A Holistic Approach to COVID-19: Prediction to Prevention

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Abstract
Throughout history, humans have faced pandemics that impact the social and economic landscape and drive innovation to overcome the crisis. The COVID-19 pandemic has affected many individuals, impacted the global economy, changed social interaction, and created pressure to find a solution. This paper provides a comprehensive review that aims to help in achieving the goal of prediction, prevention, and monitoring of the global pandemic. Various data analysis methods that use available pandemic information to project future cases and deaths have been demonstrated. Similarly, spatial investigations that visually describe the transmission of the disease and indicate the similarities between infected regions have been shown. Additionally, specific environmental factors that affect the diffusion of the coronavirus have been described. Furthermore, prevention techniques and guidelines are discussed. Then, IoT's potential in monitoring the disease, helping patients, and contributing to healthcare is highlighted. Finally, the paper provides a concluding interpretation of the pandemic problem and makes recommendations.
Keywords*:* COVID-19, pandemic, forecast, diffusion, prevention, IoT

1. Introduction

Mankind has been struck with various pandemics at different times. While some of them have been less severe, history suggests pandemics have caused tons of economic, social, and ecological damage [1]. The Black Death in the 14th century, Spanish Flu in 1918, Acute Immune Deficiency Syndrome (AIDS) in the 20th century, and more recently, COVID-19 have clearly shown the damage that can be done through pandemics [2]. Pandemics have numerous destructive consequences such as loss of workforce, economic destabilization, and various social and psychological effects. Additionally, scientists and engineers face added pressure to create solutions for diagnosing the disease or finding an effective cure.

The current pandemic started in December 2019, when atypical pneumonia was detected in Wuhan, Hubei province, China. The disease was later identified as COVID-19. COVID-19 is a disease caused by a coronavirus (SARS-CoV-2), which causes symptoms such as "fever, dry

cough, and respiratory disorders," [3]. The disease can cause death in individuals who have respiratory conditions or vulnerable immune systems.

Although pandemics have occurred in the past, various aspects of COVID-19 are unprecedented. The epicenter of the infection rapidly "shifted to other countries in Asia, Europe, and North America," owing to frequent global transportation in modern times [4]. Furthermore, it is challenging to detect sick individuals since symptoms "can take 2–14 days to appear in [the] human body" [5]. To prevent the exponential growth of cases and deaths, various countries had to implement a "complete lockdown" for the first time, which affected daily livelihoods [6].

During this outbreak, every aspect of our daily lives has been deeply impacted. Cases and deaths are drastically rising every hour. In these difficult times, the medical personnel and researchers are currently searching for new technologies and solutions to screen and control the pandemic's spread. The urgency of the issue has prompted a reconsideration of the current understanding of epidemics. To successfully counter a pandemic, five public health goals must be achieved. These are accurate predictions, reliable monitoring and assessment, prevention or containment, emergency response, and effective communication [7]. To meet these goals, various prediction models, prevention measures, and monitoring technology have been proposed to address the consequences of the ongoing crisis in this paper.

The rest of the paper is organized into five sections. Section 2 delves into the dynamics of tracking the course of the pandemic through accurate statistical models to assist health authorities. Furthermore, Section 3 presents visual models that effectively convey pandemic statistics and conceptualize the routes of transmission. On the other hand, Section 4 considers the steps to take to prevent the escalation of an outbreak and ways to contain the infection once it has spread. Subsequently, Section 5 elaborates upon the role of technology in providing excellent healthcare during current circumstances. Finally, Section 6 summarizes and concludes the paper.

2. Pandemic Forecasting

When facing a pandemic, it is essential to track the disease's spread and attempt to bring the disease under control. The science that analyses the number of infected individuals and deaths to understand the development of the pandemic and finds ways to limit the transmission of the disease is called epidemiology.

Epidemiological Models

Modern epidemiological models developed upon the Susceptible-Infected-Removed (SIR) model proposed by W. O. Kermack and A. G. MacKendrick. The model maintains separate differential equations for the Susceptible population that can catch the disease, the Infected population that can spread the disease, and the Removed population that recovered or got quarantined. All the populations evolve based on equations with arbitrary growth rates derived from the observed data.

Due to the nature of Sars-CoV-2, a research study proposed adding an Exposed group, "containing individuals in the incubation period" and a Recovered and Dead group that are

components of the Removed population [6]. After conducting various simulations with least-squares optimization, the study concluded that pandemic statistics could be accurately predicted when model parameters are periodically adjusted based on new data [6]. New data for the number of cases and deaths reflect changes resulting from new measures. Lockdown implementations decreased the growth rate parameters, which slowed down the pandemic's growth in many areas. Hence, the SIR model and its variations help justify the prevention measures taken by health officials.

Additionally, such models help assess the impact of safety strategies as done by a research study that analyzed the effect of a country's prevention measures. A modified time-series SEIR (Susceptible-Exposed-Infected-Removed) model that accounted for migration was implemented wherein equation growth parameters were set within 95% confidence intervals with adjustments for lockdown [8]. Simultaneously, a "type of Recurrent Neural Network, the Long-Short-Term-Memory Model," was used to train on 2003 SARS statistics and tested with COVID-19 parameters to forecast the pandemic [8]. The predictions for the epidemic's peak and end calculated by the different methodologies aligned closely. Surprisingly, even a slight delay in taking proactive measures could exacerbate cases and deaths massively. Thus, the study demonstrated the reliability of Machine Learning (ML) in pandemic applications, despite the outdated nature of the information.

To maximize the benefits from ML, it is vital to find an algorithm that's best suited to tell the future of the pandemic. A study implemented and compared the accuracy of frequently used supervised ML algorithms to find the optimal solution [9]. All models were provided records of cases, deaths, and recoveries and trained to predict these parameters in a future period. Researchers found that "Exponential Smoothing (ES) performed best [for] all three [variables]… even [with a] limited number of records" [9]. The ES model relies on provided data and predictions from preceding periods to make the current prediction. Thus, the influence of training data in predictions declines with a growing distance from the current period. The pandemic will encourage innovations in ML for real-time situations.

Spatial Investigations

Plotting estimates for pandemic cases and deaths using mathematical calculations doesn't provide a complete picture. The information must be pictured and analyzed in context to the world's differences, which is possible through spatial investigations.

Network analysis is a viable scientific approach for visualizing the COVID-19 pandemic. A study constructed a "pandemic network" to analyze "changes in the numbers of confirmed cases" [10]. After plotting data, network graphs were formed on world maps by connecting regions with lines if they were significantly correlated [10]. Greater connectivity between regions suggested a strong likelihood of the virus's co-evolution and risk for rapid growth in cases and deaths. The pandemic network lines often indicated where infection epicenters would eventually emerge and where the outbreak would subside in advance.

The Self-Organizing Map (SOM) is another spatial method that unravels patterns in large datasets. In this technique, a simple artificial neural network is implemented to bring related input regions together without an explicit objective. With global records for cases, recoveries, and deaths, a study sought to classify areas based on risk levels [11]. Related regions could benefit from this classification by adopting similar prevention strategies. Furthermore, countries could repurpose the mapping technology to classify their states and reallocate resources accordingly for effective pandemic management.

3. Diffusion Factors

COVID-19 is understood as a contagious, respiratory disease. Previous studies have indicated that "seasonal respiratory viruses" are affected by ambient temperature and humidity [4]. It remains to be seen whether Sars-CoV-2 is seasonal like SARS in 2003 or H1N1 swine flu in 2009.

Besides the obvious reasons for the transmission of COVID-19, studies continue to find what other factors can affect the diffusion of the disease. One such study conducted data analysis of locations, temperature, and humidity in various infection epicenters and control cities to observe the spread of the disease [4]. Through linear regression, the researchers found that the virus was transmitted mostly within the "30°N to 50°N" latitude [4]. Affected cities also had similar mean temperatures in an estimated range of "5°C to 11°C" and low humidity about a month before the emergence of community deaths. These conditions can be attributed to the winter phase of the yearly cycle that provided favorable conditions for the virus to proliferate.

Researchers have also implemented generalized additive models (GAM) to find connections between the weather and daily cases [5]. GAM is a data analysis method that obtains the dependent variable bypassing various independent variables through a linear predictor. The average temperature and relative humidity were found to be statistically significant yet again, but the relationship between weather and COVID-19 cases wasn't consistent across different regions. Nevertheless, the weather seems to play a vital role in the progression of the epidemic, as found by separate studies using different methodologies.

Certain weather conditions facilitate the propagation of mucosa and stabilize viral droplets. Current COVID-19 epicenters are predicted to experience lower infection rates later on, while the Arctic region and the Southern temperate zone are the next likely targets due to their weather.

Another study examined COVID-19 statistics in the context of a more comprehensive set of environmental variables [3]. In corroboration with reviews as mentioned earlier, lower humidity and temperature correlated with more cases. The study also found that interior regions and densely populated regions are more likely to experience infections than coastal areas. Interestingly, areas with unhealthy ozone and PM10 concentrations for more than 100 days were at high risk for developing cases. The association with air pollution was so significant that "the… accelerated transmission dynamics of COVID-19 cannot be explained without accounting for the

level of air pollution" [3]. Air pollution hurts respiratory systems and limits air circulation, which encourages the spread of COVID-19.

To curtail the spread of the infection or a predicted second wave, air pollution must be brought under control. The biological components of air pollutants facilitate the transport of pathogens in clumps and increase their activity. If unhealthy conditions persist, they will only serve as catalysts for the epidemic and future outbreaks.

4. Pandemic Prevention and Control

Disease management is extremely crucial in the wake of a pandemic. The first step towards controlling a pandemic is disease prevention. Prevention is the most vital step in disease management as it can effectively stop the loss of lives and prevent any significant damage. If this step is unsuccessful, the next step in this process is detection and verification. Fast response is hugely critical for pandemics as it prevents the situation from escalating. Once the pandemic has spread to different parts, it will be tough to contain it. It is essential to take steps for disease control to prevent the catastrophic losses people might experience due to this pandemic.

Various pandemics have different modes of spread and different forms of cure. It is extremely crucial to identify the primary medium of range and take all the necessary steps to prevent the spread of the epidemic [1]. Different strategies can also be employed depending on the specific disease and the progress of the disease [12]. Some pandemics spread at a rapid pace, and it is impossible to control it from spreading all over the world. In that case, various precautions must be taken to contain the disease, while also looking for ways to treat it. People were unsuccessful in controlling the virus when it first originated, and now this virus is wreaking havoc all around the world.

Various researchers have given different precautions to control the virus. One precaution suggested is to manage the number of accompanying family members. This is a beneficial practice as it helps in reducing the chance of the spread of COVID. Older people must be more careful than anyone else as they have the highest probability of inheriting the virus [13]. They must keep a distance from every family member as their age group faces the most fatalities. Another step to control COVID that has been suggested is to decrease hospitalization days. There is a high risk of contracting COVID in the hospital due to the number of patients in the building and the number of interactions doctors have with other people. The only options in the hands of the healthcare officials to stop the virus is to control its impact while simultaneously looking for a vaccine or drug to cure the disease.

Another challenge posed by COVID-19 is the need to protect the medical staff. Doctors and nurses have so many interactions with other patients and have one of the highest risks to contract the virus. With the massive rise in cases, there is also a shortage of healthcare specialists, and it is imperative to preserve their health. Early recognition of any symptoms is also an essential step towards controlling it.

5. Applications of IoT For Pandemic

During this COVID-19 pandemic, the lockdown period has put massive tensions in the minds of patients who are undergoing treatment and prescription and are getting severely affected by these circumstances. Patients are severely affected by the COVID-19 crisis. The majority of patients require regular check-ups with their doctors as it is an essential part of the recovery process [14]. It is very challenging for patients to make these visits with the current circumstances. Hospitals are a high-risk zone to contract the coronavirus, especially with the number of people, and therefore frequent face-to-face interactions are not possible. The pain patients experience can be too hard to deal with, and there is a huge need to come up with some advanced cloud-based services, which can help patients during this pandemic.

An answer to some of the difficulties faced during these times is the use of some Internet of Things (IoT) applications in healthcare. Internet of Medical Things (IoMT) refers to the interconnectedness of medical equipment, software applications, and data on the healthcare industry [14]. Smart healthcare monitoring is an emerging application of IoT, which is best applicable during this COVID-19 pandemic. IoMT is an essential tool for various applications to fulfill the crucial and demanding requirements of mitigating the coronavirus's effects. It analyzes previous data to help predict possible outcomes, helping us come up with precautions to counter these situations. These applications can be very helpful in managing the virus. IoMT can provide solutions to the challenges of detection, monitoring, contact tracing, and control of this disease [15].

IoMT technology enables healthcare and medical professionals to use interconnected services and resources to treat their patients. Various applications of IoT and IoMT can be used for a wide range of purposes to ensure the universal goal of controlling the virus. Hospitals make use of various IoT components such as processors, battery monitoring IC, and IoT and sensors all connected through a secure and private network, and all put to work through multiple applications. Some of the services that can be impactful towards controlling corona are a well-systemized channel of clinical advances, a digital monitoring system for patients, smart medico-care, data analysis tools, cloud-based computing, smart bed facilities, scanning appliances and many more [16]. If this technology can be successfully implemented, we can improve the efficiency of medical treatment, reducing their workload [17]. It also reduces some of the expenses borne by hospitals and medical staff, which is very helpful at the pandemic.

Clinical care is an excellent example of implementing IoT in healthcare. Clinical care is a group of integrated monitoring systems that help keep track of patients that need constant attention [18]. These monitoring systems collect the patient data through sensors, and this data is analyzed and stored in the cloud. This data is also sent to the doctors taking care of the patient, and they analyze the data again. This is a beneficial technology as it decreases the need for regular visits of the patients with the doctor.

Drones are another instance of the use of IoT in healthcare. Drones have been implemented in some countries to ensure the implementation of quarantine and mask-wearing, in this current situation of COVID-19 [19]. This technology can also be used to trace the origin of a

potential outbreak. It is hard to follow the rules of quarantine for many people, and this technology can ensure it is followed properly. Another advantage of this technology is that it can help in tracking patients who are self-quarantining at home. IoT will be a game-changer in the years to come as it will play a massive role in providing swift and accessible healthcare in the future.

IoT-based smart disease surveillance systems have the potential to be a massive breakthrough in combatting the pandemic. Most of these surveillance systems make use of existing data and infrastructure, and the main task is to just analyze the data to help control or prevent the spread of the virus [20].

6. Conclusion

Pandemics, in general, cause massive social and economic damage, but COVID-19 is a pandemic that the world has never seen before. It is crucial to proactively control the pandemic while the scientists are on the lookout for a cure. The prediction, monitoring, and containment of the pandemic are vital for public safety. In our paper, we offered some insights on how these goals can be achieved. The article starts with a detailed review of pandemics and COVID-19. Following this, the paper focuses on statistical models that can accurately predict the progression of the pandemic. It also focuses on visual models that put the pandemic in a spatial context, which provides insight into the transmission of the disease and the distribution of infections around the world. The paper then turns attention to ways to control the virus's damage once it has already spread. Finally, the focus is shifted towards IoT's role in controlling the pandemic and how its applications can be used to improve healthcare services' efficiency and effectiveness. Various countries are dealing with limited healthcare resources. It is vital to make use of prediction models and technologies such as IoT to decrease some of the burdens on the healthcare industry.

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