Hybrid Approaches to Big Data Analytics Using Machine Learning Techniques

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Abstract

The exponential growth of data generated from various sources has necessitated the development of sophisticated analytical techniques to derive meaningful insights. Hybrid approaches to big data analytics leverage the strengths of multiple machine learning techniques to enhance the accuracy, efficiency, and interpretability of data-driven solutions. This paper explores the integration of diverse machine learning methodologies—including supervised, unsupervised, and reinforcement learning—within a hybrid framework to address complex challenges in big data analytics. By combining these techniques, we aim to improve predictive modeling, anomaly detection, and pattern recognition. The hybrid approach capitalizes on the strengths of each technique while mitigating their individual limitations, leading to more robust and scalable analytics solutions. Case studies and experimental results demonstrate the effectiveness of these hybrid models across various domains, including finance, healthcare, and social media. The findings underscore the potential of hybrid machine learning approaches to advance big data analytics and offer a roadmap for future research and practical applications in this evolving field.

Keywords: Hybrid Approaches,Big Data Analytics,Machine Learning Techniques,Predictive Modeling,Anomaly Detection,Pattern Recognition,Supervised Learning,Unsupervised Learning,Reinforcement Learning,Data Integration,Scalable Solutions,Data-driven Insights,Computational Efficiency,Model Accuracy,Data Mining

1. Introduction

Different approaches have been proposed for the cleansing/matching process, but most of them focus on structured data formats and do not consider data cleansing/matching to and from unstructured data and data matching across different forms. Structured data cleansing approaches require a certain format, model, and attribute types. These approaches transform the input data into a predefined schema to cleanse it. However, crowd datasets generated by crowd-sourcing are often unstructured and contain just free text. Net Simile is a system that considers unstructured data cleansing/matching but only on the numeric attributes. A regex-based approach is proposed to cleanse the numeric attribute but other attribute types are still not considered. The proposed system in this research project will be able to cleanse/match the dataset across different formats and even on free text inputs.Big data is a term that defines a massive volume of both structured and unstructured data. Big data cannot be managed, processed, or analyzed with traditional tools. Two of the main big data sources are social media (Twitter, Facebook, etc.) and crowd-sourcing (Amazon Mechanical Turk, etc). Both sources are valuable but noisy and hence require cleansing and matching. The cleansing/matching process has a lot of challenges including, variety (different formats, models, and interpretations), veracity (irregular, incomplete, and noisy), velocity (a huge number of tuples generated per second), and volume (huge amount of data). Despite the compelling need for cleansing/matching big datasets from social media and crowd-sourcing, there is an absence of efficient approaches. The key idea in this research is to study the possibility of using a cloud computing paradigm to provide a flexible computing engine (Hadoop, PIG, and Hive).

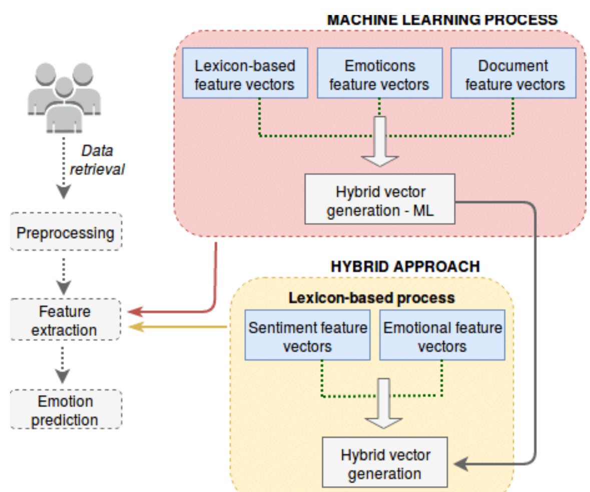

Fig 1: Features modeling for machine learning and hybrid approaches

1.1. Background and Significance

Business establishment requires knowledge about the business functioning environment to perform better than the competitors. Effective techniques and methodologies are required to analyze business datasets and generate actionable insights to assist data-driven decision-making. Big data is a term used to describe the collection and analysis of too vast and complex datasets to find patterns and trends that are beyond the analysis of current tools and exponentially grow over time. In business analytics, datasets are often unstructured or semi-structured, consisting of emails, chats, texts on social media, online reviews, and metadata which complicates and slows down the ability to extract actionable insights. Logical or mathematical rules are wrapped and abstract semantic rules are supplied to systems to limit inputs and outputs in rule-based systems. In such a fixed framework of exploitable scenarios, rule-based systems fail when input data becomes too complex and lacks parameters, and constraints for its description. Artificial Intelligence (AI) models offer significant potential to understand language, reveal patterns in data, and perform predictive analytics. AI models become decision-making advisory tool systems that analyze the piles of data, build hypotheses, and provide recommendations. In recent times, there exists a syntactic and generative perception of language in AI models that a sequence of characters is independent of its meaning and is only a random sequence of symbols. There is a statistical approach which is dealing with the frequency of symbol occurrence that can delay the ability to explain language comprehension in modeling techniques and raise concerns regarding the AI model's reliability and validity in high-stake applications. AI models become technology-free systems which are data-driven and unsuitable frameworks to describe competing AI models.Big data has been widely accepted in various fields such as healthcare, industrial establishments, social networks, and education. The emergence and wide acceptance of big data technology results in a large volume of data being generated, collected, processed, stored, and analyzed. Analyzing the huge amount of data and extracting valuable information from it is very crucial. Big data analytics is a solution for analyzing and providing valuable information from big data. It contains structured, semi-structured, and unstructured data which need different processing techniques for information extraction. Due to the large amount of big data with a wide variety of data types, traditional data analytics techniques cannot be employed. Advanced data analytics techniques like machine learning, data mining, and statistics are emerging to process big data and provide necessary information. Machine learning, data mining, and statistical techniques require some quality and data density levels for significance. Information generation using these techniques cannot be guaranteed. In current approaches, a crowd of humans picks up the complementary feature and participates in big data analytics to assist machine actions with the previous steps often performed by machines. The fusion of crowd inputs with machine efforts can achieve results with an appropriate accuracy level. Crowds can be employed to complement machine performance in big data analytics to generate results with a specified quality level. In this hybrid approach, the use of machines in the previous steps is inherent, and data is first analyzed by machines, and incorrect results are altered by people. Thus, there may still be the truth of human knowledge to achieve improved quality before machine analysis. This paper proposes an overview of combining machine and crowd approaches to big data analytics. After that, it proposes a framework to simplify the understanding of hybrid human-machine big data approaches. This framework identifies the domains of big data types and related processes and techniques. It also attempts to illustrate the implications of crowd involvement in those domains. It identifies the machine approaches used in the previous steps. In addition to that, it also specifies human actions, i.e., task types, and queries handled in those subsequent steps.

2. Big Data Analytics

Big data usually concerns data with at least 2 of the following properties: huge volume, high velocity, and high variety. From the technology viewpoint, a combination of these three properties means a paradigm shift, since the data stored with previous technologies (database systems, OLAP, etc.) can no longer be imperatively acquired and/or handled due to the necessity of different technologies to store and process data, which open a window of opportunities for new vendors. The definition of new analytical technologies for big data refers to technologies that may allow extracting knowledge using different perspectives with the use of data systems with a velocity higher than a certain threshold, variety in the data, and/or size in the order of PB (petabytes). In this increase in the variety the text origin, represented by strings should be considered. Finally, the present techniques shall be surveyed regarding this paradigm shift.Big data analytics consists of advanced analytical techniques exhibited on large data systems and is applied to big data systems which require advanced technologies for storage, analysis, and visualization. Information generated, recorded, and stored in computers has always existed in the phase of complexity and decisions. Nowadays, storing data in databases is a common task in a business, where these data banks are utilized for generating information to support long-term decisions or recurrent analysis. To get a general view of the conditions and perspectives of the business, a data cube is exhibited (many multidimensional tables). One table is the budget (what should happen) and the other is for financial facts that happened (what happened). A data mart is composed of a lower number of tables and attributes and is usually fed with a diminished time lag, which allows the executive to look for insights into the business. To support ad-hoc queries in lower-response time, OLAP systems (online analytical processing) are employed. Each data cube adds new complexity, since each additional dimension may require a new model, new procedures, new data warehouse refreshing methodologies, new front-ends, and so on, but analytical techniques shall be used in all data cubes to extract knowledge with different views.

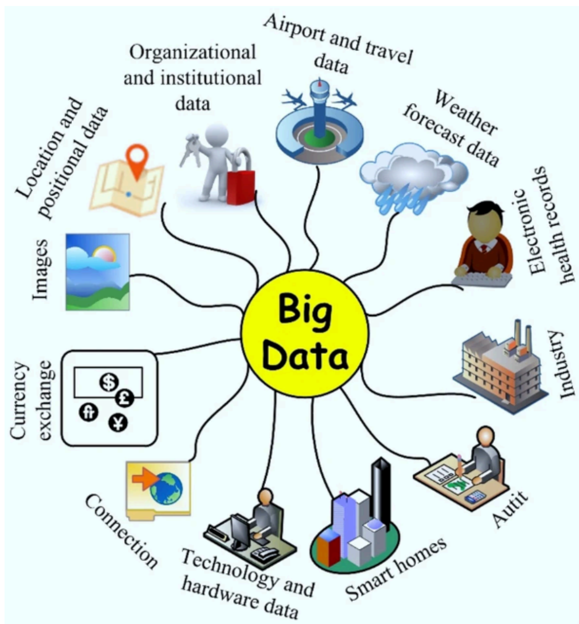

Fig 2: Big data analytics

2.1. Definition and Scope

Big data/analytics is a broad term covering several aspects (e.g. both big data and big analytics, or combinations of some of these aspects) and we do not intend to cover all possible aspects of the term big data/analytics. The different aspects of big data analytics are the data size, data clashes/sorts, geographic reach, data collection, analytic complexity, analytic method, analytic approach/model, analytic resolution, analytic diversity, analytic output, analytic perception or presentation, analytic ownership, analytic access/availability, analytic proficiency, analytic nature, analytic understanding, analytic preparation, storage format, and media type, and supportive technology. To provide clarity in defining big data analytics, the definition of big data analytics is followed by the scope of the term big data analytics (e.g. what is big data analytics and what is not), which is generally missing in the prior literature on the big data/analytics topic area.Big data analytics, separately or jointly referred to as big data/analytics, is one of the "hot" multidisciplinary topics that researchers from diverse fields of interest have taken notice of. Big data refers to the large unordered structured, semi-structured, unstructured data, collected at high velocity from different sources. Big data implies that the data is too large, complex, or nuanced for any form of analysis other than very sophisticated data analytics techniques and technologies. Recently, researchers have been drawn into looking for advanced data analytics techniques called big-data analytics techniques capable of analyzing this kind of data collection optimistically to extract valuable information. The emergence of big data, its challenges and issues, and its competitors, for limited prior literature, are well explored, which makes this piece of work unique as a survey. This study also intends to provide a brief outlook on how the field is currently being investigated and where it could thrive.

2.2. Challenges in Big Data Analytics

Distributed and Decentralized Nature: Big data sources are most often distributed over several physical locations and generated by decentralized nodes. For example, hundreds of thousands of nodes can generate data in the form of text, audio, images, and video every day. Discovering knowledge in such environments is infeasible with traditional techniques.Real-time Processing Needs: Due to the velocity of data, some data portals need real-time processing. For instance, data from stock exchanges, satellite systems, and medical monitoring systems need to be processed and analyzed within a specific time frame. Traditional data storage and processing technologies do not allow such real-time processing.Size of Data: The volume of data is one major challenge in big data analytics. It leads to data being collected and stored over time that may not be processed at the correct time. For example, web click streams can be collected over several months or even years, and due to the enormous size of the data, they cannot be processed and analyzed in their entirety by existing computing resources.Diversity of Data Types: Variety is the major characteristic of big data. This diversity leads to semi-structured, unstructured, and structured data having uncertainty, incompleteness, variety, and complexity. Administrative, web-based, textual, multimedia, and social data add to the variety of big data sources.The nature of big data analytics itself works as an obstacle in this domain. Some of the most complex challenges are made up of a combination of big data and analytics.Big data presents a multifaceted challenge due to its distributed and decentralized nature, rapid velocity, enormous volume, and diverse data types. Data is often generated by numerous decentralized nodes across various locations, producing vast amounts of text, audio, images, and video daily, which traditional techniques struggle to handle. Real-time processing is essential for certain applications like stock exchanges or medical monitoring, but conventional technologies fall short. The sheer size of data, such as web click streams accumulated over months or years, overwhelms existing computing resources, delaying timely analysis. Additionally, the diversity of data, ranging from structured to semi-structured and unstructured formats, introduces complexities such as uncertainty and incompleteness, making big data analytics particularly challenging.

Fig 3: Big Data Challenges

3. Machine Learning Techniques

In the supervised approach, the system receives a set of training data with the corresponding mapping. The training data consists of the internal data dimensions and their corresponding decisions, which are related to external factors. A trained supervised system decides on new internal data dimensions based on the patterns established in the training data. A machine learning system can generalize, which means that the corresponding decisions for new internal data dimensions are established based on past data and not on past decisions. If the training data contains an accurate understanding of the target concept, then a generalization is sufficient for making decisions with new data.Machine learning is a technique in which an artificial intelligence system learns from past experiences to make decisions about new data. Computers and software programs cannot learn from their own experiences, which leads to the inability to make decisions with new data. Machine learning takes raw data and processes it, thereby establishing a mapping of the data and utilizing the patterns for the decision-making process. A machine learning system requires past data and the corresponding decisions for the training process. Once the system is trained, it can receive new data and make decisions about that data based on the patterns established. All of this takes place in an automated manner without user intervention. Hence, machine learning systems are characterized by their ability to learn, adapt, and act out knowledge. There are three approaches to machine learning, based on the amount of information provided for the training process. The approaches are categorized as supervised, unsupervised, and semi-supervised. Each of these approaches has a different way of providing information and understanding of the target concept.In the supervised approach to machine learning, a system is trained using a dataset where each instance is paired with a corresponding decision or outcome, enabling it to learn the relationship between internal data dimensions and external factors. The goal is for the system to generalize from this training data, allowing it to make predictions or decisions about new, unseen data based on established patterns. Unlike traditional software, which cannot learn from its experiences, machine learning algorithms continuously improve their decision-making capabilities by analyzing past data and outcomes. Once trained, these systems can autonomously apply learned patterns to new data without human intervention. Machine learning approaches are generally categorized into supervised, unsupervised, and semi-supervised methods, each varying in how they use training data to build understanding and make predictions.

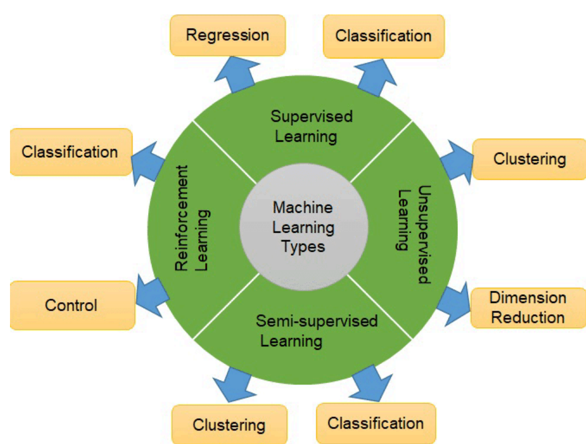

Fig 4: Machine learning Types and techniques

3.1. Overview and Types

In supervised learning, a model is trained to predict an outcome based on a training data set. Examples of supervised algorithms are Linear Regression, Logistic Regression, K-nearest neighbors, Neural Networks, Decision Trees, Naïve Bayes, and Support Vector Machines (SVM). The decision of the outcome is based on the learned rules. The rules are defined if the outcome is a known amount. Given the importance of digital data in numerous industries and branches of science, from Pollution monitoring to Financial Trading systems, an ever-increasing amount of incomplete information arrives under inappropriate formats. In some business scenarios, raw data is rich in information, but if it is outside a certain facility, its value decreases significantly. In unsupervised learning, there is no outcome attribute in knowledge, and the goal is the discovery of persisting trends and behavior within this unknown data. An example of unsupervised algorithms or techniques is K-Means Classifier, Cluster Analysis, Association Rules, Hierarchical Clustering, Self-Organizing Maps, and Principal Component Analysis. Machine learning is the field of Artificial Intelligence (AI) that allows machines to learn and behave according to the user's needs without being explicitly programmed. In other words, it studies computer algorithms that improve automatically through experience. The aim is not to replicate the human brain's neural networks but to send useful information based on data fed into it and major attributes of the data. On the received information, rules are created, and future decisions depend on those rules. Algorithms can be classified into supervised, unsupervised, semi-supervised, and reinforcement learning, which creates a task on the learned rules, modifies the learning if the outcome is not according to these rules, or a combination of the first two.

4. Hybrid Approaches

Hybrid approaches involve the use of a combination of different techniques for big data analytics. These may rely on a combination of machine learning and design modelling, machine learning and game theory, machine learning, and artificial intelligence, or cloud computing together with machine learning, among other approaches. Parallel analytical engines simultaneously run several techniques to tackle the same problem. Although computing engines address a learning or processing technique, they may help to refine the results generated by machines with the help of a crowd due to the limitations of their techniques. In applying more than one technique, different cases of intermediation are possible. The first approach may be called aggregation, where the results of different computing techniques are combined, offering the potential for better precision and control of the environment. In such an environment, a new technique may be designed based on the strengths of existing techniques, similar to how ensemble methods combine the response of individual models. A second alternative is complementing, in other words, the results of a machine production technique are refined by other techniques. In such an environment, a crowd of human experts may complement machine learning approaches, in some cases using models where machines flag results to humans. A third alternative is to act in parallel, where different techniques are used to process the same data. Here, there are different directions, and techniques can either tackle the same problem or different aspects of the data. For example, some techniques use unsupervised data analysis with subsequent supervised data analysis, while others only tackle specific kinds of data. There are many driving forces behind the forward and hybrid approaches that are based on combining techniques from different areas or computing engines. Some forces are stronger or more specific to particular combined techniques.

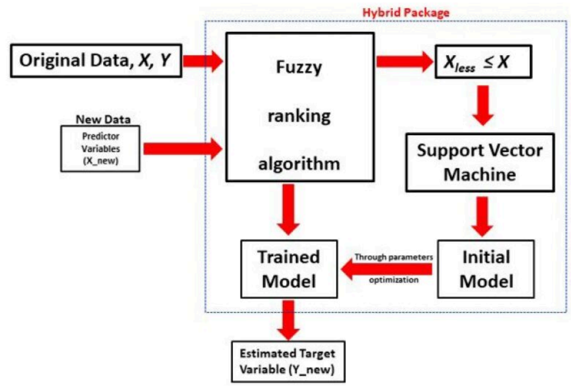

Fig 5: Hybrid Machine Learning

4.1. Definition and Motivation

Hybrid approaches have been motivated by the weaknesses of artificial intelligence-based modeling systems, as heavy reliance on a model can result in poor performance. Since different modeling paradigms are derived from different premises, they can play complementary roles. By combining two or more techniques in big data analytics using different approaches, a powerful model can handle data. Integration can be either series or parallel, providing a basis for future modeling efforts based on hybrid phenomena. These aspects have inspired researchers to investigate hybrid approaches extensively.Emerging theories have motivated the development of hybrid approaches to spring up in many fields, including machine learning (ML) and data-mining fields. A composite model known as a hybrid approach uses two or more models, i.e., soft computing (SC) models and hard computing (HC) models. The combination of two or more techniques in data mining is known as a hybrid approach. These techniques can be merged at the data or model level. A hybrid model at the data level operates on the outputs of separate models to establish a composite model. While hybrid systems at the model level simultaneously operate on the same data, different techniques are merged to develop a composite model. Recently, hybridization has emerged as a powerful technique for improving the performance of machine-learning models in various complex fields, such as big data analytics.

4.2. Advantages and Limitations

However, hybrid approaches also face several limitations in big data analytics regarding complexity, interpretability, and scalability. The integration of different techniques usually leads to increased complexity in terms of maintenance and implementation, which could make it harder for novices to apply. Several parameters need to be considered for the design of hybrid systems, including the techniques to be combined, how they will communicate, and the rationale behind the combination. If the combination of techniques also implies the use of issues or techniques outside the concerned domain or problem, then more types of knowledge and expertise need to be accounted for, increasing the overall complexity of the systems.Furthermore, hybrid techniques can leverage the balance and collaboration of different techniques. Purely machine-based systems are only capable of preprogrammed techniques that are based on mathematical or statistical principles, but errors or poor performance of such techniques are exacerbated due to the volume and complexity of big data. Thus, for the development of hybrid approaches, it becomes crucial to employ crowds at those stages where machine approaches' performance is very restricted. On the other hand, crowd-based systems can also be overwhelmed by a large number of data items, with a detailed examination of the status of mass occurrences requiring tremendous effort and on a scale not achievable by humans. In those cases, machine approaches can take precedence.Approaches that combine different methods and techniques have gained traction because of their proficiency and efficacy in handling complex occurrences. This is considered the case in big data analytics, where the complexity and variety of data have driven the creation of hybrid approaches that incorporate both machine and crowd techniques to counterbalance their respective limitations. Hybrid approaches have several advantages in terms of improving accuracy, performance, understanding, and explanation. Crowd contribution can allot a strong explanatory advantage to hybrid systems, which can provide insight into how and why they produced a certain answer. Such understanding can help to reach a more appropriate result in future occurrences. Crowd people can also better identify those results that cannot be properly decided upon by any technique, including successful systems that focus solely on machine-based big data analytics. Hybrid techniques can also be more inclusive of knowledge and expertise, as crowd people generally possess different personal features. For example, crowd contributors usually have varied nationalities, backgrounds, and professional skills, which can result in a richer set of interpretations encompassing multiple aspects.

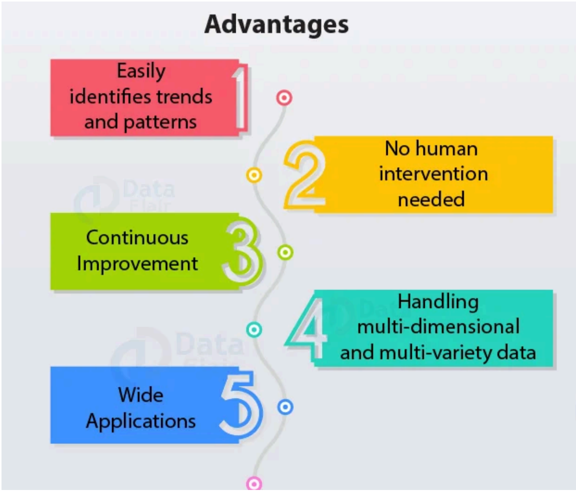

Fig 6: Advantages of Machine Learning

5. Case Studies and Applications

Examples of risk-management applications concerning the loan qualification of enterprises and property sales predictions with high accuracy from a given business environment are analyzed. A case study concerning the real estate market using a low-cost robotic sensor platform for gathering continuous information on the property and surrounding context that may affect its sale price is addressed. The versatility of large-scale systems is demonstrated through monitoring networks for data on air and water quality, or the impact of human activities on sensitive ecosystems. Finally, a case study of processing and analyzing a big data reservoir in the social network context from both content and semantic perspectives is examined.A case study concerning the empowerment of health professionals focused on avoiding the continuance of chronic conditions for potentially diseased patients is examined. Specific attention is paid to traditional approaches in contrast to a big data environment, and an architecture is developed to provide a complete set of healthcare analytics under a smart-city application. A study of biomarker discovery models, through a feature-selection framework, to identify predictive molecules associated with breast cancer survival is examined, focusing its extraction in a genomics dataset acquired through a high-throughput platform. A case study on the predictive maintenance of a complex manufacturing machine is presented, tackling the issue of modeling an evolving system where failures may not even occur within the analyzed period.

6. Conclusion

Trying to find an object of interest from a huge variation of objects, data, and uncertain situations becomes a challenging task in itself. But trying to find such an interesting object of interest from the massive data set is nothing but "Searching a Needle in a Haystack". High-Performance Computing Technologies (HPCs) try to provide speedy parallel processing to such massive data sets. Providing a guided search towards the interesting object reduces the search time. This is very common in oil, gas, telecommunications, and homeland security companies where lots of interesting objects are searched in a huge set of other objects. Designing such guided search algorithms for choosing and processing a sample is being researched. Hence hybrid approaches to big data analytics using machine learning techniques will increase the quality of work and efficiency.Today it has become very common for individuals or organizations to acquire huge data related to their business or interest area. In such a scenario it becomes a challenging factor to manage and analyze the huge data set. New Technologies and Organizations, collecting large data sets concerning their business, customer, or any object of interest have become much more common nowadays. For such a collection High Defined (HD) Sensors are being used. However such data sets become out of control for their management, analysis, and processing.

6.1. Future Trends

Focusing specifically on future trends, big data analytics will be a common and standard part of business processes in any domain not only in large organizations but also in small businesses. The growing usage of smart technologies will provide additional data to analyze the performance of various domains. Notion and usage of the computational clouds and cloud services will further improve the accessibility of data and data mining technologies and will lower the cost of their usage. Thus any organization or company will have access to the required tools – there will be small statistical, data mining, and machine learning tools, libraries, and packages fitting almost any hardware in the cloud.The usage of business intelligence tools (mainly for data summary and visualization) will be replaced with more sophisticated analytical predictive and prescriptive tools. Moreover, the growing number of sophisticated big data analytics technologies will be available only in the cloud, equipped with wide opportunities for API integration. This will likely lead to a rapid increase in data mining technology usage, improvement of obtained knowledge on process performance in a wide range of domains, and drastic improvement in competitiveness and performance ability of observed domains.

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