The Importance of Big Data in Handling and Managing COVID-19

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Abstract

This paper showed the importance of Big data analysis in understanding the nature of the COVID-19 Pandemic, the pattern of infection, and how the virus passes from one individual to the other. It highlighted the role of Big data in monitoring the disease outbreak in real-time Providing a visual overview of the outbreak, medical services, hospital equipment, and screening of contacts. The value of big data in constructing pandemic models that can predict accurately the trend of the outbreak and allows governments to make more informed and better decisions were discussed. Also, big data obtained from enrolling patient's treatments from all over the world helps us to know what treatments work and what does not work. The challenges of using Big Data on COVID-19 have also been discussed.

Keywords: *Big data, COVID -19, Hadoop, Apache Spark*

1.COVID-19

In December 2019, the outbreak of Severe Acute Respiratory Syndrome caused by Coronavirus type 2 (SARS-COV2) has started in the city of Wuhan in China and rapidly reached the entire countries of the world. On March 11, 2020, it was declared as a global pandemic by The World Health Organization (WHO).

Many different research studies have recently been published to better understand COVID-19, but the use of big data analytics in COVID-19 and its implementation is still undermined. This research highlights the role of data analysis by Hadoop and Apache spark and its implementations in COVID-19. The challenges of applying the Big Data application to COVID -19 were also addressed.

2. Big Data

Big data is huge amount of data that is not manageable using traditional programs as it overwrites the traditional capacity of storage and processing. Douglas Laney defined big data as data growing in three directions which are, volume, velocity, and variety (3 Vs) [1]. The main part of big data refers to the volume of the data whereas velocity means the speed of data collection, while variety indicates the heterogenic type of structured and unstructured data.

Other definitions added to this definition 4th V for 'veracity' [2].

The different sources of Big data that are used in COVID-19 are illustrated in figure 1.

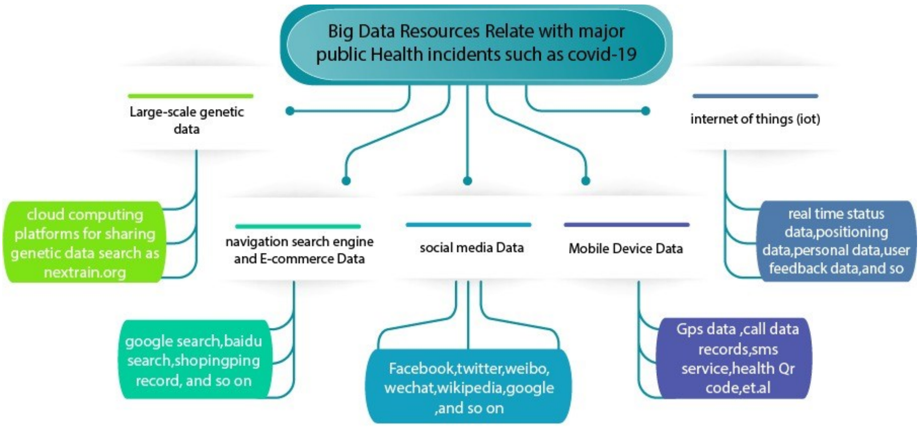

Figure 1. Taxonomy of big data resources associated with COVID -19

2.1 Internet of Things

The Internet of Things means a network that binds objects with computer chips and sensors to the Internet for data collection and transmission. It uses radio frequency identification tags and readers, and Near Field Communication devices that can collect information and interact physically.

It provides us with a stream of real-time information, personal data, positioning data from monitory the pandemic, the analysis of which reveals lots of information about the nature of the disease, the hospital equipment, and the precautionary measures that are taken.

2.2 Mobile Device Data

It is the data produced by mobile phones. Mobile devices use geo-location to track the movements of people and whether individuals have been exposed to cases of infection this enables experts to isolate the patients and treat them. The data liberated from cell phones gives a better understanding of the recent pandemic situation, the nature of the disease, and the precautionary regulations that should be taken.

Mobile device data also monitor people's compliance and which retail establishment's parks and other public spaces are still drawing crowds. It can measure the economic effect of the pandemic by monitoring the drop-off in retail customers at enterprises, the decrease in miles driven by cars, and shows the effects of the pandemic on other aspects of the economy. It also allows us to forecast how in future outbreaks the disease will spread and to consider the necessary interventions that need to be done [3].

2.3 Social Media Data

Social networking channels provide direct access to huge volumes of data for the prevention and control of diseases [4]. Social media sites such as Twitter, Facebook, and WeChat have become important resources for people's everyday life.

Taking WeChat as an example, every month there are over 1.15 billion active users [5]. Currently, WeChat has opened the "pandemic inspection" feature to supply the COVID-19 pandemic with prevention and control tools. Analyzing real-time data collected on these social networks can help a better understanding the time and geographical position of disease transmission.

The Quick Response (QR) code in healthcare, which is a two-dimensional barcode that reveals details on people's travel records and health status, is an effective practice that was developed in China to combat COVID-19. People are free to enter if the color of the code is green; otherwise, they are barred from entry. For ease of use, this program can be incorporated into We Chat (4).

2.4 Navigation and Search Engine Data

Navigation and search engine data provide important information that can be used in disease prevention and control. They have no direct rule on the diagnosis and treatment of patients, however, the important information they provide may indicate valuable data on how the disease developed and catch the interest of people in certain diseases.

Decision-makers can capture consumer needs and hotspots in real-time, based on search engine big data, to aid in pandemic prevention and control.

2.5 Large-Scale Genetic Data

Since the start of theCOVID-19 pandemic and the identification of the outbreak virus, Laboratories around the world provide data on the sequence of viral genomes that can help in performing the real-time, in-depth study of mutant microorganisms [6]. The genetic information derived from COVID-19 plays has a valuable role in monitoring the origin of the virus, finding the appropriate diagnostic tests, and developing drugs and vaccines.

In several countries, scientists and medical research centers are currently constructing different cloud computing models, such as Nextstrain.org [7], that allow scientists to track and exchange genome sequences in real-time, providing an accurate and real-time source for disease analysis.

Large-scale genetic data is collected and shared from all over the world on the website, and the virus transmission phylogenetic tree can be seen. Figure 2. shows a genomic analysis of the beginning and the evolution of the new coronavirus constructed on a platform. Mutations are displayed as colored circles and the viral sequences of similar mutation groups are shown.

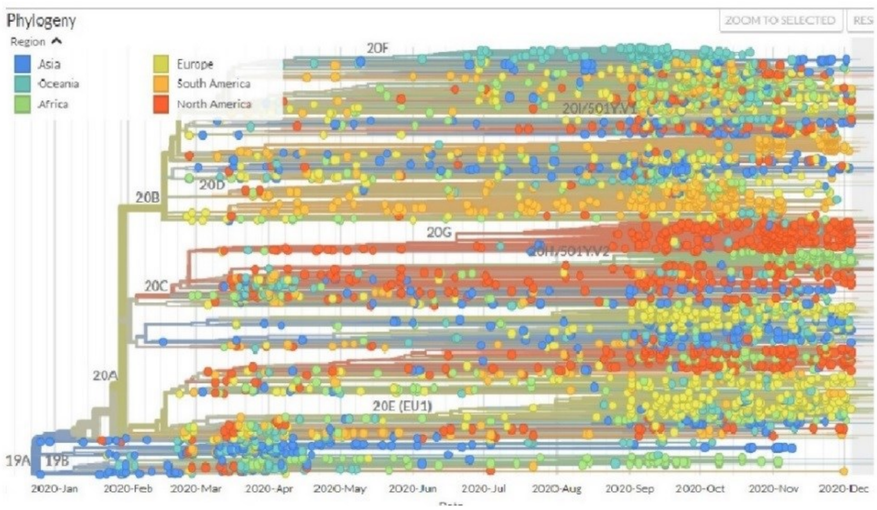

Figure 2.Next strain platform analysis of new coronavirus transmission genome [7]

3. Managing of big data

Big data elaborates enormous amounts of data that can't fit in the traditional computing clusters. Therefore, the best method to deal with such great amounts of data is by distributing and processing it in parallel on several nodes. But, since thousands of computers are needed to store and process such data in an acceptable time duration one has to consider open-source applications. Hadoop and Apache spark are the most popular open-source applications that can be used for this purpose.

First: Hadoop

Hadoop has become a well-known and outstanding processing tool for Big Data, it has secure storage and wonderful performance figure 3.

The Hadoop ecosystem has:

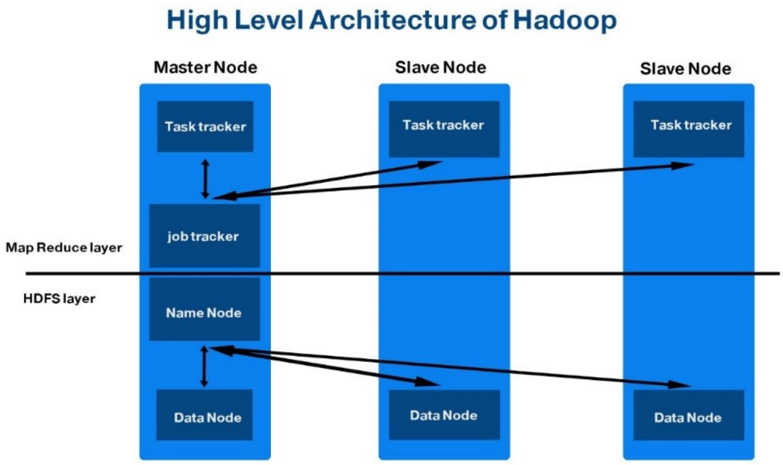

Figure 3.Structure of Hadoop

a- Hadoop Distributed File System (HDFS)

It manages massive data sets efficiently. It relies on Google File System to save data into several lumps after splitting data into small parts. It is a dispersed document structure that continues to run over the nodes' neighborhood record structures and can store massive volumes of large data suitable for gushing data.

HDFS has two nodes, Data Nodes and Name Node, which go around as a specialist [8]. These hubs are used for performing tasks such as perusing, composing, making, and omitting.

b- Map-Reduce

Map Reduce is a computational model that is used for writing distributed applications devised at Google for accurately processing huge amounts of data, on large clusters of commodity hardware in a precise manner. The Map Reduce is a program that runs on Hadoop which is an Apache open-source framework [9], The Map-Reduce algorithm contains two important functions, namely Map and Reduce figure 4. Firstly, The Map function is to process the input data by dividing the information into various nodes in a parallel way. Secondly, the reduce function is to process the data that was delivered from the mapper producing a new form of output that can be stored in the HDFS. The sequence of the name Map Reduce comes from the order of the jobs as the reduce task is always done after the map job.

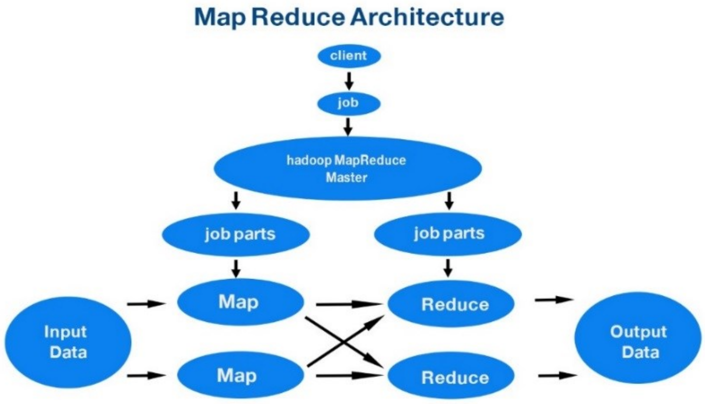

Figure 4.MapReduce Architecture

c- Other different components of Hadoop are [10]

ApachePig is a broad data set analysis software that consists of a high-level language similar in expressing data analysis to SQL, combined with infrastructure for evaluating these programs. It is composed of a compiler that generates Map-Reduce program sequences.

HBase is a distributed columnar database built to operate on top of the distributed file system of Hadoop (HDFS).

It is written in Java and is modeled after Google's Big Table.HBase is an example of a NoSQL data store.

Hive: it is used to perform Data warehousing jobs that provide the SQL interface and relational model.
Hive infrastructure is designed on the top of Hadoop to help in providing summarization, questions, and analysis.

Cascading: Hadoop abstraction software layer, intended to mask complexity of Map Reduce jobs. Cascading enables users of JVM based language to build and execute data processing workflows on Hadoop clusters.

Avro: It is a framework for data serialization and data sharing. It is used primarily with Apache Hadoop.

It is possible to use these programs together as well as separately.

Big Top: It is used for Hadoop ecosystem packaging and testing.

Oozie: is a web application built on Java that runs on Java software. Oozie uses the database to store the definition of Workflow that is a set of functions.

Apache Sqoop: is a platform designed to move large data between Hadoop and organized data stores such as relational databases efficiently.

Hadoop has many advantages: The Hadoop layout helps the user to easily write and evaluate distributed systems. It is powerful and automatically distributes the data and work over the machines and in turn uses the inherent parallelism of the cores of the CPU. Hadoop does not depend on hardware to make fault-tolerance and high availability (FTHA), but Hadoop has been constructed to find and manages failures at the application layer.

Second: Apache spark

Apache Spark is an open-source rapid processing structure used in data examination Figure 5. It can run over Hadoop HDFS. Spark, [11] the programming model is based on Hadoop Map Reduce and expands the Map-Reduce model effectively to more types of computations.

The key character of Spark is that the data is put in-memory cluster computing that increases the processing speed and makes it very useful for interactive programs, interactive queries with common parallel techniques such as join and match.

Spark was used to overcome the defect of Map-Reduce, by making processing in-memory, decreasing the number of steps in operations, and reusing the data across multiple parallel procedures.

Spark requires just one-step for data to be read into memory, operations performed, and the results written back resulting in faster execution. Spark often reuses data by using an in-memory cache to increase the speed of machine learning algorithms that repeatedly call a job on the same datasets. Data re-use is done by creating Data Frames, an abstraction of Resilient Distributed Datasets, a series of memory cached objects that are reused in several Spark operations. This significantly decreases the latency of Spark, especially when performing interactive analytics and machine learning, making it much faster than Hadoop Map-Reduce.

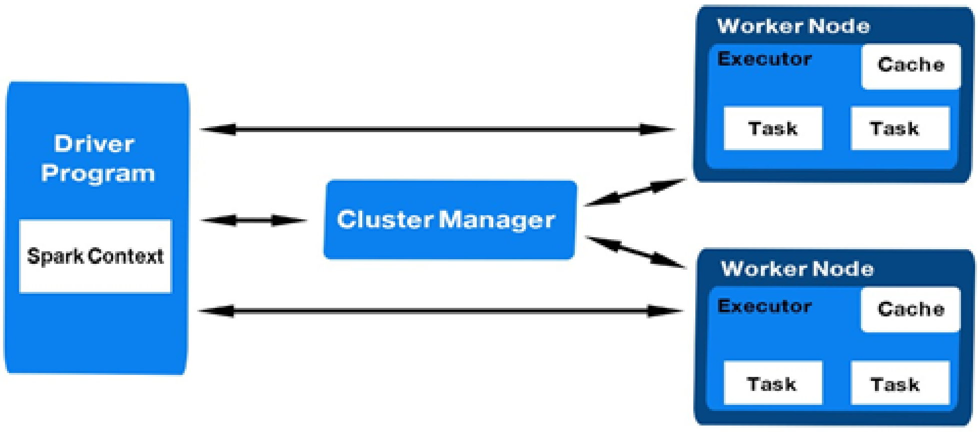

Figure 5.Apache Spark Architecture

4. Applications of big data in facing COVID-19

This section addresses the potential capabilities of Big Data in overcoming the COVID-19 pandemic through four main steps: virus visualization, prediction of outbreaks, diagnostic coronavirus tests, pharmacological treatment, and discovery of vaccine advances, as shown in Fig. 6.

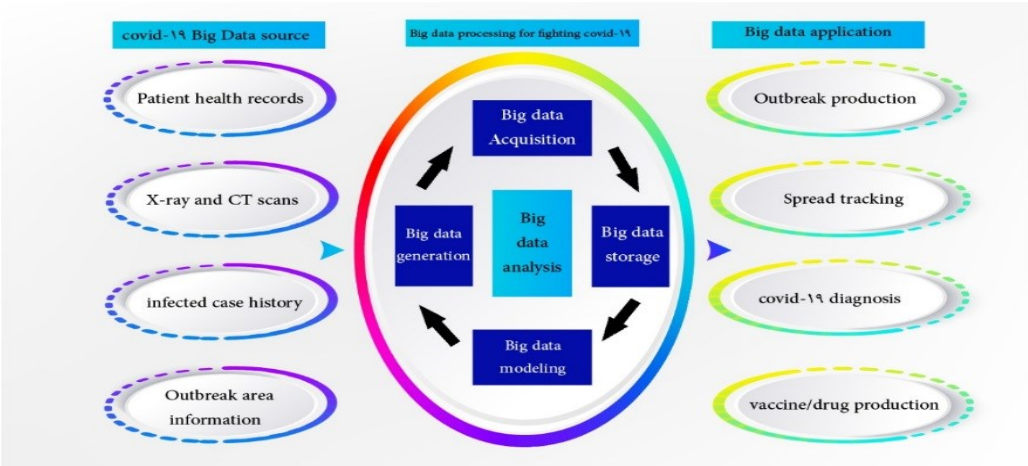

Figure 6. Big data and its applications for fighting COVID-19 pandemic

4.1 COVID-19 visualization

Big data can enable monitoring of disease outbreaks in real-time providing provides Visual analysis of the epidemic condition, medical services, hospital equipment, and precautionary measures taken to help in making proper decisions.

Visualization is done mostly through Geographical Information Systems (GIS), which is made of Computer hardware, software, and various methods. GIS technology should first be furnished with adequate big data after being converted into a digital format to better understand the spatial patterns and relationships, then processing and analysis of the data primarily through batch processes as Hadoop and Apache Spark.

The vector data topological relationship is automatically developed to realize spatial data coordinate transformation and compression processing, as well as spatial data inquiry and analysis [12].

Governments of all countries are currently using Big Data visual analysis to visualize key COVID-19 indicators in real-time, such as case data, disease spread, epidemic situation patterns, and hot areas figure 7.

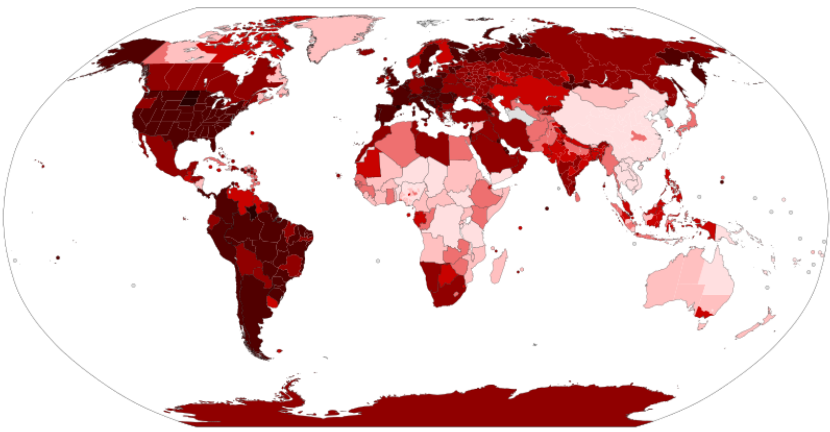

Figure 7.COVID-19 Outbreak World Map [13]

This provides people with clear information regarding the pandemic situation and aids governments to grasp the whole epidemic situation helping them to make proper decisions. Real-time visualization of the epidemiological situation is done through Google Maps by using interactive digital and virtual earth maps through Google Maps.

Outbreaks Near Me is a mobile application, that uses HealthMap [13] to help in real-time monitoring of the epidemic situation and safety of people [14].

These high-volume surveillance systems scan various organized and unorganized online data to identify and predict disease outbreaks and health problems.

4.2 Epidemic Analysis and Prediction:

Big data enables outbreak prediction. It provides sources that can implement different pandemic modeling.

Grover [15] suggested different machine learning techniques and algorithms that can analyze and predict models of the current epidemic via applications like Twitter, Markov chain model divided the epidemic into three different stages (epidemic initiation, spread, and regression) and developed a new epidemiological prediction model.

There are numerous applications of mathematical models that are applied to social media data for better analysis of the epidemic condition including susceptible–infectious–recovered (SIR) models [16], and Susceptible, exposed, infectious, and removed (SEIR).These models are based on the assumption that the population remains unchanged, the patient has some degree of infectiousness after exposure to a susceptible person, and the number of individuals removed from the number of patients per unit of time is proportional to the number of patients. But as the immunity developed after COVID-19 infection is only temporal, therefore we should add recovered individuals back to S, making it SIRS or SEIRS.

A system of differential equations for different groups of people can be developed over time on the basis of these models, which can in turn predict the inflection point and the peak value of the epidemic [17].

For example, a parametric model and a non-parametric model were adopted by Dorigatti et al. [17] to estimate the lethality of the new coronavirus.

Also, Qin and coworkers [18] used Big Data to estimate the number of suspected new COVID-19 cases. Moreover, scientists used searches in the "Social media search indexes" (SMSI)forCOVID-19 keywords such as fever, dry cough, sore throat, loss of taste, and pneumonia.

The authors found that new suspected COVID-19 cases could be identified 6-9 days in advance by using the subset selection method. The combination of these infectious disease models will more accurately forecast the pattern of an outbreak along with real-time monitoring of big data. They can also change the public policy, the quarantine, business, and the arrangements of flights.

Wu et al. [19] deemed the effects of China's quarantine policy and found that the new coronavirus had spread domestically and globally.

In order to construct a dynamic transmission, Yang and colleagues [20] used population migration data, combining the "Susceptible-Exposed-Infectious-Removed" (SEIR) model with an AI method trained on SARS data to predict the COVID-19 pandemic curve. They predicted that it would appear in China in mid and late February and then decline steadily until the end of April.

Based on the artificial intelligence deep auto-encoders (DAE) system, the researchers predicted the evolution of the epidemic situation in 34 provinces in China, concluding that the epidemic would end by mid-April.

Owing to uncertainty about the factors affecting the epidemic, such as the second peak, the forecast may not be entirely accurate, but taking into consideration such influencing factors as the second peek of the virus, the second the development pattern of an epidemic can be predicted.

This type of modeling and research serves as a significant guide for decisions makers in considering the restoration of jobs, economic restoration, and the resuming of the normal social life.

4.3 Diagnosis of COVID-19 by Big data

Big data has an essential role in determining the sensitivity and the specificity of various diagnostic tests that are used for SARS-CoV-2detection such as:

4.3.1Nucleic acid amplification test (NAAT)

It requires detection of SARS-CoV-2 RNA by reverse transcriptase-polymerase chain reaction (RT – PCR)

It's a reliable, sensitive, and specific diagnostic test in the detection of COVID-19. Optimal diagnostics consist of a NAAT assay with at least two independent targets on the SARS-CoV-2 genome.

4.3.2 Antigen testing

Antigen testing detects specific protein on the surface of coronavirus which is known as (spike protein),this protein helps the entry of the virus into the human cell and elicits the body's immune response.

World Health Organization (WHO) recommends the use of 2SARS-CoV-2 Ag-RDTs with a value of ≥80% sensitivity and ≥97% specificity compared to PCR.

The WHO recommends the use of the end 2SARS-CoV-2 Ag-RDTs in situations where the NAAT is not available or when the patient has to wait long in order to make the NAAT, or in outbreak monitoring.

The WHO is working closely on big data for evaluating the performance and operational characteristics of commercialized SARS-CoV-2 antigen detecting RDTs to systematically compile the evidence as it emerges and coordinate updates. Currently, there is insufficient evidence on performance and operational use to recommend specific commercial products.

4.3.3 Viral isolation

Virus isolation is not used in routine diagnostic tests.

4.3.4 Combining big data with Artificial Intelligence (AI)

Combining big data with Artificial Intelligence can facilitate the diagnosis of COVID-19 cases. Infer vision is a software program that performs deep learning on diagnostic scanning to help in facilitating the diagnosis of COVID-19 by detecting its peculiar lung characteristics21].

Furthermore, block chain technology is a unique decentralized system of recording, verifying, and approving data and carrying out a series of transactions.

It is characterized by a high level of security and enables the delivery of patient-centered healthcare services, enhanced public health surveillance, management of outbreaks and a quick and effective decision-making process [22].

A low-cost block-chain and AI-coupled self-assessment and tracking model have been proposed for managing theCOVID-19 pandemics, in developed settings (to avoid overwhelming and straining public health capacity and healthcare/laboratory infrastructure) and in developing, resource-limited contexts [22].

4.4 Treatment

4.4.1 Identifying a Potential Pharmacological Treatment

There are several medications that are used to treat COVID-19. However, none of them are officially approved.

Physicians provide patience with supportive and nutritional care.

There are several approaches used to search for appropriate medications, which are:

- Using already existing anti-viral drugs.
- Modifying existing anti-viral drugs to suit the biophysical and biochemical nature of the virus.
- Repositioning pharmaceutics that are used for other therapeutic options [23].

The virus is destroyed by one of the following mechanisms:

- Interfering directly with it.
- Inhibiting viral entry and replication.
- Strengthening the human immune system.

Advancements in the genomic and post-genomic fields help to know genome sequences, find similarities with other genomes, and discovering potential therapeutic targets.

Big Data helps to investigate more than 2500 small molecules that are already approved by FDA. These drugs were first screened and validated by a molecular docking software named Glide[24].As a result, fifteen out of twenty-five drugs had an inhibitory effect on SARS-COV2 and could be used in trials against COVID-19.

The WHO uses big data to recruit patients in the Solidarity Trial from over 100 countries, including patients currently being treated in hospitals, for discovering whether either of the medications delays the progression of the disease or enhances survival. Based on emerging data, some medicines can be used.

4.4.2 Corona Virus Vaccine

Efficient vaccines with wide margin of safety will be important tools to minimize and end the pandemic of COVID-19 .

However the development of vaccines is a long process that consumes many years but with the help of big data from many countries, it was possible to develop a COVID-19 vaccine in just 332 days, on December 2020, WHO provided the Pfizer –BioNTech COVID - 19 mRNA vaccine emergency validation. Moreover, there are more than 200 additional vaccine candidate (56 in clinical and 166 in preclinical development)from 172 economies enrolled in clinical trials. Big data also have an essential role in the fair distribution of vaccines.

COVAX is co-led by the Coalition for Epidemic Preparedness Innovations (CEPI), the Vaccine Alliance, and the World Health Organization (WHO) – working for a fair allocation mechanism through the COVAX facility.

4.5Applications of Big Data and Artificial Intelligence for better management of future pandemic

In order to enhance the efficiency of health, transport, electricity, education, and water services one has to consider smart cities as they use different innovations, contributing to a higher degree of satisfaction for their residents. In addition to interacting more effectively with their people to reduce costs and consumption of energy.

One of the latest technology that has tremendous potential is to support smart city services with big data analytics. As digitization is now integrated into our daily life, this leads to the collection of ahuge amount of data that can be used in different advantageous application domains. Successful analysis and application of big data is a player in the success of many enterprise and utility domains, including the smart city domain,

Jones [25] investigated the COVID-19 outbreak adopting an urban standpoint, showing how smart cities and smart networks can guarantee high-quality, enhanced standardized protocols for data sharing during emergencies, for better pandemics managements.

5.Challengesand Suggestions

Big data has great potential in the fight against the pandemic of COVID-19. It still faces various challenges, however, such as:-

5.1Accuracy of the data

Accuracy in collecting, revising, organizing and analyzing, data, represents a fundamental point. With the continuous spread of the disease, enormous amounts of information are produced online, but their importance is hidden behind the noise in the data, resulting in multiple debates about several issues for example the appropriate distance that should be kept between individuals, the susceptibility of the virus to heat, the ability of virus transmission through air, and the duration that the virus can survive on different surfaces. Yet there are several methods for providing clean and reliable data quality and measuring uncertainty about the estimates drawn, such as analyzing data sensitivity and testing simulation systems for certainty. Accountable and authoritative organizations should directly provide clean and accurate data. For example, the public GitHub repository maintained by the Center for Systems Science and Engineering of Johns Hopkins University has grown to become a standard resource for people interested in analyzing the spread of COVID-19.

5.2Lack of standard datasets

Making the datasets functional is challenging, the data from different sources need to be harmonized. For example, the different organizations may use different codes to demonstrate the same item, besides, some organizations may have more varieties in each item. This requires scientists to make sure that all these data are combined in a meaningful and accurate way.

5.3Collaboration

COVID-19 pandemic affects the lives and well-being of the whole world. Global cooperation on Big Data Sources and the applications of different policies, medical treatments, and researches are important in providing an open flow of epidemiological and clinical data [26].This collaboration is still missing among most institutes and individuals. The WHO and several scientific research institutes, however, play an important role in the collaboration of Big Data across a range of countries with varying levels of economic growth, including less developed countries, in order to help prevent and monitor epidemics.

5.4Privacy and security challenges

Although big data has a great role in pandemic control yet it raises the concern of the public regarding the security and privacy of the data. There should be firm regulations, contradictions, and legalization for using such data. For instance, The Information Commissioner's Office in the United Kingdom, the European Data Protection Board, South Korea, and Israel, have all issued statements about the use of personal data during the COVID-19 crisis and the use of mobile data to monitor infected cases [27].

6. Conclusion

This paper discussed the importance of big data in the battle against COVID-19. Firstly, it provided a brief introduction to COVID-19. Big data collection channels such as the Internet of Things, mobile devices, social media, search engines, and large-scale gene banks were addressed. Big data analysis tools like Hadoop and Apache Hadoop were discussed. Then the application of big data for the COVID-19 pandemic was reviewed, including COVID-19 visualization, outbreak prediction, diagnostic tests, treatment, vaccine, and vaccine distribution. Finally, the challenges that face big data in the battle against COVID -19 were discussed and solutions to these challenges were provided.

References

[1]. Laney D. 3D data management: controlling data volume, velocity, and variety, Application delivery strategies Stamford: META Group Inc; 2001.

[2]. Mauro AD, Greco M, Grimaldi M. A formal definition of big data based on its essential features. Libr Rev. 2016;65(3):122–35

[3]. Wesolowski A., Buckee C.O., Engø-Monsen K., Metcalf C.J.E. Connecting mobility to infectious diseases: The promise and limits of mobile phone data. J. Infect. Dis. 2016; 214:S414–S420. doi: 10.1093/infdis/jiw273. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[4]. Althouse B.M., Scarpino S.V., Meyers L.A., Ayers J.W., Bargsten M., Baumbach J., Brownstein J.S., Castro L., Clapham H., Cummings D.A.T., et al. Enhancing disease surveillance with novel data streams: Challenges and opportunities. EPJ Data Sci. 2015;4:17. doi: 10.1140/epjds/s13688-015-0054-0. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[5]. Statista Number of Monthly Active WeChat Users from 2nd Quarter 2011 to 1st Quarter 2020. [(accessed on 11 November 2020)]; Available online: https://www.statista.com/statistics/255778/number-of-active-wechat-messenger-accounts/

[6]. Zhou P., Yang X.L., Wang X.G., Hu B., Zhang L., Zhang W., Si H.R., Zhu Y., Li B., Huang C.L., et al. A pneumonia outbreak associated with a new coronavirus of probable

bat origin. Nature. 2020;579:270–273. doi: 10.1038/s41586-020-2012-7. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[7]. Nextstrain Genomic Epidemiology of Novel Coronavirus-Global Subsampling. [(Accessed on 20December 2020)]; Available online: https://nextstrain.org/ncov/global?c=region.

[8]. Chavan, V., &Phursule, R. N. (2014). Survey paper on big data. Int. J. Comput. Sci. Inf. Technol, 5(6), 7932-7939.

[9]. Kyong-Ha Lee HyunsikChoi "Parallel Data Processing with Map Reduce: A Survey" SIGMOD Record, December 2011 (Vol. 40, No. 4)

[10]. Wong, Z.S.Y.; Zhou, J.; Zhang, Q. Artificial Intelligence for infectious disease Big Data Analytics. Infect. Dis. Health 2019, 24, 44–48. [Google Scholar] [CrossRef]

[11]. Apache Spark, http://spark.apache.org/

[12]. Graham M., Shelton T. Geography and the future of big data, big data and the future of geography. Dialogues Hum. Geogr. 2013;3:255–261. doi: 10.1177/2043820613513121. [CrossRef] [Google Scholar] .

[13]. HealthMap [(accessed on 18 December 2020)]; Available online: http://www.healthmap.org.

[14]. Nagar R., Yuan Q., Freifeld C.C., Santillana M., Nojima A., Chunara R., Brownstein J.S. A case study of the New York City 2012–2013 influenza season with daily geocoded Twitter data from temporal and spatiotemporal perspectives. J. Med. Internet Res. 2014;16:e236. doi: 10.2196/jmir.3416. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[15]. Grover S., Aujla G.S. Prediction model for influenza epidemic based on Twitter data. Int. J. Adv. Res. Comput. Commun. Eng. 2014;3:7541–7545. [Google Scholar]

[16]. Daszak P., Cunningham A.A., Hyatt A.D. Emerging infectious diseases of wildlife—Threats to biodiversity and human health. Science. 2000;287:443–449. doi: 10.1126/science.287.5452.443. [PubMed] [CrossRef] [Google Scholar]

[17]. Dorigatti I., Okell L., Cori A., Imai N., Baguelin M., Bhatia S., Boonyasiri A., Cucunubá Z., Cuomo-Dannenburg G., FitzJohn R., et al. Ferguson Report 4: Severity of 2019-Novel Coronavirus (nCoV) Imperial College London; London, UK: 2020. pp. 1–12. [Google Scholar]

[18]. Qin, L.; Sun, Q.; Wang, Y.; Wu, K.F.; Chen, M.; Shia, B.C.; Wu, S.Y. Prediction of Number of Cases of 2019 Novel Coronavirus (COVID-19) Using Social Media Search Index. Int. J. Environ. Res. Public Health 2020, 17, 2365. [Google Scholar] [CrossRef]

[19]. Wu J.T., Leung K., Leung G.M. Now casting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: A modelling study. Lancet. 2020;395:689–697. doi: 10.1016/S0140-6736(20)30260-9. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

[20]. Yang, Z.; Zeng, Z.; Wang, K.; Wong, S.S.; Liang, W.; Zanin, M.; Liu, P.; Cao, X.; Gao, Z.; Mai, Z.; et al. Modified SEIR and AI prediction of the epidemics trend of COVID-19 in China under public health interventions. J. Thorac. Dis. 2020, 12, 165–174. [Google Scholar] [CrossRef]

[21]. McCall, B. COVID-19 and artificial intelligence: Protecting health-care workers and curbing the spread. Lancet Digit. Health 2020, 2, e166–e167. [Google Scholar] [CrossRef]

[22]. Mashamba-Thompson, T.P.; Crayton, E.D. Blockchain and Artificial Intelligence Technology for Novel Coronavirus Disease-19 Self-Testing. Diagnostics 2020, 10, 198. [Google Scholar] [CrossRef]

[23]. CoV2): A global emergency that needs new approaches? Eur. Rev. Med. Pharmacol. Sci. 2020, 24, 2162–2164. [Google Scholar] [PubMed]

[24]. Richard, A. F.;Robert B. M. Glide: A New Approach for Rapid, Accurate Docking and Scoring.Method and Assessment of Docking Accuracy , Journal of Medicinal Chemistry 2004 , 47(7):1739-49 ,[PubMed]

[25]. Rao, A.S.R.S.; Vazquez, J.A. Identification of COVID-19 Can be Quicker through Artificial Intelligence framework using a Mobile Phone-Based Survey in the Populations when Cities/Towns Are Under Quarantine. Infect. Control Hosp. Epidemiol. 2020. [Google Scholar] [CrossRef]

[26]. Carni Y. Why Greater Access to Global Data Is Vital to The Fight Against COVID-19 and Future Pandemics. Forbes. [(Accessed on 15 November 2020)]; Available online: https://www.forbes.com/sites/startupnationcentral/2020/05/04/big-data-COVID19-coronavirus-israeli-startups/#646501ed78b4.

[27]. Privacy Laws & Business ICO, EDPB Issue Guidance on Data Protection and the COVID-19 Coronavirus Pandemic. [(Accessed on 10 October 2020)]; Available online: https://www.privacylaws.com/news/ico-edpb-issue-guidance-on-data-protection-and-the-COVID-19-coronavirus-pandemic/