Introduction to Multimedia Big Data Computing for IoT

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Abstract The headway of new technology, the Internet of Things (IoT) assumes an active and central role in smart homes, wearable gadgets, agricultural machinery, retail analytics, engagement on energy resources, and healthcare. The boom of the internet and mobility support this proliferation in all these smart things, and massive production of multimedia big data of different formats (such as images, videos, and audios) daily. Multimedia applications and services provide more opportunities to compute multimedia big data. Most of the data generated from IoT devices such as a sensor in the devices, actuators, home appliances, and social media. In the near future, IoT will have a significant impact in broader domains such as healthcare, smart energy grids and smart cities in the name of IoT big data applications. More research work has been carried out in the multimedia big data in the different aspects such as acquisition of data, storage, mining, security, and retrieval of data. However, a few research work offers a comprehensive survey of the multimedia big data computing for IoT. This chapter addresses the gap between multimedia big data challenges in IoT, and multimedia big data solutions by offering the present multimedia big data framework, their advantages, and limitations of the existing techniques, and the potential applications in IoT. It also presents a comprehensive overview of the multimedia big data computing for IoT applications, fundamental challenges, and research openings for multimedia big data era.

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1 Introduction

Regular ascend in new technologies and their accessibility coupled with the availability of multimedia sources, the rapid and extensive use of multimedia data such as videos, audios, images, and text have been increasing day by day. Currently, sources of multimedia big data are YouTube, Facebook, Flickr, iCloud, Instagram, Twitter, etc. For example, every minute, the people are uploading 100 h of videos in YouTube, per day the user send approximately 500 million of messages in Twitter; nearly, 20 billion photos are in Instagram [1]. The statistical analysis illustrates that due to the multimedia data sharing over the internet has reached nearly 6,130 PB every month in the year 2016. In 2020, the digital data rate surpasses 40ZB [2]. From this analysis, each person in the world generates nearly 5,200 GB of data.

Due to the advancement in the technology, the people spend most of the time on the internet and social networks to share and communicate their information in the form of multimedia data [3] such as audio, videos, text, images, etc. Multimedia big data is considered as a large volume of the information. Such multimedia big data is characterized in terms of its massive volume, diverse Variety, and rapid velocity. These data are mostly unstructured and may contain much noisy information. The processing and analyzing of these data becomes difficult using the traditional data handling and analytic tools because the traditional datasets, which consist of text and number. Therefore, the multimedia big data requires more extensive and sophisticated solutions to handle the large volume of unstructured data [4]. The major problem which needs to be analyzed efficiently and effectively by multimedia big data analytics such as data handling, data mining, visualizing, and understanding the different datasets generated by multimedia sources to handle real-time challenges. Multimedia applications and services provide more opportunities to compute multimedia big data. By 2020, it is anticipated that 4×10^{24} bytes may be generated. Studies lead by CISCO, and IBM states that 2.5 quintillions of data are generated each day making it equivalent to 5200 GB per person in the universe. Most of the data is generated from IoT devices such as a sensor in the devices, actuators, home appliances, and social media. Internet of Things (IoT) also offers new challenges to multimedia big data owing to the mobility of IoT devices, data gathering from omnipresent sensor devices, and Quality of Experience (QoE). In this chapter, an extensive overview of the multimedia big data challenges, impact of multimedia big data in IoT, characteristics of multimedia big data computing in 10 V's perspective, and further, addressed the opportunities and future research direction of multimedia big data in IoT.

1.1 Big Data Era

The big data concept is essential to understand the characteristics, challenges, and opportunities for multimedia big data. The following section provides the dawn of big data and its challenges. Over the past two decades, the amount of data has increased in a huge amount in different fields. In 2011, the International Data Corporation (IDC) studied and revealed that the entire volume of data generated and the size of data copied has grown ninefold within 5 years worldwide to $01.8 \times \llbracket 10 \rrbracket \text{ ^21}$ Bytes (ZB) of data. Shortly, this numeral twice at least every 2 years [5]. Due to the massive growth in data globally, big data is predominantly utilized for explaining the huge amount of datasets. Big data needs much instant analysis as compared to traditional dataset because of unstructured data. Recently, industries and government agencies development an interest in this enormous volume of data and declared the first plans in the direction of research and applications in big data [6]. The big data challenges and concerns are extensively reported in public media [7–9]. Big data provides novel opportunities for realizing new values, to gather detailed knowledge about concealed values and also acquires in what way the data is to organize and manage multimedia datasets efficiently. At present, a large volume of data is generating rapidly from the source of Internet. For example, Facebook produces over 10 PB (Petabyte) of data log per month; Google deals with 100 s of PB of data, for online trading, Alibaba produces tens of terabyte of data for per day [10]. Advancement of IoT also contributes significantly to generating a large amount of data rapidly. For example, in YouTube, people are uploading an average of 72 h of videos per minute [10].

There is no abstract definition for big data. In 2001, Doung Laney addressed the issues and chances took by enlarged data concerning the 3 V's model, i.e., Volume, Velocity, and Variety. IBM [11] and Microsoft research department [12] have been used 3 V's model to outline the big data within the subsequent fifteen years. The 3 V's model represents Velocity, Volume, and Variety [13]. The Volume represents the large volume of data generation and collection, Velocity represents the speed of data generation, and Variety means the diverse forms of data which contain structured, unstructured, and semi-structured data such as text, audio, videos, web pages, etc. Apache Hadoop well stated the big data as the traditional computers which not able to process, and analyses the datasets in the year 2010 [14]. In 2011, McKinsey & Company defined big data as the succeeding level for the invention, rivalry, and productivity. In 2011, big data ranged from TB to PB [15]. The key features addressed by McKinsey & Company include increasingly growing of big data as well as management of big data.

The traditional database technologies could not manage the big data. Though, people still have different views, including the most powerful important frontrunner in the investigation fields of big data is International Data Corporation (IDC). IDC defines the big data as the new-fangled advancement of technologies and architectures, intended to retrieve the value economically from a huge amount of a diverse variety of data. Further, the big data considered as 4 V's such as Volume, Variety, Velocity, and Value. This characterization addressed the utmost difficult part in big

data, which is in what way to extract the values from a large volume of datasets. The extensive discussions have been carried out by academician and industry on the characterization of big data [16].

1.2   Big Data Challenges

The big data provides more challenges such as data storage, to manage the data, data acquisition, and analysis. Traditional Relational Database Management System (RDBMS) is not suitable for unstructured and semi-structured data. The database management and analysis relies on RDBMS, which uses more expensive hardware. The traditional relational database management system could not manage the large capacity and diversity of big data concerning different types of data and sources. On a different perspective, the research community has proposed a solution to handle a large volume of big data. For example, distributed file system and NoSQL [17] databases provide the permanent solution to store and manage the large-scale chaotic datasets, and the cloud computing provides a solution to satisfy the needs on infrastructure for big data. Various technologies are developed for the applications of big data applications. Some author [18] addressed the issues and difficulties of the big data applications.

Some of the big data challenges are as follows:

- **Data Representation**: The different levels of big datasets such as structure, semantics, granularity, and openness. The main goal of data representation is that the data is more significant for computer analysis and user comprehensible. The inappropriate way of data representation reduces the originality of data and analysis. An efficient data representation achieves an efficient data operation on datasets.
- **Redundancy reduction and data reduction**: Big datasets have a large number of redundant data. It is an efficient method to decrease the highly redundant data generated by sensor networks from IoT applications and reduces the cost of the whole system.
- **Analytical mechanism**: Within the limited amount of period, the analytical mechanisms of big data process the vast volume of heterogeneous data. Traditional RDBMS has the limitation of scalability and expandability, which could not encounter the performance requirements. The non-relational databases system could process the unstructured data. It is the unique advantage of non-relational databases system; still, some problems are encountered in terms of performance and specific applications. The best solution to overcome the tradeoff of relational and non-relational databases for big data is mixed database architecture (Facebook and Taobao), which integrates the advantages of both.
- **Expendability and Scalability**: The logical scheme and algorithm for big data should sustain the current as well as forthcoming datasets and process the enormous growth of complex data.

- **Energy Management**: The energy consumption is a significant problem, which brings the attention of economy of the country. The different operations of multimedia big data such as acquisition, processing, analysis, storing, and broadcasting of the huge volume of big data consumes more energy. The system-level power depletion and managing established to ensure the expandability and accessibility of big data.

1.3 Big Data Applications in Multimedia Big Data

The multimedia big data management system depends on the big data techniques to process and manipulate the multimedia big data efficiency.

The application of big data in multimedia big data analytics are as follows,

- **Social Networks**: Many research works have been performed on social network big data analysis [19]. Tufeki et al., analyses the challenges of social activities and behaviors of people on Twitter hashtags, which has a large number of datasets, visibility, and ease of access. Ma et al. address the new emerging technology called social recommender system, and it is mainly used in social networks to share multimedia information. Davidson et al. presented YouTube video framework activities in which it integrates social information and personalizes videos in a recommendation system [18].
- **Smartphones**: Recently, smartphones have overhauled the usage of other electronic devices such as personal computers, and laptops. The smartphones have advanced technologies and capabilities such as Bluetooth, Camera, network connection, Global Positioning System (GPS), and high potential Central Processing Unit (CPU), etc. Using smartphones, the user can manipulate, process, and access the heterogeneous multimedia data. Mobile sensing issues of smartphones sensors and data analyses such as data sharing, influence, security, and privacy issues are addressed by Lane et al. [19]. The other challenges of smartphones are investigated such as the large volume of data, security, and multimedia cloud computing.
- **Surveillance Videos**: The significant sources of multimedia big data is surveillance videos. Xu et al. [20] present the dawn of big data innovative solutions for multimedia big data such as volume, velocity, variety, and value of multimedia generates from surveillance sources such as traffic control, IoT, and criminal investigation. Shyu et al. [21] present the concept of how to detect semantic concept from the surveillance videos. One of the promising applications of multimedia big data is smart city surveillance.
- **Other applications**: The applications of multimedia big data can be categorized as health informatics, smart TVs, Internet of Things (IoT), disaster management system, etc. The biomedicine data and healthcare data are considered as the primary origin of the multimedia big data. It consists of variety and a huge size of data such as patient records, medical images, physician prescription, etc. Kumari

et al. [22] examined the part of IoT, fog computing, and cloud computing for health care service.

2 Definition and Characteristics of Multimedia Big Data

Multimedia big data is the theoretical concept. There is no particular description for multimedia big data. Multimedia big data concept differs from big data in terms of heterogeneous, human-centric, different forms of media, and larger size as related to the typical big data.

Some of the features of multimedia big data are given below:

- Multimedia big data comprises an enormous number of data types as compared to traditional big data. Multimedia datasets are more understandable by a human as compared to the machines.
- The multimedia big data is more difficult to processing as compared to traditional big data becausem which consists of different types of audio, and videos data such as interactive videos, stereoscopic three-dimensional videos, social videosm and so forth.
- It is challenging to model and characterize the multimedia big data as these data are collected from diverse (heterogeneous) sources such as pervasive portable mobile devices, the sensor-embedded devices, the Internet of Things (IoT), Internet, digital games, virtual world, and social media.
- It is thought-provoking to analyze the content and context of multimedia big data, which is not constant over a period of time and space.
- Security of multimedia big data is complicated due to rapid increases in the sensitive video data on communication.
- There is a necessity to process the multimedia big data swiftly and uninterruptedly in order to cope with the transmission speed of the network. For real-time computing, the multimedia big data is needed to be stored in order to transfer the enormous amount of data in real time.

From the above discussed characteristics, it is observed that the scientific multimedia big data leads to some fundamental challenges such as cognition and understanding complexity, analyzing complex and heterogeneous data, difficult to manage the security of distributed data, quality of experience, quality of service, detailed requirements, and performance restriction that arises from multimedia big data applications. The abovementioned challenges are associated with processing, storing of multimedia big data, transmission, and analysis, which leads to more research directions in an area of multimedia big data.

Figure 1 shows the diverse sources of multimedia big data. The term big data is used to refer those datasets, which could be no longer handled by traditional data processing and analyzing application software because of a large volume of size and complexity. The massive volume of datasets is both structured and unstructured, which is very challenging to perform different types of task such as querying, sharing
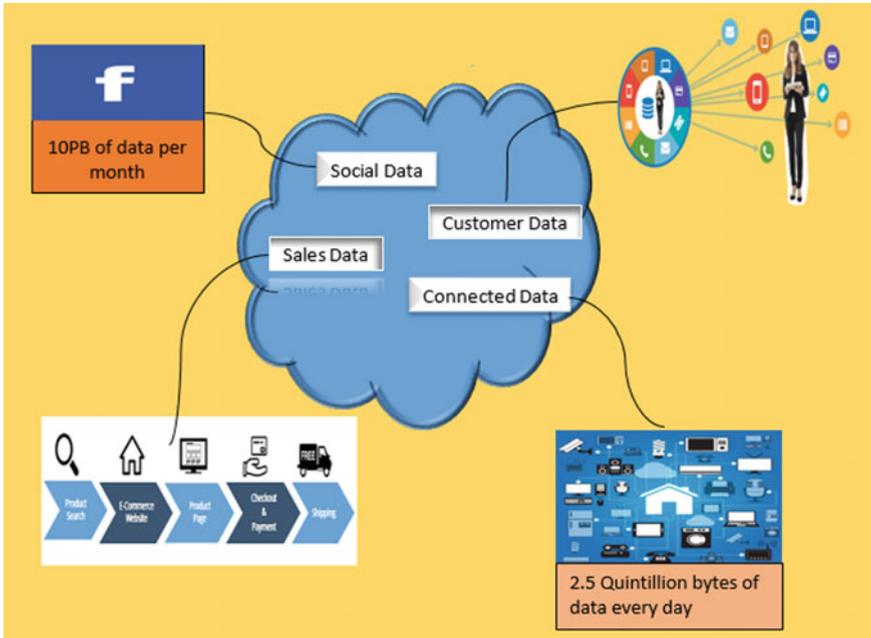
Fig. 1 Different sources of multimedia big data

of data, transferring, updating, collecting, storing, visualizing, analyzing, security, and privacy. The unstructured data does not have any fixed row and column format. Examples of unstructured data are picture files, auditory files, audiovisual files, webpages, and different kinds of multimedia contents.

It does not fit appropriately into a database. As compared to structured data, the unstructured data proliferate every second. The two different data of unstructured dataset are the captured data and user-generated. The captured data is generated based on users behavior. A user itself generates user-generated data. Examples of user-generated data are comments, posts, photos, and videos posted by a user on Facebook (Facebook.com 2016), Twitter (Twitter.com 2016), tweets, re-tweets, YouTube (Youtube.com 2016), etc. The structured data types refer to that data which has a static size and organized. It could be managed and stored easily in a database.

2.1 Challenges of Multimedia Big Data

As compared to the traditional big data(text-based big data), the multimedia big data has more challenges related to basic operations like storing of enormous datasets, processing, transmission, and analysis of data. Figure 2 depicts the multimedia big data and its challenges.
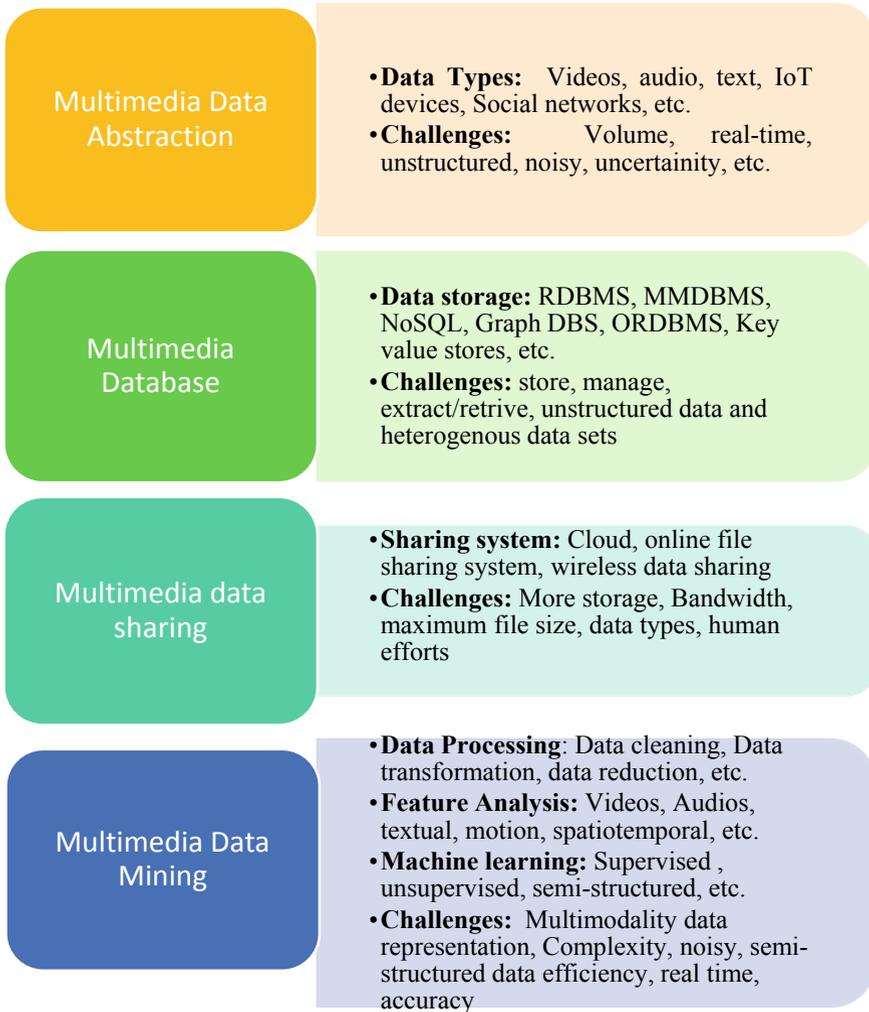
Multimedia Data Abstraction
- **Data Types:** Videos, audio, text, IoT devices, Social networks, etc.
- **Challenges:** Volume, real-time, unstructured, noisy, uncertainity, etc.

Multimedia Database
- **Data storage:** RDBMS, MMDBMS, NoSQL, Graph DBS, ORDBMS, Key value stores, etc.
- **Challenges:** store, manage, extract/retrive, unstructured data and heterogenous data sets

Multimedia data sharing
- **Sharing system:** Cloud, online file sharing system, wireless data sharing
- **Challenges:** More storage, Bandwidth, maximum file size, data types, human efforts

Multimedia Data Mining
- **Data Processing:** Data cleaning, Data transformation, data reduction, etc.
- **Feature Analysis:** Videos, Audios, textual, motion, spatiotemporal, etc.
- **Machine learning:** Supervised, unsupervised, semi-structured, etc.
- **Challenges:** Multimodality data representation, Complexity, noisy, semi-structured data efficiency, real time, accuracy

Fig. 2 Multimedia big data and its challenges

The following points are some of the challenges of multimedia data:

- **Real time and quality of experience requirements**: The services provided by multimedia big data is on real time. It is difficult to addresses the problem of Quality of Experience and its requirements, which needs to perform real-time streaming online, concurrently process the data for analysis, learning, and mining.
- **Unstructured and Multimodal data**: The representation of multimedia big data is challenging to store, and modeling due to unstructured and multimodal data which is acquired from heterogeneous sources. It is very thought-provoking to

transform unstructured multimedia data into structured data and representation of multimedia big data due to the data gathering from different sources.

- **Perception and understanding complexity**: Multimedia data cannot be readily understood by computer due to the high-level and low-level semantics gap between semantics. Furthermore, multimedia data vary for time and space.
- **Scalability and efficiency**: Multimedia big data systems are required to perform huge computation, so it must enhance communication resources, computation, and storage resources.

The above fundamental challenges lead to four logical problems as follows:

1. **Representation and Modeling**: In what way the unstructured data is converted into structured datasets? How to create representation and modeling for the multimedia data gathered from heterogeneous sources, unstructured data, and multimodal data?
2. **Data Computing**: How effectively can we can perform data mining and learning to examine the data?
3. **Online Computing**: In what way concurrently analyze, process, data mining, and learn the real-time multimedia data received in a parallel way?
4. **Computing, storage, and communication optimization**: In what way design a multimedia architecture to efficiently use storage, processing, and communication?

3   The Relationship Between IoT and Multimedia Big Data

In the rapid development of the IoT, a huge number of sensors are set into the numerous devices from personal electronics applications to industrial machines, which are connected to the internet. The embedded sensors are acquired from various kinds of datasuch as home appliances, environmental data, scientific data, geographical data, transportation data, medical data, personal human data, mobile equipment data, public data, and astronomical data. The multimedia big data, which collects from IoT devices have diverse characteristics as compared with typical big data due to the diverse characteristics of sources such as heterogeneity, different types of data (video, audio, and image), unstructured feature, noise, etc.

According to the report by IHS Markit, by 2030, the number of connected IoT devices can exceed 125 billion, and then an enormous amount of IoT data generated. Current technologies available to process the multimedia big data is not enough to face challenges in the future era. Many IoT operators realize that the importance and advancement of multimedia big data on IoT. It is essential for adopting the applications of IoT on the development of multimedia big data. The rapid growth of IoT, an enormous amount of multimedia data provides more openings for the growth of multimedia big data. These two well-known technological developments are mutually dependent on each other and should be developed together, which also provides more openings for the research on IoT.

4   Multimedia Big Data Life cycle

The emergence of IoT device is having a more significant impact on multimedia big data life cycle. The fundamental challenges addressed with the help of multimedia life cycle stages.

The figure shows the different stages of a multimedia life cycle, which consists of data collection, processing, storage, dissemination, and presentation [23]. Figure 3 depicts the multimedia big data life cycle and Fig. 4 shows the key technologies of multimedia big data.

4.1   Generation and Acquisition of Data

Data Generation. The first phase of multimedia big data life cycle is data generation. The best example of multimedia big data is Internet data. A large amount of Internet data is generated from surfing data, forum posts, chat records, blog messages, and videos. These data are day-by-day activities of people's lives, which is generated from diverse heterogeneous sources such as camera clicks, sensors, videos, etc. The primary sources of multimedia big data are sensing information from connected devices (Internet of Things), data generated from scientific research, people's communication and location information, trading datasets in enterprises, etc. Multimedia big data is mainly generated from IoT, which is the primary source of big data. Big data are generated from IoT-enabled smart cities, industries, agriculture field, traffic, transportation, medical data, public department, etc.
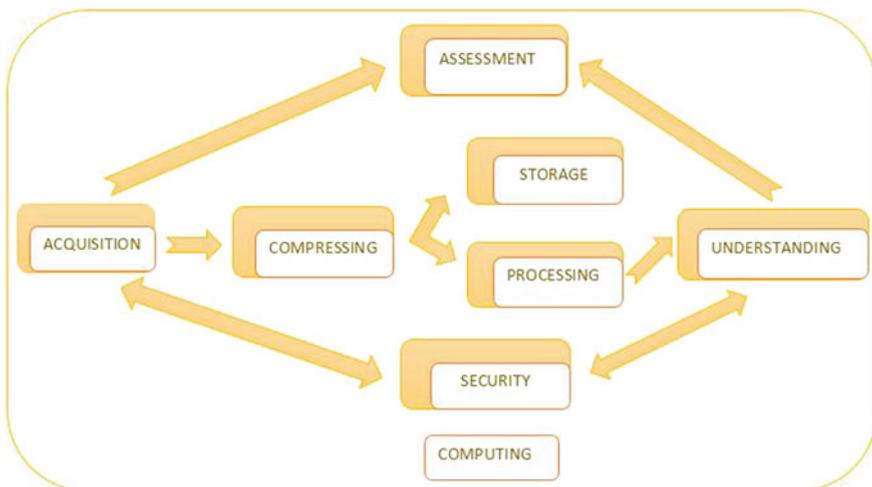

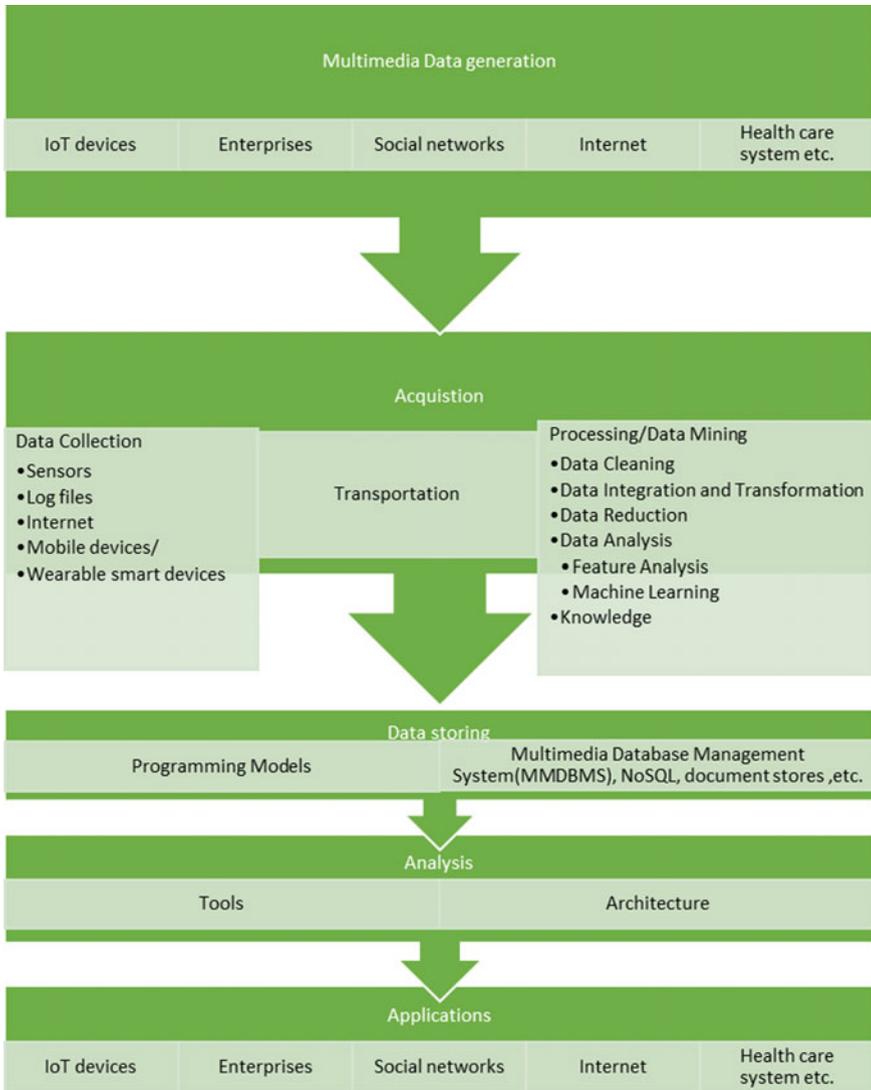**Fig. 3**   Different phases of the multimedia life cycle

Fig. 4 Key technologies in multimedia big data

Data Acquisition. Acquisition is the first phase of the multimedia life cycle to get multimedia data from heterogeneous sources, Internet of Things (IoT), sensor, actuator, social media, digital games, etc. Different types of multimedia big data are generated from the sources such as audio, 2D, 3D virtual worlds, videos from the camera, online streaming videos, social video, Hypertext Markup Language (HTML), tables, etc. Recently, researchers proposed many standards for video coding. As compared to typical big data, it has a high level of difficulty in acquiring data from different sources due to the unstructured way of data representation. The unstructured datasets are proliferating regarding volume, size, and quality. These features of multimedia big data can offer opportunities to design new representation methods to deal with complex and heterogeneous datasets. Table 1 depicts the comparison of multimedia big data sets with other datasets such as representative dataset and big data.

IoT Multimedia big data generation and acquiring. To process an acquired multimedia data from IoT devices and for transmission, the network layer is divided into different layers such as the physical (sensing) layer, application layer, and the network layer. The acquisition is carried out by sensing layer, which consists of sensor networks. The information transmission and processing are carried out by the network layer. The sensor network is responsible to perform transmission with in the range and long distance transmission is carried out with the help of internet. The application services of the Internet of Thing are carried out by the application layer. The features of data generated from IoT as follows:

- Large-scale multimedia data;
- Heterogeneity;
- A limited amount of data due to noises;
- Robust time and space correlation.

Table 1 Characteristics of multimedia big data, typical datasets, and big data

Characteristics	Typical datasets	Big data	Multimedia
Volume	Less	Medium	Big
Data size	Definite	Uncertain	Uncertain
Inferring video	Not at all	No	Yes
Representation of data	Structured data	Structured data	Unstructured data
Real-Time	Not at all	Yes	Yes
Human-centric	Not at all	No	Yes
Response	No	No	Yes
Data source	Centralized	Heterogeneous distributed	Heterogeneous distributed
Complexity	Low	Medium	High

4.2 Data Compression

The size of multimedia big data decreased to store, communicate, and process the data efficiently. Multimedia data compression refers to eliminate the redundant data in the dataset. Redundant data refers to duplications or additional data in the datasets, which increases the data inconsistency, storage space, data transmission cost and delay, and reduction of data reliability.

   Feature-transformation-based data compression: The numerical data reduction is carried out by compressive sensing and wavelet transform.

- **Cloud-based compression**: A large amount of multimedia data is produced today with the advent of IoT era. In the current scenario, many organizations are moving toward the cloud to store an enormous volume of multimedia data, which leads to storage issues in cloud computing. The storage issues are related to space, time, access control, validation, etc. Facebook has declared that 300 billion pictures are shared per day. Microsoft has announced that its cloud storage service accommodates approximately 11 billion pictures. Many efficient compressing techniques are available regarding space and time to store multimedia data efficiently in a cloud. Subsequently, research on multimedia data compression for cloud computing is of increasing importance in the computer society.

4.3 Multimedia Data Representation

The multimedia data which received from the different sources and each source represents the data in different format. For multimodal analysis, it needs a common representation of data. Multimedia data representation comprises of the following different methods:

1. **Feature-based data representation**: Some features of multimedia big data are standard regarding space or time; feature-based data representation is used to extract the data among all different combination of features. Currently, many types of research are being carried on feature vectors to retrieve the content-based multimedia data. According to the applications, from the audio, video streams, or image pixels, the features are extracted and combined into vectors. The application-based approach leads to scalability, and accuracy lack in feature-based data representation.
2. **Learning-based representation**: The common feature space extraction is a challenging task in multimedia big data due to the large volume of data gathered from different sources. A new representation which used to extract the hidden space is called learning or machine based representation.

   Many learning-based representation approaches have been suggested to signify multimedia big data. Predominantly, in recent years, deep architectures are extensively applied for data learning representation.

4.4 Data Processing and Analysis

Once the data is acquired and stored, the next phase of the life cycle is data processing and analysis. The raw multimedia data, which is received from different heterogeneous sources are unstructured and noisy. The unstructured large-scale multimedia datasets are not directly suitable for analysis because of sparse, noisy, and diverse data, which causes troublesome and sometimes unfeasible. The problem as mentioned earlier can be alleviated by preprocessing methods. Data preprocessing is the process of conversion of unusable data into new and cleaned data for further analysis. After the data preprocessing, the datasets are ready for further higher level analysis.

Multimedia preprocessing of data comprises data cleaning, data transformation, and data reduction [24] as follows:

Data Cleaning: According to the reports, data scientists are spending almost 60% of the time on data organizing and cleaning. Data organization and cleaning [23] comprises of noise reduction, acquisition, outlier identification, and avoiding inconsistencies. Data cleaning can improve the data quality and reduce the discrepancy and faultiness of data. Data imputation methods have been used to handle the missing data values. To improve the final results, error-aware data mining approach incorporates the noise information in it. The noisy semi-structured data is converted into clean data with the help of data manipulation and preprocessing tools.

Data Integration and Transformation: Data integration is the process of combining the heterogeneous sources, as well as, their metadata into a consistent source. It detects data conflicts and resolves it. Data transformation is another crucial step in preprocessing. Data transformation includes data formatting, aggregation, and normalization. Recently, extensive research work [25] is going on to develop a common representation model to transform different data into enhanced, and simplified data.

Data reduction: Recently, many data compression techniques is proposed to handle a large amount of multimedia data. Researches mainly focused on feature reduction and instance reduction. In instance reduction technique [26], the quality of mining model is improved by reducing the original datasets as well as the complexity of the data without affecting the original data structure and integrity of the data.

- **Data Analysis**: As multimedia big data research is advanced due to the development of IoT, the typical data analysis is a new complication on multimedia big data processing. A generally big data analysis is narrowed down to the single data format.
- **Feature Analysis**: The current explosion of multimedia data increases the complications of data analysis as well. Feature extraction is connected to the gap between low-level multimedia characteristics into its high-level semantic content. It is time-consuming task to extract the features from massive datasets, and for that, the whole process is parallelized and shared among numerous systems. Recently, the fast feature extraction method is studied [27], and compared the three big data techniques for multimedia feature extraction such as Apache Hadoop, Apache Strom, and Apache Spark. Schuller et al. [23] studied how to extract the features directly from compressed audio data.

- **Deep learning Algorithm**: Many researchers have been motivated by the popular Deep Learning toolboxes to extract large-scale features using deep learning algorithms. Deep learning has mainly focused on unsupervised feature learning and based on deep learning, a very less amount of work has been carried out on multimodal features. An audiovisual speech classification framework using three learning techniques are fusion-based method, a cross-modality, and shared representation learning method. In the mid-2000s, feature reduction techniques were proposed for large scale real time multimedia data. Online feature selection (OFS) in which an online learner is only allowed to maintain a classifier involved only a small and fixed number of features. The group and nonlinear feature selection methods are based on Adaptive feature scaling to increase the performance and speed of the training process.
- **Machine Learning**: Machine learning is the procedure of improving the performance of computer programs by learning the data automatically through experience. The main purpose of machine learning is to learn a specific work whose class tag is unknown. The supervised and unsupervised learning are the classifications of machine learning. In unsupervised learning, there is no label related to each data instance input. The Supervised learning use an algorithm to learn the mapping function from the input to the output.

4.5   Storage and Retrieval of Multimedia Data

The multimedia big data management and recovery are carried out with the help of annotation due to the unstructured and heterogeneity of data. Annotation [12] is categorized as the manual and automatic annotation. The manual annotation [28] is done by users, source providers, and tools. The automatic annotation is carried out by machine learning algorithms. The automatic annotations are more interesting as compared to manual annotation due to the endlessly growing data. The main problem of automatic annotation is a semantic gap. From the multimedia text documents, the semantic data are extracted by using Latent Dirichlet Modeling (LDM). Currently, the deep learning techniques have been used widely to extract annotations for videos and pictures. Generally, the Multimedia Database Management System (MMDBMS) consists of multimedia data and their relationship, which is different from traditional relational database management system. The characteristics of the multimedia database are storage, constraints on spatial and temporal, presentation of data, retrieval, etc.

The main requirements of the multimedia database are traditional database capabilities, data modeling, storage management, retrieval, integration of media, interface, and interactivity, and performance. The multimedia database management system requires to satisfy the following requirements to perform the manipulation and storage efficiency:

- **Data modeling for multimedia**. Even though the various traditional database modeling is available such as relational modeling, semantic, and network modeling, only few modeling methods proposed for multimedia databases due to the unstructured nature of multimedia data. For each type of media, the multimedia data needs an object-oriented data model. The modeling system for the multimedia document, which combines the technologies such as Object-Oriented Database Management System, Natural Language Processing (NLP), etc., to excerpt the vital information, structure the input documents and offers semantic recovery. The data modeling is mainly used to extract/retrieve the information.
- **High volume storage management**. The storage management of multimedia characterized by significant volume and variety which need a hierarchical structure. The hierarchical storage of multimedia big data increases the storage size and decreases the performance.
- **Query support and retrieval capabilities**. Multimedia data needs different queries such as content and keyword. The multimedia query typically does not return an exact match; it returns a result which contains an object similar to the query object. The multimedia consists of different media types, which require consistent ranking and pruning approaches.
- **Media Integration, configuration, and presentation**. The integration and configuration play an essential role; once unstructured data are converted into a structured data format. It ensures the truthfulness and individuality of multimedia data. The multimedia big data require an efficient and effective presentation to reduce excessive computation storage.
- **Performance**. The performance is an essential parameter of multimedia big data, such as competence, consistency, processing of data on real-time and execution, Quality of Service (QoS), Quality of Experience (QoE), and guaranteed multimedia presentation. These performances are achieved with the help of cloud computing and distributed processing.
- **Multimedia Indexing**. Generally, the traditional RDBMS is not appropriate for multimedia big data because of unstructured data format. This problem solved with the help of indexing approaches. The indexing approaches have been proposed to manage the different data types and queries. Artificial Intelligence (AI) and non-artificial intelligence are the types of indexing approaches.

4.6 Assessment

Advancements of information technologies and MEMS (Micro Electro Mechanical Sensor) technologies and its extensive growth in numerous areas resulted in an enormous amount of different data such as videos, audios, and text data. Due to the rapid development of multimedia data and services, it is vital to provide the Quality of Experience (QoE) to the users. Either the subjective or objective analysis cis arried out to test the quality of the videos. The subjective analysis is carried out in a test center which needs more human resource and expense. Generally, the subjective
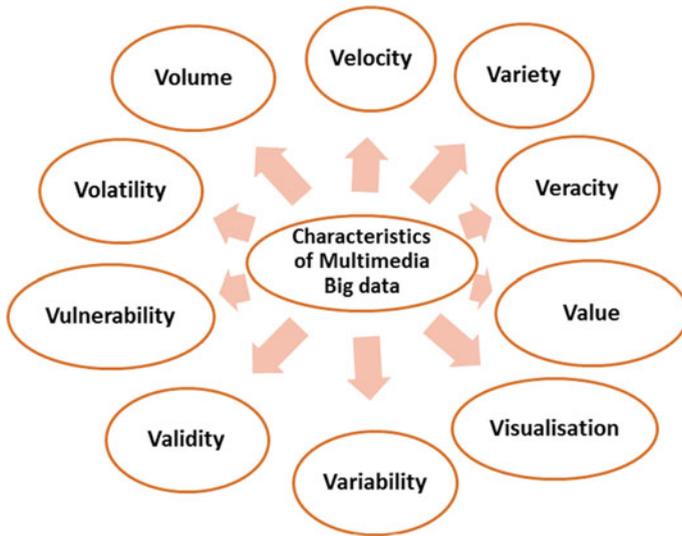
Fig. 5 Characteristics of multimedia big data

assessment is not carried out for real-time estimation. The objective test depends on the standard of Human Visual System (HVS). The objective assessment analysis is based on subjective assessment test parameters.

4.7 Computing

From the enormous amount of multimedia data, it is a challenging task to organize and process the multimedia big data. Multimedia big data computing is a novel paradigm; the data analytics is performed by combining large-scale computation with mathematical models.

5 Characteristics of Multimedia Big Data

A multimedia is a group of enormous and complicated datasets. Figure 5 shows the characteristics of multimedia big data. Figure 6 shows the five V's of multimedia big data. The following characteristics can describe it,

Volume: In big data, the volume defined as the vast volumes of data generated through the internet of things, portals, internet, etc. According to Worldometers 2016, above 7.4 billion people (Worldometers 2016) are in the world, and almost 2 billion peoples are linked to the internet, and remaining individual people are using various
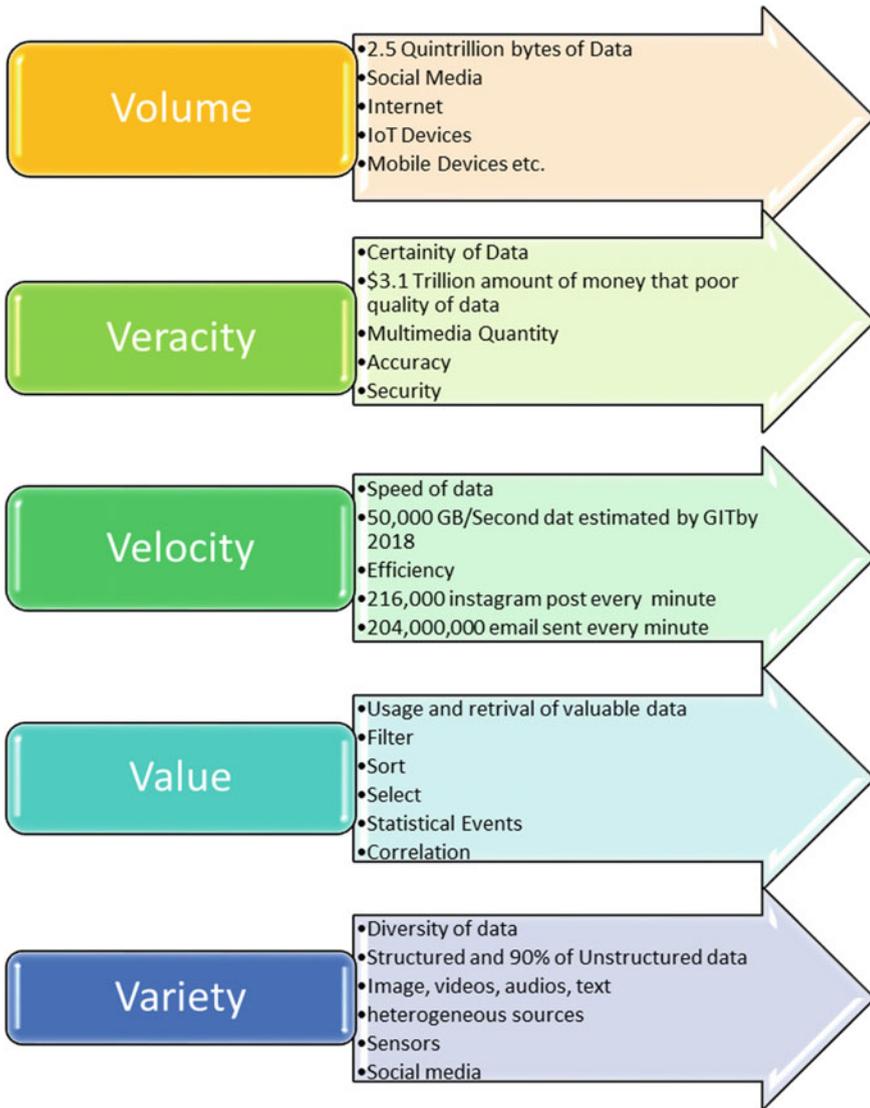
Fig. 6 Five V's of multimedia big data

portable handheld devices, i.e., mobile devices. As a result of this technological development, each product produces huge volume of multimedia data through the growth of Internet technology and the use of various devices. Especially, remote sensors embedded in the devices produce the heterogeneous data continuously either in a structured or unstructured format. In the near future, the exponential growth of multimedia data exceed yottabytes (10^{24}). For example, more than one billion users (YouTube.com 2016) are daily uploading videos over 300 h/min on YouTube. The Facebook comprises more than 1.4 billion users, 25 trillion posts as on 2016 (StatisticsBrain 2016), and a total of 74 million Facebook pages. In 2016, 6.2 billion gigabytes of global mobile traffic is estimated per month. According to the report of Digital universe study of International Data and EMC Corporation, the data has been generating tremendously, i.e., 800 EB in 2009–1.8 ZB in 2011, and in near future, data grow 40 times (40ZB) greater in 2020. It is very challenging to handle such amount of multimedia big data [26] concerning gathering, storage, analyzing, preprocessing, sharing, and visualization.

Velocity: The term velocity denotes the rate at which data has been generated, i.e., how fast the data is coming in. Hendrickson et al. [29], reports that information proliferates by one order of scale every 5 years. Every day, 5 billion users browse the internet, tweet, upload, and send both multimedia and standard data. The people generates 58 million tweets and 2.1 billion queries in tweeter per day. The number of users using YouTube increased to 40% since March 2014. Almost 50% of Facebook account holders log into Facebook account every day. Every minute, about 2 million searches and queries in Google (Google.com 2016) and Google processed 25 PB every day. The efficient management tools and techniques are required to cope up with the speed of multimedia big data.

Variety: The term variety refers to the diversity of data [29]. Examples of variety are emails, voicemails, video message, ECG reading, audio recording, etc. In the age of multimedia big data, the data gathered from heterogeneous sources are represented by either images or videos. It contains more information and knowledge. Generally, sources generate structured and unstructured data. Unstructured data does not have any fixed format which is very difficult to process. The similar formats and predefined lengths are referred to as structured data. The unstructured data can be processed with the help of Hadoop; the clustering method used to process the unstructured data in a short interval of time. The unstructured multimedia big data brings more challenges for analyzing, preprocessing, and extracting the valuable data.

Veracity: In multimedia big data, the term veracity denotes the uncertainty of data, noise, and deviation in data. It is very challenging issues in multimedia big data to ensure the precision of data which make it as difficult to determine how much data can be reliable.

Value: Value is the most critical element in multimedia big data. It denotes the usage and retrieval of the valuable information from these huge volumes and diversity of data. For the analysis of data, it is essential to filter, sort, and select data.

The other essential V's of multimedia big data is as follows:

- **Visualization**: The essential challenging characteristics of multimedia big data are in what way the data is visualized. The technical challenges confronted by tools available for visualization is due to the limitations of memory, functionality, expandability, and response time. It is not possible to plot a billion of data points using traditional graphs. The multimedia big data need different methods of representing data such as data clustering, parallel coordinates, circular network diagrams, sunbursts, etc.
- **Vulnerability**: Vulnerability refers to security concerns about multimedia big data.
- **Validity**: Validity denotes the correctness of the data for its envisioned use.
- **Variability**: It refers to the number of inconsistencies in the data, as well as, the speed at which multimedia data loaded into your database.

6 Multimedia Big Data Challenges and Opportunities

With the proliferation of IoT, the world has marched into multimedia big data. The development of multimedia big data provides a lot of challenges as well as countless chances for the betterment of IoT applications.

6.1 Acquisition Challenges

Many different types of multimedia are videos, audios, speech, online streaming videos, documents, graphics, geospatial data, 3D virtual worlds, etc. Multimedia big data is unstructured data, which have more complexity in an analysis as compared to typical big data. The unstructured data can be easily understandable by users which proliferate regarding quantity and quality. It is difficult to understand by the machines. These are the main challenges of multimedia big data acquisition. Some of the papers addressed these issues are as follows: the representation and modeling of multimedia big data is a very challenging task. Most of the studies focused on graph structure instead of video structure. Generally, the large-scale multimedia big data is acquired from the source, which contains the data in the form of incompleteness, uncertainty, communication errors, also affect from malicious attack, data corruptions mainly ignored the hidden video content and different levels of quality.

In BigKE method presents the knowledge framework to handles disjointed knowledge and E-learning methods which receives the data from heterogeneous sources. The streams feature is derived from spatial and temporal information. Wu et al. [30] presents a tag assignments stream clustering for dynamic unstructured data, which is modeled as a stream to describe the properties and interest of users. Hu et al. [11] proposed a model to manage the multimedia big data using semantic link network, which creates the relationship among different multimedia resources.

Table 2 Existing methods of acquisition process

Methods	Objectives	Limitations
BigKE [30]	Knowledge framework to handles disjointed knowledge exhibiting and E-learning methods from numerous heterogeneous sources	Not addressed IoT
Semantic link network model [11]	Manage the multimedia data using semantics	Not addressed issues on IoT
Wang [35], Pouyanfar et al. [44]	Addressed the review of multimedia big data	Not addressed issues on IoT
Kumari et al. [31]	Addressed the taxonomy and multimedia big data for IoT	Focused on IoT

Multimedia data acquisition for IoT application is categorized as three parts, namely, data gathering, compression, and representation [31]. Table 2 shows the pros and cons of existing acquisition process.

In context of IoT, the multimedia data is often collected from sensors. The data collection has been carried out from several areas such as forecasting health status of patient, wireless networks, Internet of Multimedia Things (IoMT), Healthcare I,ndustrial IoT (Health-IIoT) and personal devices. The multimedia big data collected from the IoT devices are heterogeneous in nature. The main limitations of the existing methods are each method has different views and categories. While designing a new method for data acquisition, the following factors are considered such as unstructured data, heterogeneous sources, multimodal, dynamic evolution, user's interest, spatial and temporal information, semantics, and geographically distributed data.

6.2 Compressing Challenges

The multimedia big data is a massive size of data; it must be compressed before further processing and storage.

The compression of multimedia big data brings more challenges as compared to traditional datasets and big data techniques. Due to the limited storage and processing/computational capability, it needs to be compressed effectively with the help of signal processing and transformation.

Many challenges arise while compressing multimedia big data as follows:

- Multimedia big data is difficult to handle because of unstructured data;
- Due to the large volume of data, it is challenging to compress at a fast speed;
- Data loss is very high due to diverse sources.

The traditional big data reduction approaches for compression are wavelet transform and compressive sensing. Duan et al. [32] proposed the compression technique

based on feature descriptor to attain large reduction ratio which depends on different coding approaches. Bu et al. [22] proposed a deep learning-based feature extraction context to extract the multilevel three-dimensional shape feature extraction. Xu et al. [20] proposed a latent intact space learning to acquire abundant data information by merging multiple views. Herrera et al. [33] proposed an architecture to handle the data from various multimedia streaming stations such as TV and radio stations to perform gather, process, analyze, and visualize data. The approaches mentioned above is mainly focused on high-level integrated features in multiple views. The effective description techniques are needed to extract high features. Most of the existing approaches are not focused on the application of IoT. Table 3 shows the pros and cons of existing methods of data reduction and collection.

6.3   Storage Challenges

Big volume of multimedia big data being is created continuously, and it is essential to store the large volume of data after compression. The size of multimedia big data is unlimited and has a variety of media types. With the massive evolution of multimedia big data, the quality and amount of unstructured data bring more challenges to store data as compared to typical big data. The storage system of typical big data is based on the NoSQL. In multimedia big data scenario, it is impossible to store all real-time streaming multimedia data. The limitation of existing storage methods is given in Table 4.

The challenges of multimedia big data storage addressed in the new design regarding feasibility and cost. Dede et al. [34] present a pipeline processing to combine the NoSQL storage with big data processing platform (MapReduce). Wang et al. [35] presented hybrid stream big data analytic models for multimedia big data to addresses the data video analysis which contains data preprocessing, classification, recognition, and big data overload reduction. Table 3 shows the limitations of existing storage methods.

Liu et al. [20] present a hashing algorithm based on deep learning and shallow learning to efficiently store multimedia data, indexing, and retrieval. NoSQL-based approach is introduced to manage real-time embedded database efficiently. It is mainly designed to distribute data storage for an enormous amount of data needs, which takes advantage of scaling. The concept of integrating the IP Multimedia Subsystem (IMS) with the Hadoop system increases the performance, scalable distributed storage, and computing system of IP multimedia subsystem service resources. While designing the storage system for multimedia big data, the following features should be considered to increase the performance and distributed storage. The boundaries of IoT and cloud computing should be considered.

Table 3 Existing methods of data collection and reduction

Category	Survey	Area of Interest	Pros	Cons
Multimedia data collection	Gao et al. [39]	Machine learning feature analysis	Outline of High-dimensional multimedia big data and machine learning techniques	Not focused on multimedia big data and its technical challenges on IoT
	Hu et al. [11]	Retrieval of video	An overview on video indexing and retrieval	• Limited to single multimedia data type • Lack of multimedia big data challenges
	Wang et al. [39]	Smart grid	A general overview on multimedia wireless sensor networks and its application in smart grid	Limited to multimedia big data analytics
	Madan et al. [45]	To predict health status of the patient	Low costs for providers	Not addressed wireless networks issues
	LUSTER [46], Hossain et al. [47]	• Environmental monitoring using WSN • Data collected from Internet	• Data reliability, efficient scalability • Distributed and fault tolerant storage	Prone to Security breaches
	Duang et al. [32]	• Feature descriptor based on multimedia coding approaches	• High compression ratio	Not focused on multimedia data on IoT

Table 4 Existing methods of data storage

Multimedia big data storage	Survey	Methodology	Limitation
	Dede et al. [34]	Combining NoSQL with Big data platform	Need to consider IoT and Cloud Computing to increase the performance and storage
	Wang et al. [35]	• Addressed Video data analysis • High stream big data analytics	
	Liu et al. [20]	• Hashing algorithm depend on deep and shallow learning	

6.4 Processing Challenges

The fundamental task of the processing is to extract useful information for further activities. The multimedia big data are generated from real-time applications. It is essential to process the multimedia big data effectively with limited processing time. It is essential to addresses the challenges of multimedia significant data processing is as follows:

- The larger volume of multimedia big data is generated continuously from the heterogeneous sources. It needs to be processed at high speed to store data efficiently in real-time.
- To handle the enormous amount of multimedia data, it needs to develop the automated and intelligent analytical technique to extract knowledge from heterogeneous data.
- To process the multimedia big data, it needs parallel/distributed, and real-time streaming algorithms.
- Need large-scale computation, storage, communication resources, and networking to process a huge volume of multimedia big data which should be optimized.

The sparsity, spatial-temporal information, and heterogeneity should be considered in future approaches for multimedia big data. The bottlenecks of processing such as communication, storage, and computational should be reduced.

6.5 Understanding Challenges

With the massive evolution of multimedia big data, there is a semantic gap between low-level and high-level semantics features. Multimedia big data is challenging to understand by a device; particularly, certain multimedia big data changes with respect to time and space. In order to understand the semantic gap in the multimedia big data, the efficient cross-media and multimodal systematic tools, and intelligent analytical methods are needed to overcome the limitations. Schuhmacher et al. [31] present a

knowledge graph which consists of objects, concepts, and relationships; to extract the knowledge associations from different heterogeneous data. The concept and entities reproduce the real-world concepts. The pattern matching methodologies is used to extract the information from open source before constructing the knowledge graph. The knowledge graph is used in different applications, such as big data analytics, deep learning, to search semantic data, etc. Extensive research is needed to construct the knowledge graph automatically to handle the huge scale of data. Recently, research works are going on the structured and semi-structured text data. More research is required on the unstructured knowledge graph to handle the large volume of multimedia big data.

6.6 Computing Challenges

The multimedia big data is generated from the real-time environment. It is generating continuously by more number of heterogeneous sources, which requires to process uninterruptedly to store the data efficiently and time restrictions. Multimedia big data consists of a wide variety of data and transient in nature. As a result, it is essential to design the concurrent and instantaneous online streaming processing for scrutiny of multimedia data. To perform computation on large-scale data, it is necessary to optimize storage, communication resources, and processing. Due to the development of communication technology, the multimedia big data travels through the network at very high sapped; it brings the challenges of GPU computing. The cloud-based system presented to harvest data from multimedia big data in the global camera networks. In this method, it receives multimedia data from numerous devices, and it can be evaluated instantaneously by an application programming interface. The storage and computing of multimedia big data problem can be addressed by cloud computing technology.

Sadiq et al. [36] addressed the several challenges of multimedia big data received from crowded heterogeneous sources. The author presents a framework for spatial multimedia big data and various multimedia sources. It also handled the spatial queries related to multimedia big data in real-time. Cevher et al. [37] addressed the bottlenecks in big data such as computational, storage, and communications. It also

shows that advances in convex optimization algorithms propose several unconventional computational choices. The synchronization problem in multimedia big data is addressed to exploit the therapy recorder, which can implement the two-tier synchronization process. It creates the multimedia synchronized therapy session file and separates the complex media files. Garcia et al. [38] present a pipeline media concept and Platform as a Service (PaaS) scheme. Zhang et al. [28] presents a method to efficient precision recommendation method to recover the particular image from the large size image database. The author presents three different types of content-based imageretrieval, based on the content comparison the relevant image is recovered from the image database. The authors have been analysed the platform to facilitate the public cultural services based on cloud computing and Hadoop system. The fusion of cloud computing and big data technology need to be considered to reduce computation time and improve data scalability. The data traffic can be classified based on the local and structural features to process the data in real-time.

6.7   Security and Privacy Challenges

The multimedia big data consists of different datasets, which include private/personal videos or sensitive videos [27]. With the explosion of videos, the multimedia big data must be governed in complete security. It is challenging and essential to trace and protect the multimedia big data. In order to manage and accesses the multimedia big data securely, it is essential to study the implementation of a privacy policy. In the context of IoT devices, the security of multimedia big data provides confidentiality, integrity, and availability. Due to the huge volume and heterogeneous nature of data, the security brings more challenges to deal with multimedia big data in IoT. In case of centralized data, the single point of failure reveals the user's information which violates the laws. An outset of data mining in the real world dogged to privacy issue. The encryption techniques are used to secure the confidentiality of multimedia big data. At present, the methodologies/technologies available ensure only the privacy of the static data. The protection of dynamic dataset is a challenging task.

6.8   Assessment Challenges

The Quality of Experience (QoE) plays a significant part in multimedia big data for video applications. Some of the challenges of multimedia big data assessment are as follows:

- It is a tedious task to measure and quantify user experience levels.
- In real time, it is complicated to keep track of multimedia big data applications.
- In what way to correlate Quality of Service (QoS) and QoE metrics effectively?
- In what way to obtain a standard for users?

- How efficiently analyses the customers' experience?
- In what way quickly and accurately measure the QoE under various standards?

Wang et al. [39] present the importance of monitoring and analyzing the network traffic to improve the customer experience and improving resource allocation of networks. Liu et al. [20] present the methodology to monitor and analyze the big data traffic with the help of Hadoop. Hadoop is mainly developed for batch processing, later on, used for large-scale data processing. It is a license-free Java-based distributed computing platform for big data. Google developed Hadoop for big data applications. In Hadoop, the Java language is used to write MapReduce code. The features of Hadoop are cost effective, high efficiency, scalability, tolerate the fault, and distributed concurrency computing. The significant primary challenge of Hadoop is tough to adapt it for network measurement. Recently, many research works have been carried out on QoE problems. Adaboost model presented to achieve higher accuracy which shows the relationship between the significances of the IPTV set-up box and QoE. An user-centric QoE prediction methodology depends on various machine learning algorithms such as artificial neural networks, decision tree, Gaussian Naïve Bayes classifiers, and vector regression tool. Sun et al. [4] present a decision tree video to model datasets, which achieves good service and enhance the users QoE. The main characteristics of this model provide the association between users QoE and alarming data for IPTV. The cross-layer prediction method was proposed to estimate the mobile video quality without any reference model. Recently, much research has been carried out on user-centric analysis and a likelihood of QoE based on a machine learning algorithm.

7 Opportunities

Despite all the challenges faced by the multimedia big data, it still offers considerable opportunities to the Internet of Multimedia Things (IoMT) to advance the facilities and applications through the efficient use of multimedia big data. With the proliferation of MEMS technologies, the IoT is well thought-out as one of the most transitions in today's technology. IoT offers more opportunities for multimedia big data analytics. Some examples of multimedia big data computing for IoT applications are as follows:

E-Commerce In this era, the growth of multimedia big data is very high as compared to traditional data. To process the large quantity of data in real time, the multimedia IoT big data analytics provides well-designed tools for decision-making. The integration of multimedia big data with IoT provides new challenges and openings to construct a smart environment.

Social Media Analytics collects the data from social media such as Facebook, Twitter, Google Plus, blogs, Wikipedia, etc., to analyses/statistics such data to gather the knowledge. Most of the E-commerce vendors are gathering the social media

analytics to gain business values, increase the sales and profits, customer satisfaction, build companies reputation, and create brand awareness among people.

Smart Cities The development of multimedia big data and evolution of IoT technologies have played a significant role in the initiatives of smart cities. The integration of IoT and multimedia big data is a promising new research area that brought more interesting challenges and opportunities for attaining the goal of future smart cities. IoT plays an important source for collecting a large amount of multimedia big data, which needs high-speed processing, analysis, and transmission. Tanwar et al. [40, 41] proposed an advanced security alert system architecture for smart home using pyroelectric infrared and raspberry pi module.

Healthcare: Big data has a huge potential to alter the healthcare industry. The smart healthcare devices produce a huge amount of information such as ECG, temperature monitors, sugar level, etc. The healthcare devices monitor real-time health data of patient, which reduces the overall cost for the prevention and management of illnesses. From the analysis of health data, the doctor could diagnose and detect diseases at an early stage. Due to the high-speed access to the internet, many people have started to utilize mobile applications to manage their health problems. These mobile applications and smart devices are integrated and act as a Medical Internet of Thing (MIoT).

The proper use of multimedia big data gathered from IoT increase economics, productivity and bring new visions to the world. Based on a literature review, the challenges are identified for multimedia big data analytics in Internet of Things (IoT).

8   Future Research Directions

Many of the organizations have widely acknowledged multimedia big data computing for IoT applications. Still, multimedia big data for IoT is in primary stages. Many current challenges have been not addressed. This section gives numerous challenges and its future research directions of multimedia big data computing for IoT applications.

8.1   Infrastructure

In this era, the amount of data generated from the IoT devices exceeds the computer resources. To analyze the multimedia big data, the manufacturers have to produce a high-volume solid hard disk drive to handle a massive volume of data. The solid disk drive replaced the conventional hard disk storage system. In the near future, a powerful processor is needed to process an enormous amount of multimedia big data. The diversity of real-time multimedia big data such as 3D graphics, audios, and videos are processed by more efficient Central Processing Unit (CPU) virtualization ad I/O virtualization needed, which reduces cloud computing cost. As already mentioned

that the primary source of generating multimedia data from the internet is IoT, which would need large data warehouses. Hadoop and Spark techniques would be used further to explore the data locality and transfer huge volume of big data to computing units over traditional High-Performance Computing (HPC).

8.2   Data Security and Privacy

Data security and privacy play a significant concern in multimedia big data. Still, most of the enterprises do not use the cloud to store their multimedia big data due to the nonexistence of data visibility and privacy in this new infrastructure. As mentioned earlier, data security and privacy have been a significant problem in the development of technologies and mobile devices (MIoT). The security storage and management of big data, privacy on data mining and analysis, access control are the possible mechanisms for multimedia big data. It does not increase the computational and processing cost. It should balance between access control and processing ease. The efficient security mechanism such as encryption of multimedia data is required to secure the multimedia big data. The privacy plays an significant issue in data mining. The privacy of data is achieved by encryption, anonymity, and temporary identification. Another security issue related to multimedia big data associated with IoT is the heterogeneity sources used and the nature of different types of data generated. The authentication of heterogeneous devices could be carried out by assigning a unique identification to the respective device. The architecture of heterogeneous IoT has increased the security risks to security professionals. Subsequently, any attack in IoT architecture compromises the security of the system and cutoff interconnected devices. The traditional security algorithm is not appropriate for IoT devices due to a dynamic observation of data. The security problems encountered by IoT big data are as follows: (a) dynamic updates—challenging to keep system updates, (b) identifying illegitimate traffic patterns among legitimate ones, (c) interoperability, (d) and protocol convergence—the application of Ipv4 security rules are not suitable for currently compatible IPv6.

Currently, these challenges are not addressed to accomplish the privacy and security of connected IoT devices. The subsequent strategies can overwhelme these difficulties such as (1) APIs is essential to evade compatibility and dependability problems. (2) IoT devices is well guarded while interconnecting with peers. (3) Protected devices with best-hardcoded security practices to resist against threats.

8.3   Data Mining

Data mining plays a significant part in multimedia big data, which is used to extract the interesting data for multimedia datasets. Multimedia datasets consist of structured and unstructured data such as videos, audio, images, speech, text, etc. The multimedia

data mining is further categorized as static and dynamic media. Examples of static media are text and images; dynamic media is audio and videos. The multimedia data mining mentions that the analysis of a massive amount of multimedia big data gathered from IoT devices to excerpt the useful information pattern depend on their statistical relationship.

Data mining methods offer solutions for multimedia big data to generalize for new data. IoT brought the challenges of data extraction. The main challenges related to data mining and processing are knowledge discovery, processing, and data. A large amount of big data faces the challenges due to volume, openness, exactness, and heterogeneity regarding data sources and data type. The big data sets are more irregularities and uncertainties in nature, which require additional preprocessing such as cleansing, reduction, and transmission. Recently, researchers have presented programming models based on concurrent, and serial processing and diverse algorithms are proposed to reduce the response time of query on big data. Researchers have an opportunity to address the bottlenecks of data mining in big data IoT.

8.4 Visualization

In big data analytics with IoT systems, the visualization plays a vital role in dealing with a large amount of data are generated. Visualization is difficult to process because of a large amount of data and its different dimensions. It is necessary to work faultlessly in big data analytics and visualization to obtain better results from IoT applications. Visualization is a difficult task in big data because of heterogeneous and various types of data such as structured, unstructured and semi-structured data. Designing visualization for IoT big data is an arduous task. Wang et al. [42] addressed the challenges and technology progress of visualization and big data. The visualization software is used to visualize the fine-grained dimensions based on the concept of the locality reference as well as the probability of identifying the correlations, outliers, and patterns. The concurrency is a thought-provoking task in visualization to manage the IoT big data. Most of the visualization tools used for IoT produced deprived performance regarding scalability, functionality, and response time. Gorodov et al. [43] addressed real-time analytics for IoT architecture issues of data visualization concerning the application of big data such as visual noise, information loss, great image observation, high-performance requirements due to the dynamic generation of data in an IoT environment.

8.5 Cloud Computing

The advancement of visualization technologies has motivated the development of cloud computing technologies. The cloud computing technologies characterized by virtual computers are constructed on top of the computing infrastructure. The main

limitations of cloud computing are cost of the massive amount of data storage, control over the distributed environment, security, privacy, and transfer. All these limitations is considered for future research directions.

8.6 Integration

Data integration denotes that the different formats of data can be viewed as uniform. Integration offers a single point of view of the data, which is gathered from heterogeneous sources. Multimedia big data are generated from different sources continuously. The produced data can be classified into three groups, namely, (1) structured, (2) unstructured, and (3) semi-structured. It extracts the information from different datasets. It is a challenging task to integrate different data types, and overlapping of the same data increases the scalability, performance, and enable real-time data access. These challenges related to the integration of data should be addressed in the near future.

8.7 Multimedia Deep Learning

The application of deep learning in computer vision, NLP, speech processing, etc., are growing faster as compared to current research in deep learning on multimedia big data analysis. The deep learning analysis of multimedia big data is yet in its initial stage of development. The different modularity of data needs to be analyzed using multimodal deep learning techniques. The future deep learning research is mainly focused on dealing with heterogeneous sources, high-dimensional, and un-named multimedia data. As compared to the traditional machine learning approaches, the computational efficiency of deep learning is remains a big challenge; because of the massive amount of resources and more training time is needed. The efficiency of deep learning techniques can be increased by using clusters of GPU. Lacey et al. [37] suggested the use of Field-Programmable Gate Arrays (FPGA) on deep learning, which provides an optimization, the large degree of parallelism and reduces the power consumption as compared to the GPU.

9 Summary

This chapter has presented the sophisticated approaches developed for multimedia big data analytics. The emergence of multimedia big data opens opportunities and draws more attention to researchers. First, introduce the general background of big data, challenges, and its application in multimedia big data. This chapter provides an extensive overview of the multimedia big data challenges, the impact of multimedia

big data in IoT, and characteristics have been discussed in 10 V's perspective. The different phases of multimedia big data such as data generation and acquisition, data representation, compression, processing and analysis, storage and retrieval, assessment, and computing have been discussed. Further, a comprehensive and organized framework has been discussed for each stage such as background, technical challenges, and review the recent updates in the area of multimedia big data. In addition, a list of opportunities for the multimedia big data has also been provided. In spite of all the challenges faced by the multimedia big data, it still offers huge opportunities to the Internet of Multimedia Things (IoMT) to advance the services and applications through the efficient use of multimedia big data. Many organizations acknowledged the development of multimedia big data for IoT applications. Multimedia big data for IoT is in the primary stage. These discussions aim to offer a broad overview, and perspective to make the significant advances in multimedia big data for IoT that meets futures requirement.

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