

Artificial Intelligence and Data Science in the Detection, Diagnosis, and Control of COVID-19: A Systematic Mapping Study

Verónica Tintín[1] and Hector Florez[2(✉)]

[1] Universidad de las Fuerzas Armadas ESPE, Sangolquí, Ecuador
[2] Universidad Distrital Francisco Jose de Caldas, Bogota, Colombia
haflorezf@udistrital.edu.co

Abstract. On March 11 2020, the World Health Organization (WHO) announced that the new COVID-19 disease, caused by the SARS-CoV2 could be considered a pandemic. Both this new virus and the disease it causes were unknown before the outbreak in Wuhan (China) in December 2019. Since then, the number of infections has grown exponentially causing the collapse of health-care systems, as well as socio-economic structures of countries around the world. The objective of this study is to give an overview of the application of Artificial Intelligence and Data Science in the control of the pandemic through a systematic mapping of scientific literature that determines the nature, scope and quantity of published primary studies. The research was carried out using the databases Scopus, IEEE Xplore, PubMed Central and the global research database of the World Health Organization. Thus, 372 studies were identified that met the inclusion criteria. The application of artificial intelligence techniques was observed, such as neural networks, deep learning, and machine learning in some areas including detection and imaging diagnosis, prediction of new outbreaks and mortality, social distancing, among others. In data analysis, artificial intelligence has become an important tool in the fight against COVID-19 and this study may be useful for the scientific community to direct future research into less-investigated areas.

Keywords: Artificial intelligence · Data science · COVID-19 · Deep learning · Machine learning

1 Introduction

The COVID-19 epidemic was declared by the World Health Organization (WHO) as a public health emergency of international concern on January 30 2020, and on March 11 2020, this organization announced that the new COVID-19 could be characterized as a pandemic [26,55,56].

In this pandemic crisis, the scarcity of resources and medical personnel has caused major problems in the health systems [14,36], and a negative impact on

© Springer Nature Switzerland AG 2021
O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12957, pp. 354–368, 2021.
https://doi.org/10.1007/978-3-030-87013-3_27

the socioeconomic structures of all countries around the world. Due to this, the COVID-19 pandemic poses a series of challenges for the artificial intelligence community. Among these challenges there are the tracking and predicting of the spread of the infection, conducting diagnoses and forecasting, social control, search for treatments and vaccines, among others [43].

As the virus advances at pandemic speed, scientists have been working and publishing their research on the application of artificial intelligence and data science by combining traditional mathematical and statistical models with sophisticated models from Machine Learning and Deep Learning, including the use of technologies such as the Internet of Things (IoT) and Big Data [58].

Recent studies have revealed that Machine Learning, Deep Learning and Artificial Intelligence are promising technologies used by various healthcare providers, as they allow to improve scale, accelerate processing capacity, be reliable and even outperform humans in tasks specific healthcare [39]. Therefore, healthcare industries and physicians around the world are employing these technologies to cope with the COVID-19 pandemic and provide decision support tools on what has been modeled.

In this study, a systematic mapping of scientific literature is carried out using the databases of Scopus, IEEE Xplore, PubMed and the global research database of the World Health Organization to collect the most recent information from peer reviewed articles published in scientific journals and international conference proceedings, which demonstrate the use of artificial intelligence techniques and data science in the context of the COVID-19 pandemic.

2 Method

2.1 Systematic Mapping Study

A systematic mapping study is a method that consists of a literature survey on an area of interest, in order to determine the nature, scope, and quantity of published primary studies, as well as to give an overview of the area under study through the classification and counting of literary contributions [46]. The fundamental objective is to identify, categorize, and analyze in the existing literature what is relevant to a given research topic. The steps of the systematic mapping process are: request questions, search strategy, selection of primary studies, data extraction, analysis, classification, and verification.

2.2 Research Questions

The structure of this study follows the guidelines established in the Petersen guidelines for conducting systematic studies in software engineering in order to answer the following research questions:

- RQ1: How many studies have been reported identifying artificial intelligence and data science techniques for the detection and control of COVID-19?

- RQ2: Which artificial intelligence and data science techniques are being used for the detection and control of COVID-19?
- RQ3: What are the characteristics of the techniques found and in which areas are they being applied?
- RQ4: What is the effectiveness of the techniques found in the detection and control of COVID-19?

The research questions were developed with the purpose of giving an overview of the research that has being carried out to combat COVID-19 in the field of data science and artificial intelligence. In this context, techniques and tools used are identified for diagnosis, prediction, outbreak control, sentiment analysis, contact tracing, drug development, fake news, etc.

2.3 Search Strategy

For the design of the research strategy, the PICO strategy was used, which identifies four key components: Population, Intervention, Comparison, and Outcome [35,46]. This strategy allows adjustment of the appropriate terms to structure the search chain in the different bibliographic sources and answer the research questions posed. In this study, no empirical comparison was made. Thus, the terms determined are: *Population*: `coronavirus`, `COVID-19`, or `SARS-CoV-2`; *Intervention*: `data science`, `data analytics`, or `artificial intelligence`; and *Outcome*: `prediction`, `diagnosis`, `forecast`, `detection`, or `forecasting`. Since no empirical comparison is made between the intervention alternatives, this component as well as the results are omitted as a relevant consequence of interest.

Four bibliographic databases were used for the selection of the primary studies: IEEE Xplore, Scopus, MEDLINE, which can be accessed via PubMed Central, and the World Health Organization global research database that compiles the latest research reports on COVID-19. The world documentation cited in the WHO COVID-19 database is updated daily from searches of bibliographic databases, manual searches, and other scientific articles referred by experts.

Definition of the Search String. The search string was constructed based on the structuring of regular expressions formed with keywords determined in the PICO strategy, linked with the logical AND/OR connectors and applied to the titles and abstracts. For each base the following search string was defined:

- IEEE Xplore: ((“Document Title”: “coronavirus” OR “Document Title”: “COVID-19” OR “Full Text Only”: “SARS-CoV-2”) AND (“Full Text Only”: “data science” OR “Full Text Only”: “data analytics” OR “Full Text Only”: “artificial intelligence”) AND (“Full Text Only”: prediction OR “Full Text Only”: “diagnosis” OR “Full Text Only”:“forecast” OR “Full Text Only”: “forecasting” OR “Full Text Only”: “detection”))
- Scopus: (TITLE-ABS-KEY (“coronavirus”) OR TITLE-ABS-KEY (COVID-19) OR TITLE-ABS-KEY (“data science”)) AND (TITLE-ABS-KEY (“data analytics”) OR TITLE-ABS-KEY (“SARS-CoV-2”) OR TITLE-ABS-KEY

("artificial intelligence")) AND (TITLE-ABS-KEY (prediction) OR TITLE-ABS-KEY (diagnosis) OR TITLE-ABS-KEY (forecast) OR TITLE-ABS-KEY (detection) OR TITLE-ABS-KEY (forecasting))
- PubMed(("coronavirus" [Abstract] OR "COVID-19" [Abstract] OR "SARS-CoV-2" [Abstract]) AND ("data science" [Abstract] OR "data analytics" [Abstract] OR "artificial intelligence" [Abstract]) AND ("prediction" [Abstract] OR "diagnosis" [Abstract] OR "forecast" [Abstract] OR "forecasting" [Abstract] OR "detection" [Abstract]))
- WHO: (tw:("COVID-19") OR tw:("SARS-CoV-2") OR tw:("coronavirus")) AND (tw:("artificial intelligence") OR tw:("data science") OR tw:("data analytics")) AND (tw:("prediction") OR tw:("diagnosis") OR tw:("forecast") OR tw:("forecasting") OR tw:("detection"))

The Mendeley tool was used for the management of bibliographic references and the reference period for the search was from January 2020 to the second week of February 2021. The number of results for each database are: IEEE Xplore: 264, Scopus: 340, PubMed: 193, and WHO: 262.

2.4 Selection of Primary Studies

The Backward Snowball Sampling Method was used for the selection of studies. Articles that did not meet the criteria of basic language, period of publication type, and peer review were excluded. Duplicate articles were eliminated. The inclusion and exclusion criteria were applied to titles and abstracts. Many of them were not clearly identifiable, so the full text was read. The following inclusion and exclusion criteria were applied:

Inclusion Criteria

- Studies in English peer-reviewed in conferences, journals and included in the COVID-19 Open Research Dataset, published from January 2020 to the second week of February 2021.
- Studies in which the application of artificial intelligence in the diagnosis, detection, and control of COVID-19 is identified.
- Studies in which the application of data science in the detection and control of COVID-19 is identified.
- Studies that demonstrate the effectiveness of artificial intelligence and data science in the detection and control of Covid-19, either in case studies or proofs of concept.

Exclusion Criteria

- Studies that are not written in the English language in full text and that have not been peer reviewed.
- Secondary studies corresponding to third-party studies.

The number of included articles during the study selection process are: apply search on databases: 1059 results, remove duplicates: 730 results, apply inclusion/exclusion criteria: 478 results, and full text reading: 372 results.

2.5 Data Extraction

From the total of selected main studies, it was necessary to extract the relevant information to determine the number of studies that answer the research questions. The bibliographic manager made it possible to extract the relevant information from each publication and generate a report with the data shown in Table 1:

Table 1. Data extraction form.

Data item	Value
Type	Type of article, conference article or journal article
Author	Names of the authors of the document
Date	Date of document
DOI	Digital Object Identifier
Library Catalog	DataBase where the article is hosted
Conference	Conference Name
Abstract	Article Summary
Keywords	Author keywords
Url	Resource locator
Files	Full text file

2.6 Analysis, Classification and Validity Verification

The analysis and classification was carried out using the SciMAT software (Science Mapping Analysis Software Tool). SciMAT is an open source tool that performs a scientific mapping analysis of bibliography under a longitudinal framework to analyze and track the conceptual, intellectual or social evolution of a research field over consecutive periods of time [16]. Strategic diagrams, cluster networks, and areas of evolution were used to better understand the results and to identify the thematic areas that are the object of this research.

The verification of the studies quality was carried out by reading the abstracts of the documents. The full text was read of incomplete documents to verify that the selected studies meet the following quality criteria:

- Does the selected study contribute to answering the research questions?
- Does the selected study contain references to studies published in journals or conferences?
- Is the study based on research: case study or proof of concept?
- Is there a clear statement of the research objectives?
- Is there a clear statement of the results?

3 Results and Discussion

3.1 Frequency of Publication (RQ1)

The number of selected articles published in 2020 were 306, while the number of selected articles published in 2021 were 66. Moreover, the number of selected article published in journals were 218, while the number of selected articles published in conferences were 154.

From the 218 selected articles published in journals, 23 were published in the IEEE Access journal, which is an open access scientific journal with continuous publication frequency and impact factor of 3,745. From the 154 articles published in conferences, 44 were published at conferences sponsored by IEEE, a global organization dedicated to the advancement of technology. Table 2 shows the main scientific journals of the selected articles. In general, it can be observed that the IEEE journals are preferred.

Table 2. Targeted Venues.

Journal/Conference	Articles
IEEE Access	23
IEEE Internet of Things Journal	9
Chaos, Solitons and Fractals	8
IEEE Journal of Biomedical and Health Informatics	7
Computers, Materials and Continua	6
Scientific Reports	5
Applied Intelligence	4
Journal of Medical Internet Research	4
European Radiology	4
Medical Image Analysis	4
IEEE Transactions on Medical Imaging	4
PLoS ONE	3
Informatics in Medicine Unlocked	3
Process Safety and Environmental Protection	3
Radiology	3
IEEE Sensors Journal	3
IEEE Transactions on Industrial Informatics	3
IEEE Transactions on Computational Social Systems	3
Applied Sciences (Switzerland)	3
Others	116
Total	**218**
IEEE Advancing Technology for Humanity	44
ACM International Conference Proceeding Series	4
Advances in Intelligent Systems and Computing	4
Others	102
Total	**154**

3.2 Identified Techniques (RQ2)

From the selected papers, we identified supervised classification and regression algorithms as well as unsupervised clustering algorithms. 66.13% of the papers uses Neural Networks, 6.45% uses Support Vector Machine, 5.38% uses Long Short Term Memory, 4.03% uses Random Forest, 3.76% uses Decision Tree, 3.23% uses Naive Bayes, 2.42% uses Logistic Regression, 2.42% uses Gaussian Process Regression, 2.15% uses Fuzzy C-Means, 1.88% uses K Nearest Neighbors, 0.81% uses K Means Clustering, 0.81% uses Linear Regression, 0.27% uses Hidden Markov Model, and 0.27% uses Support Vector Machine Regression.

The aforementioned algorithms were used in combination with other algorithms, techniques, statistical models and mathematical models, such as those shown in Table 3 to optimize and balance the prediction models in several studies:

Table 3. Additional algorithms, techniques and models used.

Item	Reference
ADAptive SYNthetic (ADASYN)	[9]
Differential Evolution (DE)	[60]
Particle Swarm Optimization (PSO)	[8,23,27,44,52]
Principle Component Analysis (PCA)	[8]
Sequential Minimal Optimization (SMO)	[1]
AdaBoost	[28,31]
Prophet	[4]
ARIMA	[4,15,20,25,38,49,50,54]
Stacked Long Short-Term Memory (SLSTM)	[20]
Marine Predators Algorithm (MPA)	[2]
Single Shot Detector (SSD)	[40,57]
Guided Whale Optimization Algorithm	[23]
Stochastic Fractal Search (SFS)	[23]
Epidemiological models: SEIR – SIR – SIRQ - SIRD	[4,6,12,34,45,60–62,64]
Time Series	[13,17,24,32,38,42,48,52,54]

According to [5], the convergence between data science, Big Data, advanced analytics, artificial intelligence, among others present various research and development options to combat COVID-19. In the same way, [18] states that data science is the most imperative part of medical science and is contributing significantly to finding solutions to the greatest existing obstacles in the face of the pandemic. Some of the traditional models mentioned in Table 3 have been used in the past and have given reliable prediction results, but due to the increasing complexity of COVID-19 data sets, it is necessary to combine them with recent trends in data science, including big data and the Internet of Things [44].

With many success stories, Machine Learning (ML) and Deep Learning (DL) have been widely used in our everyday lives in various ways. They have also been instrumental in addressing the Coronavirus (COVID-19) outbreak, which has been occurring around the world.

In addition, based on the approach of how machines can learn, two approaches are a subset of artificial intelligence which is being widely used to address the COVID-19 outbreak [3]. The results show the following percentages: Machine Learning (43.72%) and Deep Learning (56.28%).

3.3 Topics and Features (RQ3)

372 studies have been identified exploring different areas in which Artificial Intelligence and Data Science have been shown to be effective in the fight against COVID-19. The percentage of studies according to the areas of application are: Diagnostic imaging (50.92%), Analysis and prediction of the spread (18.45%), Detection of masks by facial recognition (4.06%), Social distancing (4.06%), Mortality prediction (3.69%), Precision diagnosis (3.69%), Cough/voice recognition diagnosis (2.21%), Contact tracing (2.21%), Drug development and reuse (1.85%), Blocking, quarantine and self-isolation (1.48%), Prediction of protein structure (1.48%), Tracking of travelers and mobility profiles (1.48%), Vaccine development (1.48%), Sentiment analysis (1.11%), Environmental intelligence (1.11%), Sanitation/Disinfection (0.37%), and Mental Health (0.37%).

The publications have shown that the main area of application of Artificial Intelligence and Data Science is diagnostic imaging. Said diagnostic test is based on X-ray images (CXR) and computed tomography (CT). Chest imaging is generally used by physicians to diagnose disease, while awaiting RT-PCR results or when RT-PCR results are negative and the person has symptoms of COVID-19 [51]. Computed tomography is considered the gold standard in diagnostic tests and is the most commonly used in studies for a more accurate diagnosis, since it is faster and cheaper [10].

Regarding the analysis and prediction of new outbreaks, several studies are being carried out. In the study by [6], a model is proposed that combines Machine Learning with traditional susceptible-infected prediction models- recovered (SIR) and susceptible-exposed-infectious-recovered (SEIR). The combination is an effective tool for outbreak modeling. Similarly, the study by [33] shows an outbreak analysis model using continuous variable quantum neural networks and the quantum backpropagation multilayer perceptron (QBMLP) thus demonstrating that there is a promising future with the use of the quantum machine learning.

Social distancing is a control measure that was implemented with the aim of reducing the spread of COVID-19. In the research presented by [53], an artificial intelligence system was proposed for the classification of social distancing using images acquired through thermal cameras to establish a complete system for tracking people, classifying social distancing, and monitoring body temperature. In the study by [41], a model created for the detection of distances and objects was trained with the OpenCV library. This model detects objects in video

streams in real time, calculates their distance, generates analytical reports, and sends notifications of safe areas. In the two mentioned studies, a state-of-the-art Machine Learning algorithm called YOLO was used.

Medical researchers from around the world have provided evidence that COVID-19 and pandemic diseases are transmitted through respiratory droplets, hence the use of a mask is an infection control measure. Few research studies have been found on the detection of face masks based on artificial intelligence technology and image processing. In the study by [22], the use of MobileNet Mask, a multiphase face mask detection model based on Deep Learning to prevent virus transmission, was proposed. However, in [59], deep convolutional neural networks (CNN) such as ResNet-50 were used for the construction of the model, which notably improved the classification of images.

The use of Machine Learning and Artificial Intelligence to predict SARS-CoV-2 infection from complete blood counts is a useful tool for precision diagnosis. In the study by [11] several Machine Learning models like Random Forest were used as classifiers. They fit a traditional logistic model, but instead of using all the predictors, they use a regularized path to select the most important variables for logistic regression. Furthermore, they define artificial neural network models.

In the study by [37] in-hospital blood samples were taken from patients at the time of admission and used for the prediction of mortality. A model was trained with the information from 28 blood biomarkers including age and gender of patients. The approach combined 5-layer Deep Neural Network (DNN) models and Random Forest in conjunction with tools such as TensorFlow, NumPy, Pandas, and Matplotlib to build the model and analyze the results. Additionally a web application (BeatCOVID19) is available so that anyone can record their laboratory tests.

3.4 Effectiveness of Artificial Intelligence and Data Science Techniques (RQ4)

Although computed tomography is considered a higher precision test, in study conducted in October 2020, a diagnostic model with X-ray images was developed. This model is based on a neural network and shows an accuracy of 99.49% for diagnosis of COVID-19 in suspected patients. It is important to indicate that this process is carried out in less than 5 min [29]. In another study by the same author [30], they propose a model that includes Deep Learning and Convolutional Neural Network (CNN) algorithms with a precision of 99.9%. Similarly, in the study by [19] the proposed model showed a 99.96% accuracy.

Regarding diagnostic tests with computed tomography, in the study by [36], a Deep Learning model was trained with a dataset of 3993 images which includes low-quality images. The model ResNet-50 showed excellent diagnostic performance (sensitivity of 99.58%, specificity of 100.00% and precision of 99.87%), being one of the models that has shown the best results. Methodologies based on Artificial Intelligence (AI) can be useful to predict, control and prevent the

spread of new outbreaks. In the study by [63], a predictive framework was proposed, which incorporates vector support machines (SVM) in anticipation of a possible COVID-19 outbreak. The results indicate that the suggested system outperformed the more advanced approaches, with 98.88% and 96.79% of results in terms of accuracy during training and training validation respectively. In another study, the assembly of decision trees and logistic regression demonstrated a model with an improved interaction effect, especially in the predictions of continuous response variables [44]. This model included swarm optimization of particles (PSO) for the adjustment of the parameters and incorporated the modeling of time series, providing levels of prediction precision of 99%.

In the study by [7], a model for tracking travelers and mobility profiles was proposed to classify daily passengers on trains according to age groups. The data set was compared to several Machine Learning algorithms and the vector support machine mobility prediction classification (SVM) reached an accuracy of up to 86.43% and 81.96% in the age groups 16 to 59 years and over 60 years.

In the model by [21] called MobileNet Mask, two different data sets of face masks have been used together with more than 5200 images to train and test the Deep Learning model. This model detects people with and without face masks from the images and the video stream. The results of the experiment show that with 770 validation samples MobileNet Mask has achieved 93% precision, while with 276 validation samples it achieved an accuracy of almost 100%. Similarly, in the study by [47], a Deep Learning model was trained with a data set of images of people with and without masks collected from various sources. The trained architecture reached 98.7% precision in distinguishing people with and without a face masks.

In the model by [37] for the prediction of in-hospital mortality based on routine blood samples, the EDRnet model based on Deep Neural Networks and Random Forest was proposed, which provided a high 100% sensitivity, 91% specificity, 92% precision, and 96% balanced precision. The training times were 796 and 126 s respectively, and the total calculation time for the EDRnet test was 72 s. This indicates that the trained model is very effective in predicting mortality. To expand the number of patient data points, a web application (BeatCOVID19) was developed in which anyone can access the model to predict mortality and can record their own blood lab results.

4 Conclusions

This study shows that, in the literature, there is a large number of research carried out in the context of the COVID-19. Artificial Intelligence and Data Analytics constitute elements of great support in several areas of application, mainly in diagnostic imaging, analysis and prediction of spread, prediction of mortality, etc.

Due to the strong impact which the pandemic has had on the health and economy of the world, there are a large number of scientific studies in the area of diagnostic imaging with excellent results. However, there are still areas that need

more attention, such as ambient intelligence which allows people to safely return to educational, commercial, and work activities, mainly in safe environments.

In diagnostic imaging, studies indicate that chest x-ray and computed tomography may be appropriate tests to confirm the diagnosis of COVID-19, mainly in people who have been diagnosed with the disease by other tests with unreliable results.

In data analysis, Artificial Intelligence has become an important tool in the fight against COVID-19. Deep Learning and Machine Learning models for pandemic prediction have shown greater precision than mathematical and statistical models previously used by epidemiologists.

Finally, it can be concluded that this study may be useful to direct the scientific community to research areas in the future which receive less attention, but are of the same level of importance, since it is necessary to carry out research that contributes to the recovery of the economy in the countries that have been the most affected by the effects of the pandemic.

References

1. Al Mahmoud, R.H., Omar, E., Taha, K., Al-Sharif, M., Aref, A.: Covid-19 global spread analyzer: an ML-based attempt. J. Comput. Sci. **16**(9), 1291–1305 (2020)
2. Al-qaness, M.A.A., et al.: Efficient artificial intelligence forecasting models for COVID-19 outbreak in Russia and Brazil. Process Saf. Environ. Prot. **149**, 399–409 (2021)
3. Alafif, T., Tehame, A.M., Bajaba, S., Barnawi, A., Zia, S.: Machine and deep learning towards COVID-19 diagnosis and treatment: survey, challenges, and future directions. Int. J. Environ. Res. Public Health **18**(3), 1117 (2021). Number: 3
4. Alazab, M., Awajan, A., Mesleh, A., Abraham, A., Jatana, V., Alhyari, S.: COVID-19 prediction and detection using deep learning. Int. J. Comput. Inf. Syst. Ind. Manag. Appl. **12**, 168–181 (2020)
5. Alwaeli, Z.A.A., Ibrahim, A.A.: Predicting COVID-19 trajectory using machine learning. In: 2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), pp. 1–4. Institute of Electrical and Electronics Engineers Inc., October 2020
6. Ardabili, S.F., et al.: COVID-19 outbreak prediction with machine learning. Algorithms **13**(10), 249 (2020)
7. Asad, S.M., Dashtipour, K., Hussain, S., Abbasi, Q.H., Imran, M.A.: Travelerstracing and mobility profiling using machine learning in railway systems. In: 2020 International Conference on UK-China Emerging Technologies (UCET), pp. 1–4. Institute of Electrical and Electronics Engineers Inc., August 2020
8. Asghar, M.A., Razzaq, S., Rasheed, S., Fawad: A robust technique for detecting SARS-CoV-2 from X-ray image using 2D convolutional neural network and particle swarm optimization. In: 2020 14th International Conference on Open Source Systems and Technologies (ICOSST), pp. 1–6 (2020)
9. Awal, M.A., Masud, M., Hossain, M.S., Bulbul, A.A.M., Mahmud, S.M.H., Bairagi, A.K.: A novel Bayesian optimization-based machine learning framework for COVID-19 detection from inpatient facility data. IEEE Access **9**, 10263–10281 (2021)

10. Babukarthik, R.G., et al.: Prediction of COVID-19 using genetic deep learning convolutional neural network (GDCNN). IEEE Access **8**, 177647–177666 (2020)
11. Banerjee, A., et al.: Use of Machine Learning and Artificial Intelligence to predict SARS-CoV-2 infection from Full Blood Counts in a population. Int. Immunopharmacol. **86**, 106705 (2020)
12. Bannur, N., Maheshwari, H., Jain, S., Shetty, S., Merugu, S., Raval, A.: Adaptive COVID-19 forecasting via Bayesian optimization. In: ACM International Conference Proceeding Series, p. 432. Association for Computing Machinery, January 2020
13. Bodapati, S., Bandarupally, H., Trupthi, M.: COVID-19 time series forecasting of daily cases, deaths caused and recovered cases using long short term memory networks. In: 2020 IEEE 5th International Conference on Computing Communication and Automation (ICCCA), pp. 525–530 (2020)
14. Butt, S.A., Misra, S., Anjum, M.W., Hassan, S.A.: Agile project development issues during COVID-19. In: Przybyłek, A., Miler, J., Poth, A., Riel, A. (eds.) LASD 2021. LNBIP, vol. 408, pp. 59–70. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-67084-9_4
15. Chatterjee, A., Gerdes, M.W., Martinez, S.G.: Statistical explorations and univariate timeseries analysis on covid-19 datasets to understand the trend of disease spreading and death. Sensors (Switzerland) **20**(11), 3089 (2020)
16. Cobo, M.J., López-Herrera, A.G., Herrera-Viedma, E., Herrera, F.: SciMAT: a new science mapping analysis software tool. J. Am. Soc. Inf. Sci. Technol. **63**(8), 1609–1630 (2012)
17. Dandekar, R., Rackauckas, C., Barbastathis, G.: A machine learning-aided global diagnostic and comparative tool to assess effect of quarantine control in COVID-19 spread. Patterns **1**(9), 100145 (2020)
18. Darapaneni, N., et al.: COVID 19 severity of pneumonia analysis using chest X Rays. In: 2020 IEEE 15th International Conference on Industrial and Information Systems (ICIIS), pp. 381–386 (2020)
19. Das, D., Santosh, K.C., Pal, U.: Truncated inception net: COVID-19 outbreak screening using chest X-rays. Phys. Eng. Sci. Med. **43**(3), 915–925 (2020). https://doi.org/10.1007/s13246-020-00888-x
20. Devaraj, J., et al.: Forecasting of COVID-19 cases using deep learning models: is it reliable and practically significant? Results Phys. **21**, 103817 (2021)
21. Dey, S.K., Howlader, A., Deb, C.: MobileNet mask: a multi-phase face mask detection model to prevent person-to-person transmission of SARS-CoV-2. In: Kaiser, M.S., Bandyopadhyay, A., Mahmud, M., Ray, K. (eds.) Proceedings of International Conference on Trends in Computational and Cognitive Engineering. AISC, vol. 1309, pp. 603–613. Springer, Singapore (2021). https://doi.org/10.1007/978-981-33-4673-4_49
22. Dey, S., Biswas, S., Nandi, S., Nath, S., Das, I.: Deep greedy network: a tool for medical diagnosis on exiguous dataset of COVID-19. In: 2020 IEEE International Conference for Convergence in Engineering, ICCE 2020 - Proceedings, pp. 340–344. Institute of Electrical and Electronics Engineers Inc., September 2020
23. El-Kenawy, E.S.M., Ibrahim, A., Mirjalili, S., Eid, M.M., Hussein, S.E.: Novel feature selection and voting classifier algorithms for COVID-19 classification in CT images. IEEE Access **8**, 179317–179335 (2020)
24. El Mouden, Z.A., Jakimi, A., Taj, R.M., Hajar, M.: A graph-based methodology for tracking covid-19 in time series datasets. In: 2020 IEEE 2nd International Conference on Electronics, Control, Optimization and Computer Science, ICECOCS 2020. Institute of Electrical and Electronics Engineers Inc., December 2020

25. Elsheikh, A.H., et al.: Deep learning-based forecasting model for COVID-19 outbreak in Saudi Arabia. Process Saf. Environ. Prot. **149**, 223–233 (2021)
26. Florez, H., Singh, S.: Online dashboard and data analysis approach for assessing covid-19 case and death data. F1000Research **9**, 570 (2020)
27. Gupta, H., et al.: Data analytics and mathematical modeling for simulating the dynamics of COVID-19 epidemic-a case study of India. Electronics (Switzerland) **10**(2), 1–21 (2021)
28. Hamida, S., Gannour, O.E., Cherradi, B., Ouajji, H., Raihani, A.: Optimization of machine learning algorithms hyper-parameters for improving the prediction of patients infected with COVID-19. In: 2020 IEEE 2nd International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS), pp. 1–6 (2020)
29. Haritha, D., Pranathi, M.K., Reethika, M.: COVID detection from chest X-rays with DeepLearning: CheXNet. In: 2020 5th International Conference on Computing, Communication and Security (ICCCS), pp. 1–5 (2020)
30. Haritha, D., Praneeth, Ch., Krishna Pranathi, M.: Covid prediction from x-ray images. In: Proceedings of the 2020 International Conference on Computing, Communication and Security, ICCCS 2020. Institute of Electrical and Electronics Engineers Inc., October 2020
31. Iwendi, C., et al.: COVID-19 patient health prediction using boosted random forest algorithm. Front. Public Health **8**, 357 (2020)
32. Johnsen, T.K., Gao, J.Z.: Elastic net to forecast COVID-19 cases. In: 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), pp. 1–6 (2020)
33. Kairon, P., Bhattacharyya, S.: COVID-19 outbreak prediction using quantum neural networks. In: Bhattacharyya, S., Dutta, P., Datta, K. (eds.) Intelligence Enabled Research. AISC, vol. 1279, pp. 113–123. Springer, Singapore (2021). https://doi.org/10.1007/978-981-15-9290-4_12 ISSN 21945365
34. Kerdvibulvech, C., Chen, L.L.: The power of augmented reality and artificial intelligence during the Covid-19 outbreak. In: Stephanidis, C., Kurosu, M., Degen, H., Reinerman-Jones, L. (eds.) HCII 2020. LNCS, vol. 12424, pp. 467–476. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-60117-1_34 ISSN 16113349
35. Kitchenham, B.: Guidelines for performing Systematic Literature Reviews in Software Engineering (2007)
36. Ko, H., et al.: COVID-19 pneumonia diagnosis using a simple 2D deep learning framework with a single chest CT image: model development and validation. J. Med. Internet Res. **22**(6), e19569 (2020)
37. Ko, H., et al.: An artificial intelligence model to predict the mortality of COVID-19 patients at hospital admission time using routine blood samples: development and validation of an ensemble model. J. Med. Internet Res. **22**(12), e25442 (2020)
38. Kumar, N., Susan, S.: COVID-19 pandemic prediction using time series forecasting models. In: 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), pp. 1–7 (2020)
39. Lalmuanawma, S., Hussain, J., Chhakchhuak, L.: Applications of machine learning and artificial intelligence for Covid-19 (SARS-CoV-2) pandemic: a review. Chaos Solitons Fractals **139**, 110059 (2020)
40. Liu, J., Zhang, Z., Zu, L., Wang, H., Zhong, Y.: Intelligent detection for CT image of COVID-19 using deep learning. In: 2020 13th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI), pp. 76–81. Institute of Electrical and Electronics Engineers Inc., October 2020

41. Melenli, S., Topkaya, A.: Real-time maintaining of social distance in Covid-19 environment using image processing and big data. In: 2020 Innovations in Intelligent Systems and Applications Conference (ASYU), pp. 1–5 (2020)
42. Mirri, S., Roccetti, M., Delnevo, G.: The New York City covid-19 spread in the 2020 spring: a study on the potential role of particulate using time series analysis and machine learning. Appl. Sci. (Switzerland) **11**(3), 1–19 (2021)
43. Naudé, W.: Artificial intelligence vs COVID-19: limitations, constraints and pitfalls. AI Soc. **35**(3), 761–765 (2020). https://doi.org/10.1007/s00146-020-00978-0
44. Ngie, H.M., Nderu, L., Mwigereri, D.G.: Tree-based regressor ensemble for viral infectious diseases spread prediction. In: CEUR Workshop Proceedings, vol. 2689. CEUR-WS (2020). ISSN 16130073
45. Nie, Q., Liu, Y., Zhang, D., Jiang, H.: Dynamical SEIR model with information entropy using COVID-19 as a case study. IEEE Trans. Comput. Soc. Syst. **8**(4), 1–9 (2021)
46. Petersen, K., Vakkalanka, S., Kuzniarz, L.: Guidelines for conducting systematic mapping studies in software engineering: an update. Inf. Softw. Technol. **64**, 1–18 (2015)
47. Rahman, M.M., Manik, M.M.H., Islam, M.M., Mahmud, S., Kim, J.H.: An automated system to limit COVID-19 using facial mask detection in smart city network. In: 2020 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), pp. 1–5 (2020)
48. Ren, J., et al.: A novel intelligent computational approach to model epidemiological trends and assess the impact of non-pharmacological interventions for COVID-19. IEEE J. Biomed. Health Inform. **24**(12), 3551–3563 (2020)
49. Saba, A.I., Elsheikh, A.H.: Forecasting the prevalence of COVID-19 outbreak in Egypt using nonlinear autoregressive artificial neural networks. Process Saf. Environ. Prot. **141**, 1–8 (2020)
50. Sadasivuni, S.T., Zhang, Y.: Using gradient methods to predict Twitter users' mental health with both COVID-19 growth patterns and tweets. In: Proceedings - 2020 IEEE International Conference on Humanized Computing and Communication with Artificial Intelligence, HCCAI 2020, pp. 65–66. Institute of Electrical and Electronics Engineers Inc., September 2020
51. Salameh, J.-P., et al.: Thoracic imaging tests for the diagnosis of COVID-19. Cochrane Database Syst. Rev. **9**, CD013639 (2020)
52. Salgotra, R., Gandomi, M., Gandomi, A.H.: Evolutionary modelling of the COVID-19 pandemic in fifteen most affected countries. Chaos Solitons Fractals **140**, 110118 (2020)
53. Saponara, S., Elhanashi, A., Gagliardi, A.: Implementing a real-time, AI-based, people detection and social distancing measuring system for Covid-19. J. Real-Time Image Process. (2021)
54. Sharma, R.R., Kumar, M., Maheshwari, S., Ray, K.P.: EVDHM-ARIMA-based time series forecasting model and its application for COVID-19 cases. IEEE Trans. Instrum. Meas. **70**, 1–10 (2021)
55. Singh, S., Florez, H.: Bioinformatic study to discover natural molecules with activity against covid-19. F1000Research **9**, 1203 (2020)
56. Singh, S., Florez, H.: Coronavirus disease 2019 drug discovery through molecular docking. F1000Research **9**, 502 (2020)
57. Szczepanek, R.: Analysis of pedestrian activity before and during COVID-19 lockdown, using webcam time-lapse from Cracow and machine learning. PeerJ **8**, e10132 (2020)

58. Vaishya, R., Javaid, M., Khan, I.H., Haleem, A.: Artificial Intelligence (AI) applications for COVID-19 pandemic. Diabetes Metab. Syndr. **14**(4), 337–339 (2020)
59. Venkateswarlu, I.B., Kakarla, J., Prakash, S.: Face mask detection using MobileNet and global pooling block. In: 2020 IEEE 4th Conference on Information & Communication Technology (CICT), pp. 1–5 (2020)
60. Wang, D., Sun, Y., Song, J., Huang, Y.: A SEIR model optimization using the differential evolution. In: Chen, X., Yan, H., Yan, Q., Zhang, X. (eds.) ML4CS 2020. LNCS, vol. 12487, pp. 384–392. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-62460-6_34 ISSN: 16113349
61. Wang, S., Fang, H., Ma, Z., Wang, X.: Forecasting the 2019-ncov epidemic in Wuhan by SEIR and cellular automata model. In: Journal of Physics: Conference Series, vol. 1533. Institute of Physics Publishing, June 2020. ISSN 17426596, Issue: 4
62. Yang, Z., et al.: Modified SEIR and AI prediction of the epidemics trend of COVID-19 in China under public health interventions. J. Thorac. Dis. **12**(3), 165–174 (2020)
63. Zagrouba, R., et al.: Modelling and simulation of COVID-19 outbreak prediction using supervised machine learning. Comput. Mater. Contin. **66**(3), 2397–2407 (2020)
64. Zhan, C., Tse, C.K., Lai, Z., Hao, T., Su, J.: Prediction of COVID-19 spreading profiles in South Korea, Italy and Iran by data-driven coding. PLoS One **15**(7), e0234763–e0234763 (2020)