Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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AI in Fighting Covid-19: Pandemic Management

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Abstract

Coronaviruses are a family of viruses found in several animal species, such as bats, cattle, cats, camels, and humans. With more than 1.6 million people dead worldwide, as of December 2020, the Covid-19 pandemic has brought about a unified need to address global health crises more aggressively. There is great urgency in decreasing the impact of a potential future outbreak, which can be done by gathering information about the disease and its effects on humans. Various artificial intelligence (AI) techniques can be utilized for the pandemic, such as COVID (CoV) management, a vast scientific field involving computers performing tasks capable of only human brains. Among the subsets of AI, there are Machine Learning (ML) techniques, which can learn from historical data examples without programming. While no prior data regarding the virus exists, the growing cases make for more data. In this research, we employ a literature review method to understand pandemic management's current state and how it can benefit by utilizing AI capabilities.

Keywords: Pandemic Management; Artificial Intelligence; Machine Learning; Coronavirus; Covid-19; Intelligent Cities; Smart Cities

1. Introduction & Background

Pandemic infections have been feared throughout human history. The Covid-19 virus spread rapidly worldwide as patients overwhelmed healthcare systems, and mortality rates saw unexpected levels, revealing how unprepared humankind is to handle such a global health crisis. The outbreak of the Covid-19 virus has fueled the demand for an

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effective pandemic management system. To effectively battle these pandemic diseases, there is always a need for a robust governance mechanism in place. Various disruptive technologies were utilized to solve crises related to critical environmental, economic, and social. One of these disruptive technologies, AI, has been changing multiple aspects of life and industries, as seen by examples such as Airbnb and Uber. This technology is becoming increasingly relevant in the post-pandemic world as it can be used to mitigate and prevent a similar future disaster. The increasing capabilities of AI are changing the way medical practice is done. With recent developments in digitized data acquisition, ML, and computing infrastructure, AI sees expansion into areas previously considered to be a domain of only human minds. Many different kinds of data mining and AI techniques have been created by experts using real Covid-19 (CoV) datasets. Despite the developments occurring in the AI domain, it is still difficult to accurately predict and diagnose such rapidly changing viruses. However, developing these systems will allow for a more accurate prediction and prevention process for future pandemics. AI has great relevance when it comes to managing a pandemic.

Managing a pandemic became all the more important in 2020, when a disease caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), a new RNA virus, more commonly known as Coronavirus, or Covid-19, quickly led to a global pandemic. As per the centers for disease control and prevention (CDC), one of the crucial aspects of these coronaviruses is that they can cause severe respiratory diseases. These can initially cause the patient to display common flu-like symptoms and develop into much more dangerous conditions, such as acute respiratory syndrome, which can involve a lower respiratory tract infection. As is the case with other coronaviruses, this virus causes an illness that spreads from one individual to another, and infections can be mild or deadly. As per the World Health Organization (WHO), while there is not enough information to thoroughly understand the virus, research from China shows that it develops into a severe and possibly life-threatening condition in around 16% of infections. Those who are more at risk of being in serious condition due to this virus are older patients and those who have compromised immune systems due to preexisting health conditions, including heart disease, diabetes, or asthma, to name a few.

Based on the literature review, after the Covid-19 virus spread, research reported the various ways that AI and ML techniques used to manage the Covid-19 virus, such as classification of the virus, developing a vaccine, and predicting the number of cases, deaths, and recoveries [1, 8,12]. These models have also developed simulations for no lockdown procedures and spread patterns based on various geographic regions.

Table 1. Literature Review Summary

Finding	Motivation	Reference
Machine learning consists of tools used to identify patterns in data. Using artificial intelligence and machine learning can identify patterns from a large quantity of data, can self- improve when new data becomes available, and becomes quicker at these tasks.	Various types of machine learning are discussed that have historically been used to predict, detect, and manage infectious diseases. It also discusses how these are currently being used to fight Covid-19.	[2]
This paper discusses an early observation of how AI can or cannot effectively fight Covid-19. How AI has been used thus far is also discussed.	It is emphasized that not enough data, combined with overwhelming data, will need to be balanced with data privacy, public health, and extensive human-AI interaction.	[7]
Advancements in artificial intelligence have made for faster processing and analysis of large and complex data. The recent developments in disease prediction and drug development during the Covid-19 pandemic are discussed.	Machine learning is discussed as a subset of AI as it creates systems capable of learning from the data using statistical methods.	[10]

Detecting Covid-19 cases has become increasingly difficult for doctors and researchers. While there is public data available on the number of cases and deaths globally and in each country, this does not address the missing infections.	A deep-learning model was developed to better the accuracy of covid testing.	[12]
The novel coronavirus has had a wide global impact, making it increasingly important for scientists and researchers to research different methods to help slow down the spread of this virus. While the growing interest in AI has addressed many medical issues, these systems remain insufficient due to the high threat of the virus.	Why is AI not being utilized? What could specific systems in AI be useful?	[1]
An artificial intelligence model, multi-gene genetic programming (MGGP), can be utilized to predict the next coronavirus outbreak metrics. While the cases have shown fluctuations, the model results in 7 countries have closely matched actual events.	How can future patterns of Covid-19 be predicted using historical data? How have different strategies factored into the virus?	[8]
Artificial intelligence can be utilized to mimic human intelligence to solve complex problems. It can be used to achieve strategic differentiation, which will improve business survival when leveraging available organizational resources.	How can AI be used by businesses to improve their business post the pandemic? What type of data is involved? What needs to be done on a business and government level for something like this to occur?	[9]
A numerical risk score was calculated for each country that publicly reported the number of Covid-19 cases, deaths, and tests. This data was grouped into four categories after being collected, and each risk class was assessed at a low, medium-low, medium-high, or high level.	To identify the pandemic risk and preparation based on attributes of demographics and geography. The transmission risk is calculated from the total Covid-19 cases per million population.	[4]

2. Effective Pandemic Management

Pandemic infections are not a new threat that has challenged the existence of the human world. The last century has seen many such threats such as SARS-CoV, Middle East Respiratory Syndrome (MERS-CoV), some of the outbreaks such as Spanish flu (H1N1), Asian flu (H2N2), and Hong Kong flu (H3N2) [15]. Despite all the previous pandemic and outbreaks, there is still a lack of an effective way to manage the pandemic, which can cause many of the world's citizens to lose trust in their leadership. To combat pandemics such as Covid-19, a more uniform and organized approach is required to effectively combat pandemic situations.

As reported by many news sources and the ScienceDaily, there was a rapid increase in the pandemic's spread; and individuals need access to already limited healthcare resources, which puts a higher strain on the entire healthcare system [15]. This strain can cause a shortage of supplies, such as PPE and healthcare workers. Additionally, as many panicked buying patterns saw customers hoarding essential healthcare supplies, this caused healthcare workers not to have access to as much as they may need to perform their job duties safely. As a result of limited supplies and what became overfilled hospitals in many areas, many healthcare workers became infected, no longer working. This put a further strain on the entire system. Therefore, the stress and decrease in capacity of the healthcare system caused patients in the system to receive inadequate care, spread the infection at increasing rates, and, overall, make the crisis even worse.

As the WHO discusses, a second vicious cycle consists of how consumers and businesses respond to the crisis. As they lose confidence in government and other leadership to manage the pandemic effectively, consumers will

decrease their spending, saving more, resulting in businesses seeing reduced demand for their products and services. As a result, companies will be forced to scale down their production and investments, causing higher unemployment rates and lower consumer spending. These factors will see effects expand across the entire national economy and decrease business activity [15].

The pandemic also affects the financial markets reacting to the virus. Throughout the Covid-19 pandemic and global shutdowns, investors lost confidence and trust in authorities to manage the crisis. This uncertainty leads to market volatility as investors react with increased nervousness to the daily news and headlines. Due to this uncertainty, and to somewhat protect themselves from it, many investors reposition their investments into safer and less vulnerable portfolios or assets. This adjustment to their financial portfolios causes a loss of potential wealth and raises an overall concern in the market.

With the rapid spread of Covid-19 worldwide, leadership needs to have an established procedure and researched actions to control and manage a pandemic. An essential aspect of pandemic management and containing the virus is establishing zones [3]. More importantly, however, it is the need to contain the spread of the virus within these designated zones, which depends on contact tracing to collect and use the information to identify, test, trace, isolate, and treat those infected. The interconnectedness of the functions involved in pandemic management is known as a pandemic management service value chain, consisting of the following stages:

- Identifying the network of people that need to get tested
- Collecting samples
- Testing and making accessible test results
- Contact tracing to find infection exposures and sources
- Enforcing a quarantine of positively-tested patients to prevent further spread
- Providing infected patients with the required treatment and equipment
- Following up with those that have been quarantining [3,15].

The speed and reliability of the above course of pandemic management are crucial in managing the pandemic effectively and ensuring that the virus does not exceed the healthcare sector's capacity. AI and ML algorithms can play a substantial role, especially as they can make manual monitoring and tracing less needed, allowing healthcare professionals to utilize their time in another area of need.

3. Machine Learning

Artificial intelligence has become an increasingly popular field of study as its power and potential for predicting future events are being realized. We see AI being used to create machines that can behave like humans to perform tasks related to reasoning, problem-solving, perception, learning, and planning, to name a few [15]. Table 2 has tabulated some of the common AI/ML methods that can help manage the pandemic.

Table 2. AI Algorithms

Name of Algorithm	Description
Decision Tree	Tree-like structure, in which each internal node is representative of an attribute, enabling the structure to split data and leaf nodes to represent classes.
Random Decision Forest	Produces various random decision trees, where each tree votes on what the classification of the input data should be. The class that gets the most votes from these trees is picked over the others (majority vote system).
K-Nearest Neighbor	A similar model to RDF as the prediction is also obtained from a majority vote. However, the decision trees are not the ones placing votes, and rather it is the data within the model that is closest relative to n-dimensional Euclidean space, in which n is how many attributes are in the model.
Gradient Boosting	Creates a set of weak learners, such as decision trees, and has the goal of reducing the loss function by using a forward additive method. This classification method seeks to minimize deviance from actual data, and at each stage or class level, a total of four trees are fit on to the model.

Naive Bayes	Uses a probability-based classifier to find the posterior probability for various hypotheses and chooses the hypothesis most likely to occur.
Linear Discriminant Analysis	Statistics based approach that has the aim of finding the optimal linear combination of inputs that characterizes or separates the different classes of data variables. This separation is then used to create a feature selection to produce a linear combination of classifications.
Quadrant Discriminant Analysis	ML algorithm that segregates each class of the data input objects. Similar to LDA, QDA predicts the covariance matrices of each object class and does not assume that they are the same.
Support Vector Machines	A method that aims to separate a set of data points by object class most accurately and does so by increasing the margins. It uses a hyperplane to best separate the input data points and then estimates a new set of data points according to the distance that is shown on the hyperplane. The use and optimization of the hyperplane is so that the data sets can be the most clearly and accurately defined with large margins separating them
Stacked Generalization	This "is a process of training a machine-learning algorithm to interpret the predictions of an ensemble of algorithms trained upon the dataset in the process of meta-learning" [4].

4. AI Uses and Future Implementation

AI capabilities can be utilized to track and predict how the Covid-19 virus may potentially spread in time and region. AI was used to alert the world and particularly the US about the possibility of Covid-19 entering the country and other risks associated with the disease by the AI-based model of HealthMap, from Boston Children's Hospital. While the lack of data on the disease and its complex nature, compared to previous outbreaks, makes it challenging to implement an AI model, as this requires a substantial amount of data, work on these models can be crucial in future pandemic management.

One of the areas AI has proven to use is healthcare, where AI impacts multiple medical fields. Artificial intelligence is shaping up to be a vital force in battling cardiovascular disease (CVD), one of the most prevalent causes of death globally [4]. Artificial intelligence can help with preventative care, diagnosing various diseases. AI is perfectly suited to examining images because it can look past scans, create a database to detect any signs of illness, and then apply them to help cure the disease. The current COVID-19 pandemic has greatly impacted the global population, but healthcare workers and the healthcare industry have taken an enormous hit. Equipment shortages are just one of the many issues that are plaguing healthcare in this time of crisis. Due to the recent closures of many "non-essential" radiology practices, market researching company IDTechEx has provided an innovative solution. Artificial intelligence, precisely the type experienced with image recognition, can assist hospitals currently filled with patients. This image recognition artificial intelligence can help healthcare workers detect anomalies faster than radiologists usually can. This type of software has approved by the FDA to be used and marketed in the healthcare industry, allowing hospitals to work with the technology and reach diagnoses faster than was usually possible. Another viable area for AI implementation is diagnostics. An increasing number of AI models have been developed to diagnose the novel coronavirus via chest radiography images. With the current issues in covid testing, including the time to get results and the accuracy of these results, this would most certainly be a breakthrough. Tested individuals could be informed of a more accurate result faster, potentially saving lives. Machine learning has also been instrumental in creating algorithms to help diagnose people who may need intensive care due to some underlying health condition or other factors. Not all patients show symptoms or need to be placed in intensive care, making it essential to narrow down the patient in need.

One of the ways to utilize AI capabilities for pandemic management is to build smart cities. Many researchers believe that AI can protect modern-day society from the damaging impacts of climate change, biodiversity loss, natural disasters, unsustainable developments, and pandemics. Many technology-based solutions and products, including autonomous vehicles, home automation systems, robots, and advanced tools for data analytics, have created new opportunities for cities to develop. "Smart city as an urban locality functioning as a robust system of systems, and whose economic, societal, environmental, and governmental activities are based on sustainable practices driven by AI technologies, helping us achieve social good and other desired outcomes and futures for all humans and non-humans" [16].

As cities become increasingly involved with more of the population shifting to these urban areas, AI systems are at the forefront of prominent smart city developments. It has become more common to combine ML with another disruptive technology to produce an advanced solution such as combining deep learning and high-performance computing to combat issues such as contact tracing and maintain social distancing.

A key aspect of pandemic management is social control, in which AI plays a significant role. AI implementation using a technique such as thermal imaging technology can help scan public areas for Covid-19 patients, enforce social distancing, mask-wearing, and identify any rule violations.

In addition to social distancing, enforcing self-quarantine has been a substantial issue. Many individuals choose not to follow the quarantine orders and risk spreading the infection to others. With the help of an AI system in place (such as 'social distancing detection' software), the people who are not following the rules can be monitored.

5. Conclusion

The Covid-19 pandemic has displayed the challenges to govern and manage the pandemic. The large streams of information regarding Covid-19 during the pandemic provide little help, as currently, there is no effective way to sort through all the information and analyze it in a reasonable time frame. Artificial intelligence can better use big data. The previous research suggests that AI can better understand critical aspects of pandemic management, such as which regions face more significant risks, including the transmission of risk, mortality risk, and testing inability risk. Machine learning algorithms especially play a crucial role in timing certain aspects of pandemic management, such as contact tracing and getting test results back in a fast manner. According to Worldometers, the US reported the highest number of overall Covid cases and total Covid deaths, followed by India and Brazil. The US and South Korea reported the first case of the novel Coronavirus on the same day. Still, South Korea's fast actions and efficient contact tracing allowed it to flatten the curve and reduce the virus's toll on the country as it continued to rampage across the US. Artificial intelligence is changing the way doctors and scientists worldwide are solving modern-day medical problems. AI is increasingly becoming more intelligent and sophisticated, doing what humans would do but quicker and more efficiently and lowering the potential costs of solving these problems [15]. Machine learning is also used in the healthcare industry to detect patterns in large complex datasets to get more precise and accurate results [4]. The smart city is another use case that utilizes AI capabilities. Singapore is a smart city with a low number of COVID-19 cases. Singapore heavily relies on intelligent systems and other forms of technology for operations and decision-making. Smart cities are known to become the future of the world.

Overall, the impact of crises such as pandemics, accidents, and environmental problems can be reduced by implementing artificially intelligent cities. With enough users, these cities would be sufficient to predict the spread of the virus, track emissions, and be more effective in maintaining and enforcing virus prevention practices such as social distancing. While managing a pandemic such as Covid-19 is a specific use case where AI can be utilized to make the process more efficient and more effective in saving lives, it is just scratching the surface of all the possibilities that AI holds.

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