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ARTIFICIAL INTELLIGENCE APPLICATIONS FOR COVID-19 PANDEMIC: A REVIEW

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ABSTRACT

The number of AI techniques has increased greatly for containment COVID-19. AI techniques differ in terms of purpose, synthesis methods, datasets, and validation approach. This increase and diversity in the numbers of proposed AI techniques can confuse decision makers and lead them to the dilemma of what is the appropriate technique under the specific conditions. Yet, studies that assess, analyze, and summarize the unresolved problems and shortcomings of current AI techniques for COVID-19 are limited. In the existing review studies, only individual parts of AI techniques, rarely the full solution, are reviewed and examined. Thus, this study aims to present a comprehensive systematic review on the application of AI techniques in containment the COVID-19 pandemic. The applied search strategy led to include 73 papers related to the Application of AI techniques for COVID-19 published from December 2019 to August 2020. Ten applications of AI for containment COVID-19 were identified. In addition, the analysis results of the systematic review revealed five deficiencies so that future research should take them into consideration.

Keywords: *COVID-19; Coronavirus; SARS-CoV-2; Artificial Intelligence, Healthcare, Review*

1. INTRODUCTION

In the middle of March 2020, the World Health Organization declared the COVID-19 to be a pandemic due to the fact of spreading it globally within a short time period (around 203 countries) [1]. Till 14th of March, there were 118, 754, 336 confirmed COVID-19 cases in a total of 223 countries that had resulted in 2,634,370 deaths [2].

As a reaction to the COVID-19 pandemic, the rapid growth of the literature review that offered different solutions in controlling and monitoring the growth of COVID-19 pandemics has been noticed. For instance, the support of existing technologies (e.g., Big Data, Internet of Things and Artificial Intelligence) are investigated to help prevent the spread of the virus by predicting high-risk patients, tracking previous infected cases and analyzing previous data of the patients [3] ensured that AI is a potentially powerful technology that can be utilized to provide sophisticated solutions to overcome the COVID-19 pandemic. AI is used in different ways and can play a significant role in the Big Data in the terms of pattern recognition, explanation and prediction. These functions can be useful to diagnose, predict, and treat COVID-19 infections. [4] stated that AI can contribute against COVID-19 at main six areas: "early warnings and alerts, tracking and prediction, data dashboards, diagnosis and prognosis, treatments, and cures, and social control". AI can be utilized to find complex relationships in a large set of data in a short period of time. Moreover, AI-based models can be used to observe more data about patients such as side effects of different cures based on patients predefined records; this can help to identify the most suitable management approach to be used for each patient and help to speed up the process of finding a suitable vaccine for the COVID-19 disease.

Therefore, due to the advantages offered by AI in containment the COVID-19 pandemic, the number of AI techniques has increased greatly. Although these techniques provide an acceptable start to COVID-19 pandemic control, they differ in terms of purpose, AI synthesis methods, data collection techniques, datasets, validation approach. This increase and diversity in the numbers of proposed AI techniques can confuse decision makers and lead them to the dilemma of what is the appropriate technique under the specific conditions.

Thus, this study aims to present a comprehensive systematic review on the application of AI techniques in containment the

COVID-19 pandemic. This study is significant due to its advantages of identifying and categorizing the applications of AI techniques in containment the COVID-19 pandemic, compare and summarize the he deficiencies of AI techniques in containment the COVID-19 pandemic. The article is organized into four sections which are: Research Background, Related Works, Methodology and Discussion of future research directions in light of the findings.

2. RELATED WORK

Review studies related to the applications of AI in COVID-19 pandemic have been identified and summarized. The majority of these studies are conducted to identify the possible applications of AI for COCID-19 pandemic. While, some of these review studies conducted to review the applications of AI techniques for (1) detecting covid-19 from chest X-ray images (2) classification medical imaging for COVID-19, managing of COVID-19 ICU patients, and critically appraise prediction models for covid-19. The details of these review studies are discussed as follows:

[3] presented a short review study aims to identify the possible applications of AI for COVID-19 pandemic. Although the study indicated the search sources (e.g., ubmed, Scopus and Google Scholar) and Keywords (e.g., COVID-19 or Coronavirus and Artificial Intelligence or AI) that were used in the process of retrieving relevant research, the studies used in the review process were not disclosed. This review concluded that seven areas in which AI can be applied to confront the COVID-19 pandemic, which are: (1) Early detection and diagnosis of the infection (2) Monitoring the treatment (3) Contact tracing of the individuals (4) Projection of cases and mortality (5) Development of drugs and vaccines (6) Reducing the workload of health care workers (7) Prevention of the disease. [5] conducted a review study to assess the role of artificial intelligence in areas in which it could be used to counter the COVID-19 pandemic. These areas such as (1) early warnings and alerts, (2) tracking and prediction, (3) data dashboards, (4) diagnosis and prognosis, (5) treatments and cures, and (6) social control. The study concludes that the lack of data and by too much noisy and outlier data; AI will not be effective in confronting the COVID-19 pandemic.

[6] conduct a review study to identify the challenges of healthcare systems respond to COVID-19. The study aims to show how artificial intelligence can be applied to solve the identified challenges. The review result identified five major challenges of healthcare systems respond to COVID-19 which are (1) managing limited healthcare resources (2) developing personalized patient management and treatment plan (3) informing policies and enabling effective collaboration (4) understanding and accounting for uncertainty (5) expediting clinical trials. To address these challenges that study suggests that implementation of proposed AI-based methods can be accomplished through three levels of human-machine interface which are (1) Individual-level interface (2) Hospital-level interface (3) Nation-level interface. Review conducted by [7] presented a review study to identify the possible application of AI for COVID-19 pandemic. The study identified five scales that AI could be used to address the COVID-19 challenges, namely patient, molecular, societal, and datasets and resources scales. Patient scale included 3 categories which are: (1) medical imaging for diagnosis (2) non-invasive measurements for disease tracking (3) protein structure prediction. While, molecular scale included (1) protein structure prediction (2) improving viral and testing (3) drug repurposing (4) drug discovery. Besides, societal scale which includes epidemiology and infodemiology. Lastly, datasets and resources scale which include case data, textual data and biomedical data.

[8] reviewed the application of AI in imaging data acquisition, segmentation and diagnosis for COVID-19. The study demonstrated the role of artificial intelligence in assisting visualization technicians (e.g., X-ray and/or CT) in imaging facilities without direct contact with the patient. Also, the study reviewed the possibility of using AI for image segmentation and assisted diagnosis. The study recommended that in order to improve the results of AI techniques that applied for imaging data acquisition, segmentation and diagnosis for COVID-19 and make them clinically useful, the quality and number of COVID-19 patient data need to be further improved. While, [9] reviewed the applications of data science for COVID-19 pandemic. The review aimed to identify the most significant challenges of COVID-19 and how data science can be used to address these challenges. Also, the study presented details of the most available datasets and resources of COVID-19 patient that could be useful for further research in this area. In addition, the study reviewed several studies that are related to image analysis, textual data mining, audio analysis, and embedded sensing.

The review results shown that the most important data science challenges for COVID-19 pandemic relate to (1) Data Limitations (2) Correctness of Results (3) challenges related to Security, Privacy, and Ethics (4) The Need For Multidisciplinary Collaboration (5) The Need For Multidisciplinary Collaboration (6) New Data Modalities (7) Solutions for the Developing World.

[10] conducted a systematic review and critical appraisal existing prediction models for COVID-19 infection. Search sources such as PubMed and EMBASE are used to retrieve related studies. Total of Twenty-seven studies describing 31 prediction models were selected for the systematic review. The study concluded that all proposed models have good predictive performance, but they are high risk due to many deficiencies, such as poor reporting and poor methodological conduct for participant selection, predictor description, and statistical methods used.

As presented discussion of current reviews, a comprehensive systematic review of the recent AI techniques that applied for containment COVID-19 pandemic is lack. Seldom is the complete picture reviewed; only portions of the applications of AI techniques have been typically reviewed and examined. This systematic review covers a greater number of AI techniques for COVID-19, where there are many studies that still need to be investigated. Therefore, this review seeks to unify recent research efforts to help in strengthening new insights in pursuing more research that could improve on current AI techniques outputs or help to develop new AI techniques with better performance and accuracy for containment COVID-19 pandemic.

3. METHODOLOGY

The review methodology used in this study follows the guidelines and procedures proposed by [11] and [12]. The current review study is conducted from the viewpoint of the two main research questions (1) what are the applications of AI for COVID-19 pandemic. The objective of this SLR is to explore and examine the AI techniques employed by researchers for containment COVID-19 pandemic. The search strategy began by determining the search period. Research published between December 2019 and August 2020 has been retrieved. The starting date (January 2010) was selected because the first positive case recorded for COVID-19 was identified on December 2019 in Wuhan, China. While, the end date (August 2020) was selected because the SLR was conducted during this period. Next, research sources were identified from which relevant AI applications for COVID-19 research will be retrieved. Seven search resources (e.g., ScienceDirect-Elsevier, IEEEXplore, PubMed, Embase and Google Scholar) were considered to include broadly related papers published and preprint during period. Subsequently, search keywords and phrases have been identified. The number of papers retrieved from the initial automatic search is 3690 papers. By reviewing the retrieved papers titles and abstracts, 3460 papers were excluded because they were beyond the scope of this SLR. The remaining 230 research papers were filtered using inclusion and exclusion criteria. Therefore, papers that matched the following inclusion criteria were included (1) Papers related to the COVID-19 domain and (2) Papers presenting AI techniques.

It is worth noting that all published and pre-prints papers are included. Although pre-prints papers still need to be peer-reviewed and evaluated for approval by the scientific community, it was included in the study because (1) to cover the largest possible number of AI techniques for COVID-19 Pandemic (2) they start getting citations from other researchers. This means that many of the current research related to the applications of AI techniques for COVID-19 pandemic started relying on these pre-prints researches which could affect the building of the body of knowledge in this research area. So, we found it necessary to include, review and investigate them. While, papers that matched at least one of the following exclusion criteria were excluded: (1) Papers not focusing on the AI for COVID-19 pandemic (2) Papers providing only recommendations, guidelines, or principles for AI for COVID-19 pandemic (3) Papers not written in English.

To answer the main research questions, 73 research papers were indexed in Appendix A and Table 1 and each paper was read in-depth. As presented in Table 1, data extraction form that consist of 12 dimensions (e.g., Application of AI (AoAI), ID, Source, Purpose, AI-Methods, Validation Approach, Limitations, Data set used for, Name of dataset, Size of data set, Country, Source of dataset) is created to (1) facilitates the process of data extraction (2) organize and record full details of the papers under review and (3) specify how each research question was addressed.

4. DISCUSSION AND FUTURE RESEARCH DIRECTION

Although studies of applying AI techniques for containment COVID-19 have been able to (1) epidemic and how it has spread, many of these studies have been viewed as providing biased, incomplete and poor trustworthiness evidence of the proposed AI techniques for containing COVID-19 pandemic. The analysis results of the systematic review revealed that studies of applying AI techniques for containment COVID-19 are undergoing a crisis that is visible through deficiencies, namely (1) small size of the dataset (2) specific context use (3) lack of giving explicit feedback (4) focus on specific types of AI techniques. Therefore, this study concludes with a set of suggestions that converge on the idea that new studies of applying AI for containment COVID-19:

1. Should use large size of dataset.

It is evident from Table 1 that the majority of the studies reviewed (1) used small dataset size, (2) used early-stage datasets, (3) most of the datasets used are Chinese datasets, and (4) neglecting the validation of the dataset. Small dataset is not sufficient to train AI techniques. This is because the performance of the most AI techniques is enhanced on large datasets. Although many AI techniques have proven its applicability for contain COVID-19 epidemics, there are doubts about the accuracy of its results. This weakens their applicability in real life for offering concrete diagnostic and treatment options, as relying on their results can affect patients' lives. Therefore. There is an urgent need to develop large international datasets about COVID-19 pandemic. It is recommended to categorized datasets under specific context. For example, in this study76 sources of datasets about COVID-19 pandemic have been identified which distributed as follows:

- Nineteen sources of dataset for COVID-19 outbreak prediction.
- Nine sources of dataset for predicting criticality of COVID-19 cases.
- Eleven sources of dataset for distinguishes COVID-19 from chest X-ray.
- Ten sources of dataset for distinguishes COVID-19 from chest CT images.

provide a good start to suggest solutions in containing the COVID-19 epidemic, (2) strengthen our understanding of the COVID-19

- Six sources of dataset for distinguishes COVID-19 from clinical tests.
- Two sources of dataset for distinguishes COVID-19 from genomic signatures.
- One source dataset for distinguishes COVID-19 from sound signal.
- Three sources of dataset for detecting and tracking COVID-19 cases.
- Twelve sources of dataset for developing COVID-19 drugs and vaccines.
- Three sources of dataset for managing healthcare resources-COVID-19

These datasets should be updated continuously. In addition, in order to generate a new and comprehensive dataset about COVID-19, data mining research is recommended to discover the pattern of these datasets. Also, the validation of these datasets is necessary to ensure their validity and safety for being used by AI techniques for containment COVID-19 pandemic. Perhaps it is better to classify these datasets by a country which it was collected from. This is important to study whether there is a difference in the results of the application of these datasets from one country to another, which in turn can help in a deeper understanding of COVID-19 disease by country and the ability of its residents to respond to this disease.

2. Should develop hybrid AI systems

As shown in Table 1 most applied AI algorithms and techniques are related to machine learning. For example, Neural Network and Deep Learning algorithms are the most two techniques applied for containment COVID-19 pandemic. As many of the reviewed studies reported that small dataset is the main limitation of their studies, to use these datasets to train and test such algorithms will lead to decrease their performance and inaccuracy of their results. Even the machine learning algorithms are powerful predictive algorithms which can be used to deal with more complex structure of data, but they need large dataset, training for a long time, and they have poor interpretability [13]. Which in turn creates a conflict for the adoption of these algorithms. However, due to fact that no single AI

techniques outperforms all other techniques. Future research should give more attention to hybrid AI systems that combined new trends of AI techniques (e.g., metaheuristic algorithm) to benefit from the different characteristics of different algorithms. For example, but not limited to, salp swarm algorithm [14], moth–flame optimization [15], and cuckoo search algorithm [16] are a very promising and interesting algorithm that has already been successfully applied to several problems in medical research area due to their contain simplicity, speed in searching, and simple hybridization with other algorithms.

Table 1: Artificial Intelligence applications for COVID-19 pandemic

AoAI	ID	Source	Purpose	AI-Methods	Validation Approach	Limitations
COVID-19 Outbreak Prediction	[S1]	MDPI	To predict the challenges of the COVID-19 in the sustainable development process	- Neural network - Group method of data handling.	Case study	- Small dataset.
	[S2]	MDPI	To Forecast confirmed cases of COVID-19	- Neuro-fuzzy inference system - Flower pollination algorithm. - Salp swarm algorithm.	Experiment	- N/A
	[S3]	ArXiv	To count infection of COVID-19 over time	- Machine Learning	Statistical analysis	- Not generalizable - Uncertainty in the prediction result
	[S4]	MedRxiv	To predict the number of confirmed cases of COVID-19	- Convolutional Neural Network	Experiment	- N/A
	[S5]	JMIR	To estimate the number of positive COVID-19 cases in Iran.	- Data mining algorithms - Linear regression	Statistical analysis	- Data access limitation
	[S6]	MedRxiv	To predict daily numbers of cumulative confirmed cases, new cases, and death cases of COVID-19.	- Eureqa tool	Experiment	- Limited to demographics factors
	[S7]	Science press	To Predict the outbreak of COVID-19 in India	- Prophet tool	N/A	- N/A
	[S8]	ArXiv	To predict the outbreak of COVID-19.	- Mathematical analysis (fractional derivative)	Example	- N/A

[S9]	F1000 research ltd.	To classify countries according to the number of confirmed COVID-19 cases.	- Unsupervised K-means algorithm	Statistical analysis	- Not generalizable - Uncertainty in the prediction result
[S10]	Sciencedirect	To predict COVID-19 outbreak.	- Fuzzy rule-based - Evolutionary algorithm (Eclass1-MIMO).	N/A	- Only applicable for regions with access to social networks such as Twitter and Facebook
[S11]	Techrxiv	To pridict the epidemiological pattern of the disease and rate of COVID-2019 cases in India	- Linear regression - Multilayer perceptron - Vector Autoregression	Experiment	- N/A
[S12]	arXiv	To predict COVID-19 activity in chinese provinces in real-time.	- Augmented ARGONet	Experiment	- N/A
[S13]	arXiv	To predict the transmission of the COVID-19.	- Classical Kermack-Mckendrick SIR model	Experiment	- N/A
[S14]	arXiv	To estimate the size, lengths and ending time of Covid-19 across China.	- Modified auto-encoders Neural network	Experiment	- N/A
[S15]	MedRxiv	To observe everyday behaviour and prediction of future reachability of the COVID-2019 across the nation	- Support vector regression - Polynomial regression - Standard deep neural network - Recurrent neural networks	Experiment	- Dataset availability
[S16]	arXiv	To analyze and forecast COVID-19 for the coming days.	- Interior search algorithm based on chaotic learning (CL) strategy - Multi-layer feed-forward neural network (MFNN).	Experiment	- N/A
[S17]	SSRN	To predict the COVID-19 outbreak.	- Multi-layered perceptron. - Adaptive network-based fuzzy inference system.	Experiment	- N/A

	[S18]	medRxiv	To forecast Covid-19 outbreak progression in italian regions:	- Neural network	Experiment	- N/A	
	[S19]	medRxiv	Forecasting the dynamics of COVID-19 Pandemic in Top 15 countries	- Auto-regressive integrated moving average model.	Statistical analysis	- N/A	
Predicting criticality of COVID-19 cases	[S20]	MedRxiv	To identify the risk factors associated with mortality of COVID-19 infected patient.	- Random forest classification algorithm.	Statistical Analysis	- Small dataset - Results not being accurate.	
	[S21]	MedRxiv	To predicting the survival of individual COVID-19 patients	- XGBoost classifier.	Statistical Analysis	- Small dataset - Results not being accurate.	
	[S22]	SSRN	To determine prognostic risks of COVID-19 patients.	- Cox regression model.	Statistical Analysis	- Results not being accurate	
	[S23]	MedRxiv	To predict the risk of positive COVID-19 diagnosis.	- Neural networks, - Random forests, - Gradient boosting trees, - Logistic regression - Support vector machines	Experiment	- Small dataset	
	[S24]	MedRxiv	To predict how much results are close to original data related to Confirmed-Negative Released-Death cases of Covid-19	- Deep-learning Neural Network	Experiment	- Small dataset	
	[S25]	MedRxiv	To determine the health risk and predict the mortality risk of patients with COVID-19.	- Neural networks. - Random forests. - Logistic regression. - Support vector machines. - Decision Tree. - K-Nearest Neighbor (KNN).	Experiment	- Small dataset	
	[S26]	MedRxiv	To predict mortality risk in COVID-19 patients before they transmit to critically ill.	- XGBoost classifier.	Statistical Analysis	- Small dataset - Need for more performance testing	

	[S27]	MedRxiv	To predicts the survival for individual severe COVID-19 patients.	- XGBoost classifier.	Statistical Analysis	-	Algorithm is exploratory
	[S28]	Sciencedirect	To estimating the death rate of a COVID-19 case in real-time.	- Mathematical model	Statistical Analysis	-	Algorithm is exploratory
Distinguishes COVID-19 From Chest X-ray	[S29]	Medium	To Distinguish chest X-rays of patients who have tested positive for COVID-19.	- Deep convolutional neural network.	Experiment	-	Algorithm is exploratory
	[S30]	MedRxiv.	To Distinguish between the COVID-19 patients and healthy individuals' patient.	- ResNet152 & SMOTE	Experiment	-	N/A
	[S31]	MedRxiv	To diagnose COVID-19 using X-ray images.	- ResNet50.	Experiment	-	N/A
	[S32]	MedRxiv	To diagnose COVID-19 using X-ray images	- Support vector machines.	Experiment	-	N/A
	[S33]	ArXiv	To diagnose COVID-19 using X-ray images	- Class Decomposition Mechanism	Experiment	-	N/A
	[S34]	ArXiv	To diagnose COVID-19 using X-ray images.	- K-Nearest neighbor. - Support vector machines. - Multilayer perceptron. - Decision trees. - Random forests.	Experiment	-	N/A
	[S35]	Google scholar	To diagnose COVID-19 using X-ray images.	- Support vector machines. - Random forest.	Experiment	-	N/A
	[S36]	ArXiv	To diagnose COVID-19 using X-ray images.	- Deep convolutional Neural Network	Experiment	-	N/A
	[S37]	ArXiv	To diagnose COVID-19 using X-ray and CT images.	- Gravitational search algorithm. - Convolutional Neural Network.	Experiment	-	N/A
	[S38]	MedRxiv.	To diagnose COVID-19 using X-ray images.	- ResNet-50 - Convolutional Neural Network.	Experiment	-	N/A

	[S39]	ArXiv	To diagnose COVID-19 using CT images.	- Convolutional Neural Network. - Deep Learning	Experiment	-	N/A
	[S40]	ArXiv	To diagnose COVID-19 using CT images.	- Convolutional neural network.	Experiment	-	N/A
	[S41]	ArXiv	To diagnose COVID-19 using CT images.	- Capsule Network	Experiment	-	N/A
Distinguishes COVID-19 From Chest CT Images	[S42]	RSNA	To diagnose COVID-19 using CT images.	- ResNet50	Experiment	-	N/A
	[S43]	arXiv	To diagnose COVID-19 using CT images.	- Grey level co-occurrence matrix. - Local directional pattern grey level run	Experiment	-	N/A
	[S44]	arXiv	To diagnose COVID-19 using CT images.	- Deep neural network	Experiment	-	N/A
	[S45]	arXiv	To diagnose COVID-19 using CT images.	- Res2Net. - VGG-16 encoder. - Global average pooling. - Squeeze-Excitation unit	Experiment	-	N/A
	[S46]	MedRxiv.	To diagnose COVID-19 using CT images.	- Multitask deep learning	Experiment	-	Small dataset.
	[S47]	MedRxiv	To extract COVID-19's graphical features from CT images	- Deep learning algorithm	Experiment	-	Small dataset.
	[S48]	MedRxiv	To diagnose COVID-19 patients	- Support vector machines. - Multilayer perceptron. - Random forests. - Deep convolutional neural network.	Experiment	-	Small dataset.
	[S49]	arXiv	To diagnosis of pandemic disease COVID-19	- Deep learning - Support vector machine - Convolutional neural network	Experiment	-	Small dataset.
	[S50]	Europepmc	To evaluate CT features of mild cases ready for discharge	- InferRead TM CT Pneumonia software	Statistical analysis	-	N/A
	[S51]	MedRxiv	To analysis Chest CT scans of suspected COVID-19 patients.	- Support Vector Machine	Experiment	-	N/A

Distinguishes COVID-19 From Clinical Test	[S52]	medRxiv	To proposed aid system for suspected COVID-19 pneumonia in fever clinics.	- Machine learning	Statistical Analysis	- Small dataset.
	[S53]	SSRN	To improve COVID-19 diagnosis accuracy for clinical purpose	- Sparse rescaled linear square regression. - Evolutionary non-dominated radial slots-based algorithm. - Attribute reduction with multi-objective decomposition-ensemble optimizer. - Gradient boosted feature selection. - Recursive feature elimination.	Experiment	- Small dataset.
	[S54]	medRxiv	To proposed aid system for suspected COVID-19 pneumonia in fever clinics.	- Machine learning	Statistical Analysis	- The effect of treatment was ignored.
	[S55]	medRxiv	To accurately identification of COVID-19 using clinical available blood test results	- Random forest algorithm	Experiment	- Small dataset.
	[S56]	SSRN	To build the COVID-19 severances detection model.	- Support vector machine	Experiment	- Small dataset.
	[S57]	medRxiv	To perform an initial screening of suspect COVID-19 cases	- K-Nearest neighbor. - Support vector machines. - Synthetic Minority. Oversampling Technique.	Experiment	- Small dataset. - The need for understanding how the COVID-19 virus alters blood components.
Distinguishes COVID-19 From Genomic Signatures	[S58]	Biorxiv	To detect 67 viral species and subspecies, including COVID-19	- A CRISPR-based nucleic acid detection method.	Experiment	- Small dataset - Samples did not include a mixture of synthetic.
	[S59]	Biorxiv	To identifying an intrinsic COVID-19 genomic signature.	- Supervised machine-learning algorithm - Digital signal processing. - Decision tree approach.	Experiment	- Results not being accurate. - Need for more performance testing

Distinguishes COVID-19 From Sound Signal	[S60]	arXiv	To develop a diagnostic test for COVID-19 based on analysis of sound signal from cough phone recordings.	- Convolutional neural network. - Transfer learning.	Experiment	- Small dataset - Quality of audio samples is not considered during the research.
Detecting & Tracking COVID-19 Cases	[S61]	OSF	To analyze cough sounds of suspected people.	- Symptom detection algorithm. - Speech-recognition.	Experiment	- N/A
	[S62]	ArXiv	To simulate how the COVID-19 virus spreads and infects healthy people.	- Deep learning algorithm.	Experiment	- Not effective if the affected population grows
	[S63]	Cambridge university press	Reduce the time to identification of a person under investigation (PUI) for the COVID-19 infection.	- Deep learning algorithm.	Experiment	- N/A
	[S64]	ArXiv	To measure the role of quarantine and isolation for controlling the reproduction number of the COVID-19.	- Neural network.	Experiment	- N/A
	[S65]	ArXiv	To control and prevent the spread of COVID-19.	- Neural network - Bayesian optimization framework - fuzzy rule-based method	Experiment	- Small dataset. - Lack of data diversity.
	[S66]	medRxiv	To forecast the fade out of the COVID-19 outbreak in Italy	Compartmental epidemiological models (SEIRD)	Experiment	- N/A
Developing COVID-19 drugs and vaccines	[S67]	arXiv	To prevent and contain ongoing COVID-19 pandemic	- AI-Powered Infodemic - Management solution WashKaro	Experiment	- Small dataset. - Lack of data diversity.
	[S68]	Biorxiv	To predict COVID-19 vaccine candidates.	- Vaxign-ML machine learning tool	Experiment	- Small dataset

	[S69]	Chemrxiv	To discover potent Covid-19 main protease inhibitors.	- Docking Algorithm - Prime MMGBSA Analysis	Experiment	- Confirmation of COVID-19 therapeutic agents need for more experimental studies.
	[S70]	medRxiv	To identify requirement of new and effective medications that can treat the disease caused by COVID-19.	- Naive Bayesian classification algorithm	Experiment	- N/A
	[S71]	arXiv	To identify ligands that can limit and/or disrupt the host-virus (COVID-19) interactions.	- Random forest - Docking simulations	Experiment	- N/A
	[S72]	Chemrxiv	To identify "progeny" drugs that are similar to the "parents" already being tested against COVID-19	- Linguistics inspired Mol2Vec embedding. - Estimated shape representation - Convolutional neural network	Experiment	- N/A
Managing Healthcare Resources-COVID-19	[S73]	Repositorio	To manage medical resources during a COVID-19 pandemic	- Deep neural networks (DNN)	Experiment	- N/A

1. Should not focus on a specific research area over another

Figure1. indicates that 45 % of AI techniques were specifically designed to diagnosing COVID-19 cases (e.g., 18% distinguishes COVID-19 from chest X-ray, 14% distinguishes COVID-19 from chest CT images, 8% distinguishes COVID-19 from clinical test, 3% distinguishes COVID-19 from genomic signatures, 2% distinguishes COVID-19 from sound signal). 38 % of AI techniques were developed to address COVID-19 prediction cases (e.g., 26% for COVID-19 outbreak prediction and 12% in predicting criticality of COVID-19 cases). While, 8% of AI techniques were specifically implemented for detecting and tracking COVID-19 cases. Also, 8% of AI techniques were used for developing COVID-19 drugs and vaccines. Finally, 1% of AI technique used for managing healthcare resources-COVID-19.

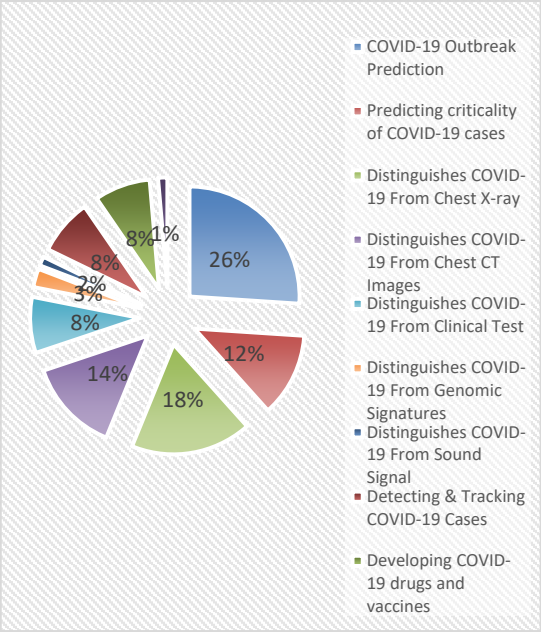

Figure.1 AI techniques Application for COVID-19

The majority of reviewed AI techniques were developed for prediction and diagnosing COVID-19 pandemic neglecting other important area such as developing COVID-19 drugs, managing healthcare resources, and detecting and tracking COVID-19 cases. Therefore, future research must take into account that developing AI techniques for these areas is no less important than others and is essential in containing the COVID-19 pandemic. For example, proposing AI techniques that aim to produce drugs and medicines to treat infected COVID-19 patients and AI techniques to investigate vaccines to prevent the virus of COVID-19 is highly recommended and persistent need. In addition, developing AI techniques for managing healthcare resources in recommended. This is because the numbers of people infected with the COVID-19 are large, widespread, and is constantly increasing, hence the management of healthcare resources is necessary to ensure the continuity of the healthcare process without interruption or congestion.

As presented in Figure 2, the majority of reviewed studies are conducted to containment COVID-19 pandemic in China (e.g., 19 studies). Following by 13 studies conducted to contain the COVID-19 pandemic in worldwide. While, USA and Italy produced 5 studies for each. Following by India 4 studies. This pandemic is not limited to a single country. It is a global pandemic. Therefore, it is necessary for future research to take into account the developing countries (e.g., African countries, middle eastern countries, Latin American countries, etc.) These countries are already suffering from a scarcity of health resources and crisis management, AI techniques for containment COVID-19 can help them in making the right decisions in managing the crisis in various level health, economically and socially.

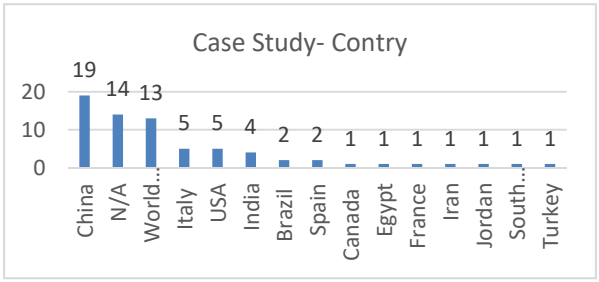

Figure. 2 AI Techniques Application- Country Case Study

5. CONCLUSION

In this paper the applications of AI techniques for containing COVID-19 were reviewed. The main contribution of this systematic literature review was to introduce new lines of inquiry that could inspire researchers to conduct further researches or improve existing studies within the field applying AI techniques for containing COVID-19 pandemic. Seventy four research papers were identified, retrieved, summarized and analyzed. The analysis result revealed that this area of using AI techniques for containing COVID-19 pandemic still in the infant stage and is not yet complete. Research in such area is undergoing a crisis that is made visible by the numerous problems and deficiencies. These deficiencies emphasize the importance of rethinking the proposed AI techniques, datasets, and research focus area for containing COVID-19 pandemic. To be accepted in the real world, these studies should increase the performance and the result accuracy of applied AI techniques by using large size of dataset, develop hybrid AI systems. Also, they should increase the generalizability of the proposed studies as the COVID-19 disease is a global pandemic. However, AI techniques are still promising, interesting and more and more becoming mature which make them more trustable

and attractive to help in containing COVID-19 pandemic.

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