Predicting COVID19 Spread in Saudi Arabia Using Artificial Intelligence Techniques—Proposing a Shift Towards a Sustainable Healthcare Approach

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Abstract Medical data can be mined for effective decision making in spread of disease analysis. Globally, Coronavirus (COVID-19) has recently caused highly rated cause of mortality which is a serious threat as the number of coronavirus cases are increasing worldwide. Currently, the techniques of machine learning and predictive analytics has proven importance in data analysis. Predictive analytics techniques can give effective solutions for healthcare related problems and predict the significant information automatically using machine learning models to get knowledge about Covid-19 spread and its trends also. In a nutshell, this chapter aims to discuss upon the latest happenings in the technology front to tackle coronavirus and predict the spread of coronavirus in various cities of Saudi Arabia from purely a dataset perspective, outlines methodologies such as Naïve Bayes and Support vector machine approaches. Also, the chapter briefly covers the performance of the prediction models and provide the prediction results in order to better understand the confirmed, recovered and the mortality cases from COVID-19 infection in KSA regions. It also discusses and highlights the necessity for a Sustainable Healthcare Approach in tackling future pandemics and diseases.

Keywords Predictive analytics · Covid-19 · Machine learning · Naïve bayes (NB) · Support vector machine (SVM)
1 Introduction

The outbreak of the new coronavirus (COVID-2019) to more countries enforce many challenges and questions that are of great value to global public-health research, and decision-making in medical analysis [1]. By May 1, 2020, a total of 3,175,207 cases had been confirmed infected, and 224,172 had died [2] and particularly in Saudi Arabia (KSA), a total of 24,104 had been confirmed infected and 167 deaths [2]. Also, early responses from the public, control actions within the infected area, timely prevention control the epidemic outbreak at its earliest stage, which increase the potential of preventing or controlling the later spread of the outbreak.

COVID-19, named as a family of Corona virus spread in the year 2019, can cause illnesses such as the fever, cough, common cold, shortness of breath, sore throat, headache etc. It has some similarity like severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) but has its own symptoms and named as SARS-CoV-2 also [3]. It was originated in China and the World Health Organization (WHO) announced the COVID-19 virus outbreak a pandemic on March 2020. World Health Organization generates COVID-19 case reports regularly. So, the identification and prevention of COVID-19 should reduce this growing death rate and also the timely data analytics may provide great value to public-health research and policy-making. The Saudi Ministry of Health provides a daily update on confirmed, death and recovered cases due to Covid-19 infections in Saudi Arabia.

As the COVID-19 spreads to KSA nowadays, the analysis of the information about this novel virus data is of great value to public-health research and policy-making as the confirmed cases with Covid-19 can lead to fatal problems. Machine learning techniques are the best to provide the useful approximation to the given data and have been widely applied in different applications. Machine learning techniques has proven importance in patient case diagnosis [4] to predict the total number of infected cases, confirmed cases, mortality count and recovered cases and have better understandings of it. The applications of predictive analytics, such as optimizing the cost of resources, the accuracy of disease diagnosis, and enhancement of patient care improves clinical outcomes [5]. In healthcare, the applications like predicting patient outcomes, ranking of hospitals, estimation of treatment effectiveness, and infection control [6] are based on the machine learning classification and prediction.

The chapter focuses on the prediction of COVID-19 case history using machine learning techniques such as Naïve Bayes, and Support vector machine (SVM) on COVID-19 dataset which is collected from the Saudi Ministry of health website [7], to gain knowledge and trends of Covid-19 spread in KSA. Following the introduction section, we highlight some of the related work in applications of machine learning techniques in healthcare. The methodology section covers the information about the dataset and its preprocessing steps, the concepts applied machine learning techniques. The results and analysis section report an analysis and findings of the machine learning classifiers and predicted results. Finally, the chapter concludes with recommendations for sustainable healthcare COVID 19 for Saudi Arabia and research directions with summary section.
2 Literature Review

This section covers the related applications of machine learning (ML) techniques in healthcare. The application of machine learning models in healthcare is a challenging task due to the complexity of the medical data. In [5, 8], the authors described the new challenges in the machine learning domain due to the emergence of healthcare digitization. The applications of various machine learning classifiers have great impact on the identification and the prediction of various leading death rate diseases globally. The application of ML techniques has great impact in diagnosis and outcome prediction of the medical field. So, it ensures the possibility for the identification of relapse or transition into another disease state which are high risk for medical emergencies.

In machine learning, classification comes under supervised learning approach in which the model classifies a new observation dependent on training data set collection of instances whose classification is known. The classification technique Naïve Bayes(NB), based on Bayes’ Theorem, assumes that the appearance of a feature is irrelevant to the appearance of other features. It is mainly used to categorize text, including multidimensional training data sets. Some examples are famously document classification, span filtration, sentimental analysis, and using the NB algorithm, one can quickly create models and quickly predict models. To estimate the required parameters, a small amount of training data is required for NB.

Ferreira et al. [9] reported in their research that Naive Bayes classifier (NB), multilayer perceptron (MLP), and simple logistic regression are the best predictive models to improve the diagnosis of neonatal jaundice in newborns. [10] proposed a novel clarification on the classification performance of Naïve Bayes which explains the dependence distribution of all nodes in a class and the performance assessment has been highlighted. The comparison results of [6] showed that the performance of decision tree and Naive Bayes classifiers applied on the diagnosis and prognosis of breast cancer had comparable results. Bellaachia et al. [11] applied Naive Bayes (NB), back-propagated neural network (BPNN), and C4.5 decision tree classifiers to predict the survivability of breast cancer patients and their findings reported that the C4.5 model has best performance than NB and BPNN classifiers.

Afshar et al. [12] proposed prediction model for breast cancer patient’s survival using Support Vector Machine (SVM), Bayes Net, and Chi-squared Automatic Interaction Detection. They compared these models in terms of accuracy, sensitivity, and specificity and concluded that SVM model showed the best performance in their research.

Sandhu et al. [13] proposed MERS-CoV prediction system based on Bayesian Belief Networks (BBN) with cloud concept for synthetic data of initial classification of patients and their model accuracy score is 83.1%. The stability and recovery from MERS-CoV infections model has been proposed by [14] using Naive Bayes classifier (NB) and J48 decision tree algorithm in order to better understand the stability and pointed that NB model has the best accuracy.

Gibbons et al. [15] proposed the models for identifying underestimation in the surveillance pyramid and compared multiplication factors resulting from those
models. MFs show considerable between country and disease variations based on the surveillance pyramid and its relation to outbreak containment. Chowell et al. [3] provide a comparison of exposure patterns and transmission dynamics of large hospital clusters of MERS and SARS using branching process models rooted in transmission tree data and inferred the probability and characteristics of large outbreaks.

Support Vector Machine (SVM) is very popular prediction models among the ML community because of its high performance for accurate predictions in dataset categories or situations where the relationship between features and the outcome is non-linear. For the dataset with ‘n’ number of attributes, SVM maps each sample as a point or coordinates in a n-dimensional space for finding the class of the sample [16]. SVM finds a hyperplane to differentiate the two target classes for the sample classification. The classification process involves the mapping of the new sample into the n-dimensional space, based on which side of the hyperplane the new sample fall in. Burges [6] described SVM as the best tool to address bias-variance tradeoff, overfitting, and capacity control to work within complex and noisy domains. However, the quality of training data [6] decides the accuracy of SVM classifier. Moreover, [17, 18, 19] concluded the scalability is the main issue in SVM. In addition, the results reported in [20, 17, 19] stated that the use of optimization techniques can reduce SVM’s computational cost and increase its scalability.

The research works reviewed in this section reveal the important applications of classification, and prediction analysis using Naïve Bayes, and SVM classifiers. Our study focuses on the prediction model by standard machine learning techniques Naive Bayes and SVM for testing on COVID-19 datasets cases from KSA.

3 Experimental Methodology

Generally, conducting a machine learning analysis covers the following steps.

- Preparing the dataset.
- Model Preparation
  - Training the ML models.
  - Testing the ML models.
  - Evaluating the models using measures.

3.1 Dataset Description and Pre-processing

For the experiments, our dataset sample period is between March 2, 2020 to April 16, 2020. We considered these datasets from 12 regions of KSA namely Riyadh, Eastern Region, Makkah, Madina, Qassim, Najran, Asir, Jazan, Tabuk, Al baha, Northern Borders, Hail.
Table 1  Description of datasets

| Date | Regions with cases counts | Class |
|------|---------------------------|-------|
| Ranges from 2nd March to 16th April 2020 | All 12 regions and their respective case counts | 0—Reported case 1—Confirmed case 2—Recovered case 3—Mortality case |

The dataset has 248 records (days) with 12 columns (regions) in which 62 records for case history, 62 records for confirmed cases, 62 records for mortality cases and 62 records for recovered cases for all the above mentioned 12 regions respectively. The dataset will most likely continue to change for different COVID-19 cases until the recovery of all infected cases. So, we have used the data for confirmed cases, mortality cases, recovered, and reported cases for all the analysis. Table 1 shows the description of the dataset structure.

The daily accumulative infection number of 2019-nCoV is collected from daily reports of the Ministry of Health [7, 21].

First, some exploratory analysis on the data was carried out along with and summarization of some statistics, plotting some trends in the existing data. Then we build the machine learning models and try to predict the count of cases in the upcoming days. The statistical analysis of all these four cases based on cumulative count on daily basin are shown in Figs. 1, 3, 5 and 7 and based on 12 regions of KSA in Figs. 2, 4, 6 and 8 respectively.

Figure 1 shows the ongoing COVID-19 pandemic cases reported and spread to Saudi Arabia from 2nd March to 16th April 2020 and the Ministry of Health confirmed the first case in the Saudi Arabia on March 2, 2020. As the reported cases gradually increased during this period, the government respond to control the cases effectively by closure of holy cities, temporary suspension of transports, curfews on limited timings in various cities.

![Reported Cases (2nd March - 16th April 2020)](image)

*Fig. 1  Daily reported cases*
Fig. 2  Daily reported cases in 12 KSA regions

Fig. 3  Reported active cases

Fig. 4  Active cases in 12 KSA regions
Fig. 5  Mortality cases

Fig. 6  Mortality cases in 12 KSA regions

Fig. 7  Recovered cases
Figure 2 shows the ongoing COVID-19 pandemic cases reported in 12 main regions of Saudi Arabia during the period 2nd March to 16th April 2020. Out of 12 regions, more cases were reported comparatively in four main cities namely Makkah, Riyadh, Eastern regions and Medina respectively. Authorities continue to urge people to stay at home and followed lockdown or strict social restrictions in the regions with more reported cases.

The active cases during the period 2nd March to 16th April 2020 is shown in Fig. 3. The gradual increase in the cases reported is an evident for the result of active medical testing procedures carried out in the entire kingdom effectively.

The active cases reported in 12 regions during the period 2nd March to 16th April 2020 is given in Fig. 4, which shows that approximately 20–80% of the reported cases were confirmed with COVID-19 infections in various regions.

Figure 5 reports that 2% of mortality rate approximately at the maximum during the period 2nd March to 16th April 2020.

There were more mortality cases in pilgrimage cities Makkah and Medina and the authorities reported that most of cases were suffering from chronic health conditions also. Saudi Arabia suspended entry and praying to the general public at the two Holy Mosques in Mecca and Medina to limit the spread of the coronavirus [22] on 20th March to control the COVID-19 cases.

The recovered cases given in Figs. 7 and 8 provided the information that nationalities abide by precautionary measures and practice social distancing to keep the virus under control, as a result of active testing carried out in crowded districts and other high-risk areas, particularly in cities like Riyadh and Makkah in which more cases were reported.

The complete case history of COVID-19 trends for the period of 2nd March - 16th April 2020 is given in Fig. 9. It is evident that mortality and recovered case rates are comparatively less than the reported and confirmed case rates. The mortality cases ratio for COVID-19 has been much lower than SARS of 2003 [23, 24] but the transmission has been significantly greater, with a significant total death toll [25].

Data preprocessing involves dividing the data into attributes and labels and dividing the data into training and testing sets. For data pre-processing, we split
the dataset into two groups based on case categories. The first group consisted of recovery cases and mortality cases based on regions for predicting the recovery from Covid-19. Second group has the reported cases to be used to predict the stability of the infection based on the active cases. Columns are the same in this two dataset groups which are 12 KSA regions related to the number of Covid-19 cases i.e. Reported, Confirmed, Death and Recovered cases for the time period 2nd March–16th April 2020.

Before simulating the algorithms, the datasets are preprocessed to make them suitable for the classifier’s implementation. First need to separate our training data by class.

### 3.2 Building Models

Classification is a widely used technique in health-care. Here, we build classification models to predict the frequency of Covid-19 infection cases. We applied two models namely Naive Bayes and SVM algorithms. The models are implemented in Python platform.

#### 3.2.1 Naive Bayes (NB)

Naive Bayes classifier is a classification algorithm for binary and multiclass classification problems using Bayes theorem and assumes that all the features are independent to each other. Bayes’ theorem is based on conditional probability. The conditional probability calculates the probability that something will happen, given that something else has already happened.

Bayes’ Theorem is stated as: \[ P(\text{class} | \text{data}) = \frac{P(\text{data} | \text{class}) \times P(\text{class})}{P(\text{data})} \], where \( P(\text{class} | \text{data}) \) is the probability of class given the provided data.
NB classifier is built in Python using machine learning library scikit-learn. A Gaussian Naive Bayes algorithm is a special type of NB algorithm which assumes that all the features are following a gaussian distribution i.e., normal distribution. It’s specifically used when the features have continuous values. Implementation details are given as follows:

- Import the required Python Machine Learning Packages using import pandas, numpy
- Data preprocessing using from sklearn import preprocessing
- Split the dataset into train and test datasets using sklearn.cross_validation and import train_test_split
- Model the Gaussian Navie Bayes classifier using sklearn.naive_bayes import GaussianNB
- Predict method of the GaussianNB class is used for making predictions.
- Calculate the accuracy score of the model using sklearn.metrics import accuracy_score

3.2.2 Support Vector Machine (SVM)

Support vector machine (SVM) classifier is a type of supervised machine learning classification algorithm. SVM differs from the other classification algorithms in the way that it chooses the decision boundary that maximizes the distance from the nearest data points of all the classes and finds the most optimal decision boundary. Implementation details simple linear SVM in Python are as follows:

- Import the required Python Machine Learning Packages using import pandas, numpy
- Data preprocessing using from sklearn import preprocessing
- Split the dataset into train and test datasets using sklearn.cross_validation and import train_test_split
- Model the SVC classifier with kernel type as linear using from sklearn.svm import SVC
- The predict method of the SVC class is used for making predictions.
- Calculate the accuracy score of the model using sklearn.metrics import accuracy_score and classification_report

After that, every dataset has been divided into, training and testing sets using the following ratios 80/20, 70/30, and 60/40, respectively. For the prediction models, the two models are applied to the original datasets and the performance of every classifier is analyzed using the metrics such as accuracy, precision and recall measures which are explained in the following section.
4 Model Evaluation Results and Analysis

We analyzed and evaluated NA and SVM machine learning classifiers using the performance metrics namely Classification accuracy, Precision, and Recall. The formulas for calculating these metrics are given in Table 2.

Performance measures, for the prediction of recover and mortality, namely classification accuracy percentage, Precision, Recall, of the models are presented in Table 3. The performance of SVM model is comparatively good in terms of classification accuracy, precision and recall values. The performance of NB model shows good results for the validation set with 70/30 for recovery-mortality dataset as shown in Table 3.

The performance of SVM classifier is good because all datasets have single-labels, which is the strength of SVM for handling single-label data. SVM has better performance than NB with 2% classification accuracy.

In this work, two classification algorithms NB and SVM are used to produce highly accurate models for COVID-19 dataset. However, the performance of the these obtained models is little bit satisfactory for application in real pandemic of COVID-19 infection cases. We believe that there is a need to increase the size of the dataset in order to improve predictions because the main limitation lies in the size of the training dataset. In addition, more medical history of the patient information should be included in the future work.

Table 2 Description of metrics

| Name of the metrics | Formula                                  |
|---------------------|------------------------------------------|
| Accuracy            | \( \frac{\text{True Positives}+\text{True Negatives}}{\text{Positives}+\text{Negatives}} \) |
| Precision           | \( \frac{\text{True Positives}}{\text{True Positives}+\text{False Positives}} \) |
| Recall              | \( \frac{\text{True Positives}}{\text{True Positives}+\text{False Negatives}} \) |

Table 3 Predicted metrics

| Method       | Accuracy                         | Precision                        | Recall                          |
|--------------|----------------------------------|----------------------------------|---------------------------------|
|              | 80/20   | 70/30   | 60/40 | 80/20 | 70/30 | 60/40 | 80/20 | 70/30 | 60/40 |
| Naïve bayes  | Recovery—mortality               | 63                               | 70.27                           | 67.57                           | 0.69 | 0.82 | 0.81  | 0.65 | 0.71  | 0.63  |
|              | Reported—confirmed               | 63.16                            | 54.83                           | 48.65                           | 0.63 | 0.52 | 0.54  | 0.63 | 0.55  | 0.50  |
| SVM          | Recovery—mortality               | 0.79                             | 0.64                            | 0.62                            | 0.80 | 0.67 | 0.70  | 0.79 | 0.64  | 0.62  |
|              | Reported—confirmed               | 0.70                             | 0.63                            | 0.61                            | 0.76 | 0.69 | 0.67  | 0.73 | 0.61  | 0.60  |
5 Sustainable Healthcare Post COVID 19 for SA

Sustainability, as a concept has vastly benefited different sectors of business including energy, agriculture, forestry, construction and tourism. It is gaining popularity in the modern healthcare system which is predominant with contemporary pharmaceutical drugs & products [26]. But different instances have proved time and again, that the contemporary medication was not found to be an effective solution against various infectious and chronic diseases.

5.1 Sustainable Healthcare

Alliance for Natural Health, USA (ANH-USA) first defined Sustainable Health in 2006 as:

“A complex system of interacting approaches to the restoration, management and optimization of human health that has an ecological base, that is environmentally, economically and socially viable indefinitely, that functions harmoniously both with the human body and the non-human environment, and which does not result in unfair or disproportionate impacts on any significant contributory element of the healthcare system” [26].

Current COVID-19 pandemic, which has devastated the world and even the best healthcare systems have crippled under its pressure, points strongly in the direction of involving all kinds of healthcare systems to be bound with the principles of sustainability and demands a paradigm shift in healthcare approach by countries for the wellbeing of its citizens. Now the time has come where the countries must have to implement and practice Sustainable Healthcare for its citizens. Traditional Medicines and Alternative Medicines such as Homeopathy, Ayurveda, Yunani, Chinese medicine, Naturopathy etc. were always questionable for their scientific basis by the practitioners of Allopathy and/or the contemporary form of medication. But then the alternative form of medication has proved its effectiveness and efficiency time and again during challenging times and are practiced since many decades now.

There is a strong need to prepare/collection, use and analyse the data pertaining to the Traditional Form of medicines and its usefulness applying AI/ML techniques.

Following and subsequent section discusses some of the recommendations regarding the current pandemic, future directions towards a sustainable healthcare system in Saudi Arabia.
5.2 Staff and Clinical Practice Sustainability During the Pandemic

- Telehealth technology allows clinicians to monitor patients in-home and make treatment recommendations. A robust infrastructure for telemedicine is also required.
- COVID-19 has an overall lower case death rate than SARS or Middle East respiratory syndrome (MERS) [27], but the stress placed on healthcare systems globally is alarming [28]. The medical agency should have well improved plan for protecting healthcare workers from infection and exhaustion in this prolonged fight against COVID-19.
- Many healthcare offices have limited due to the lockdown timings, touch with policy makers as they design programs for government relief and support.

5.3 Expand Hospital-at-Home During the COVID-19 Pandemic

- Hospital-at-home program can reduce healthcare costs and mortality rates.
- During the pandemic, providing hospital care at home can reduce the risk of COVID-19 transmission, especially for vulnerable patients.
- For effective hospital-at-home, interdisciplinary social and behavioral health services are required.
- Primary care and hospital-at-home services should cover social and behavioral health requirements also.

5.4 COVID-19 Pandemic and Sustainable Development Groups

- Towards 2030, the World is expected to assure Peace and Prosperity for all People and the Planet through Partnerships (Governments-Private-NGOs-CSOs-Individuals) in the Social, Economic and Environmental Spheres. These ‘COVID-19 Pandemic Benefits’ should be optimized for ‘Sustainable Development’ by the nexus with the SDGs.
- Medical council should continue the expansion of primary care and hospital-at-home services in remote areas as well. The patients and primary care teams should improve their services both during and after the pandemic.
- The technical guidance for strategic and operationally focused actions to support health service planners and health-care system managers in the Region to maintain the continuity and resourcing of priority services while mobilizing the health workforce to respond to the pandemic. This will help ensure that people continue to seek care when appropriate and adhere to public health advice.
5.5 Research Directions

The technology of machine learning can generate new opportunities for Sustainable Healthcare and the researchers can focus on the areas:

- Automated analysis and prediction of COVID-19 infection cases.
- Automated discovery of COVID-19 patient cases dynamically.
- Automation on existing consolidated portal to support future pandemics.
- Building a novel Pilot COVID-19 Data Warehouse for future reference.
- Improved techniques for capturing, preparing and storing data meticulously.
- Supportive platform for creating a community of medical practitioners for pandemic crisis.

6 Conclusion

Finding the hidden knowledge in the data is a challenging task in machine learning. This chapter focuses on the classification and prediction by standard machine learning techniques (Naive Bayes and SVM) when tested on COVID-19 datasets cases from KSA. Covid-19 dataset was converted into patients’ cases (reported and confirmed, recovered and death) classification problem, and the respective target prediction has been carried out. The performance of each model forecasts was assessed using classification accuracy, precision and recall. Our results demonstrate that Naive Bayes and SVM models can effectively classify and predict the cases of COVID-19 data and we discussed the sustainable healthcare of COVID 19 for Saudi Arabia.

This chapter also reports the applications of some of the well-known machine learning algorithms for the prediction of the frequency of COVID-19 disease. We found that SVM, and NB models can give relatively higher accuracy results.

The performance of the two models NB and SVM was evaluated and compared. In general, we found that the accuracy of the models is between 63% and 80%. In Future, the performance of the prediction models can be improved with the use of more COVID-19 datasets. The motivation of this chapter is to support the medical practitioners for choosing the appropriate machine learning classifiers for the analysis of various COVID-19 samples. For our future work on COVID-19 data, we plan to collect more data related to patients with COVID-19 cases directly from hospitals in KSA.

Together, we, as an organization, as a community, and as global citizens, can beat this disease, better prepare for the next pandemic, and ensure the safety and care of all our patients.

Acknowledgements We acknowledge MoH - KSA data repository for datasets.
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