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Artificial Intelligence Applications with Covid-19 in the First Year of the Pandemic: A Review Study

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Abstract

Background: World Health Organization declared COVID-19 as a pandemic in March 2020. This crisis made artificial intelligence (AI) intensively used to serve healthcare providers to diagnose, monitor and treat patients through AI-based solutions and applications. The aim of this review was to review the existing literature that applied AI and Machine Learning algorithms to deal with COVID-19 during the first year of the pandemic from January 2020 until March 2021.

Methods: Data collection was performed to retrieve research studies from PubMed and Google Scholar. Studies were scrapped using the *PubMed API widget* in *Orange*. This resulted in 421 studies. For Google Scholar, *Serp API*, to scrape the search results as *JavaScript Object Notation* (*JSON)* files. A simple *Python* program using *PyCharm* were used to parse the *JSON* and extract the required information for retrieved studies which resulted in 981 studies.

Results: Attention was focused on Prediction and Diagnosis categories. Mostly for predicting and forecasting the number of new cases; the Outbreak has gained the most attention then Predicting the severity level of Covid-19 patients with 75 and 37 published studies. In diagnosis most publications applied chest-radiography followed by clinical data subcategories. The categories of Screening, Classification of Genomes, and Prognosis have not gained much attention.

Conclusion: An accelerated growth/increase in research, and published studies concerning the employment of AI/ML technologies to deal with the Covid-19 pandemic overtime was observed. AI methods and techniques helped understand and analyze the pandemic data and prepare resilient evidence-based/driven plans and technologies to deal with COVID-19.

Keywords: Artificial Intelligence, Machine Learning, Coronavirus, Review.

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1. Introduction

Artificial Intelligence (AI) is defined as the science of designing and building intelligent machines and computer software that are capable of imitating human behavior, thinking, perception, reasoning, and acting. Machine Learning (ML) is a subfield of AI where machines use data to imitate the learning process of humans and improve their experience with minimal intervention. AI and ML have strengthened their roots in the field of health care in the last decade. Different AI-based solutions and applications were developed to deal with the Covid-19 pandemic and help healthcare practitioners accomplish several related tasks such as patients' diagnosis, monitoring, prediction, and treatment. AI tools have been used for early detection of breast cancer by analyzing mammographic data, which led to improved diagnosis [1]. AI is applied to differentiate pancreatic cancer from acute pancreatitis, which contributes to the appropriate treatment [2]. Algorithms and techniques of AI were intensively used to handle the challenges and urgent needs posed by the Covid-19 pandemic and actively contribute to containing and managing this global health crisis.

Covid-19 diagnosis is one of the most important fields where AI algorithms were applied. Since the pandemic's beginning, the detection of covid-19 positive cases relies mainly on the Reverse Transcription-Polymerase Chain Reaction (RT-PCR) test, which is time-consuming and poses additional stress on healthcare systems. Thus, applying and developing AI and Machine Learning (ML) Algorithms, to help achieve faster and highly accurate detection systems of positive COVID-19 cases has gained much attention. Computed tomography (CT) scans and X-radiation (X-ray) images were input to machine learning models [3]. By processing the chest radiology of patients, positive Covid-19 cases could be detected even before any symptoms were developed by patient [4] . AI has been used for early detection of COVID-19 cases in China, by enabling thermal imaging cameras to detect and flag the person with fever through a distance of 3 meters in crowded places [5]. AI was applied to control the spread of COVID19 infection, TraceTogether, a phone application that works on identifying the exposure to an infected person in the previous 30 min by using Bluetooth, invented by the Singapore Government [6]. The adoption of AI algorithms and techniques by governments and research communities as a leading solution to handle the current pandemic [7, 8] has resulted in accelerated growth and an exponential increase in the body of (related) research (concerning the AI in Covid-19) within a short period of time [9].

The main objective of this study was to review the existing literature that applied artificial intelligence and machine learning algorithms to deal with COVID19 during the first year of the pandemic starting from January 2020 until March 2021.

2. Subjects and Methods

2.1 Data collection

Data collection was performed to retrieve research studies that fit our search query from both databases: PubMed and Google Scholar. For PubMed, studies were scrapped using the *PubMed API widget* in *Orange*, an open-source tool for data mining. This resulted in 421 studies. For Google Scholar, since it does not provide an official API to retrieve search results, we employed a third-party API, *Serp API* (developer plan), to scrape the search results of Google Scholar as *JavaScript Object Notation* (*JSON)* files. We then implemented a simple *Python* program using *PyCharm* to parse the *JSON* and extract the required information related to each retrieved study. This results in 981 studies.

2.2 Data Extraction and Analysis

The data collection process resulted in a total of 1402 studies. These studies then underwent several filtration and assessment steps to get the final set of publications used in this review. First of all, out of the 1402 initial publications, 252 duplicates were removed, resulting in a total of 1150 unique and potentially eligible publications. Next, the title and abstract of each remaining publication were independently screened by the two reviewers (IA and SA). This process resulted in the further removal of 707 publications. After that, the remaining 443 publications were further assessed for eligibility and underwent a full-text assessment by the two reviewers. Disagreements between the reviewers were resolved by the review of a third independent reviewer (AA). This process resulted in the further removal of 69 publications. After that, the remaining 374 eligible publications were further analyzed and underwent a full-text assessment by the two reviewers to extract the required information related to the characteristics of the study and the Artificial Intelligence models used. Finally, the data extraction and analysis results were summarized in tables, following the aim of this review.

2.3 Inclusion and exclusion criteria

The search and data collection process resulted in a total of 1402 studies published during the first year of the Covid-19 pandemic starting from January 2020 to March 2021. Figure 1 shows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) flow chart of the systematic identification, screening, eligibility, and inclusion of studies that applied artificial intelligence and machine learning techniques to deal with the COVID-19 pandemic. The inclusion and exclusion criteria followed in the study selection process is defined as follows:

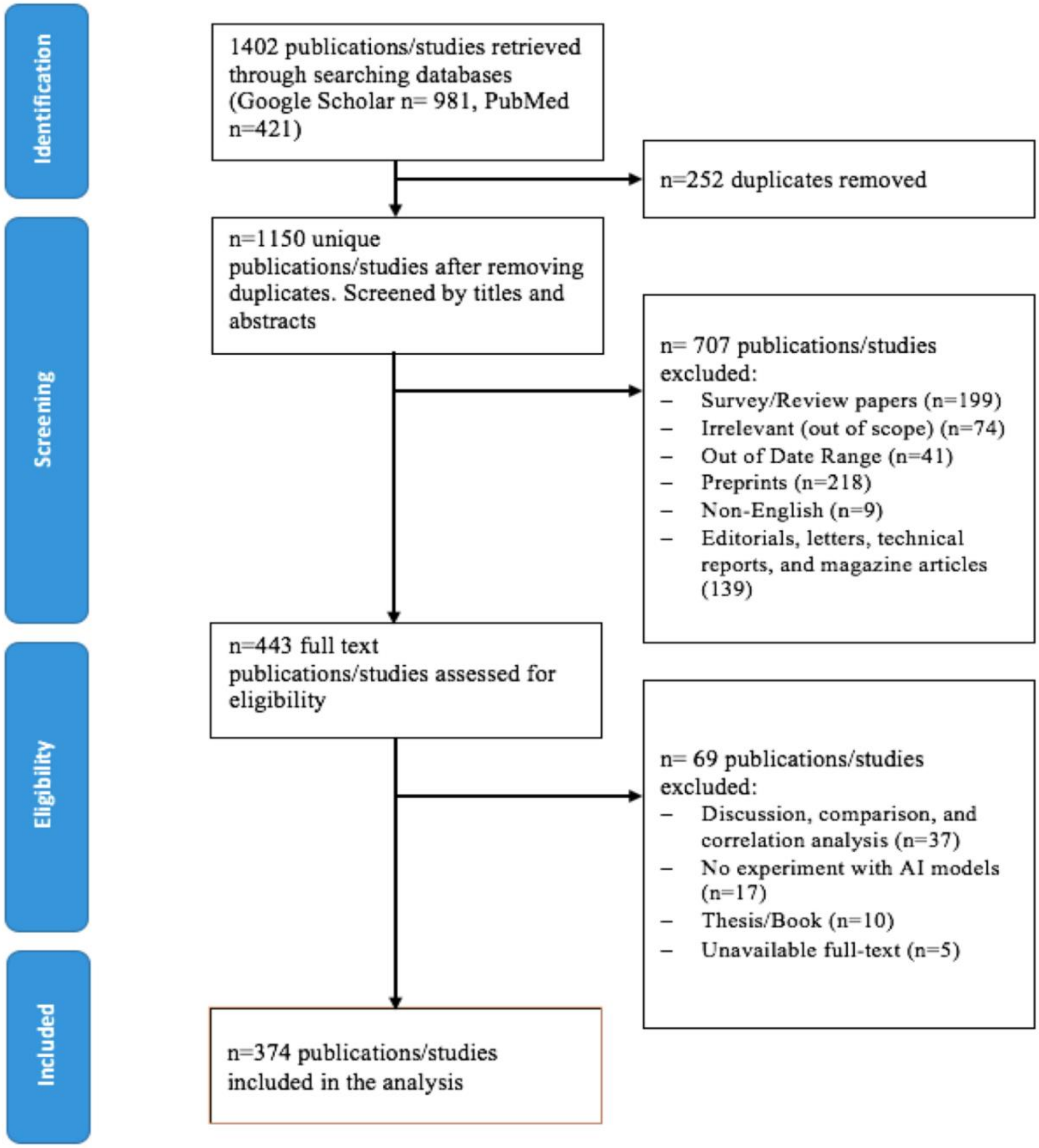

Figure 1: PRISMA flow chart of the selection process of studies for this review.

Inclusion criteria:

- Studies that apply at least one AI algorithm.
- Studies with precise experimental settings and results of applying AI in Covid-19.
- Studies that use Covid-19 datasets.
- Studies that are published in English only.
- Studies Published within the first year of declaring Covid-19 as a pandemic.
- Studies with Full text available.

Exclusion criteria:

- Extended abstracts, poster work, discussions, comparisons, and simple correlation analysis.
- Studies applying AI techniques but are not part of the Covid-19 outbreak.
- Studies that do not address specific challenges posed by the COVID-19 pandemic. E.g., surveys, reviews, and literature reviews.
- Studies that did not apply any AI techniques. I.e., theoretical studies that mentioned AI and COVID-19 but did not use any AI techniques.

The study selection process described above resulted in the exclusion of 776 studies and 252 duplicates. The remaining 374 studies were selected for further analysis in this review.

3. Results

The included 374 publications were categorized based on the study's main objective into one of the following main categories: Prediction, Diagnosis, Screening, Monitoring, Prevention and Management, Treatment, Prognosis, Classification of Genome, and Text mining.

Figure 2 shows the distribution of publications of each category over a period of one year, starting from January 2020 to March 2021. The categories of Prediction and Diagnosis have gained the most attention of researchers. This is clearly reflected by the number of studies published in these categories. Glancing at the distribution of such publications over time, one can notice that the number of published works increases over time. On the other hand, the categories of Screening, Classification of Genomes, and Prognosis have not gained much attention over the first year of the pandemic.

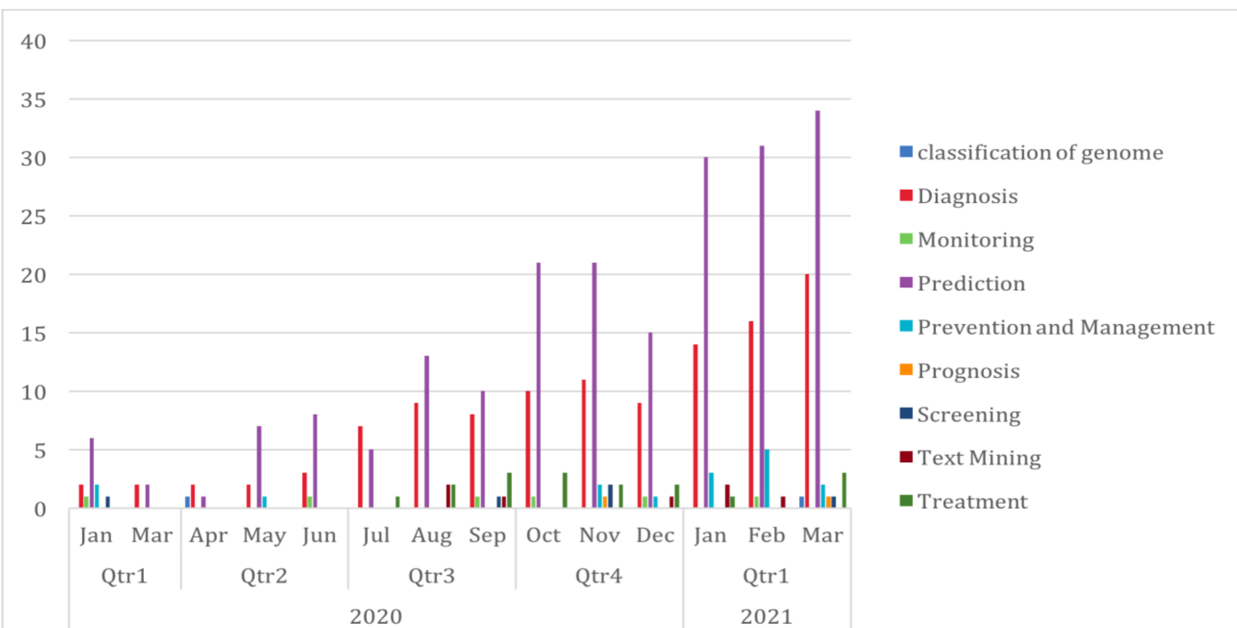

Figure 2: Distribution of publications of each main category over the period from January 2020 to March 2021.

Figure 3 shows the subcategories of each main category along with the total number of studies published in each of them. Most of the effort in the Prediction category was in predicting and forecasting the number of new cases, severity levels of patients, and mortality rates. Among these three subcategories, forecasting the number of new cases and the pandemic outbreak has gained the most attention, with 75 published studies. Predicting the severity level of Covid-19 patients came second with 37 published studies. In the Diagnosis category, most works were published under the diagnosis using chest radiography followed by diagnosis using patients' clinical data subcategories. Studies under the subcategory of Covid-19 diagnosis using chest radiography fall into two main sub-subcategories diagnosis using CT-scans and diagnosis using X-rays with a total of 32 and 27 studies, respectively. Diagnosis using patients' clinical data came next with a total of 32 published studies.

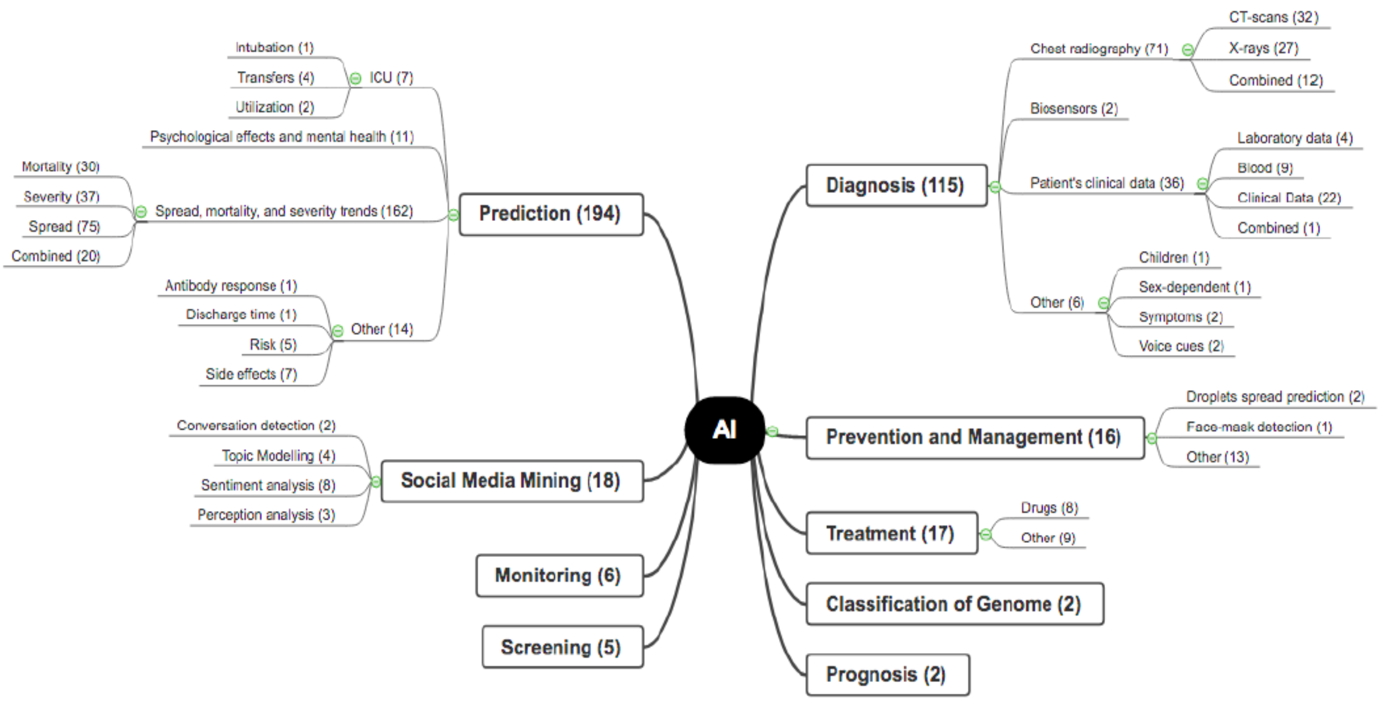

Figure 3: The distribution of included studies in each main category into subcategories and the total number of publications in each of them.

Figure 4 shows the most adopted AI/ML algorithms and techniques in the selected studies/publications for this review. Ensemble methods have been widely adopted by researchers, especially the Random Forest model. Simple classifiers such as Support Vector Machine (SVM) and Logistic Regression (LR) were also widely adopted, followed by Artificial Neural Networks (ANN) and Deep Learning (DL) models.

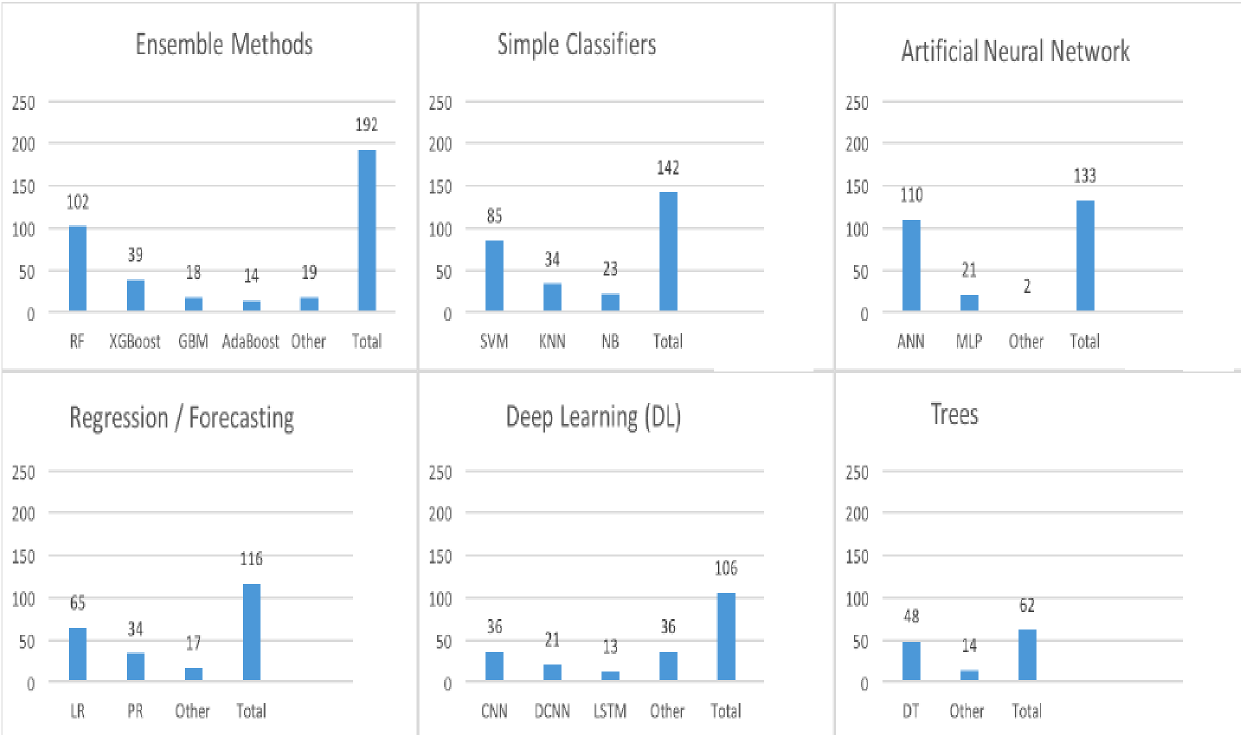

Figure 4: Top Artificial Intelligence and Machine Learning methods used with Covid-19

Figure 5 shows the total number of publications based on the country of origin of the study. North America has the most published studies with a total of 77, followed by Europe with a total of 69, then China with a total of 63, and India with 54 published studies.

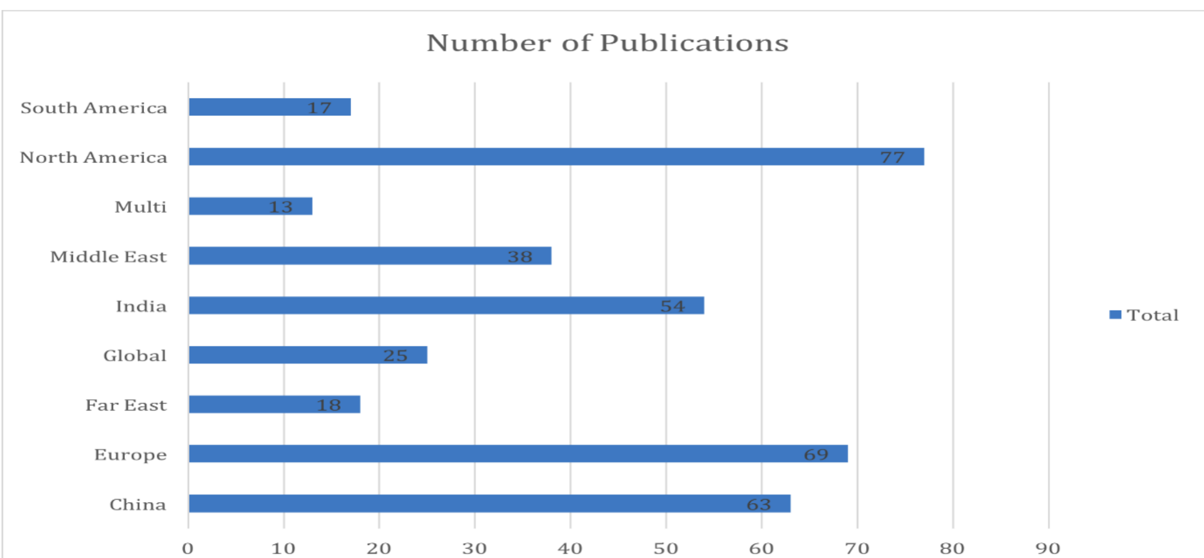

Figure 5: The distribution of studies based on the country of origin.

4. Discussion

Since the early beginning of the Covid-19 pandemic, Artificial Intelligence (AI) has played an important role as a non-medical intervention in the war against Covid-19 [7, 8]. AI has a potentially high number of applications and tools to help overcome the current global health crisis and move faster towards recovery. For instance, AI helped understand the disease, its symptoms, and side effects [12-14], diagnosing positive Covid-19 patients [15-18], tracking confirmed, recovered, and death cases of patients [19, 20]. AI also helped achieve better analysis of the disease spread data and build stronger forecasting models to predict the future spread of the virus [21-23], identify high-risk Covid-19 patients [24] and at-risk areas [25], and predict the mortality rate of such patients [26-30]. Moreover, AI helped develop drugs [31] and vaccines [32], develop proper population-wide screening technologies [33], issue warnings and notification, and generate recommendations about infection control procedures [8]. Furthermore, AI methods and techniques helped analyze and understand the pandemic data and prepare resilient evidence-based/driven preparation plans and technologies to deal with and recover from future epidemics.

This review results show an accelerated growth and increase in the body of research and published research studies concerning the employment of AI/ML technologies to deal with the Covid-19 pandemic overtime. Furthermore, the results express that the focus of researchers has shifted over time from being primarily on developing prediction and diagnosis models towards including other domains of AI applications such as monitoring, prevention and management, and treatment [31, 32, 34]. This is expected as a reflection of health authorities' early efforts to understand and contain the pandemic, utilize available resources, and prepare suitable plans, policies, and procedures. Over time, more data about the virus, its behavior, and the patients' symptoms were available which encouraged AI technologies to be further utilized to handle the pandemic more broadly.

Most of the included studies in this review fall into the prediction category, most of the efforts in the prediction category focused mainly on predicting/forecasting the number of new cases and the pandemic outbreak in the near future. For example, the Autoregressive Integrated Moving Average model (ARIMA), which is one of the most used forecasting algorithms nowadays [35], was used to predict the new cases in the next few days [36, 37]. Similarly, ARIMA and Seasonal Auto-Regressive Integrated Moving Average model (SARIMA) were used to develop forecasting models for the epidemiological trends of the pandemic in the 16 countries containing around 80% of the global cumulative cases [37]. CNN, ANN, and LSTM models were also used to develop forecasting models for predicting the global number of new cases in the next week [38]. The wide adoption of AI for prediction/forecasting reasons during the pandemic can be justified as follows. First, daily comprehensive Covid-19-related data is continuously collected from all over the world . This time-series data is publically available for researchers and interested parties to utilize and use . Furthermore, several fast and strong AI/ML algorithms exist to model sequential (time-series) data and build robust forecasting systems [40]. These AI/ML algorithms are capable of learning the spread characteristics of the Covid-19 virus, understanding its nature, predicting the density of its presence in the affected areas and the potential trajectory of its spread in different countries and communities [8].

Diagnosing Covid-19 patients has also gained much attention during the first year of the pandemic with a total of 115 studies selected for this review. AI/ML algorithms and techniques are capable of quickly detecting the underlying patterns and learning infrequent/irregular symptoms of patients from available data. This makes AI an ideal choice for diagnosing Covid-19 patients [8]. Most of the efforts in the Diagnosis category focused on implementing high-performance image-based diagnosis systems. For example, several AI models were developed for diagnosing Covid-19 patients using CT scans and X-rays such as DL models including CNN, DenseNet, Inception, ResNet, SqueezNet, VGG16, VGG19, Simple Classification models including ANN, DT, and Ensembles Methods including RF [16, 41, 42], Ensembles of CNNs [15, 17], and XGBoost models [43]. Two reasons could be behind focusing on developing image-based diagnosis systems. First, the availability of medical imaging techniques for chest radiography, such as computed tomography (CT) scans and X-rays. Second, the significant advancements /achievements of applying the AI Computer Vision techniques in the healthcare domain. For instance, one major achievement of applying AI for diagnosis purposes in healthcare is developing a ConvNet DL breast cancer detection model with 100% accuracy [44]. Furthermore, many studies in the Diagnosis category have leveraged the availability of patients' clinical and laboratory data to implement Covid-19 diagnosis systems using different ML models such as Deep Neural Networks (DNN), ANN, SVM, DT, NB, RF, AdaBoost, and GBM models [45-47]. This is due to clinical results of patients indicating unfavorable progression of COVID-19 such as increased white blood cell count, increase neutrophil count, decreased lymphocyte count, decreased albumin, increased lactate dehydrogenase (LDH), increased alanine aminotransferase (ALT), increased aspartate aminotransferase (AST), increased total bilirubin, increased creatinine, increased cardiac troponin, increased D-dimer, increased prothrombin time (PT), increased procalcitonin and Increased C-reactive protein (CRP) [48].

Although most of the efforts were directed towards early diagnosis of patients and predicting the spread, severity, and mortality rates in these patients, this does not (reduce) the importance of developing preventive and treatment measures to help suppress the virus diffusion, contain its spread, and provide better management of patients to reduce severity and mortality rates [49]. Specific antiviral treatment of

Covid-19 capable of defeating the virus in infected patients can be very effective in reducing the virus spread and eliminating its existence in the affected populations. However, to develop effective drugs for the novel virus, long-term research and experiments are necessary for several purposes such as production, standardization, and assessment of the new drug [49]. Preventative measures such as vaccinations are also of utmost importance to control the infections and spread of the COVID-19 virus [49, 50]. Nevertheless, vaccine development requires the study of the nature of the novel virus, understanding its features, and to determine the best animal models that "closely resemble the clinical disease caused by SARS-CoV2 infection in humans and its etiopathogenetic mechanisms" [49]. The reasons mentioned above could be the reason behind the limited number of published studies targeting the Treatment and Prevention categories in the first year of the pandemic. Treatment and Prevention and Management of Covid-19 categories were covered by 16 and 17 studies selected for this review, respectively. The focus of studies in the Treatment was mainly on developing possible therapeutics for COVID-19 [31] and assessing the repurposing of existing antiviral drugs [51, 52]. Studies in the Prevention and Management category covered different aspects such as vaccination [32], detecting face masks [53], predicting sneeze droplets spread [54], and assessing the utilization of hospitals' resources [55].

In the Social Media Mining category, much attention was directed toward analyzing textual data available in social media websites and platforms using Natural Language Processing (NLP) algorithms and techniques. NLP algorithms were applied in 18 studies selected for this review for topic modeling [56-58] and conversation detection [59, 60] purposes. Recognizing the strong effects of textual data and word-of-the-mouth has caused NLP methods and other ML algorithms to be employed by researchers in the war against Covid-19. Furthermore, social media has proven to be a potent tool in recent years in terms of understanding the public, empowering them with knowledge, monitoring the spread of misinformation and rumors, disease outbreak detection, and disease surveillance. Since the Covid-19 pandemic is a public health matter, applying NLP methods on social media textual data is a natural direction to investigate, as has been the case with other viruses in the past. For example, ML techniques were applied to develop a tool for tracking misinformation related to the Zika virus on Twitter [61], to investigate the impact of social media on the number of infections and deaths caused by the influenza virus [62], and to forecast the influenza virus outbreak using Twitter's data [63]. NLP methods were employed mostly around the first and the second waves of the Covid-19 outbreak as shown in Figure two. This is when worldwide organizations, research centers, and governments were investing more in monitoring, understanding, and analyzing what the public says and their perception of different aspects of the crisis, such as the new regulations and policies, vaccines, and lockdown procedures. More investigation of applying NLP algorithms and techniques to handle Covid-19-related textual data is expected to be seen in the future.

Surprisingly, published studies related to Covid-19 Screening are limited in the first year of the pandemic with a total of five studies only. For example, an Extra-tree classifier algorithm was employed to develop a preliminary patient filtering system for COVID-19 [64]. Testing for Covid-19 is currently mainly done via the Nasopharyngeal Swab Reverse transcription polymerase chain reaction (RT-PCR) testing, which although is currently considered as the gold standard diagnostic test is not ideal for screening [65-67]. Although the sensitivity of the RT-PCR test was reported to be 89% in the latest meta-analysis, it is an expensive and an uncomfortable test for the patient [68, 69]. Early detection of Covid19 cases is a foremost step in combating the spread of the disease. However, it is extremely difficult to clinically examine everyone who falls in the suspect category, and ministries of health around the globe were not able to meet the standard for screening for COVID19 among all of those defined suspects. Moreover, the infection transmission rate is exponential in COVID19, and it gets to the pandemic situation in a short time. Furthermore, it is difficult to reach each suspect in the proper time due to the limitations facing healthcare systems and the risk of infection for healthcare workers. Also, the dynamic nature of the novel virus and the uncommon/irregular symptoms of patients have complicated the task of population-scale screening. Furthermore, successful screening has to be performed on a massive scale to test both symptomatic and non-symptomatic individuals. This massive amount of testing mandated by the screening process requires allocating a considerable volume of medical and nonmedical resources and a wide-scale collaboration and coordination between healthcare providers, governments, and research organizations [70]. Moreover, it requires the screening process to be performed with high speed and frequency to contaminate and reduce the virus's rapid spread through a population [71]. All these requirements of efficient screening can quickly drain the limited resources and supplies in many countries and affect their infrastructures. Thus, implementing an effective population-scale screening for Covid-19 has become a challenging and resource-consuming task [72]. As a result, the focus on diagnosing symptomatic individuals was prioritized over implementing wide-scale screening during the first outbreak of the pandemic with a total of 115 studies for Covid-19 diagnosis.

Monitoring Covid-19 patients has gained limited attention in the first year of the pandemic as well with a total of six studies included in this review. For example, unsupervised ML methods were employed to develop Covid-19 surveillance systems based on identifying groups of connected individuals [34]. The limited number of studies in this category is possibly due to the lock-down procedures and the other precautionary measures that were forced by governments worldwide, which decreased the need for monitoring and tracking Covid-19 patients and resulted in little attention in this domain compared to other domains such as diagnosis and prediction.

Ensemble methods were the most used AI models and were applied in 193 of the selected studies for this review for several purposes such as Predicting the severity of COVID-19 patients [73-76], the mortality rate [26-30], Diagnosing Covid-19 patients using chest radiography [15-18] and clinical data [77, 78], Treatment [79, 80], and Prevention and Management [81]. In Ensemble Methods, a predictive model is built by integrating multiple single weak classifiers. Making Ensemble Methods well-known for outperforming single models in achieving higher classification accuracy and lower prediction errors [82]. This justifies the wide adoption of these models in dealing with Covid-19, especially with the lack of data where simple classifiers are likely to not achieve high classification accuracy. Furthermore, Ensemble methods of ML and their applications in healthcare are popular, especially for diagnosis and other classification tasks [83]. For instance, an Ensemble model consisting of SVM, NB, KNN, and DT base classifiers was developed to predict hyperlipidemia in patients with an accuracy of 97% [84]. Similarly, an Ensemble model consisting of RF, SVM, NB, NN, and LR base classifiers was developed to predict heart diseases with the highest accuracy of 98.17% for the RF algorithm [85]. Furthermore, Ensemble Methods were employed to develop Decision Support and Health Care Monitoring Systems [86] and to improve Cardiovascular Disease Prediction [87].

Support Vector Machines (SVM) models were applied in 85 of the selected studies for this review for many purposes such as Prediction of new Covid-19 cases (pandemic outbreak) [21-23], the severity of patients [3, 88, 89], the mortality rate [29, 90, 91], the side effect in patients [12-14], the mental health [92-94], for the Diagnosis of Covid-19 using chest radiography [16, 95, 96], using clinical data [97-99], and using biosensors [99], for Prevention and Management [53, 100], for Classification of Genome [47, 101], Prognosis [102], Screening [33], and Treatment [103]. SVMs were widely adopted for classification and regression tasks related to the Covid-19 pandemic. SVMs are the most popular AI models in the healthcare domain for medical-related classification tasks [104] and several studies have shown that simple classifiers such as SVM outperformed other ML models in many applications [105]. Furthermore, SVMs are widely adopted in many applications in the healthcare domain. For instance, an SVM model was employed to develop a decision-support system for diagnosing various periodontal diseases with 88.7% classification accuracy [106].

Artificial Neural Networks (ANN), a subfield of machine learning, were among the most adopted AI algorithms to deal with the pandemic as well. ANNs were applied in 133 of the selected studies for this review for several purposes such as Predicting the severity of COVID-19 patients [107-109], the mortality rate [29, 91], Diagnosing Covid-19 patients using chest radiography [110] and clinical data [98, 99], Treatment [103, 111], and Prevention and Management [100]. The choice of ANNs by researchers to model Covid-19 data and build prediction, diagnosis, and decision-support systems is predictable. ANNs are actively employed in healthcare for many applications such as diagnosis, prediction, forecasting, drug development, and utilization of resources [112]. These artificial networks have achieved high performance on many tasks and applications. For example, ANNs were applied in healthcare for heart disease diagnosis and achieved an accuracy of 83% [113] and for pulmonary tuberculosis diagnosis in hospitalized patients where it achieved a 98.5 % negative predictive value, suggesting the safety of using such models for medical use [114].

Logistic Regression models are among the top adopted ML models in healthcare for prediction purposes [115]. LRs are well-known for providing faster and high-performance prediction systems which lead to better healthcare and reduced costs. LRs were applied in 65 studies in this review for Prediction of new cases (spread) of the disease [116], the severity levels of patients [88, 117], the mortality rate [118, 119], the effects on mental health [92, 93], the side effect in patients [13, 14], and the risk [120], for Diagnosis of Covid-19 using chest radiography [121-123], using clinical data [97, 124, 125], and for Treatment [126]. For example, a LR model was developed to detect children's health conditions related to cerebral palsy with an average accuracy of 90% [115].

Deep Learning algorithms were also among the most adopted AI models in the selected studies, which is expected. The significant advancements of DL algorithms in recent years have shaped the way we look at AI nowadays [127]. DL algorithms can effectively model complex correlations and extract hidden features from data compared with other ML algorithms [127]. Convolutional Neural Network (CNN) and its variations were the most used among the DL algorithms to deal with the Covid-19 pandemic, especially in the chest radiography diagnosis and other image-related tasks. These DL models are very promising algorithms in the field of Computer Vision and Pattern Recognition and classification. DL models were applied in 106 of the selected studies for this review for several purposes such as the Prediction of new Covid-19 cases (pandemic outbreak) [38, 128], the severity levels of patients [129-131], the side effect in patients [132], Diagnosis of Covid-19 using chest radiography [133-135], for Prevention and Management purposes [136, 137], Screening using NLP [59], and Treatment [138, 139].

Decision Trees (DT) are well-known in healthcare as reliable and effective decision-making techniques. These models are capable of providing a simple representation of the data and building high-performance classification models [140]. DTs are used in healthcare to build Clinical Decision Analysis (CDA) tools with the aim of overcoming the complexity and uncertainty issues in medical problems [141]. DTs provide objective evidence of the final judgment of a decision-support system and help achieve a consistent and reproducible decision-making process. DTs also learn and reveal the predictable variables that have to be considered by the decision-maker [141]. These advantages of DTs and DT-based systems justify the wide adoption of these models to deal with the complexity and uncertainty issues related to Covid-19. DTs models were applied in 48 of the selected studies for this review for several purposes such as the Prediction of new Covid-19 cases (pandemic outbreak) [116, 142], the severity levels of patients [3, 143], the mortality rate [107, 144], the side effect in patients [12], Diagnosis of Covid-19 using chest radiography [16, 41], using clinical data [97, 145], for Prevention and Management purposes [53], and Classification of Genome [101].

During the first year of the pandemic, North America, Europe, China, and India have suffered the most from the crisis and reported the highest number of active cases and mortality rate of Covid-19 patients worldwide . Most of the selected/published studies that adopted AI/ML techniques to deal with the Covid-19 pandemic originated in these countries/regions, as shown in Figure five. This is expected for two main reasons. First, the Covid-19 pandemic/outbreak has significantly impacted many aspects of the public's life, including health, economy, and society. The unknown and unpredictable nature of the new virus, the rapidity of its spread, the massive loss in human lives it costs worldwide, the significant shortage in medical staff, supplies, and resources put the healthcare systems in many countries under a tremendous amount of pressure in a very short period of time. This resulted in substantial economic and social disruption. Almost all other aspects of public life were affected by the crisis as well. As a result, worldwide governments, organizations, and researchers are intensively investing in managing and minimizing the negative impacts of the pandemic on the world. Second, successful employment of AI/ML algorithms requires the availability of large, representative, and high-quality datasets in the problem domain. During the Covid-19 pandemic, data availability was one of the significant challenges faced by researchers in the field, especially at the beginning (early stages) of the outbreak. One can easily spot this in many earlier works that used small datasets to develop different AI models. After the massive

5. Conclusion

It is observed that there is an accelerated growth and increase in the body of research and published studies concerning the employment of AI/ML technologies to deal with the Covid-19 pandemic overtime. AI methods and techniques helped analyze and understand the pandemic data and prepare resilient evidence-based/driven preparation plans and technologies to deal with and recover from the pandemic. AI also helped achieve better analysis of the disease spread data and build strong forecasting models to predict the future spread of the virus. AI Algorithms are capable of learning the spread characteristics of the Covid-19 virus, helping to understand its nature, predicting the density of its presence in the affected areas and the potential trajectory of its spread in different countries and communities.

6. Declarations

6.1 Abbreviations

Abbreviation	Definition
AI	Artificial Intelligence
ALT	alanine aminotransferase
ANN	Artificial Neural Networks
ARIMA	Autoregressive Integrated Moving Average model
AST	aspartate aminotransferase
CDA	Clinical Decision Analysis
CNN	Convolutional Neural Network
COVID-19	Coronavirus disease 19
CRP	C-reactive protein
CT- scans	Computed tomography scans
DL	Deep Learning
DNN	Deep Neural Networks
DT	Decision Trees
JSON	JavaScript Object Notation
LDH	lactate dehydrogenase
LR	Logistic Regression
ML	Machine Learning
NLP	Natural Language Processing
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PT	prothrombin time
RT-PCR	Reverse Transcription-Polymerase Chain Reaction test
SARIMA	Seasonal Auto-Regressive Integrated Moving Average model
SVM	Support Vector Machine
WHO	World Health Organization
X-ray	X-radiation

6.2 Conflict of Interest Statement

The authors have no conflict of interests to declare.

6.3 Funding Disclosure

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

6.4 Ethical Considerations

Ethical approval or informed consent is not required for this review. The research does not involve human subjects or animals, case reports, or case series.

6.5 Acknowledgements

SAA: Conceptualization, Methodology, Software, Investigation, Resources, Data curation, Writing - Reviewing & Editing. AIA: Conceptualization, Methodology, Supervision, Writing - Reviewing & Editing. IAA: Conceptualization, Data curation, Writing - Original Draft. YAA: Writing - Reviewing & Editing. All authors have contributed to the design of the work, reviewed and approved the final draft, and are responsible for the content and similarity index of the manuscript.

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