A Concise Review on Developmental and Evaluation Methods of Artificial Intelligence on COVID-19 Detection

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Alagbe Adeyinka Solomon, Monalisha Mishra, and Sukant Kishoro Bisoy

Abstract

COVID-19 pandemic is now transferring the digital era into high gear. Artificial Intelligence (AI) approaches are tremendously applied over several fronts to astound the unseen situation. Medical imaging modalities like computed tomography and X-ray play a critical role to combat COVID-19, whereas the intrusion of AI techniques strengthen further the diagnostic process and help medical experts. However, several obstacles inhibit greater implementation of the optimized methods in clinical arena. The main contribution of the review is to provide insights to the researchers and clinicians with the introduction of certain AI concepts responding to the terrific COVID-19 pandemic. Initially, the review describes the requisites of Machine Learning (ML) and Deep Learning (DL) methods followed by the comprehensive illustration of prevailing existing ML and DL modalities involved in the precise and rapid diagnosis of the lung disorders with COVID-19 on primary focus. Several information relevant to detection of outbreak, tracing contact, forecasting models, prognostication as well as drug and vaccination development are incorporated. Finally, the paper discussed the major challenges and limitations pertaining to resolve the real-world issue with prominent AI methods. Equipped with great understanding of streaming Feature extraction approaches and classification methods like Convolutional Neural Network (CNN), Long Short Term Memory (LSTM), the radiologists and other medical experts may overcome the obstacles preventing further widespread application of management scenario of the current and future outbreaks.

A. A. Solomon · M. Mishra · S. K. Bisoy (✉)
Department of CSE, C.V. Raman Global University, Bhubaneswar, India
e-mail: sukantabisoyi@cgu-odisha.ac.in

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Keywords

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9.1 Introduction

The pandemic outbreak of COVID-19 made the entire world in unprecedented complex situation (Alakus and Turkoglu 2020; Ji et al. 2020). COVID-19, a short term for Coronavirus disease 2019 is a highly infectious disease caused by SARS-CoV-2 (Bhargava and Bansal 2021; Zeroual et al. 2020). The cough, shortness of breath, cold and fever are the most common symptoms of COVID-19. Diarrhoea, sore throat, muscle pain, abdominal pain, loss of taste and smell and sputum production are the additional symptoms of COVID-19 (Kwekha-Rashid et al. 2021). Moreover, majority of the cases ends with mild symptoms like fever, cough and muscle pains and some of the cases ends with multi organ failures and death. The artificial intelligence (AI) is widely used for various COVID-19 crises like drug development, epidemiology, socio-economics, molecular research, medical diagnosis and treatments (Warman et al. 2020). DL process is an artificial intelligence function, which imitated the function of human brains to process data and making patterns for decision-making. For unlabelled and unstructured data the DL techniques (subset of machine learning) were used with wireless network (Driggs et al. 2021). The wide range of data is accessible and shared through the fin-tech applications such as cloud computing. For the unstructured data, the human takes more decades to extract and comprehend the relevant information. Now, companies have realized the potential of AI and its emergence in the decade years and started to adopt the system in all field. The impact of AI on COVID-19 is positively associated with the patience rapidly in the decade years. To review the dynamics of AI process during COVID-19, the following are the sources used, such as PubMed, Google Scholar, Medline and PubMed central. In this study, it is aimed to present the clinical applications of DL and ML with AI process where electronic medical records, clinical characteristics, medical images like X-ray, CT and ultrasound images for the COVID-19 diagnosis (Saha et al. 2021). The current issues and challenges were provided to deal with COVID-19 pandemic with deployment of AI technology. Due to the radical spread of COVID-19, many researchers were working on finding the solutions for these challenges and issues in this pandemic. In the field of medicine and diagnostic process, the DL and ML were widely used to get accurate output from this process. In this study, models based on ML and DL methods were developed and designed for the detection of healthy and diseased. Hence, this review could able to investigate the general diagnosis index with AI for improving the diagnosis accuracy for clinical purpose.

9.2 Diagnosis of COVID-19 with Machine Learning and Deep Learning Approaches

DL has recognized to be a remarkable approach to explore massive high-dimensional features from medical images. For rapid diagnosis there is always a need for better alternative with accessibility and in such exploration (Brinati et al. 2020) developed two kinds of ML classification approaches using haematological examination values that assess biochemical parameters such as WBC, platelets, plasma levels, etc. The results of the model possess accuracy of 82% to 86% and sensitivity of 92% to 95%. These results are not observed to be more deviated from gold standard method. This analysis also framed a Data Table (DT) model for making simple decision in accordance with the blood tests for COVID-19 diagnosis. Thereby this research demonstrated the possible feasibility and clinical soundness of utilizing blood test analysis correlated with ML approaches as a better alternative to rT-PCR to determine COVID positive cases. Hence, this approach would be highly helpful in those developing countries suffering with shortage of rT-PCR equipment. Accordingly this study also developed a web-based tool (https://covid19-blood-ml.herokuapp.com/) for evaluating clinical parameters.

The existing research Kassania et al. (2021) compared popular DL-based FE model for the automatic classification of COVID-19 images. The study selected popular DL frameworks like ResNet, Xception, DenseNet, VGGNet and Inception for obtaining most accurate features. The features extracted were then passed to various ML classifiers for precise classification of COVID-19 case and control. The suggested approach prevented task-specific pre-processing method in order to favour better generalization of unobserved data.

This paper stated that DenseNet 121 feature extraction associated with bagging tree classifier obtained better effectiveness with 99% of accuracy in COVID-19 detection. Further hybridization of ResNet 50 FE associated with Light GBM with 98% accuracy also proves to be efficient.

Similarly, Khanday et al. (2020) attempted to classify textual clinical results to four different classes by the use of conventional and EML algorithm. This analysis employed 212 clinically labelled classes such as SARS, COVID_ARDS, COVID, ARDS. This study performed FE with Bag of Words, Term Frequency/Inverse Document Frequency (TF/IDF) and report length. The extracted features are classified and observed that logistic regression (LR) and multinomial NB depicted better effectiveness than other ML approaches with more than 96% of testing accuracy. This study also planned to utilize RNN for yielding still more accuracy.

This review paper Roberts et al. (2021) considered various existing ML approaches from CT or CXR images within the time period of January and October 2020. The review analyses 2212 papers to detect the underlying biases and underlying flaws. This study strongly recommended to frame novel AI models with reliable accessibility to overcome the prevailing challenges.

Authors in According Sedik et al. (2021) provided a promising solution by suggesting COVID-19 detection system based on CNN and Conv LSTM. The study evaluated the effectiveness of the suggested model with two datasets with

X-ray and CT images each. In addition to that COVID-19 case and pneumonia case were also classified for validating the presented modality. High accuracy (100%) and F score (100%) obtained from this model recommend the utilization of adopted model for rapid COVID screening without the aid of rT-PCR.

For analyzing COVID-19 cases from viral and bacterial pneumonia as well as from normal people with chest X-ray images, the authors of Jain et al. (2020) employed deep residual learning network system. Accuracy of more than 97% has been obtained from the suggested model with high reliability, rapidity, and less computational complexity. This scenario enables the medical experts to provide appropriate treatment in right time.

The mentioned paper Ni et al. (2020) utilized DL approach for the automated diagnosis of chest abnormalities from COVID-19 patients in CT images followed by the comparative analysis with radiologists in a quantitative manner. DL algorithm comprising characteristics like detection of lesion, segmentation as well to location of the abnormality has been trained and evaluated with 14,435 participants. The suggested algorithm has also been validated with an overlapping dataset comprising 96 images from China hospitals. Quantitative detection performance was also been tested with three radiologists as reference and assessed in terms of sensitivity, specificity, accuracy, and F score. The result proved that the presented DL algorithm attained superior performance with particularly high speed. Hence, these studies ensure better assistance to radiologists to attain superior diagnostic performance.

Automatic classification of pulmonary disorders from X-Ray images has been performed by Apostolopoulos et al. (2020) with DL methods. The paper employed MobileNet V2 approach to obtain excellent results from a large-scale dataset comprising 3905 images (6 diseases). Further, the results obtained from this study suggested training CNN could able to reveal vital biomarkers for diagnosing COVID-19 disease.

Cardiovascular disorder monitoring in accordance with wearable medical device could able to efficiently decrease the mortality rates of COVID-19. Due to various technical limitations such as lacking of satisfactory application in real-time basis and dealing with complex and huge data. To address such issues, the research Tan et al. (2021) suggested 5G real-time monitoring system using DL methods. CNN-LSTM based automatic prediction of cardiac status of COVID patients reported evidential performance for improving the prediction accuracy of more than 99%. This study planned to use Generative Adversarial Network (GAN) for enhancing inadequate data.

9.3 Review on Benchmark Dataset Utilized for the Assessment of Prevailing Artificial Intelligence Approaches

Several researches were developed for generating benchmark dataset to facilitate researchers for validating their COVID-19 combating model. A few of the existing dataset has been described in this section.

COVID cases were identified in Chowdhury et al. (2020) and Wang et al. (2020) which comprise 14,914 training images and 1579 testing images and three

classes (pneumonia, normal and COVID-19). Likewise Bougourzi et al. (2021) provided Per-COVIDx 19 dataset for determining the infection percentage for both patient level and slice level. The generated dataset comprise 183 CT scans estimated by two expertise radiologists. This work explained a finer granularity of Coronavirus existence and how to resolve the challenge through precise estimation. This dataset has been made available in https://github.com/faresbougourzi/Per-COVID-19. The paper Monshi et al. (2021) optimized data augmentation and CNN HP for COVID-19 detection from X-ray images for accuracy validation. The suggested CovidXRayNet model increased the effectiveness of popular CNN approaches like VGG 19 and ResNet 50 that has been validated by the COVIDx and the generated COVIDcxr dataset.

This review paper Ye et al. (2020) deployed α-Satellite dataset for public testing and for the automatic detection of risk index in accordance with country, stat, specific location and city. This evaluation protects daily activities by minimizing disruptions. This system has observed to be available at https://COVID-19.yes-lab.org. The authors in Wang et al. (2020) introduced COVID-Net a deep CNN mode for the COVID-19 detection from cxr images. The study investigated the way of COVID Net predictions for providing deeper insights about the critical factors associated with COVID cases. Accordingly, authors of the existing article Jain et al. (2020) utilized two open sourced image database Cohen and Kaggle comprising four classes like normal/healthy in first row, bacterial pneumonia in second row, viral pneumonia in third row followed by COVID-19 in the fourth row. The cxr images of the patients were got from GitHub delivered by Dr. Joseph Cohen comprising annotated cxr and CT scan images of ARDS, COVID-19, MERS and SARS. This presented repository comprised 250 cxr images of confirmed COVID-19 infections. Further, the cxr images of normal, bacterial infection and viral infection were got from Kaggle repository (Fig. 9.1 (Jain et al. 2020)).

9.4 Comparative Analysis of Various Nature Inspired and Other Deep Leaning Algorithms on the Detection of COVID-19 Detection

Table 9.1 provides a comparative analysis of several algorithms prevalent in the existing research for the detection of COVID-19.

9.5 Dealing with COVID-19 Application of Artificial Intelligence and Machine Learning

AI-based developed protocols could be effectively utilized by the radiology to interpret. Also it could reduce workload burden of radiologist and have a great impact on an auxiliary tool.

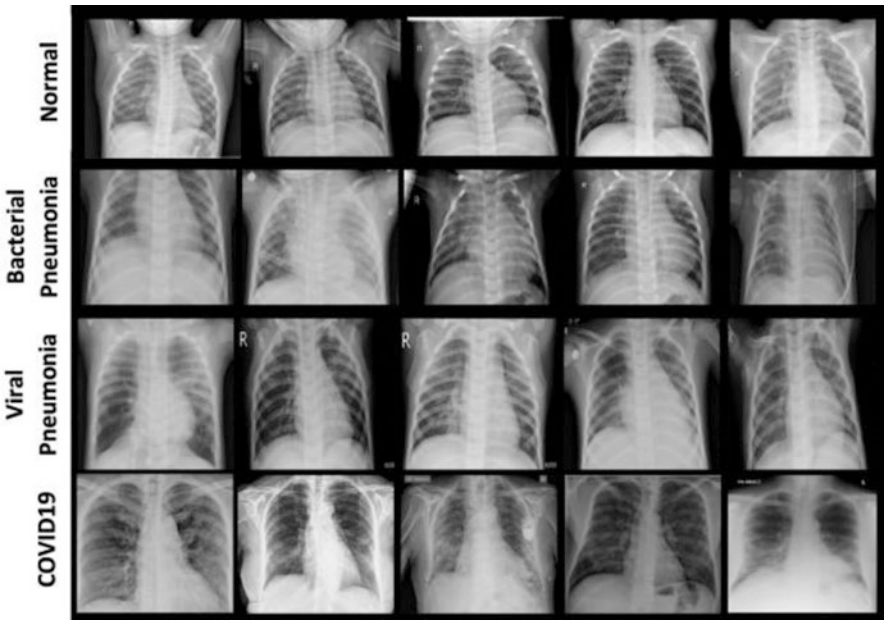

Fig. 9.1 Chest X-ray images of four different classes such as healthy, viral pneumonia, bacterial pneumonia and COVID-19 (Jain et al. 2020)

9.5.1 Early Detection and Prompt Diagnosis

AI could able to rapidly analyse the irregular symptoms and other such red flags thereby alarming the healthcare authorities and patients. This system could optimize decision-making regarding a reliable and cost-effective diagnostic system with hybridized DL and ML algorithms. Various ML algorithms like Support Vector Machine (SVM) (Yao et al. 2020; Hazarika and Gupta 2020), Random Forest (RF) (Cobb and Seale 2020), Multi-Layer Perceptron(MLP) (Ahsan et al. 2020), Decision Tree (DT) (Yu et al. 2020) and Artificial Neural Network (ANN) (Rajpoot et al. 2022) have been found in literature with better performance metric values. Similarly, various DL algorithms like CNN (Aslan et al. 2021), LSTM (Demir 2021), LSTM-NN (Jelodar et al. 2020), RNN (Zeroual et al. 2020) proved to be effective in disease diagnosis. These are utilized for under said applications like screening, contact tracing, mortality projection, drug and vaccine development, decreasing the workload of medical experts and in prevention of disease.

9.5.2 Treatment Monitoring

Intelligent platform for the automatic supervision as well as the prediction for the disease spreading could be developed by artificial intelligence platform. Neural

Table 9.1 Survey on various existing algorithms and their performance analysis in the detection of outbreak

S. No	Author	Data sources	Number of patients	Type of images	Number of classes	Artificial techniques employed	Outcomes
1	Ardakani et al. (2020)	Real-time data from the author's university hospital	510 COVID-19 and 510 non-COVID-19 patients and hence in total 1020 patients.	Computed tomography	Two (COVID-19 and non-COVID-19 classes)	MobileNet-V2, AlexNet, SqueezeNet, Xception VGG16, GoogleNet VGG-19, ResNet-50, ResNet-18, ResNet-101	Accuracy = 99.51, Precision = 99.27, NPV = 100AUC = 99.4, Specificity = 99.02, Sensitivity = 100
2	Rahimzadeh and Attar (2020)	RSNA pneumonia datasets and COVID-19 cxr images	Normal 8851 images, pneumonia 6054 images and COVID-19,180 images and in total 15,085 images	X-ray	Three (COVID-19, normal and pneumonia)	Concatenated-CNN	Accuracy = 99.5 Specificity = 99.5 Sensitivity = 80.5
3	Apostolopoulos and Mpesiana (2020)	Kaggle dataset and COVID-19 X-ray image	Normal 504 images, pneumonia 714 images and COVID-19 224 images and in total 1442 images	X-ray	Three (COVID-19, normal and pneumonia)	MobileNetv2, VGG19, Xception, Inception, ResNetv2	Accuracy = 96.7 Specificity = 96.4 Sensitivity = 98.6
4	Cifci (2020)	Kaggle	5800	Computed tomography	Two classes comprising COVID-19 and other pneumonia	Inception-V4, AlexNet	Accuracy = 94.74, Sensitivity = 87.37, Specificity = 87.45
5	Wu et al. (2020)	Beijing Yuan Hospital and China Medical University	127 pneumonia images and 368 COVID-19	Computed tomography	Two classes comprising COVID-19	ResNet50	Accuracy = 76 AUC = 81.9

(continued)

Table 9.1 (continued)

S. No	Author	Data sources	Number of patients	Type of images	Number of classes	Artificial techniques employed	Outcomes
			cases and in total 495 images		and other pneumonia		Specificity = 61.5 Sensitivity = 81.1
6	Loey et al. (2020)	COVID-19 X-ray images	Normal 79 images, viral pneumonia 79 images, bacterial pneumonia 79 images and COVID-19 69 images and in total 307 images	X-ray	Four (COVID-19, normal, bacterial and viral pneumonia)	GAN, GoogleNet, Resnet18, AlexNet	Precision = 80.6 Accuracy = 85.2
7	Ozturk et al. (2020)	COVID-19 X-ray images, CXR8	1127 comprising 127 COVID positives, 500 pneumonia and 500 nil finding cases	X-ray	Three (COVID-19, could not find and pneumonia)	DarkNet	Accuracy = 98.08 Specificity = 95.3 Precision = 98.03 F1Score = 96.51 Sensitivity = 95.13
8	Amyar et al. (2020)	COVID-19 CT segmentation dataset, COVID CT and a hospital named Henri-Becquerel Center	A total of 1044 images (449 COVID-19 and 595 non-COVID-19 images	Computed tomography	Two (COVID-19 and non-COVID-19 classes)	Encoder-decoder with MLP	Accuracy = 86 Specificity = 79 AUC = 93 Sensitivity = 94
9	Hasan et al. (2020)	SPIEAAPM NCI lung-nodule classification challenge and COVID-19 dataset	107 normal images and 118 COVID-19 images (Total of 321 images)	Computed tomography	Three (COVID-19, normal and pneumonia)	QDE-DF	Accuracy = 99.6

network has been developed for extracting the visual features of the pandemic and has the capacity of providing day-to-day updates. These updates enable the effective monitoring system with prompt treatment options.

9.5.3 Contact Tracing

AI could able to analyse the infection level by determining the hot spots and clusters and could employ the contact tracing of the patients for better monitoring. This process could able to predict the future course of the outbreak and the chance of reappearance (Allam et al. 2020).

9.5.4 Mortality Rate

AI could forecast and track the nature of disease spreading through social media, available data and other platforms associated with likely spread. This DL mechanism predicts several positive cases and mortality in any region. AI enables the identification of vulnerable regions, countries and people with appropriate measures.

9.5.5 Vaccine and Drug Development

With the utilization of AI, the available data on COVID-19 will be used for drug delivery and design. The algorithms can be used for speeding up the drug testing in real-time basis whereas standard testing consumes more time and hence accelerates the impossible events significantly. Further prioritized and powerful treatment methods can be adopted for clinical trials (Arora and Bist 2020).

9.5.6 Work Load Reduction of Healthcare Experts

The healthcare professionals have to face the sudden and massive number of patients during this scenario. The utilization of digital approaches especially with decision tree models provides better training to the doctors and students regarding the new disease. AI addresses more potential measures for reducing the doctor's workload.

9.5.7 Disease Prevention

With the analysis of real-time data, AI could able to provide recent information that is helpful for preventing the disease and to determine the probable infection site, virus influx and status of available beds and medical experts during such terrible crisis. AI is largely helpful for the preventing future outbreak with the information collected during various time. It also determines the causes, traits and reasons for the

spread of deadly infection. Preventive and predictive healthcare could be offered by AI (Salman et al. 2020).

9.6 Shortcomings of Current Methods

Few of the existing studies did not compare the effectiveness of the suggested CAD system with the radiologists (Ardakani et al. 2020). Hence, in future it is suggested that the performance of the prevailing artificial intelligence algorithms has to be compulsorily compared with the performance of the radiologists for the precise determination of accuracy. Further, some of the COVID-19 patients with false negative RT-PCR results were excluded incorrectly from the prevailing investigation.

Real-time polymerase chain reaction is observed as the standardized method for COVID-19 diagnosis. However, the assays possess several limitations such as high cost, time consumption, kit shortage and requirement of well-equipment laboratories. These limitations are devastating particularly in the low- and middle-income countries leading to reduced effectiveness in disease control measures. The network architecture of the existing AI methods lacks in true positive rate for the detection of COVID-19. Jain et al. (2020) elaborated the misclassification of viral pneumonia as bacterial or healthy fails to further processing of COVID-19 detection and treatment. Further constrained number of COVID-19 images has been observed to be complex for training the deep learning methods from scratch.

Several existing methods are retrospective and hence the effectiveness of the DL model on real clinical situation is not evaluated. Real-time application was found to be in a different perspective (Ni et al. 2020). The radiologists have more expertise on the subject and practising for adopting the high level approaches. The existing studies used dataset images from one or two institutions that cause bias in results. Furthermore, reproducibility of the effectiveness of the presented approaches remains unclear when handled with other datasets. This imbalanced database issue has to be sorted out by the upcoming studies.

Transferring the developed approaches to large-scale dataset is quite complex due to the underlying bias and non-generalizability. The sample collected were done from severe patients where proper analysis is mandatory and hence cases with mild or nil symptoms are found to be missed from public (Apostolopoulos et al. 2020). Consequently, most of the studies adopted older pneumonia samples that do not involved pneumonia images from COVID suspected patients. This remains to be a major clinical hindrance for evaluating the present scenario. Then the data correlated with the demographic characteristics and other such risks were not clearly focussed or considered. The above discussed constraints impede the prevailing holistic methods and analysis to face hurdles in real-time applications.

9.7 Critical Analysis

Figures 9.2 and 9.3 illustrate the year-wise distribution of the presented articles in this review. Figure 9.2 illustrates that most of the studies in this review belongs to the year 2020 while Fig. 9.3 is incorporated for providing deeper insights of the information about COVID-19 detection.

9.8 Conclusion

COVID-19 outbreak transformed the people life to a complex unseen situation that renders a frightening halt and claimed thousands of lives. This review paper provided insights in combating the virus through AI. Various deep and machine learning approaches were illustrated to attain the goal comprising LSTM, CNN, GAN, RNN, etc. This review delineates integrated bioinformatics approach from a

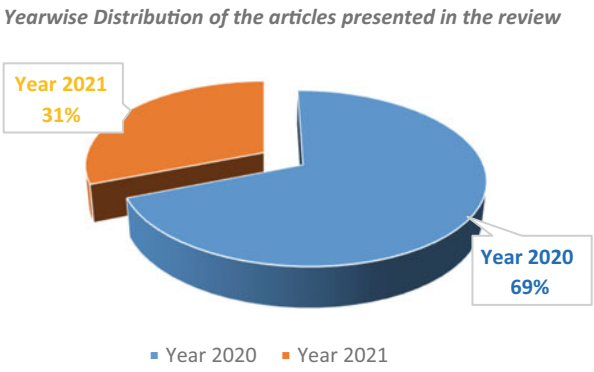

Fig. 9.2 Year-wise distribution of the presented articles

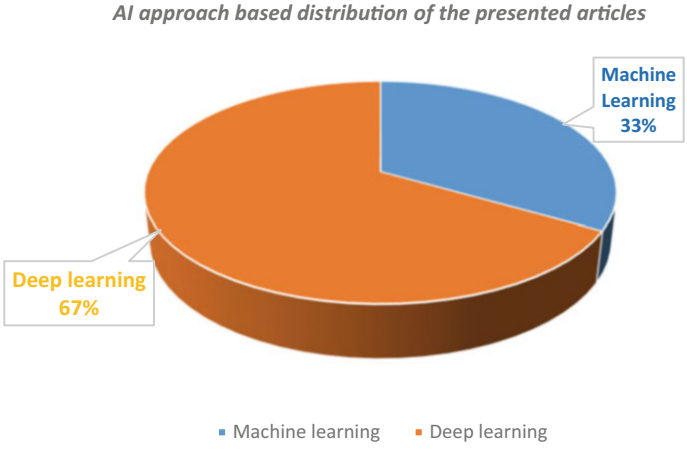

Fig. 9.3 The number of machine learning and deep learning-based articles

cohort of unstructured and structured data sources to reveal a user-friendly platform for the researchers and physicians. The major advantage of the AI methods is to stimulate the diagnostic and treatment process for the outbreak. The paper investigated more recent publication from standardized journal belonging to the year 2020, 2021 and a few from 2022. This information has been provided with the purpose of choosing inputs and targets that may facilitate reliable neural network approaches. The study ensures that AI approaches in correlation with precise medical treatment have improved the present strategy and increase the best performance in practical scenario.

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