the Internet of Things and Artificial Intelligence algorithms, various human-centered smart systems are proposed to provide higher quality services such as smart healthcare, emotional interaction, and automated driving. Cognitive computing is an important technology for the development of these systems according to big data analysis. Analyzing big data by humans is a long process and cognitive computing can be used to process these large volumes of data. Cognitive computing is the concept of observation, interpretation, evaluation, and decision that are mapped to five features of big data that is volume, variety, veracity, velocity, and value. However, the perspectives expressed on these features are yet to be widely explored in the existing literature. The aim of this manuscript is to review the links between big data and cognitive computing in past, present, and future studies. Surveys show that the major emphasis is the creation of value by the process of data to information to knowledge to wisdom. Moreover, we present a conceptual model for linking cognitive computing features using the benefits of big data that can help to better understand the complexity of data deluge.

KEWWORDS: Big Data Analysis, Cognitive Computing, Artificial Intelligence, Human-Centered Smart Systems, Knowledge Extraction.

ORGINAL ARTICLE

Received 26 September 2020
Accepted 7 March 2021

CITATION

Sechin Matoori, S., Nourafza, N. (2021). Big Data Analytics and Cognitive Computing: A Review Study. Journal of Business Data Science Research, 1(1), 23-32.

1. Introduction

The number of machines and the connections between them is constantly increasing, and this had led to an explosion of data large volumes (Gupta et al., 2018). This data is known as big data and is continuously generated (Kreps & Kimppa, 2015). In the Wamba et al. (2015) research, different definitions of big data concepts and their comparison are presented. Big data analysis is important because it promotes firms and corporations in marketing superiority over their competitors (Bumblauskas et al., 2017; Jimenez-Marquez et al., 2019; ur Rehman et al., 2016). The urgent need to reduce concerns about data interpretation has led to the emergence of big data analytics (Jimenez-Marquez et al., 2019; ur Rehman et al., 2016). Data analysis by a human is a time-consuming activity that can use advanced cognitive systems to process this large volume of data and solve this problem (Chen et al., 2018). Brian Krzanich (2016), the Intel CEO, states that "artificial intelligence is based on the ability of machines to sense, reason, act and adapt based on learned experience". The systems based on artificial intelligence, work according to a set of programmed rules and parameters. This is while systems based on cognitive computing works by interpolating commands and inference and then suggesting possible solutions.

Cognitive computing is one of the new domains in technology and is known as an ideal of artificial intelligence. Generally, this pattern is the integration of artificial intelligence and cognitive sciences (Graessley et al., 2019). Cognitive computing helps humans make decisions, whereas systems based on artificial intelligence work on the basis that these machines are able to make better decisions than humans. Simulation of human thought process in cognitive

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• http://www.jbdsr.com/article_680446.html

computing is emphasized as a computerized model and this field has been widely considered by the academic and scientific community in recent years (Coccoli et al., 2017). Cognitive computing applications evolved from simple calculators in the early 1900s to modern programmable devices (Sangaiah et al., 2020). Cognitive computing is a type of computation based on cognition of human brain processes so that they have the ability to learn, pattern recognition, language understanding, combine, programming, and work on large volumes of data with different sources (Zhang et al., 2018). Most importantly, cognitive computers are able to adapt to changing needs or information and use the context for learning. Theoretically, there is never a need to intervene in the cognitive system, because these systems are able to change parameters according to user needs (Aggarwal et al., 2020).

Many studies with the aim of developing big data have collected various sources from academic domains (Raghupathi & Raghupathi, 2014). Cognitive computing can be used to reduce shortcomings when faced with big data analytics (Coccoli et al., 2020). Cognitive computing uses a computerized model to capture the human thought process as well as the mistakes that the system commits each time (Gupta et al., 2018). This learning technique can have great benefit on the way of analyzing large volumes of data for better decision making (Coccoli et al., 2017; Sangaiah et al., 2020). Implementing cognitive computing to analyze big data is the beginning of progress, so studying and understanding this issue is very important.

The organization of this paper is as follows; Section 2 provides a classification of cognitive computing. The links between big data and cognitive computing are discussed in Section 3. The literature review is given in Section 4. Section 5 focuses on analysis and discussion. Finally, in Section 6 conclusions and future research are presented.

2. The Cognitive Computing

Generally, computing can be classified into three periods of tabulating (the 1900s -1940s), programming (1950s - present), and cognitive (2011s - present). In the tabulating period, computing devices were in the form of calculators with single-purpose mechanical systems. These systems were limited to academia and large companies (Kelly, 2015). The programming period began with the invention of the microprocessor and then bulky computers. The capacity and speed of computers continued at a rapid pace for six decades, where this development led to the production of compact computers and smartphones (Kelly, 2015). Due to the increasing volume of data in computer systems, the need to help humans in decision-making was felt (Changchit & Chuchuen, 2018). The cognitive period gave rise to systems that had the ability to turn raw data into useful knowledge (Kelly, 2015).

The origins of big data can be traced back to the mid-1990s when John Mashey was involved in the Silicon Graphics project for big data processing (Diebold et al., 2012). Eric Schmidt (Google CEO) commented that the volume of data generated in two days is equal to the total volume of data from the dawn of civilization to the 2003s (Schmidt, 2010). The volume of data generated is increasing exponentially, and this challenge has led to the rise of big data analytics. In addition, with the widespread connection of devices via the Internet of Things (IoT), the problem of data volume has become a concern.

In 2011, IBM Watson used a supercomputer (with more than 90 servers) to replicate the human path. Watson is used in the healthcare industry as a well-known assistant to assist physicians (Khalil et al., 2020). Cognitive computing systems have the ability to process human thinking and use their mistakes to learn. This is evident in IBM Watson's recommendations, where the healthcare industry has evolved to help physicians make better decisions. The department of cognitive computing at the University of Illinois is one of the active groups in the field of cognitive computing (Daniel et al., 2017). This group's research focuses on the computing basis of smart behavior. The demand for cognitive systems is so high, where global revenue from these systems is expected to rise to USD 47 billion by the 2020s (Wang & Chiu, 2020). In International Data Corporation (IDCs), North America (United States and Canada) has the constitute the biggest share with 78%, and Europe, the Middle East, and Africa (EMEA) is the second biggest trading region in the world (Wang & Chiu, 2020).

Cognitive computing approaches typically work on vectors with objective data, where machine learning techniques learn on these data. However, big data analysis can provide information visualization in unstructured data (Ragini et al., 2018). Integrating these approaches first requires converting unstructured data into objective or quantitative parameters that are derived as vectors. These vectors are then used with multiple instances to train an algorithm in cognitive computing. This process can make it possible to predict the hidden content on test instances. In order to derive the benefits of cognitive systems, a large volume of data must be used. Therefore, researchers of big data and cognitive computing will strive to achieve this objective.

3. Links between Big Data and Cognitive Computing

Various human-centered smart systems have been proposed with the development of the internet of things and artificial intelligence algorithms. These systems provide services such as intelligent healthcare, emotional interaction and automated driving with higher quality. Cognitive computing through big data analysis is a necessary technology for the development of these systems. Therefore, in this section, we highlight the applications and challenges that make the link between big data and cognitive computing.

3.1. The Big Data Position in the Cognitive Computing Evolution

The linguistics rapid advancement, information theory and data science as well as the popularity of computer technology, has led to an impressive cognitive revolution. Here, cognitive science has emerged as an interdisciplinary subject, where it examines the information circulation in the human brain (Chen et al., 2018). Therefore, the cognitive sciences go beyond topics such as linguistics, psychology, artificial intelligence, philosophy, neuroscience, and anthropology.

Figure 1 shows the evolution of cognitive computing. Cognitive computing often focuses on advances in processing techniques and develops algorithms using cognitive computing theories. Finally, these techniques enable machines to achieve cognitive intelligence, such as the human brain. The purpose of human brain-like computations is to enable computers to understand the real world like humans. In addition, cognitive technologies can be combined with information communication systems to create new cognitive radio networks. For example, (Tian et al., 2016) introduced the first application of multiple-input-multiple-output (MIMO) based on cognitive radio to improve the performance of vehicular networks.

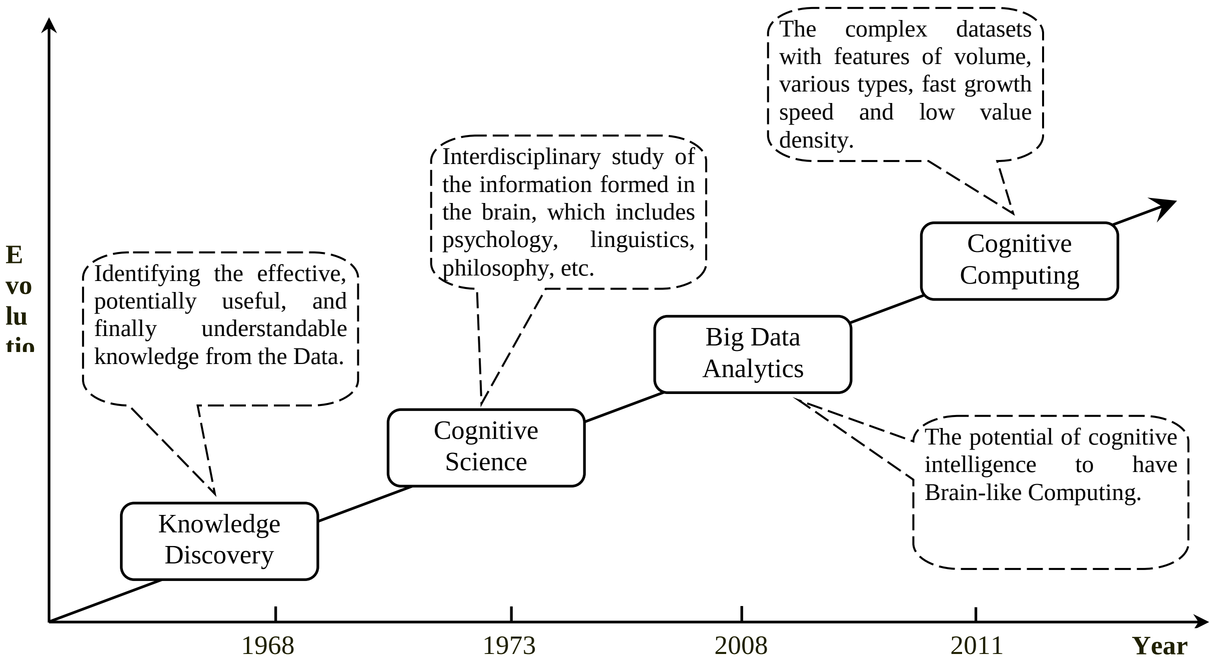

Figure 1. The cognitive computing evolution (Tian et al., 2016)

3.2. Cognitive Computing Architecture Based on Big Data

The architecture of the cognitive computing system includes network technologies (for example, internet of things), analytics (for example, deep learning and reinforcement learning), and cloud computing (for example, task scheduling systems) (Chen et al., 2018). Figure 2 shows the architecture of the cognitive computing system. The major applications of the cognitive computing system include health monitoring, cognitive health care, smart city, intelligent transportation system and so on. Therefore, every layer in system architecture faces technological challenges and system needs. The internet of things can collect variety and valuable information about objects from the real world. This technology can process relevant information using intelligent computing techniques (for example, cloud computing, machine learning, and data mining) to make decisions. Therefore, the development of the internet of things will lead to greater understanding and transmission of data, where it can provide an important source of information for the realization of cognitive computing.

Before the age of big data, cognitive computing has not been seriously studied and discussed (Chen et al., 2016). But now, the rise of artificial intelligence and support for cloud computing resources has provided benefits for advancing cognitive computing. The internet of things and cloud computing can present software and hardware-based cognitive computing, while big data analytics provides ways to explore novel opportunities for data. One of the links between big data analysis and cognitive computing is human big data thinking (Chen et al., 2018). However, data processing according to the human brain is the main way to distinguish big data analysis from cognitive computing. Here, the machine must be able to understand information about the environment by knowing the data concepts just like humans.

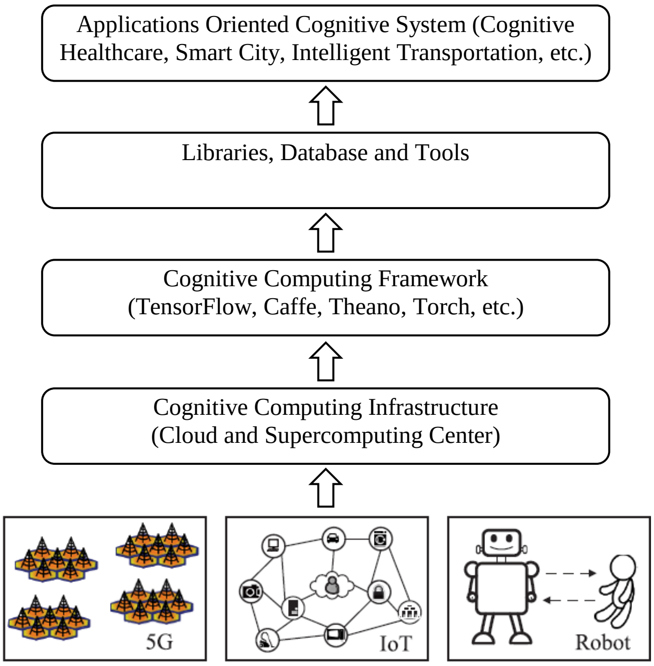

Figure 2. The cognitive computing system architecture (Chen et al., 2018)

3.3. Features Related to Links Between Cognitive Computing and Big Data

Generally, the features that determine the capability of a cognitive computing system can also be effective in the successful implementation of big data analysis (Gupta et al., 2018). This section discusses the features associated with the link between big data and cognitive computing. Figure 3 shows the mapping between features of big data and cognitive computing, where this mapping is based on reference (Gupta et al., 2018).

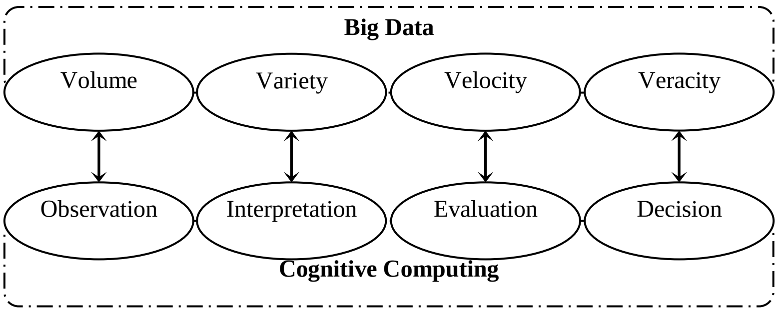

Figure 3. Mapping between features of big data and cognitive computing

Observation is the most important requirement of a cognitive computing system in which data aggregation, integration, and examination are performed. Data volume must be available for observation by a cognitive computing system. A cognitive computing system for better data analysis can manage, cleanse and normalize them. Interpretation leads to a better understanding and solving of complex problems in the presence of a variety of information sources. Variety states that data can be sourced in a variety of ways, including social media, the internet of things, GPS, email, and so on. Evaluation is part of the natural ability of a human being to produce information. Processing large volumes of data requires evaluation in a very short time frame by the cognitive computing system. Velocity is a feature of big data, in which data production control and processing speed are important. Meanwhile, in order to achieve a reliable and accurate evaluation, efficacy in data analysis must be considered. Veracity deals with quality prediction, uncertainty, and reliability of data. Decision feature refers to the ability to make decisions by a cognitive computing system according to the analyzed data. One of the effective criteria in decision-making is the availability of evidence. Finally**,** the value feature shows the worthlessness of large volumes of data before it becomes knowledge. This feature can repurpose data and increase processing for knowledge creation.

4. Literature Review

In this manuscript, the basis for selecting papers for literature review is the use of the keywords "big data" and "cognitive computing". These features are searched for from the title, abstract, and keywords of the papers. Table 1 shows the details of the search process. Here, the search process is based on online digital databases including Scholar, Scopus, Web of Science, and DBLP. The highest number of papers reviewed was indexed on Scholar compared to the other three digital databases.

Table 1. The search details for selecting papers in the literature review

Data Source: End of June 2020	Title	Abstract	Keywords	Document Types	Timespan	Language
Scholar	"bd" or "cc"	"bd" and "cc"	"bd" and "cc"	Article or Review or Conference or in-Press	2013 - Present	English
Scopus	"bd" and "cc"	"bd" and "cc"	"bd" and "cc"	Article or Review	2013 - Present	English
Web of Science	"bd" and "cc"	No default	No default	Article or Review	All years	English
DBLP	"bd" and "cc"	No default	No default	Article or Review	All years	English

"bd" is big data and "cc" is cognitive computing

According to the selected keywords, a total of 73 papers from Scholar, 68 papers from Scopus, 29 papers from Web of Science, and 18 papers from DBLP were selected for review. Here, all papers except 8 from Scopus, 5 from Web of Science, and 2 from DBLP were not part of the Scholar search result. Therefore, a total of 88 papers were considered and after filtering trivial papers based on the abstract, the search result was reduced to 81 papers. Then all the articles were downloaded and by studying them, it was found that 78 of them are related to the topic of this manuscript. Details of these papers can be found in the references of this manuscript.

In addition, the report of these papers based on the publishing year in Table 2, shows that this issue has been emphasized since 2015s and the academic output in this field is nascent. Generally, digital databases provide an overview of scientific and academic progress in all spheres of research. However, the papers considered in this study also show this spectrum. In Figure 4, the breakdown of papers by topic is reported.

Table 2. Report of selected papers based on the publishing year

Paper Type	2013	2014	2015	2016	2017	2018	2019	2020	Total
Conference Paper	-	1	3	2	2	4	3	1	16
Journal Paper	1	2	8	8	9	16	11	6	62
Total	1	4	11	10	11	20	14	7	78

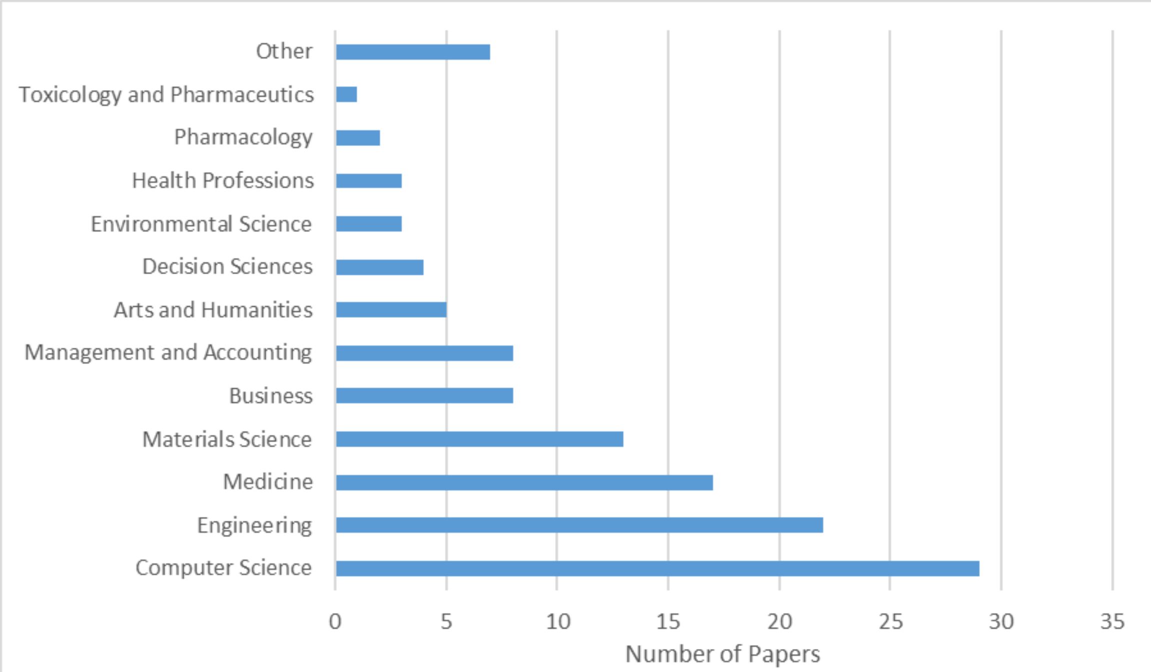

Figure 4. Separation of selected papers according to the topic

The results of a review of selected papers by country show that United States, Netherlands, Canada, and China have the largest share of progress, respectively. Moreover, less than 10% of the papers are based on international collaboration. However, most of the reported countries have the highest percentage of international cooperation (Gupta et al., 2018). International collaboration can come up with new ideas and develop a research topic much faster. In addition, it is one of the most important topics in the healthcare industry, where lots of selected papers are related to IBM Watson and have been suggested to help physicians make better decisions.

5. Analysis and Discussion

Cognitive computing can interpret a wide range of different types of data to produce more rich insights (Gupta et al., 2018). Hypotheses are formed, formulated, and tested in cognitive computing. Here, according to the gathered results, the system can make decisions based on existing hypotheses. This attribute makes the thinking process as close as possible to humans. Because the number of superfluous calculations is reduced, the whole process is scalable as it saving cost and time. Generally, model adjustments in big data analysis must be done manually (Chen et al., 2018). However, cognitive computing can compare the analysis of these changes with the prior experimented results. Therefore, it can be proved that cognitive computing is more dynamic than big data analysis because the system can show changes in content dynamically.

The features required for the successful implementation of big data analysis are classified into five categories: volume, variety, velocity, veracity, and value (Gupta et al., 2018). These five categories are known by the symbol 5V. These features are related to both cognitive computing and big data (Ragini et al., 2018). The ability of firms to effectively manage big data features (5V) using cognitive computing can enable them to be more efficient and enterprise (Chen et al., 2018). Figure 5 presents a conceptual model of cognitive computing that can help to better understand the complexity of data deluge.

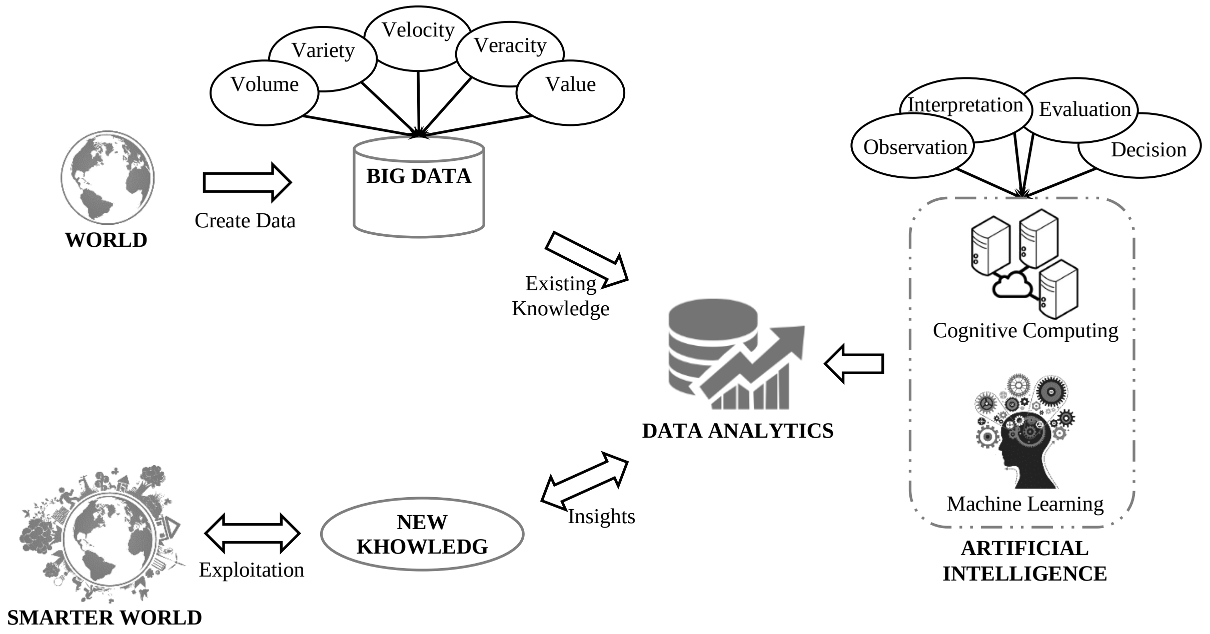

Figure 5. Conceptual model for big data and cognitive computing

The proposed conceptual model highlights the links between features of cognitive computing using the benefits of big data. Here, the use of virtual libraries such as CrossRec can be an appropriate suggestion to support software developers (Zhang et al., 2018). CrossRec is a big social data-based recommendation system that reduces the problems of cold-start users based on cognitive computing. The application of data-based industrial marketing can be described based on the integration of cognitive computing and big data analysis (Lytras et al., 2020). This pattern has stabilized the position of industrial marketing management for local and global business decision-making. The major reason for not accepting big data analysis is the lack of understanding of strategic values by companies and organizations (Verma & Bhattacharyya, 2017). Moreover, comparative benefit, security concerns, high managerial support, technology readiness, competitive pressure, and trading partners pressure are recognized as important reasons for companies and organizations to adopt cloud computing. In Haldorai et al. (2019) research, big data innovation for stable cognitive computing is discussed. Industrial big data analysis is important for the cognitive internet of things, including wireless sensor networks, intelligent computing algorithms, and machine learning techniques, whereas conceptual modeling of structural equations has been used.

The hybrid fuzzy multi-objective optimization algorithm (NSGA-III-MOIWO) is a cognitive computing system based on big data for optimizing social media analysis (Sangaiah et al., 2020). NSGA-III-MOIWO includes the non-dominated sorting genetic algorithm III (NSGA-III) and the multi-objective invasive weed optimization (MOIWO). This algorithm is proposed to solve the E-projects portfolio selection (EPPS). Big data decision-making in EPPS is very important in web development environments. Various models have been widely developed to solving the EPPS problem (Kolm et al., 2014). The literature review shows that the EPPS problem is complex in nature, so researchers have turned their attention to meta-cognitive computing. Meanwhile, a multi-objective model with five functions to represent the risk and expected performance in Pala (2016) research is presented, where it is considered as the objective function for meta-cognitive computing. This method includes three popular meta-heuristic algorithms including genetic algorithm, simulated annealing, and taboo search to solve the EPPS problem.

Big data and cognitive computing have been shown to play an effective role in the learning process (Coccoli et al., 2017). Here, a smart university model is used to find out how big data and cognitive computing systems are enhanced in redesigning the labor market and influencing learning processes. Moreover, education is considered as a process and to overcome the existing problems, suggestions have been made to the improvement of universities' performance. The created solution is based on a new paradigm called the Smart University, in which knowledge grows rapidly, is easily shared, and is considered a common heritage of teachers and students. The important conclusion is that there is a high demand for competencies and skills, which leads to the integration of disciplines in the curriculum by the education system. Here, cognitive computing systems and big data utilization can accelerate the repairing process main components of the academic community.

The combination of Resource-Based View (RBV) theory based on institutional theory is effective in creating work in the field of information systems (DeVaujany et al., 2014). The relationship between learning analysis and cognitive computing can be used to classify big data into micro-learning video collections, which uses (i) a speech-to-text tool to get video transcripts, (ii) cognitive computing and natural language processing to extract semantic concepts and keywords from video text, and (iii) Apache Spark as bid data technology for scalability (Dessì et al., 2019). Table 3 shows what features of big data and cognitive computing have been highlighted in their papers. Given the breadth of the papers, this review is reported here only for selected papers from the 2019s and 2020s.

Table 3. Mapping selected papers based on features of big data and cognitive computing

S.No.	Authors	Big Data					Cognitive Computing			
		Volume	Variety	Velocity	Veracity	Value	Observation	Interpretation	Evaluation	Decision
1	Jimenez-Marquez et al. (2019)	1	1	1	-	1	1	1	1	1
2	Graessley et al. (2019)	1	1	1	1	1	1	1	1	-
3	Dessì et al. (2019)	1	1	1	1	1	1	1	1	1
4	Haldorai et al. (2019)	1	1	-	1	1	1	1	1	-
5	Graessley et al. (2019)	1	1	1	1	1	1	1	1	-
6	Chen et al. (2019)	-	-	1	-	1	1	1	1	-
7	Park et al. (2019)	1	1	1	1	1	1	1	1	1
8	Duan et al. (2019)	1	1	-	-	-	1	1	1	-
9	Coccoli et al. (2020)	1	1	1	1	1	1	1	1	1
10	Wu et al. (2019)	1	1	1	1	1	1	1	1	1
11	Zhang and Abbas (2019)	1	1	1	1	1	1	1	1	-
12	Lytras et al. (2019)	1	1	1	1	1	1	1	1	1
13	Lin et al. (2019)	1	1	1	1	1	1	1	1	1
14	Xu et al. (2019)	1	1	1	1	1	1	1	1	1
15	Sangaiah et al. (2020)	1	1	-	-	1	1	1	1	1
16	Aggarwal et al. (2020)	1	1	1	1	1	1	1	1	-
17	Coccoli et al. (2020)	1	1	1	1	1	1	1	1	1
18	Khalil et al. (2020)	1	1	1	-	1	1	1	1	-
19	Wang and Chiu (2020)	1	1	1	1	1	1	1	1	1
20	Lytras et al. (2020)	-	1	-	-	1	1	1	1	-
21	Wan et al. (2020)	1	1	1	-	1	1	1	1	-

6. Summary and Conclusion

A cognitive computing system has a limited understanding of risk, because the natural language may not be part of the structured or unstructured data. For example, a cognitive computing system can recommend a country to invest in a government-related project without considering the factor of socio-economic conditions like government change. Organizations can use the potential of cognitive computing systems to extract business knowledge from data. Therefore, the output of big data analysis can be considered as input for cognitive computing systems. However, the way humans indulge are inferred in the decision-making process must be examined. A classification of these processes includes observation, interpretation, evaluation, and decision. In order to make effective decisions, there is a need to be captured, sorted, prepared, and analyzed at every moment. However, big data management is a challenge for management researchers for various reasons such as huge volume, high production velocity, different sources, data quality, resource reliability, and so on.

This manuscript focuses on the existing literature analysis in the field of big data and cognitive computing. Selected papers show that this issue has been emphasized from the year 2015s and could be the appropriate future research opportunities. According to the results of the reviewed papers, it can be inferred that cognitive computing has been effective in absorbing the benefits of big data analysis, where this inference can be seen in the real world (for example, the healthcare industry). The success of using cognitive computing technologies for big data analytics in the healthcare industry will pave the way for this to be implemented in other areas. However, cognitive computing is in its nascent stages. Meanwhile, the use of cloud computing is one of these possible and new ways for the problem of big data and cognitive computing. Generally, with the coming of cloud-based services, products are no longer exclusive. Hence, how to use cloud computing to make massive use of cognitive computing and big data can be interesting for future studies.

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